DECEMBER 1971

MDC G2539

SPACE STATION

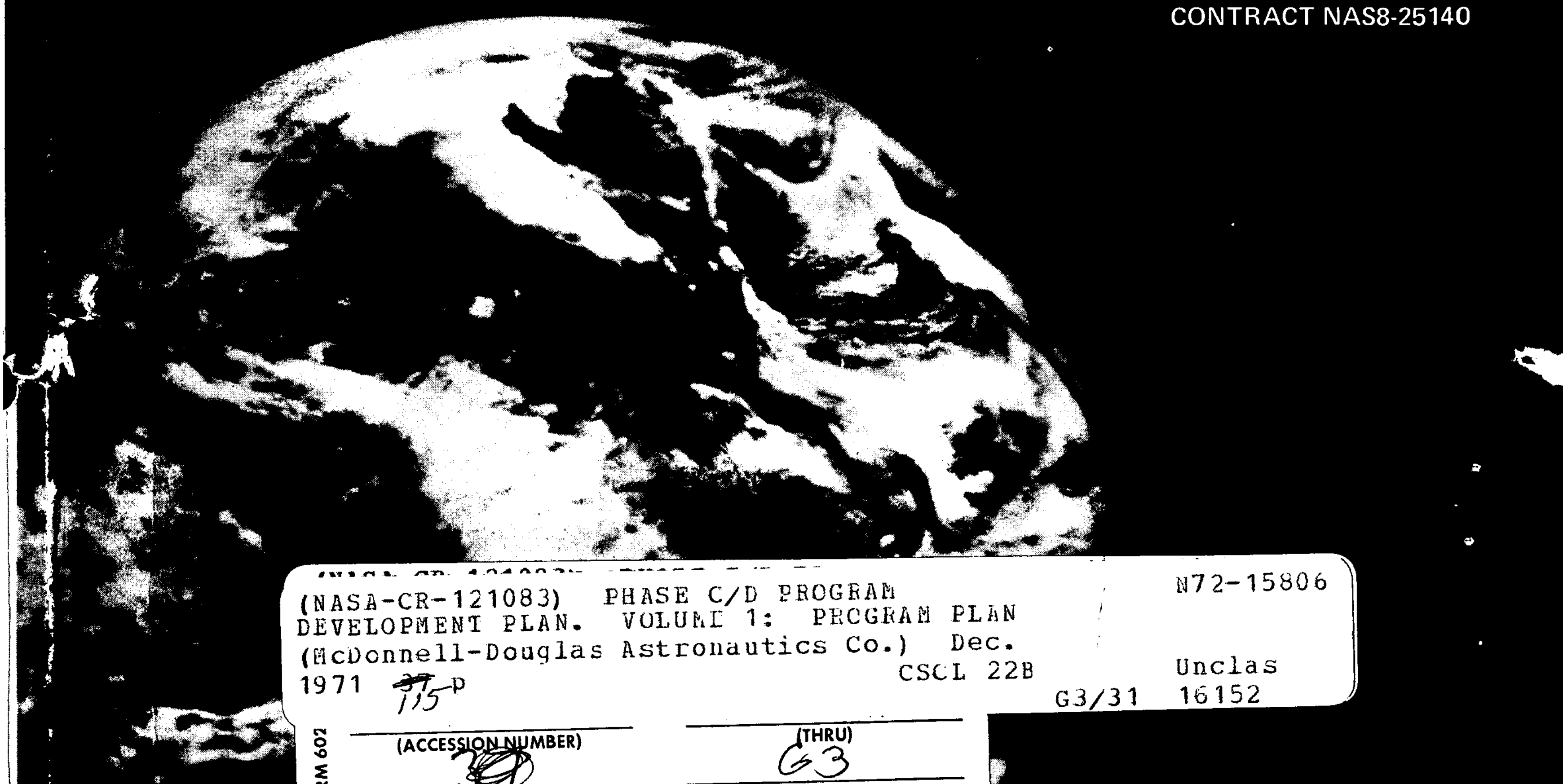
MSFC-DPD-235/DR NO. MA-05

PHASE C/D PROGRAM DEVELOPMENT PLAN

VOLUME I

Program Plan

CONTRACT NAS8-25140



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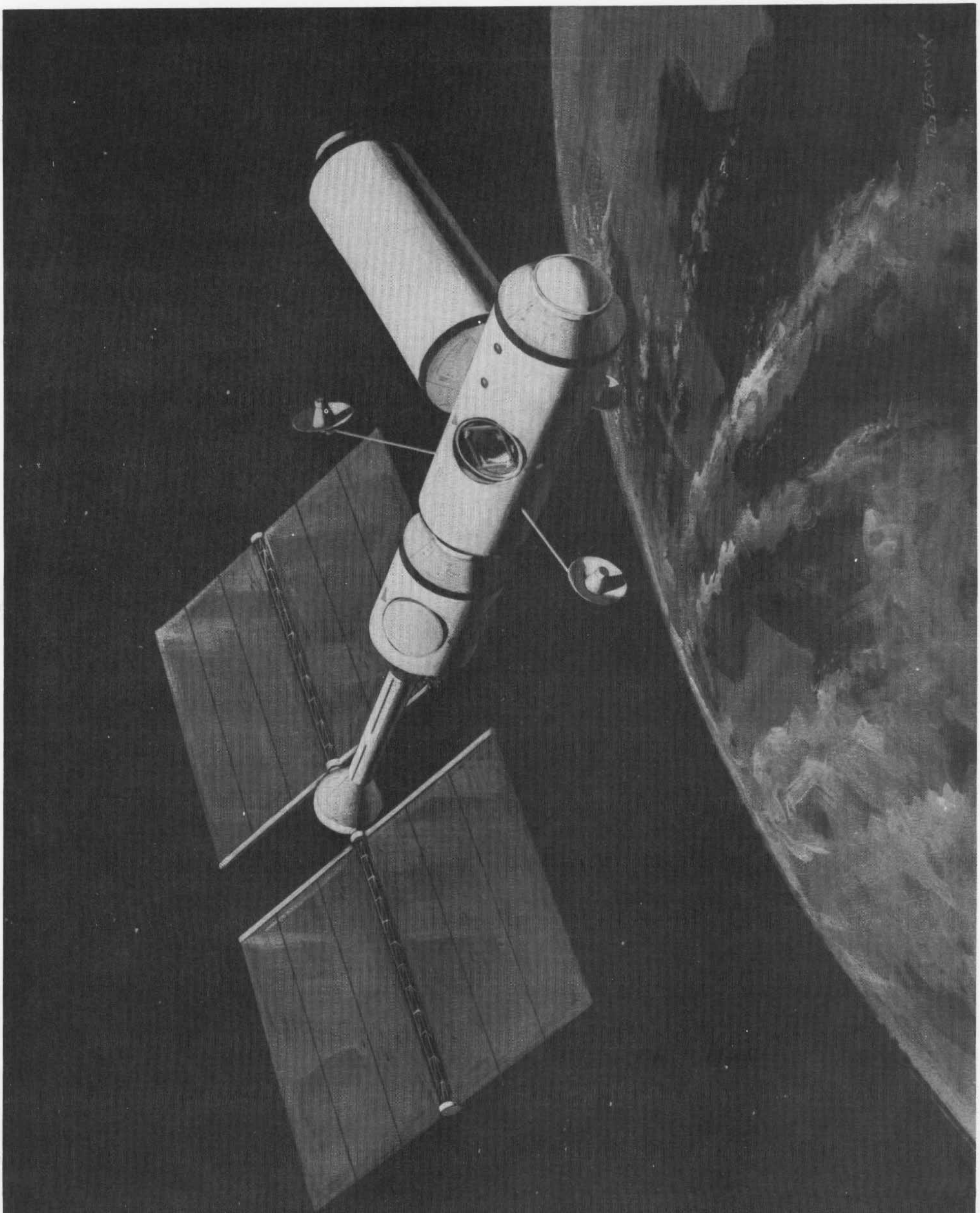
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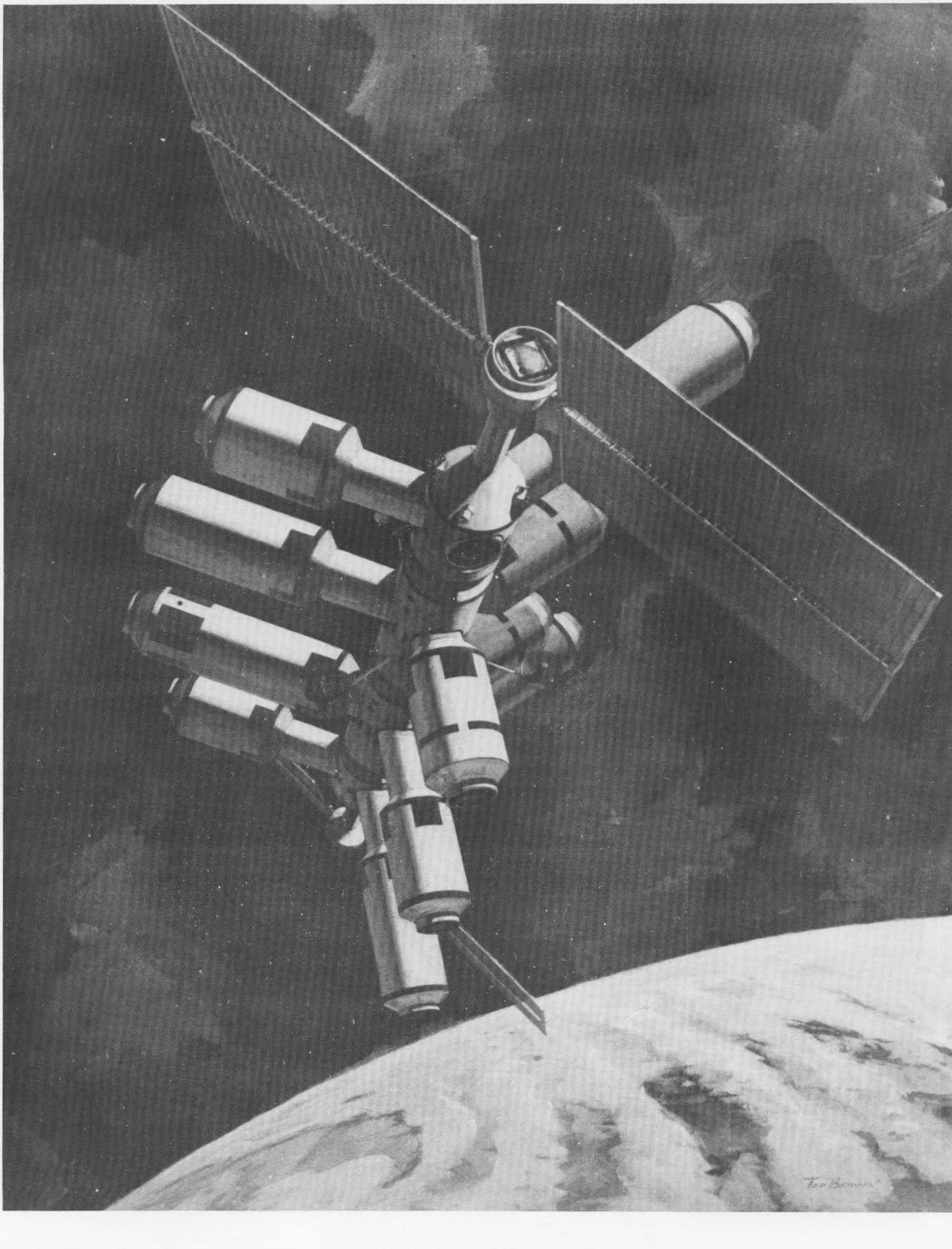

PREFACE

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

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

The second phase of the study (15 April to 3 December 1971) consisted 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 MA-05, Phase C/D Program Development Plan, which consists of the following volumes:

Volume I: Program Plan

Volume II: Phase C/D Program Plan Requirements

DATA REQUIREMENTS (DRs)
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 Reveiw Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase C/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes

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FOLDOUT FRAME 2

SUBJECT REFERENCE MATRIX

LEGEND:

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

	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								X											
2.3 Modular Space Station Configuration and Subsystems Definition														X					
2.4 Technical and Cost Tradeoff Studies							X												
2.4.4 Modular Space Station Option Summary											X								
2.5 Modular Space Station Detailed Preliminary Design														X					
Mass Properties																X			
2.6 Crew Operational Analysis									X										
2.7 Crew Cargo Module															X				
Mass Properties																X			
2.8 Integrated Mission Management Operations										X									
2.9 Hardware Commonality Assessment													X						
2.10 Program Support					X														
2.11 Requirements Definition																			
Space Station Program (Modular)	X																		
Space Station Project (Modular)		X																	
Modular Space Station Project—Part 1 CEI			X																
Interface and Support Requirements				X															
2.12 Plans					X														
2.13 Costs and Schedules							X												
2.14 Special Emphasis Task Information Management (IMS)												X							
Modular Space Station Mass Properties																X			
User's Handbook																	X		
Supporting Research and Technology																		X	
Technical Summary													X						
MOD 29																			X
MOD 40						X													

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GLOSSARY

ACE	Aerospace Checkout Equipment
A/D	Analog-to-Digital
AGE	Aerospace Ground Equipment
ATP	Authority to Proceed
AVE	Aerospace Vehicle Equipment
BIT	Built-In Test
BITE	Built-In Test Equipment
CCM	Crew Cargo Module
CH&P	Crew Habitability and Protection
CMG	Control Moment Gyro
C/O	Checkout
DMS	Data Management Subsystem
DRSS	Data Relay Satellite System
EC/LS	Environmental Control/Life Support
ECS	Environmental Control System
EDS	Emergency Detection System
EFC	Equipment Functional Check
EMI	Electromagnetic Interface
NTO	Nitrogen Tetroxide
NTO/MMH	Nitrogen Tetroxide/Monomethylhydrazine
OCS	Onboard Checkout System
PCM	Pulse Code Modulation
P/L	Payload
PM	Permanent Magnet
PMN	Program Management Network
POP	Perpendicular to Orbit Plane
P/RCS	Propulsion and Reaction Control Subsystem
PRD	Program Requirements Document
RAM	Research Applications Module
RCS	Reaction Control System
RF	Radio Frequency
RMS	Remote Maneuvering
S/AC	Stabilization and Attitude Control

SAM	Stimuli and Measurements
SC	Spacecraft
SRT	Supporting Research and Technology
SS	Space Station
SSM	Space Station Module
SU	Switching Unit
TBD	To Be Determined
TM	Telemetry
WBS	Work Breakdown Structure
WMS	Waste Management System

Section 1
INTRODUCTION

1.1 BACKGROUND

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

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

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

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

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

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

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

Experiment modules will be delivered to the Space Station by the Shuttle as required. On return flights, the Shuttle will transport data from the experiments, 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-foot INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module capabile of transporting a crew of six.

During ISS operations, a total of five Research Applications Modules (RAM's) will be attached to the Space Station for various intervals. Three of these will be returned prior to completion of the GSS. 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. The GSS has a capability for accommodating 10 RAM's simultaneously.

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

1.2 SCOPE OF THIS VOLUME

This volume covers the Space Station Program with the Space Station Project being covered in depth, the RAM project being limited to a project-level definition, and the Shuttle operations included for interface requirements identification, scheduling, and costing.

1.2.1 Baseline Configuration Description

The Space Station baseline configuration consists of 5 modules, three of which (Power/Subsystem, Crew/Operations and General Purpose Laboratory) provide a 1980 Interim Capability 6-man Space Station (ISS) over a 5-year period. Two additional modules (Crew/Operations, and Power/ Subsystems) provide a 12-man Growth Space Station (GSS) capability. This would occur in 1985 and provide for further expansion of the experiment program. The ISS is manned with 6 crewmen. Modules are carried into a low earth orbit of 246-nmi altitude and 55-degree inclination in the cargo bay of the Space Shuttle and joined together on orbit to form the ISS and GSS configurations.

Crew manning and rotation and logistic resupply are provided at 30-day intervals by a Space Shuttle. A Logistics module (Log M) that fits in the cargo bay of the Shuttle Orbiter is used to transport cargo between the Earth and the Space Station for the ISS. The crew is transported to an from the station in the Shuttle Orbiter in increments of two crewmen per flight. The Shuttle Orbiter remains in a station-keeping mode approximately 1,000 yards from the station for a nominal three days while the return crew prepares for departure. The Shuttle retrieves a Log M and returns to Earth from one to five days after its launch. A crew cargo module (CCM) which is capable of housing up to six men replaces the Log M during the Growth Space Station phase. Experiments are accommodated either integrally in the Space Station or in experiment modules (RAM's). Depending upon the experiment requirements, these modules may either be permanently attached to one of the Space Station docking ports or be in a free-flying mode. The free-flying experiment module is unmanned and contains propulsive and attitude control subsystems for station-keeping in the general vicinity of the Space Station, returning periodically for maintenance and servicing. The experiment modules are carried into orbit by the Space Shuttle.

1.2.2 Phased Project Planning

NASA Phased project planning, while perhaps applicable to projects that are contained within the management purview of a single program manager, is extremely difficult to apply in an instance such as the Space Station Program. The three basic problems encountered in its application may be summarized as follows:

A. There are at least two major independent programs (Space Station and Space Shuttle) that will interface significantly both with regard to design and operations. Both programs are now in their respective definition phases; however, it appears that the Shuttle Program requires additional definition before these interfaces and their requirements can be defined and detailed.

B. The Space Station Phase B Study is in its terminal stages without having the benefit of the interface requirements and definitions noted above. One goal of phased project planning is to assure entry into the implementation phase with a set of requirements for the program and its respective projects that are sufficiently defined to assure that projected costs for development and operations are reasonable and realistic.

C. At present, there are certain project and system level areas within the Space Station Program that require additional effort to bring their level of definition up to the level required for the implementation phase. The RAM Project is an example of this asynchronous condition.

NASA's recent activities in the area of concept verification testing (CVT) offer an outstanding approach to the resolution of these anomalies. By using CVT as a "preimplementation problem solver", the CVT phase can produce as an output the definition of:

A. Interface requirements (design and operational).
B. Design and test requirements to be accomplished in the implementation phase for any project or system participating in CVT.
C. Revised specifications, plans, facility requirements, etc., for any program or project that is a CVT participant

With these types of outputs, CVT can be an effective vehicle for overcoming the disadvantages noted earlier in this Section.

1.2.3 Schedules

The Space Station Program schedule identifies the top-level activities required from each of the project elements to advance from the current Phase B status to an operational system by March, 1981. The schedule indicates the major development and operational events required to support the Space Station Program. The Space Station and RAM Project schedules are more detailed and define activities within each of their component systems.

The pacing project is the Space Station. Several key program milestones must be achieved to meet the initial launch date of October 1980. Figure 1-1 illustrates the relationships of these milestones to the functions occurring during Phase C/D. Among these milestones are a Phase C start date in October 1975 and a Phase D start date in October 1976. The preliminary design review should be completed in 1976, followed by peak developmental test activity in 1977. The critical design review is to be completed the latter part of 1977, with qualification testing at a maximum level several months later. Subsystem and system integration testing and

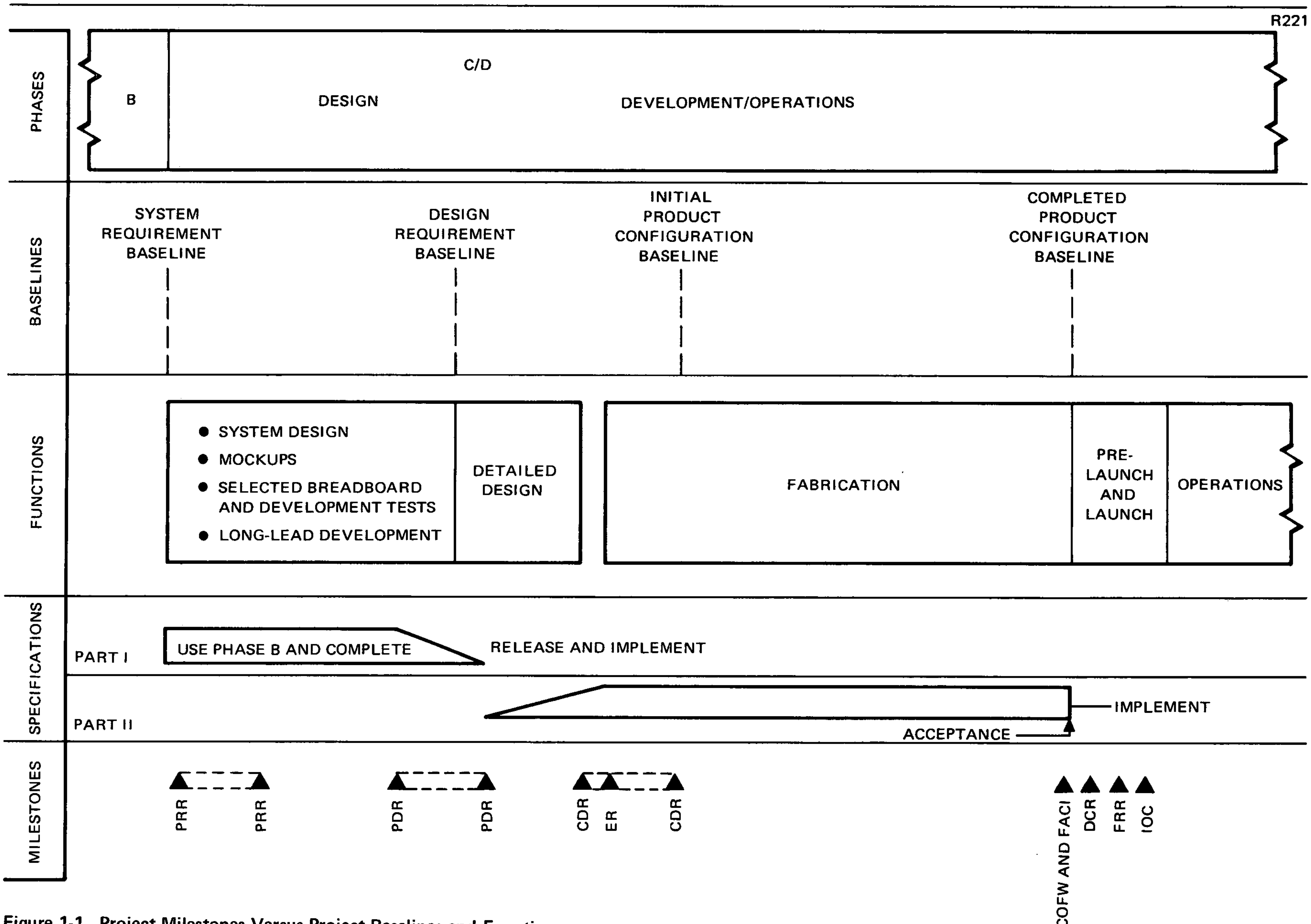

Figure 1-1. Project Milestones Versus Project Baselines and Functions

software development are performed on two near-full configuration test tools, one of which is referred to as the functional model (FM) and the other as the Flight Integration Tool (FIT). The bulk of this effort transpires during 1978 and 1979. The first Space Station Module (Power Module) must be at the Kennedy Space Center (KSC) two months prior to launch.

1.2.4 Management Concept

The problem of properly managing the Space Station Program, which contains a large number of major elements, is at least as challenging as the technical aspects of the total concept. Management techniques developed on the Apollo Program and in the commercial aviation industry will be combined and refined to form a suitable management base. Once this base is established, extrapolations can be made to the level required to resolve or aid in adjusting to the many anticipated problems. Among these problems are funding uncertainties, evolution of a realistic and credible baseline program for entrance into the development phase, maintaining adequate visibility and control, and definition and incorporation of an experiment program that best serves national and foreign interests.

To accomplish the Space Station Program within defined cost and schedule estimates, a number of management policies are necessary. Included in these policies is the establishment of a single contractor MSS CEI procurement philosophy with direct lines of authority and responsibility from NASA to the working level of the contractor whereby duplicate responsibilities are eliminated and organizational interfaces are minimized. In addition, data flow should be reduced by minimizing data and status reports. Effective communication and coordination methods should also be facilitated by use of program- and project-level data in summary form. It is further recommended that, for a program of this magnitude, this document be expanded during the initial portion of the implementation phase to define the roles and responsibilities between concerned contractors and the responsible government agencies.

1.2.5 Ground and Flight Operations

The ground and flight operations for the Space Station program have been studied in an effort to ascertain the most cost-effective approaches. Standard methods of operating established in previous programs were critically analyzed, and many cost-saving changes that did not degrade overall mission success were identified. Among the more significant operating recommendations are: (1) Imposition of the requirements and disciplines necessary to limit prelaunch testing to critical function checks, and (2) elimination of the requirement for clean-room operations and minimization of subsystem testing at KSC.

Several flight operations concepts have also been instituted to minimize costs:

A. Full support of the Ground Network Institutional Base will be required only for the first 4 months of operation of the Space Station, after which the Space Station will be manned and the Communication Network Institutional base requirements will be reduced.

B. The Space Station will become operational immediately after activation in orbit through a turnkey operation. Thus, no shakedown period is required.

C. The planning and implementation of day-to-day activities be the sole responsibility of the on-orbit crew.

1.2.6 Facilities

Existing government and contractor facilities can be used to support the Space Station program with minor modifications necessary in order to accommodate functions such as inventory control, training, and crew accommodation.

1.2.7 Logistics

Logistics is the function of delivering resupply cargo to the orbiting Space Station on a timely basis to prevent reserves and residuals from dropping below safe minimum levels. The logistic function is responsible for forecasting needs and the procuring and storing of each item until it is needed. The logistic operation is also responsible for assuring that the items are packaged to be compatible with the logistics or crew cargo modules and on-orbit handling and storage. Other logistic responsibilities include preventive and corrective maintenance activities, configuration control, and recruitment training, and accommodation of flight crew personnel.

1.2.8 Financial and Manpower

The total cost of the Space Station Program (ISS and GSS) in GFY 1972 Dollars is estimated to be $6,563 million, of which the DDT&E costs are $3,714 million, production costs $644 million, and operations costs $2,205 million.

Discounted at 10 percent per year, with GFY 1975 as the base year, the total cost of the Space Station Program is estimated to be $3,419 million. Both funding and manpower are constrained by the Phase C/D ATP, which is scheduled for October 1975, and the Initial Space Station (ISS) six-man first operational launch scheduled for October 1980. Operations effort is scheduled to begin prior to the first launch and to continue for ten years after the launch. The schedule constraints cause a funding peak of $691 million in GFY 1984 and a manpower peak loading of about 14,500 in the same fiscal year.

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Section 2
BASELINE PROGRAM AND PROJECT DESCRIPTIONS

2.1 INTRODUCTION

Brief summary descriptions of the baseline Space Station Program and project elements are provided since, together with the associated plans, schedules, specifications and cost data, they establish the basis for future program development. The overall objectives of the Modular Space Station are discussed along with a listing of significant guidelines under which the study was conducted.

The Modular Space Station definition study evolved a management and development approach which utilized a program structure consisting of an interrelating Technical Requirements Structure, Work Breakdown Structure, and Management Structure that are consistent in regard to leveling and the assignment of responsibility and authority. This structuring is totally correlatable and permits a very rapid assessment of program management and development status, including cost and schedule information.

2.2 SUMMARY

The Space Station will be a low-cost, centralized facility in Earth orbit, supporting a wide variety of space activities designed to provide immediate, tangible benefits to the man on the street, as well as long-term research data. The Space Station will be analogous to a highly flexible multidisciplinary research, development and operations center on Earth, and will utilize and exploit the unique features provided by its location in low Earth orbit: weightlessness, unlimited vacuum, continuous Earth viewing, and unobstructed celestial viewing, as well as a wide variety of research and applications activities.

The Space Station complex will consist of modules provided by the Space Station project and the research and applications Module (RAM) project. The Space Station project will provide the modules which will make up the basic Space Station facility and which will contain the living quarters for the crew, the power supply, life systems, integral experiments, general purpose laboratory, and experiment provisions, as well as RAM accommodations. The Space Station project will also provide the logistics module, which will accommodate passengers and cargo during transportation to and from orbit and provide for orbital storage while attached to the station.

Three modules (one each of power/subsystems, crew/operations, and GPL) are joined on orbit to provide a six-man ISS capability in 1980. Five years later, in 1985, the addition of one power/subsystem module and one crew/operations module complete the GSS 12-man capability for continuation of the 10-year program.

The RAM project will provide specialized modules and their associated experiments, which will be capable of a broad spectrum of space research. RAM missions will be capable of being supported by the Space Station, and the RAM design and operation philosophy shall provide for maximum commonality with the Space Station to minimize development costs.

The Space Shuttle system will be the primary method of transporting Space Station modules, RAM modules, and logistics modules to and from the low Earth orbit, and will serve as a tug in the assembly and operation of the Space Station.

2.3 OBJECTIVES

The primary objective is to develop and implement the concept of a long-term manned Space Station complex in near-earth orbit, which will be supported and serviced by the shuttle.

