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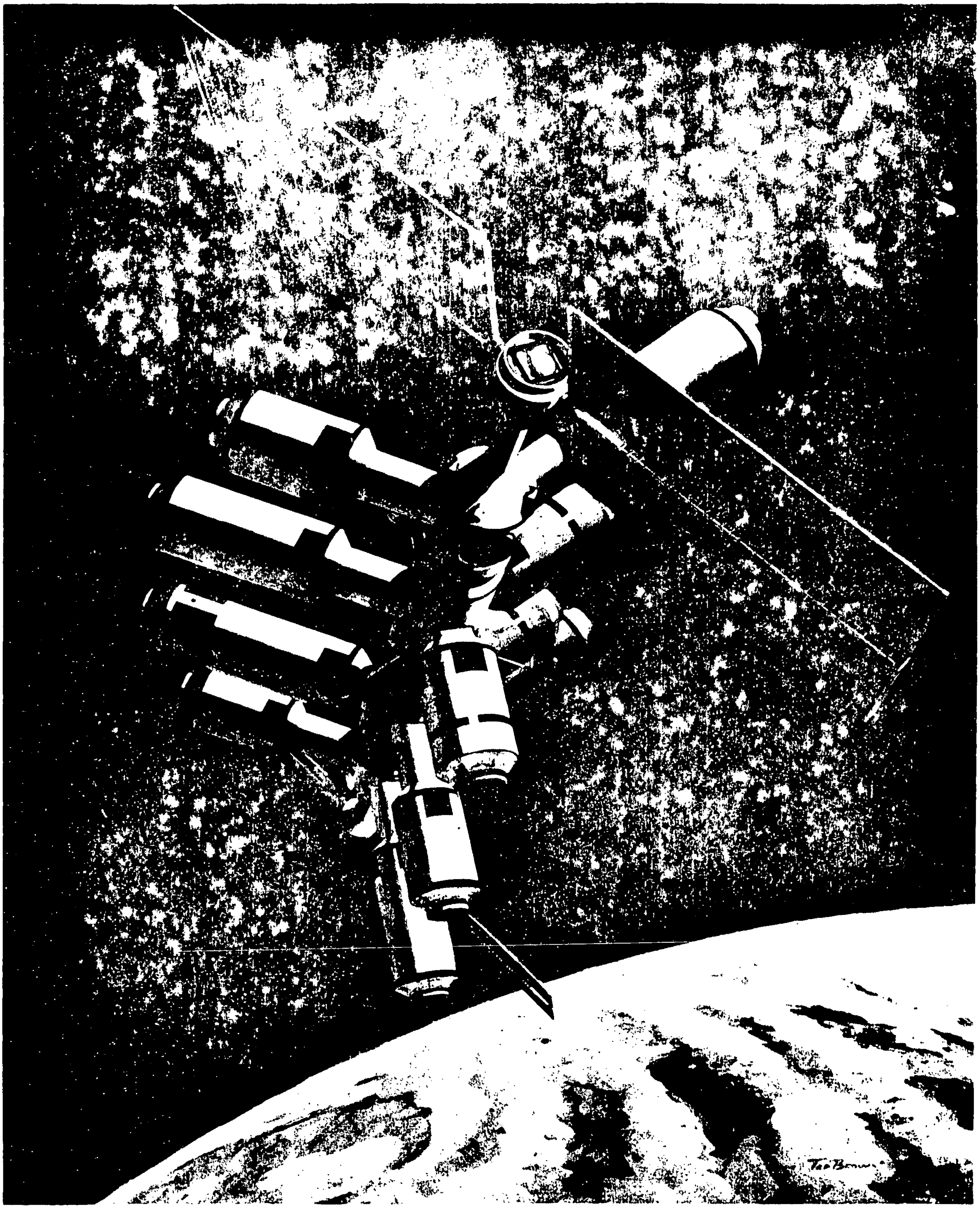

PREFACE

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

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

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

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

This report is submitted as Data Requirement SE-06.

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

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

SUBJECT REFERENCE MATRIX

LEGEND:
CM Configuration Management
MA Program Management
MF Manning and Financial
MP Mission Operations
SE System Engineering and Technical Description

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part I CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part I CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

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Section 1
INTRODUCTION

1.1 BACKGROUND

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

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

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

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

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

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

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

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

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

During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

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

1.2 SCOPE OF THIS VOLUME

The Space Station logistics system provides for transportation of cargo to and from the Space Station, rotation of Space Station crews and rescue of the entire crew in an on-orbit emergency situation. In the selected logistics system concept for ISS, crews are transported in the crew compartment of the Space Shuttle orbiter vehicle, while cargo is transported in a logistics module which is housed in the orbiter cargo bay. Crew rescue is accomplished by the Shuttle with a logistics module specially outfitted to house and support six men for an emergency return. The selected logistics system approach is one which satisfies all program and mission requirements at minimal cost prior to IOC. For the GSS phase of operations, a crew cargo module is utilized. This module houses six men in addition to cargo.

The Logistics Module provides a major supplement to the Space Station on-orbit cluster. This added capability is provided because the Logistics Module remains attached to the Station during resupply intervals. It, therefore, provides for (1) storage of consumables; (2) storage of return cargo (such as wastes and experiment hard copy data); and (3) storage of equipment (such as CMG's), which is carried onboard and installed to complete Space Station buildup. The storage volume provided in the Logistics Module minimizes the storage space required in Station modules. In addition, it provides the capability for contingency uses (such as extra crew accommodations).

Figure 1-1 shows the Logistics Module in perspective and indicates the cargo storage concept and the transfer of a large item of cargo. Routine items of cargo are stored in standardized modules and submodules which are moved into the Station on demand. Transfer of large items of cargo is accomplished by the crew with the assistance of a cable/brake device which is temporarily installed for that purpose.

The Logistics Module is 4.3m (14 ft) in diameter and 8.5 m (28-ft) long and incorporates a pressurized and unpressurized compartment as shown in Figure 1-2. The interior of the pressurized compartment is arranged, into two basic areas: (1) special-cargo area, and (2) palletized-cargo area. The special-cargo area is sized to accept items such as CMG's, a food freezer, trash compactor, and experiment items. The palletized area is configured to support 0.61 by 0.61 m (2 by 2 ft) carry-on containers. The unpressurized compartment houses the propellant (N_2H_4) tankage and high-pressure gaseous nitrogen tanks. A two-man EVA airlock is provided from the pressurized compartment to the Orbiter interface. The airlock also serves as an egress/ingress path from the Orbiter to the Logistics Module.

Only minimal subsystems are incorporated to support the Logistics Module since the required services are supplied by the Orbiter and Space Station. Structural design of the Logistics Module is highly common with the design of Space Station modules. Common elements include the neuter docking mechanism, conical sections, and cylindrical pressure shell/insulation/ meteoroid bumper assembly. Items peculiar to the design of this module are the end dome of the pressurized compartment and the crew transfer tunnel. Fully loaded, the module may weigh up to 9,072 kg (20,000 lb). Empty weight is 3,011 kg (6,638 lb). Cargo capability is, therefore, 6,061 kg (13,362 lb).

A Logistics Module outfitted for a rescue mission would include seats, interior lighting, communications, and status displays. Weight of these

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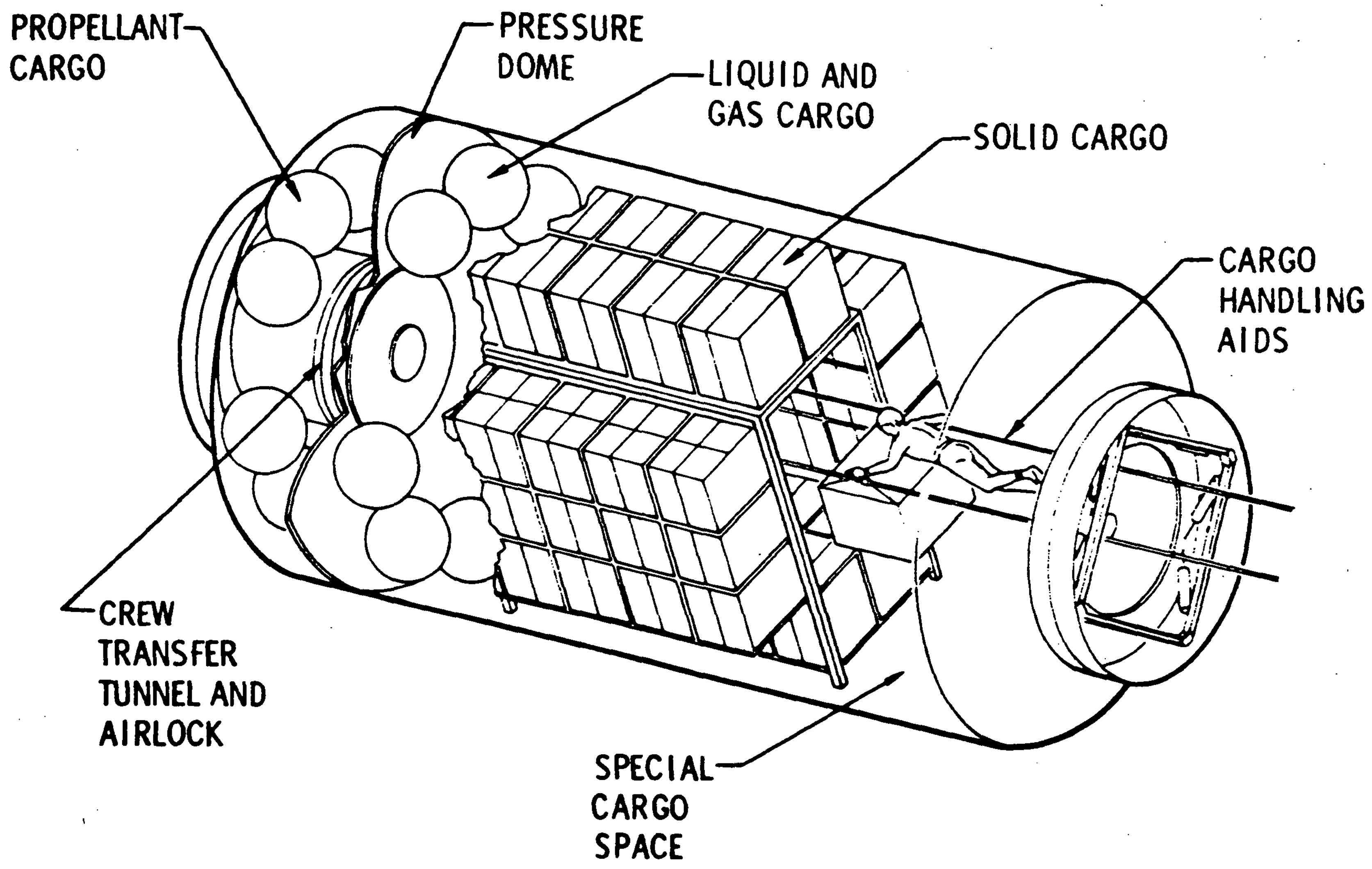

Figure 1-1. Logistics Module

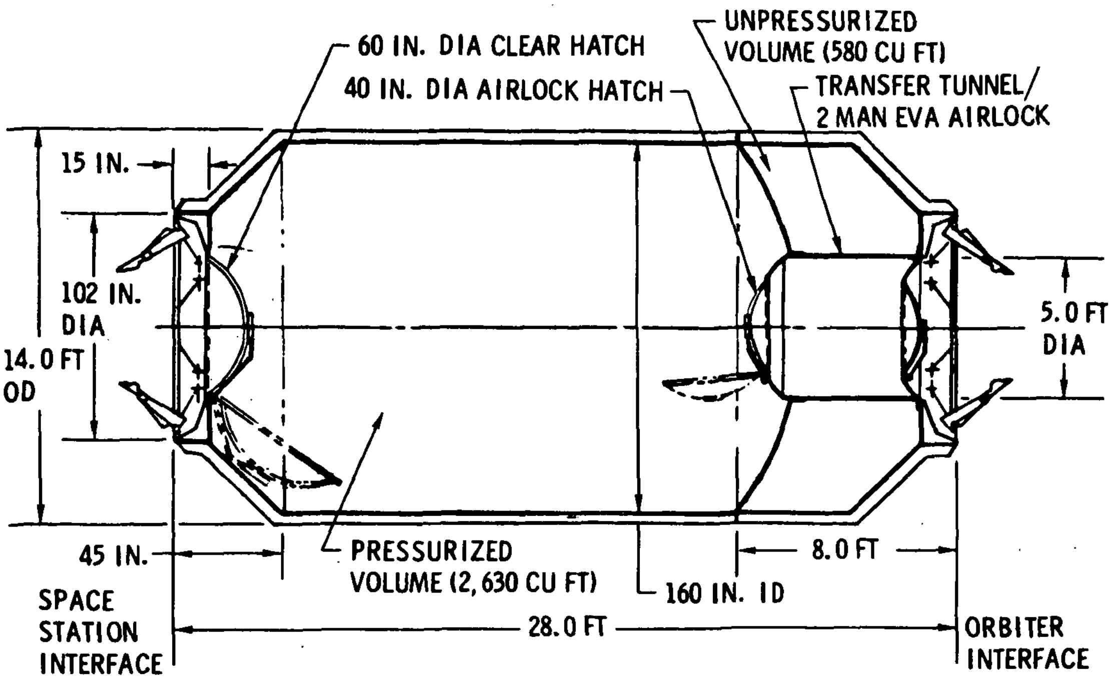

Figure 1-2. Logistics Module Inboard Profile

provisions is not critical since, including the weight of six man and their provisions, the total module weight is well within 9,072 kg (20,000 lb).

The following section of this report describes the requirements for cargo transportation to and from the Space Station. Section 3 discusses the selected method of crew and cargo transportation and the rationale for that selection. Design and operation of the system is described in Sections 4, 5 and 6. Section 7 contains a brief description of the Space Shuttle design and operational characteristics used in this study and a definition of the interfaces between the logistics system and the Space Station and Shuttle.

Section 2

LOGISTICS REQUIREMENTS

2.1 SPACE STATION CARGO

Analyses were performed throughout the Modular Space Station Phase B study to identify the initial and resupply requirements for spares, consumables, and expendables required to support the 6-man ISS and 12-man GSS on-orbit operations. Specific cargo items, quantities, and frequency required to sustain the crew and Modular Station subsystems operation were identified together with the requirements for equipment during buildup. The delivery of ISS and GSS Station modules for buildup requires "off loading" subsystem equipment to meet the design-to-weight constraint of 20,000 lb and still maintain weight margins for the station modules. The off-loaded equipment is included as initial cargo for the first, second, and third logistics flights. The 90-day spares resupply requirements (defined in Subsection 2.1.2) are based on establishing an initial spares inventory on-board the station and then resupplying the inventory at an estimated average rate.

2.1.1 Initial Buildup

The maximum discretionary payload for the Space Station modules is obtained by transporting some equipment and expendables in the logistics module. Candidate options for logistic transport are those items that are not mission critical during activation and are either designed for periodic replacement or have a simple installation interface. The Station cargo requirements, therefore, include the following items for buildup.

- A. Station subsystem equipment off-loaded for module delivery.
- B. Spares inventory.
- C. Thirty-day contingency consumables, expendables, and spares stored on-board the station.

Items currently considered as logistics options for the Power/Subsystems Module, Crew/Operations Module and General Purpose Laboratory modules are shown in Table 2-1.

The first Logistic Module, concurrent with the first operational crew, would transport expendables and most of the crew-related items. The second Logistics Module launch would bring up additional expendables, two additional crewmen and crew equipment needed for the additional crew. Logistics options not required for early operation (mainly added GPL equipment) will be transported to orbit as the logistic payload permits.

Note that while some propellants are listed as options, sufficient propellant is onboard the modules when launched for 120 days of unmanned operation and activation. Similarly, batteries are logistics options but sufficient batteries for activation operations are launched onboard. Makeup atmosphere is also included onboard, although complete repressurization gases are considered an acceptable option prior to manned operation. A portable checkout unit is included for use of the activation crew. The onboard spares inventory required for ISS includes 4,200 lbs of replacement parts, modules, and components and requires approximately 60 ft^3 of storage space aboard the Station.

The GSS onboard inventory includes 5,400 lb of components, parts, etc. and requires approximately 72 ft^3 of storage volume aboard the GSS module.

2.1.2 90-Day Resupply

Mission planning and resupply for the Modular Space Station is recommended based on a 90-day cycle for both ISS and GSS (90 days is the nominal on-orbit stay-time for each crew member). Thus, experiments that a crew is to operate would also be planned for a 90-day cycle. The consumables, spares, and expendables required to support the crew's effort would be planned for the nominal 90-day cycle. Space Station subsystem resupply is also planned on a 90-day basis. Tables 2-2 and 2-3 define the ISS and GSS items required for an average 90-day-resupply cycle. Items identified with an asterisk are planned for replacement at cycles greater than 90 days.

Table 2-1

LOGISTIC OPTIONS FOR SPACE STATION BUILDUP

Power/Subsystems Module

	Log M-1		Log M-2	
	Kg	lbm	Kg	lbm
CMG's (4)	728	1,605	-	-
Battery Set No. 2	-	-	724	1,596
Repressurization O_2 (1 tank)	133	293	-	-
Repressurization N_2 (4 tanks)	481	1,060	-	-
Metabolic O_2 (Reserve)	163	359	163	359
Metabolic O_2 (Contingency)	163	359	163	359
Computers No. 5 and 6	18	40	-	-
Pumpdown Accumulators (2)	-	-	146	322
Misc/Spares	49	108	TBD	TBD
	1,735	3,824	1,196+	2,636+

Crew/Operations Module

	Log M-1		Log M-2	
	Kg	lbm	Kg	lbm
Battery Sets (Both No. 1 and 2)	724	1,596	724	1,596
Water (Contingency	246	523	246	523
Portable Life Support Units	111	245	111	245
Food and Container (backup)	143	315	143	315
Food and Container (nominal usage)	143	315	286	631
Trash Compactor/Dryer	50	110	-	-
Trash Cannisters	51	112	TBD	TBD
Housekeeping Items	33	73	48	106
Furnishings	190	419	156	344
Personal Hygiene	14	31	28	62
Exercise Gear	34	75	TBD	TBD
Spares/Miscellaneous	31	68	TBD	TBD
	1,770	3,882	1,742+	3,507+

General Purpose Laboratory Module

	Log M-1		Log M-2	
	Kg	lbm	Kg	lbm
Battery Sets (Both No. 1 and 2)	724	1,596	724	1,596
C. O. Units (2)	90	198	-	-
B & C Microfilm Viewer/ Handcontroller/etc.	40	88	-	-
Data Management Recorders and Film Digitizer	198	437	-	-
Film Vault (3500 lb) Launch No. 3	-	-	-	-
Micro Film Retrieval Unit (700 lb) Launch No. 1	318	700	-	-
Miscellaneous GPL Gear (620 lb)	-	-	-	-
	1,370	3,019	724	1,596

As an example the batteries are replaced every 2 years on a scheduled basis. In the actual operational program the batteries might be delivered on one or two flights. However, the battery weight shown represents the average weight required for each 90-day increment.

The packaging weight required for solid cargo was calculated using an estimated percentage of the item weight. The value used for solid cargo was generally 10 percent, derived from the previous 33-ft station study. For certain items (food, batteries, CMG's) an adjusted cargo packaging weight was established due to the nature and characteristics of the item. Weight of tanks, food lockers, freezers, refrigerators, battery clamping devices, straps, etc. were calculated separately. The average 90-day resupply required to sustain ISS subsystems and crew is 7,132 lb requiring a volume of approximately 295 ft^3. The average 90-day return cargo is 4,663 lb requiring 295 ft^3 of storage volume.

The type of subsystems selected for the Space Station have a large impact on logistics resupply requirements. The open loop oxygen system for the EC/LS subsystem, for example, accounts for 32.5 percent of the resupply weight. (Oxygen is stored gaseously in the Logistics Module.) The battery energy storage system accounts for another 14 percent of the resupply. Food accounts for still another 24 percent of the 90-day resupply.

2.1.3 Return Cargo

Return cargo requirements for the crew and space station subsystems are shown in Tables 2-2 and 2-3. All return cargo is packaged in the replacement cargo container (except for trash) and transferred to the same Logistics Module storage racks, bins, etc., assigned to the up cargo item. Empty trash containers would be delivered to exchange with the full containers. Also, the food storage lockers provide delivery of food and then are used for trash containers. Liquids and gases would be depleted by topping off onboard tanks.

Table 2-2

MODULAR SPACE STATION (ISS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 1 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item G

	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
Subsystem	Type	Description	IW + Pkg	TW	(ft^3)	IW + Pkg	TW	(ft^3)
A. Structural/Mechanical	S-Spares	Latches, seals, motors, etc.	* (see sub-system G)		*	*		*
	L or G	None required			--	--		--
B. Electrical Power								
Power Distribution and Power Conditioning	S-Spares	Relays, switches, converters	*		*	*		*
	L or G	None required	--		--	--		--
Primary power	S-Expend	Batteries	932 + 47	979	3.0	932 + 47	979	3.0
C. Propulsion								
High Thrust	S-Spares	Valves, regulators, burst disc, seals, etc.	*	*	*	*	*	*
	L-Fuel	N_2H_4 at 250 psig	20 + 4	24	1.0	2 + 4	6.0	1.0
	G-Press.	GN_2 at 3,000 psig	1.5 + 1.6	3.1	0.5	0.1 + 1.6	1.7	0.5
Low Thrust	S-Spares	Valves, seals, etc.	*	*	*	*	*	*
	F-Fuel	--	--	--	--	--	--	--
	G-	None required	--	--	--	--	--	--
D. Navigation and Guidance	S-Spares	Sensors, electronics actuators	*	*	*	*	*	*
	S-Spares	CMG bearing	2 + 0.5 ft	2.5	0.25	2 + 0.5	2.5	0.25
	L or G	None required	--	--	--	--	--	--
E. Vehicle Electronics								
Onboard Checkout	S-Spares	Sensors, circuit boards displays	*	*	*	*	*	*
	L or G	None required	--	--	--	--	--	--
Communications	S-Spares	Switches, relays, tube, motors, etc.	*	*	*	*	*	*
	L or G	None required	--	--	--	--	--	--
Data Management	S-Spares	Switches, displays, lights, electronics	*	*	*	*	*	*

Table 2-2

MODULAR SPACE STATION (ISS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 2 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item G

Subsystem	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
	Type	Description	IW + Pkg	TW	(ft^3)	IW + Pkg	TW	(ft^3)
E. Vehicle Electronics (Continued)								
	S-Consum	Video tape, voice cart, TV film, digital tape, etc.	250 + 25	275	7.0	230 + 25	255	7.0
	L or G	None required	--	--	--	--	--	--
Wiring	S-Spares	Wire, connectors, J-boxes	5 + 0.25	5.25	0.1	1 + 0.25	1.25	0.1
F. Crew Systems								
Crew Life Support	S-Spares	Valves, sensors, restraints, lights, etc.	*	*	*	*	*	*
	S-Consum	Food (frozen; dehydrated; wet pack; perishable)	1,376 + 335	1,711	53.5	10 + 335	345	53.5
	S-Consum	Wipes, liners, soap, wicks, charcoal, towels, bedding, vacuum bag liners, personal equipment	353 + 70	423	23.5	130 + 70	210	23.5
	S-	Trash cont	75 + 5	75	105	433 + 5	438	105
Crew Equipment	S-Spares	Exercise equipment, medical facility	*	*	*	*	*	*
	C-Consum	Medical supplies, paper, hobby, sports, etc.	25 + 3	28	1	5 + 3	8	1
	L or G	None required	--	--	--	--	--	--
G. Items Identified by *	S-Spares	Spares for all subsystems to include both wearout and random failure based on an initial inventory	330 + 33	363	8	330 + 33	363	8
						2,519 (O_2; GN_2;		
TOTALS			5,195 + 1,937	7,132	295	2,726 + 1,937	4,663	295

Table 2-2

MODULAR SPACE STATION (ISS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 3 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item G

	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
Subsystem	Type	Description	IW + Pkg	TW	(ft^3)	IW + Pkg	TW	(ft^3)
H. Environmental and Life Support								
Environmental Thermal Control and Atmosphere Reconditioning	S-Spares	Heat exchangers, valves, pumps, control assy, accumulators, sensors, etc.	*	*	*	*	*	*
	S-Consum	Wicks, charcoal beds, filters, water transfer discs, etc.	380 + 38	418	24	380 + 38	418	24
	L-	None required	--	--	--	--	--	--
	G-Consum	O_2 (metabolic)	1,058 + 1,267	2,327	34	3 + 1,269	1,272	34
	G-Consum	O_2 Airlock make-up	15.3 + 18.4	33.7	1.5	0.5 + 18.4	18.9	1.5
	G-Consum	GN_2 Airlock make-up	58.2 + 10.0	128.2	5.5	1 + 70.0	71.0	5.5
I. Life Support Pallet	S-	Replacement unit (Average weight/90 days)	88 + 5	93	10	88 + 5	93	10
J. IVA/EVA								
Port. Life Support	S-Spares	None required	--	--	--	--	--	--
	C-Consum	Battery modules 5.5 lb/4 hr LiOH 5 lb/4 hr O_2 1.6 lb/4 hr 108 hr/yr	82 + 5	87	3	170 + 5	1.75	3
		2 EVA/IVA suits	140 + 7	147	14	140 + 7	147	14

Table 2-3

MODULAR SPACE STATION (GSS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 1 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item J

Subsystem	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
	Type	Description	IW + Pkg	TW	(ft^3)	IW + Pkg	TW	(ft^3)
A. Structural/Mechanical	S-Spares	Latches, seals, motors, etc.	*	*	*	*	*	*
	L or G	None required						
Electrical								
Power Distribution and Conditioning	S-Spares	Relays, switches, converters, etc.	*	*	*	*	*	*
	L or G	None required						
Primary Power	S-Expend.	Batteries	1, 303 + 65	1, 368	4. 5	1, 303 + 65	1, 368	4. 5
B. Propulsion								
High Thrust	S-Spares	Valves, regulators, burst disc, seals	*	*	*	*	*	*
	L-Fuel	N_2H_4 at 250 psig	75 + 15	90	3. 5	1 + 15	16	3. 5
	G-Gas	GN_2 at 3, 000 psig	5 + 6	11	2. 0	0. 5 + 6	6. 5	2. 0
Low Thrust (Resistojet)	S-Spares	Valves, seals, etc.	*	*	*	*	*	*
	L-Fuel	Water (1989 – 1999) for solar year	--	--	--	--	--	--
C. Navigation and Guidance	S-Spares	Sensors, eletronics, actuators	*	*	*	*	*	*
	S-Spares	CMG bearings	4 + 1	5	0. 5	4 + 1	5	0. 5
	L or G	None required	--	--	--	--	--	--
D. Vehicle Electronics								
OCS	S-Spares	Sensors, circuit boards, displays	*	*	*	*	*	*
	L or G	None required	--	--	--	--	--	--
Communications	S-Spares	Switches, relays, tubes, motors, etc.	*	*	*	*	*	*
	L or G	None required	--	--	--	--	--	--

Table 2-3

MODULAR SPACE STATION (GSS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 2 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item J

	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
Subsystem	Type	Description	IW + Pkg	TW	(ft^3)	IT + Pkg	TW	(ft^3)
E. Vehicle Electronics (Continued)								
Data Management	S-Spares	Switches, relays, electronics	*	*	*	*	*	*
	S-Consum	Video tape, voice cartridges, TV film, tape, etc.	300 + 15	315	10	275 + 15	290	10.0
	L or G	None required	--	--	--	--	--	--
Wiring	S-Spares	Wire, connectors	10 + 0.5	10.5	0.3	2 + 0.25	2.5	0.1
F. Environmental and Life Support								
Environmental Thermal Control and Atmosphere	S-Spares	Heat exchangers, valves, control assy, sensors, accumulators, etc.	*	*	*	*	*	*
	S-Consum	Wicks, charcoal beds, filters, water transfer discs, etc.	695 + 65	710	40	645 + 65	710	40
	L-	None required	--	-	--	--	--	--
	G-Consum	O_2 (metabolic)	1,935 + 2,315	4,250	67	10 + 2,315	2,325	67
	G-Consum	O_2 (airlock make-up)	23 + 27	50	2.0	1 + 27	28	2.0
	G-Consum	GN_2 (airlock make-up)	88 + 106	194	7.0	3 + 106	109	7.0
Life Support Pallet	S-	Replacement Unit Average weight/90 day	88 + 5	93	10	88 + 5	93	10
G. IVA/EVA								
Port Life Support	S-Spares	None required	--	--	--	--	--	--
	G-Consum	Batteries, LiOH, O_2	120 + 6	126	5	80 + 6	86	5
	S-	2 EVA/IVA suits	140 + 7	147	14	140 + 7	147	14
H. Crew Systems								
Crew Life Support	S-Spares	Valves, sensors, restraints, lights	*	*	*	*	*	*
	S-Consum	Food (frozen; dehydrated; wet-pack; perishable)	2,752 + 670	3,422	107	20 + 670	690	107

Table 2-3

MODULAR SPACE STATION (GSS) AVERAGE 90-DAY RESUPPLY REQUIREMENTS (page 3 of 3)

LEGEND: S = Solids, L = Liquids, G = Gases, IW = Item Weight, TW = Total Weight, Pkg = Packaging, * = See Item J

Subsystem	Resupply Item		Delivery Weight Including Packaging (lb)		Delivery Volume	Return Weight Including Packaging (lb)		Return Volume
	Type	Description	IW + Pkg	TW	(ft^3)	IW + Pkg	TW	(ft^3)
I. Crew Systems (Continued)								
Crew Life Support (Continued)	S-Consum	Wipes, liners, soap, towels, bedding, personal equipment, vacuum bags, etc.	705 + 140	845	47	250 + 140	390	47.0
	S-Trash	Trash containers	100 + 5	105	210	2,540 + 105	2,645	210.0
Crew Equipment	S-Spares	Exercise equipment, medical facility	*	*	*	*	*	*
	C-Consum	Medical supplies, paper, hobby, etc.	40 + 5	45	2.0	20.5	25	1.5
	L or G	None required	--	--	--	--	--	--
J. Items Identified above by *		Spares for above subsystems to include both wearout and random failure based on an inventory of 5,400 lb	390 + 39	429	9	390 + 39	429	9
			Totals	12,210	481		9,405	481
K. H_2O for Resistojet	L-Consum	If X-POP required (see Exp Supply)						
L. GSS GPL		Equipment	465 + 24	489	12	465 + 24	484	12
M. ISS GPL		Equipment	350 + 18	368	8	350 + 18	368	8

2.2 EXPERIMENT CARGO

The experiment resupply and initial experiment equipment requirements are dependent upon the experiment program selected. Table 2-4 lists by FPE the initial, resupply, and return requirements for consumables, expendables, and spares for each FPE. This data is based on a 30-day resupply cycle. Down cargo requirements are also provided for each item. These requirements were derived from an analysis of the 1971 NASA Blue Book. Experiment case 534G shown in Table 2-5 was selected as a baseline experiment program for planning purposes. Based on this FPE schedule and the cargo requirements shown in Table 2-4, the average 90-day experiment resupply during ISS operations is 5, 200 lb and during GSS is 8, 835 lb. These values include all experiment equipment, solids, liquids, and gases to support the operation of integral, attached, and free-flying RAM's, but does not include the delivery or return of the actual RAM's. The delivery weight of RAM Modules is shown in Table 2-6.

Figure 2-1 shows a flight schedule for the baseline program with experiment case 534G. Figure 2-7 is a cargo manifest for each Shuttle flight.