The specific objectives listed below indicate both the value of the Space Station Program in its own right and its value as a precursor to further manned activities in space:

A. Conduct beneficial space applications programs, scientific investigations, and technological and engineering experiments.

B. Demonstrate the practicality of establishing, operating, and maintaining long-duration manned orbital stations.

C. Develop a design approach for systems and subsystems that permits an increase in useful space system life by at least several orders of magnitude.

D. Develop new operational techniques and equipment that can demonstrate substantial reductions in operating costs.

E. Extend the present knowledge of the long-term biomedical and behavioral characteristics of man in space.

2.4 PROGRAM GUIDELINES

A number of ground rules, or guidelines, were established by NASA at the beginning of the study to provide reasonable boundaries within which to perform the study. These guidelines were revised periodically throughout the study and now represent both NASA and contractor inputs. Some of the more significant of these guidelines, from both configuration and programmatic standpoints are:

A. Minimum cost to ISS

B. Minimum total program cost

C. Commonality is a primary consideration. This has been interpreted to include:

   1. Utilization of current technology

   2. Space Station and RAM module design commonality

D. Safety is a mandatory consideration

E. Flexibility (experiment, accommodation, manning, and funding)

F. Minimum GSE and facilities

G. Minimum testing

   1. Reduced number of test articles

H. Incremental manning (6 to 12 men)

I. Phase C ATP in FY 1975

J. Utilization of the shuttle as a launch vehicle
K. Minimum operational life of 10 years
L. No artificial "g" capabilities

2.5 WORK BREAKDOWN STRUCTURE

The work breakdown structure for the Space Station Program is shown in Figure 2-1, and the performance requirements structure (specifications) in Figure 2-2. The performance requirements structure provides a vehicle for consistent allocation of performance requirements and the WBS provides for a systematic accumulation of the cost, schedule, plans, and management data necessary to define the program.

2.6 SCHEDULE SUMMARY

Space Station Program development involves a 5-year design development, verification, and fabrication cycle with first launch in October 1980. The initial Space Station (ISS) will continue with a six-man crew for 5 years, with logistic and experiment support provided by the shuttle every 30 days. Growth Space Station (GSS) operation will be initiated at the end of the 5-year ISS mission. For GSS, the two addition modules will be added to the orbital assembly by shuttle operation. Crew capacity is expanded to 12 men, who will be supported and recycled by a shuttle transported crew/ cargo module. Detailed schedules and supporting information are contained in Section 4.

2.7 MISSION PROFILE

Three Space Station modules are launched into orbit at 30-day intervals by three Space Shuttle flights in late 1980. Thirty days later, 90 days after initial Space Station launch, a Space Shuttle delivers a two-man activation crew and the first logistics module to orbit. The Space Shuttle docks the logistics module to the Space Station, transfers the activation crew to the Space Station and returns to the launch site. The shuttle makes a trip to the Space Station every 30 days with two fresh crewmen and supplies or with a crew and RAM module. Logistics modules are returned for refurbish each 30 days. Crew rotation is 90 days on station, with one-third of the crew exchanged every 30 days.

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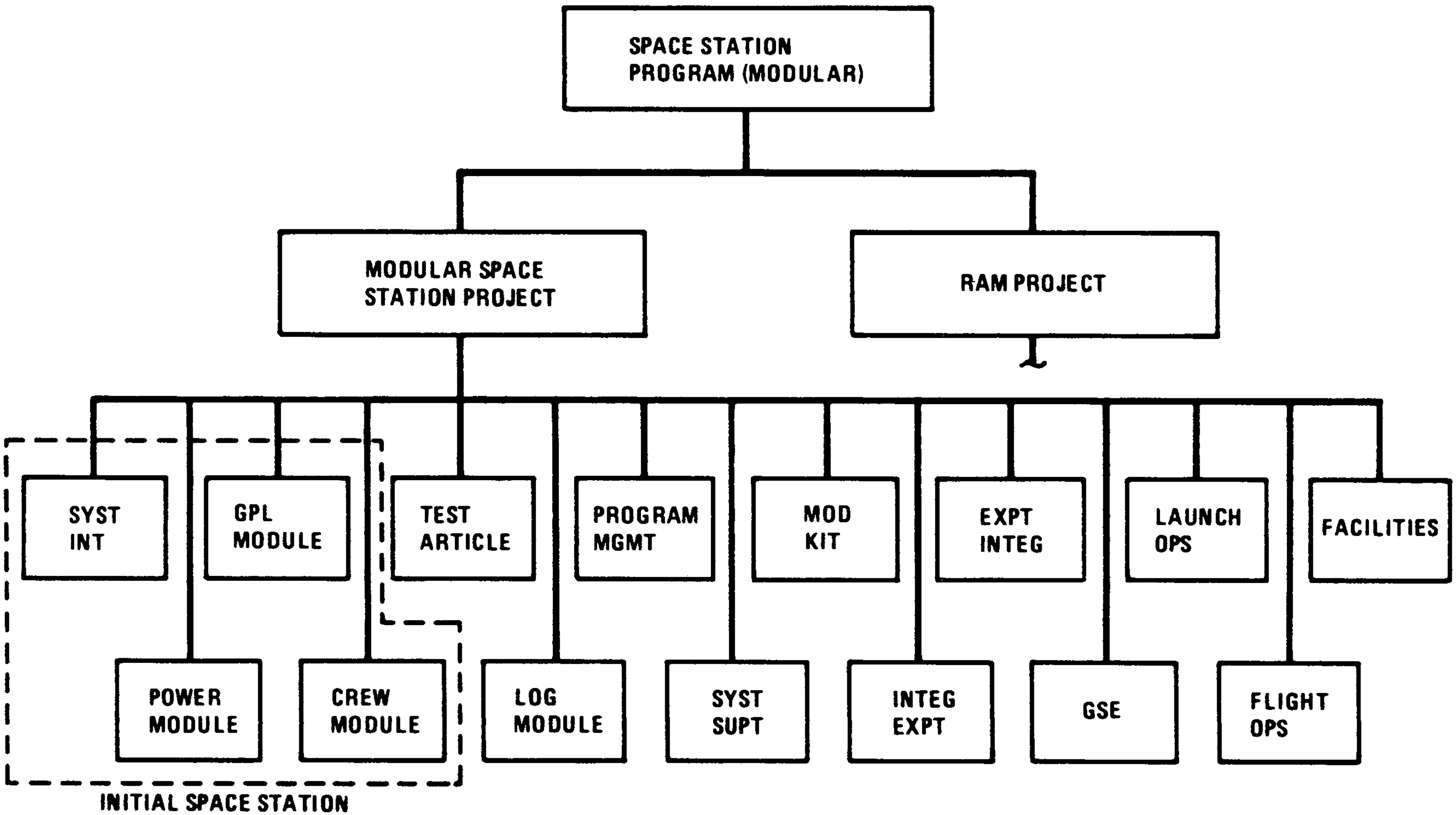

Figure 2-1. Work Breakdown Structure for Space Station

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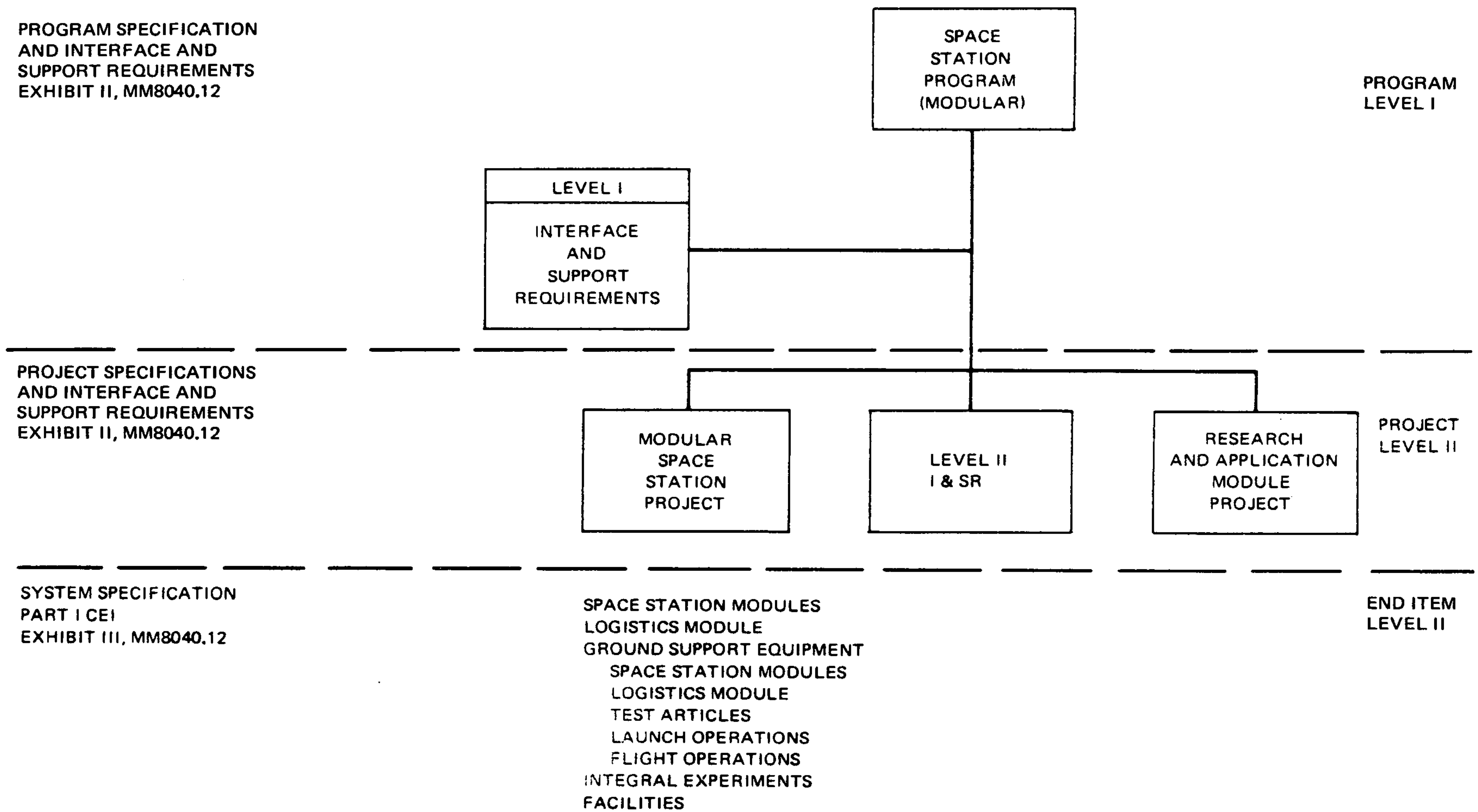

Figure 2-2. Space Station Program (Modular) Requirements Structure

Initial buildup of the ISS is at an orbital altitude of 270 nmi and an inclination of 55 degrees. During buildup, the altitude will be allowed to decay to 246 nmi, which will be maintained during and after manning.

2.8 SPACE STATION PROJECT ELEMENTS

The project elements of the Space Station Program are the Modular Space Station project, and the Research Applications Module Project.

2.8.1 Space Station Project

The Space Station project is composed of several systems or contract end items, all of which, from a development viewpoint, are characterized by a high degree of subsystems and assembly-level commonality. The following systems are defined for development and delivery under the Modular Space Station project; each will be briefly discussed.

A. Space Station Modules
B. Logistics Modules
C. Ground Support Equipment
D. Integral Experiments
E. Test Articles

2.8.1.1 Space Station Modules

Space Station modules are designed for minimum cost initial operation but provide for incremental growth to accommodate twelve men and a complete program of experiments. All modules are compatible with shuttle operations having external diameters of fourteen feet and lengths less than 60 feet. The 20,000-lb weight limitation creates problems in module design, but it is achievable by off-loading noncritical equipment for subsequent installation on orbit. Development cost reductions have been accomplished in a number of ways. A high degree of equipment commonality has been designed into all modules and multiple redundancy for safety critical functions reduces development and subsequent operational maintenance cost. Whenever possible, testing is limited to subsystems level and below and design margins are selected to reduce testing requirements. Long-life-time high-reliability parts are avoided, and the 10-year operational life is supported with planned maintenance and replacement. These factors lead to the establishment of a single CEI encompassing the modules comprising the ISS. The major subsystems and their constituents are listed in Table 2-1. Significant cost reduction is realized by the existence of one engineering design organization, and the attendant elimination of integration and coordination functions, duplicate design and verification requirements and multiple exchange hardware and interface validation functions.

A 5-year development cycle is planned. This is followed by the transportation and orbital assembly of a Power Module, Figure 2-3, Crew Module, Figure 2-4, and General Purpose Laboratory Module, Figure 2-5, by the Shuttle Orbiter. The configuration is illustrated in Figure 2-6. After manning, the Initial Space Station experiment program is conducted for a period of five years. The shuttle transports and docks attached modules. The shuttle also transports new Space Station integral experiments. After the fifth year of operations the two additional modules (power and crew) are transported and docked to the orbiting configuration by the Shuttle Orbiter. The GSS is shown in Figure 2-7. The remainder of the experiment program is conducted in the subsequent five years.

2.8.1.2 Logistics Module

This module provides to the Space Station logistic support, resupply of expendable and experiment equipment. It remains docked between resupply shuttle flights in a storage capacity. The logistics module is compatible with Shuttle operations and is capable of being loaded and refurbished on the ground at the launch site. The logistics module inboard profile is illustrated in Figure 2-8.

During GSS, expanded crew functions and crew recycling requirements necessitate modifying the logistics module design. Crew habitability and life support functions are added to create a crew/cargo module which is used to transport, to and from orbit in the Shuttle Orbiter, six men in a shirtsleeve environment.

Table 2-1

SPACE STATION SUBSYSTEM CHARACTERISTICS

ELECTRICAL POWER

- Double Gimballed Solar Array/Battery (±180 deg Outer, ±235 deg inner) trailing cable
- Array Size

	Power Requirements	Capacity (kw)	m^2/ft^2
ISS	12.3 Kwe + 4.8 Kwe experiments	17.3	490/ 5,300
GSS	19.5 Kwe + 12.1 Kwe experiments	32.1	980/10,600

- Flexible Type Array
- Growth Accommodation - by addition of solar arrays
- Use multiples of equal size arrays
- 100 A-hr Ni Cd batteries; 8 batteries per station module
- Load bus power characteristics:

  115 ± 3.0 vdc

  115/200 ± 2-1/2 percent vac, 3Ø, 400 ± 1 percent Hz, sine-wave and square wave

  115 ± 5 percent vac, 1Ø, 60 ± 1 percent Hz, sine-wave (GPL)

EC/LS

- Open Oxygen, High-Pressure Gas Resupply
- Molecular Sieve CO_2 Control; CO_2 Storage
- Reverse Osmosis Wash Water Recovery; Air Evaporation Urine Recovery
- 1 ATM: O_2/N_2
- Solar Heat Collector - Flex Hose Interconnect

  ISS - 14 M^2 (150 ft^2)

  GSS - 28 M^2 (300 ft^2)
- 6 Man Units (Redundant)
- Station provides pump-down and 60 cu ft storage (at 300 psia) for GPL Isolation/Test Facility and for RAMS. RAMS provide additional storage as required. Module airlocks are vented.

Table 2-1

SPACE STATION SUBSYSTEM CHARACTERISTICS (Continued)

GUIDANCE AND NAVIGATION

- Stellar/Inertial Reference
- CMG's (4 on-line; 1 spare)
- Ground Tracked Navigation
- Manual Docking Control
- All Attitude Capability, Nominally Trimmed-Horizontal Orientation (γ)

DATA MANAGEMENT

- Centralized Multiprocessors and Distributed Computers
- Remote Data Acquisition Units - Low Level Data Processing
- Data Bus - Low/High Rate TDM on Subcarriers
- Multipurpose Central and Local Displays

ONBOARD CHECKOUT

- Automated Operation
- Crew Cognizance and Participation
- Hybrid of Built-In and Separate Elements
- Integrated with Data Management
- Independent Warning System
- Self-Check Capability

PROPULSION

- Hi Thrust - N_2H_4 Monopropellant
- Lo Thrust - Biowaste Resistojet (CO_2 only)

COMMUNICATIONS

- Distributed Intercom Via Data Bus
- VHF System to Shuttle
- ISS - S-Band Direct to MSFN
- ISS/GSS - VHF and Ku-Band to DRSS (2); Ku Band to FFM's at GSS

CREW HABITABILITY

- Sized for 6-men Units
- Zero-G Interior Arrangement
- Private Crew Quarters - 5.66M^3 (200 ft^3) each

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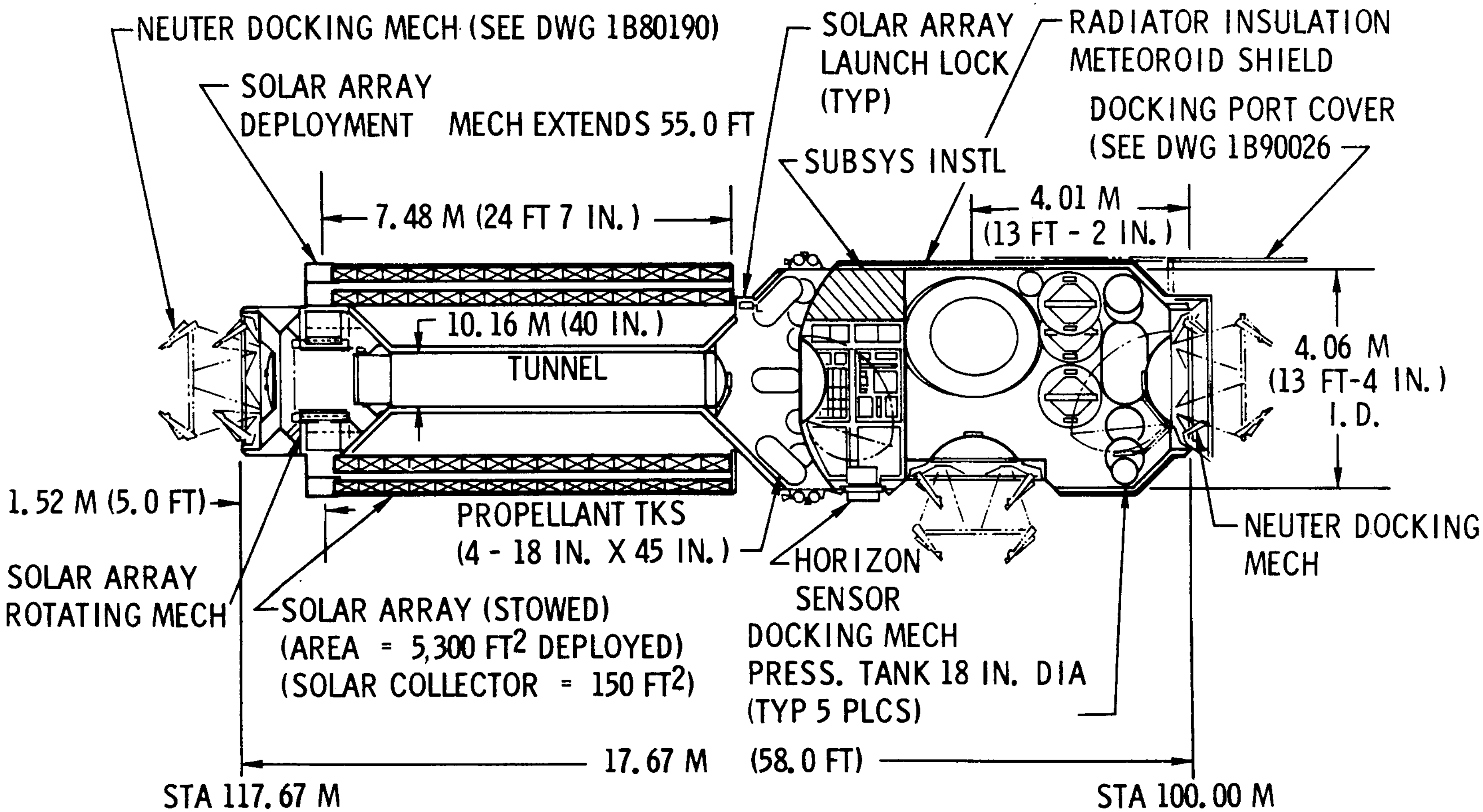

Figure 2-3. Modular Space Station Power/Subsystem Module

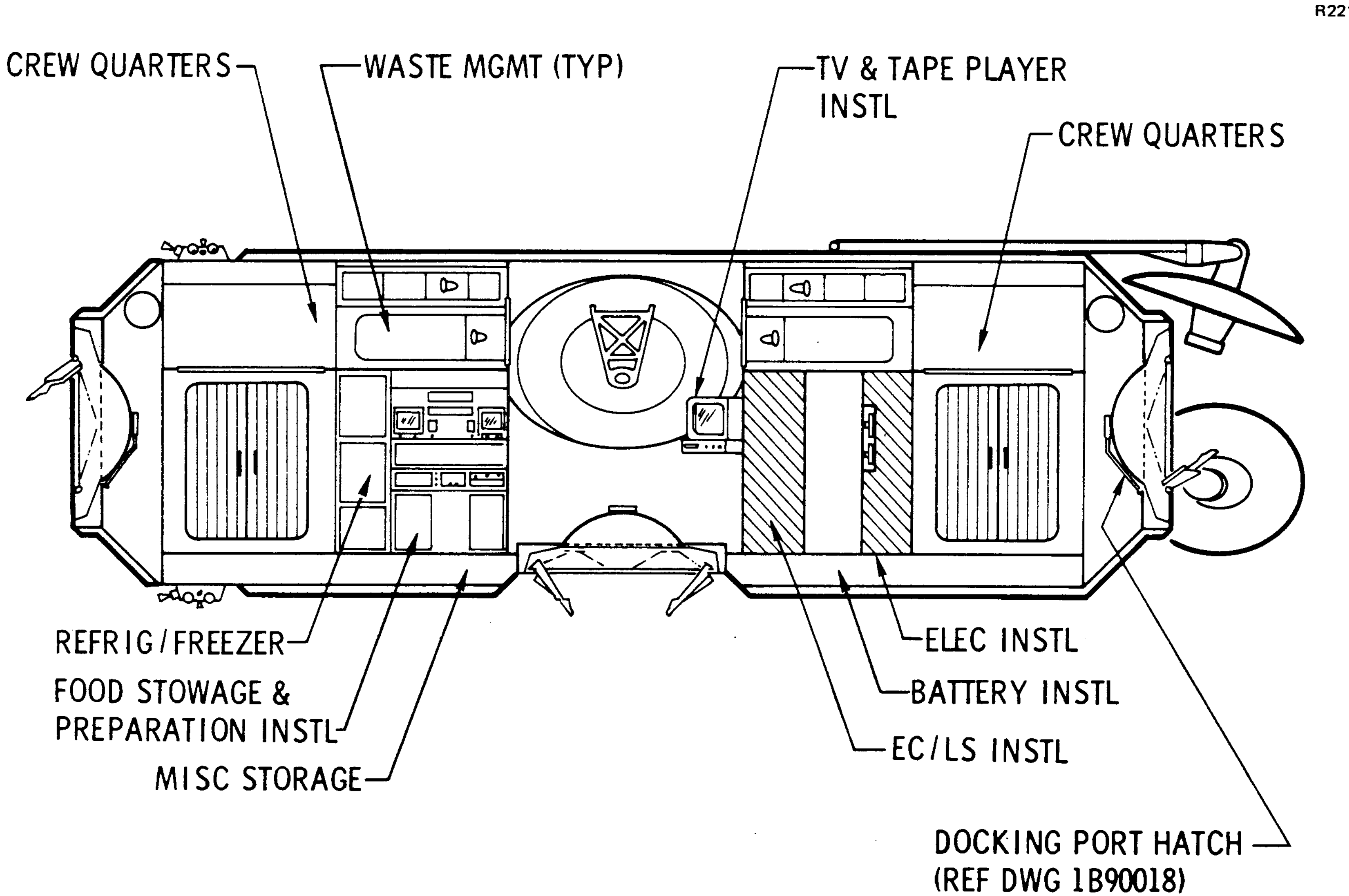

Figure 2-4. Modular Space Station Crew Operations Module

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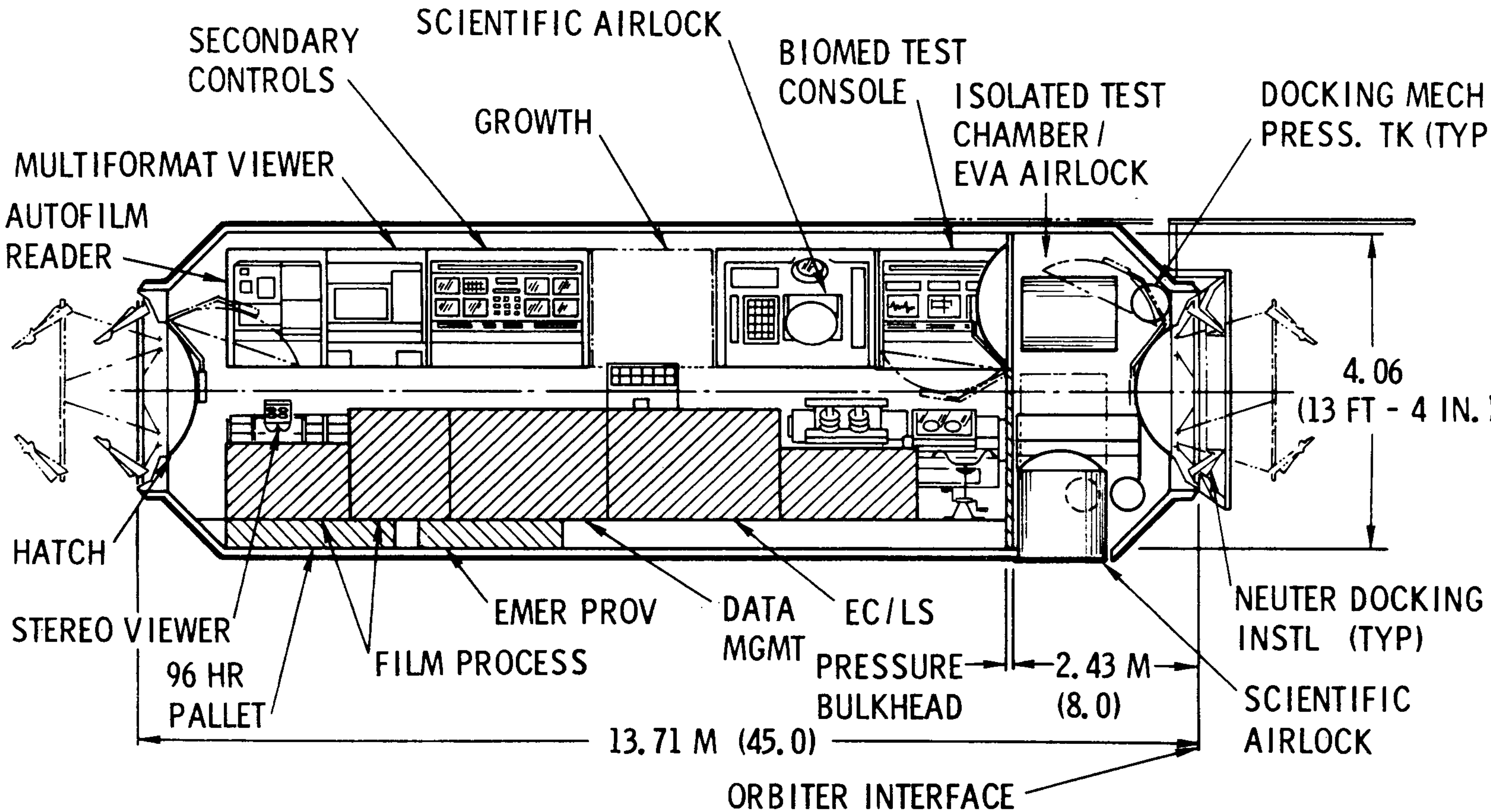
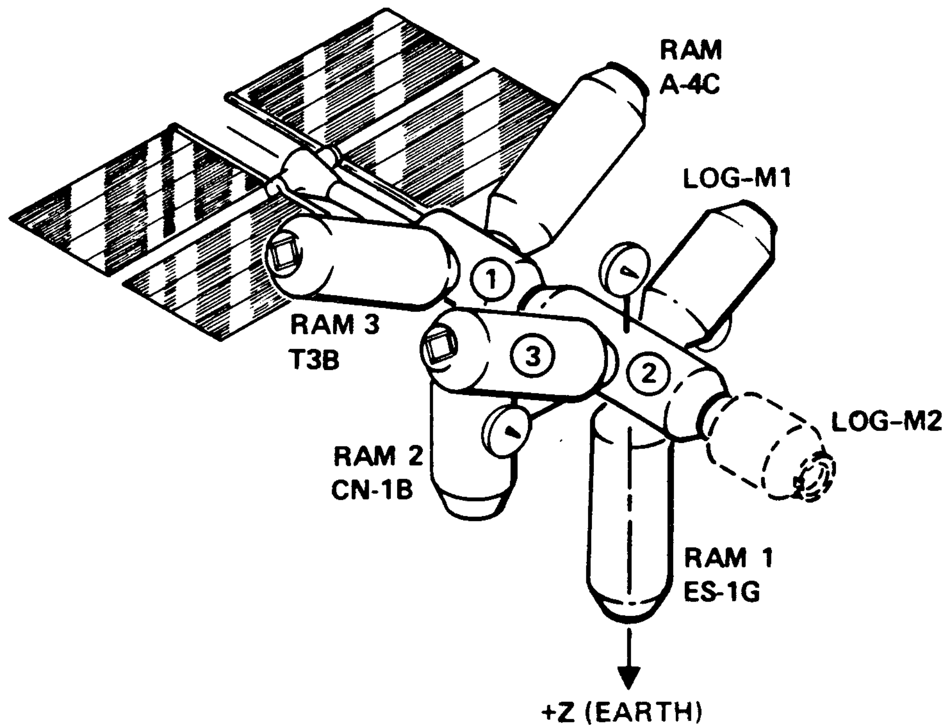