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
A1 X-Ray Astronomy														
- Rí RES Telescope	None	0	0	0	0	0	0	25.2 (56)	0.06 (2)	12.6 (28)	0.03 (1)	12.6 (28)	0.03 (1)	
- Large Area Telescope	Cryogenics	20 (44)	0.03 (1)	3.3 (7.3)	0.005 (0.14)	0	0	22.2 (48.8)	0.06 (2)	11.1 (24.4)	0.03 (1)	11.1 (24.4)	0.03 (1)	
- Supplementary Experiments	None	0	0	0	0	0	0	0	0	0	0			
Station	Cryogenics	20 (44)	0.03 (1)	3.3 (7.3)	0.005 (0.14)		0	47.4 (104.8)	0.12 (4)	23.7 (52.4)	0.06 (2)	23.7 (52.4)	0.06 (2)	
30-Day Shuttle	Cryogenics	20 (44)	0.03 (1)	0	0	0	0	23.7 (52.4)	0.06 (2)	N/A	N/A	23.7 (52.4)	0.06 (2)	
Subgroup A-2A														
-2 Meter Telescope	Film	37 (81)	0.06 (2)	37 (81)	0.06 (2)	37 (81)	0.06 (2)	2.3 (5)	0.01 (0.3)	2.3 (5)	0.01 (0.3)	2.3 (5)	0.01 (0.3)	Update of exp will require approximately 306 KG (675 lb); 1.3 m^3 (26.3 ft^3) per year
Station	Same ←													→ Same
30-Day Shuttle	Film	37 (81)	0.06 (2)	N/A	N/A	37 (81)	0.06 (2)	2.3 (5)	0.01 (0.3)	N/A	N/A	2:3 (5)	0.01 (0.3)	
5-Day Shuttle	Not a logical candidate - 5-day mission could be used for checkout and testing													
Subgroup A-3A														Note: Operational consumables listed are to support a film system, if used
- 1.5 M Photoheliograph - XUV Spectroheliograph - X-Ray Crazing		93.6 (207.7)	0.16 (5.12)	93.6 (207.7)	0.16 (5.12)	93.8 (207.7)	0.16 (5.12)	26.7 (58.8)	0.04 (1.35)	26.7 (58.8)	0.04 (1.35)	26.7 (58.8)	0.04 (1.35)	
Station	Same ←													→ Same
30-Day Shuttle	Same		Same	N/A	N/A	Same			Same	N/A	N/A	Same		Same
5-Day Shuttle	Not a logical candidate - 5-day mission could be used for checkout and testing													

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
Subgroup A-3B														Note: Operational consumables listed are to support a film system, if used
Solar coronagraph		10.7 (23.3)	0.02 (0.5)	10.7 (23.3)	0.02 (0.5)	10.7 (23.3)	0.02 (0.5)	3.3 (6.2)	0.005 (0.17)	3.3 (6.2)	0.005 (0.17)	3.3 (8.2)	0.005 (0.17)	
Station	Same ←													→ Same
30-Day Shuttle		Same	Same	N/A	N/A	Same	Same	Same	Same	N/A	N/A	Same	Same	
5-Day Shuttle	Use 1/6 of 30-day quantities; see note													
Subgroup A-3C														
- Photoheliograph (Ref. ATM F/O)	None							41 (9.1)	0.066 (2.44)	2.3 (5.1)	0.004 (0.14)	2.3 (5.1)	0.004 (0.14)	Assumes all electronic imaging - no film
Station								41 (9.1)	0.066 (2.44)	2.3 (5.1)	0.004 (0.14)	2.3 (5.1)	0.004 (0.14)	Same
30-Day Shuttle								2.3 (5.1)	0.004 (0.14)	N/A	N/A	2.3 (5.1)	0.004 (0.14)	Same
Subgroup A-3D														
- X-Ray Spectroheliograph (Ref. ATM F/O)	None							76 (174.8)	0.118 (4.23)	4.3 (9.7)	0.007 (0.24)	4.3 (9.7)	0.007 (0.24)	Assumes all electronic imaging - *no film*
Station								78 (174.8)	0.118 (4.23)	4.3 (9.7)	0.007 (0.24)	4.3 (9.7)	0.007 (0.24)	Same
30-Day Shuttle								4.3 (9.7)	0.007 (0.24)	N/A	N/A	4.3 (9.7)	0.007 (0.24)	Same
5-Day Shuttle	None													

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
Subgroup A-3E														
- XUV Spectrometer (Ref. ATM F/O)	None							15.5 (34.6)	0.017 (0.61)	0.9 (1.9)	0.001 (0.03)	0.9 (1.9)	0.001 (0.03)	Assumes all electronic imaging - no film
Station								15.5 (34.6)	0.017 (0.61)	0.9 (1.9)	0.001 (0.3)	0.9 (1.9)	0.001 (0.03)	Same
30-Day Shuttle								0.9 (1.9)	0.001 (0.03)	N/A	N/A	0.9 (1.9)	0.001 (0.03)	Same
5-Day Shuttle	None													
Subgroup A-4A														
- 0.94 M Narrowfield UV Telescope	35 MM Film	33.6 (74)	0.057 (2.0)	5.7 (12.3)	0.017 (0.6)	5.7 (12.3)	0.017 (0.6)	0	0	0	0	0	0	
Station	35 MM Film	Same ←											→	Same
30-Day Shuttle	35 MM Film	5.7 (12.3)	0.017 (0.6)	N/A	N/A	5.7 (12.3)	0.017 (0.6)	0	0	N/A	N/A	0	0	
5-Day Shuttle	35 MM Film	1.2 (2.5)	0.004 (0.15)	N/A	N/A	1.2 (2.5)	0.004 (0.15)	N/A	N/A	N/A	N/A	N/A	N/A	
Subgroup A-4B														
- 0.3 M Widefield UV Telescope	150 MM Film	33.6 (74)	0.057 (2.0)	9.1 (20)	0.017 (0.6)	9.1 (20)	0.017 (0.6)	0	0	0	0	0	0	
Station	150 MM Film	Same ←					→ Same							
30-Day Shuttle	150 MM Film	9.1 (20)	0.017 (0.6)	N/A	N/A	9.1 (20)	0.017 (0.6)	0	0	N/A	N/A	0	0	
5-Day Shuttle	150 MM Film	1.8 (4)	0.004 (0.15)	N/A	N/A	1.8 (4)	0.004 (0.15)	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
Subgroup A-4C														
Small UV Survey Telescope	Film	27.3 (60)	0.06 (2.1)	9.1 (20)	0.03 (0.8)	9.1 (20)	0.03 (0.8)	0	0	0	0	0	0	
Station	Same													Same
30-Day Shuttle		9.1 (20)	0.03 (0.8)	N/A	N/A	9.1 (20)	0.03 (0.06)	0	0	N/A	N/A	0	0	
5-Day Shuttle	Film	4.65 (10)	0.01 (0.35)	N/A	N/A	4.65 (10)	0.01 (0.35)	N/A	N/A	N/A	N/A	N/A	N/A	
Subgroup A-5A														
- Lower Energy Experiments - Align/Calibrate/Acquire	Gas	8.0 (17.6)	0.3 (10.7)	8.0 (17.6)	0.3 (10.7)	0	0	37.0 (83)	0.2 (7.0)	37.0 (83)	0.2 (7.0)	37.0 (83)	0.2 (7.0)	
Station	Same													Same
30-Day Shuttle		8.0 (17.6)	0.3 (10.7)	N/A	N/A	0	0	37.0 (83)	0.2 (7.0)	N/A	N/A	37 (83)	0.2 (7.0)	
5-Day Shuttle	Gas	5.6 (12.6)	0.21 (7.3)	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
Subgroup A-5B														
- Higher Energy Experiments	Gas	1.6 (3.7)	0.04 (1.4)	1.6 (3.7)	0.04 (1.4)	0	0	0	0	0	0	0	0	
- Align/Calibrate/Acquire	Solid Cryogenics	3.3 (7.4)	0.11 (4)	3.3 (7.4)	0.11 (4)	0	0							
Station	Same													Same
30-Day Shuttle	Same	Same	Same	N/A	N/A	0	0	0	0	0	0	0	0	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
Subgroup A-5B (Continued)														
5-Day Shuttle	Gas	1.1 (2.6)	0.03 (0.97)			0	0	N/A	N/A	N/A	N/A	N/A	N/A	
	Solid Cryogenics	2.3 (5.2)	0.08 (2.8)			0	0							
A6 Infrared Astronomy														
Station	Cryogenics													
	L Ne	273 (600)	0.23 (8)	45.5 (100)	0.04 1.4	0	0	0	0	0	0	0	0	
	L He	227 (500)	1.53 54	38 (83.4)	0.25 8.8									
30-Day Shuttle	Same	Same	Same	N/A	N/A	0	0	0	0	N/A	N/A	0	0	
5-Day Shuttle	Same	Same	Same	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
P-1 Space Physics Research Lab														
P-1A Atmospheric and Magnetospheric Science														
Station	Film	4.54 (10)	0.028 (1.0)	2.27 (5)	0.014 (0.5)	2.27 (5)	0.014 (0.5)	10 (22)	0.042 (1.5)	5 (11)	0.021 (0.75)	5 (11)	0.021 (0.75)	
30-Day Shuttle	Film	2.27 (5)	0.014 (0.5)	N/A	N/A	2.27 (5)	0.014 (0.5)	5.9 (13)	0.022 (0.8)	N/A	N/A	5.9 (13)	0.022 (0.8)	
5-Day Shuttle	Film	0.91 (2)	0.0056 (0.2)	N/A	N/A	0.91 (2)	0.0056 (0.2)	N/A	N/A	N/A	N/A	N/A	N/A	
P-1B Cometary Physics														
Station	NH_3 Canisters	4.54 (10)	0.084 (3)	2.27 (5)	0.042 (1.5)	2.27 (5)	0.042 (1.5)	1.45 (3.4)	0.019 (0.68)	0.72 (1.7)	0.010 (0.34)	0.72 (1.7)	0.010 (0.34)	Average of 1 canister every 2 mo

Table 2-4
LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
P-1B Cometary Physics (Continued)														
	ICN Canisters	0.68 (1.5)	0.0002 (0.0075)	0.34 (0.75)	0.0001 (0.0038)	0.34 (0.75)	0.0001 (0.0038)							
	Film	0.91 (2)	0.0056 (0.2)	0.46 (1)	0.0028 (0.1)	0.46 (1)	0.0028 (0.1)							
30-Day Shuttle	NH_3 Canisters	45.4 (100)	0.84 (30)	N/A	N/A	45.4 (100)	0.84 (30)	0.72 (1.7)	0.010 (0.34)	N/A	N/A	0.72 (1.7)	0.010 (0.34)	
	ICN Canisters	6.8 (15)	0.002 (0.75)	N/A	N/A	6.8 (15)	0.002 (0.075)							
	Film	9.1 (20)	0.056 (2)	N/A	N/A	9.1 (20)	0.056 (2)							
5-Day Shuttle	NH_3 Canisters	45.4 (100)	0.84 (30)	N/A	N/A	45.4 (100)	0.84 (30)	N/A	N/A	N/A	N/A	N/A	N/A	
	ICN Canisters	6.8 (15)	0.002 (0.075)	N/A	N/A	6.8 (15)	0.002 (0.075)							
	Film	9.1 (20)	0.056 (2)	N/A	N/A	9.1 (20)	0.056 (2)							
P-1C Meteroid Science (Exclusive of T.M.M.P.D.)														
Station	Film	0.114 (0.25)	0.0007 (0.025)	0.057 (0.12)	0.0004 (0.06)	0.057 (0.12)	0.0004 (0.06)	2.0 (4.4)	0.64 (1.4)	1.0 (2.2)	0.32 (0.7)	1.0 (2.2)	0.32 (0.7)	
	Impact Plates	2.7 (6)	0.011 (0.4)	2.7 (6)	0.011 (0.4)	2.7 (6)	0.011 (0.4)							
30-Day Shuttle	Film	0.057 (0.12)	0.0004 (0.06)	N/A	N/A	0.057 (0.12)	0.0004 (0.06)	1.0 (2.2)	0.32 (0.7)	N/A	N/A	1.0 (2.2)	0.32 (0.7)	
5-Day Shuttle		0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
P-1D Thick Material Meteoroid Penetration (T.M.M.P.D.)														
Station		0	0	0	0	0	0	0.18 (0.4)	0.0006 (0.02)	0.09 (0.2)	0.0003 (0.01)	0.09 (0.2)	0.0003 (0.01)	
30-Day Shuttle		0	0	0	0	0	0	0.09 (0.2)	0.0003 (0.01)	N/A	N/A	0.09 (0.2)	0.0003 (0.01)	
P-1E Small Astronomy Telescopes														
Station		0	0	0	0	0	0	3.8 (8.4)	0.02 (0.72)	1.6 (4.2)	0.01 (0.36)	1.6 (4.2)	0.01 (0.36)	
30-Day Shuttle		0	0	N/A	N/A	0	0	1.6 (4.2)	0.01 (0.36)	N/A	N/A	1.6 (4.2)	0.01 (0.3o)	
5-Day Shuttle		0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
P-2 Plasma Physics Laboratory														
P-2A Wake Measurement from Station and Booms														
Station	Poloroid Film	1.4 (3)	0.01 (0.3)	1.4 (3)	0.01 (0.3)	1.4 (3)	0.01 (0.3)	10 (21)	0.01 (0.5)	5 (11)	0.01 (0.3)	5 (11)	0.01 (0.3)	
30-Day Shuttle		1.4 (3)	0.01 (0.3)	N/A	N/A	1.4 (3)	0.01 (0.3)	5 (11)	0.01 (0.03)	N/A	N/A	5 (11)	0.01 (0.03)	
5-Day Shuttle		1.4 (3)	0.01 (0.3)	N/A	N/A	1.4 (3)	0.01 (0.3)	N/A	N/A	N/A	N/A	N/A	N/A	
P-2B Wake Measurement from Subsatellite														
Station	Poloroid Film Balloons Batteries	238 (552)	0.24 (8.4)	221 (487)	0.23 (8.2)	58 (127)	0.23 (8.2)	15 (32)	0.02 (0.8)	7 (16)	0.01 (0.4)	7 (16)	0.01 (0.4)	
30-Day Shuttle	Subsatellite Fuel	238 (522)	0.24 (8.4)	N/A	N/A	74 (162)	0.24 (8.4)	7 (16)	0.01 (0.4)	N/A	N/A	7 (16)	0.01 (0.4)	

Table 2-4
LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
P-2B Wake Measurements from Subsatellite (Continued)														
5-Day Shuttle		256 (562)	0.24 (8.6)	N/A	N/A	92 (202)	0.24 (8.6)	N/A	N/A	N/A	N/A	N/A	N/A	
P-2C Plasma Resonances														
Station	Poloroid Film	1.8 (4)	0.01 (0.4)	1.8 (4)	0.01 (0.4)	1.8 (4)	0.01 (0.4)	3 (6)	0.01 (0.2)	1 (3)	- (0.1)	1 (3)	- (0.1)	
30-Day Shuttle		1.8 (4)	0.01 (0.4)	N/A	N/A -	1.8 (4)	0.01 (0.4)	1 (3)	- (0.1)	N/A	N/A	1 (3)	- (0.1)	
5-Day Shuttle		1.8 (4)	0.01 (0.4)	N/A	N/A	1.8 (4)	0.01 (0.4)	N/A	N/A	N/A	N/A	N/A	N/A	
P-2D Wave Particle Interactions														
Station	Polaroid Film Batteries Subsatellite Fuel	438 (964)	0.31 (10.6)	256 (564)	0.25 (8)	111 (244)	0.25 (8.8)	4 (9)	0.01 (0.2)	2 (4)	- (0.1)	2 (4)	- (0.1)	
30-Day Shuttle		438 (964)	0.31 (10.8)	N/A	N/A	293 (644)	0.03 (10.6)	2 (4)	- (0.1)	N/A	N/A	2 (4)	- (0.1)	
5-Day Shuttle		640 (1404)	0.31 (13.0)	N/A	N/A	493 (1084)	0.37 (13.0)	N/A	N/A	N/A	N/A	2 (4)	- (0.1)	
P-2E Electron and Ion Beam Injection														
Station	Polaroid Film Batteries	202 (444)	0.07 (2.6)	35 (77)	0.02 (0.8)	35 (77)	0.02 (0.8)	6 (14)	0.01 (0.3)	3 (7)	0.01 (0.2)	3 (7)	0.01 (0.2)	
30-Day Shuttle		202 (444)	0.07 (2.6)	N/A	N/A	202 (444)	0.07 (2.6)	3 (7)	0.01 (0.2)	N/A	N/A	3 (7)	0.01 (0.2)	
5-Day Shuttle		202 (444)	0.07 (2.6)	N/A	N/A (444)	202 (2.6)	0.07	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
P-3 Cosmis Ray Physics Laboratory														
P-3A Lab Without TAD	Argon/Methane, Emulsions and Magnet/Dewar	66 (146)	1 (35.7)	186 (410)	1.2 (40.5)	141 (333)	1.2 (90.5)	243 (535)	0.51 (18)	6.1 (134)	0.13 (4.5)	6.1 (134)	0.13 (4.5)	
Station and Shuttle/FF		Magnet and Dewar Included in launch weight		Magnet/Dewar once per year										
				1360 (3000)	5.6 (197)	680 (1500)	5.6 (197)							
P-3B Lab with 1/2 TAD														
Station and Shuttle/FF	Argon/Methane, Emulsions and Magnet/Dewar	66 (146)	1 (35.7)	166 (410)	1.2 (40.5)	151 (333)	1.2 (40.5)	258 (568)	0.51 (19)	65 (142)	0.13 (4.7)	65 (142)	0.13 (4.7)	
		Magnet and Dewar included in launch weight		Magnet/Dewar once per year										
				1360 (3000)	5.6 (197)	680 (1500)	5.6 (197)							
P-3C Plastic/Nuclear Emulsions														
All Missions	Emulsions	Included in launch weight		120 (264)	0.15 (5.3)	120 (264)	0.15 (5.3)							
P-4 Physics and Chemistry Laboratory														
P-4A Airlock and Boom Experiments														
Station	Gas, Test Surfaces Film Mag Tape, etc.	172 (380)	0.125 (4.5)	86 (190)	0.056 (2)	45 (100)	0.028 (1)	9.8 (21.6)	0.019 (0.68)	4.9 (10.8)	0.009 (0.34)	4.9 (10.8)	0.009 (0.34)	
30-Day Shuttle	Gas, Test Surfaces Film, Mag Tape, etc.	86 (190)	0.62 (2.25)	N/A	N/A	45 (100)	0.028 (1)	4.9 (10.8)	0.009 (0.34)	N/A	N/A	4.9 (10.6)	0.009 (0.34)	
5-Day Shuttle	Gas, Test Surfaces Film, Mag Tape, etc.	22 (48)	0.16 (0.57)	N/A	N/A	11 (25)	0.007 (0.25)	N/A	N/A	N/A	N/A			

Table 2-4
LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol. M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
P-4B Flame Chemistry and Laser Experiments														
Station	Fuels and Oxidant Contamination Coupons Film, Mag Tape, etc.	225 (500)	0.364 (13.0)	112 (250)	0.364 (13.0)	22.5 (50)	0.026 (1)	18.8 (41.5)	0.16 (5.7)	9.4 (20.6)	0.08 (2.9)	9.4 (20.6)	0.08 (2.9)	
30-Day Shuttle	Fuels and Oxidant Contamination Coupons Film, Mag Tape, etc.	112 (250)	0.192 (6.5)	N/A	N/A	22.5 (50)	0.028 (1)	9.4 (20.6)	0.08 (2.9)	N/A	N/A	9.4 (20.6)	0.08 (2.9)	
5-Day Shuttle	Fuels and Oxidant Contamination Coupons Film, Mag Tape, etc.	28 (12)	0.004 (0.14)	N/A	N/A	5.5 (12.5)	0.007 (0.25)	N/A	N/A	N/A	N/A	N/A	N/A	
P-4C Test Chamber Experiments														
Station	Liquid Helium Nitrogen, Freon Film, Mac Tape, etc.	150 (330)	0.16 (5.8)	75 (165)	0.08 (2.9)	45 (100)	0.05 (1.8)	9 (19.7)	0.048 (1.7)	45 (10.4)	0.024 (0.85)	4.5 (10.4)	0.024 (0.65)	
30-Day Shuttle	Liquid Helium Nitrogen, Freon Film, Mac Tape, etc.	75 (165)	0.08 (2.9)	N/A	N/A	45 (100)	0.05 (1.8)	45 (10.4)	0.024 (0.85)	N/A	N/A	45 (10.4)	0.024 (0.55)	
5-Day Shuttle	Liquid Helium Nitrogen, Freon Film, Mag Tape, etc.	19 (41)	0.02 (0.7)	N/A	N/A	11 (25)	0.013 (0.45)	N/A	N/A	N/A	N/A	N/A	N/A	
ES-1 Earth Observation														
ES-1A Met and Atmos C1 (I)														
Station	Magnetic Tape, Film	60 (134)	0.09 (3.4)	60 (134)	0.09 (3.4)	60 (134)	0.09 (3.4)	112 249	0.17 (6.1)	112 (249)	0.17 (6.1)	112 (249)	0.17 (6.1)	1. No maintenance or spares for 5 day shuttle missions.
30-Day Shuttle		61 (136)	0.09 (3.5)	N/A	N/A	61 (136)	0:09 (3.5)	114 (252)	0.17 (6.2)	N/A	N/A	114 (252)	0.17 (6.2)	2. Max facility per MSFC best judgment from blue book.

Table 2-4
LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
ES-1 Earth Observation (Continued)														
5-Day Shuttle		16 (36)	0.02 (0.9)	N/A	N/A	16 (36)	0.02 (0.9)	N/A	N/A	N/A	N/A	N/A	N/A	3. Areas I - VI and min payload scaled by weight (Wx/W max facility).
ES-1B Land Use (I)														
Station	Magnetic Tape, Film	53 (83)	0.08 (2.1)	53 (83)	0.08 (2.1)	53 (83)	0.08 (2.1)	99 (155)	0.15 (3.9)	99 (155)	0.15 (3.9)	99 (155)	0.15 (3.9)	4. Based on 2 cycles per 30 days for each experiment on station and 30 day shuttle; 1 cycle on 5-day shuttle (max facility and min payload in continuous operation).
30-Day Shuttle	Magnetic Tape, Film	53 (83)	0.08 (2.1)	N/A	N/A	53 (83)	0.08 (2.1)	99 (155)	0.15 (3.9)	N/A	N/A	99 (155)	0.15 (3.9)	
5-Day Shuttle		18 (28)	0.03 (0.7)	N/A	N/A	18 (28)	0.03 (0.7)	N/A	N/A	N/A	N/A	N/A	N/A	
ES-1C Pollution (IV)														
Station	Magnetic Tape, Film	28 (61)	0.04 (1.5)	28 (61)	0.04 (1.5)	28 (61)	0.04 (15.)	51 (113)	0.08 (2.8)	51 (113)	0.08 (2.8)	51 (113)	0.08 (2.8)	
30-Day Shuttle		33 (73)	0.05 (1.8)	N/A	N/A	33 (73)	0.05 (1.8)	61 (135)	0.10 (3.3)	N/A	N/A	61 (135)	0.10 (3.3)	
5-Day Shuttle		14 (32)	0.02 (0.8)	N/A	N/A	14 (32)	0.02 (0.8)	N/A	N/A	N/A	N.A	N/A	N/A	
ES-1D Resource RE (IV)														
Station	Magnetic Tape, Film	32 (69)	0.05 (1.7)	32 (69)	0.05 (1.7)	32 (69)	0.05 (1.7)	59 (128)	0.09 (3.2)	59 (128)	0.09 (3.2)	59 (128)	0.09 (3.2)	
30-Day Shuttle		32 (69)	0.05 (1.7)	N/A	N/A	32 (69)	0.05 (1.7)	59 (128)	0.09 (3.2)	N/A	N/A	59 (128)	0.09 (3.2)	
5-Day Shuttle		10 (23)	0.02 (0.6)	N/A	N/A	10 (23)	0.02 (0.6)	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
ES-1E Disasters (V)														
Station	Magnetic Tape, Film	74 (162)	0.12 (4.0)	74 (162)	0.12 (4.0)	74 (162)	0.12 (4.0)	136 (301)	0.21 (7.5)	136 (301)	0.21 (7.5)	136 (301)	0.21 (7.5)	1. No maintenance or spares for 5 day shuttle missions.
30-Day Shuttle		73 (160)	0.12 (3.9)	N/A	N/A	74 (160)	0.12 (3.9)	134 (296)	0.21 (7.4)	N/A	N/A	134 (296)	0.21 (7.4)	2. Max facility per MSFC best judgment from blue book.
5-Day Shuttle		22 (47)	0.03 (1.2)	N/A	N/A	22 (47)	0.03 (1.2)	N/A	N/A	N/A	N/A	N/A	N/A	3. Areas I - VI and min payload scaled by weight (Wx/W max facility).
ES-1F Ocean Resources (VI)														
Station	Magnetic Tape, Film	48 (106)	0.07 (2.7)	48 (106)	0.07 (2.7)	48 (106)	0.07 (2.7)	90 (197)	0.14 (4.9)	90 (197)	0.14 (4.9)	90 (197)	0.14 (4.9)	4. Based on 2 cycles per 30 days for each experiment on station and 30 day shuttle; 1 cycle on 5-day shuttle (max facility and min payload in continuous operation).
30-Day Shuttle		62 (137)	0.09 (3.5)	N/A	N/A	62 (137)	0.09 (3.5)	116 (255)	0.18 (6.3)	N/A	N/A	116 (255)	0.18 (6.3)	
5-Day Shuttle		23 (50)	0.04 (1.3)	N/A	N/A	23 (50)	0.04 (1.3)	N/A	N/A	N/A	N/A	N/A	N/A	
ES-1G Min Payload														
Station	Magnetic Tape, Film	89 (197)	0.14 (4.9)	0	0	89 (197)	0.14 (4.9)	165 (370)	0.26 (9.2)	165 (370)	0.26 (9.2)	165 (370)	0.26 (9.2)	
30-Day Shuttle		89 (197)	0.14 (4.9)	N/A	N/A	89 (197)	0.14 (4.9)	165 (370)	0.26 (9.2)	N/A	N/A	165 (370)	0.26 (9.2)	
5-Day Shuttle		22 (48)	0.03 (1.2)	N/A	N/A	22 (48)	0.03 (1.2)	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
C/N-1 COM/NAV Research Facility														
CN-1A Experiments 1 - 7														
Station	Magnetic Tape, Film	14.3 (32)	0.02 (0.5)	14.3 (32)	0.02 (0.5)	14.3 (32)	0.02 (0.5)	20 (44)	0.06 (2.2)	10 (22)	0.03 (1.1)	10 (22)	0.03 (1.1)	
30-Day Shuttle		14.3 (32)	0.02 (0.5)	N/A	N/A	14.3 (32)	0.02 (0.5)	10 (22)	0.03 (1.1)	N/A	N/A	10 (22)	0.03 (1.1)	
5-Day Shuttle		14.3 (32)	0.02 (0.5)	N/A	N/A	14.3 (32)	0.02 (0.5)	N/A	N/A	N/A	N/A	N/A	N/A	
CN-1B Experiments 1 - 7, 12, 13														
Station		21.5 (47)	0.02 (0.8)	21.5 (47)	0.02 (0.8)	21.5 (47)	0.02 (0.6)	21 (46)	0.07 (2.4)	11 (23)	0.04 (1.2)	11 (23)	0.04 (1.2)	
30-Day Shuttle		21.5 (47)	0.02 (0.8)	N/A	N/A	21.5 (47)	0.02 (0.8)	11 (23)	0.04 (1.2)	N/A	N/A	11 (23)	0.04 (1.2)	
5-Day Shuttle		21.5 (47)	0.02 (0.8)	N/A	N/A	21.5 (47)	0.2 (0.8)	N/A	N/A	N/A	N/A	N/A	N/A	
MS-1 Materials Science and Manufacturing														
MS-1 IIIA (Station)														
1. Crystal growth from solution	Exp. Materials	0	0	12 (26.4)	0.003 (0.10)	12 (26.4)	0.003 (0.10)	0	0	0	0	0	0	
2. Crystal growth from melt	Exp. Materials	0	0	13 (28.6)	0.006 (0.22)	65.5 (114.4)	0.048 (1.7)	0	0	0	0	0	0	
3. Biological Separation	Exp. Materials	0	0	240 (528.0)	0.24 (8.5)	0	0	0	0	0	0	0	0	
4. Preservation of Biochemicals	Exp. Materials	0	0	160 (352.0)	0.16 (5.7)	156 (343.2)	0.08 (2.85)	0	0	0	0	0	0	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
MS-1 Materials Science and Manufacturing (Continued)														
5. Physical process in fluids	Exp. Materials	0	0	80 (17.6)	0.01 (0.35)	0	0	0	0	0	0	0	0	
Support Equipment	None			0	0	0	0	61.8 (136	0.38 (13.5)	31 (68)	0.19 (6.8)	31 (68)	0.19 (6.8)	
MS-1 IIB (Station														
MS-1 IIIA Plus														
1. Crystal growth from vapor	Exp. Materials	0	0	10 (22.0)	0.019 (0.7)	10 (22.0)	0.019 (0.7)	0	0	0	0	0	0	
2. Free-casting from vapor	Exp. Materials	0	0	32 (70.4)	0.006 (0.22)	32 (70.4)	0.006 (0.22)	0	0	0	0	0	0	
Support Equipment	None	0	0	0	0	0	0	61.8 (136)	0.38 (13.5)	31 (68)	0.19 (6.8)	31 (68)	0.19 (6.8)	
MS-1 IIIC (Station)														
MS-1 IIIB Plus														
1. Metal matrix composites	Exp. Materials	0	0	72 (158.4)	0.014 (0.51)	48 (105.6)	0.01 (0.35)	0	0	0	0	0	0	
2. Controlled density materials	Exp. Materials	0	0	16 (35.2)	0.048 (1.7)	8 (17.6)	0.024 (0.85)	0	0	0	0	0	0	
3. Preparation of glasses	Exp. Materials	0	0	2.4 (5.28)	0.011 (0.4)	2.4 (5.28)	0.001 (0.40)	0	0	0	0	0	0	
Support Equipment	None	0	0	0	0	0	0	63.6 (140)	0.39 (14)	31.8 (70)	0.19 (7)	31.8 (70)	0.19 (7)	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
MS-1 IIID (Station														
MS-1 IIIC Plus														
1. Liquid Dispersions	Exp. Materials	0	0	72 (158.4)	0.024 (0.84)	48 (105.6)	0.01 (0.34)	0	0	0	0	0	0	
2. Class processing	Exp. Materials	0	0	3.6 (7.92)	0.001 (0.04)	3.6 (7.92)	0 (0.04)	0	0	0	0	0	0	
Support Equipment	None	0	0	0	0	0	0	63.6 (140)	0.39 (14)	31.8 (70)	0.19 (7)	31.8 (70)	0.19 (7)	
MS-1 IIIE (Station														
MS-1 IIID Plus														
1. Supercooling and homogeneous Nucleation	Exp. Materials			10 (22.0)	0.005 (0.17)	40 (88.0)	0.005 (0.17)	0	0	0	0	0	0	
Support Equipment	None	0	0	0	0	0	0	63.6 (140)	0.39 (14)	31.8 (70)	0.19 (7)	31.8 (70)	0.19 (7)	
MS-1 IIA (30-Day Shuttle)														
1. Crystal Growth from Solution	Exp. Materials	0	0	N/A	N/A	12 (26.4)	0.003 (0.10)	0	0	N/A	N/A	0	0	
2. Crystal Growth from Melt	Exp. Materials	0	0	N/A	N/A	104 (228.8)	0.10 (3.40)	0	0	N/A	N/A	0	0	
3. Biological Separation	Exp. Materials	0	0	N/A	N/A	0	0	0	0	N/A	N/A	0	0	
4. Preservation of Biochemicals	Exp. Materials	0	0	N/A	N/A	156 (343.2)	0.08 (2.85)	0	0	N/A	N/A	0	0	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
MS-1 IIA (30-Day Shuttle) (Continued)														
5. Physical processes in fluids	Exp. Materials	0	0	N/A	N/A	0	0	0	0	N/A	N/A	0	0	
Support Equipment	None	0	0	N/A	N/A	0	0	63.6 (140)	0.39 (14)	N/A	N/A	31.8 (70)	0.19 (7)	
MS-1 IIB (30-Day Shuttle)														
1. Metal Matrix Composites	Exp. Materials	0	0	N/A	N/A	48 (105.6)	0.01 (0.35)	0	0	N/A	N/A	0	0	
2. Controlled Density Materials	Exp. Materials	0	0	N/A	N/A	8 (17.6)	0.024 (0.85)	0	0	N/A	N/A	0	0	
3. Liquid Dispersions	Exp. Materials	0	0	N/A	N/A	23.6 (52.8)	0.005 (0.17)	0	0	N/A	N/A	0	0	
4. Preparation of Glasses	Exp. Materials	0	0	N/A	N/A	1.2 (2.64)	0.001 (0.02)	0	0	N/A	N/A	0	0	
5. Glass Processing	Exp. Materials	0	0	N/A	N/A	1.8 (3.96)	0.001 (0.02)	0	0	N/A	N/A	0	0	
Support Equipment	None	0	0	N/A	N/A	0	0	0.57 (126)	0.34 (12)	N/A	N/A	28.6 (63)	0.17 (6).	
MS-1 IIC (30-Day Shuttle)														
1. Crystal Growth from Vapor	Exp. Materials	0	0	N/A	N/A	10 (22.0)	0.019 (0.70)	0	0	N/A	N/A	0	0	
2. Supercooling and Honogeneous Nucleation	Exp. Materials	0	0	N/A	N/A	40 (88.0)	0.005 (0.17)	0	0	N/A	N/A	0	0.	
3. Free Casting of Metals	Exp. Materials	0	0	N/A	N/A	42.2 (93.5)	0.008 (0.29)	0	0	N/A	N/A	0	0	
Support Equipment	None	0	0	N/A	N/A	0	0	56 (124)	0.34 (12)	N/A	N/A	28.2 (62)	0.17 (6)	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
MS-1 IA Biological (5-Day Shuttle)														
1. Separation of Biologicals	Exp. Materials	90 (198)	0.096 (3.5)	N/A	N/A	90 (196)	0.096 (3.5)	N/A	N/A	N/A	N/A	N/A	N/A	
2. Preservation of Biologicals	Exp. Materials	60 (132)	0.059 (2.1)	N/A	N/A	60 (132)	0.059 (2.1)	N/A	N/A	N/A	N/A	N/A	N/A	
MS-1 IB Levitation Experiments (5-Day Shuttle)														
1. Glasses	Exp. Materials	4.0 (8.8)	0.13 (0.46)	N/A	N/A	4.0 (8.8)	0.13 (0.46)	N/A	N/A	N/A	N/A	N/A	N/A	
2. Supercooling	Exp. Materials	10 (22.0)	0.005 (0.17)	N/A	N/A	10 (22.0)	0.005 (0.17)	N/A	N/A	N/A	N/A	N/A	N/A	
3. Some Crystals	Exp. Materials	10 (22.0)	0.005 (0.17)	N/A	N/A	10 (22.0)	0.005 (0.17)	N/A	N/A	N/A	N/A	N/A	N/A	
MS-1 IC Furnace Experiments (5-Day Shuttle)														
1. Composite	Exp. Materials	60 (132.0)	0.12 (0.42)	N/A	N/A	60 (132.0)	0.12 (0.42)	N/A	N/A	N/A	N/A	N/A	N/A	
2. Directional Solidification	Exp. Materials	20 (44.0)	0.059 (2.1)	N/A	N/A	20 (44.0)	0.059 (2.1)	N/A	N/A	N/A	N/A	N/A	N/A	
MS-1 ID Small and Low Temperature (5-Day Shuttle)														
1. Physics of Fluids	Exp. Materials	3.0 (6.6)	0.004 (0.13)	N/A	N/A	3.0 (6.6)	0.004 (0.13)	N/A	N/A	N/A	N/A	N/A	N/A	
2. Zone Refining	Exp. Materials	7.5 (16.5)	0.003 (0.12)	N/A	N/A	7.5 (16.5)	0.003 (0.12)	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
T-1 Contamination Measurements														
T-1A Experimental														
Station	Film	1.8 (4)	0.011 (0.4)	0.9 (2)	0.006 (0.2)	0.9 (2)	0.006 (0.2)	6.36 (14)	0.024 (0.84)	3.18 (7)	0.012 (0.42)	3.18 (7)	0.012 (0.42)	
	Samples (Optical and Thermal)	0	0	0.9 (2)	0.011 (0.4)	0.9 (2)	0.011 (0.4)							
	N_2	4.54 (10)	0.018 (0.64)	2.27 (5)	0.009 (0.32)	0	0							
30-Day Shuttle	Film	6.8 (15)	0.042 (1.5)	N/A	N/A	6.8 (15)	0.042 (1.5)	3.18 (7)	0.012 (0.42)	N/A	N/A	3.18 (7)	0.012 (0.42)	
5-Day Shuttle	Film	4.5 (10)	0.028 (1)	N/A	N/A	4.5 (10)	0.028 (1)	N/A	N/A	N/A	N/A	N/A	N/A	
	N_2	0.45 (1)	0.002 (0.06)	N/A	N/A	0	0							
T-1B Monitor														
Station	Samples (Optical and Thermal	0	0	0.9 (2)	0.011 (0.4)	0.9 (2)	0.011 (0.4)	1.36 (3.0)	0.021 (0.75)	0.68 (1.5)	0.011 (0.36)	0.68 (1.5)	0.011 (0.38)	
30-Day Shuttle		0	0	N/A	N/A	0	0	0.68 (1.5)	0.011 (0.38)	N/A	N/A	0.68 (1.5)	0.011 (0.38)	
5-Day Shuttle		0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
T-2 Fluid Management														
T-2A Long-Term Storage of Cryogenics														
Station	Liquid Hydrogen	0	0	200 (435)	4.9 (174)	0	0	10.2 (27)	0.007 (0.25)	10.2 (27)	0.007 (0.25)	10.2 (27)	0.007 (0.25)	Spares are electronic and mechanical parts
30-Day Shuttle	None	0	0	N/A	N/A	0	0	10.2 (27)	0.007 (0.25)	N/A	N/A	10.2 (27)	0.007 (0.25)	Spares are Engineering and mechanical parts
5-Day Shuttle	Not a Logical Candidate													
T-2B Short-Term Cryogenics														
Station	Liquid Hydrogen	0	0	250 (550)	6.1 (217)	0	0	9.1 (20)	0.007 (0.25)	0	0	9.1 (20)	0.007 (25)	Spares are electronic and mechanical parts
30-Day Shuttle	Liquid Hydrogen	0	0	N/A	N/A	0	0	9.1 (20)	0.007 (0.25)	N/A	N/A	9.1 (20)	0.007 (25)	Spares are electronic and mechanical parts
5-Day Shuttle	None	0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
T-2C Slush Propellant														
Station	None	0	0	0	0	0	0	16.4 (36.0)	0.012 (0.45)	0	0	16.4 (36.0)	0.012 (0.45)	Spares are electronic and mechanical parts
30-Day Shuttle	None	0	0	N/A	N/A	0	0	16.4 (36.0)	0.012 (0.45)	N/A	N/A	16.4 (36.0)	0.012 (0.45)	Spares are electronic and mechanical parts
5-Day Shuttle	None	0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	

Table 2-4
LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 $(Ft^3$	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
T-2D Non-Cryogenics (1)														
Station	None (Required only if Alternate Small Fluid Tanks are used)	0	0	0	0	0	0	8 (17.5)	0.006 (0.21)	0	0	8 (17.5)	0.006 (0.21)	Spares are electronic and mechanical parts
30-Day Shuttle	None (Required only if Alternate Small Fluid Tanks are used)	0	0	N/A	N/A	0	0	8 (17.5)	0.006 (2.1)	N/A	N/A	8 (17.5)	0.006 (0.21)	Spares are electronic and mechanical parts
5-Day Shuttle	None	0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
T-2E Non-Cryogenics (2)														
Station	None	0	0	0	0	0	0	11 (32)	0.014 (0.39)	0	0	11 (17.5)	0.014 (0.39)	Spares are electronic and mechanical parts
30-Day Shuttle	None	0	0	N/A	N/A	0	0	11 (32)	0.014 (0.39)	N/A	N/A	11 (32)	0.014 (0.39)	Spares are electronic and mechanical parts
5-Day Shuttle	None	0	0	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
T-3 EVA														
T-3A Astronaut Maneuvering Unit														
Station	Oxygen (LSS and Propulsion)	16 (36)	0.024 (0.84)	8 (18)	0.012 (0.42)	0	0	38.6 (85.6)	0.4 (14.3)	2.4 (5.3)	0.012 (0.4)	2.4 (5.3)	0.012 (0.4)	Initial spares includes spare O_2 tank
	Film (16 mm)	17.2 (38)	0.006 (0.24)	8.6 (19)	0.003 (0.1)	8.6 (19)	0.003 (0.1)							
	Video Tape (25 mm)	14.4 (32)	0.003 (0.1)	0	0	14.4 (32)	0.003 (0.1)							Assume 4 reels with dump to ground after each AMU flight on missions over 5 days long.