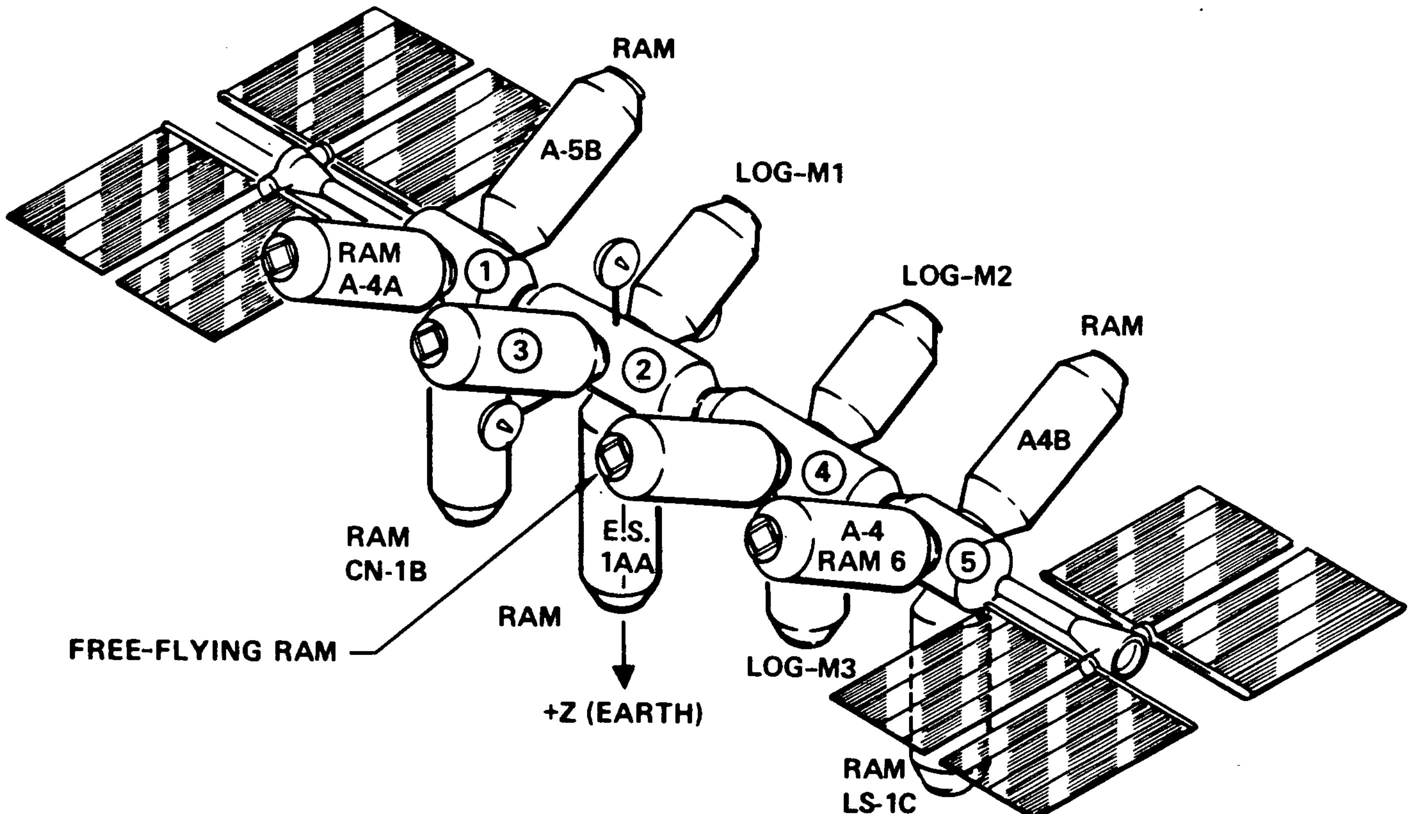
Figure 2-5. Modular Space Station General Purpose Laboratory



LAUNCH SEQUENCE/MODULE	1*	2*	3*	
PRIMARY FUNCTION	POWER/ SUBSYS	CREW/ OPNS	GPL	LOG M
CREW LAUNCHED	0	0	0	2

* 2 MEN ACTIVATION CREW POTENTIAL FOR SHUTTLE ORBITAL DURATION

Figure 2-6. Initial Space Station (ISS) -- Maximum Cluster During Quarter 15



LAUNCH SEQUENCE/MODULE	1	2	3	4	5
PRIMARY FUNCTION	POWER / SUB/SYS	CREW / OPS	GPL	CREW / OPS	POWER SUB/SYS
MINIMUM LAUNCH WT (LB)	18,932	17,562	18,378	16,562	18,932
			ISS		GSS

Figure 2-7. Growth Space Station (GSS) -- Maximum Cluster During Quarter 28

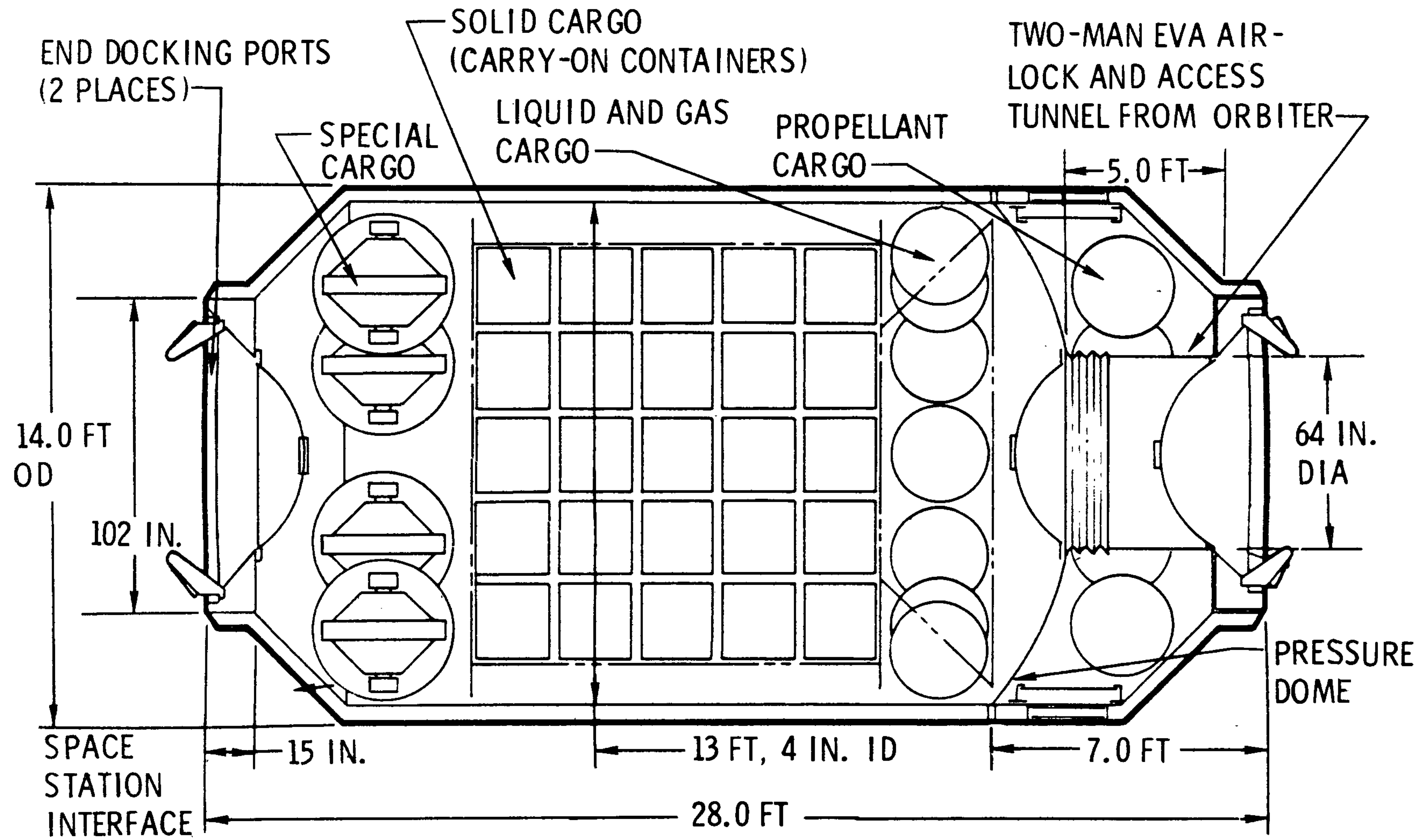


Figure 2-8. Logistics Module -- Inboard Profile

2.8.1.3 Ground Support Equipment

Several factors in Modular Space Station design suggest the applicability of commercial aircraft practice and a significant reduction in extensive ground support equipment. These factors in turn reduce prelaunch test and check-out requirements and associated facilities development or modification. The following factors reduce GSE to a minimum and permit it to be designed, delivered and controlled with the flight hardware it is to support.

A. Utilization of the Space Station On-Board Check-out and Fault Isolation Subsystem wherever practical for ground testing.
B. Minimum launch critical equipment
C. Unmanned module launches
D. On-orbit assembly and maintenance
E. Logistics resupply and crew support
F. Minimum or flight configured test articles

GSE will support Logistics and Crew Cargo Module launch site operations, experiment launch rate support, consummable resupply and the ground monitoring or support of functions which require ground backup beyond that normally anticipated for Shuttle launch and flight operations.

A major requirement for GSE exists in those ground management functions associated with short and long range orbital mission planning, logistics, data management experiment support, and orbital configuration identification. The Modular Space Station development concept coordinates these critical ground functions into an integrated mission management concept. This concept combines and correlates all of the functions necessary for ground mission control into one entity. This then permits the integration of personnel and equipment into a single management and facility capability to perform multiple, but related tasks.

2.8.1.4 Facilities

Modular Space Station development emphasized the utilization of existing technology. This approach together with the GSE philosophy works in the direction of either reduced facilities requirements or the ability to use existing facilities. A further advantage of a modular approach is that the reduced unit volume, linear dimensions and weights place no burden on existing facilities capacities. Systems analyses show no requirements for new facilities.

2.8.1.5 Integrated Experiments

The Modular Space Station definition study has made very comprehensive trade studies associated with the placement, manning, scheduling and cost relationships of experiment Functional Program Elements (FPE's). A number of variables influence decisions regarding the placement of an experiment FPE in an attached or free-flying module or incorporating it into a Space Station integral experiment. However, overall cost and orbital facility effectiveness can be significantly impacted by the balance. The ability to consolidate integral experiment with station operations and logistics is an important cost and design driver.

Present studies indicate that a significant segment of the experiment program can be accomplished as integral experiments, particularly during ISS where cost reduction is a significant goal. This includes experiments in the following disciplines; all materials science experiments, most of the physics and technology experiments and all of the biomedical experiments which are more than half of the life science disciplines.

The integral experiments shall be identified as a separate CEI(s) to insure proper Space Station support, resources, and interface compatibility. Experiments in attached and free flying modules will receive orbital Space Station support, however, interface and support requirements will be assigned by the Modular Space Station/RAM Projects.

2.8.1.6 Test Articles

The point has been made previously that a possible development cost reduction concept would be the reduction in both number and complexity of test articles. Two test articles have been identified for Modular Space Station development; the Function Model (FM) and the Flight Integration Tool (FIT). The FM will be composed of development, hardware/software and will be used for subsystem integration and for integration of the various on-board computer programs.

The FIT will be constructed using qualification test hardware, refurbished as required. The FIT is flight configured and will be used to verify flight systems functions, validate flight hardware including RAM's, interfaces, ground configuration control and crew familiarization. This is illustrated in Figure 2-9. The FIT will be maintained in functional readiness and will be available to verify GSS module interfaces.

2.8.2 RAM Project

All elements of the RAM Project are configured to operate with the Shuttle. The various possible modes of operation are illustrated in Figure 2-10. These operational modes fall in two general categories, Shuttle supported modes and Shuttle/Space Station supported modes. RAM definition studies are still in process and subsequent discussions of RAM functions should be considered to be representative in the sense that they illustrate the support provided by the Shuttle and the Space Station.

Shuttle supported RAM operation is limited only by the Shuttle operational envelope for a selected RAM experiment. Two possible Shuttle RAM missions have been suggested. The first if the RAM free flyer which is capable of semi-independent orbit operation and which is placed in orbit by the Shuttle and subsequently maintained or retrieved from orbit by the Shuttle. The second is the RAM Sortie in which a module is carried to a selected orbit by the Shuttle Orbiter supported in orbit without undocking from the Orbiter. This mode of operation is limited to a seven day mission.

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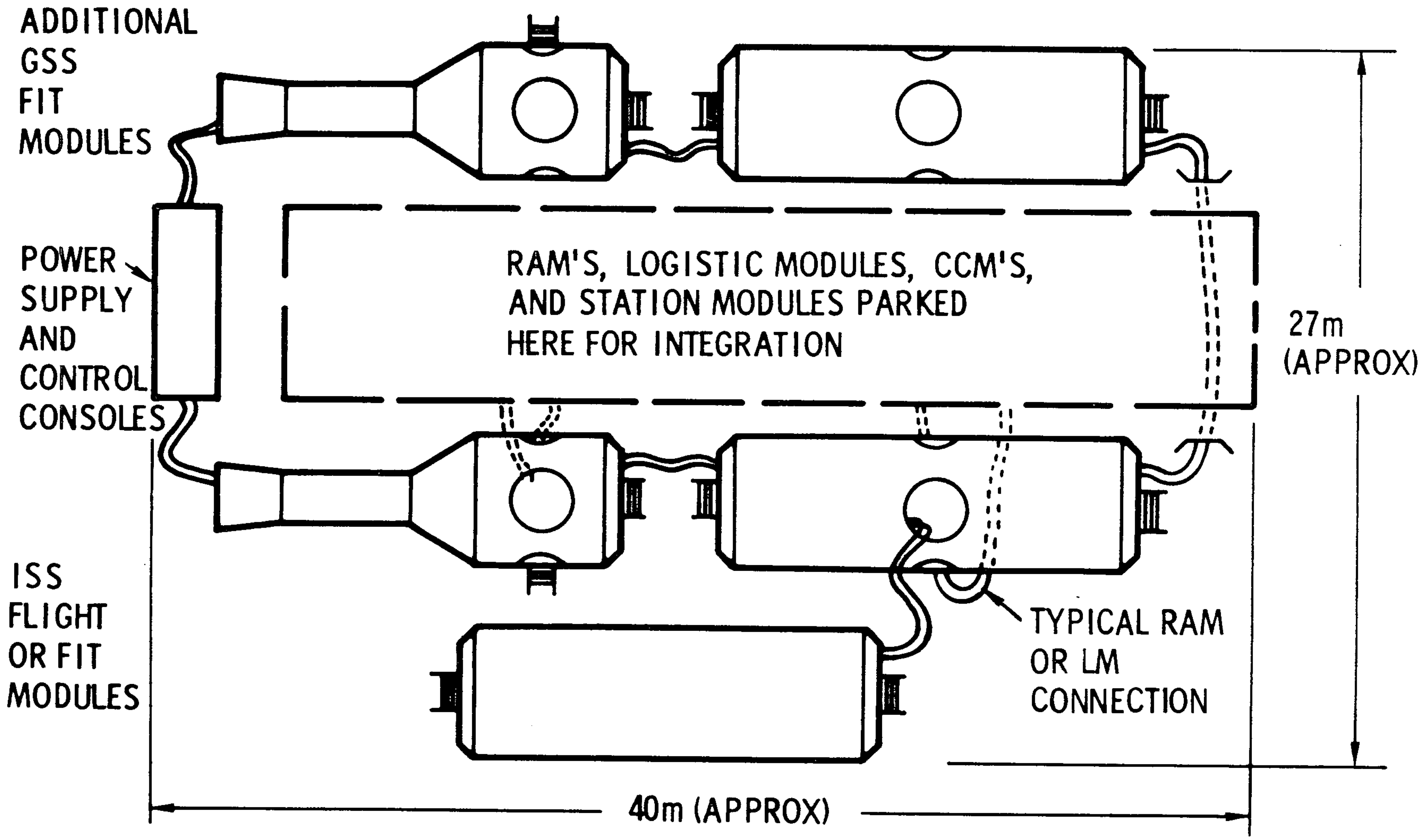

Figure 2-9. Typical Flight Integration Tool Layout

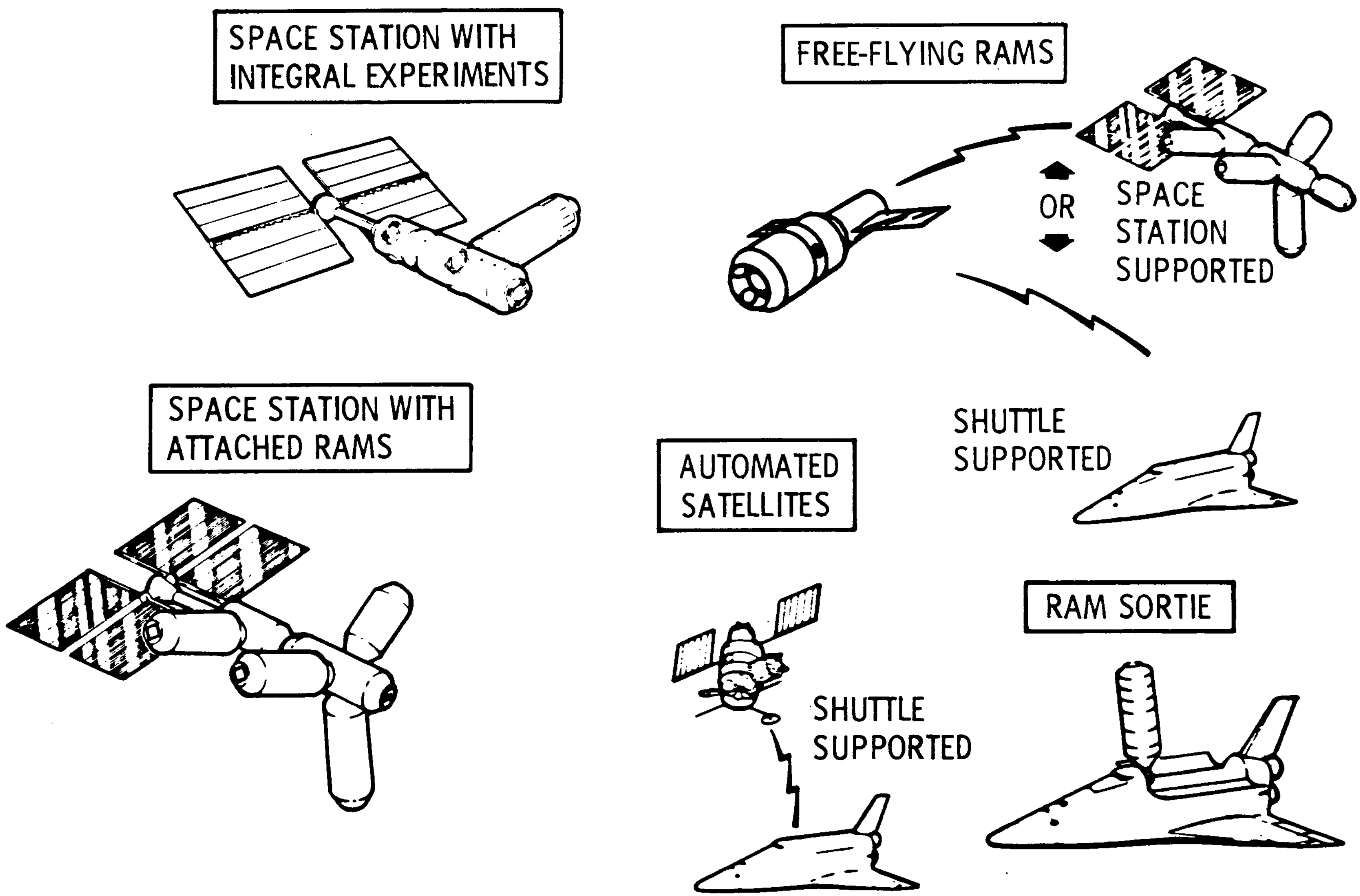

Figure 2-10. Potential Mission Modes Available For An Orbital Scientific Program

Experiments associated with the Modular Space Station Program are contained in free flying or attached modules or are integral to the Space Station. A representative grouping of experiments together with their modes of accommodation are scheduled in Figure 2-11. The Growth Space Station is capable of supporting any experiments in the Blue Book dated January 1971. The experiments selected for ISS are those which best comply with ISS cost guidelines and provide a reasonable mix of experiment disciplines for early operational implementation.

The baseline RAM's are a family of configurations designed to accommodate many FPE's. Each RAM nominally consists of a subsystem compartment and an instrument compartment. Physical characteristics and operational capabilities are summarized with ranges of values indicating the variance among modules.

External Diameter:	4.27 M (14 ft)
Length Range:	11.4 to 17.7 m (37.5 to 58 ft)
Weight Range:	6,480 to 10,440 kg (14,277 to 23,995 lb)
Maximum Pointing Requirement:	28×10^{-5} deg (1.0 arc sec) free-flying RAMS
	28×10^{-5} deg (1.0 arc sec) attached RAMS
Maximum Stabilization Rate Requirement:	1.4×10^{-6} deg (0.005 arc sec) for 4 hr (free-flying RAMS)
	28×10^{-5} deg (1.0 arc sec) for 24 hr (attached RAMS with gimbal system)
"g" Level Requirement Range:	10^{-5} to 10^{-3} "g's"
Logistics Support Requirement Range:	32 to 4,350 kg (50 to 9,600 lb)/90 days

RAM/Space Station subsystem interface and service requirements are shown in Table 2-2.

2.8.3 Space Shuttle

This section contains a description of the Space Shuttle features which are pertinent to the preliminary design of the Space Station. Also included is a description of the Shuttle operations as they impact the Station design.

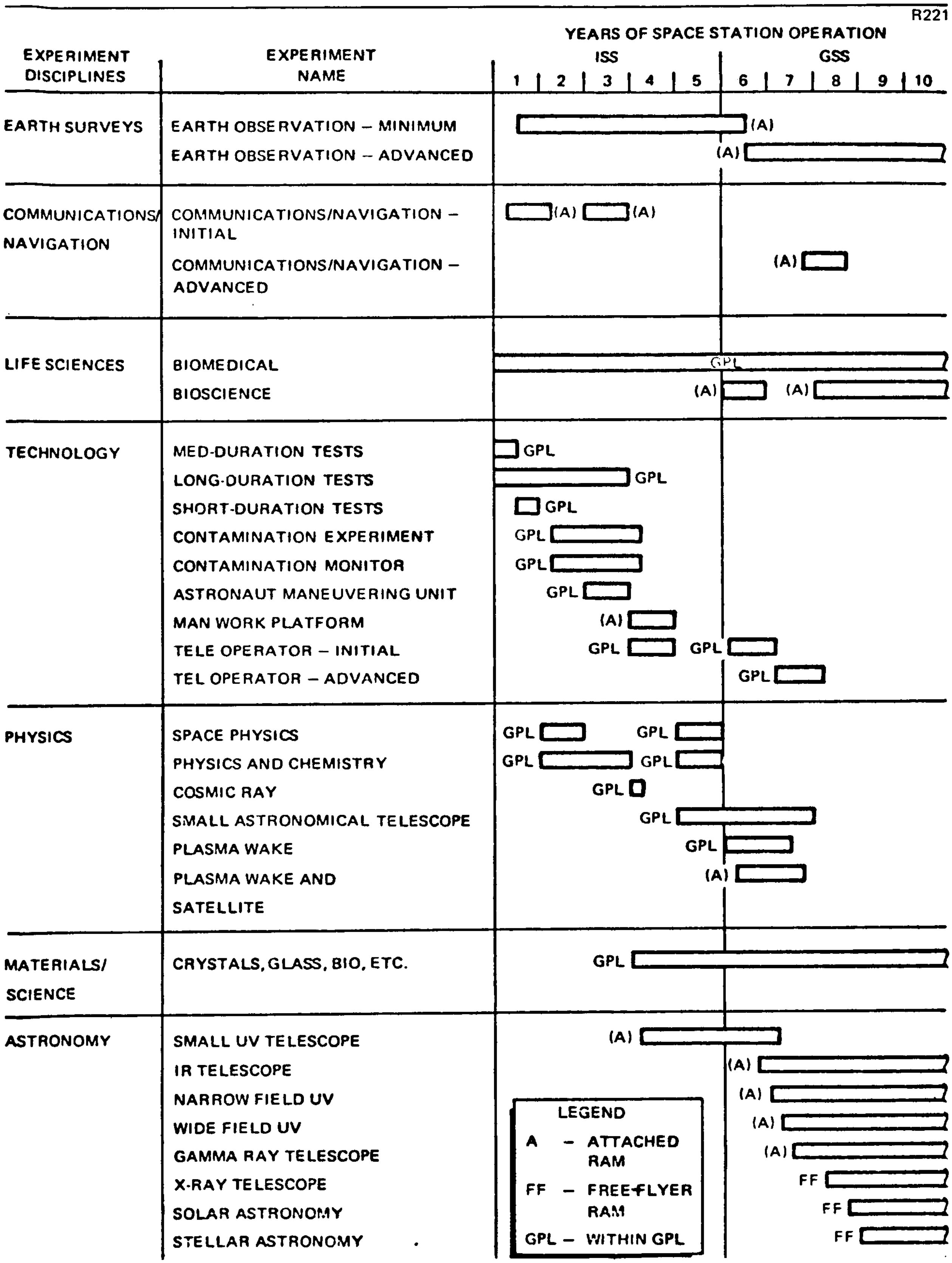

Figure 2-11. Baseline Research and Applications Programs

Table 2-2

RAM/SPACE STATION SUBSYSTEMS/INTERFACES

Subsystem	SS/RAM Interface Services	RAM Characteristics/Reqmts (Free-Flying Mode)
EC/LS	1 Atmosphere O_2/N_2 pumpdown and repressurization flow rate to 0.135 Kg/sec (17.8 lb/min)	Two fluid module loop—294 ± 3 K (70° ± 5° F) 1 Atmosphere O_2/N_2
	Pumpdown gas storage capacity is 60 ft^3 at 300 psia	
GNC	Inertial System Initial Acquisition ± 0.25 deg	CMG's with magnetic torquers
	Pointing command	Fine pointing reference
	Navigation data ± 1,850 M (±1 nmi)	
Propulsion	Liquid Transfer Coupling for hydrazine transfer—0.95 cm (3/8 in.) dia	50 lb Thrust N_2H_4 monopropellant Metal bellows tankage
	Coupling for GN_2 transfer—0.95 cm (3/8 in.) dia	
Communications and data	Signal multiplexing, demultiplexing and display Automatic or remote control Voice communications Data processing and storage	Transmissions to SS 10^3 to 10^7 BPS digital data 6.0×10^6 Hz video Bandwidth/channel 3×10^7 RF bandwidth
Onboard checkout	Status monitoring Test sequencing Fixed and portable control and displays General purpose stimuli	2,567 checkout data points/module data acquisition Unique stimuli generation

Table 2-2

RAM/SPACE STATION SUBSYSTEMS/INTERFACES (Continued)

	ISS			GSS			RAM Characteristics/ Requirements (Free Flying Mode)
	Max 24 Hr Avg	1 Hr Avg	5 Min Peak	Max 24 Hr Avg	1 Hr Avg	5 Min Peak	
Electrical Power							
Each RAM							Up to 2.6 KW Solar Array/ Battery Source
115 vdc	2.4	3.6	---	4.0	6.0	----	
400 Hz 115/200 VAC	0.5	0.75	---	0.5	0.75	----	
Total of RAMS and Integral Experiments							
400 Hz							
115/200 VAC	---	2.4	2.8	----	6.0	7.1	
Ac + dc Total	4.8	7.2	8.4	12.1	18.1	21.2	

These allocations include power for (1) experiments; (2) experiment subsystems, and (3) experiment support and integration (displays/controls), but do not include experiment related power for GPL.

2.8.3.1 Vehicle Description

In order to define the Interface Requirements and Interface Characteristics of the Space Station on the Shuttle, a baseline shuttle orbiter was utilized. This baseline is depicted in Figure 2-12.

Characteristics of the Shuttle orbiter which are of interest 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 2-12. This vehicle is designed to accommodate a crew of four (2 orbiter crew and 2 Space Station crew). The cargo bay is sized to accommodate a payload of up to 4.55 m (15 ft) in diameter and 18.2 m (60 ft) in length (includes 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 RAM modules 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 of the payload bay, on the upper longerons at the center of the bay 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 2-13 shows the Shuttle docking/deployment mechanism which interfaces with payload modules. 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.

The orbital maneuvering system (OMS) is required to perform all major translation maneuvers during the orbital phase of the mission. The OMS engines are mounted in the upper aft fuselage.

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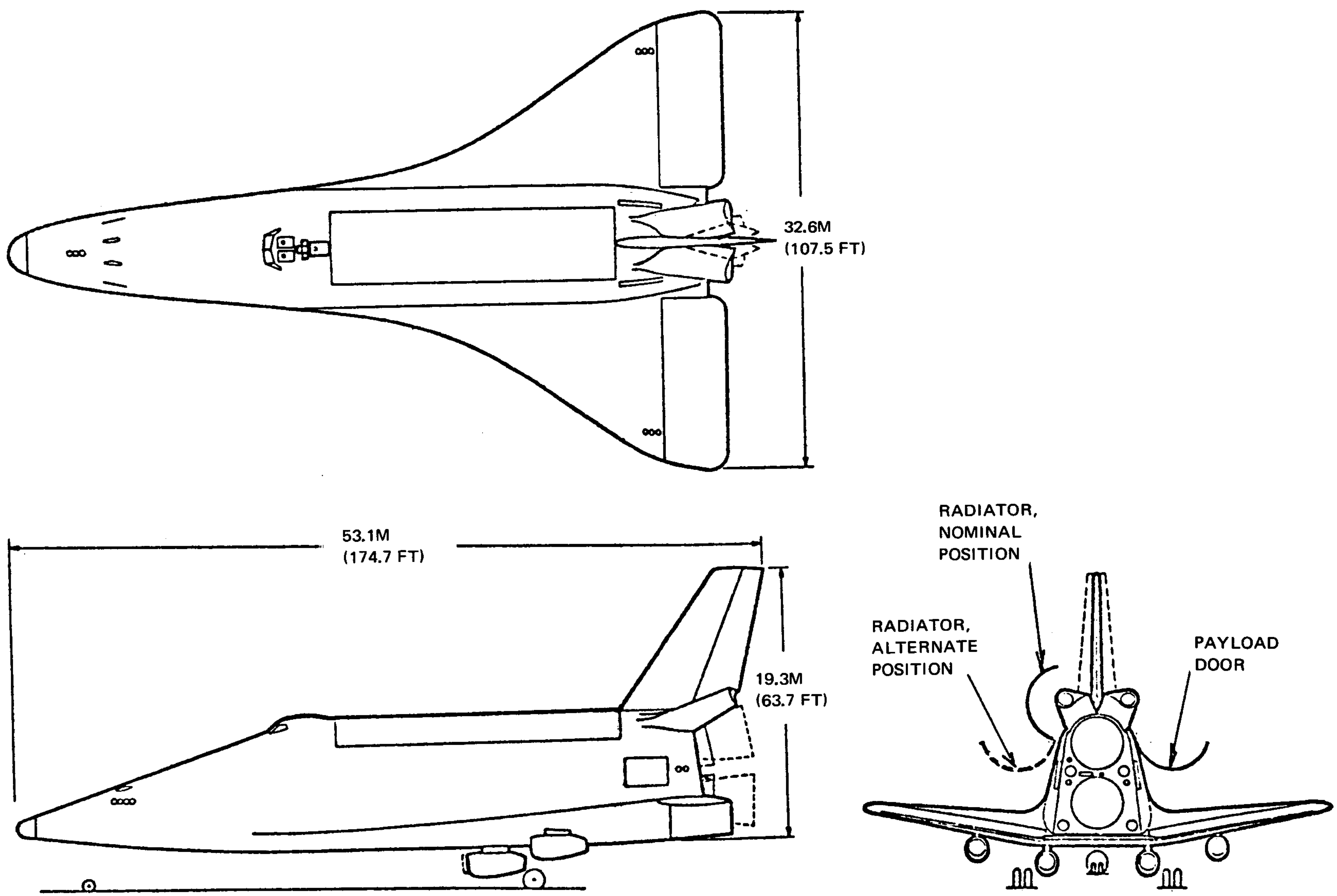

Figure 2-12. Baseline Orbiter Configuration

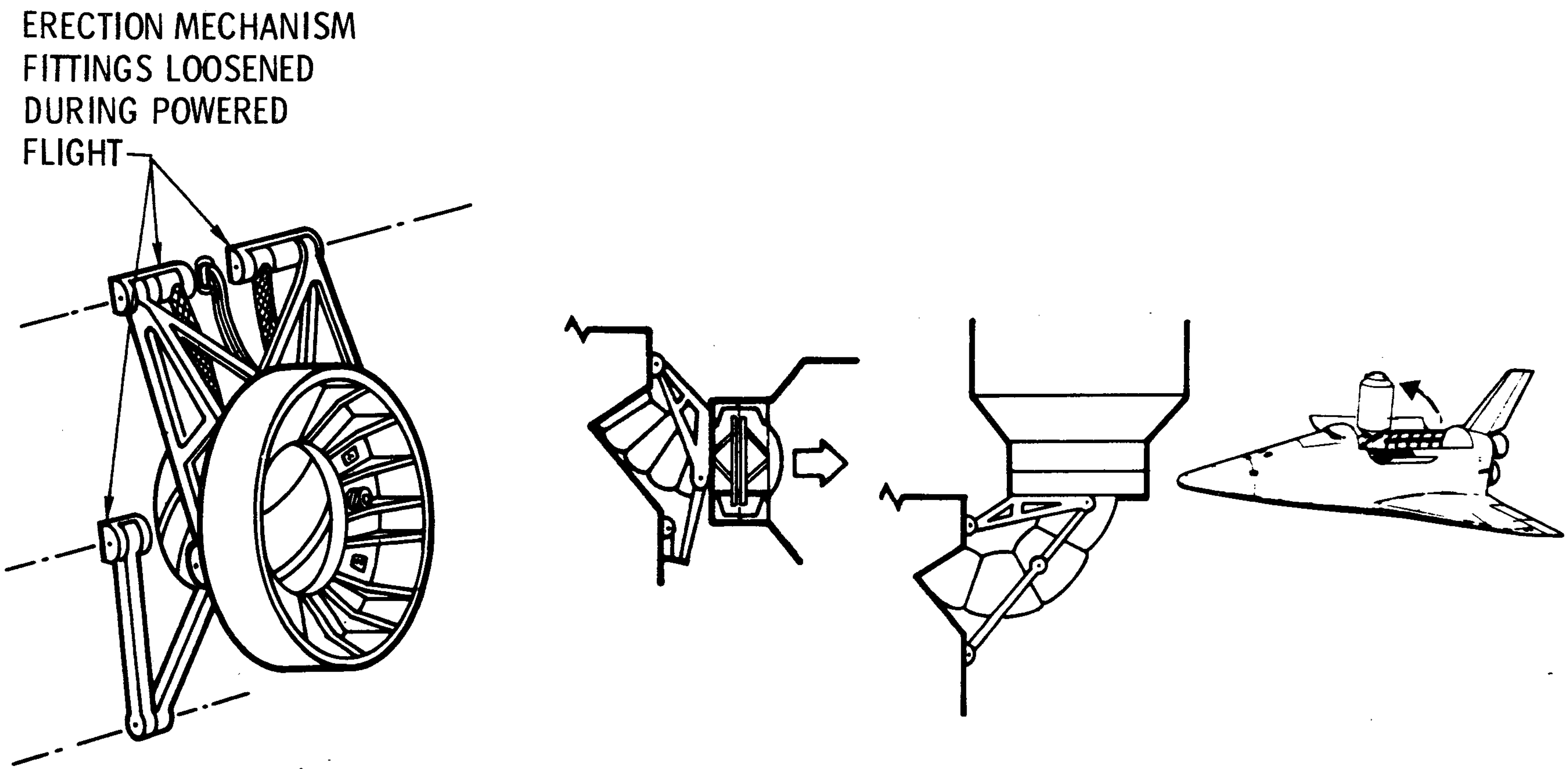

Figure 2-13. Shuttle Docking/Deployment Mechanism

Figure 2-14 shows the general arrangement and geometry of the crew accommodations. Of interest 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 prior to launch with the Shuttle in the erected position would be difficult. Transfer of equipment or cargo to the Space Station of Logistics Modules through the tunnel would be even more difficult and should therefore be considered for contingency operations only.

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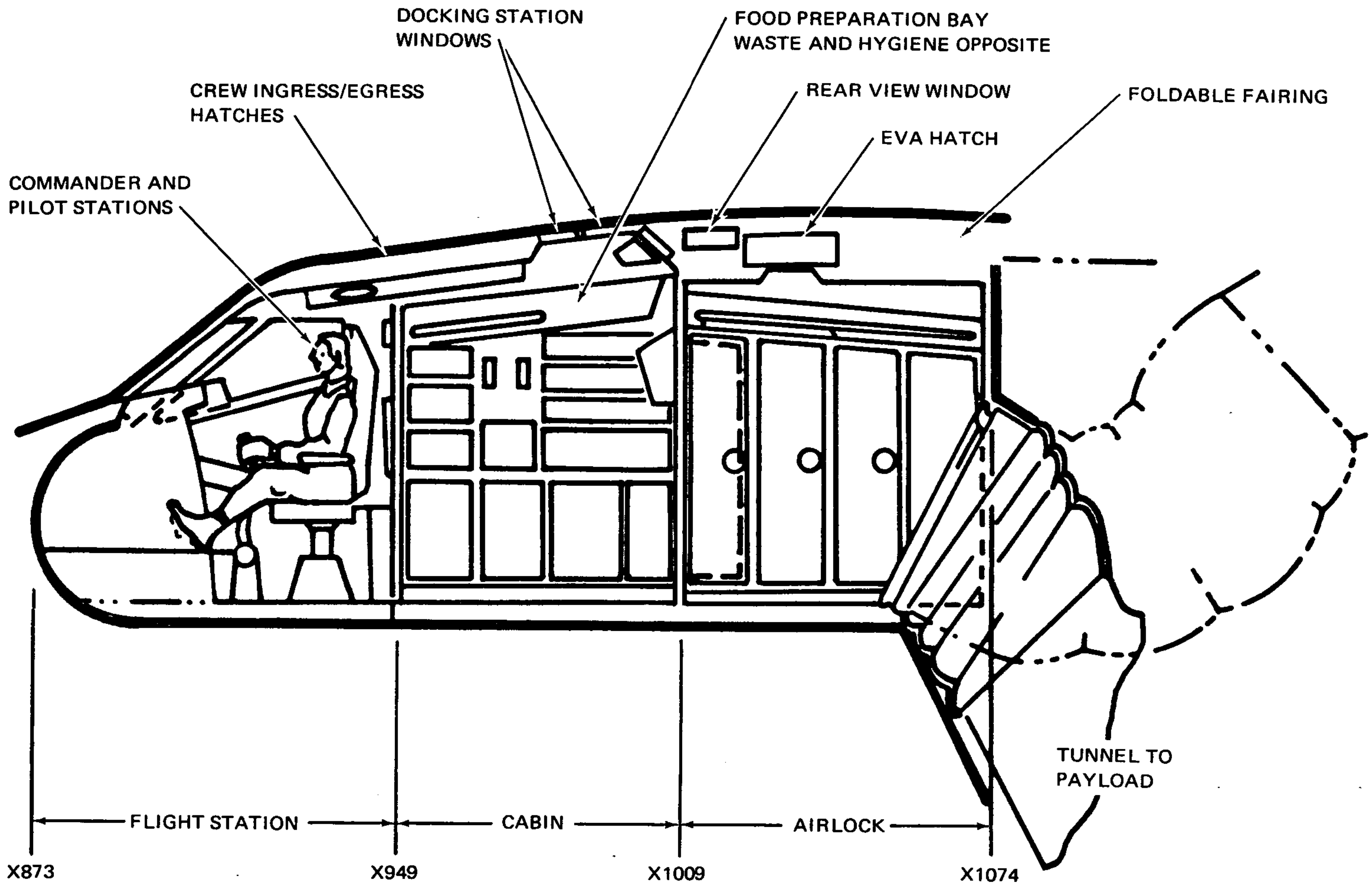


Figure 2-14. Orbiter Crew Accommodations

Section 3
PHASED PROJECT PLANNING

This section described the program activities required to proceed from Phase B to completion of Phase D. An evaluation of the various projects' readiness for Phase C entry and a summary of key features and recommendations are included.

The three objectives of phased project planning which are addressed in this section are:

A. To increase the probability of achieving performance within original resource and schedule estimates.
B. To evaluate the project planning effort at critical points.
C. To provide a progressive buildup of knowledge on all aspects.

The Modular Space Station Program has various projects and systems which are presently in Phases A and B. The purpose of the present Phase B study is the establishment of a single set of Space Station performance/envelope/design requirements suitable for implementation in Phase C. These requirements are documented in the specifications contained in DPD-235, CM-01 through CM-04. During this Phase B study, alternative concepts were considered, and single concepts selected for the Modular Space Station Program, an experiment program, the Space Station modules, Research Application Modules, crew operations, GSE, and facilities. The approaches to these areas are recorded in the user's handbook (SE-08), the detail preliminary design document (SE-04), crew operations document (MP-02), the integrated mission management document (MP-03), and the Space Station Program Plan (MA-05, Volume I).

In the conduct of system analysis, future missions were postulated, and a Growth Space Station (GSS) was synthesized to develop interface requirements and to define critical interdependence areas. This system analysis was continued for the same purpose with both the Crew Cargo Module, the RAM Project and the Experiment Program. The GSS Phase and RAM Project analyses were considered to constitute a partial Phase A. Tradeoff analysis, normally conducted as a subfunction of system analysis, was formalized where critical assessments required visibility.

Payload, mission, and operation support requirements are analyzed and defined in MP-01. An experiment program for both the ISS and GSS phases was postulated from the "Blue Book" and the experiments were defined to the FPE level. This level of experiment definition satisfies Phase A (preliminary analysis) output requirements.

The manufacturing requirements are presented in MA-05, Volume II (Manufacturing Requirement Plan); Verification requirements are given in Section 4 of the Program, Project and CEI Specifications (CM-01, CM-02, CM-03). Further amplification of the Verification requirements and philosophy are contained in MA-05, Volume II (Verification Requirements Plan). As indicated in the Space Station Program Schedule shown in Figure 4-1 of Section 4, the SRT categories of research, advanced technology, advanced development, and supporting development have been time-phased to the Space Station Program phases. The probability of achieving Space Station performance requirements at minimum cost is enhanced by terminating experiment research SRT prior to January 1979 for ISS and October 1982 for GSS, terminating experiment advanced technology SRT prior to February 1980 (ISS) and October 1983 (GSS), terminating advanced development SRT prior to initiation of the preliminary design review, and terminating supporting development SRT prior to the completion of critical design review. SRT cost is reduced by controlling the start of the advanced development and supporting development categories to minimize concurrence, overlap, and duplication. All recommended SRT items are recorded in SE-10 (SRT document).

The program and project costs and schedules are presented in this document. The definitive costs and schedules for budgetary and planning purposes are in MF-01 (Costs and Schedules document). The management and procurement approach are discussed herein.

Design (Phase C) activities will be initiated in October, 1975, ISS operations begin in October, 1980 and continue until October, 1985 with GSS continuing until October, 1990.

Three distinct requisites during Phase C are notable: (1) specific definition of the goals and scope of the program, (2) use of the application planning technique in all objective areas of the program, and (3) a detailed, time-phased experiment plan, including the experiments integrated in the Space Station and mounted in attached and free-flying modules. Definitive results from the SRT program are also needed for final system definition. Unresolved technological issues may be classified as supporting developments. These efforts can be initiated during Phase C.

During Phase C, firm costs, schedules, and plans are prepared for the development portion of Phase D, and the costs, schedules, and plans for the operation portion are further expanded. Specifications are amended, engineering critical component specifications are prepared, preliminary designs are completed, and preliminary design reviews are initiated.

The Initial Space Station (ISS) development portion of Phase D will start in October, 1976. The RAM project development will continue until the last attached or free-flying module is launched.

Supporting development SRT may continue until initiation of the critical design reviews. The development portion of Phase D consists of development and the fabrication of development hardware, test, and evaluation.

The production portion of Phase D for the ISS will start in April, 1978. This phase is concerned only with the fabrication, assembly, and checkout of the flight articles.

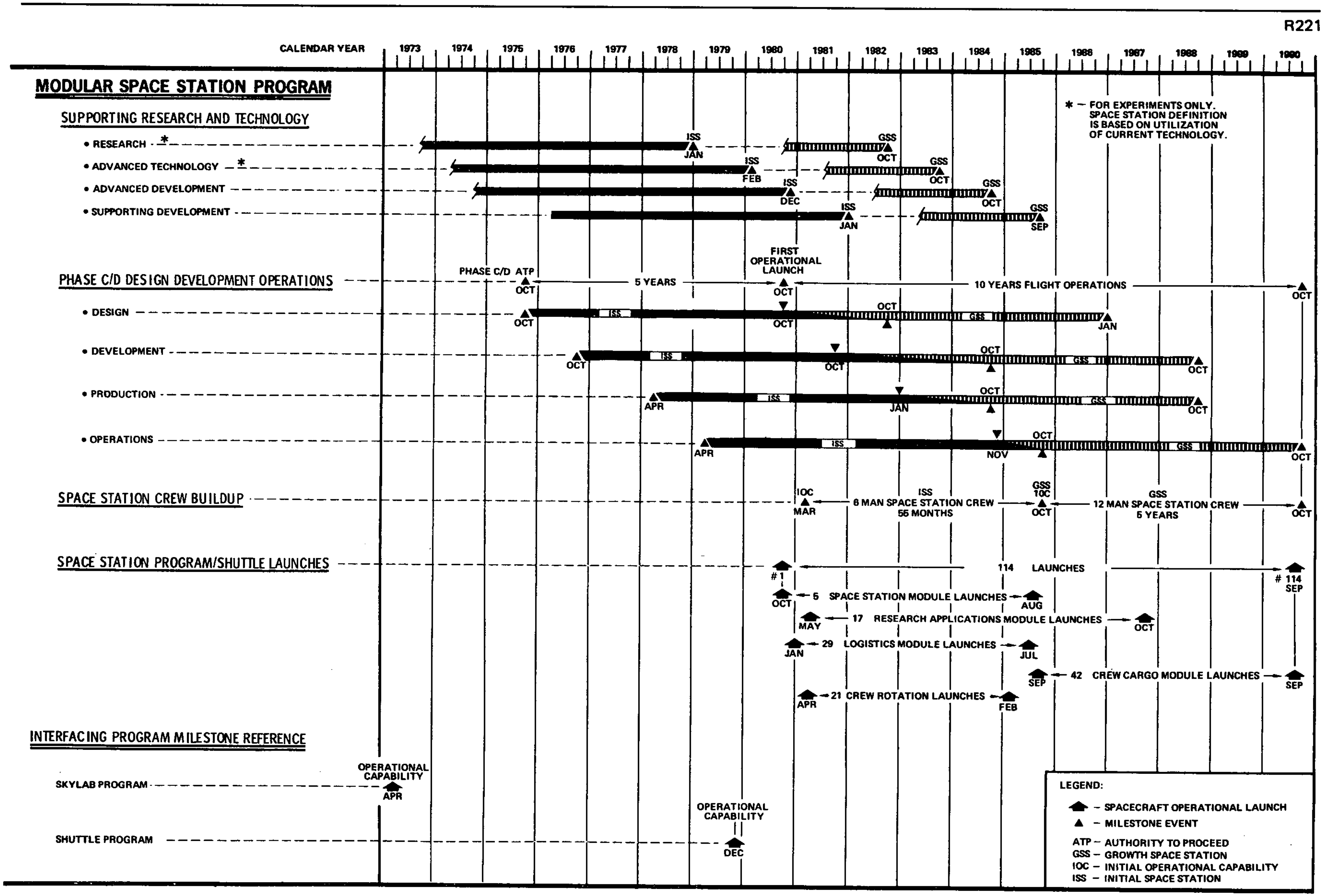
The operation portion of Phase D consists of prelaunch, launch, and flight operations. This phase starts in April, 1979 for the ISS.

Section 4
MODULAR SPACE STATION PROGRAM SCHEDULE

The Modular Space Station Program baseline schedule (Figure 4-1) provides a 6 man Space Station crew capability with a subsequent planned Growth Space Station (GSS) to 12 men. The schedule is based on a Phase C/D design, development and operations authority to proceed (ATP) in October 1975. Design, development, test and evaluation (DDT&E) of the Space Station Modules for the initial 6 man crew capability requires 5 years and is complete at the first Space Station module operational launch in October 1980. Test article development continues to October 1984 to support Integral Experiment integration. Ten years of flight operations are assumed beginning with the first operational launch and are complete in October 1990. Production (recurring) begins with the start of detail fabrication of the first projected operational vehicle which overlaps DDT&E by 30 months. Operations begin with Site Activation, April 1979, 13 months before initial delivery of the first Logistics Module to the launch site.

The engineering design and development will begin at Phase C/D ATP, October, 1975. Completion of the Space Station Module preliminary design review (PDR) is scheduled for October 1976, 12 months after ATP to establish the module and subsystem configurations for detail design. The critical design review (CDR) will be completed October 1977, to assure that specified design requirements have been met.

The ground test program will require test articles which will be used primarily to satisfy various development integration, and multiple testing objectives. Test models at the subsystem level and below will be required



ORIGINATION DATE 9-13-71
REVISION DATE 9-31-71

Figure 4-1. Modular Space Station Program Schedule of breadboard, prototype, and flight types. These subsystem models will be used for concept and design development and design qualification. Qualification of subsystems will be complete October 1979, 4 years after ATP.

At the system level, two test articles are required for the development phase. The system level test articles will be used in the ground test program for subsystem integration and interface verification activities. The test articles are the functional model and the flight integration tool. The planning has been organized to limit the test articles to a minimum number that satisfy the system level development and operational requirements including integration of experiments and ground support equipment. An example of this is the use of the Flight Integration Tool for: (1) manufacturing development and tool fabrication; (2) factory system integration and interface verification testing, software development, and operating procedure development; and (3) factory integration and checkout of new or modified subsystem equipment required during the flight operations phase.

The Functional model is a development tool that will functionally represent an operational vehicle, but in a rack and panel type assembly. The FM will consist of qualifiable-type, prototype, flight-equivalent, and simulated aero-space vehicle equipment (AVE). The major objective of the FM is to perform interface development testing among AVE subsystems and between AVE subsystems and Ground Support Equipment in preparation for support of the system-level development testing. The requirements are to establish the integration of subsystems, development of software, and development of procedures. The FM will be in continuous use throughout the subsystem and system development.

2

The Flight Integration Tool initially will be used for manufacturing development and tool fabrication and will provide a check of the physical compatibility of subsystem design configurations early in their development. The primary test objectives are:

A. To verify manufacturing methods
B. To check assembly procedures
C. To assist in determining tooling requirements
D. To establish control line and cable routing
E. To establish electrical wire harness routing
F. To verify component accessibility
G. To develop and verify maintenance procedures
H. To facilitate design change feedback
I. To serve as an additional man-system procedure definition tool
J. To verify mechanical clearances

The Flight Integration Tool will subsequently be used to verify complete development at the factory and will include people, procedures, facilities and production equipment. The FIT will be produced in the same factory manufacturing and testing facilities where the operational vehicle will be produced. It will be developed in a production-like manner including acceptance tests. The Flight Integration Tool will be used to perform system integration and interface verification testing, software verification, and operating procedure verification. Upon completion of these tests, the Flight Integration Tool will be maintained as a development tool for integration and interface verification of new or modified experiments and subsystem equipment for on-orbit installation during the flight operations phase.

The flight operations begin with three Space Station Shuttle launches which delivers to the planned orbit a Power/Subsystem Module, a Crew/Operations Module, and a General Purpose Laboratory Module. The Space Station

V

Modules are launched at 30 day intervals beginning with the first launch October 1980. All modules can be docked in sequence with a single docking operation. Early Space Station buildup orbit activities of the unmanned vehicle consist of solar array deployment, including vehicle orientation and alignment, power system activation, antenna deployment, and preliminary subsystem checks. The orbit emphemeris data and station habitability verification are the remaining key events of early orbit. Mission control center evaluates the data and signals the "go" for manning.

Four Logistics Modules (LOG M) are required to support the initial 6 man Space Station. Ninety days after the first Space Station module launch, the first Shuttle (LOG M) is launched and delivers a 2 man crew for initial Space Station activation and experiment operations. The third Shuttle LOG M launch in March 1981 establishes the 6 man Space Station operational capability 5 months after first Space Station launch. A total of 29 Shuttle LOG M launches are required over a period of 55 months to support the 6 man crew capability flight operations phase.

Five Space Station attached research application modules (RAM) are required for the initial Space Station experiment program. The first shuttle RAM launch occurs in May 1981, 7 months after the first Space Station operational launch. Four more attached RAM's are launched over the next 33 months. The last Shuttle RAM launch of the ISS phase is February 1984, 20 months before the completion of ISS operations.

DDT&E for the GSS 12-man capability begins in October 1980 with the start of design for the GSS Associated Integral and RAM Experiments. DDT&E for the Space Station Modules requires 42 months and is complete at the first GSS Space Station module operational launch, May 1985. Test article development continues to October 1988 to support Free Flying module experiment integration. GSS production begins with the manufacturing detail fabrication start of the first GSS attached RAM module and Experiment "N" in April 1983. Operations begin with reactivation of launch operations GSE, November 1984, 4 months before the GSS Crew Operations module is delivered to the launch site.

The technology of initial capability modules will be maintained for the GSS including common structural, thermal and docking design for all modules. The engineering drawing release for GSS Space Station Modules will occur in January, 1982. The GSS Space Station Modules PDR and CDR are scheduled for March 1982 and September 1982.

The GSS requires two additional Space Station modules to achieve the 12-man operational flight program. Two 6-man Crew Cargo Modules (CCM) are required in addition to two LOG M's reconfigured to CCM's from the Initial Space Station operational program for a total of four CCM's to support the GSS crew rotation and cargo supply requirements.

A 12-man GSS orbit configuration is achieved October 1985 with four Shuttle launches which include a second Crew/Operations Module, a second Power/Subsystem Module and two CCM's. The 12-man orbit configuration is maintained for a period of five years. A total of two Space Station modules, 42 CCM, and 12 RAM Shuttle launches are required to support the GSS flight operations phase.

The initial Space Station Shuttle launches occur at a maximum launch rate of 30 day intervals. The Growth Space Station Shuttle launches occur at a maximum launch rate of 30 day intervals with 7 exceptions which occur at 60 day intervals. A total of 114 Shuttle launches occur over a period of 10 years.

4.1 MODULAR SPACE STATION PROJECT SCHEDULE

The Modular Space Station Project includes the Space Station Module, Logistics Module, Crew Cargo Module, and Integral Experiment Flight Equipment. In addition to the flight hardware systems, there is the Experiment Integration, Test Articles, Ground Support Equipment, Facilities, System Support, Project Management, Launch Operations and Flight Operations required to support the design, development, launch and mission operations.

The schedule (Figure 4-2) covers design, development, and operations activities required to design, test, produce, and operate the Modular Space Station Project systems. It provides major milestones, key events, and critical actions pertaining to the project and its systems that are vital to the timely execution of the program.

ISS flight operations begin with three Space Station Shuttle launches which delivers to the planned orbit a Power Subsystem Module, a Crew Operations Module, and a General Purpose Laboratory Module. The Space Station Modules are launched at 30-day intervals beginning with the first launch October 1980. All modules can be docked in sequence with a single docking operation. Early Space Station buildup orbit activities of the unmanned vehicle consists of solar array deployment, including vehicle orientation and alignment, power system activation, antenna deployment, and preliminary subsystem checks. The orbit emphemeris data and station habitability verification are the remaining key events of early orbit. Mission control center evaluates the data and signals the "go" for manning.

Four Logistics Modules (LOG M) are required to support ISS flight operations. Ninety days after the first Space Station Module launch, the first Shuttle Log M is launched and delivers a 2-man crew for Space Station activation operations. Space Station activation is complete and the 6-man ISS crew is established at the third Shuttle Log M Launch, March 1981. The first crew rotation Shuttle only launch occurs April 1981. A total of 29 Shuttle Log M launches and 21 crew rotation Shuttle only launches are required over a period of 55 months to support the 6-man crew ISS flight operations phase.