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

FPE Potential Subgroups \ Requirements	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
T-3A Astronaut Maneuvering Unit (Continued)														
30-Day Shuttle	Same	Same	Same	N/A	N/A	Same	Same	2.4 (5.3)	0.012 (0.4)	N/A	N/A	2.4 (5.3)	0.012 (0.4)	
5-Day Shuttle	Oxygen (LSS and Propulsion)	1.7 (4.0)	0.003 (0.1)	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
	Film (16 mm)	1.9 (4.2)	0.001 (0.026)	N/A	N/A	1.9 (4.2)	0.001 (0.026)							
	Video Tape (25 mm)	1.6 (3.6)	- (0.011)	N/A	N/A	1.6 (3.6)	- (0.011)							
T-3B Maneuverable Work Platform														
Station	Hydrazine	250 (550)	0.17 (6)	250 (550)	0.17 (6)	0	0	58 (128)	0.24 (8)	29 (64)	0.12 (4)	29 (64)	0.12 (4)	
	Oxygen	34 (75)	0.05 (1.5)	34 (75)	0.05 (1.5)	0	0							
	Emergency O_2	1.5 (3)	0.003 (0.1)	1.5 (3)	0.003 (0.1)	0	0							
	LiOH	22.5 (50)	0.1 (3.5)	22.5 (50)	0.1 (3.5)	0	0							
	H_2O	135 (300)	0.1 (3.5)	135 (300)	0.1 (3.5)	0	0							
30-Day Shuttle	Same	Same	Same	N/A	N/A	0	0	29 (64)	0.12 (4)	N/A	N/A	29 (64)	0.12 (4)	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
T-3B Maneuverable Work Platform (Continued)														
5-Day Shuttle	Hydrazine	25 (55)	0.017 (0.6)	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
	Oxygen	3.4 (7.5)	0.005 (0.15)	N/A	N/A	0	0							
	Emergency O_2	0.15 (0.3)	- (0.01)	N/A	N/A	0	0							
	LiOH	2.25 (5.0)	0.01 (0.35)	N/A	N/A	0	0							
	H_2O	13.5 (30)	0.01 (0.35)	N/A	N/A	0	0							
T-4 Advanced Spacecraft Systems Tests														
T-4A Long Duration														
Station	None	0	0	0	0	0	0	8 (17)	0.014 (0.5)	4 (8.5)	0.007 (0.25)	4 (8.5)	0.007 (0.25)	Spares are electronic and mechanical parts
30-Day Shuttle	Not a Logical Candidate													
5-Day Shuttle	Not a Logical Candidate													

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
T-4B Medium Duration														
Station	None	0	0	0	0	0	0	12 (26)	0.017 (0.6)	6 (13)	0.008 (0.3)	6 (13)	0.008 (0.3)	Spares are electronic and mechanical parts
30-Day Shuttle	Not a Logical Candidate													
5-Day Shuttle	Not a Logical Candidate													
T-4C Short Duration														
Station	ACS Fuel	0	0	75 (165)	0.08 (3)	0	0	10 (22)	0.014 (0.5)	5 (11)	0.007 (0.25)	5 (11)	0.007 (0.25)	Spares are electronic and mechanical parts
30-Day Shuttle	None	0	0	N/A	N/A	0	0	10 (22)	0.014 (0.5)	N/A	N/A	10 (22)	0.014 (0.5)	Spares are electronic and mechanical parts
5-Day Shuttle	Not a Logical Candidate													
T-5 Teleoperations														
T-5A Initial Flight Experiment														
All Missions	Cold Gas (N$_2$)	42 (90)	1.26 (45)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
T-5B Functional Manipulation Experiment														
Station	Cold Gas (N^2)	30 (67)	0.9 (32)	30 (67)	0.45 (16)	0	0	27 (60)	0.17 (6.2)	13.5 (30)	0.08 (3.1)	13.5 (30)	0.08 (3.1)	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements		Operational Consumables						Spares and Maintenance Consumables						
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
FPE Potential Subgroups	Type	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Remarks
T-5B Functional Manipulation Experiment (Continued)														
30-Day Shuttle		Same	Same	N/A	N/A	0	0	13.5 (30)	0.08 (3.1)	N/A	N/A	13.5 (30)	0.08 (3.1)	
5-Day Shuttle		15 (34)	0.5 (16)	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
T-5C Ground Control Experiment														
Station and 30-Day Shuttle	Cold Gas (N_2)	65 (150)	2.0 (71)	0	0	0	0	25 (56)	0.16 (5.7)	0	0	25 (56)	0.16 (5.7)	
5-Day Shuttle		16 (37)	0.5 (18)	N/A	N/A	0	0	N/A	N/A	N/A	N/A	N/A	N/A	
Life Sciences														
LS-ST/A Minimal Medical Research Facility (Station)	Electronic Spares	-	-	-	-	-	-	13 (28.6)	0.1 (3.5)	6 (13)	0.06 (2.1)	6 (13)	0.06 (2.1)	Spares @ 4% Launch Wt. and Vol.
	Skin Electrode Kit	1 (2.2)	0.003 (0.1)	1 (2.2)	0.003 (0.1)	1 (2.2)	0.003 (0.1)	-	-	-	-	-	-	Resupply Spares @ 2%.
	Blood, Feces, Urine Samples	-	-	-	-	12 (26)	0.01 (0.3)	-	-	-	-	-	-	Assume disposable electrodes. Electrode kit contains skin cleanser (need 30 resupply)
LS-ST/B Minimal Life Science Facility (Station)	Gas, Food, Charts, Containers, Samples	56 (123)	0.2 (6)	50 (110)	0.15 (5.6)	0.09 (19.4)	0.02 (0.88)	20 (44)	0.04 (2)	20 (44)	0.04 (2)	4.5 (86)	0.03 (1.2)	

Table 2-4

LOGISTIC SUPPORT REQUIREMENTS (Continued)

Requirements / FPE Potential Subgroups	Type	Operational Consumables						Spares and Maintenance Consumables						Remarks
		Initial		Resupply (30 Days)		Return (30 Days)		Initial		Resupply (30 Days)		Return (30 Days)		
		Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	Wt Kg (lb)	Vol M^3 (Ft^3)	
LS-ST/C Interim Life Science Facility (Station)	Gas, Food, Charts, Containers, Samples	85 (191)	0.2 (9.3)	77.5 (170)	0.23 (8.7)	0.14 (30)	0.04 (1.4)	31 (68.2)	0.06 (3.1)	31 (68.2)	0.06 (3.1)	7.1 (133)	0.05 (1.9)	
LS-ST/D Dedicated Life Science Facility (Station)	Gas, Food, Charts, Containers, Samples	140 (308)	0.4 (15)	125 (275)	0.38 (14)	0.22 (48.5)	0.06 (2.2)	50 (110)	0.1 (5)	50 (110)	0.1 (5)	11.4 (215)	0.08 (3)	
LS-SH/A 5-Day Life Science Facility (Shuttle)	Equipment Spares	N/A	N/A	N/A	N/A	N/A	N/A	20 (44)	0.04 (2)	N/A	N/A	20 (44)	0.04 (2)	
LS-SH/B 30-Day Life Science Facility (Shuttle)	Equipment Spares	N/A	N/A	N/A	N/A	N/A	N/A	31 (68.2)	0.06 (3.1)	N/A	N/A	31 (68.2)	0.06 (2)	

Table 2-5

EXPERIMENT FLIGHT SCHEDULE—CASE 534G

```
                  ISS                 GSS
          ********************************************************************************
FPE / QRTS      8       16      24       32       40      48      56       64      72      80
          ********************************************************************************

LS-1A     XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
T-4B      XX
T-4A      XXXXXXXXX
CH-1A     -AAAA
ES-1G     --AAAAAAAAAAAAAA
T-4C      --XX
P-1D      -----XXX
P-4B      -----XXX
T-1B      ------XXXXX
T-1A      ------XXXXX
T-3A      ---------XX
P-4A      ---------XX
CH-1B     ---------AA
MS-3A     ------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MS-3B     ------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MS-3C     ------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MS-3D     ------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
MS-3E     ------------XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
T-5A      ------------XXX
T-3B      ------------AAA
P-3C      ------------X
A-        -------------- AAAAAAAA
P-1B      ------------------XXXX
P-1C      ------------------XXXX
P-1E      ------------------XXXXXXXX
P-4C      ------------------XXXX
P-1A      ------------------XXXX
P-2A      ----------------------- XXXX
LS-1B     -----------------------XX
T-5B      ------------------------ XX
P-2BB     ------------------------ AAAA
ES1AA     --------------------------AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
A-6       ----------------------------AAAAAAAAAAAAAAAAAAAAAAAAA
A-4A      ---------------------------- AAAAAAAAAAAA
T-5C      -------------------------------XX
A-4B      -------------------------------AAAAAAAAAA
A-5B      --------------------------------AAAAAAAAAAAAAAAAAAAAAA
CN-1      -------------------------------- AA
LS-1C     --------------------------------AAAAAAA
A-5A      --------------------------------- FFFFFFFFFFFFFFFFFFFFFF
A-30C     -----------------------------------FFFFFFFFFFFFF
A-2A      ------------------------------------- FFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
```

Table 2-6
RAM DELIVERY WEIGHT

RAM	FPE	Delivery Weight kg	Delivery Weight (lb)
R-1	CN-1A	6,755	(14,891)
R-2	ES-1G	7,949	(17,525)
R-1A	CN-1B	6,784	(14,955)
R-3	T-3B	7,804	(17,205
R-4	A-4C	6,634	(14,626)
R-5	LS-1B	1,212	(2,673)
R-6	P-2BB	8,490	(18,717)
R-7	ES-1AA	8,957	(19,747)
R-8	A-6	8,984	(19,806)
R-9	A-4A	9,072	(20,000)
R-10	A-4B	6,767	(14,918)
R-11	A-5B	8,263	(18,216)
R-12	CN-1	7,042	(15,525)
R-5A	LS-1C	1,869	(4,121)
R-13	A-5A	8,589	(18,936)
R-14	A-3CC	6,313	(13,917)
R-15	A-2A	7,775	(17,141)

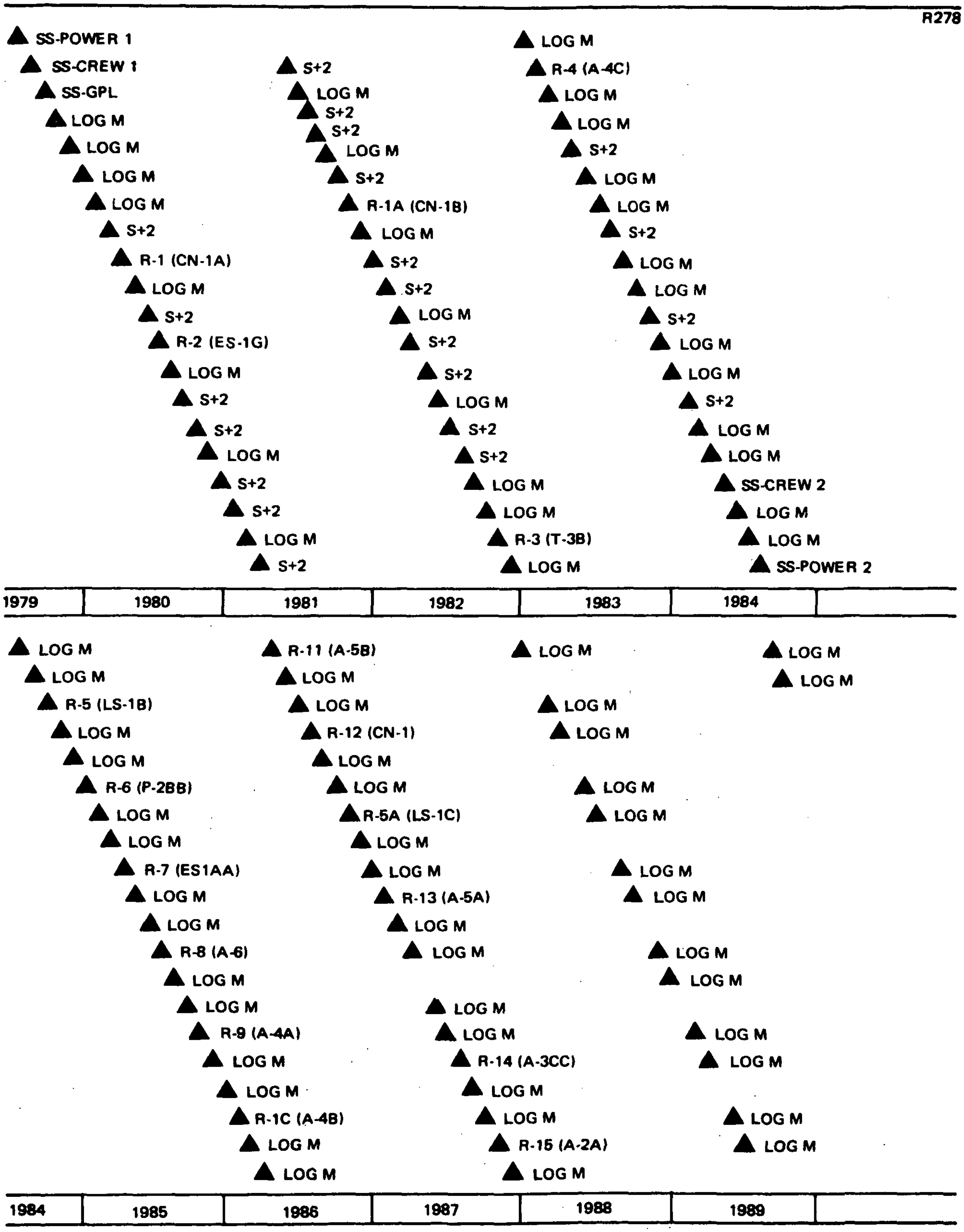

Figure 2-1. Launch Schedule for Case 534-G

Table 2-7

SPACE STATION FLIGHT SCHEDULE

Case 534G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
1	0	1-Oct-79	SS-Power-1		18,322
2	0	31-Oct-79	SS-Crew-1		17,242
3	0	30-Nov-79	SS-GPL		17,630
4	1	30-Dec-79	2 Shuttle passengers	684	
			Logistics Module (LM)	5,969	
			Station Resupply (SR)	8,932	
			Experiment Resupply (ER)	788	16,373
5	1	29-Jan-80	(Same as previously scheduled flight)		16,373
6	1	28-Feb-80	(Same as previously scheduled flight)		16,373
7	2	29-Mar-80	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	824	14,977
8	2	28-Apr-80	2 Shuttle passengers		684
9	2	28-May-80	R-1 (CN-1A) + 2 SP	684	15,575
				14,891	
10	3	27-Jun-80	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	1,962	
			ER (Advance)	1,276	17,391

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 534G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
11	3	27-Jul-80	2 Shuttle passengers		684
12	3	26-Aug-80	R-2 (ES-1G) + 2 SP	17,527	18,211
				684	
13	4	25-Sept-80	2 SP	684	
			LM	5,969	
			SR	7,500	
			EP	3,400	17,553
14	4	25-Oct-80	2 Shuttle passengers		684
15	4	24-Nov-80	2 Shuttle passengers		684
16	5	24-Dec-80	2 SP	684	
			LM	5,969	
			SR	7,500	16,865
			ER	2,712	16,165
17	5	23-Jan-81	2 Shuttle passengers		684
18	5	22-Feb-81	2 Shuttle passengers		684
19	6	24-Mar-81	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	2,104	16,257
20	6	23-Apr-81	2 Shuttle passengers		684
21	6	23-May-81	2 Shuttle passengers		684

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
22	7	22-Jun-81	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	2,104	16,257
23	7	22-Jul-81	2 Shuttle passengers		684
24	7	21-Aug-81	2 Shuttle passengers		684
25	8	20-Sept-81	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	4,190	18,343
26	8	20-Oct-81	2 Shuttle passengers		684
27	8	19-Nov-81	R-1A (CN-1B)	14,955	
			2 SP	684	15,639
28	9	19-Dec-81	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	2,070	16,223
29	9	18-Jan-82	2 Shuttle passengers		684
30	9	17-Feb-82	2 Shuttle passengers		684
31	10	19-Mar-82	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	2,070	16,223

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
32	10	18-Apr-82	2 Shuttle passengers		684
33	10	18-May-82	2 Shuttle passengers		684
34	11	17-Jun-82	2 SP	684	
			LM	5,969	
			SR	7,500	
			ER	2,070	16,223
35	11	17-Jul-82	2 Shuttle passengers		684
36	11	16-Aug-82	2 Shuttle passengers		684
37	12	15-Sept-82	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	3,794	14,197
38	12	15-Oct-82	Same as Flight No. 37		14,197
39	12	14-Nov-82	R-3 (T-3B)	17,025	
			2 SP	684	17,700
40	13	14-Dec-82	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	4,512	14,915
41	13	13-Jan-83	Same as Flight No. 40		14,915
42	13	12-Feb-83	R-4 (A-4C)	14,626	
			2 SP	384	15,010

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
43	14	14-Mar-83	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	4.401	14,804
44	14	13-Apr-83	Same as Flight No. 43		14,804
45	14	13-May-83	2 Shuttle passengers		684
46	15	12-Jun-83	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	4,401	14,804
47	15	12-Jul-83	Same as Flight No. 46		14,804
48	15	11-Aug-83	2 Shuttle passengers		684
49	16	10-Sept-83	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	5,202	15,605
50	16	10-Oct-83	Same as Flight No. 49		15,605
51	16	9-Nov-83	2 Shuttle passengers		684
52	17	9-Dec-83	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	3,110	13,513

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
53	17	8-Jan-84	Same as Flight No. 52		13,513
54	17	7-Feb-84	2 Shuttle passengers		684
55	18	8-Mar-84	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	3,110	13,513
56	18	7-Apr-84	Same as Flight No. 55	15,931	13,513
57	18	7-May-84	SS Crew - 2		
			2 SP	684	16,615
58	19	6-Jun-84	Same as Flight No. 59		17,378
59	19	6-Jul-84	2 SP	684	
			LM	5,969	
			SR	3,750	
			ER	6,975	17,378
60	19	5-Aug-84	SS-Power-2	17,330	
			2 SP	684	18.014
61	20	4-Sept-84	2 SP	684	
			LM	5,969	
			SR	9,300	
			ER	2,203	19,950
62	20	4-Oct-84	Same as Flight No. 61		19,950
63	20	3-Dec-84	R-5 (LS-1B)		1,934

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
64	21	3-Dec-84	CCN	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
65	21	2-Jan-85	Same as Flight No. 64		20, 000
66	21	1-Feb-85	R-6 (P-2BB)		18, 717
67	22	3-Mar-85	CCM	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
68	22	2-Apr-85	(Same as previously scheduled flight)		
69	22	2-May-85	R-7 (ES1AA)		19, 747
70	23	1-Jun-85	Logistic Module	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
71	23	1-Jul-85	(Same as previously scheduled flight)		
72	23	31-Jul-85	R-8 (A-6)		19, 806
73	24	30-Aug-85	LM	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
74	24	29-Sept-85	(Same as previously scheduled flight)		

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
75	24	29-Oct-85	R-9 (A-4A)		20, 000
76	25	28-Nov-85	LM	3, 447	
			SR	6, 850	
			ER	4, 703	20, 000
77	25	28-Dec-85	(Same as previously scheduled flight)		
78	25	27-Jan-86	R-10 (A-4B)		14, 918
79	26	26-Feb-86	LM	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
80	26	28-Mar-86	(Same as previously scheduled flight)		
81	26	27-Apr-86	R-11 (A-5B)		18, 216
82	27	27-May-86	LM	8, 447	
			SR	6, 850	
			ER	4, 703	20, 000
83	27	26-Jun-86	(Same as previously scheduled flight)		
84	27	26-Jul-86	R-12 (CN-1)		15, 525
85	28	25-Aug-86	LM	8, 447	
			SR	6, 850	
			ER	3, 654	18, 951

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
86	28	24-Sept-86	(Same as previously scheduled flight)		18, 951
87	28	24-Oct-86	R-5A (LS-1C)		3, 382
88	29	23-Nov-86	LM	8, 447	
			SR	6, 850	
			ER	3, 751	19, 048
89	29	23-Dec-86	(Same as previously scheduled flight)		
90	29	22-Jan-87	R-13 (A-5A)		18, 936
91	30	21-Feb-87	LM	8, 447	
			SR	6, 850	
			ER	4, 116	19, 413
92	30	23-Mar-87	(Same as previously scheduled flight)		
93	31	22-May-87	(Same as previously scheduled flight)		
94	31	21-Jun-87	(Same as previously scheduled flight)		
95	31	21-Jul-87	R-14 (A-3CC)		13, 917
96	32	20-Aug-87	LM	8, 447	
			SR	6, 850	
			ER	4, 132	19, 429

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
97	32	19-Sept-87	(Same as previously scheduled flight)		19,429
98	32	19-Oct-87	R-15 (A-2A)		17,141
99	33	18-Nov-87	LM	8,847	
			SR	6,850	
			ER	4,457	19,754
100	33	18-Dec-87	(Same as previously scheduled flight)		
101	34	16-Feb-88	(Same as previously scheduled flight)		
102	34	17-Mar-88	(Same as previously scheduled flight)		
103	35	16-May-88	(Same as previously scheduled flight)		
104	35	15-Jun-88	(Same as previously scheduled flight)		
105	36	14-Aug-88	(Same as previously scheduled flight)		
106	36	13-Sept-88	(Same as previously scheduled flight)		

Table 2-7

SPACE STATION FLIGHT SCHEDULE (Continued)

Case 543G

Flight Number	Quarter	Date	Payload Description	Weight	Total Weight (lb)
107	37	12-Nov-88	(Same as previously scheduled flight)		19,754
108	37	12-Dec-88	(Same as previously scheduled flight)		
109	38	10-Feb-89	(Same as previously scheduled flight)		
110	38	12-Mar-89	(Same as previously scheduled flight)		
111	39	11-May-89	(Same as previously scheduled flight)		
112	39	10-Jun-89	(Same as previously scheduled flight)		
113	40	9-Aug-89	(Same as previously scheduled flight)		
114	40	8-Sept-89	(Same as previously scheduled flight)		

Section 3

CONCEPT SELECTION

A principal task of the Space Station study was selection of the mode of crew transportation and cargo delivery. The selected mode is primarily dependent on the size of the crew and the orbital stay time. During the ISS phase of operation, the crew size is six men; during the GSS phase of operation, 12. While the on-orbit staytime of the Space Station crews has not been firmly established, an average stay time of 90 days has been used for planning purposes.

The basic alternative means of crew transportation are (1) in the orbiter crew compartment, and (2) in a module housed in the orbiter cargo bay.

3.1 ORBITER CREW ACCOMMODATION

A primary factor in the selection of the crew accommodation mode is the crew capacity of the Orbiter. The requirement in the Phase B Shuttle definition study consisted of two Orbiter crews and two mission specialists (or Space Station crew). An investigation of the MDAC Shuttle design, however, indicated that additional crewmen could be accommodated; i. e., the cabin volume and crew consumables would accommodate more than two Space Station crewmen, at least for short duration logistics missions. Figure 3-1 shows a concept for accommodating six men (plus Orbiter crew) in the cabin. In this concept, two crewmen are located in the normal position, two are accommodated in the airlock (since the airlock is not required for Space Station missions), one occupies the area normally occupied by food management facilities, and another occupies the area normally reserved for wase management facilities. The accommodations shown in Figure 3-1 are considered adequate for Space Station crews since the duration of the logistics mission is short; maximum ascent phasing duration is 25 hours, maximum descent phasing is also 25 hour not considering the reduction due to orbiter cross-range capability and for return to KSC (one of 15 alternate

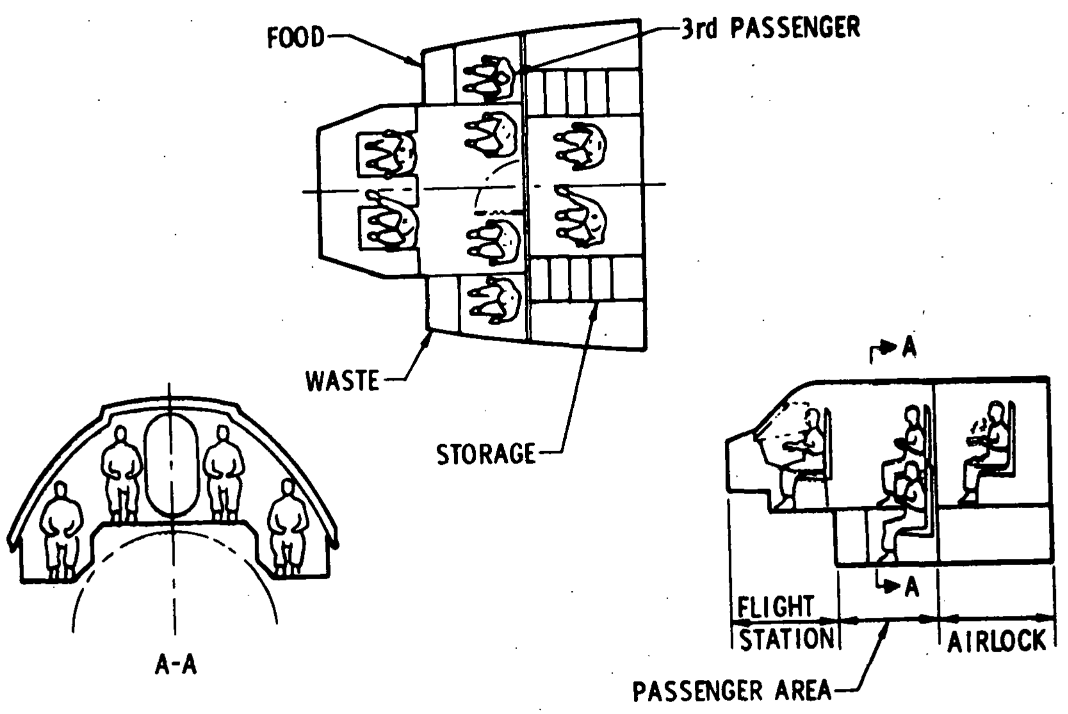

Figure 3-1. Six-Passenger Accommodation in Orbiter

sites can be reached with 3 hours phasing or less). The nominal ascent and descent mission requires less phasing than the maximums indicated. The maximum total (up and down) duration for an aborted mission is approximately 40 hours.

Accommodation of six men (plus two Orbiter crew) would require 16.6 mandays of consumables (8 men, 50 hours), whereas the Shuttle system is designed to provide 28 mandays (4 men, 7 days). Table 3-1 shows the impact on the Orbiter vehicle of additional crew accommodation in comparison with the baseline of 2 plus 2. This impact is shown in terms of Orbiter scar weight (that weight which is non-removable from the Shuttle) and additional weight chargeable to payload. The latter includes the weight of such items as the crew, seats, consumables, and other support provisions. As seen from Table 3-1, minimal scar weight is required to accommodate up to six passengers. The weight chargeable to payload for six passengers is 898 kg (1, 980 lb). Total weight for six passengers is 938 kg (2, 068 lb). The weight chargeable to payload in the case where six passengers are carried in a Crew Cargo Module exceeds 938 kg (2, 068 lb) (a comparison of the payload impact of a six-man Crew Cargo Module relative to a cargo only module is given in Section 3.2). From the standpoint of payload impact, therefore, the preferred approach is to transport six men in the Orbiter cabin. This is also the preferred approach from a cost-standpoint since it does not require development of a Crew Cargo Module (also discussed in Section 3.2).

3.2 EVALUATION OF OPTIONS

Because of the uncertainty of the final design characteristics of the Space Shuttle, however, NASA/MSFC directed that Shuttle crew sizes beyond 2 plus 2 be deleted from further consideration and that the Space Station Program define a logistics system within this constraint. Two options were therefore evaluated for the ISS phase. These are shown in Table 3.2. together with the impact of each.

The impact of rotating two men in the Shuttle on 30-day intervals increases operational costs due to the increased frequency of Shuttle flights. In addition, it is necessary to rotate crews on RAM delivery flights since two

Table 3-1

PAYLOAD WEIGHT PENALTY AS A FUNCTION OF THE NUMBER OF ORBITER PASSENGERS

(2-Day Mission)

Baseline: 2 Crewmen and 2 Passengers

No. of Passengers	Total Weight kg	(lb)	Orbiter Scar wt kg	(lb)	Weight Chargeable to Payload kg	(lb)
2	299	(660)		0	299	(660)
3	459	(1,012)	9.8	(22)	449	(990)
4	625	(1,378)	26	(58)	599	(1,320)
6	938	(2,068)	40	(88)	898	(1,980)
10	2,355	(5,191)	515	(1,135)	1,840	(4,056)
12	3,674	(5,895)	535	(1,179)	2,139	(4,716

Table 3-2

ASSESSMENT OF CREW ROTATION OPTIONS FOR ISS

Option	Impact
1. Rotate 2 men in Shuttle every 30 days	● Higher Shuttle operations costs due to higher frequency ● Requires crew rotation on RAM flights
2. Rotate 6 men in Crew Cargo Module every 90 days	● Requires development of crew support module ● Reduced cargo capability per flight ● Complicated Shuttle interface (life support, power and emergency egress)

men must be rotated on every flight due to the limitation on Shuttle flights of once every 30 days. With this option, a rescue module capability is required for emergency return of the six-man crew within 96 hours of an emergency. It is important to differentiate between a requirement to rescue six men and normal transportation of a six-man crew; design of a module to rescue six men does not automatically provide the capability to transport six men in normal operations. Differences in design requirement arise from the fact that the rescue module is manned only during the descent phase of a mission and that emergency rescue is a contingency operation only (i. e., the probability of emergency rescue during 10 years of Space Station operation is low).

Table 3-3 shows the impact on Logistics Module subsystems for utilization of the module for six-man crew rotation. Note that the impacts shown in Table 3-3 are relative to a Logistics Module which has the inherent capability for rescue of six men. A significant impact to the structural-mechanical subsystem is the emergency egress hatch in the pressure shell/radiator assembly. This hatch is required for egress on the launch pad and on the ground (following landing) in emergency situations. IVA suits are included under crew accommodations. These are required during a Shuttle docking operation with the Crew Cargo Module since the module is occupied. An accident during this operation could result in loss of pressure in the module. IVA suits provide protection for the crew in this event.

The impacts listed in Table 3-3 result in significant differences in the weight and hence cargo carrying capability of a manned module in comparison with an unmanned module. Table 3-4 shows a comparison of the weight of a Crew Cargo Module and a cargo-only module. The additional empty weight of a Crew Module reduces its cargo carrying capability relative to a cargo-only module by 1,159 kg (2,553 lb).

Table 3-5 shows the costs of a six-man crew cargo module relative to an unmanned logistics module (unmanned module costs include the DDT&E necessary to utilize the module for rescue). Qualification of systems to the Shuttle environment (man-rating of the structure to Shuttle loads for example) is a significant additional cost. The total difference in DDT&E is

Table 3-3

DESIGN REQUIREMENTS OF A SIX-MAN CREW CARGO MODULE RELATIVE TO A CARGO-ONLY MODULE

Structure

1) 5-ft length increase
2) Emergency egress hatch in pressure shell/radiator

EC/LS

1) O_2/N_2 supply, CO_2 removal, humidity control or interface with Shuttle for air supply and return
2) Water and freon boiler system for heat rejection during extended orbital phasing and re-entry

Crew Accommodations

1) Seats
2) Hygiene compartment
3) IVA suits
4) Critical-parameter display

Data Management

1) Monitoring od crew critical parameters

Shuttle Interfaces

1) Emergency hatch in cargo bay door
2) Electrical power (500 watts; 30 kwh)

$24.8M and in production is $14.1M per article or $56.4M for four flight articles. In the case of a logistics-only module, one flight article is designed for use as a rescue flight article. The cost difference between these two approaches is therefore $71M. Note that these costs do not include Shuttle costs, but that additional costs would be incurred for the Shuttle to accommodate a Crew Cargo Module. For example, means of emergency egress from the cargo bay and ground support systems for rapid transport of the crew to a safe area would be required. The lowest initial program cost is therefore achieved by development of a cargo-only module.

Figure 3-2 shows a cumulative cost comparison. The cost difference at IOC reflects the cost differences just described. The difference in the expenditure rate following IOC reflects the lower Shuttle operations costs for the Crew Cargo Module option.

Table 3-4
WEIGHT COMPARISON

	Crew Cargo Module		Logistics-Only Module	
	kg	(lb)	kg	(lb)
Structure	1,349	(2,974)	1,201	(2,647)
Meteoroid and Thermal Protection	544	(1,200)	501	(1,104)
Docking	279	(616)	279	(616)
Propulsion	72	(158)	72	(158)(1)
Power Distribution and Electronics	363	(800)	317	(698)(2)
Environmental Control	521	(1,148)	336	(740)
Crew Support and Interiors	220	(485)	197	(435)(3)
Empty Weight	3,348	(7,381)	2,902	(6,398)
Crew and Crew Support	694	(1,530)	0	
Residuals, Reserves, Flight Losses	127	(280)	109	(240)(4)
Cargo	4,902	(10,809)	6,061	(13,362)
Total	9,072	(20,000)	9,072	(20,000)

(1) Tanks, Lines
(2) Wiring, RDAU's, etc.
(3) Handrails, restraints, lighting, fans, ducting, etc., for on-orbit atmosphere conditioning
(4) Trapped atmosphere

Table 3-5

COST* OF SIX-MAN MODULE RELATIVE TO UNMANNED MODULE

	DDT&E ($M)	Production ($M)/Unit
Qualification Test	10.0	--
ECLS (Includes Thermal Control)	1.5	2.2
Emergency Hatch	3.7	2.2
Crew Accommodations	4.5	5.5
Caution/Warning (Sensors, Displays)	1.5	1.8
Subsystem Integration	3.6	2.4
TOTAL	$24.8	$14.1
Estimated Unmanned LM Cost	40.0	10.0
	$64.8	$24.1

*Project Level

Since minimum initial cost to IOC is the overriding Study guideline, the selected approach for planning and costing purposes is to rotate Space Station crews two at a time in the Shuttle with flights every 30 days. It should be noted, however, that the design of the Space Station does not preclude the utilization of a Crew Cargo Module, and that this approach could be readily implemented should NASA so elect.

3.3 GSS LOGISTICS SYSTEM

The selected approach for rotation of the GSS crews is use of a crew cargo module. Crew rotation is accomplished six men at a time and therefore the CCM is sized to accommodate six men. Design of the CCM is very similar to the CCM as defined in the 33 ft Space Station study except that docking by the orbiter vehicle is utilized (in the previous study, the CCM concept is capability to affect rendezvous and docking). The current CCM concept is highly common with the Logistics Module and it is therefore feasible to convert logistics modules to CCM's at the time of GSS operations.

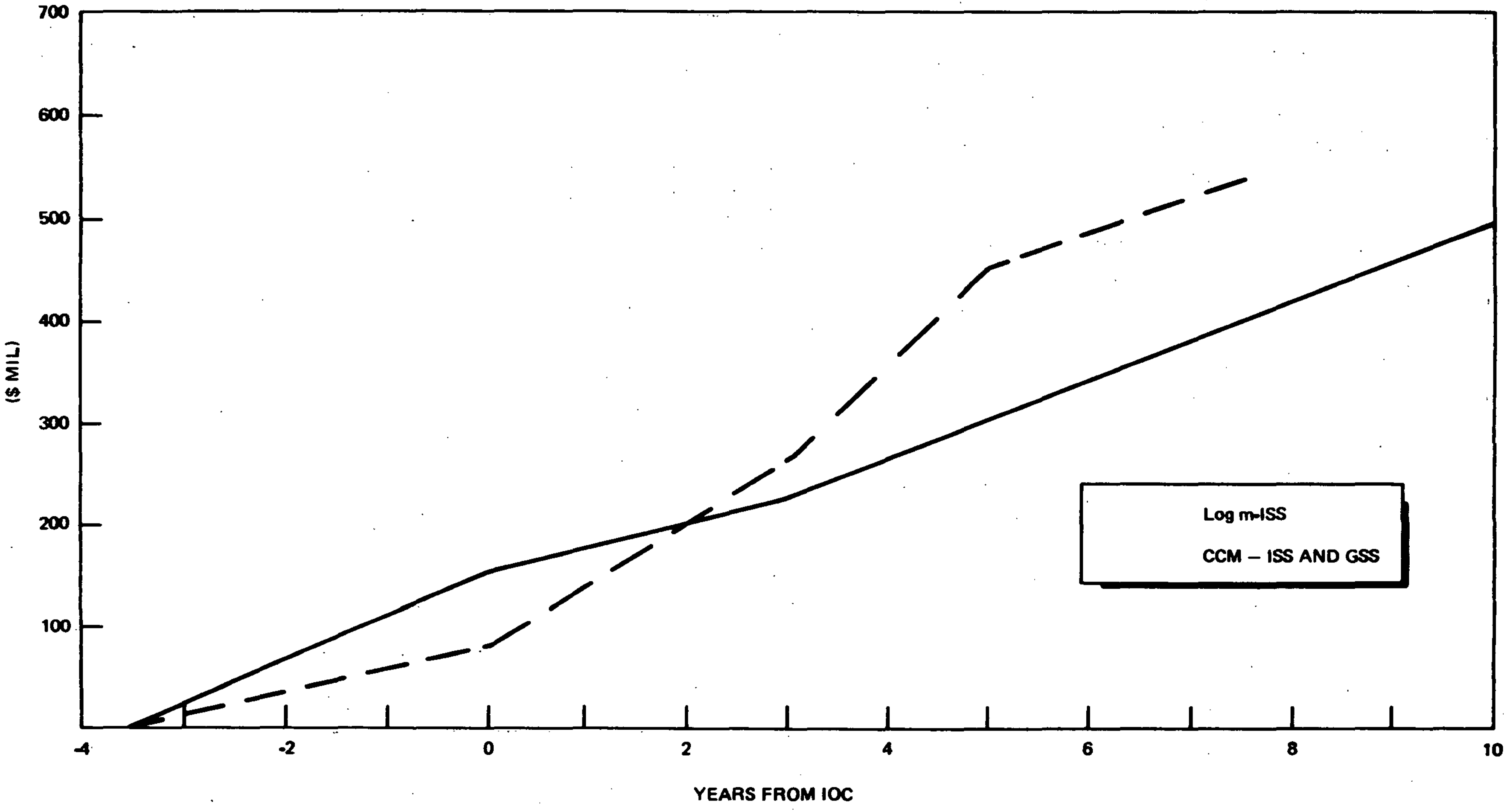

Figure 3-2. Option Comparison

The potential for conversion of the basic Logistics Module to a Crew/Cargo Module is illustrated in Figure 3-3. The mission duration (occupied) of this module requires the addition of life support and hygiene accommodations for the crewmen. Crew seats for this module are a reversible design to permit orientation for both the ascent and descent modes. A 30 by 40 in. emergency egress hatch for the crew is included adjacent to the hygiene compartment. Considerable solid cargo capacity is retained in the pressurized compartment of the module. The fluid carry capacity of the Logistics Module unpressurized area remains intact.