ISS modules designs will be maintained for the two additional modules comprising the GSS (Power/Subsystem Module and Crew/Operations Module) including common structural, thermal, and docking design for all modules.

The GSS Space Station Project design phase begins in October 1980 with the design initiation of those Integral Experiments to be flown in the GSS time frame.

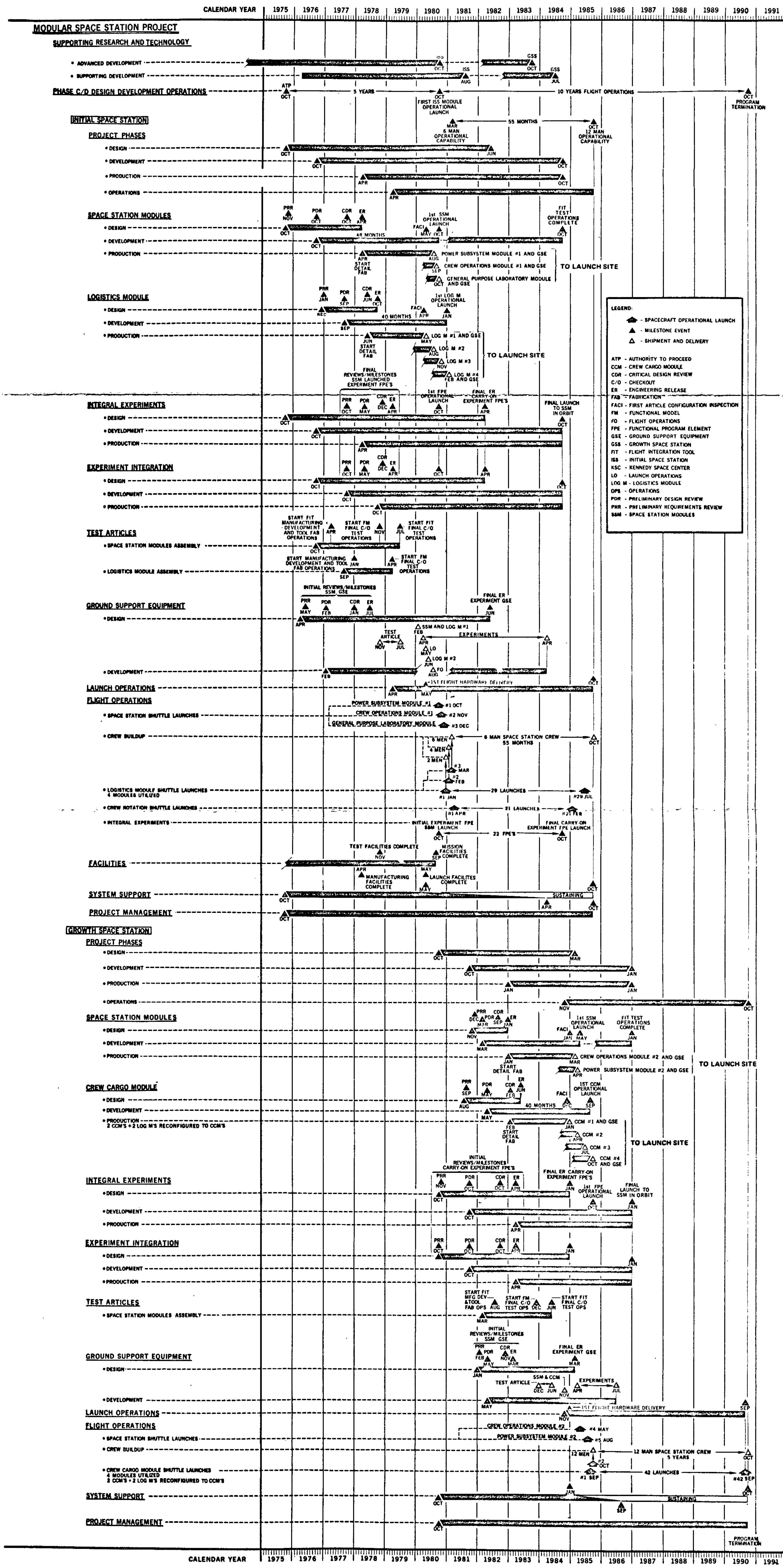


Figure 4-2. Modular Space Station Project Schedule

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Four 6-man Crew Cargo Modules (CCM) are required to support the GSS crew rotation and cargo supply operational flight requirements. Two CCM's are manufactured and two LOG M's from the ISS are reconfigured to CCM's.

A 12-man GSS orbit configuration is achieved October 1985 with four Shuttle launches which include a second Crew Operations Module, a second Power Subsystem Module, and two CCM's. The 12-man orbit configuration is maintained for a period of five years. A total of two Space Station modules and 42 CCM Shuttle launches are required to support the GSS flight operations phase.

4.2 RESEARCH APPLICATIONS MODULE (RAM) PROJECT SCHEDULE

The Research Applications Module Project includes the Attached Module, Free Flying Module and their associated Experiments. In addition to the flight hardware systems, Experiment Integration, Test Articles, Ground Support Equipment, Facilities, System Support, Project Management, Launch Operations and Flight Operations are required to support the design, development, launch and mission operations.

The schedule Figure 4-3 covers design, development, and operations activities required to design, test, produce, and operate the Research Applications Module Project systems. It provides major milestones, key events, and critical actions pertaining to the project and its systems that are vital to the timely execution of the program. Interrelated activities are presented with logic, feasibility, and maximum applications of existing technology and capability.

The schedule provides for a total of 17 Research Applications Modules (RAM's) over the life of the Space Station Program. Five Attached Modules to accommodate the Initial Space Station (ISS) phase. Nine Attached and three Free Flying Modules to accommodate the Growth Space Station (GSS) phase.

The schedule is based on a Phase C/D design, development and operations ATP in May 1976. The first operational launch occurs 5 years after ATP, May 1981. Nine and one-half years of flight operations are complete in October 1990.

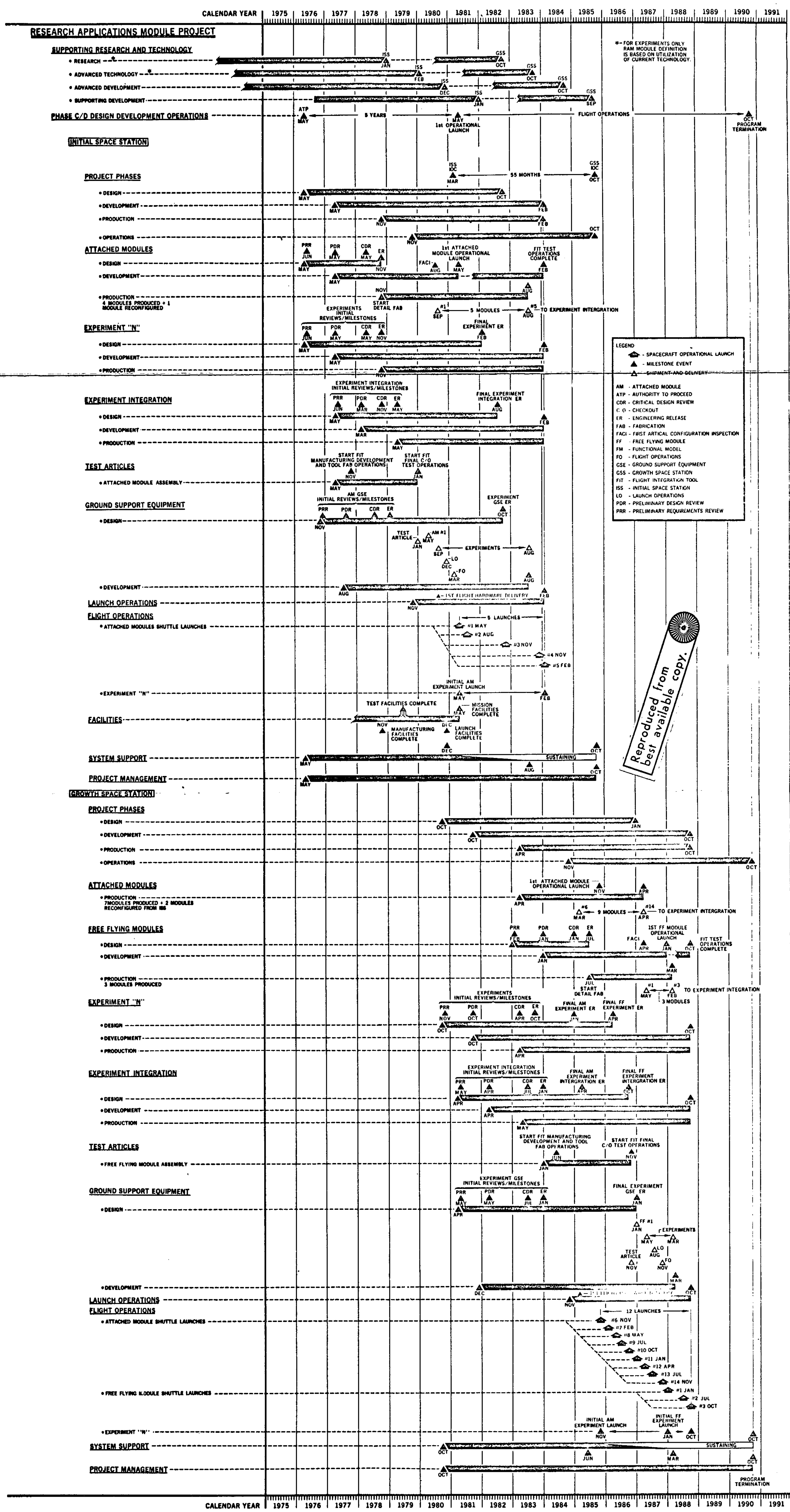


Figure 4-3. Researcn Applications Module Project Schedule

The ISS Research Applications Module Project design phase begins at Phase C/D ATP, May 1976, with the design start of the attached modules and Experiment "N" systems.

Design is complete at final engineering release (ER) in October 1982. The development phase is initiated in May 1977. The operations phase begins with detail fabrication of the first Attached Module and its related experiments.

ISS/RAM flight operations begin with the first RAM launch in May 1981. RAM's are delivered to orbit in the Shuttle cargo bay and docked to the Space Station with a single docking operation. RAM launches take place at the rate of 2 the first year, 1 the second year and 2 the third year to complete the last ISS RAM launch in February 1984, 20 months before the completion of ISS operations. Four of the five RAM Attached Modules required for the ISS flight operations are manufactured and one module is reconfigured and reused.

The GSS/Research Applications Module Project design, development, test and evaluation (DDT&E) phase begins in October 1980 with design initiation of those experiments that are to be flown in RAM's during the GSS time frame. Design is complete in January 1987. The development phase is initiated October 1980. The production phase begins in April 1983 with the detail fabrication of the first Attached Module and its associated experiments. The operations phase begins 17 months before the first operational launch and the program operations are complete in October 1990.

The GSS requires twelve Research Applications Modules to achieve the experiment operational flight program. GSS flight operations begin with the first RAM Attached Module launched in November 1985. Eight additional Attached Modules are launched over a 2 year period ending in November 1987.

Three Free Flying Modules are launched over a 9 month period beginning in January 1988 and ending in October 1988, two years before the completion of program operations. Seven of the nine RAM Attached Modules required for the GSS flight operations are manufactured, and two modules are reconfigured and reused. Three Free Flying Modules are manufactured.

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Section 5
PROGRAM MANAGEMENT PLAN

5.1 INTRODUCTION AND PURPOSE

Two aspects of the Space Station program present a unique challenge to both NASA and industry, and dictate the development of new approaches to program management. These aspects are (1) the five-year development cycle required for implementation and (2) the 10-year on-orbit operational phase. The purpose of this plan is to establish an integrated approach to program management which spans all phases of the program and functions at all levels of effort. Any approach selected must recognize the variation in management requirements between phases, and must strive to minimize the level of personnel required to support routine on-orbit mission management.

Many benefits may be derived from the Apollo and Skylab Programs and the experience gained therein. In applying these benefits to the Space Station Program, however, there are specific analyses of current practices which must be made.

A. Management techniques developed for the prior programs which addressed many of the problems that will be encountered on the Space Station Program require review and consolidation to permit their implementation as "Cost Conscious" Space Station Program management policies.

B. The system and subsystem technology base developed for these programs which is generally applicable must be modified to permit the incorporation of on-orbit maintainability requirements. Components, engineering skills, and development facilities required to fabricate maintainable systems and subsystems are in being and form a vital part of the industrial base that will be required to implement the Space Station Program.

C. Extensive industrial and government facilities which have been erected to fabricate, test, and launch the Saturn Apollo systems virtually eliminate the need for construction of any new facilities for the Space Station Program; only the addition of minor facilities is required to support assembly, test, and launch of the Space Station.

Utilization of modified submarine and commercial airline management practices in conjunction with the Apollo-Skylab base should permit the evolution of an effective Space Station management approach. This is possible because characteristics evolving during development of the Space Station are similar in concept to the development of commercial jet aircraft operations. However, systems reliability and ease of maintenance must significantly advance beyond present aircraft practice because they must be supported primarily by the orbital crew. Thus, the Space Station Program requires that the design and manufacture of Space Station hardware be supplemented by extensive maintainability analyses and effective crew participation in the design.

A major design goal of day-to-day Space Station autonomy with ground participation limited to long-term trend analyses, configuration verification, experiment data handling, and mission support requirements can be realized through the combined use of high-reliability systems design, multiple redundancy, onboard checkout, and ease of replacement of failed parts. These elements, integrated with routine Space Shuttle operations, also help to assure the required high degree of crew safety and mission success.

The management philosophy presented recognizes the technical features of the Space Station developed during this study and is derived to assure a successful Space Station Program that achieves significant cost reductions relative to prior development. This plan takes maximum advantage of the unique capabilities and experience gained from previous programs, and applicable commercial experience.

5.2 SCOPE

This plan sets the overall requirements applicable to Phase C/D of the Space Station Program using the specified Phase B program work breakdown structure (WBS) shown in Figure 2-1. The plan also establishes the philosophy for the translation from a single program structure used during Phase B to the program structure (and the interface considerations) which will develop during Phase C/D.

5.3 KEY ISSUES

Fundamental issues that must be addressed in the management of the Space Station Program are described in this subsection. These issues are vital to assure that the program can successfully move from Phase B Definition through its 10-year operational life.

A. Funding uncertainties during the Phase C/D implementation dictate a need for flexibility in design and operations, including predefined program options which permit adjustments in program scope with minimum impact on the attainment of program objectives.

B. A realistic baseline program which will stand tests of credibility and incorporates the flexibilities noted above will be established as a result of the Pre-Phase C/D activities. Because the Space Station Program is likely to experience more complete scrutiny prior to initiation of Phase C/D than any program in history it will invoke the critical attention of Congress, the scientific community, and the public.

C. Program and project level management must identify and maintain visibility and control over critical program milestones and development status, and delegate adequate authority to assure design and verification schedule accomplishment.

D. Definition and management of an experiment program that best serves national goals; i.e., assurance of international cooperation, must also be obtained if foreign interests are to be satisfied.

E. Establishment of long-duration space operations will require the development and use of management techniques which permit orbital maintenance, replacement, refurbishment, and reconfiguration.

F. Management of multiproject interfaces during the entire program will be accomplished using the I&SR Documents and ICD's as vehicles for accomplishing this management control.

5.4 ESTABLISHMENT OF BASELINE PROGRAM

NASA/industry-wide experience has demonstrated that it is essential to establish a realistic baseline program and critical interface relationships prior to the start of Phase C/D. The initial baseline has been prepared in Phase B and includes:

A. Definition of program, project, and system requirements that is sufficiently complete to support a realistic Phase C/D.

B. The establishment of a design concept responsive to these requirements.

C. The development of realistic schedules at all levels of the program that are directly related to the program Work Breakdown Structure.

D. Realistic cost and funding requirements that are directly supported by the design and schedule baseline.

E. A definition of program priorities capable of accommodating changes in systems availability or funding levels.

F. Sufficiently detailed and coordinated program development plans requirements to assess industrial response to Phase C/D implementation.

Prior to the initiation of Phase C/D, reviews with all decision-making functions should be accomplished with the objective of realistically assessing program benefits, funding requirements, and anticipated funding availability. This should be followed by as near a total commitment as possible prior to the ATP decision.

Maintenance of traceability between performance, schedules, and costs provided by this approach will permit real progress in achieving cost and schedule targets while minimizing costly and time-consuming replanning, redesign, and rework efforts.

5.5 PREPHASE C/D PROGRAM DEFINITION

Prior to the initiation of Phase C/D it is vital that the program baseline be reviewed and, where necessary, revised to reflect changes which must become a part of this baseline. Several factors contribute to baseline revisions depending upon the period between the completion of an initial Phase B definition and the initiation of Phase C/D implementation. These include: (1) technology changes which might have significant impacts on performance, cost, or composite schedules, (2) changes in goals, objectives, and performance requirements on interrelated programs not on concurrent or synchronous schedule (Phase C development activity on Shuttle or RAM which significantly precedes the initiation of Phase C on Space Station), (3) schedule cost or funding revisions which may have interacting or singular influence on one or more programs or projects, (4) redirection which results from shifts in national space priorities or basic changes in any interacting programs or projects. The necessary realignment of program/projects in interface areas may require substantial revision of the initial phase definition to assure responsive Phase C/D implementation.

5.6 PHASE C/D SPACE STATION PROGRAM ORGANIZATION FUNCTIONS

The contractor organization developed for the conduct of Phase C/D activities shall be structured to perform the functions associated with the WBS and technical performance requirements structures of the Space Station Program/Project, interprogram integration, and management associated with support of mission operations.

5.6.1 Space Station Program Management Functions

Program management policies will reflect the allocation of organizational responsibility to ensure successful task completion of each of the specific tasks associated with the program as they apply within the contractor organization, and between NASA and the contractor.

The major responsibility of program management is to continuously assess program development status and to assure NASA that development progress is responsive to all levels of specifications and interface requirements. Associated with this responsibility is the capability to rapidly evaluate and report the impact of performance requirement change, regardless of origin, redirection or unsatisfactory performance.

The established organization shall eliminate duplicate responsibilities and minimize organization interfaces, and must emphasize the following key features:

A. A director responsible directly to top Company management for project success.

B. Management which assures end-item performance.

C. A strong technical organization.

D. Minimization of status surveillance functions by delegating responsibilities directly to the technical organizations and the authority to accomplish and report upon their delegated responsibilities.

E. Functional line managers responsible to the director for personnel and performance.

F. A minimum size, multi-disciplinary program integration organization as a line function responsible to the director.

Inherent in this organizational structure will be the requirement for the organization to be tailored to the specific problems of the Program/Project.

Additionally, program management must reflect a streamlined data flow responsive to the following program data objectives:

A. Common program summary-level data requirements.

B. NASA/Contractor data agreements based on NASA requirements but emphasizing the fullest feasible use of the contractor's data system.

C. Minimized government detail data requirements (below Level 3)

D. Maintenance of bulk data at contractor's facility which is available, at all times, to NASA representatives.

E. Concise management decision-oriented data maintained at summary level. (Level 3 - System/CEI.)

F. Maximum utilization of Program Integration for problem survey analyses.

5.6.2 Program Integration Functions

Integration functions are as follows:

A. Program integration requirements shall be derived from the program/project systems engineering management methodology, and in accordance with the engineering and management structures.

B. Integration requirements involve the management relationships associated with the WBS, particularly at Level 2 and below, specification maintenance and conformance, performance identification, and status.

C. Program integration requirements involve the assessment of development status, verification and technical capability measurement results, and correlations with management networks and schedules.

D. Program integration requirements shall address the development of plans and procedure documentation, reporting, and the interrelationship of various functional support activities to the availability of hardware/software.

E. Program integration shall provide interface coordination and the necessary negotiations with various program/project management levels with respect to operations planning, procedures, functions, and implementation.

F. Program integration shall review and report on the status of other program/project integration functions, experiment and software, test article status, and the requirements for crew training.

G. Program integration shall provide to management the status of logistics activities, quality, reliability, maintenance and safety in conjunction with operational availability, and development schedules.

H. Using the management approach defined in the Program Integration Plan, program integration shall coordinate and correlate all program/project activities so that a management assessment can be made of design performance capabilities with specification requirements, and the comparison of composite performance with current costs and schedules.

5.6.3 Mission Operations Management Functions

An integrated operations management organization will be defined to encompass the following:

A. Utilization of selected management and technical personnel that have gained experience through the development, production, integration and test of the Space Station for operations, configuration management, etc., during the operational phase. This "rolling wave" concept should minimize training requirements and assure organizational continuity and efficiency.

B. Utilize TDY people for one-time events, i.e., Space Station launch: e.g. 500 people for 6 months.

C. Consolidate responsibilities, activities, and locations to maximum extent.

   1. Launch, flight recovery, logistics, refurbishment, crew operations, mission control.
   2. NASA management
   3. Number of prime contractors

D. Project contractor locations should provide sustaining hardware and support as required by operations program management, i.e., spares, follow-on experiments, support, etc.

E. Consistent with an integrated Mission Support concept, the project contractor must be prepared to provide all required support from his area of responsibility.

5.7 ROLES AND RESPONSIBILITIES

Prior to the Implementation of Phase C/D a program-level Roles and Responsibilities (R&R) document shall be established outlining the interrelationships between concerned contractors/agencies responsible for the conduct of all elements of the Space Station, Shuttle, and Experiment Launch Vehicle Program/Projects.

During Phase C, it shall be the responsibility of all organization management elements to participate in developing a Roles and Responsibilities Matrix and to assist in identifying interface requirements of those roles. After incorporation of accepted recommendations from contractors, the

NASA will promulgate the refined R&R document. The Contract Work Statements, the Program Summary Work Breakdown Structures, and the designated responsibilities of government agencies and/or working agreements between government agencies and the NASA Space Station Program will be consistent with that document.

A. An initial display of Phase C/D Roles and Responsibilities (R&R) matrix will show, for example, that with respect to Program Integration, NASA is responsible for establishing requirements and monitoring activities, whereas industry is responsible for implementing those requirements and supporting the monitoring function.

B. NASA Prime R&R

   1. Develop, production, hardware/software integration phase—requirements and monitoring.
   2. Operations Phase—requirements, monitoring, program-level operations management.

C. Industry Prime R&R

   1. Development, productions, hardware/software integration phase—implementation to meet requirements.
   2. Operations Phase—Project— and integration-level support, i.e., manpower, hardware/software, management.

The contractor shall prepare these implementation plans in accordance with the Plans Requirements identified in the sections that follow and before the initiation of the development phase.

5.8 IMPLEMENTATION MANAGEMENT STRUCTURES

At least two additional structuring techniques should be anticipated during the design/development phase activities. To ensure visibility and control, a Program Management Logic Network should be established and implemented as soon as a baseline program is firmly established. Figure 5-1 (shown on page 117) describes the summary-level requirements in terms of milestones and decision points for which a functional network should be fully developed and implemented. Lower level networks must be organized for each level of development and the complexity of the network should be minimized and kept consistent with the level it supports. Key events (PRR, PDR, CDR, FACI) should be designed and related to the submittal of critical planning or implementation documentation.

A technical capability measurement structure shall be developed in conjunction with test implementation planning. The measurement structure shall illustrate how each CEI Part I will be verified and how these functions relate to upper level functions such as test articles and mission operation functions. The technical capability measurement structure must be relatable to the WBS and management network at appropriate levels and milestones.

Section 6
OPERATIONS

This section describes the Ground and Flight Operations of the Space Station and presents the concept for Integrated Mission Management of the Space Station Program.

The Ground Operations are divided into eight relatively independent functions: (1) manufacturing, (2) tests, (3) site activation, (4) transportation, (5) prelaunch, (6) launch and postlaunch, (7) launch control center/Space Station operations, and (8) Logistics Module refurbishment.

The significant results of the analysis of ground operations are as follows:

- Factory checkout crew travels with modules and becomes prelaunch checkout crew.
- Minimum clean room operations.
- Maximum use of existing facilities at the launch site with minor modification.
- Minimized system testing at the launch site.
- Space Station launch operations require minimal direct personnel and hardware operations from receipt of the Space Station at the launch site.
- Space Station manufactured in five parts for assembly on orbit. Three modules for ISS (power/subsystem module, crew/operations module and general purpose laboratory module), and two additional modules. (Power/subsystem and crew/operations) for GSS.
- Turnkey operations; the development program is designed so that the Space Station can be considered operational as soon as it is assembled and activated in orbit.

The Mission Operations subsection develops the concepts for operations and support of the ascent, early orbit, on-orbit, disposal, recovery phases, and ground support of the Space Station program elements.

The significant results of the Flight Operations Analysis are:

- MSFN support required only during first year of operation of Space Station.
- Two of 6 personnel onboard are flight crew who also are utilized in ground operations on a rotational basis.
- Remaining 4 personnel are Principal Investigators and/or experiment scientists.
- Experiments performed onboard with real-time data.
- Crew rotated every 90 days.
- On-orbit operations are autonomous on a day-to-day basis: long-range planning done on the ground.
- Logistics module can be docked to Space Station by space shuttle Orbiter.

The Integrated Mission Management concept develops the management, under a centralized control philosophy, for the functions and activities of flight operations support, mission planning and analysis, experiment support and control, logistical support and flight control.

6.1 OPERATIONAL CONCEPT

6.1.1 Mission Description

The Space Station modules will be assembled and integrated into the complete Space Module at the factory, then disassembled, transported to the launch site, launched individually and assembled on orbit.

The summary definition and schedule of the baseline Space Station experiment Program Flight Plan is shown in Figure 2-11, Section 2 of this volume. As noted, the experiment hardware is either integral to the Space Station vehicle at launch, carried onto the station from logistics flights, or is contained in modules delivered to orbit on subsequent space shuttle launches. These modules are designed to operate either attached to the station or free-flying in orbit.

The launch schedule summary is shown in Figure 2-3, Section 2.

6.1.2 Mission Objectives

The Space Station Program objectives have been well established by NASA and are detailed in the Space Station Program Specification, CM-01.

6.1.3 Integrated Mission Management

A major design goal of the Space Station Program is to maximize autonomy and minimize the amount of ground support. The flight crew size (6-12 men), the physical size, and subsystem limitations of the Space Station and the cost per man-hour of functions performed in space, dictate that some ground systems must be utilized. This section presents an integrated mission management concept and discusses the functions which must be performed.

6.1.3.1 Integrated Mission Management Concept

Total program management is accomplished on the basis of an Integrated Mission Management Concept, dedicated to assuring close coordination between all program elements to ensure that total operations for a 10-year program are accomplished with the necessary precision and at minimum costs.

6.1.3.2 Mission Management

Mission management, as currently envisioned, will provide the capability to control the sub-elements of Flight Operations, Experiment Operations, Logistic Support Operations, and Mission Analysis and Planning required for support of the Space Station as shown in Figure 6-1. These activities do not necessarily have to be collocated geographically. Mission management also will coordinate space shuttle launch operations. Existing facilities with modifications are available.

Flight Operations Support

Flight Operations Support will have the primary goal of maximizing the utilization of mission resources. This function begins during the prelaunch phase and continues throughout the life of the Space Station Program; however, the duties performed and the number of personnel required vary according to mission phase. During prelaunch and launch phases, the primary duties are

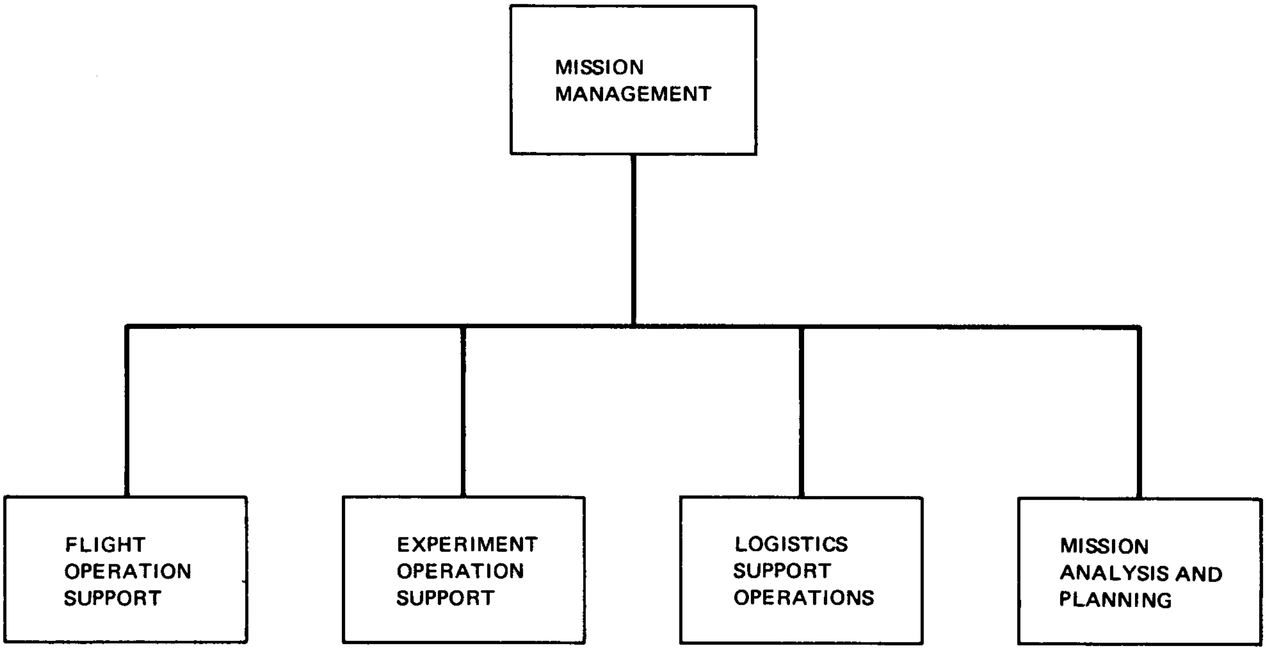

Figure 6-1. Mission Management Block Diagram

to support systems integration and flight readiness testing, monitor boost vehicle systems performance during prelaunch tests, verify status of that portion of the tracking capability which has been called up to support the mission, verify the capability of the communications system to support the mission, participate in the generation of launch and flight mission rules and procedures, etc.