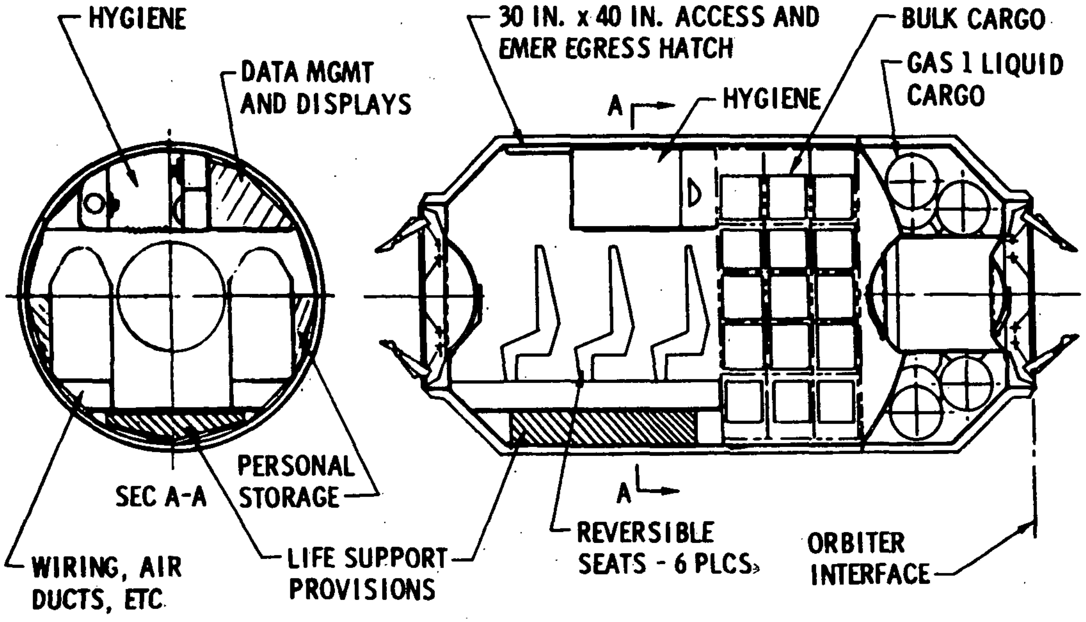

Figure 3-3. Logistics Module Conversion to Crew/Cargo Module

Section 4

CONFIGURATION

The recommended Logistic Module (LOG M) configuration for the Modular Space Station ISS phase is shown in Figure 4-1. The primary requirements for this module are resupply of solid and fluid cargo, low initial cost and high payload capacity. The total "design-to" weight of this module is 9,072 kg (20,000 lb). The nominal design weight of the module is 3,011 kg (6,638 lb) leaving a discretionary cargo payload capacity of 6,061 kg (13,362 lb). The module design is essentially void of active subsystems. The configuration shown in Figure 4-1 is a typical internal arrangement for the module, consisting of space for containerized and bulk solid cargo, and tankage for both volatile and non-volatile fluid transport. This configuration provides carry capacity for 13.6 m^3 (480 ft^3) of solid cargo in 60 by 60 by 60 cm (2 by 2 by 2 ft) standard containers, approximately 3.40 m^3 (120 ft^3) of bulk solid cargo and 5.95 m^3 (147 ft^3) of liquid and gaseous cargo.

The module O.D. has been constrained to the 4.26 m (14.0 ft) Shuttle Orbiter payload bay envelope which results in an overall module length of 8.53 m (28.0 ft) to produce the desired internal volume. The proposed module design is a fixed primary structure concept which provides a large pressurized volume for solid cargo and an unpressurized compartment equipped with permanent tankage for transport and storage of high quantity fluids utilizing an on-orbit hardline transfer mode for fluid movement. The design provides a 1.52 m (5 ft) diameter two-man airlock which serves as a crew transfer tunnel across the unpressurized compartment/orbiter interface and provides EVA capability to the basic station.

Alternate configurations to the baseline, discussed in this section, include a six-man rescue configuration and one which provides crew quarters for two short-term principle investigators.

4.1 CARGO VOLUME REQUIREMENTS

Analysis of the cargo requirements to support the ISS experiment program and Station subsystems for 5 years of flight operations has producted volume requirements for the Logistics Module design. Experiment support requirements are based upon case 534G which represents a balance of program constraints and experiment discipline desires. Support requirements established for this case are quite representative of the typical cargo quantity and mix to be anticipated for the modular station program. Summary evaluation of the analysis conducted produced the following cargo volume design criteria for the Logistics Module configuration design. These requirements are based upon one Logistics Module flight per quarter through the 12th quarter of operation and 2 flights per quarter during the 13th through 20th quarters.

- A solid cargo capacity of 13.6 m^3 (480 ft^3) is sufficient for all quarters of operation except the 13th. In this quarter a large volume of material science equipment is scheduled, exceeding this capacity by approximately 10.8 m^3 (380 ft^3). Spreading of this excess on preceding or subsequent flights or inclusion of an additional Logistics Module flight is planned in lieu of using this one time only occurrence as the Logistics Module design point.
- Provisions for solid cargo transport shall accommodate a palletized to bulk cargo ratio of 80:20. A Standard container size of 60 cm square by 60 cm deep (2 by 2 by 2 ft) is the baseline design. The module design accommodates a minimum of 11.33 m^3 (400 ft^3) of palletized cargo.
- Provisions for approximately 3.68 m^3 (130 ft^3) of gaseous fluids is provided in the Logistics Module design. Approximately 70 percent of this tankage volume is dedicated to GO_2 with the remainder being GN_2. The tankage design for these two gases reflects an on-demand availability concept, i.e., tanks plumbed together which interface to the basic vehicle systems thus permitting normal station consumption from the Logistics Module in a pantry concept.
- The Logistics Module design provides capacity for a maximum of 0.4 m^3 (14 ft^3) of hydrazine (N_2H_4) fuel. The normal fuel resupply for the Station and experiments is 0.06 m^3 (2.0 ft^3) per flight for the 20 quarters of program operation. During the 12th through 16th

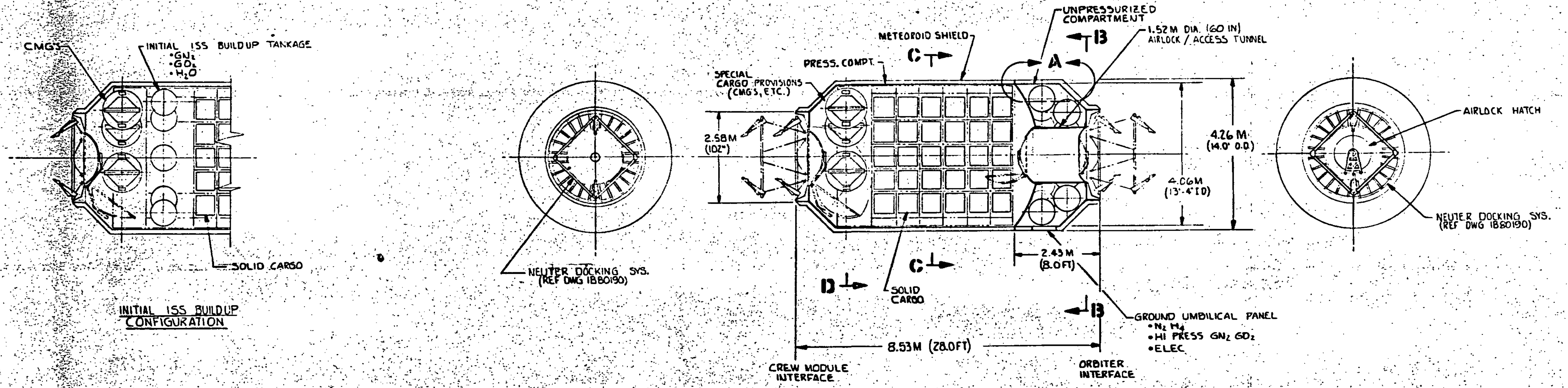

Figure 4-1. Modular Space Station Logistics Module

quarter this demand increases by 0.34 m^3 (12 ft^3) for support of a teleoperator experiment. Accommodations are provided in the initial design to permit carry of this cargo in a vented/unpressurized volume for safety.

- Cryogenics and other fluid transport requirements are accommodated in the pressurized compartment because of their small quantities and on-orbit transfer difficulties. Physical transport of the container to the use location is the on-orbit transfer concept.

4.2 CONFIGURATION DESIGN

Configuration evaluations were performed to establish a module design which provides good payload efficiency, commonality with other Space Station modules and flexibility in the cargo mix whuch can be accommodated. This evaluation task utilized the results of the detailed Crew Cargo Module analysis performed during the 33 ft Space Station study.

The selected design is an integral structure concept with provisions for mixes of palletized, bulk and fluid cargo. The configuration provides considerable structural commonality with the RAM, SOAR MSM, and Modular Station Modules.

In addition to the basic Logistic Module proposed, two alternate capability modules were investigated. One (discussed in Section 4.3) is a version of the basic module configured to include crew quarters for two short-term scientific principle investigators (PI's). Availability of these quarters permits special skill PI's to be present on Station during the orbiter stay period for conduct or support of certain short-term experiment tasks. The utility of this concept is of course dependent upon the orbiter vehicle having the capability to transport PI personnel in addition to the two crewmen being rotated on each 30-day Shuttle flight.

The second alternate studied was a six-man rescue configuration. The concept proposed is a reconfiguration of a basic Logistic Module by addition of six crew seats in the pressurized compartment. Section 4.4 discusses this configuration.

4.2.1 Selected Baseline

The Logistic Module is an integral structure design which through the use of a cage type dodecagon shaped internal support structure and secondary mounting adapter units can accommodate a variety of cargo mixes. The 9,072 kg (20,000 lb) gross weight module is 8.53 m (28.0 ft) in length and 4.26 m (14.0 ft) in diameter. The module design provides a discretionary payload capacity of 6,061 kg (13,362 lb). Table 4-1 shows a detail breakdown of the Logistic Module weight.

The module contains a pressurized and an unpressurized section as shown in Figure 4-2. The pressurized section which is approximately 7.32 m (24 ft) in length is formed by the cylindrical shell with a conic and docking port structure at one end and an internal module membrane-type dome-shaped bulkhead at the other. The unpressurized section is formed by the internal bulkhead wall, the cylindrical shell, conic end and a 1.52 m (5 ft) tunnel section which accommodates crew and cargo transport through the section and serves as a two-man EVA airlock.

The pressurized compartment is configured to accommodate bulk and palletized solid cargo, and in some instances temporary tankage to accomplish station buildup or to support special or short term non-volatile gas requirements for experiments. All basic station and experiment gaseous cargo and all hydrazine fuel transport provisions are incorporated in the unpressurized section.

The cylindrical portion of the module structure shell is 4.06 m (160 in.) inside diameter and is stiffened with 24 integral, longitudinal ribs and rings spaced every 20.32 cm (8 in.) along the length. The 0.15 m (.060 in.) spherical membrane dome and the integrally stiffened conic structures will be fabricated from 2219-T87 alloy material as will the cylindrical shell. Bolted joints are used to assemble the major structure sections (pressure shell, conics, bulkhead, etc.) to facilitate manufacture and assembly of the module.

Meteoroid protection for the Logistics Module is achieved by using a double-wall meteoroid bumper design. The double wall consists of an 0.016 in.

Table 4-1
LOGISTIC MODULE MASS SUMMARY

Code	Description	Mass			
		(kg)		(Lb_m)	
02.00	Structure	1200		2647	
02.10	Unpressurized Compartment		0		0
02.11	Pressurized Compartment		1183		2609
02.15	Finish, Seals, and Spares		17		38
03.00	Meteoroid and Thermal Protection	501		1104	
03.02	Passive Thermal Protection		155		342
03.04	Meteoroid Protection		346		762
04.00	Docking Provisions	279		616	
04.05	Docking Structure		279		616
06.00	Propulsion	72		158	
06.07	Fuel Container		14		30
06.09	Pressurization and Control		23		50
06.10	Fuel Distribution and Control		6		13
06.14	Umbilical		14		30
06.15	Support Structure		15		35
08.00	Power Conditioning and Distribution	35		77	
10.00	Electronics	207		456	
10.01	Guidance and Control		3		7
10.02	Onboard Checkout		103		227
10.03	Data Management		28		61
10.06	Communication		29		64
10.15	Displays and Controls		44		97
11.00	Wiring	75		165	
12.00	Atmosphere and Thermal Control	336		40	
12.02	Atmosphere Control and Supply		336		40
14.00	Crew Life Support and Interiors	197		435	
14.01	Hand Rails and Restraints		31		69
14.03	Cargo Handling		23		51
14.04	Interior Furnishings		143		315
21.00	Residuals	109		240	
21.13	Other Residuals		109		240
	Total	3011		6638	

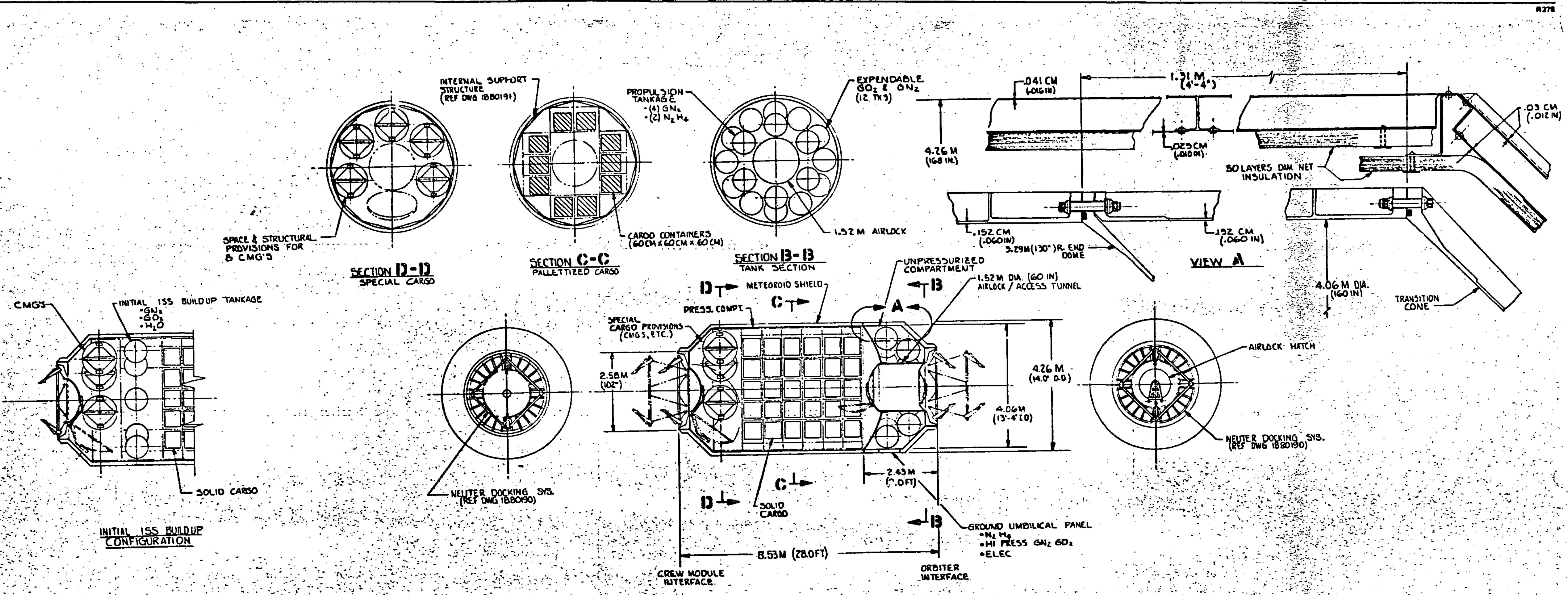

Figure 4-2. Logistics Module Configuration and Structural Design

thick beaded outer sheet and an 0.010 in.-thick inner shield separated 1.125 in. by ring frames on 20.32 cm (8 in.) centers. High-performance insulation is mounted beneath the inner shield, supported on the inner leg of the ring frame stiffeners. The insulation blanket design provides the needed thermal characteristics to maintain the pressure shell wall temperature above that of the ambient module air to eliminate wall condensation.

The Space Station interface end of the module contains the standard 2.58 m (102 in.) diameter docking ring structure and neuter docking mechanism utilized on all other modular station modules. A 1.52 m (5 ft) diameter clear opening hatch is provided at this interface for ground loading of cargo and on-orbit transfer.

The orbiter interface end of the module is also equipped with a standard docking port mechanism and interface structure. An EVA airlock has been incorporated at this end to serve not only as an airlock but also to accommodate crew transfer across the unpressurized section. This design concept effectively provides the airlock capability at the cost of adding the inner hatch to the tunnel section. The airlock has been sized for two-man occupancy. The cylindrical section is 1.52 m (5 ft) diameter and is 1.52 m (5 ft) long. 1.02 m (40 in.) diameter hatches have been incorporated in the airlock. Size selection was based upon personnel transfer as the prime function. The hinged hatch is openable from either side and is identical to the hatch proposed for the turret end (orbiter docking end) of the basic station power subsystems module.

Primary subsystem support (airlock pumpdown; supply, control and conditioning of metabolic and thermal functions; etc.) for the EVA operation will be resident in the basic station modules. The subsystem equipment in the Logistics Module interfaces with these Station functions, however, with the exception of local monitoring at the airlock unit, the module contains few active elements. This approach minimizes complexity of the Logistics Module and reduces the tare weight and volume of the module dedicated to this operation. An additional consideration was that EVA operations are conducted from other station compartments (test and isolation laboratory in the GPL and the tunnel section of the Power Subsystem Module) with common equipments for the control, conditioning and supply functions.

Figure 4-3 shows the high degree of commonality which exists between the Logistics Module and the basic station modules. Foremost in this commonality is the carryover in the structure/mechanical subsystem. Specifically, this includes the pressure shell sections (different only in length), the end conics, docking interface structure and docking mechanism as well as the dodecagon shape internal support structure. The hatch designs as noted earlier are used on the basic station modules. Similarily the internal membrane dome bulkhead is used in the Power/Subsystem Module. Most of the subsystem equipments for such functions as communications, data access, airlock monitoring, caution and warning, pressure control and air circulation, although not shown on the figure, will be the same as or similar to equipments presently planned for the basic station modules. The high degree of commonality existing in this module enables a low initial cost logistics approach.

4.2.2 Solid Cargo Accommodations

Accommodations for both palletized and bulk solid cargo items are provided in the pressurized section of the Logistics Module as shown in Figure 4-3. Key to the accommodation of these cargo items is the internal support structure which provides the primary interface for the individual or modular cargo support adapters. This cage type structure is composed of 12 longerons and interconnecting beams spaced at intervals along the longitudinal axis. These beams connected at the longerons form a dodecagon shape (12 sided) which fits within the 4.06 m (160 in.) diameter of the pressure shell. The cage is pinned to the pressure shell at one end of each longeron, thus, longitudinal loads, both tension and compression, are transmitted to the shell through these pins. Radial loads are transmitted to the pressure shell through blocks which are spaced along each longeron and attached to the pressure shell. Using this structure as an effective strongback, considerable flexibility in cargo mix and arrangement is achieved with little impact upon the modules primary structure elements.

Palletized cargo is accommodated in this system through the use of a modular framing adapter designed to support various standard sized pallets in

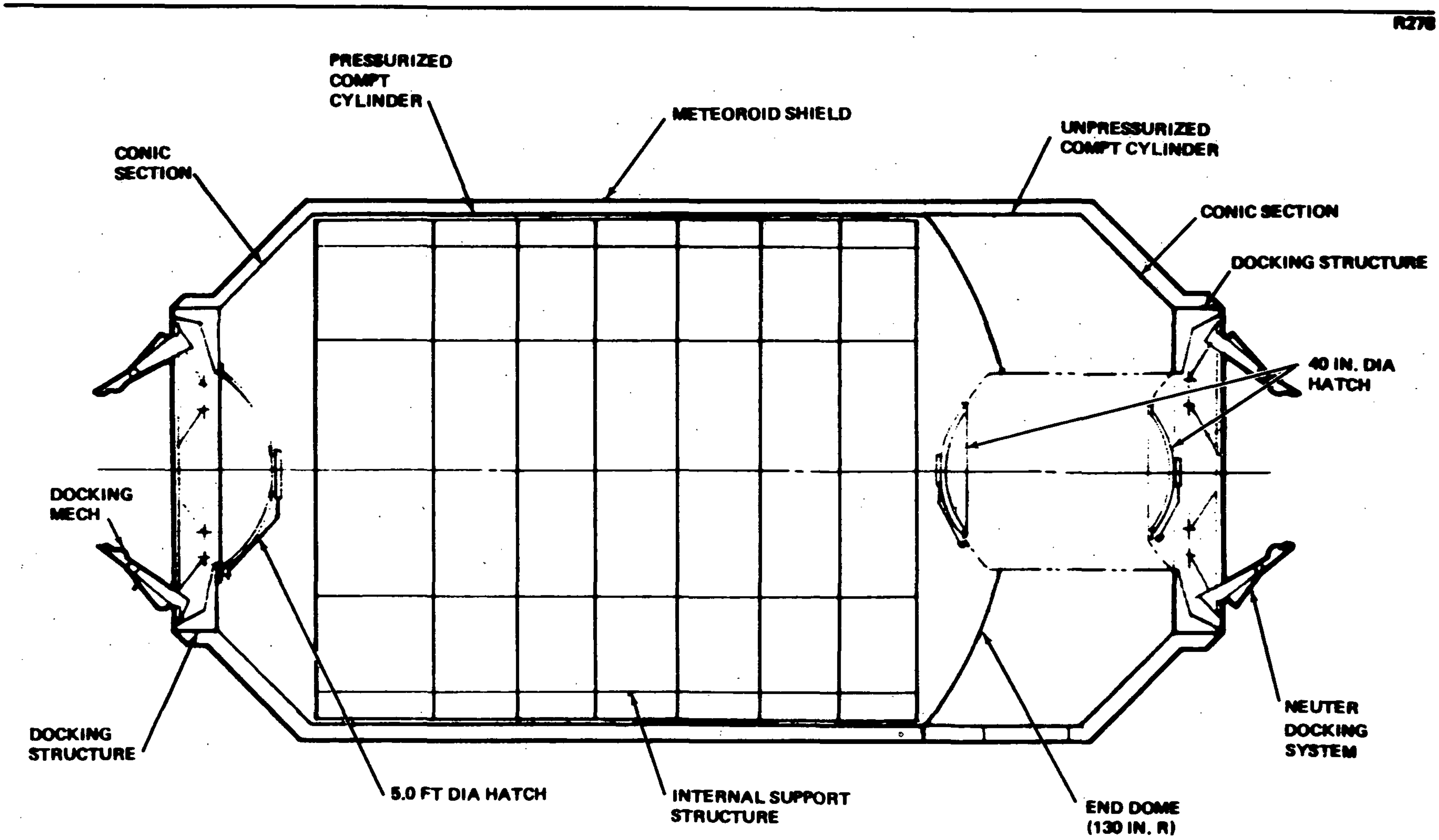

Figure 4-3. Logistics Module – Commonality

increments of 60 cm (2 ft) cubes. In the baseline configuration six bays of 10 pallets each can be accommodated. This modular framing adapter is nominally configured by removal/relocation of support members to accept cargo up to the size that will pass through the 1.52 m (5 ft) diameter docking hatch. The nominal palletized cargo capacity provided in the baseline configuration is 13.6 m^3 (480 ft^3).

The forward or docking end of the module is utilized for stowage of bulk or special cargo items. This area is sized to accept items such as CMG's, food freezers, trash compactor and experiment items of a shape and size not conducive to efficient volumetric palletized packaging. Approximately 3.4 m^3 (120 ft^3) of useful cargo space is provided. The support concept for these items includes the use of special adapters tailored to the individual cargo units for support/interface to the strongback cage type support structure described earlier.

As the need arises, the bulk cargo volume can be increased by the removal and replacement of bays or rows of the modular support structure for palletized cargo with additional special support adapters. Using this technique, near unlimited flexibility/versatility of cargo mix in the unpressurized compartment is achieved.

4.2.3 Fluid Cargo Accommodations

The prime configuration considerations relative to fluid cargo transport are a) the on-orbit transfer concept --- hardline transfer or bottle carry-on; b) safety --- volatility of the fluid and exposure of tankage to physical damage and; c) the variation in fluid cargo mix to be accommodated.

The baseline Logistics Module utilizes the unpressurized compartment to house the majority of fluid tankage required for Space Station and experiment program support. Compartmentation of the tankage is based upon an on-orbit transfer concept in which high-quantity fluids will be hardline transferred to other vehicle tankage or will be interfaced to the Station subsystems and used in a tank-farm fashion.

This fluid transport approach not only provides convenience in the on-orbit fluid handling task but also enhances safety and provides certain reliability and ground operations advantages. Safety is enhanced in two ways. First, the bulk of fluid tankage is in an unpressurized section, thus volatiles or potentially hazardous high pressure leaks are automatically vented to space. Secondly, the internal bulkhead provides an isolation barrier against possible physical damage to the tankage by the crew during on-orbit solid cargo transfer operations or by ground crews during module loading. Operationally, although the use of permanent tankage produces excess capacity for certain fluids on some flights, the time savings accrued by eliminating reconfiguration of the tankage during turnaround are expected to be significant. Additionally, leak tight integrity and hence reliability is improved through the use of brazed type permanent joints in lieu of mechanical connectors on interconnecting plumbing.

The modular station logistics analysis established the following unpressurized compartment tankage requirements needed to support the worst case mix and quantities expected for the baseline program analyzed.

Fluid		Quantity of 30 in. Tanks Required
Metabolic GO_2		8
Experiment Support GO_2		3
Propulsion System GN_2		4
Atmospheric GN_2		1
Propulsion (hydrazine) N_2H_4		2
	Total	18 tanks

The 30 in. diameter tank size was selected for the Logistics Module to retain commonality with the pneumatic tanks used in the basic station modules. Consideration was given to the cylindrical hydrazine fuel tanks in the Power Subsystems Module for use in the Logistics Module. However, because of favorable cost, volumetric efficiency and installation considerations, 30 in. spherical tanks (with teflon bellows) were also selected for hydrazine.

Two additional fluid support groups, namely one-time only and small quantity special fluids will be accommodated in the pressurized solid cargo compartment. The one time only group essentially consists of the optional off-loaded or buildup tankage for the basic Station modules. These will be accommodated as bulk cargo items for delivery on the first three Logistics Module flights of the program.

Included are:

Fluid	Quantity of 30 in. Tanks
Atmospheric GN_2	4
Repressurization GO_2	1
Metabolic GO_2	2
Water	1

The small-quantity fluid group includes such fluids as liquid helium, liquid nitrogen, water, etc., for support of experiment tasks; all of the fluids identified utilize the carry-on transfer approach hence, will be accommodated as palletized or bulk cargo.

A manual external umbilical is provided on the module for loading of the unpressurized compartment tankage. Portable loading equipment/drag-on hoses will be used for ground loading of the bulk cargo type tanks which exceed ground carry-on capability limits.

4.3 CREW QUARTERS ALTERNATE

Versatility of the selected Logistic Module design is indicated in Figure 4-4. The configuration shown is the basic Logistic Module modified to include quarters for two crewmen. Availability of these quarters permits special skill PI's to occupy the Station for short periods to perform experiment setup, or repair tasks. PI's could also be utilized in this mode to perform real time interpretative or control tasks on critical experimentation.

Support functions for two crewmen are supplied or shared from the basic Station resources with the Logistics Module providing only crew quarters.

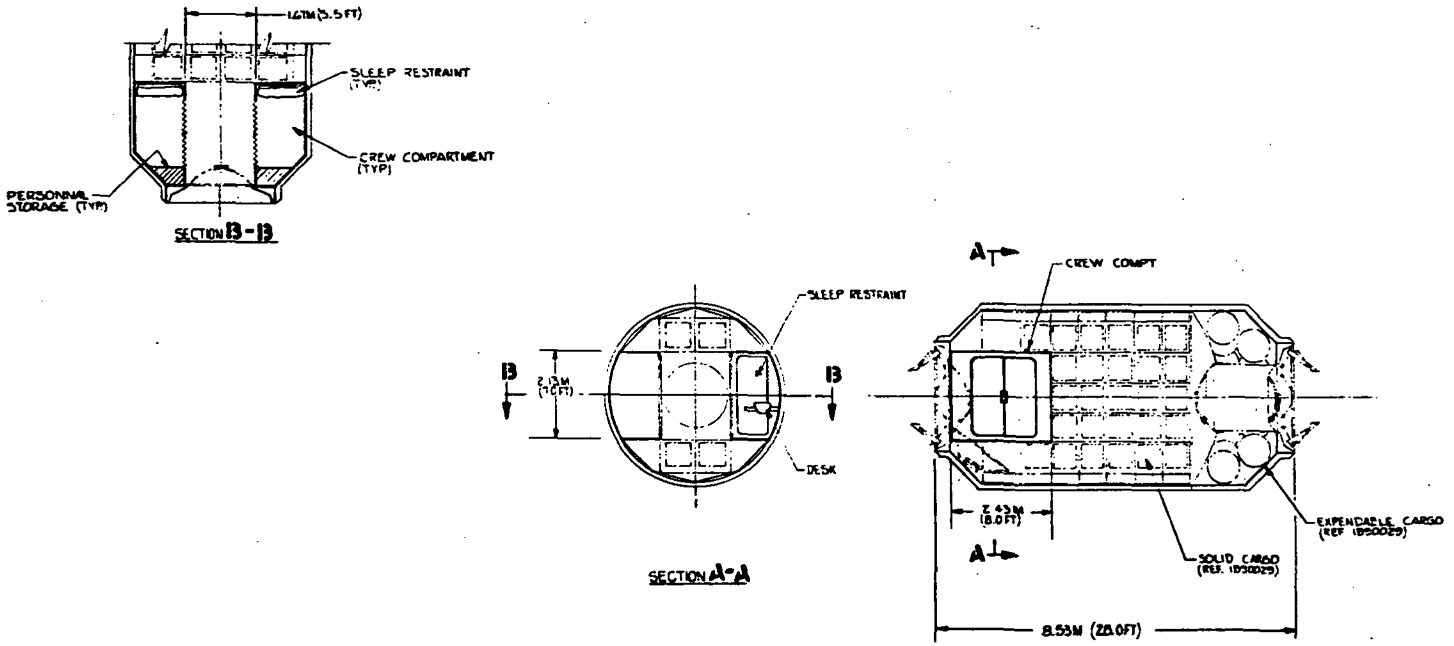

Figure 4-4. Logistics Module With Two Crew Compartments

The period of residency will normally be limited to the orbiter stay time (5 days maximum).

The purpose of this investigation was to determine the impact on the basic module produced by the required reconfiguration. As can be seen from Figure 4-4, the volume loss is confined to the bulk cargo area in the forward end of the module and the side sections of the first palletized cargo bay. This reduces the nominal bulk cargo volume from 3.4 m^3 (120 ft^3) to approximately 0.85 m^3 (30 ft^3) and reduces the palletized cargo volume by 1.36 m^3 (48 ft^3) to a net 12.23 m^3 (432 ft^3). Although the baseline design bulk cargo capacity is reduced by 23 percent in this alternate the 13.08 m^3 (462 ft^3) remaining volume still exceeds the "average" solid cargo volume predicted for all Logistic Module flights.

The crew quarter units proposed are very similar to the basic station quarters in features and size, however, their design will be somewhat unique relative to assembly and mounting on the module support structure. A free-standing modular design is envisioned which when installed is not dependent upon adjacent integral structure for integrity. The units are designed in sections to permit installation and assembly through the 1.52 m (5 ft) diameter docking port hatch. Accommodations provided in the compartment include a sleep restraint, a desk with writing surface, storage for personal items and an emergency oxygen mask with portable oxygen bottle supply.

4.4 RESCUE MODULE CONFIGURATION

A second module alternate studied was a six-man rescue configuration. Since the module is manned only during the descent phase, seat orientation and crew egress requirements need only consider the reentry and landing conditions. The configuration shown in Figure 4-5 is a modified Logistics Module approach with six crew seats installed. The seat design is a simple web structure mounted between rails that extend between top and bottom attach points on the module internal support structure. The seats are adjustable from an upright seated position to a fully-reclined position. The adjustment is made by sliding the back section up the rails and locking in the desired position. The seats are oriented in a rearward facing position for proper alignment for reentry and landing forces.

The web structure of the seat provides a large body contact area for absorbing the "g" forces of deceleration and landing. The flexibility provided in the seat position as shown in Figure 4-5 allows the crewman to assume any desired optimum position. The seat design accommodates not only the normal load conditions but will also sustain the crewman during potential crash landing load conditions (8.0 g).

Simplicity of the seat design allows installation in the module to be performed in a relatively short time. Each seat is an independent unit for ease of entry through the 1.52 (5 ft) diameter hatch. The seats are arranged in two rows, three deep, with a center aisle between the rows for ingress/egress. Arranged in this fashion the seat modules are identical.

Support services including power and communications are supplied from the orbiter subsystems. Each seat station will be equipped with an emergency oxygen mask and portable oxygen bottle supply. Space is also available in the module for incorporation of contingency equipment such as survival gear, if these provisions are not available from the orbiter.

Normal egress from the module after landing occurs is through the orbiter tunnel interface; the orbiter crew provisions are used for alighting to the ground.

It should be noted that the Logistics Module configuration shown is a feasible solution for emergency rescue based upon the assumption that a Logistics Module is available for reconfiguration within the 96-hour time-to-orbit constraint. Additional time line analysis on Logistics Module availability and turnaround tasks is required to determine if other alternates such as a dedicated module held in a ready-to-load posture might be a more appropriate solution.

4.5 OTHER CONFIGURATIONS

The design of the Logistics Module allows for a multiplicity of uses; i.e., the structural support and accommodation concept enables a wide variety of not only cargo but equipment to be accommodated. One potential use of the Logistics Module is for emergency or backup power. Should a backup or supplementary electrical power system (beyond that provided in the station electrical power system) be required, a Logistics Module could be outfitted with batteries or a fuel cell system, delivered by the Shuttle and docked to the station for as long as required.

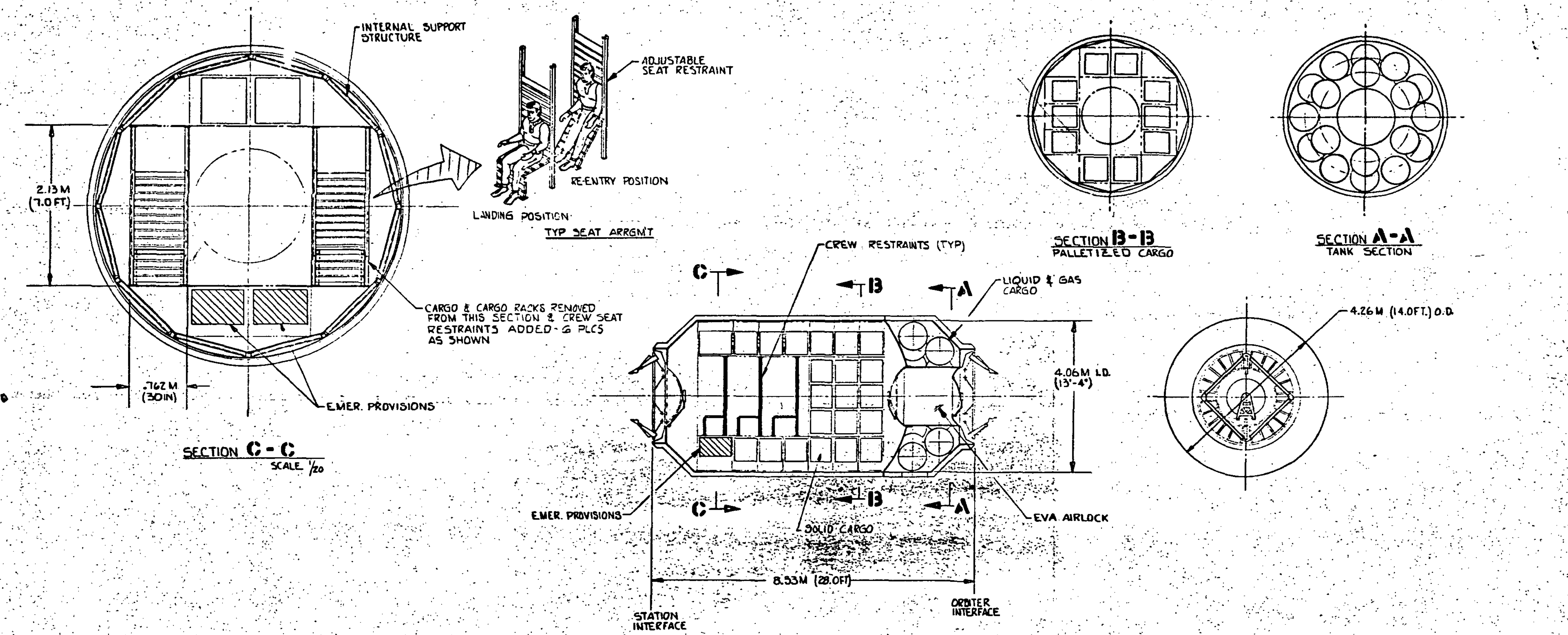

Figure 4-5. Modular Space Station Logistics Module Rescue Configuration

Section 5
SUBSYSTEMS

The Logistics Module requires only minimal subsystems since it (a) is unmanned except when on orbit and when used for a rescue mission and (b) receives support services from the Space Station and orbiter vehicle. These support services consist of power, conditioned air, and monitoring, warning and display of parameters associated with module habitability, (on-orbit only) system status and cargo status. This section describes the structural/mechanical, Data Management/Communications, environmental control and crew provisions of the Logistics Module.

5.1 STRUCTURAL/MECHANICAL

The primary structure of the Logistics Module is highly common with that of the basic Station modules. This commonality results in lower cost because engineering design, fabrication and assembly tooling, manufacturing processes and procedures, and development testing have direct carry-over.

The design criteria for the structure/mechanical subsystem of the Logistics Module is essentially the same as that for the basic station modules. Environmental stresses occur periodically for the Logistics Module due to its multi-mission usage, however, the overall influence of these effects is minimal, being well within the limits of the design of the basic Station modules.

The following paragraphs provide a summary description of the Logistics Module structure/mechanical elements. A detail analysis of each major structure element of the Space Station modules is included in Section 4.2 of SE-04 and is not repeated herein.

The cylindrical pressure shell structure for the Logistics Module is identical to that used on the other Station modules with the exception of length. The shell is 4.06M (160 in.) inside diameter and is stiffened with 24 equally spaced integral longitudinal ribs with rings spaced every 20.32 cm (8 inches) along the length. Integral end flanges provide a bolted and sealed interface with the conic transition structure. Details of the structural arrangement are shown in Figure 4-2. All stiffening ribs are located on the outside surface of the shell leaving the internal surface smooth for the accommodation of installations and to facilitate on-orbit repairs. The shell is fabricated from 2219-T87 alloy in three segments and welded along longitudinal seams. The membrane is 0.152 cm (0.060 in.) thick and the external stiffeners are 2.54 cm (1.0 in.) high measured from the inside surface. A short section of this structure is also used for the cylindrical portion of the unpressurized compartment of the module. The design and fabrication of this shell section is identical (except length) to the pressurized shell described.

The integrally stiffened conic structures provide the transition from the 4.06m (160 in.) diameter to the 2.58m (102 in.) diameter docking interface at each end of the module. The 0.152 cm (0.060 in.) membrane of the 45 degrees conic is stiffened with 24 integral radial ribs spaced to match the integral longerons of the cylindrical shell.

The internal bulkhead dome separating the two module compartments is a 3.30m (130 in.) radius spherical membrane dome 0.152 cm (0.060 in.) thick. Machined ring flanges on the O.D. and I.D. of the dome provide bolted and sealed interfaces at the pressure shell and the 1.52m (5 ft) airlock/access tunnel joints.

The docking structure is a multi-purpose fitting which forms the end closure of the module, provides the structural interface with other modules, provides structural support for the docking mechanism, and forms the frame of the pressure hatch at one end and the airlock/access tunnel at the other. The fitting is machined from a ring forging of 2219-T87 alloy.

The primary EVA airlock for the Space Station has been incorporated in the outboard (Shuttle dock) end of the Logistics Module. Since through-access between the orbiter and Logistics Module is required, a tunnel section through the unpressurized compartment is required. The addition of an inside hatch to this tunnel resulted in an EVA airlock at a minimal structure weight increase. The cylindrical section is 1.52m (5 ft) in diameter, approximately 1.52m (5 ft) in length, and with 1.02m (40 in.) diameter hatches at each end. The 1.02m (40 in.) hatch size was selected based upon personnel transfer as the prime function and for commonality to the Power Subsystems Module tunnel hatches. The inside hatch is hinged inboard and the outside hatch is hinged outward allowing unobstructed use of the airlock's internal volume. The volume is sufficient for simultaneous occupancy by two pressure-suited crewmen. Umbilical feed through provisions are incorporated on the unit to permit interface of the Space Station supplied life support functions across the airlock pressure barrier during use. Pump-down of the airlock volume is accomplished with the pumping system installed in the Space Station.

The tunnel section through the unpressurized compartment undergoes structural deflection between the internal bulkhead and docking frame as a result of pressure differential in the module compartments during ascent and descent. Two conventional designs considered were (1) a bellows section in the tunnel, and, (2) the use of a soft joint at one of the tunnel/support structure interfaces. The latter design concept is favored for the Logistics Module because it accommodates the structural deflection and also provides the opportunity to incorporate the required thermal isolation in a single design.

The three pressure hatches in the Logistics Module utilize the same hatch design which is used throughout the basic Space Station. The hatches are domed spherical sections, aluminum honeycomb construction, openable from either side and capable of differential pressure in either direction. A dual seal arrangement is employed which consists of an inflatable seal plus a static "0" ring seal. The hatch at the station docking end of the module provides a 1.52m (60 in.) clear passage while the airlock hatches provide 1.03m (40 in.) clearance for personnel transfer. Each hatch contains a 15.3m (12 in.) diameter viewing port for observation of activities, inspection, and assessment of conditions on the other side of the hatch.

The docking mechanism used on each end of the Logistics Module is again a common design used on all Space Station modules. The neuter, clear-center design has a structural mating interface that is 2.58m (102 in.) diameter and a clear passage 1.52m (60 in.) in diameter. All docking interfaces are the same, and, therefore, any module may be docked with any other. The mechanism consists of a square frame with guide arms and capture latches mounted in two opposite corners. The frame is supported and deployed on eight hydraulic shock absorber/actuators. The displacement of the frame against the force of the actuators absorbs the docking impact energy. After stabilization the actuators are retracted, the structural latches engaged and the pressure seal inflated. After two modules are docked, pressurized access to the docking mechanism and structural latches is inherent in the design.

The meteoroid shielding provided on the Logistics Module is sized to exceed the NASA specified 0.90 probability of no puncture for the total Modular Space Station during the 10-year mission life. The shielding design used on the basic Station modules has been retained on the Logistics Module except that since no ECS radiator is required on the Logistics Module the integral tube section frames of the basic design have been replaced by integral T section ring frames. The design for the pressure shell section and conics is shown in Figure 4-2. The shielding on the constant section encapsulates the pressure shell with a double wall bumper consisting of an 0.041 cm (0.016 in.) outer skin and an 0.025 cm (0.0.0 in.) inner skin separated by integral ring frames on 20.32 cm (8 in.) centers. The inner skin is used to protect the high performance insulation blanket from spauling effects of the outer skin. The blanket consists of 50 layers of double aluminized Mylar and Dacron net installed beneath the inner bumper skin. Installed on the pressure shell the meteoroid/thermal blanket assembly has an outside diameter of 4.26m (168 in.). Fiberglas insulators are used to support the assembly on the shell structure. The conic section bumper design consists of two 0.03 cm (0.012 in.) skins with external radial stiffeners on the outer skin. This design is consistent with the induced environment effects and provides ease of construction to the conic shape.

Each of the docking ports on Space Station modules may be exposed for extended periods of time on orbit and must be protected from meteoroids and insulated thermally. This condition occurs on the outboard (shuttle dock) end of the Logistics Module, hence, a protective cover has been incorporated. A track and hinge mechanism is used to stow the cover within the 4.57m (15 ft) diameter shuttle cargo bay envelope when open, permitting attachment of the module to the shuttle docking mechanism. The mechanism which rotates the cover open and then traverses it along the longitudinal axis is electrically driven and is remotely controlled from within the Space Station on orbit.

The internal support structure is a cage type composed of 12 longerons and interconnecting beams spaced at intervals along the longitudinal axis and is similar to that used in the Space Station modules. These beams form a dodecagon shape which fits within the 4.06m (160 inch) diameter of the pressure shell.

The cage is pinned to the pressure shell at one end of each longeron, thus, longitudinal loads, both tension and compression, are transmitted to the shell through the pins. Radial loads are transmitted to the pressure shell through blocks which are spaced along each longeron and attached to the pressure shell. The internal support structure provides the mounting for all internal equipment and allows flexibility of arrangement and assembly. Support of solid cargo items on this structure is accomplished with secondary structure consisting of individual and modular support adapters. Standard size palletized cargo is supported in a pigeon-hole frame type structure capable of accepting and securing packages of 60 cm (2 ft) cubes. Flexibility in the frame assembly permits easy reconfiguration to eliminate sections or for the removal of members to accommodate different package sizes in the noted increments such as 120 by 120 by 60 CM deep (4 by 4 by 2 ft deep). This degree of flexibility is the product of a versatile framework design. This flexibility when coupled with the near unrestricted attachment capability of the modules internal support structure provides a cargo carry concept with the versatility demanded by the Modular Space Station program.

Space is allocated in the module configuration for unique items of cargo which because of size and shape are not conducive to palletization. These items are expected to represent less than 20 percent of the solid cargo volume to be transported and will require the design of special support/ interface adapter units for mounting to the internal support structure. Items such as CMG's, food freezer, trash compactor and experiment equipment will be accommodated in this manner. As the need arises, the bulk cargo volume can be increased by the removal and replacement of bays or rows of the frame structure for palletized cargo with additional special support adapters.

The selected mounting arrangement for supporting the Logistics Module in the cargo bay of the Shuttle/Orbiter is shown in Figure 5-1. In this scheme, which is common for all Space Station modules, all fore and aft loads are reacted at a single point on the keel of the cargo bay at the forward joint between the cone and cylinder of the module pressure shell. A titanium fitting on the module engages a clevis pin which is mounted in the cargo bay keel so that it is free to rotate and move in or out along its axis to accommodate tolerances. This pin thus reacts only axial and lateral loads and does not restrain the module vertically or in pitch.

A titanium fitting on the module at the aft cone cylinder joint engages the slot in the cargo bay keel. Thus, this fitting reacts only lateral load and does not restrain the module axially, vertically, or in pitch or roll, but, with the forward keel fitting, provides yaw positioning.

Vertical loads are reacted by a single fitting at the aft (in shuttle bay) cone/ cylinder joint and an identical pair of fittings at the forward cone/cylinder joint. These fittings also provide restraint in the pitch and roll axis but do not constrain the module axially and laterally. This fitting arrangement eliminates load interaction with shuttle body bending hence structural weight of the module is not penalized. Additionally, the fitting locations permit the loads to be taken directly into the end ring of the module with a minimum of supplemental structure.

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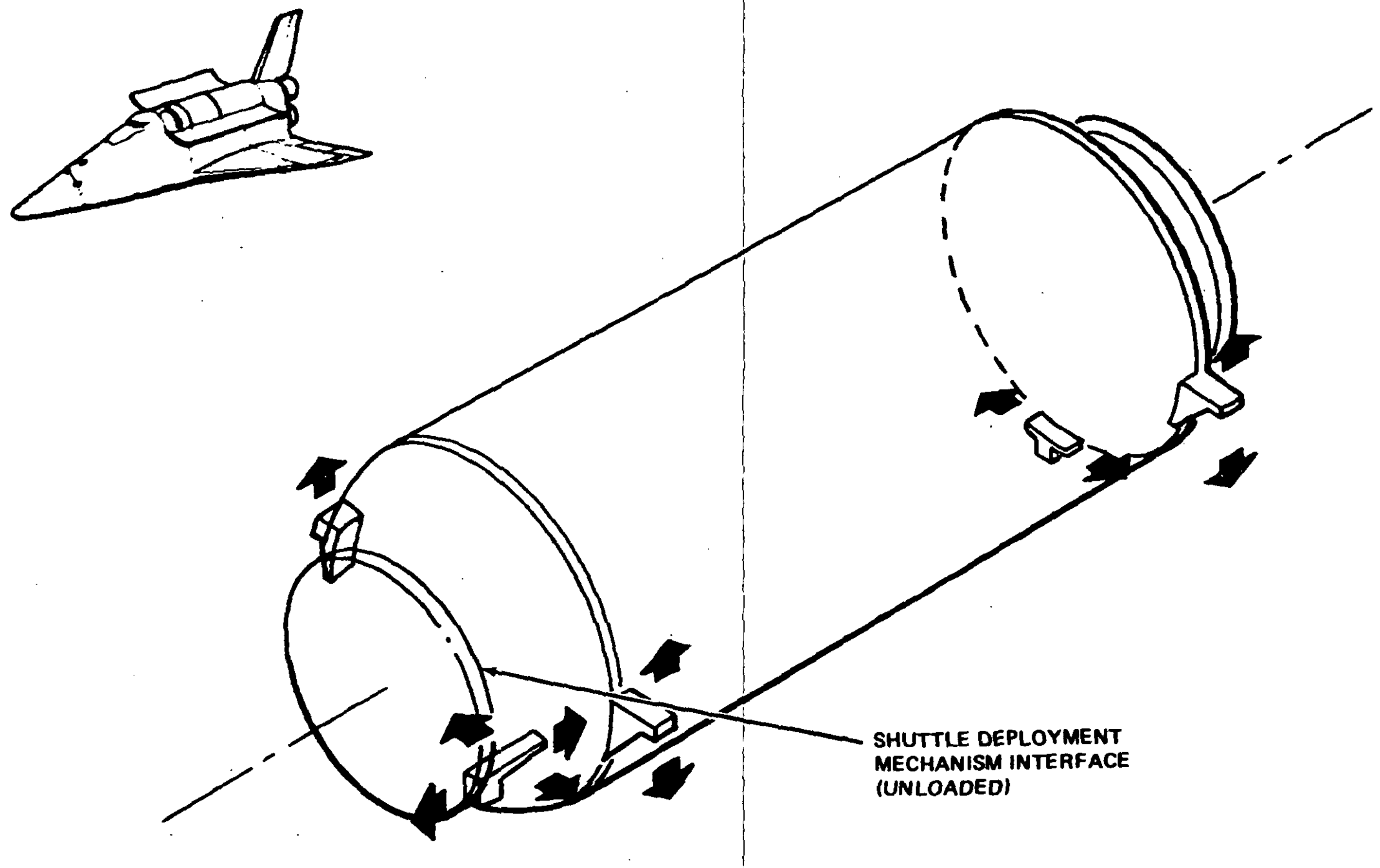

Figure 5-1. Recommended Concept for Logistic Module Support in Shuttle Cargo Bay

5.2 ENVIRONMENTAL CONTROL

The environmental control system provides atmosphere distribution, atmosphere dump and relief, module pressurization, resupply gas pressure regulation, pumpdown pressure control and post landing ventilation during normal operation. Atmosphere conditioning is provided by interchange air from the core modules.

Emergency provisions are also included in the design to provide essential EC/LS functions when the Logistics Module acts as a crew refuge or an emergency rescue vehicle. Essential services include metabolic O_2 supply, humidity and CO_2 control, cooling, emergency food, waste management, and medical supplies.

An active thermal control system is not required during normal operation; the thermal capacitance of the structure and low heat leak prevents excessive interior temperature excursions. Cooling is required during emergency crew occupancy and this is provided by the water boiler in the 96-hour pallet. During normal operation, when the Logistics Module is attached to the station, thermal control is provided by the interchange of air from the core modules.

5.2.1 Requirements

The Logistics Module must be maintained as a habitable volume during both normal and emergency operation. Detailed performance requirements are given in Table 5-1. Table 5-2 defines cargo temperature control require-requirements.

5.2.2 System Description

Figure 5-2 is a schematic of the selected design for the Logistics Module. During normal operation the design provides for atmosphere distribution, atmosphere dump and relief, module pressurization, resupply gas regulation, pumpdown pressure control and post landing ventilation. Emergency provisions are included in the design to provide essential EC/LS functions by use of the 96-hour pallet.

Table 5-1

ENVIRONMENTAL CONTROL SYSTEM PERFORMANCE REQUIREMENTS

Atmosphere Supply and Control	
Atmosphere Relief	Relieves cabin pressure at 105.5 ± 1.4 kn/m^2 (15 ± 0.2 psia). Dump largest compartment to 6.89 kn/m^2 (1 psia) or less in 3 minutes.
Atmosphere	
Oxygen Partial Pressure	21.4 kn/m^2 (3.1 psia)
Total pressure	101 kn/m^2 (14.7 psia)
Atmosphere Reconditioning	
CO_2 Partial Pressure	Normal - 0.4 kn/m^2 (3 mmHg) or less Emergency 1.0 kn/m^2 (7.6 mmHg) maximum for 7 days
CO_2 Generation Rate, Peak/ Average	0.354/0.260 kg/hr (0.78/0.575 lb/hr)
O_2 Use Rate, Average	0.218 kg/hr (0.481 lb/hr)
Free Moisture in atmosphere	none allowed
Metabolic levels	Normal - 136 watts (465 Btu/hr) for 24 hr. Design - 235 watts (800 Btu/hr) (2 men)
Atmosphere temperature	18.4 - 23.9°C (65 - 85°F)
Dew point temperature	7.2 - 14.5°C (45 - 58°F) with transients allowed to 4.5°C (40°F)
Velocity in occupied regions	0.1 - 0.25 m/sec (20 - 50 ft per min)
Design Latent load	310 watts (1060 Btu/hr)

Table 5-2

CARGO TEMPERATURE CONTROL REQUIREMENTS

			Allowable Temperature (°F)	
Item	Description		Minimum	Maximum
Propulsion and Reaction Control	Valves, Filters	(S)	-65	160
	Pressurant - N_2	(G)	-65	160
	Low-Thrust Water Supplement	(L)	40	160
	High-Thrust Fuel (N_2H_4)	(L)	40	120
G&N/Attitude Control	Electronic Spares	(S)	-65	160
Vehicle Electronics	Onboard Checkout Spares	(S)	-65	160
	Communication Spares	(S)	-65	160
	Data Management Spares	(S)	-65	160
	Video Tape Resupply*	(S)	0	100*
	Voice Cartridges*	(S)	0	100*
	Digital Tape*	(S)	0	100*
	Teletype	(S)	-65	160
	Microfilm	(S)	32	75
	TV Film	(S)	0	75
	Film Protection	(S)	32	80
Environmental Control/Life Support	Thermal Control Spares	(S)	-65	160
	Environmental Control Spares	(S)	-65	160
	EC Nitrogen	(G)	-65	160
	EC Oxygen	(G)	-65	160
	Water Management Spares	(S)	-65	160
	Water Management Consumables**	(L)	40	160
	Waste Management Spares	(S)	-65	160
	Waste Management Consumables	(S)	-65	160
Crew Systems	Recreation Supplies	(S)	-65	160
	Exercise Equipment	(S)	-65	160
	Washable Wipes	(S)	-65	160
	Drugs and Medicine	(S)	32	40
	Dehydrated Food	(S)	65	100
	Wet Pack Food	(S)	32	100
	Perishables	(S)	32	60
	Frozen Food	(S)	-65	15
	Personnel Clothing	(S)	-65	160
	IVA/EVA Life Support Units	(S)	-65	160
	IVA/EVA Life Support Spares	(S)	-65	160
	Cleanser	(S)	-65	160
	Personnel Equipment	(S)	-65	160
	Personal Gear	(S)	40	100
	Space Suits	(S)	-65	160
	Trash Management Equipment	(S)	-65	160

*Assumes tape is hermetically sealed.

**Only pretreatment chemicals.

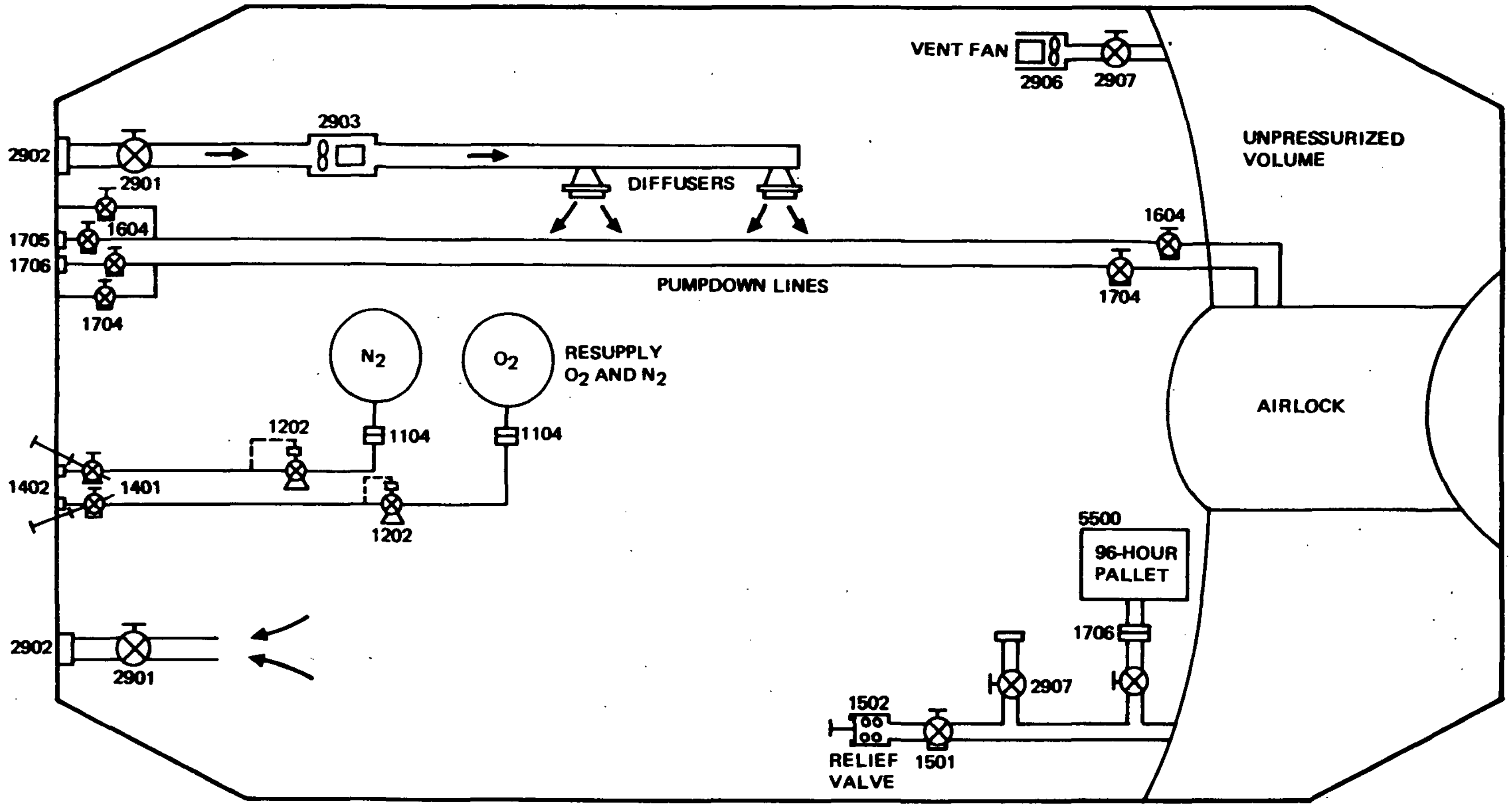

Figure 5-2. Schematic of the EC/LS System

Conditioned air is provided by the EC/LS equipment located in the basic Space Station modules and distributed within the Logistics Module with a fan (item code 2903) and distribution duct. The air is introduced into the module atmosphere through diffusers which ensure air velocity in the range of 0.1 to 0.25 m/sec (20 - 50 ft/min). The distributed air picks up humidity, CO_2 and contaminant loads within the module; they are returned to the basic Space Station EC/LS through a return duct to be processed again. Valves (2901) in the supply and return ducts enable the Logistics Module to be isolated from the core module when atmosphere reconditioning is not required.

A relief and dump valve (1502) is installed in the module overboard line to prevent atmospheric overpressure and to allow dumping of the atmosphere in the event of fire or contamination. A shutoff valve (1501) is installed just downstream of the relief and dump valve to facilitate maintenance and as a backup in the event of a failed open relief and dump valve.

In the event repressurization of the Logistics Module becomes necessary, valves (1401) provide for this function. The valves can be actuated from either side of the hatch with a manual control. An additional function of the valves is to shut off the O_2 and N_2 supply when the Logistics Module is not docked to the Station.

The normal resupply O_2 and N_2 is stored in tanks at 2.06×10^4 kn/m^2 (3000 psia). As a safety precaution the gas is reduced in pressure before being withdrawn for use in the Space Station. Pressure regulating valves (1202) reduces the pressure to 410 kn/m^2 (60 psia) at the tank outlet lines. An additional safety feature is the relief function incorporated in the valves to prevent overpressurization of downstream equipment in the event of a valve malfunction.

The airlock located at the end of the Logistics Module is used as an EVA airlock during normal mission operations. In order to conserve the airlock gas during crew egress, the design provides for airlock pumpdown. The pumpdown system located in the Crew/Subsystems Module pumps the air from the airlock through lines running through the Logistics Module. The pumpdown air is stored in an accumulator in the Power/Subsystems Module. Upon crew ingress the airlock is repressurized with the accumulator air. Valves (1604 to 1704) provide pressure control during these operations. Additional control valves are provided at the interface to the basic Space Station modules which enables the pumpdown lines to be isolated if desired and to control pumpdown/repressurization of the section between modules.

A post landing ventilation capability has been included in the design to allow ambient air to be drawn into the module when used as an emergency rescue vehicle. An investigation has shown that the cargo bay temperature in the shuttle will be sufficiently low near landing so that ambient air ventilation can be used. The air is drawn into the module through a vent fan (2906) and shutoff valve (2907). Air leaves the module through a relief valve (1502) which has been locked open for this purpose.

During normal Logistics Module use, a 96-hour pallet (5500) is located onboard for crew use during an emergency. The pallet provides essential services for a three-man crew and relies in no way on other Space Station support. The design of the pallet is described in report SE-04.

The Logistics Module serves as backup function for crew rescue. The module is outfitted with restraints and essential services for return of the six-man crew. Two 96-hour pallets are used during this mode to support the crew. The pallet provides crew metabolic O_2, potable water, food, waste storage and emergency medical supplies. A water boiler is provided which cools the atmosphere and condenses out excessive humidity. This boiler functions while in orbit and during reentry until the atmosphere is encountered. There is sufficient thermal capacitance in the module atmosphere and equipment to absorb thermal loads and humidity until the post landing fan is activated just prior to landing. A canister of LiOH removes crew-produced CO_2 from the air. Sufficient batteries are included to operate the pallet equipment and provide for minimal lighting.

5.2.3 Thermal Control

Thermal control for the Logistics Module includes maintaining equipment and atmosphere within reasonable levels during all mission phases. Prelaunch does not represent a thermal problem because the bay is purged with dry temperature-controlled gas. The module is exposed to a cold radiation environment from the lower bay, but this will be compensated for by the warmer upper bay environment. The pressure shell is sufficiently thick to preclude large temperature gradients around the periphery of the module. The super insulation will provide sufficient insulation to prevent large losses of heat from the module. During prelaunch and launch no appreciable electrical power is being generated within the module.

The Logistics Module will be subjected to temperatures during launch of up to 149°C (300°F) in the shuttle bay. Computer analyses were run with various payloads for this environment as part of the Shuttle Orbital Applica-Applications/Requirements (SOAR) Study. The results showed that only surfaces of zero thermal capacitance become hot (82.2° to 110°C) (180° to 230°F). The Logistics Module has considerable thermal capacitance especially around the pressure shell. Therefore, excessive temperatures are not likely to occur.

However, since mylar super insulation can be distorted by temperatures above 107°C (225°F), the outer few layers of insulation should be made of Kapton, which can tolerate temperatures up to 426°C (800°F).

Once the Logistics Module achieves orbit, the super insulation is effective in maintaining a low heat exchange between the module and the surrounding shuttle bay. This is due in part to the low emissivity in the current design for the shuttle bay interior walls.

While the Logistics Module is attached to the Space Station, conditioned atmosphere will be supplied from the Space Station EC/LS. As much as 136 cfm may be supplied which enters the module near the selected Space Station temperature. Assuming the air enters the module at 240°C (75°F) and leaves at 18.3°C (65°F) about 420 watts (1430 Btu/hr) of heating is provided. In a similar manner, about the same amount of cooling can be provided. By reduction of heat shorts in the structure and by proper outer surface coating design, the heat loss or gain through the module surface can be kept below these values.

During descent, local surface temperatures on the module may approach 93.3°C (200°F) in areas with small thermal capacitance. With the outer few layers of insulation made of Kapton, the anticipated temperature levels should not present a problem.

Cargo items having temperature control requirements were identified in Table 5-2. Most of the items in the list require no special thermal control beyond that provided passively.

Frozen food is stored in well-insulated containers, but must be transferred to the Space Station freezers promptly after arrival. Figure 5-3 indicates that frozen food reaches -9.5°C (+15°F) about 84 hr after loading if it is initially subcooled to -54°C (-65°F). This time is adequate to affect transfer. Fresh perishable foods must also be carried in insulated containers, but canned ice can be used to keep them cool. Drugs and medicine requiring refrigeration can also be stored in dewar-type containers until they are transferred to refrigerated storage on the station.

The Logistics Module has a second mission objective of serving as an emergency crew rescue vehicle. If a Space Station abort becomes necessary, a Logistics Module is outfitted with the necessary provisions and used in the rescue mode. The necessary thermal control provisions are included in the 96-hr pallets. A water boiler and water supply serve to provide crew and equipment cooling on orbit and during reentry down to an altitude of 30,500m (100,000 ft). During the time from this altitude to landing, the thermal capacitance of the module interior is expected to keep module interior temperatures below 37.8°C (100°F).

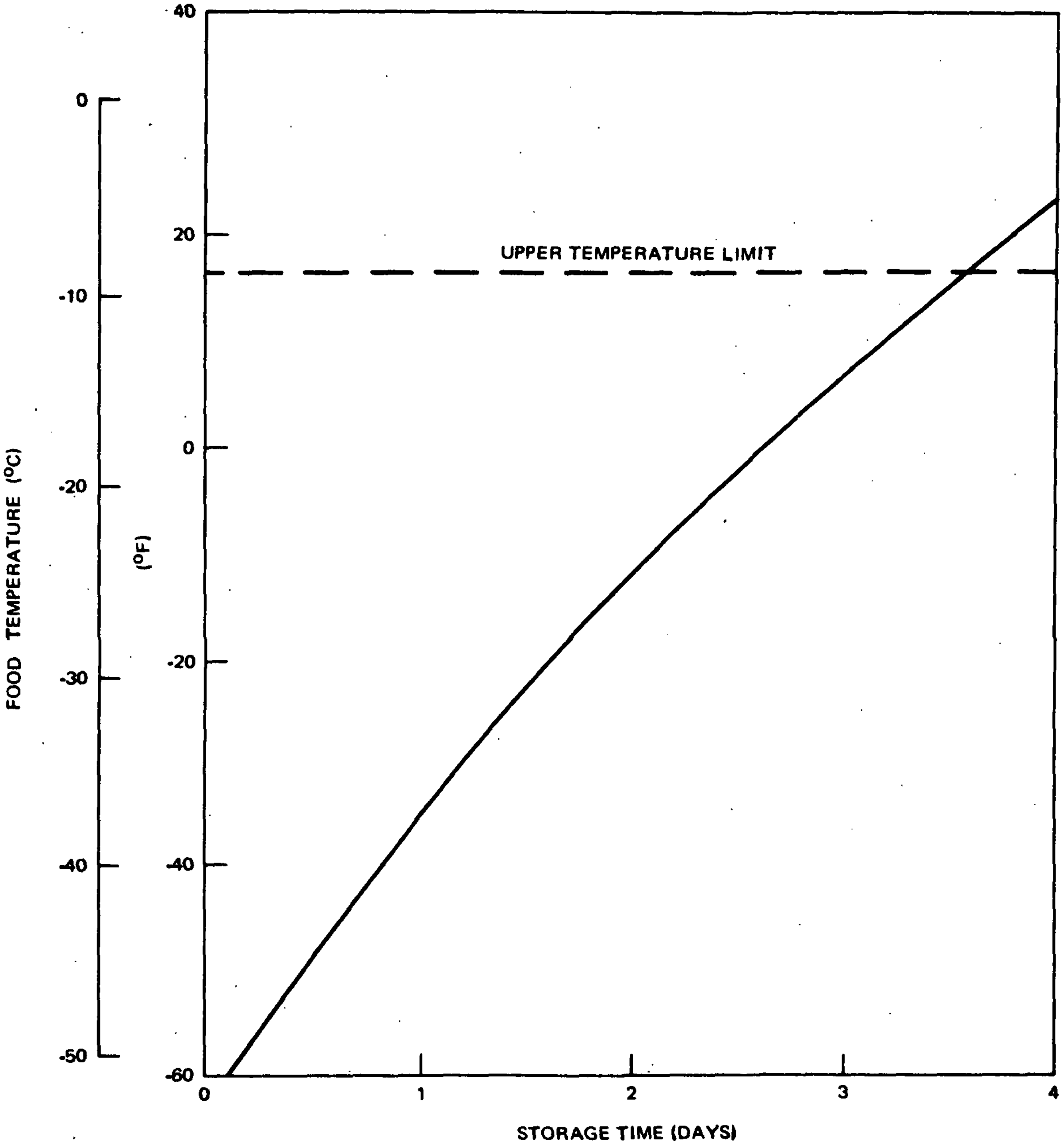

Figure 5-3. Frozen Food Temperature History

The thermal control considerations discussed above are based largely on the SOAR Study and results of the 10 m (33 ft) diameter Space Station Study. Before definitive thermal results can be obtained, more detailed thermal control analyses are required. Performance of these analyses in the current study was not considered appropriate due to the lack of definition of the Space Shuttle cargo bay environment.

5.3 DATA MANAGEMENT AND COMMUNICATIONS

The communications and data management subsystems within the Logistics Module support the following functions:

1. Voice communications
2. Monitoring of critical measurements
3. Determination of system compartment status
4. Periodic subsystem checkout
5. Spares/Consumables Management

Provisions for modifying and/or enlarging these functions will be incorporated to allow reconfiguration of the module into an emergency rescue vehicle.

The interface between the various elements of the subsystem is a data bus accepting and transferring both video and digital data. An additional interface is provided in the form of hard wire for critical or safety measurements. Ideally, since the Logistics Module must operate in conjunction with the payload support system of the shuttle during ground checkout and ascent to orbit and the Space Station while on orbit, their bus systems would be identical. Should the systems be incompatible, a digital bus interface adapter would be required in the Shuttle. Figure 5-4 shows the manner in which system assemblies are interconnected and the functions performed by each, It also indicates that the primary equipments providing the services for the Logistics Module are actually resident within the payload support system of the orbiter or the Space Station. As a result, equipment located within the Logistics Module consist only of input and output devices such as data acquisition units, sensors and display devices.