During the orbit operations phase Flight Operations Support performs the mission control function supporting onboard status monitor and fault isolation/ analysis. Flight Operations Support also coordinates all systems status and trend data for operations such as logistics resupply planning.

A functional system diagram of the proposed Flight Operations Support is shown in Figure 6-2. This figures illustrates the manner in which various support areas/facilities/centers (depending upon the nature and final location of the appropriate resource) are related and how they interact with each other and the Space Station.

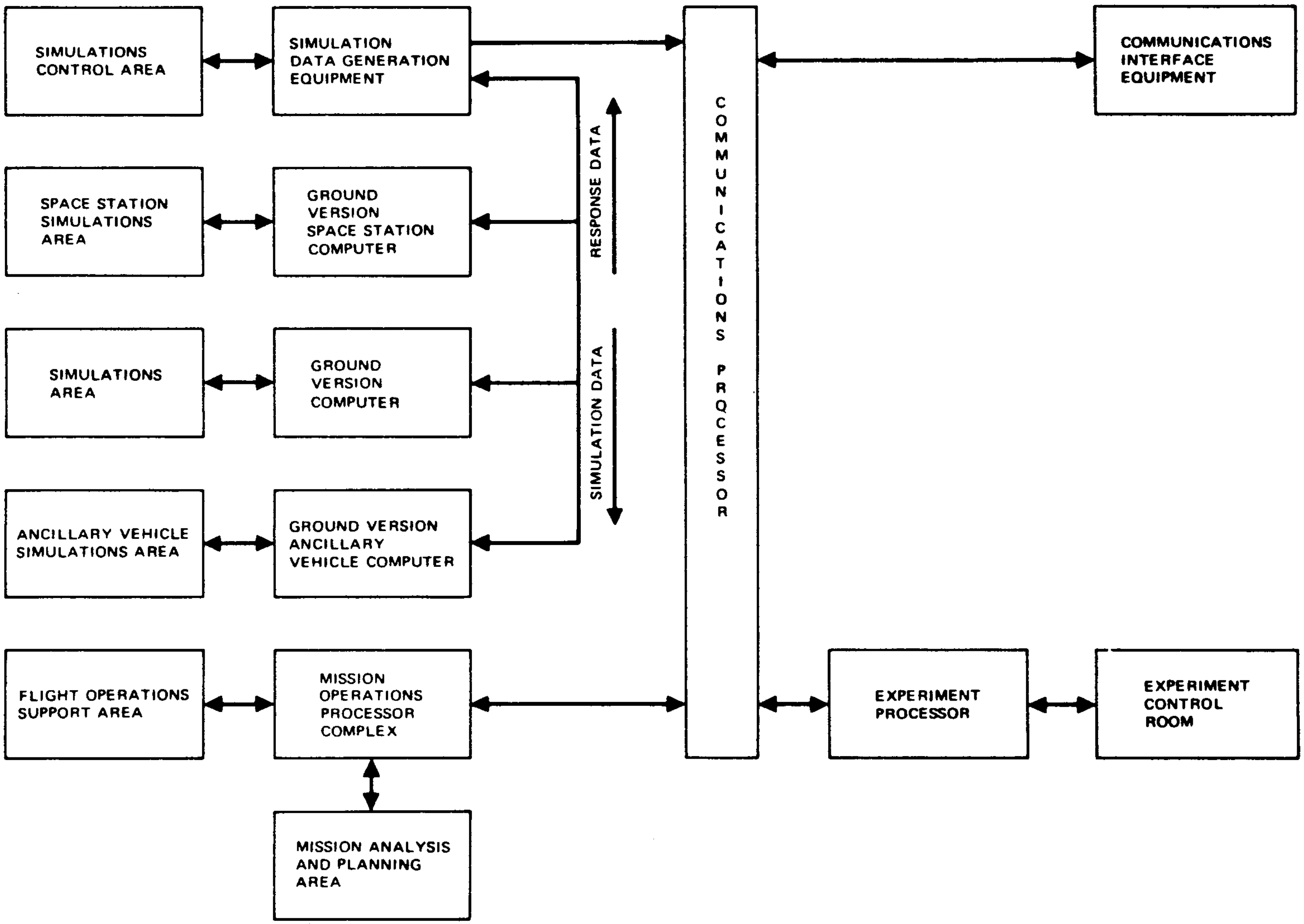

Figure 6-2. Flight Operations Interfaces

Experiment Operation Support

The Experiment Operations Control Center will provide for the storage of scientific data which will be downlinked by the Space Station-to-ground communication link. Reception and storage of these data will be a near continuous real-time function. Ground-based computers will store and perform data reduction to allow analysis of the data by PI's.

The experiment Control provides experiment operational support and data collection, real-time experiments data preprocessing and distribution, experiments monitoring, planning for future experiment programs and coordination, experiments data analysis, and experiments data archiving and retrieval. These experiment support activities will require the following subsystems:

A. Communications Processor.
B. Operational Computer Complex.
C. Experiments Control.
D. Experiments Support, including an experiments, data base, central experiments analysis laboratory, and physical data receiving laboratory.
E. Remote Experiment Analysis Laboratories and data receiving terminals.

Logistics Support Operations

Centralized logistics control is a management function performed in parallel with mission control, mission planning and experiment control operations and will consist of Inventory Control, Material, Maintenance, Procurement, Transportation, Logistics Module loading and "Cargo Master" operation, Configuration Control, and Personnel Management sub-elements. Each of these sub-elements is charged with management and control of its particular activities and for integration and interface with other technologies within and external to logistics structure. Logistics Support will coordinate with Experiment Operations in supporting payload integration.

Mission Analysis and Planning

Mission Analysis and Planning will involve all planning, documentation, and procedures required to support the total program including operations, ground and vehicle resource utilization, simulations, logistics functions and the experiments program. These planning functions will begin at the mission design level and continue until the mission is terminated, and will involve development of, and modifications to, mission rules and constraints, hardware, and software. The broad scope of mission planning and analysis for the Space Station program encompasses tasks performed from early mission concept through the mission accomplishment to effect the achievement of the mission objectives. Mission Management will participate in the mission planning function through all phases of mission design, mission operations planning and mission conduct.

6.2 PRELAUNCH AND LAUNCH OPERATIONS

6.2.1 Space Station Project

The Space Station mission requires launch of the Space Station Modules (Power/Subsystems, Crew/Operations, and GPL) at 30-day intervals starting in October 1980 to achieve a six man capability. Modules are launched individually in the cargo bay of the Space Shuttle Orbiter. A Space Shuttle launch orbits the first flight crew, with subsequent Shuttle launches for crew rotation, Space Station resupply, and delivery of experiments into orbit.

The Space Station Modules upon arrival at the launch site are examined for transportation damage. Functional check-out tests are confined solely to functions which are critical to flight or flight safety. GSE, connected and verified during internal inspection, supplements the OCS by providing functions which normally can occur only in flight, e.g., inputs to sensors, power, RF communications, etc. GSE also may process downlink telemetry data and uplink commands. Space Station or experiment subsystems tests are not performed at the launch site unless needed to verify that repair activities have been successfully completed. Experiment operations are limited only to health checks. Space Station and Orbiter are functionally mated after both have completed individual integrated tests. The Space Vehicle integrated test is then performed to verify the Space Station Module/Orbiter interface. Space Station and Orbiter ordnance installation are the last operations performed before moving the Shuttle to the launch pad.

Control and monitoring of the Space Station module is accomplished externally using uplink commands, telemetry and external OCS control provided by GSE connected to OCS through an umbilical. Personnel are allowed onboard only to repair malfunctions. The Space Station Module is serviced as much as possible prior to its insertion into the Shuttle. Liquid/Gas loading and final servicing and top-off of Space Station Module fluid systems are accomplished during countdown on the pad. Experiment activities on the pad are limited to status monitoring. All Space Station Module systems are shut down for launch except those necessary to sustain the Space Station Module until the first crew arrives.

6.2.2 RAM Project

Two areas of activitiy must be considered when discussing experiment program prelaunch and launch operations; the experiments, and the experiment modules. Considering the experiments first, when the functional program element is not time sensitivie, is dormant at lift-off, and has an on-orbit verification capability, flight readiness will be established at the factory or at a Payload Integration Center. Launch site prelaunch and launch operations will be limited to loading into the Logistics Module, monitoring and maintaining experiment status. This mode of operation applies generally to all but the space biology experiments. The time-sensitive nature of the biological specimens and the fact that the experiments are active at lift-off dictates that final flight readiness and payload integration be accomplished on pad for this class of experiments.

Experiment Module ground operations will consist of complete module verification to ensure that the module can deliver the experiment equipment safety to the Space Station on-orbit. Detailed subsystem verification tests will be performed at the factory or Payload Integration Center. Launch site checkout will be primarily gross system level and status checks. Log-M loading of experiments into the shuttle vehicle, can occur up to 4 days before launch; biological specimens will be taken from a biological laboratory and installed in the modules less than 12 hours before launch.

6.3 MISSION OPERATIONS

The Mission operations of the Modular Space Station have been divided into four major phases. These phases are primarily concerned with the Space Shuttle support required for the completion of orbital assembly of the Space Station; detailed activities associated with the buildup and initiation of Space Station sustained operations; the Space Station operations on-orbit during the mission duration; and, the logistics support required throughout the Mission.

6.3.1 Ascent

The Initial Space Station (ISS) is comprised of three modules (Power/Subsystems, Crew Operations, and General Purpose Laboratory). These modules are delivered to orbit in the order shown above, on 30-day launch centers. In order to conserve the propellant required for the Space Station during the 60-day buildup period, the Space Station is placed in a 500 km (270 nmi) orbit and then the orbit of the configuration is allowed to decay, to an altitude of 444 km (242 nmi). Therefore, the Power/Subsystems module ascent will be to a circular orbit of 500 km (270 nmi), 55 degree inclination. The ascent of the Crew Operations module will be to a circular orbit of 492 km. (265 nmi), for rendezvous and docking to the Power/Subsystem module. The GPL ascent will be to a circular altitude of 485 km, (262 nmi) for docking to the orbiting Space Station configuration.

The ascent operations of the Space Shuttle during these missions includes Space Shuttle Booster flight and Orbiter first burn to the insertion orbit at 185 km. (100 nmi). Approximately 42 minutes later the Orbiter main engines thrust raises the orbital apogee to approximately 462 km. (249 nmi). Forty-five minutes later, at apogee, the main engines of the orbiter are fired again to raise the perigee to 462 km. (249 nmi) and the apogee to the target altitude. Approximately 47 minutes later a coelliptic burn raises the perigee to the target altitude. Circularized at the target altitude the Space Shuttle begins the on-orbit operations for power/subsystem operations. During the ascent of the Crew Operation's module, the Space Shuttle will perform phasing at the 185 km. (100 nmi) orbit for a period of approximately 3.5 hours. The GPL module will require a phasing period of approximately 8.5 hours during its ascent and rendezvous mission.

Throughout the delivery operations of the Space Station Modules, the Space Shuttle will provide an average power of 500 watts to the module, with peak load requirements not to exceed 800 watts. Also, during the ascent operations, the Space Shuttle will monitor critical payload parameters through the data bus umbilical supplied at the Space Station module interface. These parameters will be displayed on the Space Shuttle payload caution and warning indicators located in the Space Shuttle cabin.

During the ISS portion of the Space Station mission, the Space Shuttle will always carry two Space Station crewmen as passengers. The Shuttle will be required to provide 14 man-days of life support for these crewmen on all missions. During the buildup operations these crewmen will be assembly and checkout technicians, and these crewmen will return with the Space Shuttle to the earth.

6.3.2 Buildup and Activation

The buildup and activation of the Modular Space Station presented new problems in operations. For the first time in manned space flight, a complete integrated space system will be required to be launched in discrete parts and assembled in earth orbit. In addition to the problem of assembly, the Space Shuttle launch constraint of no more than one launch every 30 days requires that the early portions of the Space Station be operated in an unmanned mode until the orbiting configuration is completed and can be manned for sustained operation.

The Space Shuttle launch weight constraint of 9080 kg. (20,000 lb) requires that some limited equipment of the Space Station modules be off-loaded for launch and then delivered using the Logistics Module for installation on orbit. This offloading scheme was devised to minimize the total number of Space Station modules required for the orbiting vehicle, in order to minimize the Space Station DDT&E costs. This period of assembly of offloaded equipment, along with the crew buildup to six crewmen, is called the activation phase of the mission.

The delivery, mating, and checkout of the three Space Station modules is called the buildup phase of the mission. As presented on Figure 6-3, this phase of the mission covers the first 60 days (three launches) of the Space Station Program. During this phase of the mission, two assembly crewmen will accompany each of the Space Station modules to orbit as passengers in the Space Shuttle. These assembly crewmen will perform the interface mating, checkout, and operation functions on the Space Station, while the Space Shuttle remains attached to the configuration. During their orbital stay, these crewmen will derive their life support from the Space Shuttle, eating and living on the Shuttle, and working in the Space Station module(s).

6.3.2.1 Power Module

The first Space Station module launched is in the power/subsystems module. This module is equipped with one set of batteries and the required electrical power is provided by these batteries until solar array deployment and checkout.

The power module also supplies its own atmosphere from oxygen and nitrogen storage provided onboard the module and controlled by partial pressure sensors and a control module. While this power and atmosphere capability will provide for assembly crew shirtsleeve entry into the module, for a conservative approach, it has been assumed that the assembly crew will enter this module (and the other two modules during buildup) suited in helmets and gloves, and prepared for possible decompression. The two assembly crewmen, in their IVA suits, enter the Space Shuttle airlock. An expandable tunnel is used for crew transfer from the Space Shuttle to the Power/Subsystems hatch. At the module hatch there is a viewing window and a habitability verification readout station. The crew can equalize pressure across the entry hatch at this location, and they can activate the internal communication systems and lighting systems in the module.

Once the habitability of the module has been verified the crew opens the hatch and enters the module. Following crew entry, the crew will use the portable display and control unit (PDCU). It operates with the data management system computer and has the capabilities of the control and display unit scheduled for delivery in the Crew Operations Module, but it operates in a manual,

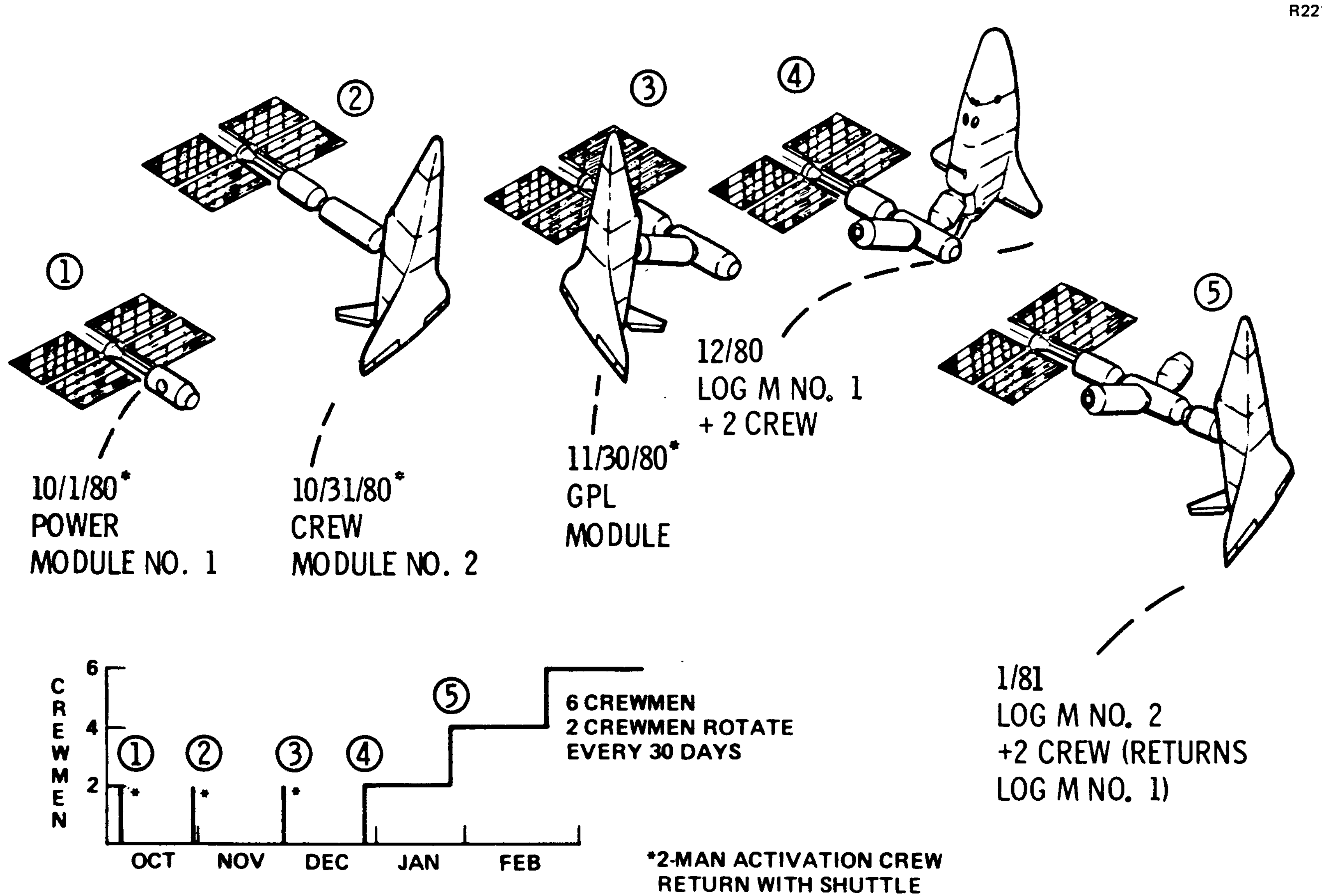

Figure 6-3. Space Station Buildup Operations

one command at a time, mode. The PDCM can thus be used for command activities and for diagnostic routines for fault detection and isolation. Following these activities the crew returns to the Shuttle, removes their helmet and gloves, and completes a food and hygiene cycle.

The crew will then reenter the power module in shirtsleeves and begin the checkout operations. The first activity commanded by the crew is deployment of the solar array system. During ascent the array support housings are stowed along the array boom. These arrays are released at their outboard attach fittings and are then rotated outward by means of a motor-driven screw jack. Once the array support beams are in place and held by removable over-center locks, the twelve array panels are deployed by means of the Astromast assembly. This assembly consists of a collapsed truss beam which snaps into place, one section at a time, thereby extending the sections ahead of it. This entire deployment operation can be done manually if a failure would preclude the deployment sequence; however, the manual operations would require EVA and thereby require the crew to suit up and prebreathe for the operation.

Once the arrays are deployed, the crew checks the power generation capability of the system and then switches the power source to the arrays. The batteries onboard the module are then switched to the recharge mode, initiating normal power system operation. At this point in time the solar array orientation control system is activated and checked out. Proper system response and panel operation can be evaluated by the crew while the Space Shuttle maintains orbital rate of the total configuration.

With the module on solar array power, the assembly crew begins a communication-test on the VHF and S-Band systems with the ground network.

While one crewman is performing these tests, the second crewman begins the next activation sequence for the high-thrust, N_2H_4, propulsion system. The power module is launched with approximately 317 kg. (700 pounds) of propellant onboard to maintain control for 120 days. This propellant loading is required, since the first resupply flight is not required until 90 days following the launch of the module. The propulsion system is checked by the crewman by means of a series of controlled tests that are repeated several times to accumulate a reasonable amount of operating time in the space environment. The checkout test consists of having the Shuttle fly a predetermined attitude profile, while the crewman ascertains that proper error signals, valve commands, and engine firings result. With verification of this system operation the system is deactivated and the initial certification of the module operational readiness is attained. The crew returns to the Shuttle, debriefs with mission operations support on the ground, and prepares for a sleep cycle onboard the Shuttle.

Following 24 hours of operational verification the crew will prepare for release of the module and return of the Space Shuttle. This operation will begin once the on-orbit crew and the ground have established the module's readiness for 60 days of unmanned operations. The Power/Subsystems module will be configured for unmanned operations by activation of the atmosphere supply onboard the module. The crew will then transfer to the payload tunnel area and secure the module hatch. Following this securing, the crew will disconnect the umbilicals across the interface and then enter the Space Shuttle airlock, securing the tunnel hatch. The tunnel will then be depressurized and the Shuttle will orient the module to its separation attitude. Once the desired attitude has been attained, the Space Shuttle will separate from the power/subsystems module. Following separation the module propulsion system will be activated and the hatch cover closed over the exposed hatch, by RF command from the Space Shuttle. For one orbit (or more) the Shuttle will station-keep with the module monitoring proper subsystem operation. At the proper time, the Space Shuttle, with the assembly crewmen onboard, will initiate the retro-firing for return to earth and completion of the first phase of the buildup operations.

6.3.2.2 Crew Operations Module

The second flight of the Space Station mission profile will be the delivery of the crew operations module and the mating of this module to the power/subsystems module. Figure 6-4 presents a summary of the interfaces between the Crew Operations module and those modules included in the Space Station initial configuration. As shown on this figure, once the crew operations module is delivered to orbit and docked to the longitudinal docking port of'the Power Subsystems module, 36 interfaces will be mated between the

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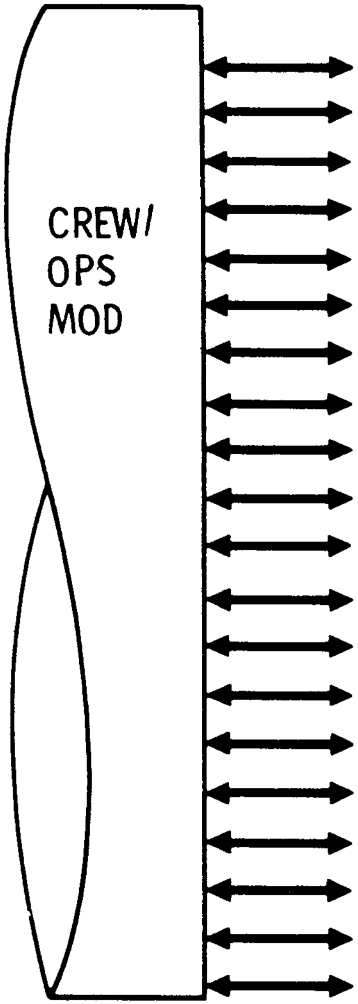

		POWER MOD	GPL MOD	LOG MOD
ECLS	6 IN. CONDITIONED AIR	●	●	●
	6 IN. CONTAMINATED AIR	●	●	●
	1/2 IN. O_2 SUPPLY (2)	●	●	●
	1/2 IN. N_2 SUPPLY (2)	●	●	●
	3/4 IN. COOLANT H_2O (2)	●	●	
	3/4 IN. HEATING H_2O (2)	●	●	
	1/2 IN. CONDENSATE H_2O (2)		●	
	1/2 IN. WASH H_2O (2)		●	
	3 IN. VACUUM (2)	●	●	●
	2 IN. AIR ACCUMULATOR (2)	●	●	●
	1/2 IN. POTABLE H_2O (2)		●	
PROP.	3/8 IN. GN_2 (2)	●		●
	3/8 IN. N_2H_4 SUPPLY (2)	●		●
	1/2 IN. N_2H_4 FEED (2)	●		
	1/4 IN. CO_2 (2)	●		
	THRUSTER CONTROL (2)	●		
DMS	DATA BUS (4)	●	●	●
	CAUTION AND WARNING (2)	●	●	●
POWER	115V DC (4)	●	●	●
	115V AC (2)	●	●	

Figure 6-4. Module-to-Module Interfaces

two modules. To perform the operations of mating these module-to-module interfaces, two assembly crewmen will accompany the crew operations module to orbit, as Space Shuttle passengers.

This second flight of the buildup operations also includes the first direct docking operations of one module to another, utilizing the Space Shuttle systems. The technique for direct docking utilizes manual control by a Space Shuttle crewman located at the docking station in the Space Shuttle airlock. The Space Shuttle will have completed rendezvous with the power/subsystems module and the Shuttle bay door will be opened and the module deployed for docking. As during the power/subsystems module delivery mission, the freon loop of the crew operations module will be activated following module deployment from the Shuttle payload bay. During the ascent of the Space Shuttle, the mission operations support personnel have completed their operational commanding to the target module, activating the rendezvous and docking aids and deploying the hatch cover over the target docking port.

Before initiating the terminal docking maneuver, the high-gain antenna located on the Crew Operations module must be rotated to the docking orientation. This orientation eliminates any interference with the docking operation, including the docking pilot's view. Also, the RF link between the Space Shuttle and the Power/Subsystems module will be verified, as it is required for the nominal docking operation.

At a ground elapsed time of approximately six hours, the docking operation will be completed. Immediately following docking completion, the Space Station attitude control system will be deactivated and the orbiting configuration attitude orientation will be controlled by the Space Shuttle until completion of the on-orbit activities. Once this system has been deactivated, the crew will transfer to the Shuttle airlock and enter the crew transfer tunnel. Once the two assembly crewmen arrive at the entry hatch into the Crew Operations module they will activate the module lighting and intercomm systems and perform visual checks to establish the habitability of the module.

Following the initial tests, the assembly crew will perform a total of 10 hours of subsystems tests on primary, redundant, and backup systems to establish the operational readiness of the two modules.

Once the operational readiness of the modules has been established, the crew will prepare the module systems for operations and then transfer to the payload tunnel area and secure the crew operations module hatch. Following this, the crew will disconnect the umbilicals to the Shuttle and then enter the Space Shuttle airlock. The tunnel will then be depressurized and the Shuttle will orient the modules to their separation attitude. Once the attitude is attained, the Shuttle will separate from the modules, activate the configuration propulsion system and close the hatch cover over the exposed hatch. For one orbit (or more) the Shuttle will station keep with the modules, and at the proper time return to the earth, completing the second phase of the buildup operations.

6.3.2.3 General Purpose Laboratory

The third and final flight of the buildup operations is the delivery and mating of the General Purpose Laboratory (GPL) to the crew operations module. Figure 6-5 presents a detail summary of the interfaces between the GPL and the Crew Operations module. As shown, once docking has been completed, 32 interface connectors will be mated between the two modules.

Following docking, the two assembly crewmen transfer to the Space Shuttle airlock and tunnel, to the GPL test and isolation chamber hatch. At this position the crewmen verify the habitability of the chamber, activate the lighting system and the intercomm system, and enter the chamber with their IVA suits, helmet and gloves on. The crew performs a visual inspection of the chamber and then transfers to the GPL hatch. The crew establish the habitability of the GPL and then enter the laboratory portion of the module for visual inspection. Following inspection the crew move to the GPL hatch located at the CPL/crew operations modules interface. The two assembly crewmen then pressurize the natural airlock at the interface, equalizing pressure across the hatch, and they enter the airlock. Following a visual check of the crew operations module through the viewing window in the hatch, the crew equalize the pressure across the crew operations module hatch and enter the crew operations module. Following a visual inspection of that module, the crew returns to the GPL, securing the crew module hatch.

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CONNECTION	NUMBER	HOOKUP TIME (MIN)	CHECKOUT TIME (MIN)	TOTAL TIME (MIN)
AIR DUCTS	2	42	6	48
ATMOSPHERE SUPPLY	4	64	12	76
POWER (VDC)	4	70	20	90
CAUTION AND WARNING	2	42	20	62
H_2O THERMAL	4	24	20	44
H_2O LIFE SUPPORT	6	36	30	66
ATMOS PUMPDOWN	4	24	12	36
DATA BUS	4	24	40	64
POWER (VAC)	2	10	20	30

TOTAL TIME = 516 MAN-MINUTES

Figure 6-5. Crew/GPL-Detail Interface Estimates

The two crewmen then begin the required interface mating operations, which require a total of six hours and thirty minutes. Once the interface mating has been completed, the crewmen transfer to the Space Shuttle for normal operations of food, hygiene, and sleep. Following these activities the crew transfer to the GPL and perform ten hours of subsystem operations and checkout to verify the operational readiness of the configuration. Following these activities, preseparation operations are begun. The remaining activities parallel those described previously for separation, station-keeping, and return.

6.3.3 On-Orbit Operations

The on-orbit operations are initiated with the terminal rendezvous and docking of the first manned logistics flight. The initial manning operations impose requirements on the Space Station operations peculiar only to one occurrence in the 10-year mission.

With the Space Station in a quasi-passive role during the rendezvous, the orbiter pilot will maintain total authority to effect the rendezvous. Following circularization and braking maneuvers, the logistics vehicle will approach the Space Station target. Following the final braking maneuver, the docking pilot will maneuver around the Space Station for visual inspection of the external configuration. During this maneuver, the logistics vehicle will photograph the configuration for record of any external condition anomalies. The orbiter pilot will then maneuver the logistics vehicle in line with the appropriate docking port. After rendezvous and docking have been completed and prior to crew transfer, a verification inspection of critical Space Station functions will be accomplished by the 2-man Space Station crew. Current status of all life-critical functions (atmosphere pressure, content, humidity, and temperature; communications; power; and guidance and control) will be related from the Mission Support Team to the logistics vehicle.

Following verification of habitability, 2 crewmen will prepare for transfer of off-loaded equipment into the Space Station and follow a detailed checklist of inspection of the operation systems. Upon verification of the Space Station systems operations, the orbiter will de-dock from the logistics module which remains with the Space Station configuration. The orbiter will remain in stand-by status for approximately 24 hours and then returns to earth.

6.3.3.1 ISS Operations

A total of three of these missions are required to complete the activation operations and build the on-orbit crew to a six-man level. Figure 6-6 shows the first 180 days of operation and the initiation of crew re-cycle. These flights are 30 days apart, resulting in total buildup and activation completion five months after the first Space Station launch. During the buildup and activation operations a crew duty cycle day of 20 hours is utilized. The short duration of the missions indicate that the crew does not require the nominal 4-hour recreation period each day, therefore none is scheduled. This approach enables greater utilization of the crew time on-orbit, however, during sustained operations, with the crew on-orbit for extended periods, the recreation/relaxation periods should be and are included in the daily schedules.

6.3.3.2 Growth Space Station Operations

The Modular Space Station Program includes the growth to a twelve-man capability, five years following the first launch of the initial six-man Space Station. The growth step includes the addition of two Space Station modules; a crew operations module, and a power/subsystem module.

The buildup to the Growth Space Station (GSS) will occur during ISS operations. During the final year of ISS operations a second Crew Operations module will be delivered to orbit and docked to the longitudinal docking port of the first Crew Operations module. The on-orbit ISS crew will perform the interface mating of the second crew operations module to the first. Ninety days following the delivery of the second crew operations module, a second power/subsystems module will be delivered to the Space Station. Prior to docking this module, the Space Shuttle will deploy the module, activate its attitude control system and then release the module. The Space Shuttle will then dock to the docking port on the solar array tunnel of the second power/subsystems module, deactivate its attitude control system and dock it to the longitudinal docking port of the second crew operations module. The on-orbit ISS crew will then perform the interface mating and checkout between the Space Station configuration and the second power/subsystems module.

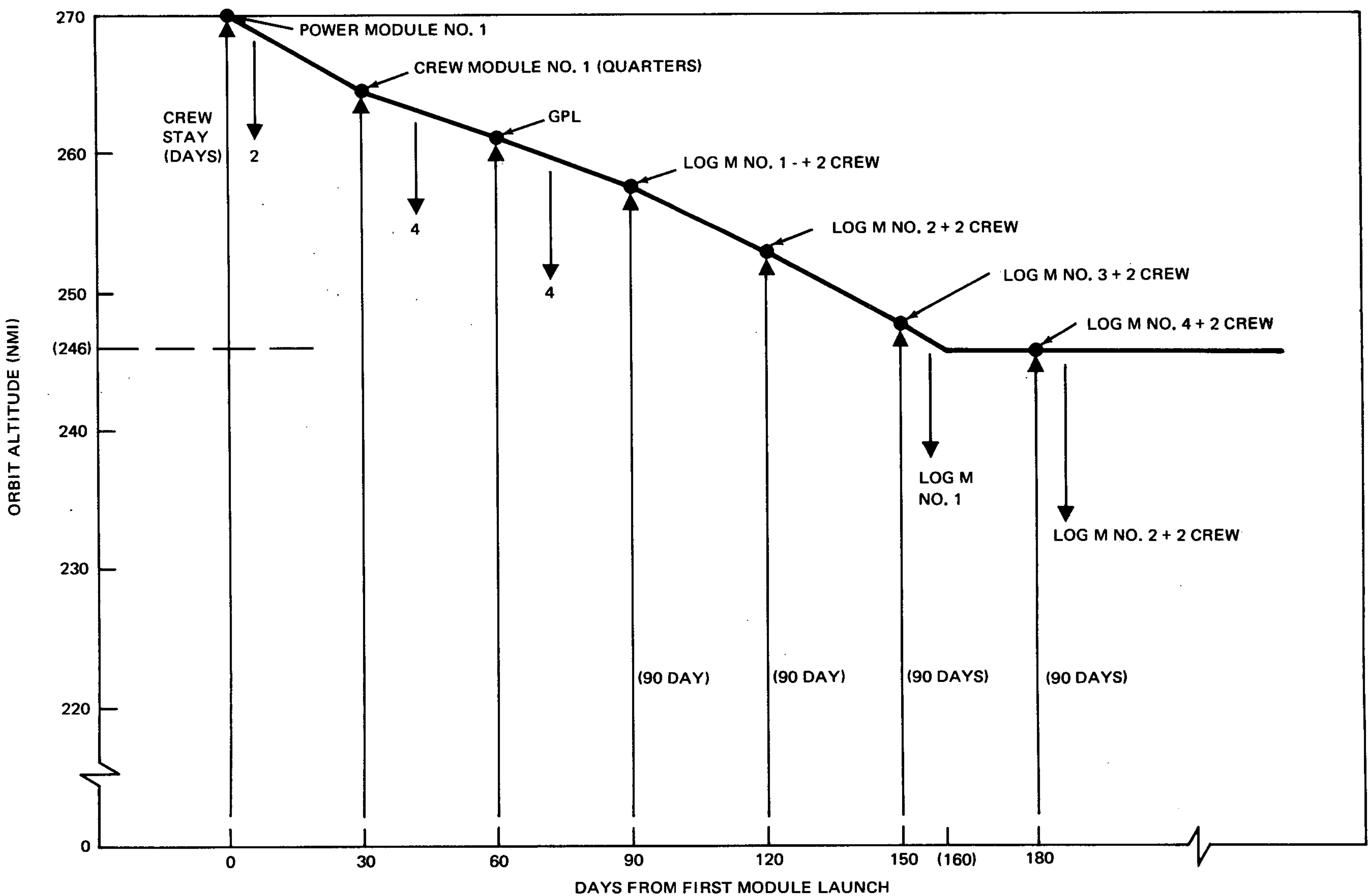

Figure 6-6. Mission Scenario for First 180 Days

Following the configuration buildup to GSS, the next two logistics flights, thirty days apart, will deliver crew cargo modules with six crewmen onboard each module. These operations will build up the on-orbit crew to the GSS level. Thirty days later a logistics flight of the Log M will deliver the off-loaded equipment and spares inventory buildup, completing the buildup operations to the GSS.

6.3.3.3 Experiment Operations

During initial manning buildup the experiment program is based upon the integral experiments contained in the General Purpose Laboratory. The first Shuttle flight in the second quarter delivers and docks to the orbital configuration the first Attached Module containing earth survey experiment equipment. During ISS a total of five modules are utilized for the experiment program. The communications and navigation attached module is returned to earth once during ISS. It is reconfigured and returned to earth once during ISS. It is reconfigured and returned to orbit during the initial five years of operation.

At the initiation of GSS the five module, 12-man Space Station has the capability of performing all of the identified experiments in the Experiment Blue Book. During that period the crew cargo module, a modified logistics module is available for transporting to and from orbit, six additional crewmen. The GSS is capable of docking seven attached or free flying RAM's. During the five years of GSS the experiment program continues at an accelerating rate using all experiment configurations including free flying modules. Free flying modules are unmanned and are capable of operating independently of Space Station support. These modules dock to the Station periodically for maintenance and/or calibration.

6.4 MISSION PLANNING

Space Station mission planning is both motivated and constrained by intrinsic characteristics of the Space Station Program and the physical environment in which the Space Station must operate. The most significant factors in this regard include:

A. Long-life requirements of the Space Station.

B. Technical-economic constraints on the Space Station Program.

C. Complexity of overall Space Station operations.

D. Stochastic influences induced by the physical environment.

Each of the above suggest the need for a departure from mission planning methods employed on past manned and unmanned space exploration programs.

Space Station long-life requirements impose a planning horizon of mission and on-orbit activity scheduling which is an order of magnitude longer than any encountered thus far in the US space program. It thus follows that experimental program composition, crew composition and skill mix, logistic resupply requirements, on-orbit facilities and experimental hardware; as well as national priorities, and program funding will each, most probably change within the Space Station life span. These program uncertainties complicate both the Space Station design and mission planning efforts. To minimize the impact of program uncertainties, mission planning must be dynamic (incorporate status feedback) and encompass both premission and intramission planning functions.

The implications to mission planning include: (1) reducing operational costs both on-orbit and for ground support, (2) planning mission and task level activities in a highly resource constrained environment, and (3) selection and efficient utilization of a balanced mix of resources throughout the Space Station lifetime.

Complex Space Station operations will arise from the variety of sohpisticated experimentation being performed, complexity of supporting hardware, the dynamic interactions between on-orbit and ground support crewmen, and operational constraints imposed by limited resources. In general, successful performance of a specific operation requires performance of a set of complex tasks (some with uncertain outcomes) which depends on the availability of numerous interrelated resources (crew skills, experimental hardware, subsystem outputs, etc.) and, in many cases, targets of opportunity. Further, all of these conditions must be satisfied at a coincident point in time. Space Station operational complexity suggests the need for premission analyses aimed at illuminating fundamental system dynamics (basis for resource planning) and intramission real-time scheduling of tasks employing system state feedback.

6.5 ORBIT OPERATIONS SCHEDULING

Task level orbital operations scheduling involves scheduling all salient on-orbit resources on a minute-by-minute basis. Scheduling methods and dynamic modules of on-orbit operations used for detailed task scheduling will be based on analyses performed in previous planning functions. Task scheduling will be implemented using "the-man-on-the-scene" assisted by the onboard computer. Feedback of system status in the scheduling process will allow smoothing of on-orbit resources utilization and reduce the impact of uncertainties caused by subsystems failure, crew illness, estimated task performance times, and environmental stochastics. When scheduling or resource allocation conflicts arise in the nominal schedule, conflicts will be resolved by the on-orbit planner assisted, when required, by the onboard computer or ground support.

6.6 EXPERIMENT MISSION PLANNING AND SCHEDULING

A top-level experiment scheduling approach was used to develop a baseline experiment flight program. The basic constraining resources used in establishing this program were: (1) available funds, (2) Space Station volume, and (3) mandatory free-flying or attached module accommodations. Iterations were then made to achieve a program within the Space Station resource capabilities of manpower, electrical power, and data handling.

Mission planning and scheduling for operations for the Space Station Program will provide data for two time increments; near-term periods of 1 to 4 weeks, and near-real-time periods of from several hours to one day.

6.7 INFORMATION MANAGEMENT

Information Management refers to all aspects of information and data exchange between the Space Station and the ground and the operations associated with this exchange. Included are the communications network and its operations, the generation and issuance of backup commands, the receipt, processing, and distribution of Space Station and experiment data, and a ground-based design reference library.

Section 7
FACILITIES

7.1 FACILITIES SUMMARY

This section describes the facilities and related resources required to support Space Station manufacturing, test, prelaunch, launch, and flight operations.

7.1.1 Facilities Concept

Both Government and contractor facility resources are utilized in support of the Space Station. Maximum use is made of existing facilities to minimize cost.

7.1.2 Facilities Selection

Facilities selection is required for three functions: prelaunch and launch, flight support, and contractor operations.

7.1.2.1 Prelaunch and Launch

Prelaunch and launch facility resources selection criteria are predicated on requirements arising from concepts for the Space Station configuration and launch operations. The impact of using existing resources versus possible new resources is considered in finally establishing a Space Station and launch operations plan which optimizes and most effectively utilizes existing resource capabilities without compromising the Space Station's mission. Three Space Station module launches in a 60-day period, followed by the launch of two Growth Space Station modules 5 years later are factors bearing on facility selection. The Space Station's operations baseline is identified in Section 6. The following concepts from this baseline form the basis for selection of prelaunch and launch facilities and related ground resources:

A. Space Station and RAM Modules will be integrated into the Shuttle Orbiter after arrival at the launch site. They are transported separately from their manufacturing/test locations to the launch site. Assemblies to undergo separate shipment and their means for transportation are:

(1) Station, logistics and RAM modules by air shipment.

(2) All other equipment by surface vehicle or aircraft.

B. Space Station Modules are individually moved by transporter into the shuttle maintenance area after arrival at the launch site. On removing transportation shrouds and accomplishing an external visual inspection, non hazardous flight servicing is performed and batteries are installed in the Power Module. Integration of the Space Station Modules and Shuttle Orbiter is accomplished. The orbiter is erected and mated to the booster. Complete assembly and integrated testing of the Booster/Orbiter is accomplished.

C. The Booster/Orbiter with Space Station Modules in the orbiter cargo bay are to be transported to the launch pad.

D. Limited on-pad access to the Space Station Module is provided. Hazardous fluids and electrical umbilical interface support are to be provided from the LUT. The MSS is not required for support of Space Station launch operations.

E. Space Station launch control and monitor GSE is to be installed in the Shuttle launch control center.

7.1.2.2 Flight Support

Flight Support ground facilities and related resources are dictated by the unique needs created by the orbital environment and mission. The Integrated Mission Management section of this Plan identifies the functions to be performed. It is estimated that an average of about 300 direct contractor personnel will be required to support the integrated mission management functions for the Program's duration.

7.2 GOVERNMENT FACILITIES

7.2.1 Prelaunch and Launch

Launch site facilities and resources are used to used to support receiving, inspection, integration, and launch operations of the Space Station.

7.2.1.1 Shuttle Landing Strip and Roads

The Modules will be transported to the Shuttle landing strip via Super Guppy after which it will be transported by road to the Shuttle Maintenance Area.

7.2.1.2 Shuttle Maintenance Area

The Space Station modules will be uncovered and the exterior inspected for damage. The Transportation Status Monitoring unit will be checked to confirm that shipping environment is within tolerance. Internal access will be required only on the power module to install batteries. Non hazardous servicing will be performed and the module moved to the Shuttle Orbiter, installed in the cargo bay and interfaces verified. After the Space Station module installation in the cargo bay, the facility requirements are those of the shuttle except for the provisions identified in the following paragraphs.

7.2.1.3 Launcher Umbilical Tower

Space Station control-monitor interface GSE is installed in the LUT Base for use during launch pad operations. Certain hazardous servicing and electrical GSE is installed on select levels of the LUT.

7.2.1.4 Launch Pad

Propellants and other fluids are stored at the launch pad. Propellants and fluids are loaded through GSE into Space Station Modules during launch countdown operations.

7.2.1.5 Launch Control Center

The Shuttle LCC is used by the Shuttle/Space Station for maintaining and monitoring range safety, for monitoring countdown operations and initiating launch, and for coordinating resupply payload integration.

7.2.1.6 Central Instrumentation Facility

The CIF provides instrumentation support for the Space Station during launch pad operations. A cable interface is established with the installed control and monitor GSE, and RF link is established with the Space Station on the launch pad.

7.2.1.7 Other Launch Site Support Facilities

Other support and service facilities may be required for the Space Station operations. These are to be shared with the activities normally requiring their use. These facilities are listed in Table 7.1. New support facilities are not required.

7.2.2 Flight Support

Flight support facilities include those which provide the means for Space Station ground consulation, direction, and control for experiment, engineering, and other mission data transmitted between the Space Station and the Earth throughout the 10-year orbital period.

7.2.2.1 Mission Management

Mission Management performs mission control functions which include ground-based OCS backup, monitor of Space Station guidance and navigation, long-term trend analysis, initial checkout and activation of the Space Station, launch support, crew assistance during initial manning and activation of the Space Station, crew assistance during high activity periods, flight crew training and mission simulation, and mission planning.

The Mission Management is contained in a standard-type building or centralized grouping of rooms consisting of offices, administrative/technical services and support, briefing/conference rooms, data center, communications center, and Control/Status Room(s). Critical communications and data systems have emergency power backup and a TV system to monitor orbital operations TV displays. Depending on availability of space and other facilities, it may be possible to locate Mission Management in the MSOB.

7.2.2.2 Ground Network

A NASA provided Ground Network Station to provide the ground terminal for RF transmission to and from the TDRS. The ground station receives data and relays it as necessary to mission management.

Table 7-1

OTHER LAUNCH SITE SUPPORT FACILITIES

Administrative	Technical
Offices	Mechanical GSE Maintenance Area
Conference and Briefing Rooms	Electrical GSE Maintenance Area
Supplies Storage	Machine Shop
Safe Storage Facilities	Fluids Laboratory (Hydraulic Test)
Waste Repositories and Disposal	Cryogenic Laboratory
Mail Services	LO_2 Clean Area
Packaging and Packing	Calibration and Standards Laboratory
Reproduction Facilities	Chemical Analysis Laboratory
Badge and Lock	Biological Analysis Laboratory
Parking Facilities	Physiological Laboratory
Technical Library	Communication Equipment Maintenance Area
Telephone, Datafax, and TWX	Electronics Laboratory (Breadboard/Mockup)
Leased Lines	X-Ray Laboratory (Radiographic)
Fire Protection	Welding Shop
Safety Surveillance and Equipment	Vacuum Test Area
Security Guards and Control	Telemetry Systems Maintenance Area
Cafeteria	Screen Room
First Aid/Emergency Treatment	Photographic Laboratory
Warehousing	Optical Laboratory
	Materials Laboratory
	Acoustics Laboratory
	Clean Benches
	Centrifuge
	Computers
	Hypergolic Analysis
	Gas Analysis
	Guidance System Laboratory (Rate Table)
	Heat Treating Laboratory (Small Items)
	Meteorological Forecast

7.2.3 Logistics Support

Logistics facilities include those which support the planning of and providing of sustaining materials and services for the orbiting Space Station throughout its 10-year orbital lifetime. These facilities do not include those which support prelaunch and launch of the Space Station Modules.

7.2.3.1 Logistics Control

The Logistic Control maintains centralized surveillance, control, and management over Space Station logistics support subelements. These subelements include Inventory Control, Materiel, Maintenance, Transportation, Configuration Control, and Personnel Management. Logistics Control is a standard-type building or centralized grouping of rooms consisting of offices, adminstrative/technical services and support, briefing and conference rooms, data center, and a control center. The Logistics Control Complex may be a part of Mission Management. Primary and secondary voice communications interconnect this facility with Mission Management. Other communications and data links are established between this facility, Inventory Control. Critical communications and data systems have emergency power backup.

7.2.3.2 Inventory Control

Inventory Control maintains centralized control over specialized activities dealing with Space Station inventory resupply. Functions include determining the logistics vehicle cargo constituents, procurement, and control of inventory item quality, and preparation of the resupply cargo for flight. Inventory Control is a standard-type building having a multipurpose capability. It contains a data and control facility and a resupply cargo storage and loading facility. Included in these two functions are areas which support procurement, quality control, resupply test and evaluation, shipping and receiving, installation and loading simulation, packaging, storage, and logistic module loading. Cold storage and special environmental control provisions are provided. Communications and data links are established with Logistics Control. Emergency power is provided for the cold storage and clean areas and for other critical communications and data systems.

7.2.3.3 Crew Training

The Crew Training Complex is a NASA controlled function charged with training of Space Station flight crews and other ground support personnel throughout the 10-year orbital period. The center establishes training programs and curriculum, provides student adminstration, and controls equipment necessary for training. The Crew Training Area is a standard-type building or centralized grouping of rooms consisting of offices, classrooms, and adminstrative/technical services and support. Trainers and other training equipment are installed in this area.

7.2.3.4 Crew Accommodation Building

Crew accommodations provide a live-in capability for flight crew personnel who are in final preparations/training for transfer to the Space Station; they are also used by flight crew personnel who have just returned from orbit and undergoing debriefing.

The Crew Accommodation Building is a standard-type building consisting of living quarters, sanitary, dining, physical conditioning, medical, and flight-suit-donning facilities. The facilities are to be designed to accommodate 32 flight crew personnel for both the Space Station and logistics vehicle and 8 supporting personnel—two doctors, two nurses, one laboratory technician, one receptionist/secretary, and two food preparation/service specialists. These facilities have a high degree of self-sufficiency during periods of isolation prior to flight.

7.3 CONTRACTOR FACILITIES

7.3.1 Manufacturing

Manufacturing facilities include those which support Space Station Module fabrication, assembly of components into subsystems and subassemblies, and final integration of the modules into an ISS assembly. These facilities provide floor space, sufficient crane hook height and capacity, handling room, holding fixtures and other tooling, proper environment, electrical power and other utilities, and the means necessary for accomplishing manufacturing operations. Separate facilities are identified for separable, individually producible Space Station assemblies and systems to be integrated by the contractor. These facilities may be provided by a single contractor or various contractors either at a centralized location or remotely. Space Station spares and GSE are manufactured in these facilities and others as necessary. Space Station spares refurbishment is accomplished in these facilities and others as necessary.

7.3.2 Test

Test facilities are those which support Space Station system integrated functional test. These facilities provide floor space, sufficient crane hook height and capacity, handling room, holding fixtures and other tooling, proper environment, electrical power and other utilities, GSE installation and deployment areas, and the means necessary for accomplishing test operations. The test capability is incorporated in manufacturing facilities where possible. Special provisions are provided for testing where this is technically impractical or not cost effective.

7.3.3 Development

Development facilities include those which support development testing of unique or critical Space Station items in instances where development test data are nonexistent. These facilities in most cases are special and separate from manufacturing and test facilities. Existing capabilities are used where practicable and cost effective. Development activities include destructive and nondestructive structural testing, propulsion systems testing, EC/LS testing, etc. Although identified as a contractor responsibility, certain Government development facilities are to be evaluated for Space Station applications and will be utilized if possible, i.e., those existing at MSFC, Michoud, White Sands, etc.

Section 8
LOGISTICS

8.1 LOGISTICS SUMMARY

8.1.1 Definition

Space Station Program logistics is the process of planning for and providing of material and services required for sustained support of Space Station orbital operations. Functional disciplines charged with achieving this support include supply, procurement, maintenance, transportation, configuration management, personnel, and their attendant reporting and documentation methodologies. Under these functional disciplines are further identified elements and tasks which collectively fulfill the complete logistic obligation for Space Station support, e.g., provisioning of spares, source coding, technical orders, high-value time identification and control, data collection, hardware and software improvement, packing, preservation, warehousing, inspection, skill requirements, training and associated curriculum and equipment, etc.

8.1.2 Logistics Concept

Logistics for the Space Station Program has a high degree of centralized management and control because of the critical timing and qualitative/quantitative constraints imposed by the orbital environment. The manned, Earth-orbiting operational station will be supplied and maintained for 10 years through the integrated efforts of Earth-based logistics support, a fixed number of periodically launched logistics resupply vehicles, and the necessary orbital implementations. The Space Station is completely dependent on the logistics vehicles for normal and emergency resupply. Logistics interfaces and flow are shown in Figure 8-1.

The shuttle Orbiter will transport logistics modules containing expendables, consumables, spares, experiments, and any other commodity required to

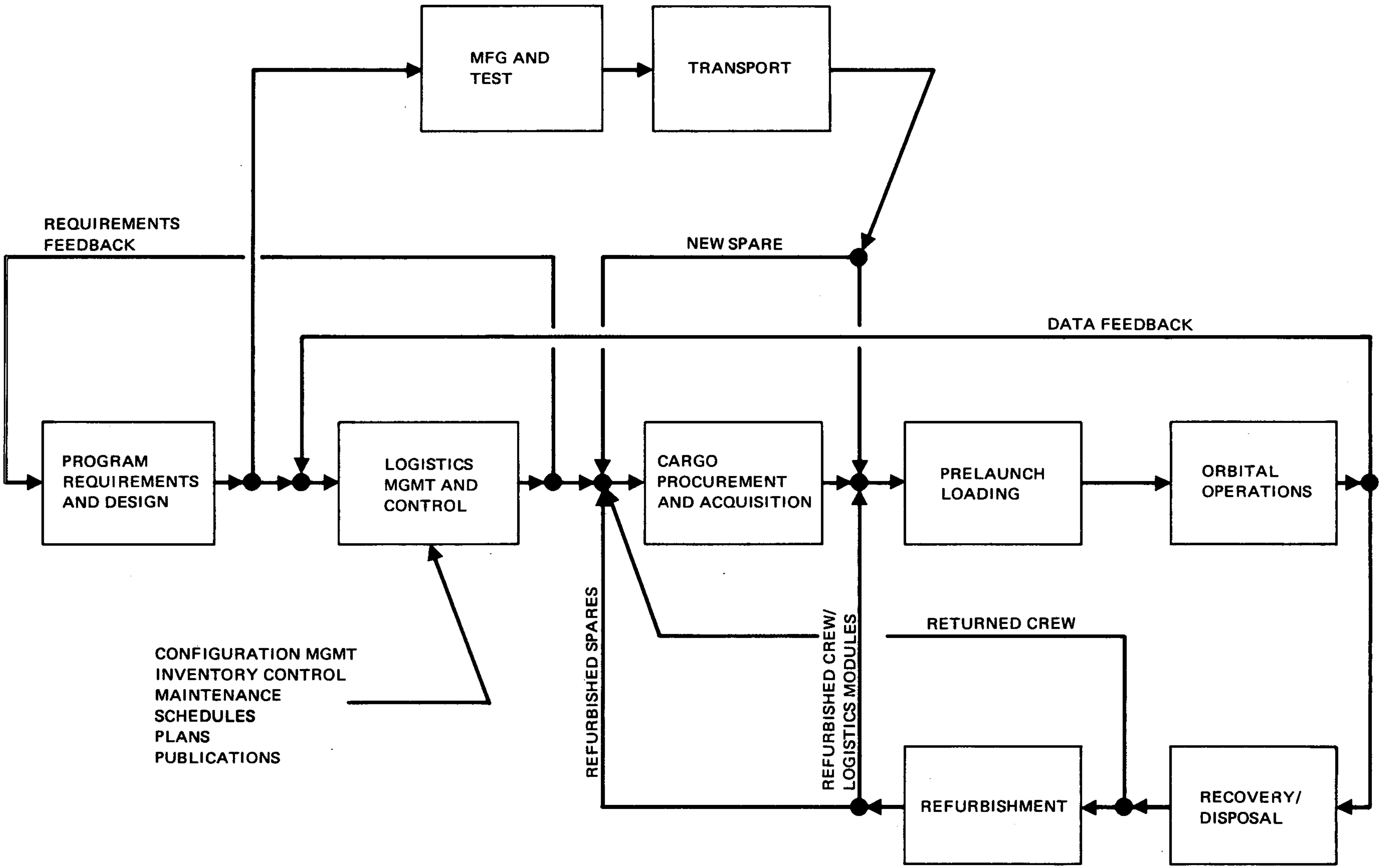

Figure 8-1. Space Station Logistics Interfaces and Flow

sustain or support the Space Station. The storage capability of the Space Station is limited, which dictates that the resupply cargo be sufficiently accurate in content and mix and be delivered on time to prevent reserves and residuals from dropping below safe minimums.

All resupplies intended for shipment to the Space Station will be processed through the Space Station Inventory Control Complex. All items to be transferred from the logistics module to the Space Station will undergo careful packaging to enhance utility and protection and to ensure ease of handling, movement, and stowage in the on-orbit environment. Items will be fitted and tested for feasibility of transfer operations on the ground prior to loading in the logistics module. Proper design of logistics sub-elements and establishment of organization relieves the flight crew of involvement as much as practicable while not compromising beneficial aspects of Space Station autonomy.

8.2 LOGISTICS SUPPORT OPERATIONS

For the Space Station Program, Logistics Support Operations is a management function in parallel with flight operations, Experiment Operations, and Mission Analysis and Planning under the Mission Management concept.

Centralized logistics will consist of inventory, material, maintenance, transportation, support operations, configuration and personnel subelements (Figure 8.2). Each of these subelements is charged with management and control of their particular activities and for integration and interface with other technologies within and external to the logistics support activity.