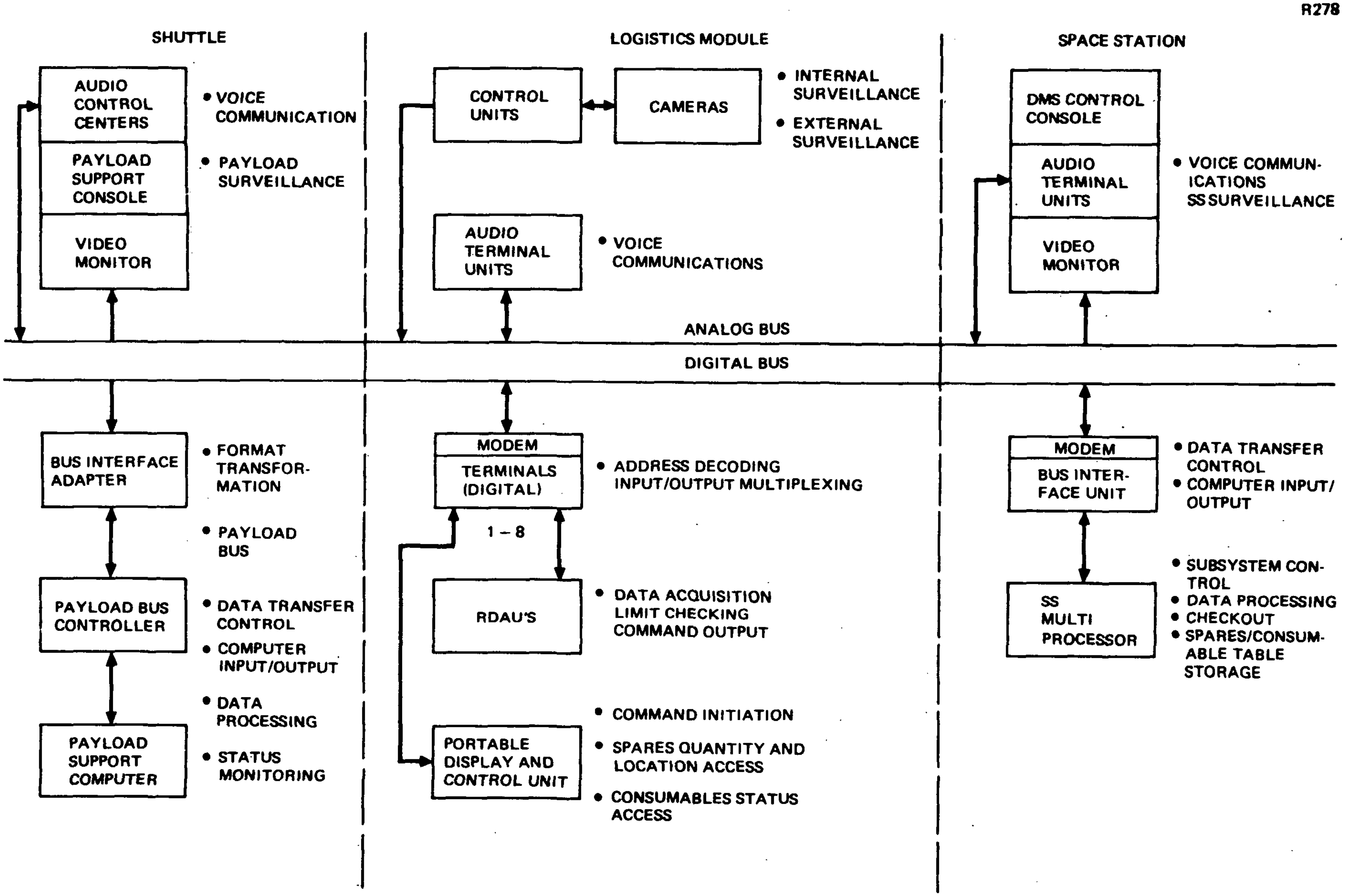

Figure 5-4. Logistics Module Interface Block Diagram

5.3.1 Data Bus

The data bus within the Logistics Module is an extension of the station bus system which is coupled to the main bus via branch couplers. Ingress and egress to the bus through data "terminals" is accomplished using data bus terminal couplers. The bus itself employs frequency division multiplexing to enable the simultaneous transfer of multiple voice, analog, video and digital data on analog and digital bus cables. Redundant cables provide a fail operational capability.

5.3.2 Voice Communications

Sixty-four channels on the analog data bus spaced at 4 KHz intervals between 60 and 316 MHz are apportioned between 48 audio terminal units (ATUs). Three (3) of these terminal units have been assigned to a Logistics Module; i.e., each module would contain ATUs with individual unique transceiver frequencies to which they would respond. Each ATU would also include amplifiers for operating at baseband, this mode to be used for emergency alert or public address. This baseband system should be compatible with the orbiter intercom system which utilizes audio control centers composed of microphone and earphone amplifier and voice switching and selection circuits.

Following docking, SS crewmen entering the Logistics Module would converse with the orbiter crew by plugging suit audio umbilicals into jacks provided at each ATU. A serious drawback of this system would be the transmission of Orbiter/Logistics Module conversations throughout the Station. A more desirable approach would be to incorporate transceivers within the orbiter audio system tuned to Logistic Module frequencies.

5.3.3 Critical Measurement Monitoring

The monitoring of critical measurements will be performed locally using standard local display and monitor units (LDMUs). These units process and display all such data which result in the generation of caution or warning audio and visual alarms. Signals of the caution type are then relayed to the central control facility via the data bus while warning signals are transferred via hard wire. Three (3) such units are located in the Logistics Module monitoring environmental parameters such as O_2, N_2, CO_2, temperature and pressure as well as safety status signals from airlock monitoring transducers, leak detectors, fire detectors, interlocked controls, etc. A small panel will be located within the airlock operating in conjunction with pressurizing and evacuation controls to inform crewmen engaging in EVA activities when hatches may be opened.

5.3.4 System Status Determination

System status is provided by remote data acquisition units (RDAU'S) operating in conjunction with data bus terminal units and their associated modems. The RDAUs will accept 40 millivolt or 5 volt full scale signal levels and perform acquisition, conversion, limit checking and transfer of individual channels or data frames composed of thirty (30) analog and sixteen (16) discrete channels to the station subsystem computer, storage, or communications under centralized control. During ground checkout, launch and ascent to orbit in the Shuttle, the payload support system will perform this control function. Upon the connection of umbilicals during Station activation, control will revert to the station system. Status measurements will periodically be obtained by the central system in the form of pressures and temperatures for O_2 and N_2 make up gases, N_2H_4/N_2 propellant cryogenic tanks containing experiment stores, and O_2 and H_2O stores within the 96-hour pallets. Battery charge will also be monitored.

In addition to the assessment of status via measurements, compartment status is also monitored visually by a TV monitor on the shuttle payload support console and the station central control and display console; the latter is available after umbilical connection. Two (2) cameras and their associated control units will be available for this function.

5.3.5 Subsystem Checkout

Checkout of the Logistics Module will be performed utilizing equipment such as RDAU's and terminals previously mentioned under System Status

Determination. The limit check function within the RDAU whereby each channel value is compared to previously established high and low limits provides a continuous assessment that channels are within tolerance, or, should an out of limits condition occur, an out of limits flag is placed in the RDAU memory (limit check enable bit goes to zero) and output to the central computer when accessed. Periodically a more complete checkout of all subsystems is performed by the central computer. Commands are issued via a stimuli generator to provide the requisite signal levels and frequencies to enable checkout to be performed. Channel outputs are then transferred to the computer for processing by a checkout algorithm.

An additional piece of equipment, the portable monitor and control unit, is provided for local checkout and maintenance within the module. It consists of a keyboard, CRT and associated electronics allowing the crewman to display particular parameter values, ascertain trends, and obtain procedural information as to how to perform repair or replacement operations.

5.3.6 Spares/Consumables Management

The portable monitor and control console is also used as an input/output device for determining the level of spares or consumables available and for the location of spares within the storage bins of the module. Withdrawals and additions (where parts are shifted from one Logistics Module to another) are entered via the keyboard after call-up of a particular item's name or part number which would also result in a display of the quantity of spares remaining and their bin location.

5.3.7 Physical Characteristics

The communications and data management subsystems will require the components or assemblies shown in Table 5-3. Also included in the table are power and weight resource requirements.

5.4 CREW SYSTEMS

During normal on-orbit operations the Logistics Module(s) serves as a "pantry" for the Space Station in order to take full advantage of the volume

Table 5-3
LOGISTICS MODULE EQUIPMENT LIST

Name	Quantity	Weight (lb)	Power W (max)
RDAU	12	12	60
Terminal	3	15	60
Bus (Couplers + Coax)	n/a		
ATU	3	12	12
Portable Monitor + Control Unit	1	100	125
TV Camera	2	4	n/a
Camera Control Unit	2	16	30
LDMU	3	12	21
Wiring	n/a	89	0
n/a = not applicable			
Total		262	308

which its presence adds to the total Station volume. Expendables (e.g. atmosphere, food, spare parts) are retained (stored) in the Logistics Module until they are required. When required, they are manually transferred (except fluids and gases stored in the unpressurized area) by the crew from the Logistics Module directly to the place where they are to be used.

In order to facilitate the manual transfer of solid cargo from the Logistics Module to the modules of the station, all cargo will be packaged, to the fullest extent practical, in standard sized containers that can be easily handled by a single crewman without mechanical aids (other than normal handholds, rails, etc., provided for routine mobility purposes).

Ninety-five percent of the anticipated cargo can be accommodated in the standard containers (60 x 60 x 60 cm) (2 x 2 x 2 ft). The remaining 5 percent, because of their weight, size or inertia, may require mechanical aids to insure positive control at all times during transfer. A system for this purpose is described in Section 6.

The seating and restraint systems for use in the rescue module is indicated in Figure 4. 5. It is designed for minimum weight, simplicity of operation (ie., adjustment in crewman's position with change in the direction of "g" forces for different phases of the mission), a maximum of crew comfort for extended duration use, and ease of installation and removal.

The seat is a simple web structure mounted between rails that extend from floor to ceiling. Adjustment is provided from an upright seated position to a fully-reclined position. This adjustment is made by sliding the back section up the rails and locking in the desired position. The seat provides support equally from front or back and can be reversed by removing the anchor pivots, passing them through the rails, and anchoring on the opposite side. Full adjustment is available from either side of the seat with the proper positioning of the anchor pivots.

The webbing of the seat provides a large body contact area for absorbing the deceleration and landing "g" forces. The wide flexibility in position and direction enables the crewman to assume an optimum position for reentry, and landing. For the rescue mission the seats are arranged in the aft facing position. For reentry, the position is reclining to distribute reentry forces. After reentry, the seat is moved to the seated position for landing. Even potentially severe crash landing forces will be distributed on the crewman by the total body contact webbing holding the body in an optimum aft facing position. In case of extended phasing periods, the extended seat provides a comfortable sleep position.

Section 6

OPERATIONS

This section describes the ground and flight operations concept of the logistics module and the related operations of the Space Shuttle. Design requirements stemming from these operations are summarized at the conclusion of the ground and flight operations sections. Additional information on operations of the Space Shuttle system are described in Section 7, logistics system interfaces.

6. 1 GROUND OPERATIONS

The basic concept for Logistics/Crew Cargo Module operations is similar to that developed for the 10 m (33 ft) diameter Station, i. e.,

A. Existing facilities will be used for Logistics Module and Crew Cargo Module operations (the VAB low bay area).

B. Logistics Module and Crew Cargo Module operations will be a continuing effort for the duration of the Space Station Program (with up to one launch per month except when superceded by a Space Station module or research and applications module launch).

C. There will be no flight operations support impact (in terms of Logistics Module and Crew Cargo Module mission control facilities and GSE) beyond that required for Space Station and Shuttle mission control operations.

The nature of Logistics Module and Crew Cargo Module activities at KSC is described in more detail in the following sections.

6. 1. 1 Logistics Module Prelaunch and Launch Operations

Logistics Module operations at KSC have several unique features which depart significantly from previous manned and unmanned spacecraft programs. The modules will carry a large quantity of cargo relative to its overall size (4. 3 m (14 ft) diameter by approximately 9 m (30 ft) long). It will be returned to KSC after its mission to be reused many times. As a result, Logistics Module ground operations must consider post-orbiter landing activities, i. e., refurbishment and maintenance, cargo loading and unloading in addition to more familiar prelaunch and launch operations associated with any launch. The operational flow typical of Logistics Module processing at KSC, and illustrating these features is summarized in Figure 6-1. Operations interfacing with Logistics Module operations are shown for reference (connected with dashed flow lines). Note that Logistics Module operations marked with an asterisk (*) are new to KSC, and will have significant impact. Logistics Module ground operations must be accomplished efficiently, as the launch rate will approach one every 30 days on the average.

6. 1. 1. 1 Operational Flow

Overall operational flow proposed for the Logistics Module at KSC, and the related cargo handling flows are shown in Figure 6-2. Note that the flow shows three major branches; the flow for the initial flight of a Logistics Module, originating at the factory with manufacturing and shipment to KSC; the flow for repeated flights of a Logistics Module returned from orbit; and the flow for cargo and supplies to be loaded on the Logistics Module. These branches converge to a common flow for later stages of Logistics Module operations, beginning with final checkout of the Logistics Module and terminating with launch.

Significant features of the operational flow which should be noted include:

A. First flight flow branch for the unmanned Logistic Module is simple, i. e., it is received and offloaded, inspected, verified for proper configuration, and given very limited checks (since there are few functional subsystems on the Logistics Module). No unique requirements are evident for this phase of Logistics Module operations other than facilities necessary for accomplishment of the operations. The nominal means of shipping the Logistics Module to KSC will be by air, although other means will be possible. The facility proposed for conducting operations is the VAB low bay.

B. A Logistics Module may require major overhaul after a number of flights. The Logistics Module would be returned to the manufacturer or to KSC shops with remanufacturing capabilities in this

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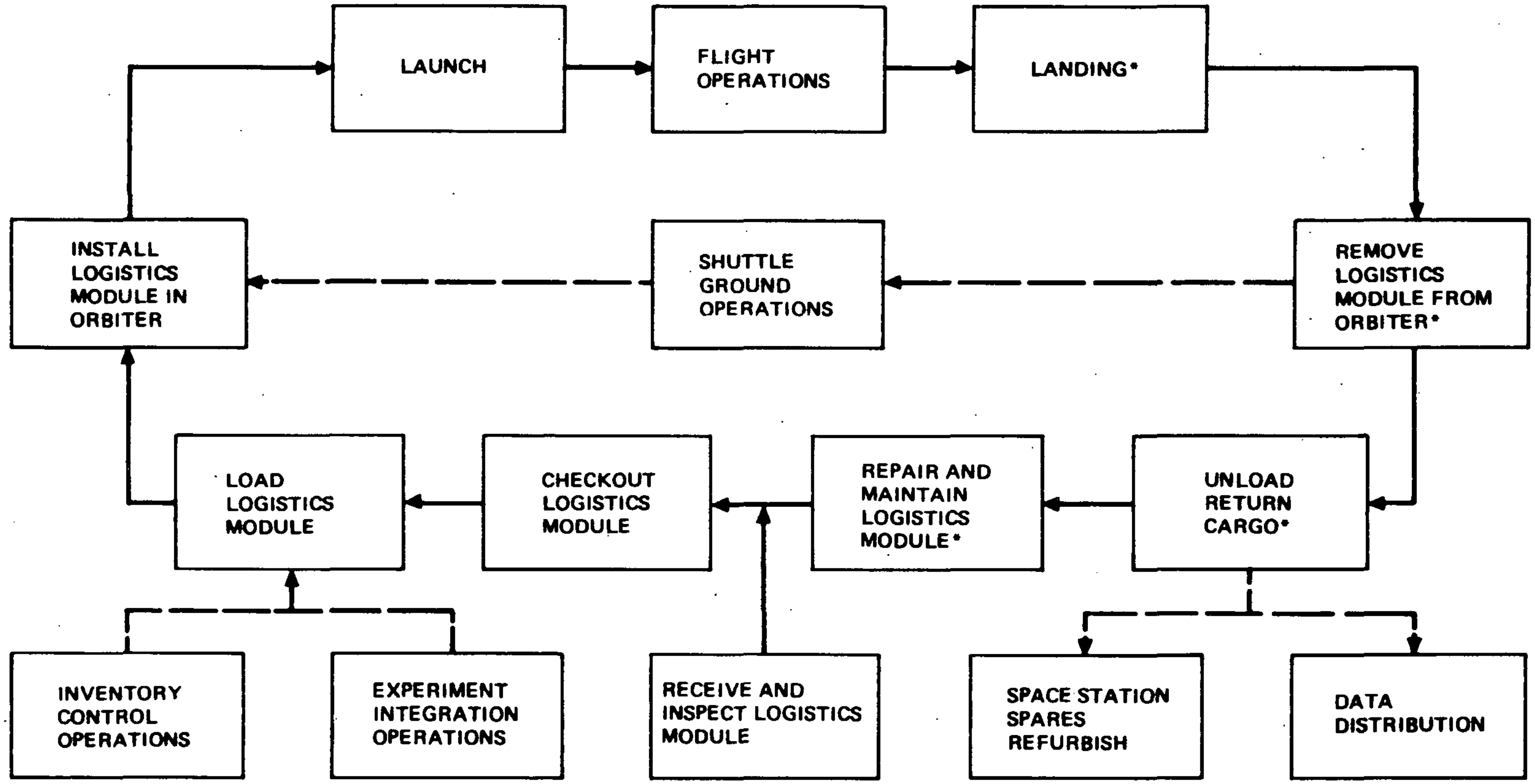


*NEW TO KSC

Figure 6-1. Logistics Module Processing – Typical Operational Flow case, and treated as a new Logistics Module arriving at KSC for its first flight when it is returned to operational status.

C. The repeat flight flow branch for the Logistics Module has several unique features:

1. The Logistics Module will be returned to KSC by the Shuttle orbiter. Time-critical data will be removed as soon as the Shuttle orbiter rolls to a stop. Returning Space Station crew members will also egress from the Shuttle passenger compartment at this time. Portable stairs similar to those used by airlines or other means for passenger removal will be required at the Shuttle rollout area. It is assumed that the Shuttle will provide any equipment for crew ingress and egress.
2. The Logistics Module must be safed when it arrives (lands) at KSC since it will contain residual Space Station propellants and EC/LS expendables and residual experiments expendables. This will be accomplished as soon as the Shuttle crew and passengers have left and the Shuttle has cooled. Logistics Module servicing equipment will be required at end of the Shuttle runway for Logistics Module safing.
3. It will contain cargo of various types (experiment data and samples, Space Station parts which have malfunctioned, waste, reusable packaging, etc.) which must be unloaded and given proper disposition. Unloading will be accomplished more easily after Logistics Module removal from the orbiter, since access to all hatches will then be possible.
4. A postflight inspection and check of the Logistics Module will be performed to determine if there are any malfunctions or defects which must be repaired in addition to scheduled maintenance. Subsystem tests will ensure that all repairs and reconfiguration have been successfully accomplished, and that the Logistics Module is again flight ready except for loading.
5. Logistics Module reconfiguration will be required occasionally as dictated by changes in cargo mix. Therefore, Logistics Module design must be capable of quick change accommodation of different types cargo, e.g., palletized fluid tank complexes.

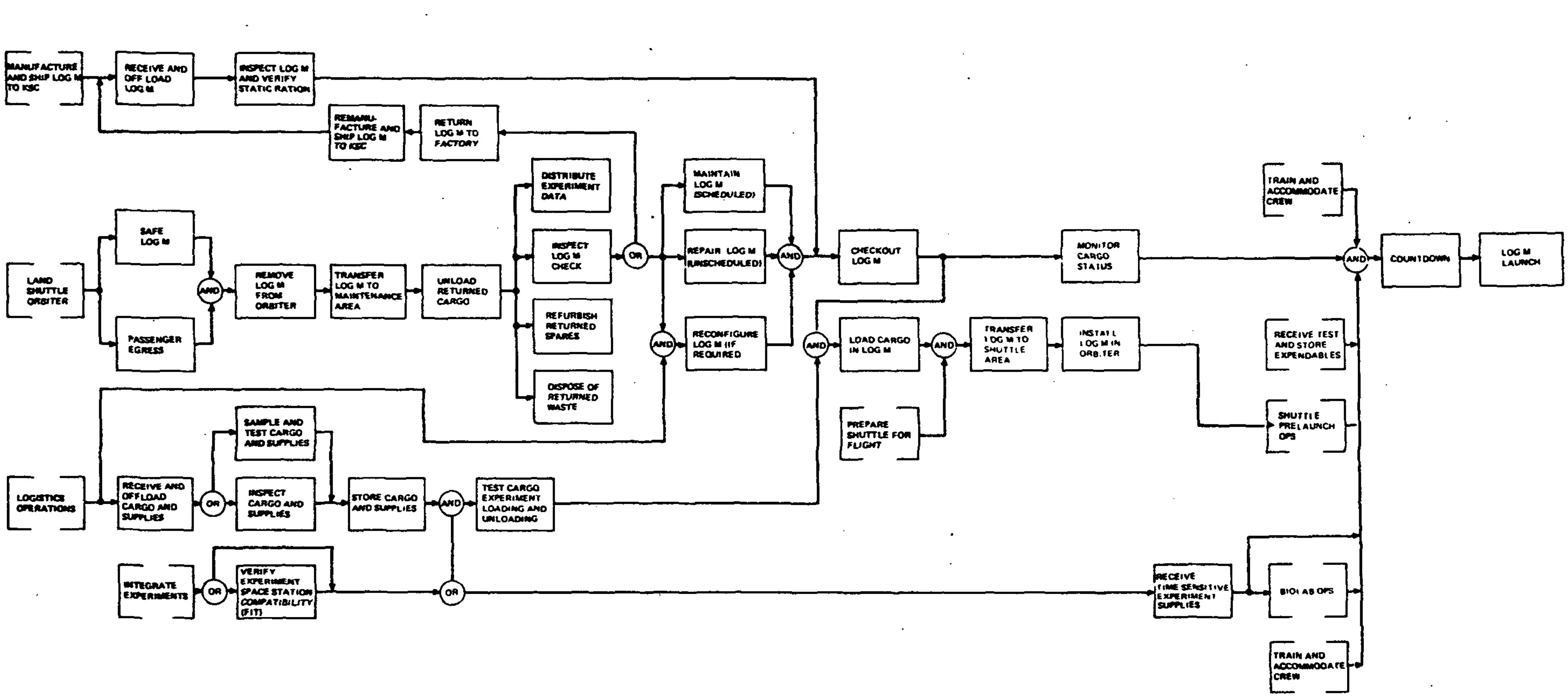


Figure 6-2. Logistics Module Prelaunch and Launch Operations

D. Operations occurring in the common part of the flow also have several unique features:

1. Logistics Module cargo status (e. g., expendable tank pressures, valve positions) will be continuously monitored after checkout has been completed until countdown and liftoff.
2. Cargo loading will include loading of all solid and fluid cargo except time sensitive, and hazardous items which will be loaded during countdown. Weight and cg equipment must be located at the cargo loading area to verify the actual weight and cg of the flight loaded Logistics Module.
3. The Logistics Module will be top loaded in the Shuttle orbiter while it is still horizontal in the Shuttle maintenance area, although it will be possible to load the Logistics Module into the Orbiter with the orbital vertical in the VAB high bay.
4. Shuttle operations pace the Logistics Module operations after it is installed in the Orbiter.
5. Logistics Module countdown will be integrated with the Shuttle countdown. Logistics Module activities during this period will include loading of propellants, cryogenics, and other hazardous fluids, activation of Logistics Module flight systems and verification of status, and time sensitive cargo ingress.

Several operations which interface with Logistics Module operations are shown as reference blocks on the diagram. Experiment integration includes mating experiments with the FIT before delivery to the Logistics Module. Logistics control operations track supply usage, plan procurement of cargo and supplies, and determine cargo mixes. Shuttle operations include refurbishment and preparation of both booster and orbiter for the next flight, erection and stacking, and Shuttle countdown. Space Station crews are processed through the crew training and accommodation operations block. Finally, biological laboratory operations provide for experiment specimens until launch and support orbital experimentation by performing control experiments on the ground in parallel with orbital experiments.

Figure 6-3 is an estimated timeline of Logistics Module operations. Note that approximately 18 working days (3.6 weeks) will be required from time of arrival of the module through liftoff.

6.1.1.2 Ground Handling Approach

It is obvious that handling and transporting of a Logistics Module returned from orbit will be necessary considering the impracticality of accomplishing Logistics Module repair, checkout, and cargo loading while it is in the Shuttle cargo bay. A number of module handling options were investigated during earlier study efforts, (refer to DRL 160, Line Item 22, Appendix O). The option which results in the least handling, and hence the least risk of damage during ground operations, is one in which the module is shipped installed on a transporter or dolly or installed on one immediately upon removal from the Shuttle, and remains on this transporter throughout all subsequent operations until it is loaded into a Shuttle.

6.1.1.3 Turnaround and Maintenance Activities

Logistics Modules will be maintained through an airline method of operation as illustrated in the flow, i.e., preflight and postflight checks, correction of malfunctions experienced during flight, and periodic maintenance. However, this ideal, as in the case of aircraft, cannot be realized initially. Early repeat flights of the Logistics Module will require extensive post/preflight testing similar to that required for the first flight. These early flights are analogous to certification flights of aircraft before they are put in regular service. As experience and confidence in test procedures is gained, the amount and complexity of inspection and test will be reduced.

Corrective maintenance of fluid cargo handling equipment can be performed on the modules during flight as well as during postflight turnaround. Certain critical spares will be carried onbaord the Logistics Module and the Space Station to allow inflight removal and replacement. The bulk of preventive and corrective maintenance performed on the modules will be accomplished on the ground between flights. Regardless as to where maintenance is accomplished, removed hardware will be inspected and refurbished if possible.

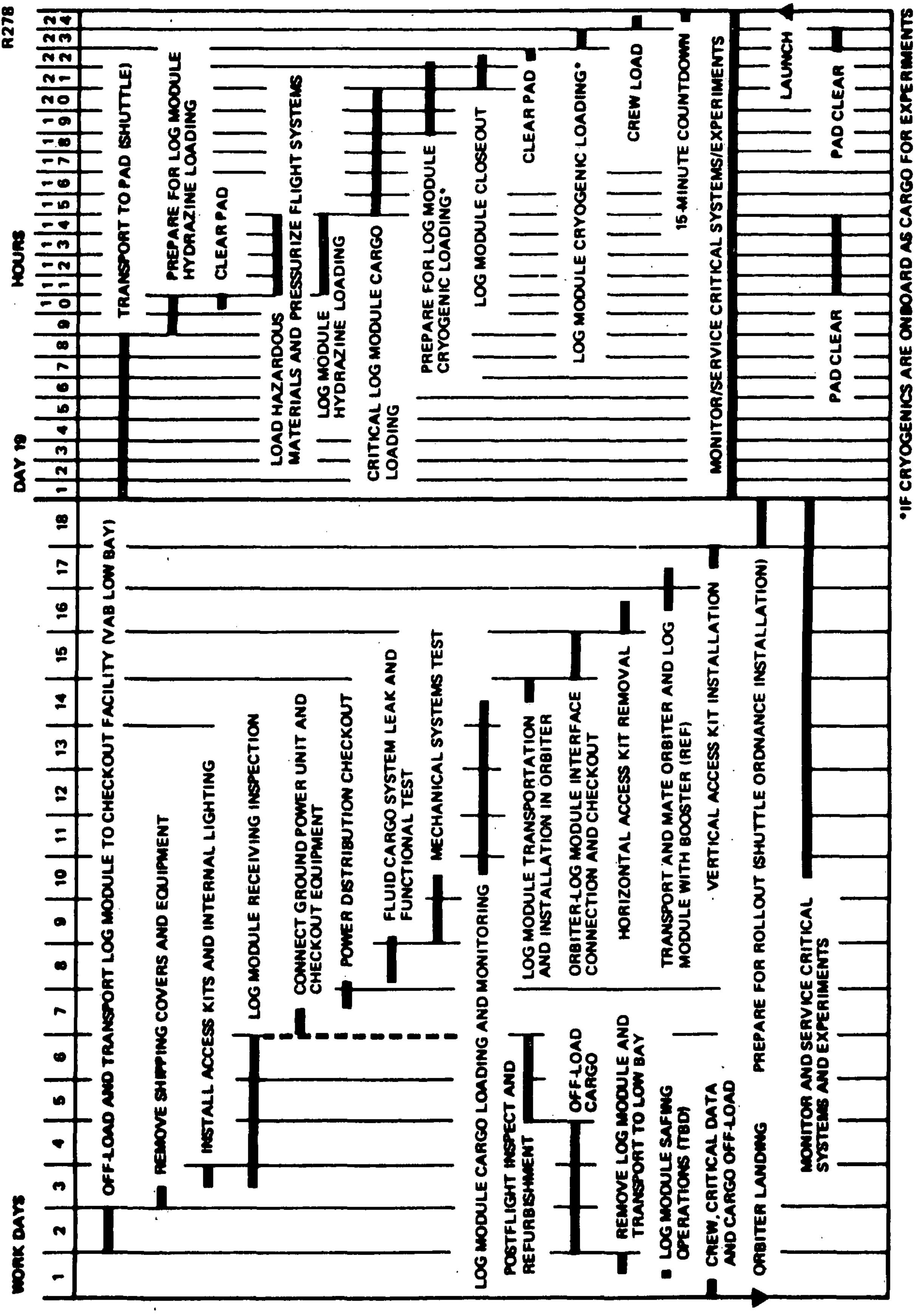


Figure 6-3. Preliminary Master Schedule-Logistics Module

Refurbishment operations include the activities necessary to rework, repair, and recommission Logistics Module subsystems and subassemblies or components thereof which have been removed because of failure or limited-life considerations.

The items to be refurbished will be sent to Inventory Control and then shipped to the refurbishment centers operated by contractors or by the Government.

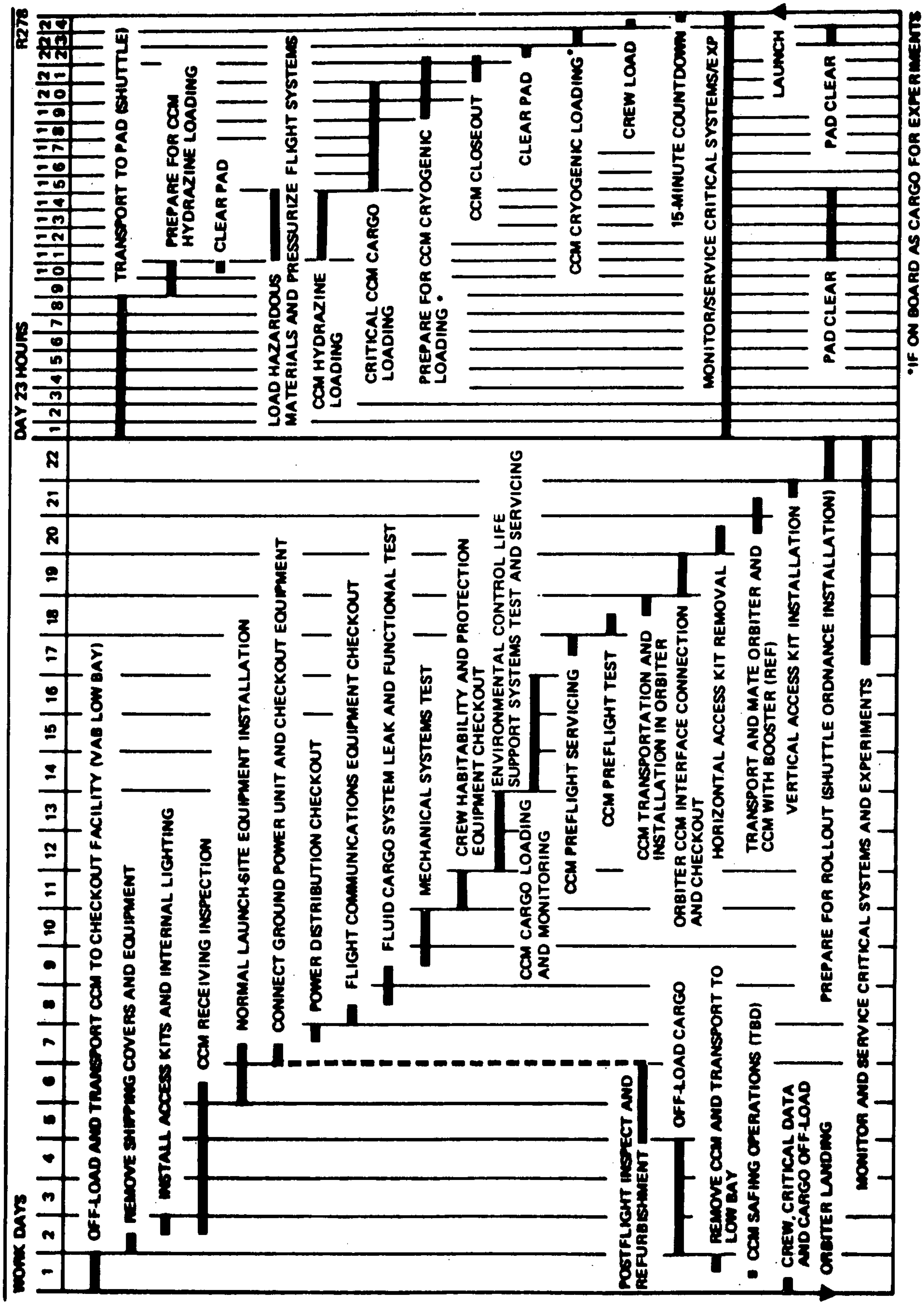
Refurbishment begins with receipt and inspection of the returned items at the refurbishment centers. This activity will determine the reusability of the item and its future disposition. Some returned equipment will have been so badly worn or damaged that it will only be used in further destructive testing and analysis and to satisfy other needs. Other equipment will be in such a condition that it can be returned to serviceability after some repair or rework. On determination that the returned equipment can be returned to serviceability, it will be sent to either contractor or Government repair and rework agencies. Factors influencing selection of the rework and repair agency will include capability to handle the job relative to personnel, equipment, and facilities; cost; and time required to return the item to the spares inventory.

6.1.2 Crew Cargo Module Prelaunch and Launch Operations

Crew Cargo Module prelaunch and launch operations will be essentially the same as those for the Logistics Module. The primary difference will be the additional servicing and checkout required for the six-man EC/LS subsystem. An estimated time line of Crew and Cargo Module operations is shown in Figure 6-4. In this case approximately 23 working days (4.6 weeks) will be required to turnaround a module.

6.1.3 Contingency (Rescue) Capabilities

Should a contingency arise on orbit requiring rescue of the crew, it will be necessary to return all six crew members simultaneously. A quick installation kit or separate rescue module will be available to accommodate the



*IF ON BOARD AS CARGO FOR EXPERIMENTS

Figure 6-4. Preliminary Master Schedule-Crew Cargo Module orbiting crew. Installation of rescue provisions will require 3 to 6 hours, depending on the status of the Logistics Module to be used, i. e., loaded, empty, in the Shuttle, etc.

The Crew and Cargo Module will normally be outfitted to transport six men. In case of rescue, however, the necessary equipment will be installed, thereby increasing Crew and Cargo Module passenger capability for rescue to 12 men.

6. 1. 4 Logistics Module Ground Operations Requirements Summary

A number of requirements and constraints for both the ground system and Logistics Module are inherent in this operational concept and are listed below:

A. Logistics Modules shall accommodate performance of all ground processing in a horizontal position.

B. Logistics Modules shall provide for direct attachment of hoisting GSE while in the orbiter cargo bay (with orbiter horizontal or vertical - although attach points need not be the same for each position).

C. Logistics Module servicing (umbilical) connections shall be accessible for Logistics Module servicing when the Logistics Module is installed in the shuttle orbiter, with the orbiter vertical (for loading of hazardous fluids on pad and final top off of others during countdown), and with the orbiter horizontal (for safing after landing and initial servicing).

D. Interior equipment, cargo stowage racks, etc., shall be in a heads-up position during ground processing of the Logistics Modules in the horizontal position.

E. The Logistics Modules shall not require a clean room environment.

F. Logistic Module design shall be such that reconfiguration due to cargo mix changes will be minimal, i. e., the Logistics Module cargo carrying accommodations shall be as independent of cargo mix as practical.

G. Reconfiguration of Logistics Modules, when necessary, shall be easy to implement. Access to all joints and interfaces which must be broken or mated shall be provided. Simple standardized interfaces shall be a goal.

H. Readily accessible test connectors shall be provided for checkout. It shall not be necessary to disconnect flight connectors during ground processing (except for repairs).

I. Umbilical connections shall be provided for monitoring system status after checkout has been completed.

J. Logistics Module fluid cargo servicing equipment shall be located at the Shuttle landing site and the pad, or shall be portable.

K. All Logistics Module assembly, integration, and acceptance testing shall be accomplished prior to delivering the Logistics Module to KSC.

L. Logistics Module interior arrangements and provisions shall allow ground personnel easy access, in a 1 g environment, to all cargo securing and tie down areas, and all maintenance areas.

M. It shall be possible to open all Logistics Module docking ports and hatches during ground operations except when the Logistics Module is installed in the Shuttle orbiter.

N. Active Logistics Module equipment shall operate in the 1 g Earth environment with the Logistics Module horizontal or vertical.

O. Active thermal control of the Logistics Module shall not be required on the ground.

P. Any Ordnance arming or connecting points shall be accessible with the Logistics Module installed in the orbiter on pad.

Q. The Logistics Module design shall not require installation of flight hardware on pad (except ordnance igniters).

R. Prelaunch testing of the Logistics Module shall be structured to duplicate actual launch and flight operation to the extent practical.

S. Logistics Module checkout procedures shall be standardized to the extent possible for use at the factory, at KSC, and on orbit.

T. Logistics Module preventive and corrective maintenance shall be accomplished by the removal and replacement of "plug-in" modules.

U. Installation/loading of hypergolics, cryogenics, and ordnance initiator devices in the VAB shall not be permitted. Installation of any ordnance should be planned as late as possible in the processing flow.

V. Ground access shall be provided for loading live specimens and perishables in the Logistics Module while on the launch pad.

W. Hazardous liquids and gases shall be loaded in the Logistics Module on the launch pad.

6.2 FLIGHT OPERATIONS

6.2.1 Shuttle/Logistics Module Operations

6.2.1.1 Ascent, On-Orbit Flight, Return Operations

The Space Station crew, as Shuttle passengers, are assigned a passive role during Shuttle flight and will not be required to perform any Shuttle or cargo tasks during ascent, rendezvous, docking, or return flight operations. Only two Space Station crewmen can be accommodated on each Shuttle flight; therefore, a crew delivery and return flight is scheduled every 30 days in order to rotate six crewmen for each 90-day mission phase. Logistic Module delivery and return is required nominally once each 90 days, thus every third crew rotation flight will also have an Logistics Module payload.

Certain items of cargo in the Logistics Module will require monitor and control by the shuttle pilots during ascent, rendezvous, docking and the return flight. These items are the liquids, gases, and cryogenics stored in the unpressurized compartment of the Logistics Module that potentially could cause an unsafe condition. Critical Logistics Module data (pressure, temperature, etc.) would be displayed and controlled from the Shuttle cockpit by the Shuttle pilots. All other cargo will nominally not require monitor or control during flight. The LM cargo area is pressurized prior to liftoff at 14.7 psia and will nominally remain within ±1 psia of the launch environment. The cargo characteristics peculiar to a specific item (temperature, pressure, vibration, g loading, radiation limits) shall be accommodated by the packaging or container design. It was determined that cargo such as specimens and animals require special containers to accommodate the environment during ascent, and reentry phases of Shuttle flight.

6.2.1.2 Docking Operations

The baseline operational concept for docking all modules to the Space Station is the direct docking mode with manual control. The Shuttle will dock the

Logistics Module as described in MP-01 which presents the operational description, procedures, timelines, docking interfaces, requirements, etc. Additional information on Shuttle docking operations is contained in Section 7.0.

6.2.2 Station/Logistics Module Operations

6.2.2.1 Crew Transfer (Logistics Module)

Once the docking operations (docking collar capture, latching and seal pressurization) have been completed the crew transfer operations will begin. The crew will transfer from the Shuttle to the station via the Logistics Module in a shirtsleeve environment (14.7 psia, 60°-80°F). The onboard Station crew will operate the equalizing valve in the Station hatch allowing Station air to pressurize the LM/Station docking interface area. Once the pressure on each side of the Station hatch has been equalized and held at steady state conditions for 10 minutes, the Station hatch will be opened. Verification of air pressure will be registered on a gauge located near the hatch. The Shuttle pilots will turn on the Logistics Module interior lights. The on-board Station crew will proceed to equalize the Logistics Module interior pressure to the docking interface area and Station by the same procedure and then open the Logistics Module hatch. Simultaneously the Shuttle pilots will pressurize the Shuttle air lock and tunnel leading to the Logistics Module. The Station crewmen located in the Shuttle will then proceed to the Shuttle air lock, open the hatch and enter the air lock. They would then open the tunnel hatch and proceed to the end of the tunnel and verify the Shuttle/Logistics Module docking interface area is equalized. The crew would then open the Shuttle tunnel hatch, enter the docking interface area, verify the Logistics Module and Shuttle docking interface area are equalized and open the last hatch or Logistics Module hatch. The new crew would then proceed through the Logistics Module into the Station. The returning Station crewmen would board the Shuttle in the reverse procedure. The new crewmen will report to the Station commander and begin briefing operations with the two crewmen being rotated. Two other crewmen would begin connecting the interface connectors between the Logistics Module and Station as described in MP-01.

6.2.2.2 Crew Transfer (Crew and Cargo Module)

During GSS operations six station crewmen shall be accommodated in the Crew and Cargo Module. The Shuttle will dock to the assigned docking port via the Crew and Cargo Module using the same docking procedures as for the Logistics Module. Again, the Station crew has the same passive role as Crew and Cargo Module passengers during shuttle launch and flight operations as described in the previous paragraph for Shuttle passengers. Additional requirements for Shuttle air, power, communications, and monitor and alarm functions are imposed on the Shuttle and pilots to monitor and control those functions. Once the Shuttle/Crew and Cargo Module docking operations are completed crew transfer operations will proceed. The crew will transfer in a shirtsleeve environment of 14 psia and 60°-80°F. The Station on-board crew will equalize the pressure in the docking area by the same procedure described for the Logistics Module and open the Station docking hatch. Completing this task the onboard Station crew will equalize the pressure on each side of the Crew and Cargo Module hatch and open the Crew and Cargo Module hatch. The new crew is now ready to transfer to the Station. The on-board Station crew continues to connect the interface connectors between the Station and Crew and Cargo Module, and make final preparations for the returning Crew and Cargo Module. The returning flight crew members would transfer from the Station to returning Crew and Cargo Module by the reverse procedure of the arriving crew after the Shuttle had separated and docked to the returning payload.

6.2.2.3 Cargo Storage and Transfer

The onboard "pantry concept" developed during the 33-ft Station study was reevaluated for the Modular Station design and operation. The reevaluation concluded that the "pantry concept" continued to provide the best concept and operational mode for on-orbit storage, inventory control, and daily utilization by the crew. Tradeoffs emphasized crew time, storage requirements aboard the station, and scheduling of cargo tasks. The pantry concept continues to provide the minimum onboard storage requirements for other Station modules, minimum crew time required for cargo transfer, and allows the transfer of cargo on an as needed basis or non-interference scheduling with experiment operations. Figure 6-5 shows a Logistics Module and indicates the cargo storage concept and also the concept for crew transfer of a large item of equipment.

The requirement for 120 days of supplies on orbit after each resupply cycle is satisfied by having 30 days of operating spares, consumables, and expendables on board the Station and 90 days of supplies in the Logistics Module. With the arrival of the next logistics flight, the Logistics Module returning also returns the supplies not utilized plus the return cargo from the Station. The new Logistics Module delivers 90 days of supplies and the cycle continues. Another approach is to off-load the remaining supplies not utilized on the Station rather than return all unused cargo to ground inventory. An analysis of the cargo manifest indicated that almost all of the unutilized items would be spares for the first 11 quarters of ISS operations. The spares would be added to the inventory and controlled by the combined on-orbit/ground inventory control system. Future flights would then be void of these items. The additional onboard storage for these items would be minimal.

The remaining quarters (11-20) of ISS operations requires two Logistics Module deliveries for each 90-day phase to satisfy resupply requirements. GSS operations require two Crew and Cargo Module deliveries during each 90-day cycle to achieve crew rotation. Again each module would provide 90-days of resupply plus the 30-day supply onboard the Station. However, the return, unused cargo now consists of fuel, food, and other consumables, expendables and spares. Two approaches were investigated. The first was to increase the onboard storage capability to provide 90 days of onbaord capability and 30 days of resupply in the Logistics Module. The design weight penalty on the Station modules and poor utilization of Logistics Module capability during the first half of ISS operations was unacceptable. Since the crew rotation flights are independent of Logistics Module payloads, the overall Shuttle flights were not reduced.

The second approach was to review the initial requirement. The intent of the requirement was to establish a contingency supply aboard the Station to allow for a late resupply of up to 30 days. A change of the requirement to

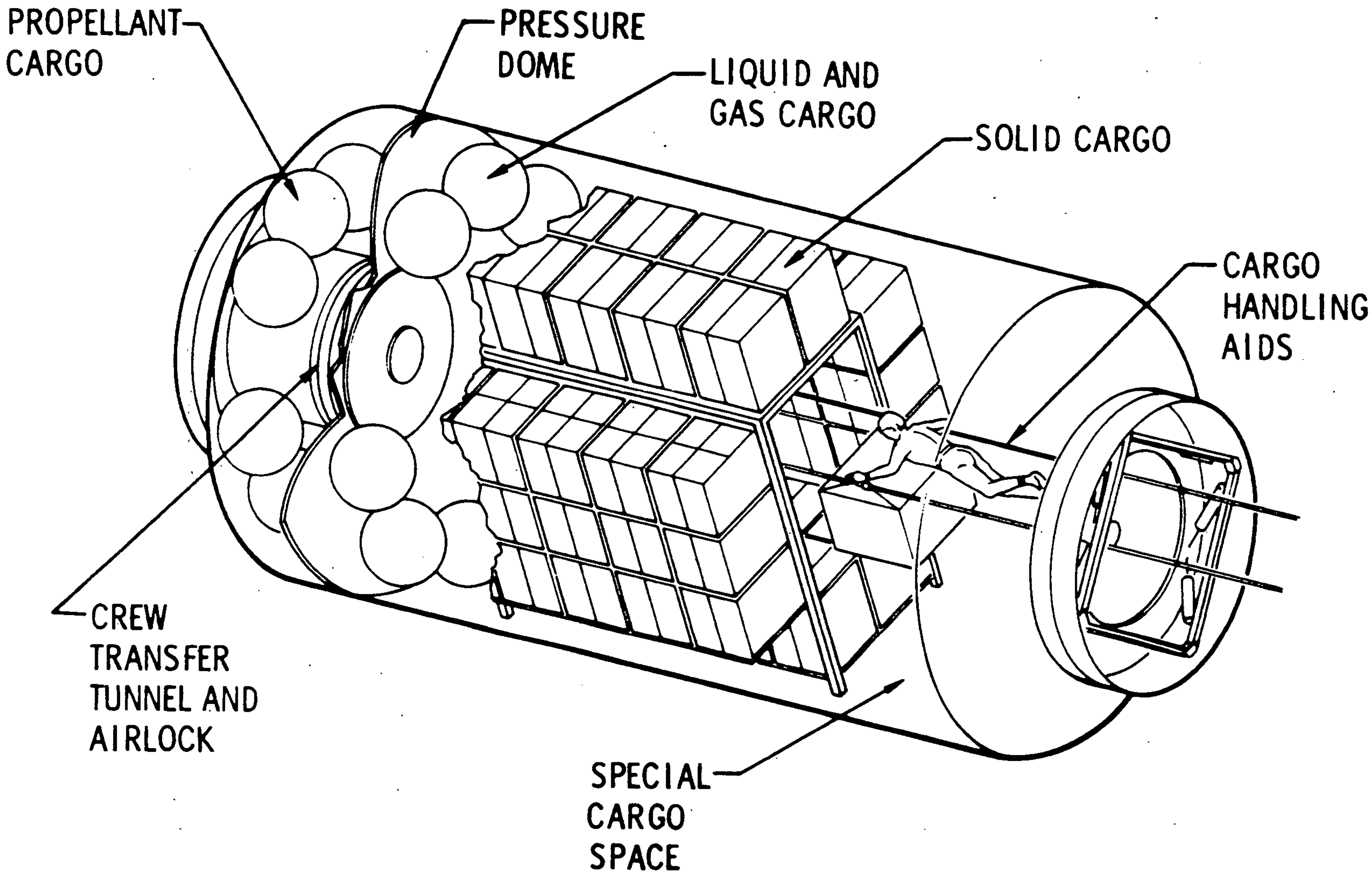


Figure 6-5. Logistics Module

establish 30 days of contingency supplies with each resupply flight results in an optimum utilization of Logistics Module, Crew and Cargo Module, and onboard storage. If a Logistics Module or Crew and Cargo Module is scheduled to stay on-orbit for 60 days then a total of 90 days of supplies would be established with the arrival of the Logistics Module or Crew and Cargo Module. That is, 60 days of supplies in the Logistics Module or Crew and Cargo Module stores and 30 days onboard the Station. Thus, at the end of 60 days a minimum of unused cargo would be returned, whereas, in the current baseline, 30 days of unused food, fuel, etc., would be returned. MDAC has therefore recommended a change of the level 1 requirement which currently reads,

> "The initial Space Station shall have the capacity for independent operation with a full crew for a period of 120 days. This capacity can be included in a cargo module."

to read:

> "The Space Station during any level of operation capability (i. e., ISS or GSS) shall have the capacity for independent operation with the full crew for no less a period than the nominal resupply mission plus 30 days. This capacity can be included in a logistics or cargo module."

Cargo transfer operations are similar to those developed for the 33-ft Station with some exceptions. Selected liquids and gases are transferred under control from the Space Station control console to the subsystem using point (RCS, RAM, GPL, etc.). Each neuter docking port on the Modular Space Station has the interface connectors and capability to mate to the Logistics Modules for these transfer operations. Cryogenics are of limited quantity and are manually transferred by the crew from the Logistics Module to the GPL or RAM.

Solid cargo transfer will be accomplished primarily by the crew. The majority of solid cargo items can be safely handled and transferred by the crew from the Logistics Module or Crew and Cargo Module to the power, crew, or GPL modules without the aid of a cargo handling system. However, the characteristics of a few items exceed the capability of a crewman to safely control and constrain the movement of the item without the assistance of a mechanical aid or cargo-handling device. These characteristics include size and shape, moment of inertia, and potential hazards (such as high pressure bottles). Some items are resupplied periodically throughout ISS and GSS operations and will require a transfer from the Logistics Module to a Station module. The experiments will also require the periodic delivery and transfer of equipment or resupply of cargo having the characteristics requiring a transfer system to assist the crew. Since the usage rate of the transfer system is periodic rather than routine with each resupply flight, a simple system that can be easily installed and removed for onboard storage is desired rather than a more sophisticated and permanent system throughout the Station. A proposed concept for a minimum system is presented in the following paragraphs and would be delivered to the station on the first Logistics Module.

A dual cable cargo moving system is depicted in Figure 6-6. The system functions as follows:

A. Two cables (e. g. nylon) are attached to fixtures located in the aisleways of each Station module and Logistics Module.
B. The cables are anchored at convenient intervals.
C. Removable cable trackers are installed.

Equipment requiring use of the system during ISS activation would include those described in Table 6-1.

To operate the system the crew would attach the cable runs from the Logistics Module to the equipment location aisle zone in the Station module where the equipment or item is to be transferred. The crew would then attach one cable tracker to the cable. The tracker is clamped and locked onto the cable and is normally spring-loaded to the brake position. The crew depresses the trigger mechanism releasing the brake and the tracker is free to slide along the cable. Releasing the trigger automatically engages the tracker brake.

With one tracker installed, the crew would then attach an adjustable cargo constraint cable. One end anchors to the tracker and the other end attaches to the cargo packaging fitting.

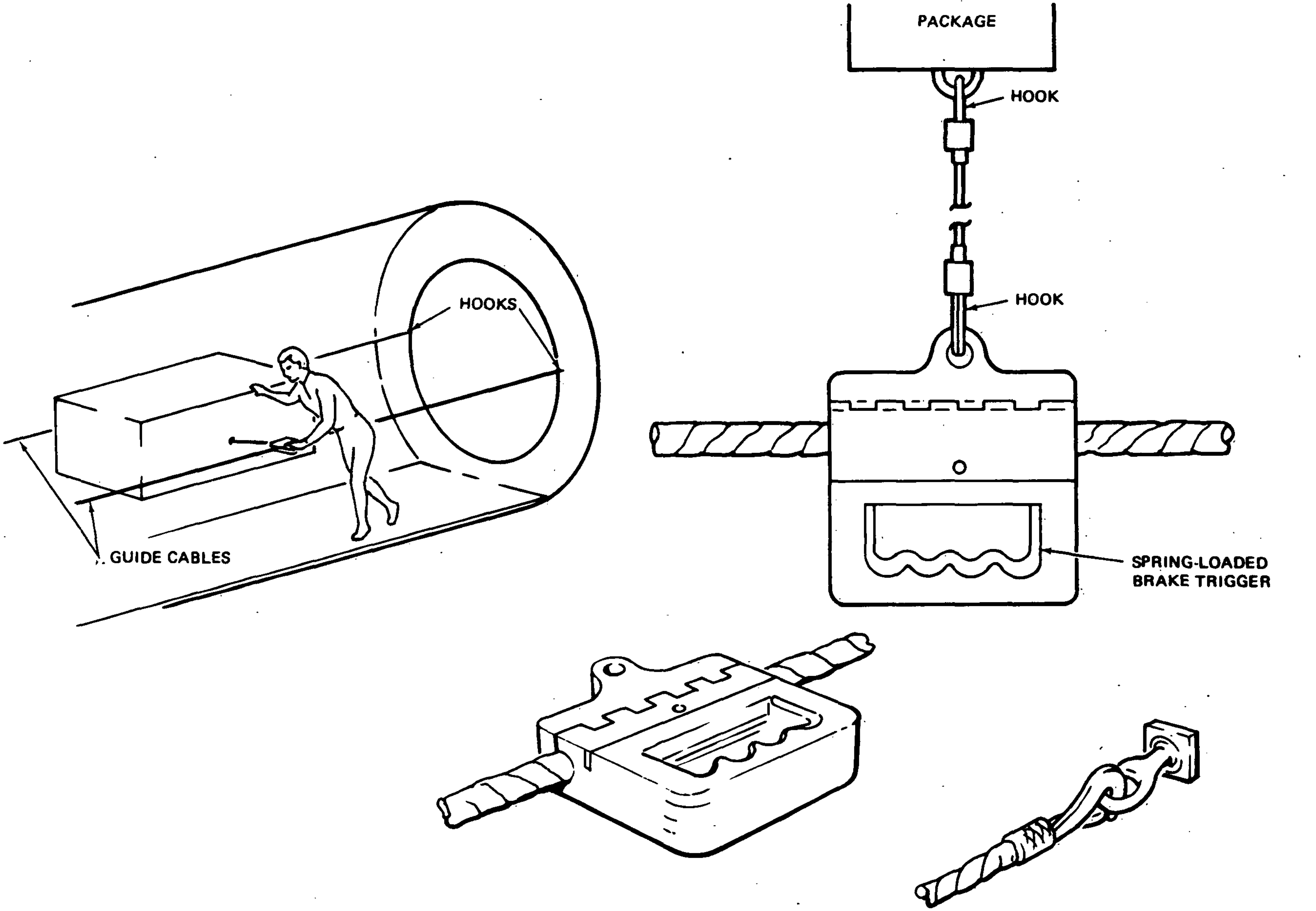


Figure 6-6. Dual Cable Cargo Moving System

Table 6-1

CANDIDATE EQUIPMENT REQUIRING TRANSFER SYSTEM

Item		Qty	Transfer From LM To
1. CMG's		4	Power Module
2. Repressurization Gas			
	O_2	1	Power Module
	GN_2	4	Power Module
3. Metabolic Gas			
	O_2	2	Power Module
	O_2	2	Crew Module
4. Pumpdown Accumulators		2	Power Module
5. Water Tanks		2	Crew Module
6. Batteries		1 set	Power Module
		2 sets	Crew Module
		2 sets	GPL
7. Food (Refrig.)		2	Crew Module
(Freezers)		2	
8. Trash Compactor		1	Crew Module

The cargo item is pulled into the aisle-way sufficient to allow installation of the second tracker and guide cables are then adjusted to the proper tension to constrain the cargo. The crew is now ready to translate the cargo along the cable run.

Each crewman releases the tracker brake and provides the force to translate the item. This system has the advantages of simplicity, ease of operation, together with minimal storage and maintenance requirements, and low cost.

6.2.3 Mission Performance Requirements

The following summarizes the general mission performance requirements of the Logistics Module:

A. The Logistics Module primary mission shall be the transportation of cargo to and from the orbiting Space Station.

B. The Logistics Module shall transport six crewmen from the orbiting Space Station in an emergency rescue mission.

C. The Logistics Module shall support the cargo in a fully operational mode for two days, and in an emergency mode for two days.

D. The Logistics Module shall use available Shuttle support (consumables, power, etc.).

E. The Logistics Module shall be docked to the Space Station by the Shuttle by the direct docking mode.

F. The primary on-orbit function of the Logistics Module shall be storage for periods of 30, 60, or 90 days.

G. The Logistics Module shall provide provisions for two cargo transfer systems. One system shall provide automatic transfer of liquids and gases controlled from the Space Station. The second system shall provide fittings for periodic installation of a cargo cable system to assist the crew with translation and control of cargo items from the Logistics Module to Station.

H. The Logistics Module shall be capable of mission accomplishment with a cargo weight ranging from zero to maximum capacity.

I. The Logistics Module shall be designed to be docked and operational at any docking port of the Space Station.

J. The Logistics Module will deliver and return spares, consumables and equipment to support the Space Station crew, subsystems, and experiments. The cargo characteristics and mix provide the criteria for (1) Logistics Module compartment sizing and design, (2) cargo packaging, loading and unloading within the Logistics Module, and (3) cargo storage access and on-orbit handling within the Logistics Module.

K. Gases in significant quantity are GO_2 and GN_2. These are stored in the unpressurized area.

L. Liquids in significant quantities are N_2H_4, H_2O, and cryogenics (LHe, LN_2). The N_2H_4 is a candidate for storage in the unpressurized area while the cryogenics and H_2O would be stored in the pressurized area and transferred by the crew.

Section 7

LOGISTICS SYSTEM INTERFACES

The major interfaces between the Logistics System and (1) the Space Shuttle and (2) the Space Station are summarized in this section as a convenience to the reader.

7.1 SPACE SHUTTLE

This section contains a description of pertinent Space Shuttle features and operations as they impact the logistics system. Design requirements stemming from interfaces with the Shuttle are summarized. Certain of these requirements were provided by NASA. Supplemental information on the Space Shuttle was utilized in this study. This information is based on the MDAC Phase B Shuttle Design performed under Contract NAS 8-26016.

7.1.1 Vehicle Description

Pertinent characteristics of the Shuttle Orbiter are the vehicle configuration, payload accommodation, on-orbit propulsion/reaction control system, crew accommodations, payload access, and the docking/erection mechanism.

The Space Shuttle Orbiter vehicle is a delta-wing configuration, as shown in Figure 7-1. This vehicle is designed to accommodate a crew of four: two Orbiter crew and two Space Station crew). The cargo bay is sized to accommodate a payload of up to 4.6 m (15 ft) in diameter and 18.2 m (60 ft) in length (including protuberances beyond the payload cylinder). A large door provides access to the cargo bay. This door, the Delta wing, vertical stabilizer, and radiator are potential sources of interference with the Space Station and attached Research and Application Modules (RAM) during docking operations.

Structural accommodation of the payload in the Orbiter is provided by a series of attach points. These attach points are located at the forward end

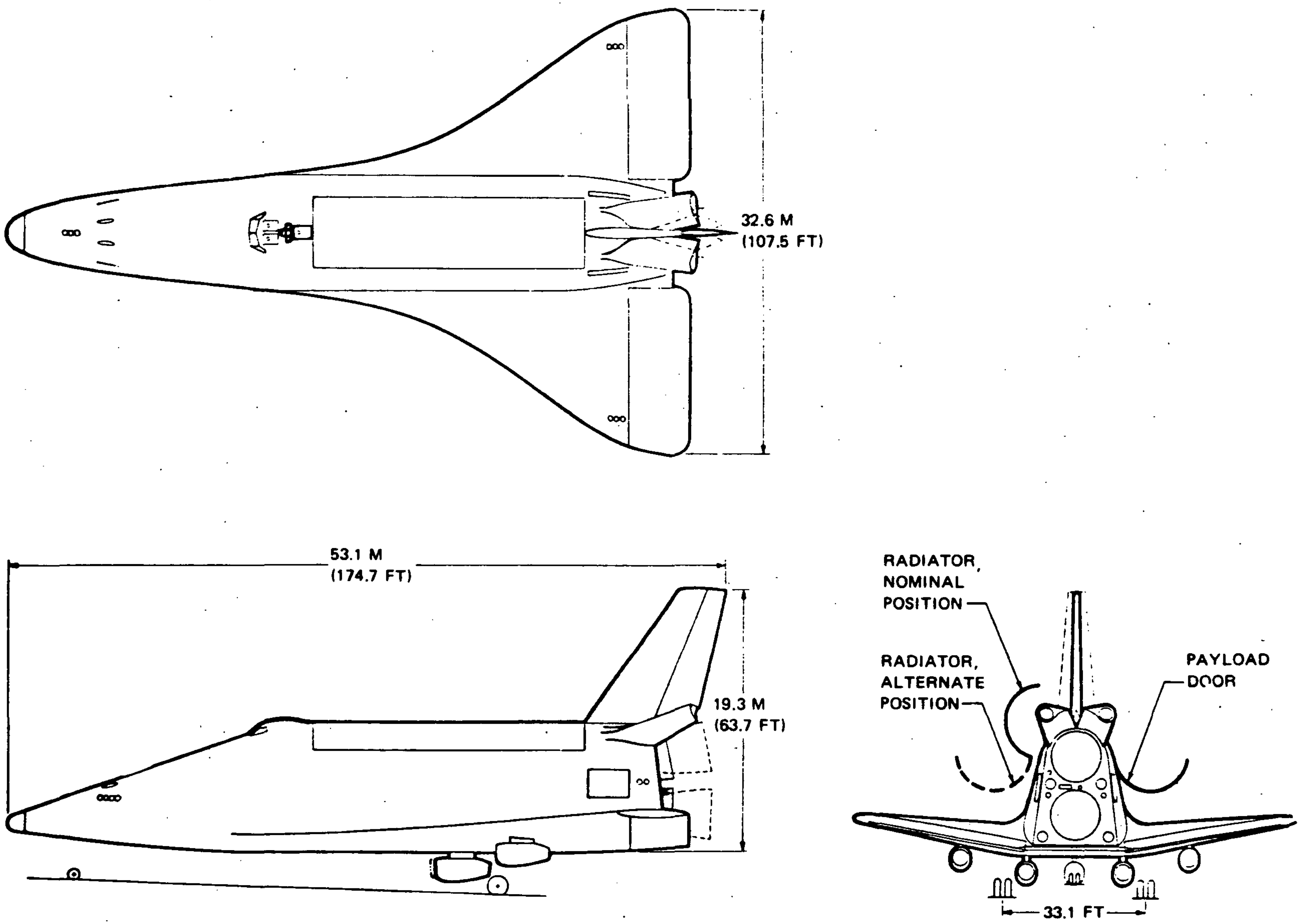


Figure 7-1. Baseline Orbiter Configuration

of the payload bay, on the cargo bay door sill and one on the bottom centerline. Alternate support point locations are possible at any of the upper body frames for payloads less than 17.6 m (58 ft) in length.

Figure 7-2 shows the Shuttle docking/deployment mechanism which interfaces with the Logistics Module. The fittings about which this mechanism rotates are free during boost flight. This precludes loads being transferred to the module except through the payload attach points. An expandable tunnel with a hatch at the upper end is used for crew transfer.

On-orbit propulsion/reaction functions are performed by the Attitude Control Propulsion System (ACPS) and the Orbital Maneuvering System (OMS). The ACPS is used for attitude control and micro-translation maneuvers. Jets are located on the Orbiter vehicle as indicated in Figure 7-3. Thrust magnitude of each engine is 7,100 N (1,600 lb) (vacuum). The ACPS is a high-pressure GO_2/GH_2 bipropellant reaction control system. Propellants are stored in secondary tanks which also contain OMS propellant, fuel cell, and environmental control fluids.

A minimum number of thrusters are fired per axis to minimize angular accelerations; however, they are always fired in couples to minimize translational disturbances. The acceleration characteristics (Orbiter vehicle only) per axis are:

	Angular Acceleration (deg/sec^2)
Pitch	1.66 (up)
	0.83 (down)
Yaw	0.78
Roll	1.74

Minimum impulse per engine is 214 N-sec (48 lb-sec)(based on minimum thruster pulse duration of 0.03 sec).

The Orbital Maneuvering System (OMS) is required to perform all major translation maneuvers during the orbital phase of the mission. The OMS consists of two RL10A-3 engines mounted in the upper-aft fuselage.

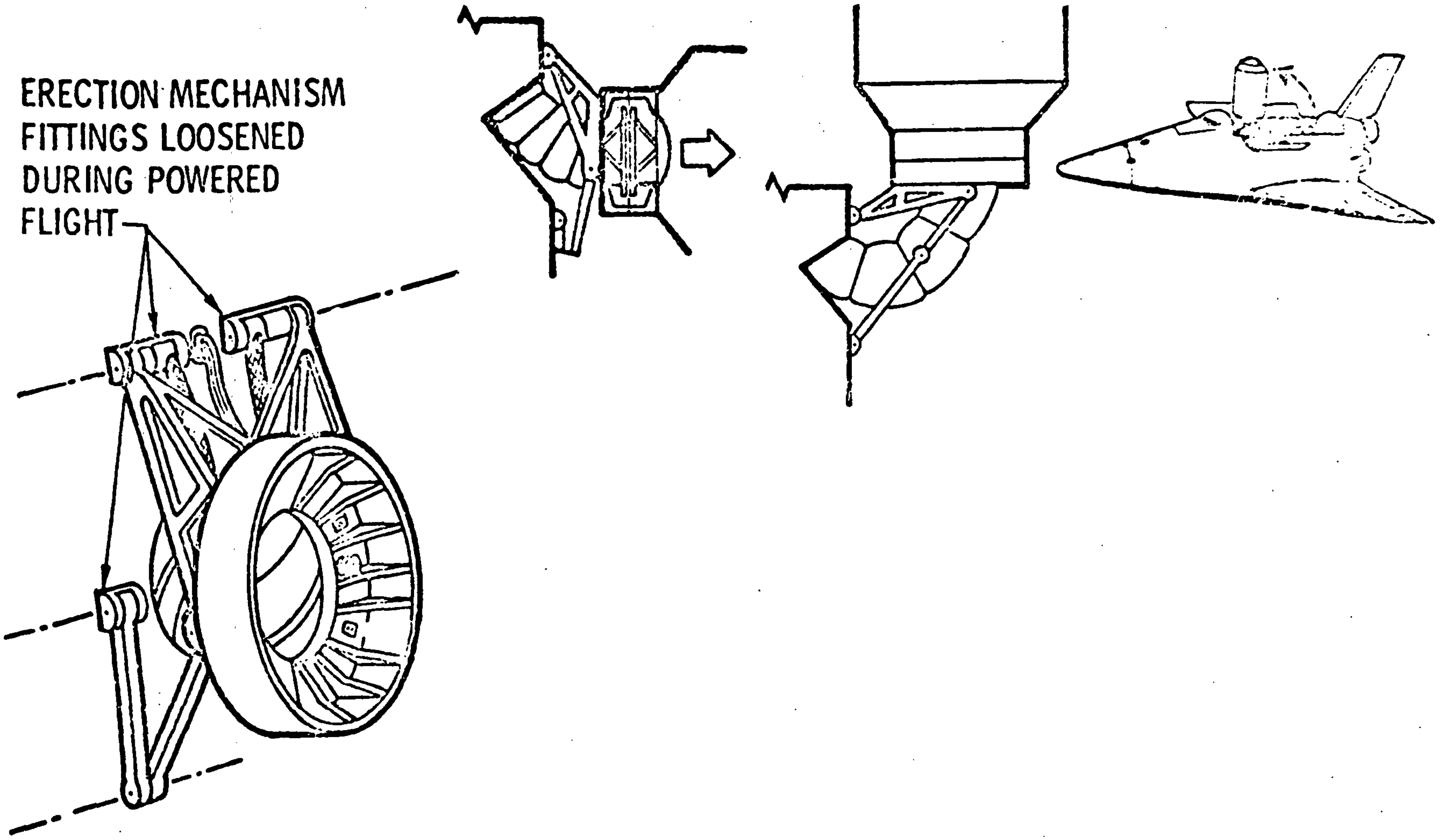


Figure 7-2. Shuttle/Module Interface

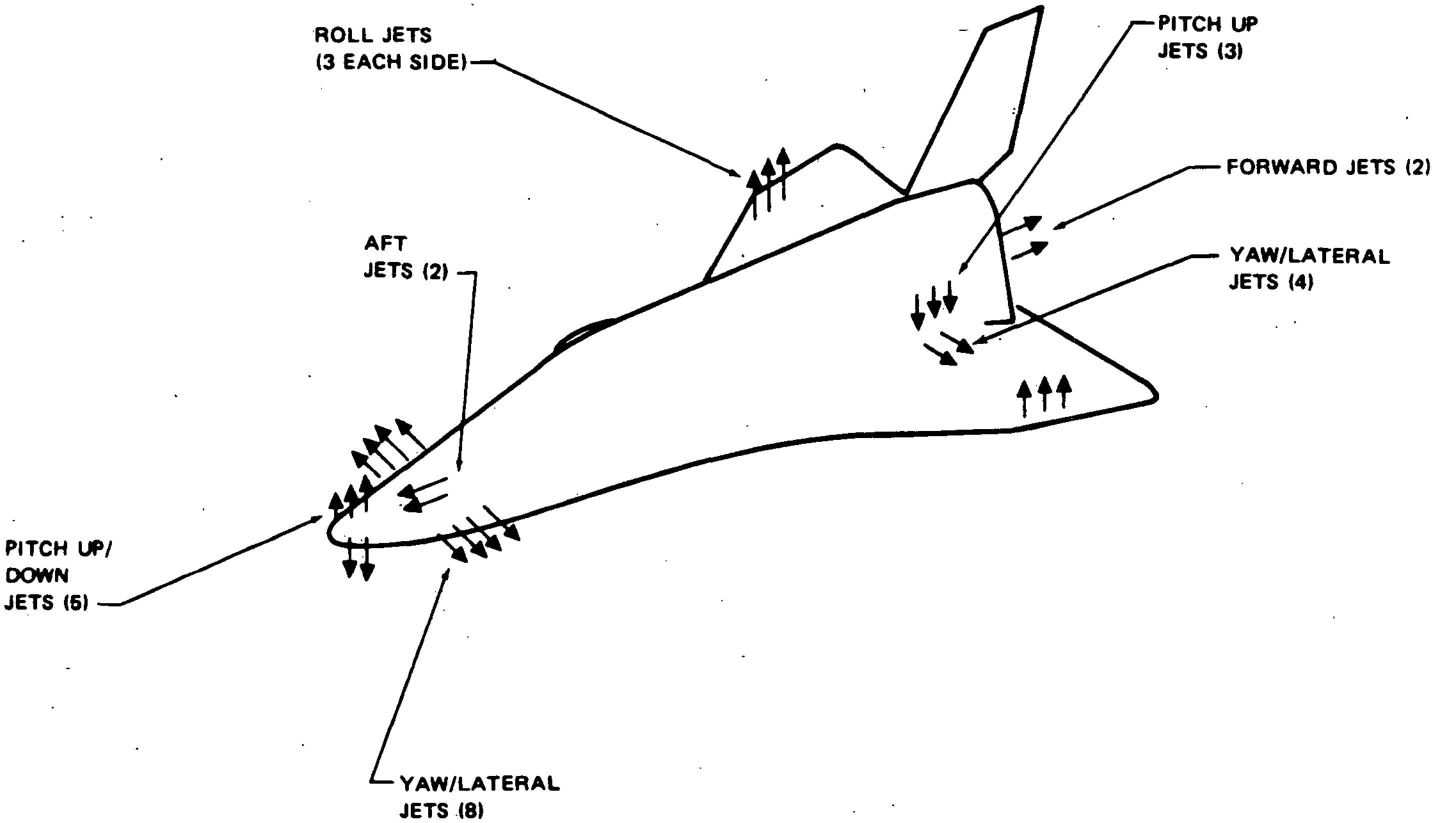


Figure 7-3. Orbiter Attitude Control Jets

Figure 7-4 shows the general arrangement and geometry of the crew accommodations. Illustrated are the docking station location, crew ingress/ egress hatches, airlock, and payload access tunnel. It can be seen that manned-access to the payload from the crew compartment before launch with the Shuttle in the erected position would be difficult. Transfer of equipment or cargo to the Logistics Modules through the tunnel would be even more difficult and should therefore be considered for contingency operations only.

Weight of the Orbiter vehicle at the time of docking is 131,000 kg (288,000 lb) including the 9,100 kg (20,000 lb) payload.

7.1.2 Operations

Shuttle operations which particularly impact the logistic system are those of prelaunch, docking, post-docking, and rescue. These are described in the following subsections.

7.1.2.1 Ground Operations

Figure 7-5 shows the flow of Shuttle operations from t-6 days to launch. Normally, the payload is loaded in the Orbiter while it is in the horizontal position at approximately t-5 days. Access to the payload from the time of loading until launch is limited and dependent upon the type of Shuttle prelaunch operation in process. Figure 7-1 indicates the time periods wherein access is either (1) possible on a noninterference basis, (2) limited to connection of umbilicals, or (3) precluded. Due to the limited capability for access, as seen from Figure 7-5, the design of logistics modules must result in minimal requirements for checkout, servicing, calibration, etc., during this time period (post-loading to launch).

7.1.2.2 Docking Operations

Docking of all modules to other modules on-orbit is performed by the Orbiter vehicle. The operations of braking, docking, separation, attitude control, and Station keeping are performed by the Attitude Control Propulsion System (ACPS).