8.2.1 Inventory

The Inventory subelement is responsible for management and control of specialized activities dealing with tracking of Space Station utilization of consumables and expendables and providing necessary resupplies to permit continuous operations. Inherent in this responsibility is a close interrelation with other program elements (Space Shuttle and Experiments) and the command, communications, and data functions.

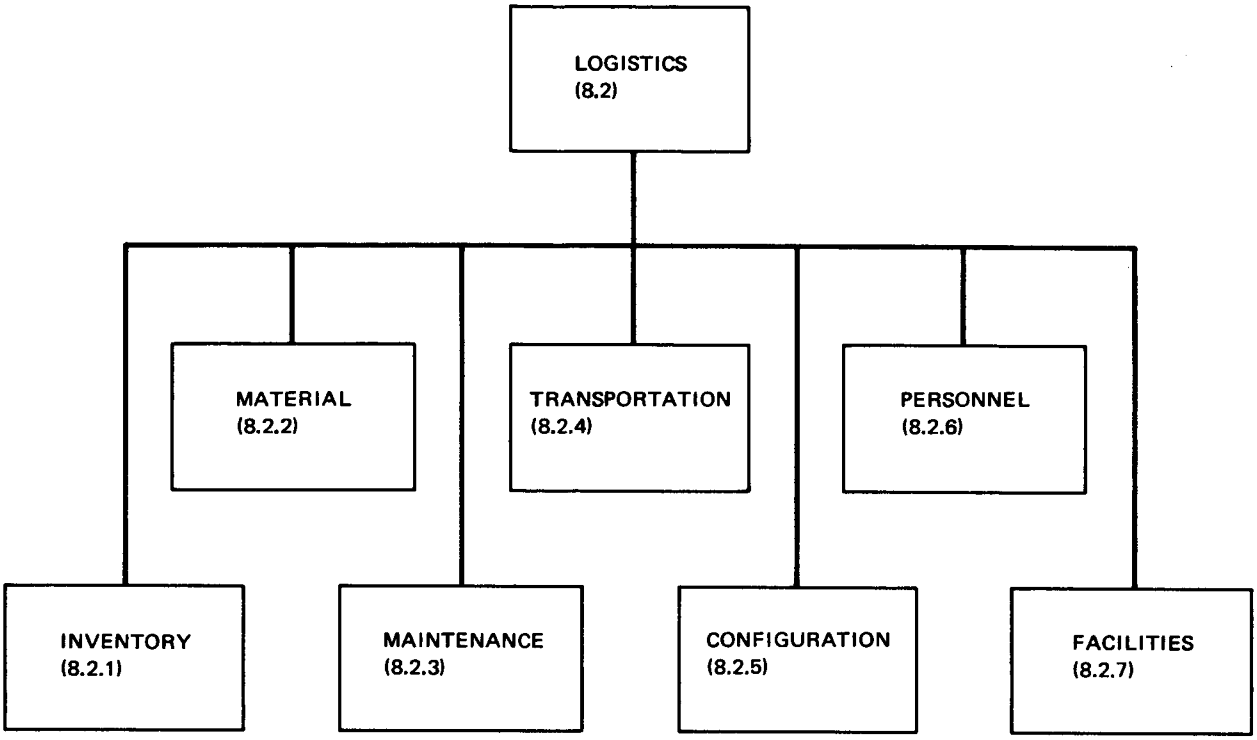

Figure 8-2. Logistics Management

The inventory function commences first with initial provisioning of the Space Station and the first logistics flight. This provisioning is to be based on estimates of crew consumption, utilization of expendables, and experiment activity.

The system is structured around a ground-based control and data complex which receives utilization data from the Mission Management Communications Processor. These data are automatically processed to yield next resupply flight cargo mix and procurement information. Special computer programs will allow instant analysis of utilization trends and pending shortages of certain items carried in inventory, both on-orbit and ground.

The inventory control system is designed and mechanized to reduce flight crew responsibilities to the lowest level practicable. Occasional, regularly scheduled inventory checks to verify proper operation of the system, periodic utilization/consumption reports, and unloading and loading the logistics module are the maximum requirements for the flight crew. The flight crew will transmit utilization/consumption rates by voice communications or data link. They will keep track of utilization/consumption through data cards attached to the particular hard cargo items. These cards will be collected as each item is utilized or consumed and the data processed weekly. Fluid reserves will be determined by reading quantitative instruments and the information transmitted the same as hard cargo utilization/ consumption.

Since there is a requirement to always maintain a certain minimum level of supplies onboard the Space Station, it might be possible for certain items not to be used for long periods of time, thus creating the possibility for accumulation of certain aged quantities. To prevent this occurrence, it will be a policy to first use those items which have been in storage on the Space Station the longest. Proper storage of supplies will enhance this first-in-first-out (FIFO) utilization/consumption policy.

8.2.1.1 Space Station Inventory Resupply Estimating

Quantity/quality of resupplies will be predicted on originally conceived data, estimated prior to Space Station launch and logistics resupply vehicle flight through detailed analyses and study, and modified as necessary to more realistically suit immediate and forecasted needs of orbital operations. This latter adjustment will arise through evaluation of the flight crew's actual consumption and utilization and applying changes as necessary.

The resupply mix will be established through evaluation of priorities versus cargo-carrying capacity of the logistics resupply vehicle and Space Station storage capacity. To minimize the number of resupply flights and costs per pound of cargo transferred on orbit, logistics vehicles will be loaded with the maximum cargo consistent with the Space Station storage capacity. Resupply quantities for the Space Station will be organized and sufficiently mixed to never allow the life and mission sustaining resources to drop below a 3-man-year minimum at any time.

8.2.1.2 Space Station Resupply Procurement

Procurement of Space Station resupplies is one of the forcing functions of the logistics process. Originally conceived plans and estimates of resupplies have to be very accurate to preclude shortages or overstocks. Long-lead ordering is accomplished in some cases (experiments, vehicular hardware, spares, etc.) even before the Space Station is placed on-orbit. Sufficient spares are in inventory to allow contingency resupply before their normally scheduled preventive maintenance cycle. Procurement of items of this nature considers premature failure contingencies, later to be influenced by actual case histories. With exception of certain fluids, consumables and expendables are not so constrained by ordering lead time and can be considered short-lead items.

Lead times for procuring resupply items consist of that aggregate time from when they are loaded on the logistics vehicle back through preparation for shipment, transportation, manufacture/production/test, design (if necessary) to procurement contract negotiation.

8.2.1.3 Space Station Resupply Handling

Space Station resupplies undergo special sorting, batching, and packaging for ready adaptation to the needs of the on-orbit environment. Other special attention will include placing the resupplies in containers specially designed to facilitate ease of handling on-orbit and to fit in optimally available storage locations, test loading the aggregate cargo in a simulated logistics module to establish feasibility of actual loading and unloading, and passing the cargo containers through simulated docking ports into areas simulating the Space Station to verify proper sizing of containers and ability to be handled satisfactorily. Approved containerized resupplies will be temporarily stored until a time for loading in the logistics modules.

8.2.2 Materiel

Ground operations in support of the Space Station program necessitate extensive traditional supply activity. This activity is managed and controlled under the Materiel subelement. The activity is conducted remote to and at the launch site and the functions performed pertain to Space Station resupply as well as ground operations.

Functions performed under Materiel include material identification, material selection and procurement, refurbishment and spares control, stock control, high value control, documentation, publications, and the necessary warehousing, preservation, packaging, and packing. Materiel receives procurement orders from the Inventory subelement and coordinates with the Maintenance, Transportation and Configuration subelements in conduct of its activities.

8.2.3 Maintenance

8.2.3.1 Functions and Control

Maintenance functions include maintenance consultation and analysis for on-orbit activities, repair and modification kit assembly, development of maintenance procedures and instruction, and calibration and certification. Maintenance management and control is established as a management subelement directly under Logistics management. Maintenance control's responsibility includes scheduling preventive maintenance, tracking of failures and trends, planning, and directing maintenance activities.

8.2.3.2 Orbital Support

Orbital support maintenance includes preventive and corrective types performed in flight on spacecraft hardware. Orbital support maintenance is a continuous function throughout the Space Station's 10-year orbital lifetime. The degree or level at which orbital preventive maintenance is accomplished is dependent on the system. Some electrical/electronic systems require periodic removals and replacements at the printed circuit board level while others require module or blackbox removal and replacement. Certain structural, mechanical, and fluid systems components require periodic removal and replacement, and these items include seals, hinges, EC/LS components, propulsion system components, attitude control system components, etc. Corrective maintenance represents a less known quantity as always and the degree of activity depends greatly on the reliability and

(b)

maintainability designed in the systems. Selected spares for critical systems are carried onboard the Space Station to provide for this contingency. Utilization of these spares is tracked by the Maintenance subelement as well as periodically used spares, and replacements are provided during the next logistics resupply mission. Much will be learned from analyzing on-orbit failures during initial Space Station operations, and these data will be used to modify originally conceived preventive and corrective maintenance plans, schedules, and spares inventory concepts.

Orbital Support maintenance is closely allied with the capability of the Space Station Onboard Checkout System (OCS), and the Inventory subelements. These activities require integration to assure availability of properly configured spares for scheduled maintenance and responsive support for random failures and breakdowns.

8.2.3.3 Ground Support

Ground support maintenance includes preventive and corrective types performed on grounded vehicular equipment, logistics modules, GSE, and facilities. Spares are carried in inventory for periodic maintenance and to allow for failures and breakdowns. Control and operating functions are the same as orbital support maintenance. Ground support maintenance assumes greatest importance during launch activities and as associated with items in direct support of the orbiting Space Station. These items include flight operating data and communications, simulator, crew training, and inventory management and control.

8.2.4 Configuration

Configuration management and control tracks, supervises, and establishes the Space Station hardware and software configuration. Serialization of orbital equipment is maintained and all changes are tracked as a result of periodic maintenance reports from the flight crew. Configuration control utilizes the FIT in maintaining a ground simulation of the current orbital configuration.

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8.2.5 Transportation

Space Station Program transportation is responsible for identifying and providing for transportation and shipping needs. Major Space Station Program elements require special handling, equipment, and means of transportation. GSE and other hardware and software will utilize standard techniques and methods of transportation.

8.2.6 Personnel

Personnel management within logistics is responsible for recruitment, training and accommodation of the specialized ground support personnel who are involved in launch and orbital sustaining operations.

8.2.7 GSE

Specialized GSE which supports logistic activities include the Inventory Control data processing equipment, resupplies handling and loading equipment, maintenance GSE, and resupplies sampling and test equipment. Other GSE which can be considered as supporting logistic activities include Space Station flight hardware, transportation GSE, handling and protection GSE.

8.2.8 Facilities

Specialized government facilities which support logistics activities include the Logistics Control Complex, Inventory Control Complex, Crew Training and Accommodation Facilities, and the facilities necessary for refurbishment and overhaul of logistics modules and spares.

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Section 9
FINANCIAL AND MANPOWER

9.1 INTRODUCTION AND SUMMARY

This section presents an overview of the Space Station Program's financial and manpower requirements. The cost estimates have been developed in consonance with the Work Breakdown Structure and the available program definitions.

The total cost of the Space Station Program in GFY 1972 dollars is presently estimated to be $6,563 million, of which the DD&TE cost is $3,714 million, the Production cost is $644 million, and the Operations cost is $2,205 million. Discounted at 10 percent per year, with GFY 1975 as the base year, the total cost of the Space Station Program is estimated to be $3,419 million. Both funding and manpower are constrained by the Phase C/D ATP, which is scheduled for October 1975, and the Initial Space Station (ISS) first operational launch scheduled for October 1980. Operations effort is scheduled to begin prior to the first launch and to continue for about 10 years following the launch. The schedule constraints, together with the planned Experiment Program, both integral and RAM's, cause a funding peak of $691 million and a manpower peak loading of about 14,500 in the same fiscal year (FY 1984).

The following paragraphs highlight: (1) the cost assumptions, ground rules and rationale upon which the cost estimates have been based; (2) the program costs down through the Project Level; and (3) funding and manpower projections.

9.2 COST ASSUMPTIONS, GROUND RULES, AND RATIONALE

A. Cost estimates have been developed in consonance with the Work Breakdown Structure (WBS) as presented in the Space Station Phase B Extension Study Plan, (MDC-G2127), dated March 1971.

B. Cost estimates are commensurate with the program definitions available at this time, the relative level of study effort, and with the understanding that the estimates are only for preliminary planning and tradeoff study purposes. Detailed costs are presented in DPD-235, MF-D1.

C. Costs are stated in Government Fiscal Year (GFY) 1972 dollars.

D. Costs are reported by Government Fiscal Year, 1 July through 30 June.

E. Cost estimates reflect the baseline definition and mission profile as published in the Baseline Program and System Definition Document, dated 1 June 1971, with the following comments:

   1. Cost estimates include ISS capability encompassing a Power/Subsystems Module, a Crew/Operations Module, a General Purpose Laboratory Module, and four Logistics Modules. The cost estimates also include the Growth Space Station (GSS) consisting of one additional Crew/Operations Module, and an additional Power/Subsystems Module.

   2. The Space Station Project costs do not provide for an artificial-g experiment.

   3. Costs of the Space Station modules assume: "commonality" as a primary consideration, that the same prime contractor will have responsibility for designing and producing all of the modules; that the same designs for one module will be employed to the maximum extent possible for succeeding modules; and that current technology will be utilized.

   4. The Space Station Project cost estimates reflect reduced testing program concepts made possible by the concept of "commonality." Cost of the Test Articles for the Space Station Modules and the Logistics Module include restoration and assembly of existing subsystems development test hardware for incorporation in the Functional Model (FM), and existing qualification test hardware for incorporation in the Flight Integration Tool (FIT).

5. Prime contractor costs of integrating subsystems into a system, such as a module, have been included in the System Level costs for the Module. System Support includes the costs for integration of Space Station to RAM Modules, and System Integration includes the costs for integration of the three Space Station Modules into the single CEI.
6. Production (recurring) costs include the cost of flight articles, with no provision for any backup.

F. The Shuttle Booster and Orbiter are assumed to be GFE and all nonrecurring costs therefore have been excluded.

G. Shuttle recurring cost estimates are based on a Logistics Module having a 20,000 pound design constraint, which results in a requirement for 114 Shuttle launches. Shuttle Project costs reflect only recurring operational costs at $4.5 Million per launch, per NASA direction.

H. Project Level costs include Project Management and Systems Support for all Projects. This excludes the NASA institutional base by NASA direction.

I. Nonflight hardware used as ground test articles for crew training, simulation, and/or problem evaluation are assumed to be developed, operated and maintained by the NASA.

J. Recurring (Operations) costs do not include the cost of any modifications to the ground network that might be required.

K. Estimated costs for the RAM Project and for the Integral Experiment "N's" in the Space Station Project have been developed in association with Martin-Marietta Corporation based on the NASA Experiments Blue Book dated 1 January 1971, and the Baseline Experiment Program developed by MDAC.

L. Cost estimates for the Space Station project have been estimated at the project and system levels based upon costs developed and reported in MSFC-DRL-231 Line Item 17, Costs and Schedules Data, dated February 1971, which costs, in turn, were derived from cost history on the Skylab, Gemini, S-IVB Stage, MOL, and other NASA-funded studies, and from the establishment of cost relationships reflecting Modular Space Station Program requirements.

9.3 PROGRAM COSTS

For planning purposes, the current estimate of the Total Cost (excluding fee) of the Space Station (Modular) Program is $6, 563 million in FY 1972 dollars as detailed in Table 9-1.

9.4 SPACE STATION FUNDING AND MANPOWER

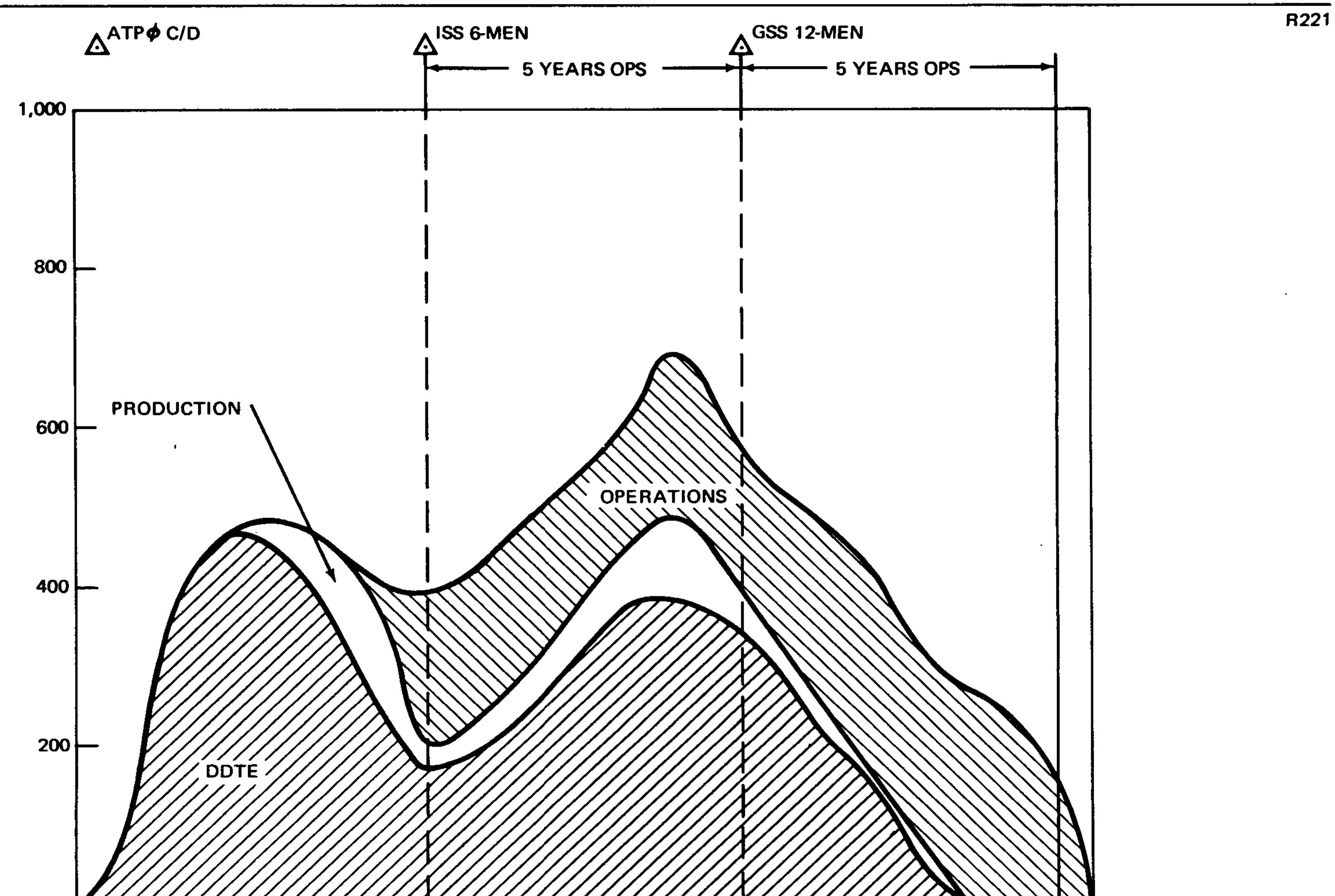
The currently estimated total cost of the Space Station Project has been allocated by Government Fiscal Year in accordance with the schedules presented in Section 4 of this volume. Both funding and manpower are constrained by the Phase C/D ATP scheduled for October 1975 and the Initial Space Station launch date of October 1980. The peaking of GSS DD&TE in FY 1984, along with the buildup of production and operations, cause the funding peak of approximately $691 Million in Fiscal 1984 (Figure 9-1). Figure 9-2 presents a preliminary funding of discounted values, which shows a peaking at $390 Million in FY 1977. Manpower has been allocated by year, and peak-loading of about 14, 500 occurs in Fiscal 1984, as shown in Figure 9-3.

Table 9-1

TOTAL SPACE STATION PROGRAM (MODULAR)

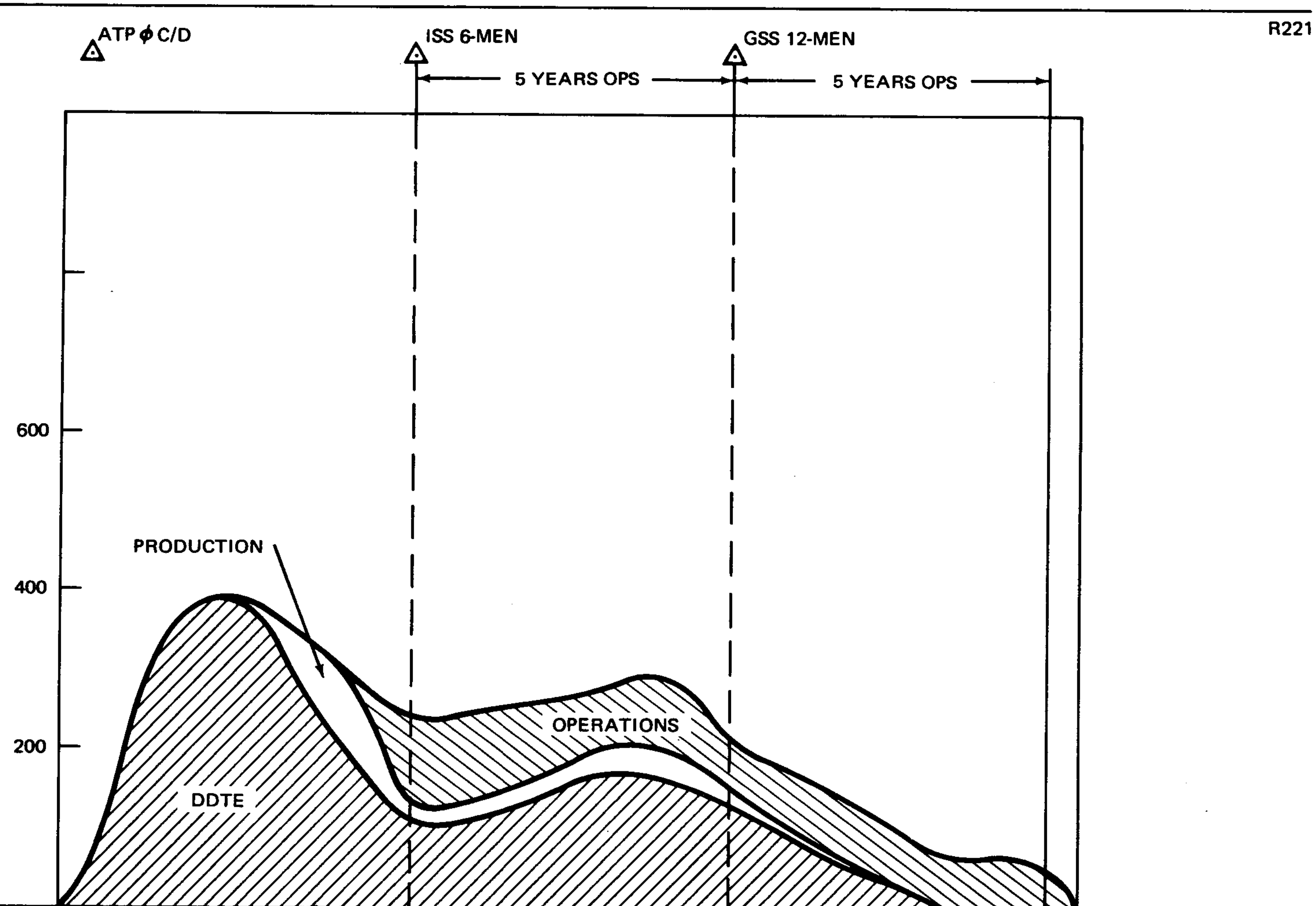
GFY 1972 Dollars in Millions

	DD&TE	Production	Operations	Total
Space Station	$3714	$644	$1695	$6053
Shuttle Operations	–	–	$510	$510
Total Project	$3714	$644	$2205	$6563



FISCAL YEAR	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
DDTE	61	342	470	418	288	165	200	270	366	380	340	235	150	29	–	–	3,714
PRODUCTION	–	–	3	60	131	33	46	64	75	102	53	45	22	10	–	–	644
OPERATIONS	–	–	–	–	–	189	194	177	150	209	172	213	253	248	247	153	2,205
TOTAL	61	342	473	478	419	387	440	511	591	691	565	493	425	287	247	153	6,563

Figure 9-1. Baseline Modular Space Station Program (5 Modules) 1972 Dollars in Millions (Mid-Year Plot)



FISCAL YEAR	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
DDTE	61	310	388	313	196	102	112	138	170	161	131	82	47	8	–	–	2,219
PRODUCTION	–	–	2	45	89	20	25	32	35	43	20	15	7	2	–	–	335
OPERATIONS	–	–	–	–	–	117	109	90	70	88	66	74	80	71	64	36	865
TOTAL	61	310	390	358	285	239	246	260	275	292	217	171	134	81	64	36	3,419

Figure 9-2. Baseline Modular Space Station Program (5 Modules) 1972 Dollars in Millions Discounted at 10 Percent Per Year (GFY 1975 Present Value Factor Equals 0)

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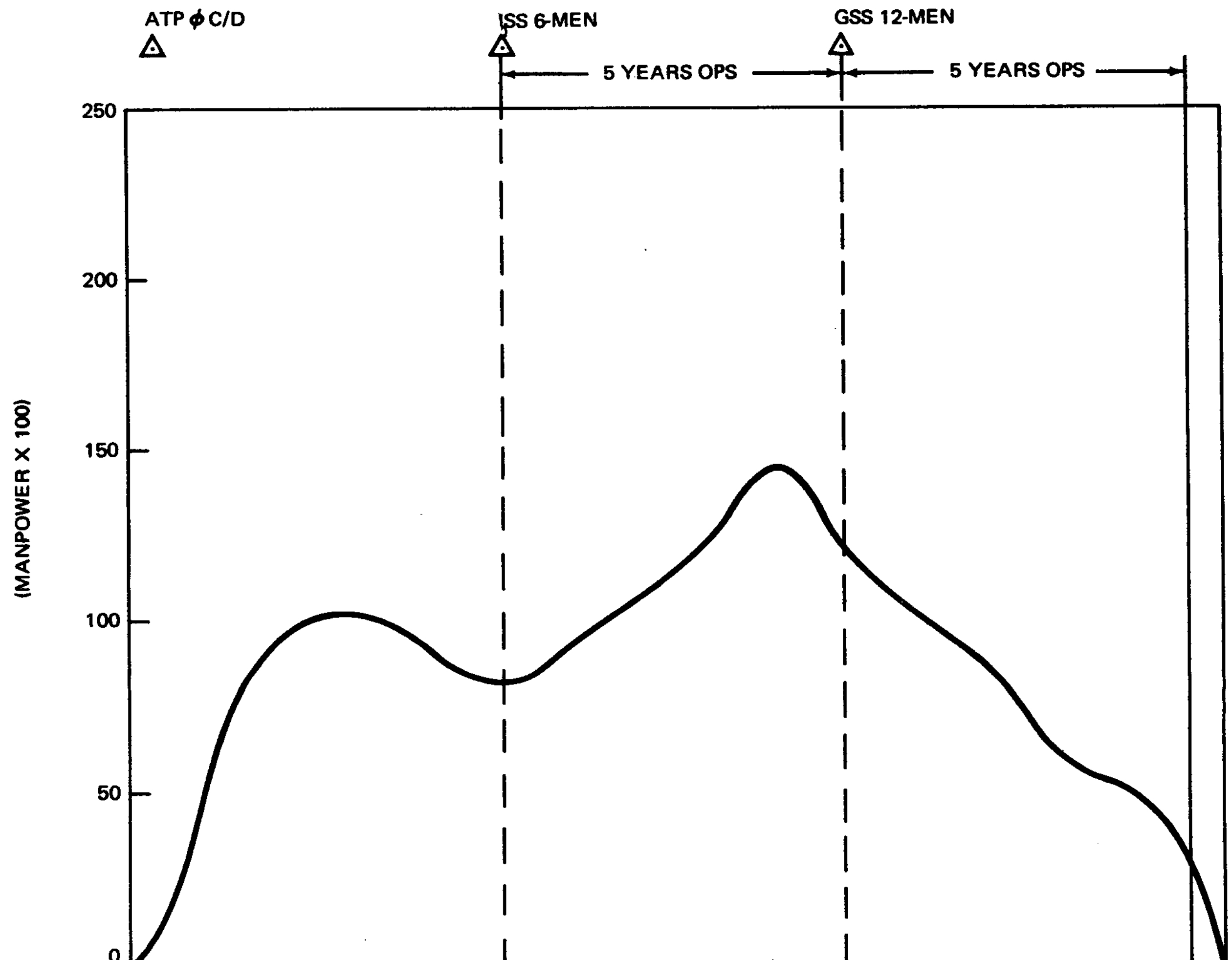

FISCAL YEAR	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	
TOTAL	13	72	99	100	88	81	92	107	124	145	118	103	89	60	52	32	

Figure 9-3. Baseline Modular Space Station Program Manpower in Hundreds

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