During docking operations, the Space Station is essentially passive, but retains command of the maneuver, i.e., the Station crew commands the

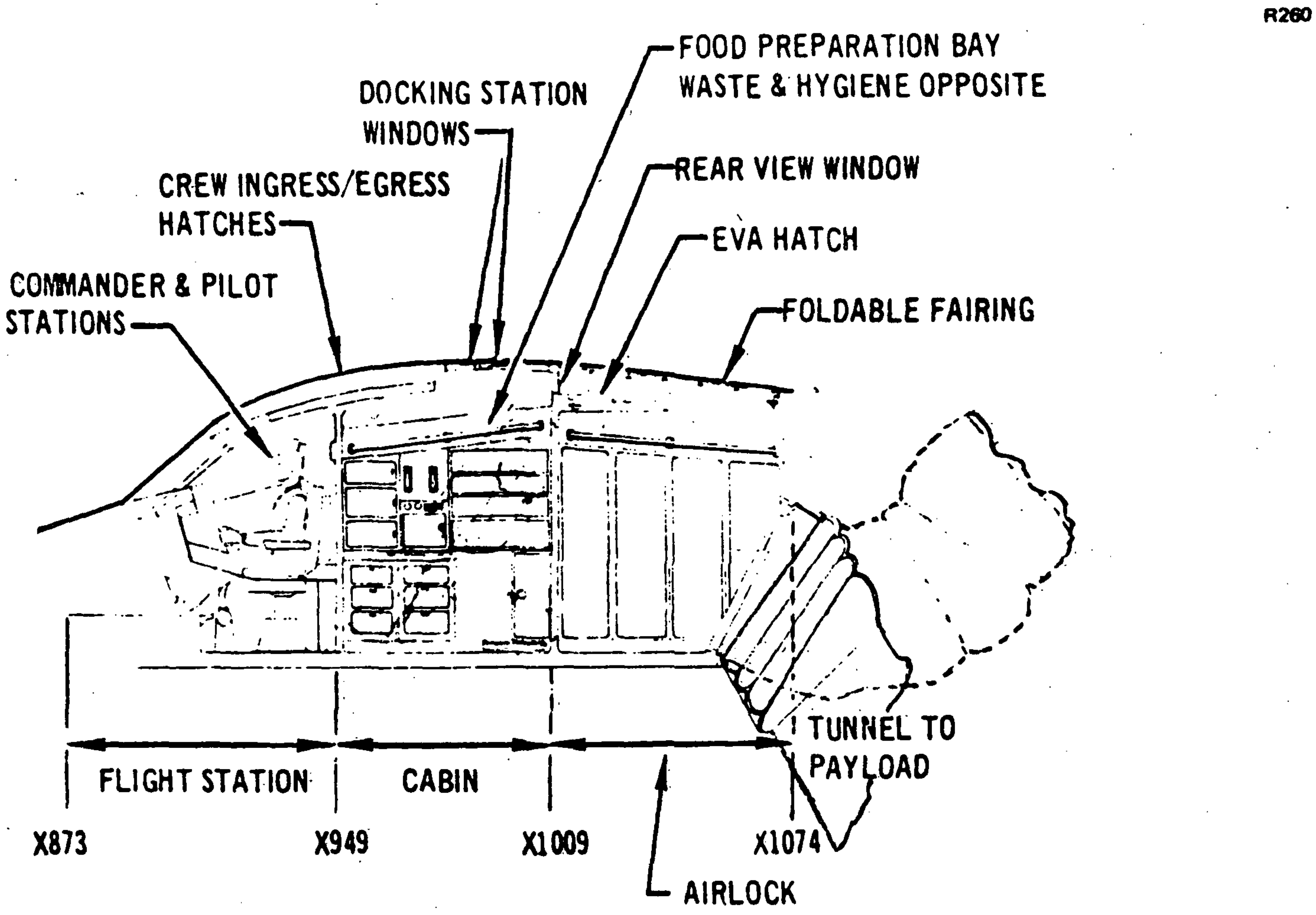


Figure 7-4. Orbiter Crew Accommodations

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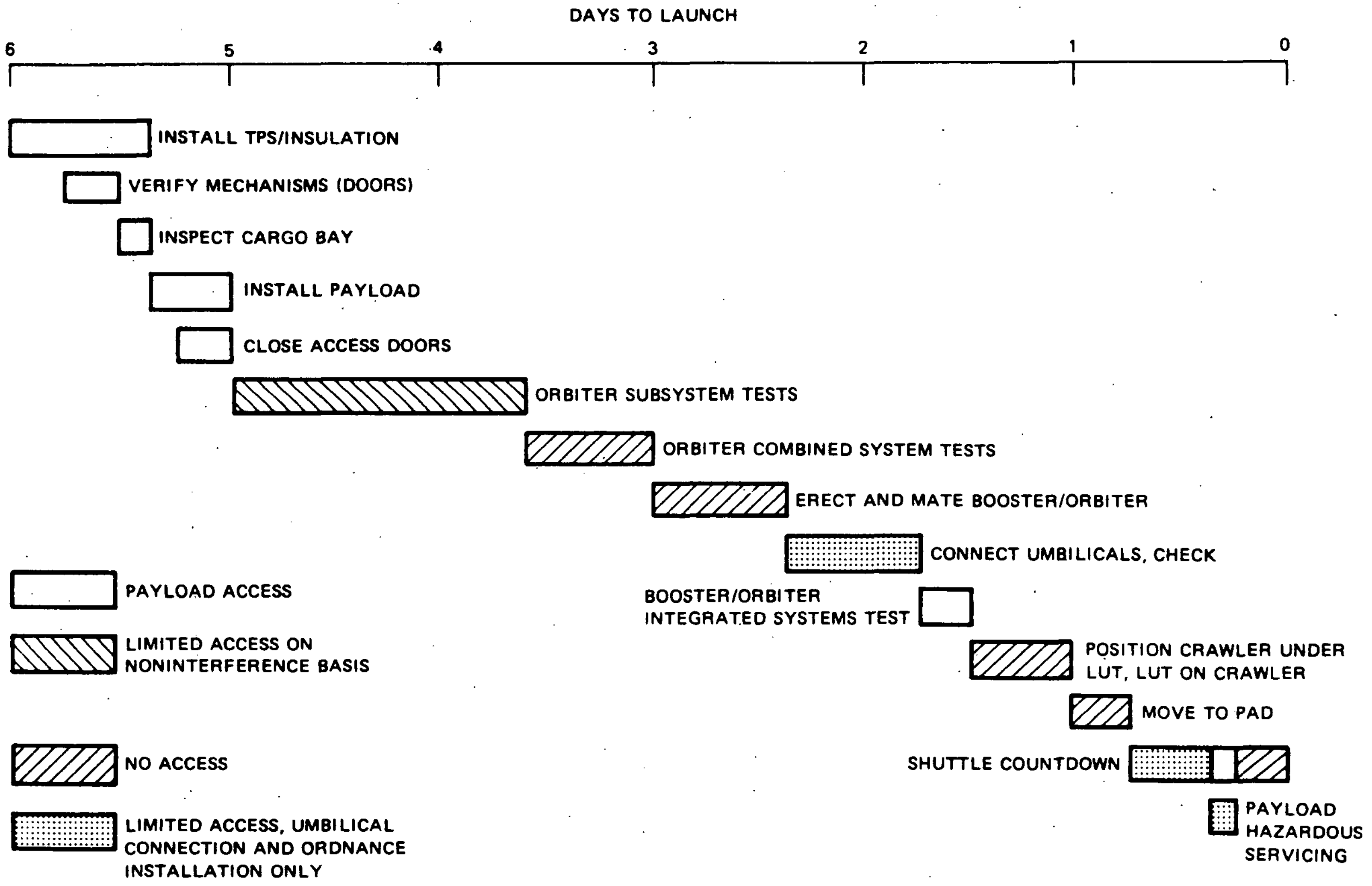

Figure 7-5. Payload Interface with Shuttle Operations

initiation of the docking maneuver and visually monitors the operation while in voice communications with the docking pilot.

Figure 7-6 shows the clearances available between the Orbiter and Station for docking operations. Maximum clearance when docking a Module is obtained with the Orbiter door and radiator in a partially-open position rather than a fully-open position. The partially-open door position provides adequate clearance when the Orbiter is docking to a module without an interspersed module (module retrieval operation). The Orbiter approach is constrained within a corridor which is well within these clearance limits. A positive cue is provided to the docking pilot when the vehicle approaches the limits of this corridor. The cue is provided by light sources on the Space Station; when the light source is visible to the pilot, corrective action is indicated.

The docking aid chosen to apprise the pilot of displacement errors is a T-Bar device (shown in Figure 7-7). The T-Bar is located above the docking hatch and, when viewed through the reticule in the orbiter, it gives relative information with respect to the lateral and vertical displacement of the Shuttle. The T and the target circle are both electro-luminescent.

The Shuttle-mounted docking aid consists of a reticle telescope arrangement (telescopic sight). The reticle within the Shuttle telescope, when used with the T-Bar, gives relative pitch, yaw, and roll information. The different circles of the reticle allow estimation of range, as noted in the diagram.

The direct docking mode, using manual control, was further assessed by an evaluation of data from a man-in-the-loop docking simulation (performed under the Space Shuttle Phase B-Contract. This data verified the docking design criteria and the capability of Orbiter control within translational and attitude limits. The simulation employed 6 degrees of freedom. Target alignment aids were similar to those defined above. Onboard docking displays provided range-to-docking, relative range rate, and attitude rate.

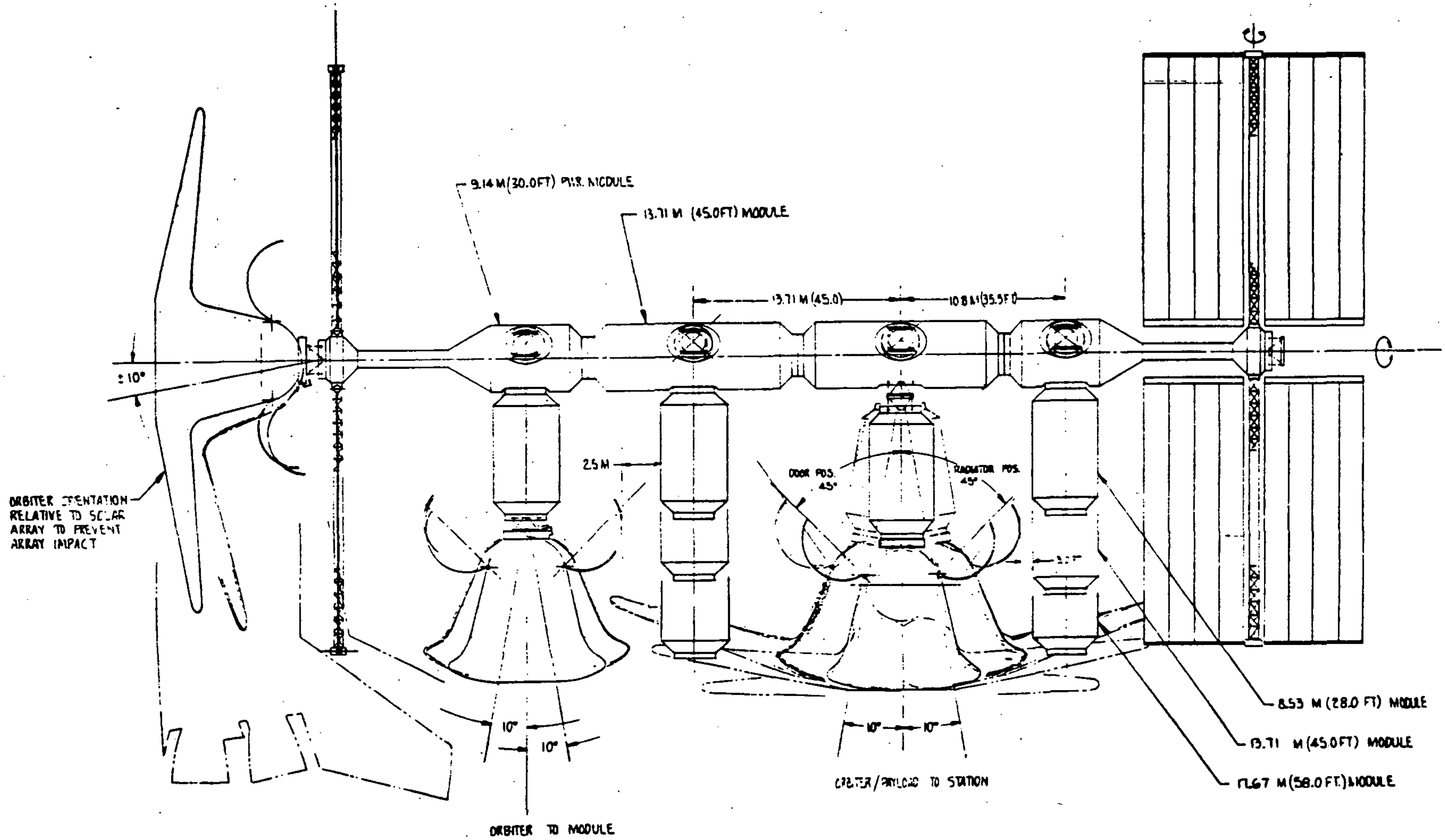

Figure 7-6. Docking Clearance

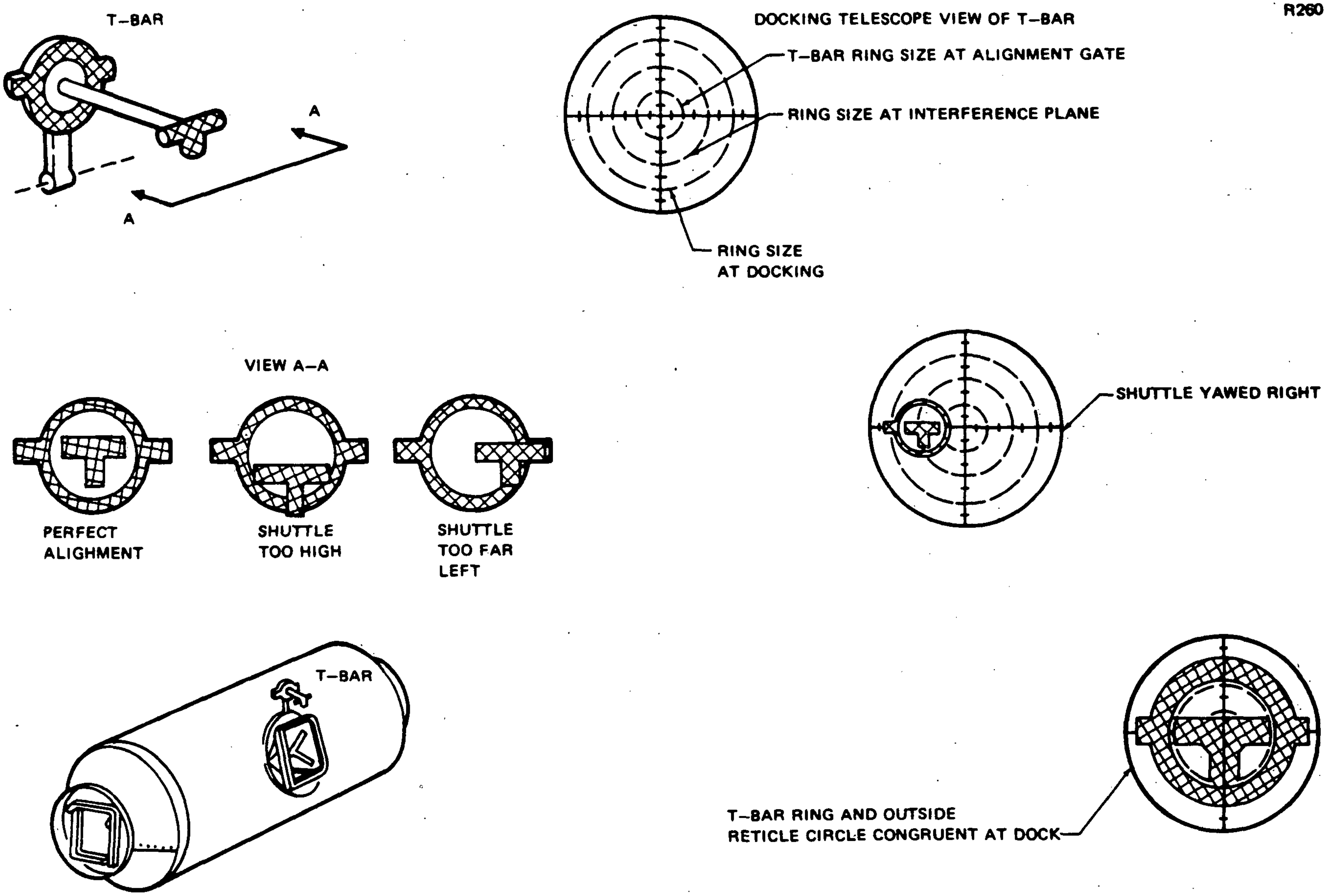

Figure 7-7. T–Bar Docking Aid

In the simulation, the payload module was mounted with the centerline parallel to the Orbiter centerline in contrast to the current design wherein the module centerline is perpendicular to the Orbiter centerline when erected. Results of the simulation are considered representative however; in both cases there is a large distance between the pilot and the docking interface and rotation about the orbiter center-of-gravity results in significant translation of the pilot and the docking interface.

Figure 7-8 shows the docking precontact conditions (mean and worst case) in comparison with the values used for the Space Station design. The results shown include data from all 34 simulations and they are within the specified design criteria values.

Another objective of the simulation was to determine the accuracy of Shuttle position and attitude control relative to a target. The results are applicable to the determination of position and attitude control during approach to the Station in a docking operation. These results are shown in Figure 7-9. This figure shows the longitudinal, lateral, roll and yaw error distributions. The pilot's objective was to null these errors and maintain a fixed position and attitude relative to the target. As indicated, displacement errors are generally less than 0.305 to 0.456 m (1.0 to 1.5 ft) and angular errors less than 3 degrees.

7.1.2.3 Post-docking Operations

The sequence of events following docking in a nominal logistics/crew rotation mission is as follows: (1) the crew transfers from the Orbiter cabin through the tunnel and into the Logistics Module; (2) the Logistics Module hatch at the Logistics Module/Orbiter interface is secured, and (3) the crew transfers to the Station. Following crew transfer and verification of pressure integrity of the Logistics Module and Orbiter, the orbiter dedocks and orbit keeps in the vicinity of the Station for the duration of crew overlap (nominally 24 hours). The Orbiter then redocks to the returning Logistics Module, crew transfer is completed, followed by pressure integrity verification and separation of the Logistics Module from the Station by the Orbiter.

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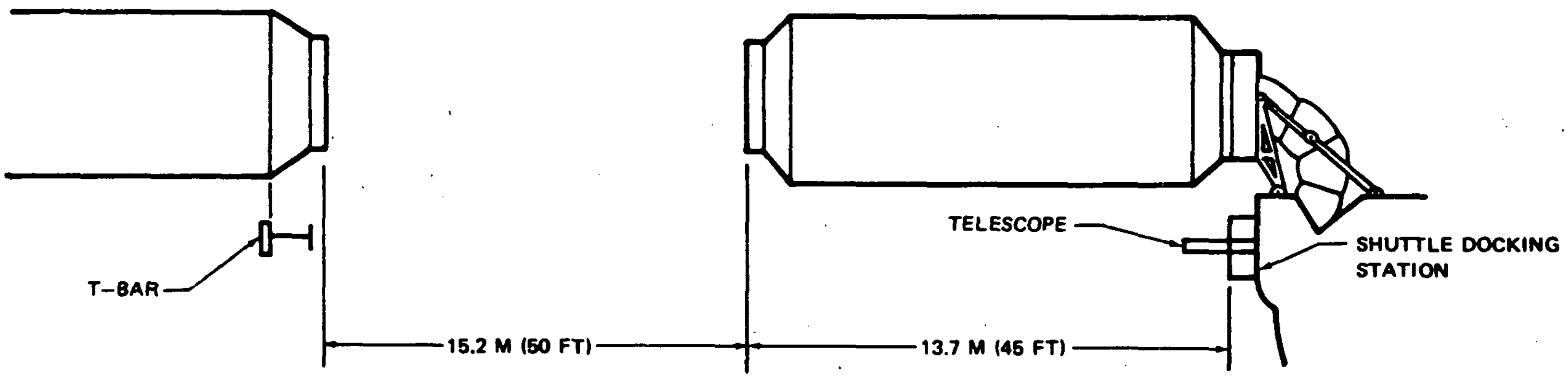
SIMULATION GEOMETRY



RESULTS (34 RUNS)

	MEAN	WORST CASE	DESIGN CRITERIA
MISS DISTANCE, M (FT)	0.152 (0.5)	0.274 (0.9)	0.305 (1.0)
LONGITUDINAL VELOCITY, MPS (FPS)	0.037 (0.12)	0.07 (0.23)	0.305 (1.0)
LATERAL VELOCITY, MPS (FPS)	0.021 (0.07)	0.033 (0.11)	0.076 (0.25)
MISS ANGLE (DEG)	0.9	1.7	5.0
ANGULAR RATE (DEG/SEC)	0.1	0.15	0.5
ROLL ANGLE (DEG)	1.5	3.5	5.0
ROLL ANGULAR VELOCITY (DEG/SEC)	0.1	0.17	0.5

Figure 7-8. Docking Simulation

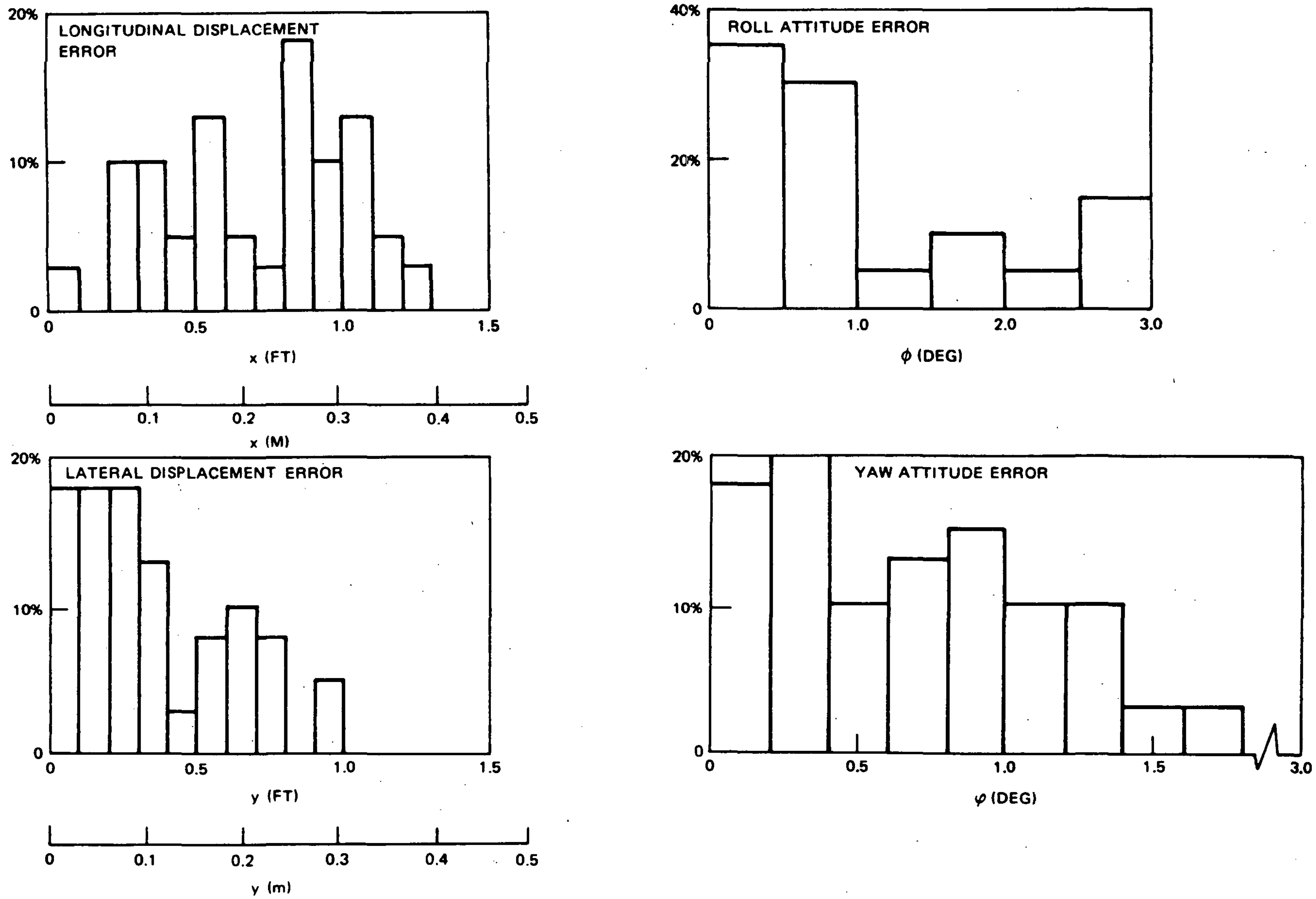


Figure 7-9. Distribution of Orbiter Control Errors

Figure 7-10 shows the operations (including crew transfer) of the initial manning with the first Logistics Module. For this initial manning operation, the Orbiter is docked to the Station for 32 hours.

7.1.2.4 Rescue Operations

Guidelines for the Space Station Program included a requirement that the Space Station design have provisions and habitable facilities adequate to sustain the entire crew for a minimum of 96 hours during an emergency situation requiring Shuttle rescue. An analysis was performed to determine the Shuttle reaction capability to verify the adequacy of 96 hours as a design requirement. Table 7-1 indicates the reaction time or time from emergency to rescue. The total reaction time shown is the maximum that would be required. This time is 58 hours during the period the Shuttle launch rate is less than 50 per year. In the high launch-rate phase of the Shuttle Program, the maximum reaction time is 90 hours (reaction time is less than 58 hours, 60 percent of the time). The reaction times shown do not require a Shuttle vehicle dedicated to a Space Station rescue mission, nor do the attainment of these reaction times create a significant impact on the Shuttle prelaunch operations.

7.1.3 Interface Requirements

This section contains a brief summary of Logistics Module requirements which arise as a result of operations with the Space Shuttle.

7.1.3.1 Payload Launch Weight

Maximum weight of Space Station modules was directed by NASA as follows: "The design-to-weight of Shuttle-transported modules shall not exceed 20,000 lb." This guideline was interpreted by NASA to apply to descent missions as well as ascent missions.

7.1.3.2 Payload Size

Maximum size of Space Station modules was directed by NASA as follows: "The maximum external dimensions of the modules shall be 14 ft in diameter and 58 ft in length. Mechanisms that are external but attached to the module,

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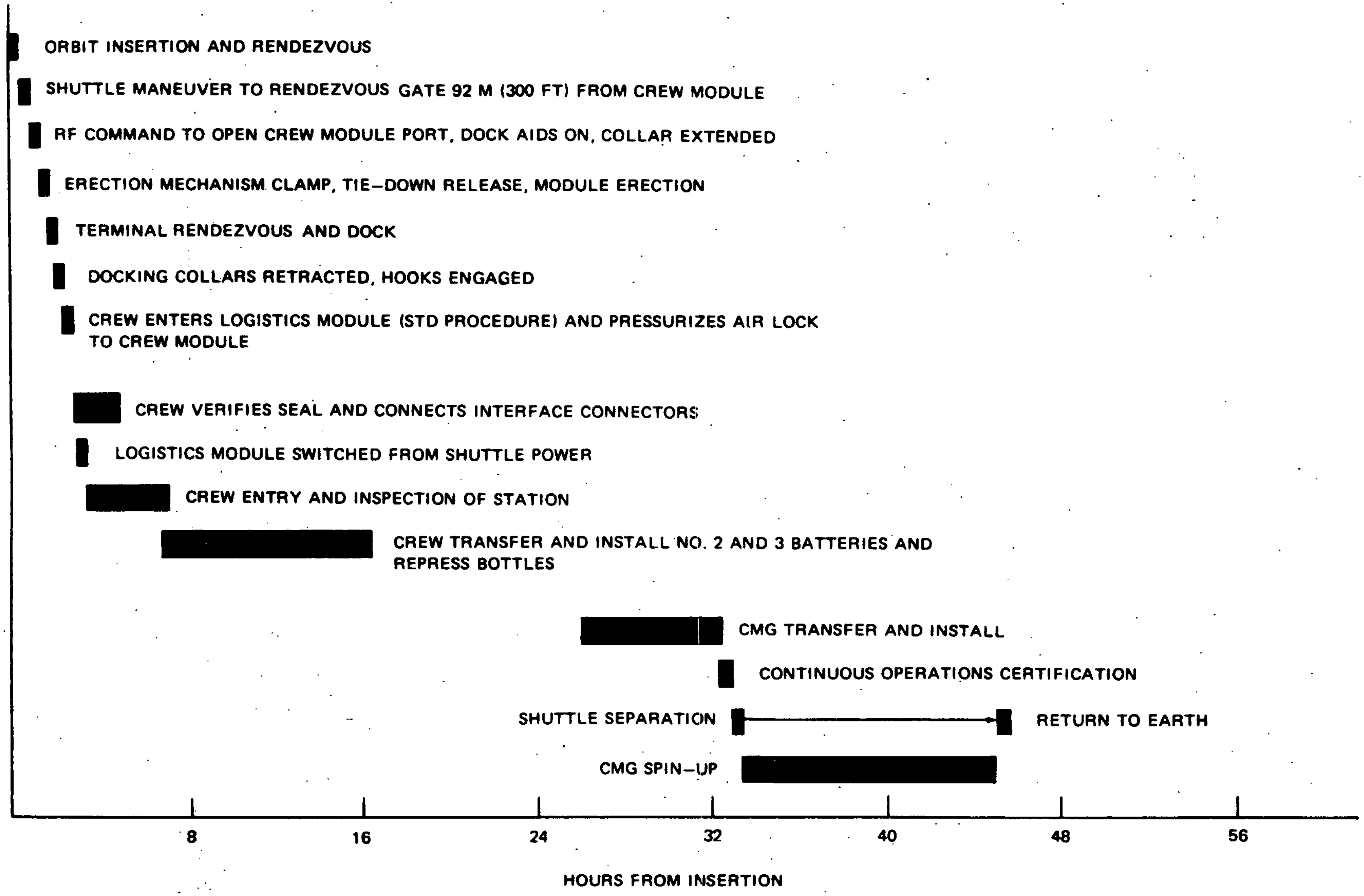

Figure 7-10. Final Manning Operations - First Logistics Module

Table 7-1

SHUTTLE RESCUE CAPABILITY
(WORST CASE)

	Low and Medium Launch Rate (<50/hr) (hr)	High Launch Rate (75/hr) (hr)
Launch preparation	24	56
Ground hold for window	15	15
Rendezvous	16	16
Rescue Operations	3	3
Total	58	90

NOTES:

(1) Four Orbiters and three Boosters available.

(2) Worst-cast phasing

(3) Maximum ground hold for launch opportunity.

(4) Vehicle maintained at T-24 hr status for low- and medium-rate case.

such as handling rings, attachment for deployment, docking mechanisms, storage fittings, thrusters, etc., shall be contained at launch within an envelope 15 ft in diameter and 60 ft in length."

7.1.3.3 Center-of-Gravity Location

The allowable payload center-of-gravity envelope is based on the MDAC Phase B Shuttle Design. The allowable longitudinal center-of-gravity envelope is shown in Figure 7-11. Lateral and vertical center-of-gravity axis limits are ±0.30 m (12 in.).

7.1.3.4 Load Factors

Design load factors are listed in Table 7-2.

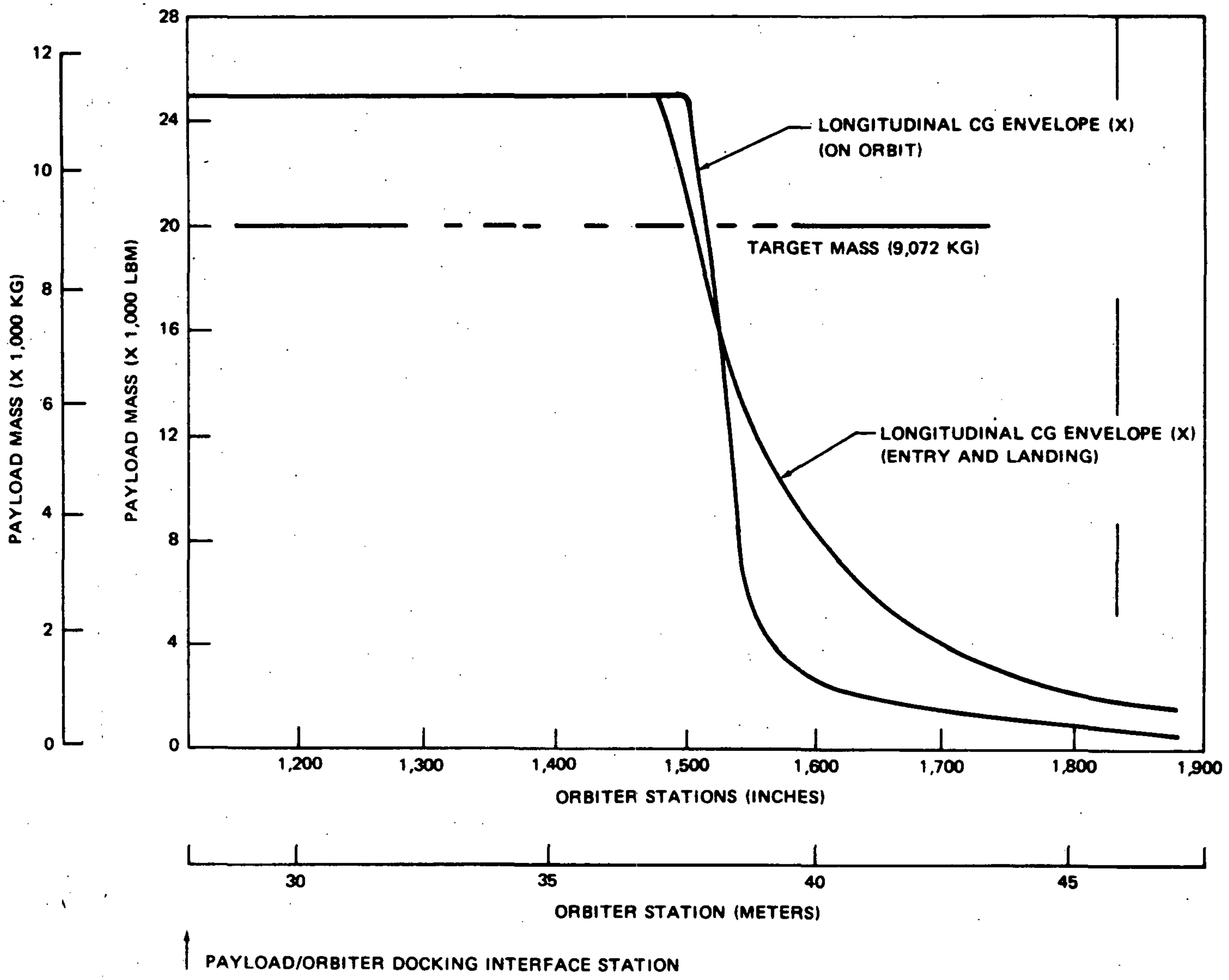

Figure 7-11. Longitudinal cg Limitation

Table 7-2

LOAD FACTORS*

	Axial (n_x)	Lateral (±n_y)	Vertical (n_z)
Launch	1.5	0.5	0.5
High Q	1.9	1.0	±1.0
End Boost (Booster	3.3	0.6	-0.6
End Boost (Orbiter)	3.3	0.5	-0.5
Entry	-0.5	1.0	-2.0
Flyback	-0.5	1.0	1.0
			-2.5
Landing	-1.3	0.5	-2.7
Emergency Landing	-8.0	1.5	-4.5
	÷1.5		÷2.0

*Load factors are in the direction of the acceleration (n_x positive forward; n_z positive down) the load factors for each condition can act simultaneously.

7.1.3.5 Orbiter Support Functions

The design of Logistics Modules is based on using selected services from the Shuttle during logistics missions. These services include limited electrical power, limited use of the Orbiter caution, warning, and onboard checkout capability; limited use of Orbiter data management systems for mocule command and control functions; and a supply of conditioned air.

7.2 SPACE STATION INTERFACES

Interfaces between the Space Station and the Logistics Module are of two types: (1) those required for support of the Logistics Module on-orbit and (2) those required to transfer consumables from the Logistics Module to the Station. These interfaces are summarized as follows: (1) 1/2 in. O_2 line, (2) 1/2 in. N_2 line, (3) 6-in. air supply/return lines, (4) 3/8 in. GN_2 line, (5) 3/8 in. N_2H_4 line, and interface connections for (6) caution and warning, (7) data bus, and (8) DC power.

The Growth Space Station is logistically supported with a Crew/Cargo Module (CCM). The physical and operational interfaces of the CCM with the Space Station, however, are the same as with the Logistics Module.