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SD 71-225

MODULAR **space station** PHASE B EXTENSION

PROGRAM MASTER PLAN



PREPARED BY PROGRAM BUSINESS MANAGEMENT
DECEMBER 1971



Space Division
North American Rockwell

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DOWNEY, CALIFORNIA 90241

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Approved by

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Space Division
North American Rockwell

TECHNICAL REPORT INDEX/ABSTRACT

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ABSTRACT DEFINES THE PROJECT FOR DESIGN, DEVELOPMENT, FABRICATION, TEST, PRE-MISSION AND MISSION OPERATIONS OF A SHUTTLE-LAUNCHED MODULAR SPACE STATION. DEFINES PROJECT MANAGEMENT APPROACH IN TERMS OF ORGANIZATION, MANAGEMENT REQUIREMENTS, WORK BREAKDOWN STRUCTURE, SCHEDULE, TIME-PHASED LOGIC, IMPLEMENTATION PLANS, MANPOWER AND FUNDING. IDENTIFIES PROGRAMMATIC AND TECHNICAL PROBLEMS WITH RECOMMENDATIONS FOR SOLUTION.

FOREWORD

This document is one of a series required by Contract NAS9-9953, Exhibit C, Statement of Work for Phase B Extension-Modular Space Station Program Definition. It has been prepared by the Space Division, North American Rockwell Corporation, and is submitted to the National Aeronautics and Space Administration's Manned Spacecraft Center, Houston, Texas, in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 76.

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

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

This plan, in conjunction with the Level 3 MSS Project Preliminary Performance Specification, SD 71- 215-2, defines the programmatic and technical requirements for the design, development, and operation of the modular space station.

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1.0 INTRODUCTION

1.0 INTRODUCTION

BACKGROUND

Under prior provisions of Contract NAS9-9953, North American Rockwell conducted a comprehensive 11-month Phase B Definition Study of a 12-man, 33-foot-diameter, monolithic space station which would be placed in earth orbit by a Saturn V class launch vehicle. An additional 6-month study that provided technical clarification for electrical power systems, experiments, thermal control, and modes of operation followed the Phase B study. These efforts have resulted in the development of a comprehensive data file pertaining to systems and operational capabilities that are supportive to the conduct of long-term earth-orbital space programs.

Although the additional 6-month study was initiated primarily to expand certain technical and operational areas that could not be investigated fully during the basic Phase B study, a shift in the national space program emphasis toward the earlier development of a reusable space shuttle necessitated a modification in the original requirements to include a Phase A-level conceptual analysis of a modular space station (MSS). This concept uses the space shuttle to launch a number of individual modules for assembly in earth orbit to form a space station configuration that provides a capability equivalent to that of the original zero-g, 12-man, 33-foot-diameter station. Delivery of the station modules via the space shuttle eliminates requirement for the non-recoverable Saturn V launch vehicle, and thus provides a cost-effective approach to future earth orbital operations.

The concepts and approaches identified during the Phase A study formed the basis for the NASA's decision to select a single MSS approach and define it at the preliminary design level. The current MSS Phase B definition study will provide technical and programmatic data to the depth necessary for the initiation of Phase C.

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OBJECTIVES

The objectives of the Modular Space Station Program are:

1. Design, develop, fabricate, test, and operate a space station consisting of a semipermanent cluster of modules, each of which can be transported to and from orbit in the cargo bay of the space shuttle orbiter.
2. Conduct beneficial space applications programs, scientific investigations, and technological and engineering experiments similar to those planned for the 33-foot-diameter space station at an earth orbital altitude of 445 to 500 kilometers (240 to 270 nautical miles) with an inclination of 55 degrees.
3. Size the initial station assembly to accommodate a crew of six with the first module to be launched via the space shuttle in the calendar year 1981.
4. Provide the initial station with a potential for growth to a capability equivalent to that of the originally defined 33-foot-diameter space station by calendar year 1987.
5. Provide for 5 years of operations subsequent to attainment of the growth capability.
6. Provide operational and experiment capability at each stage of orbital buildup from the initial 6-man station to the 12-man growth concept.
7. Demonstrate the practicality of establishing, operating, and maintaining long-life manned orbital stations.
8. Extend technology and develop space systems required to increase useful life by at least several orders of magnitude.
9. Develop new operational techniques and equipment that can demonstrate substantial reductions in unit operating costs.
10. Extend the present knowledge of the long-term biomedical and behavioral characteristics of man in space.

2.0 PURPOSE AND SCOPE

2.0 PURPOSE AND SCOPE

PURPOSE

The purpose of this plan is to define the overall management approach to conduct a project for design, development, fabrication, test, and operation of a modular space station, as an element of the NASA Earth Orbital Space Station Program. The programmatic route defined by the plan provides for:

1. Achieving operational capability of an initial 6-man version of the modular station during calendar year 1982.
2. Attaining a capability equivalent to that of the zero-g, 33-foot-diameter station through buildup to a 12-man growth version of the modular station by calendar year 1987.
3. Performing beneficial space operations for 5 years subsequent to attainment of growth capability.

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SCOPE

This plan pertains to the accomplishment of only that portion of the NASA Space Station Program related to the modular space station and the associated activities of pre-mission and mission operations. Interface considerations are provided for other elements of the NASA program such as the space shuttle, experiment payloads, and research and applications modules (RAM). Activities begin with initiation of the design phase (Phase C) and extend through the development and operations phase (Phase D), for both the initial 6-man station and the 12-man growth station.

SUMMARY OF THE PLAN

The remaining sections in this report, summarized in the following paragraphs, provide baseline and reference data for more detailed development in future phases of the project.

Section 3.0 - Definition of the Prime Contractor's Project

The total project to be conducted by the prime contractor is defined in terms of a technical description of the modular station; a definition of the work to be performed as portrayed by the work breakdown structure; the time phasing of effort as presented by a project management network, major milestones, and a master schedule; and a summarized description of all key events and activities occurring during the life of the project.

Section 4.0 - Organization

The contractor's project organization, authorities, and responsibilities are described in this section.

Section 5.0 - Management

Presents the contractor's approach to management and defines specific requirements that will be met by contractor business systems in the special emphasis management areas of performance management, configuration management, data management, system safety management, external interface management, cost reduction management, reliability management, and quality assurance management.

Section 6.0 - Program Plans

Summarized descriptions of essential Phase C/D program implementation plans are provided. These plans will provide integrated direction to all project personnel for the conduct of specific aspects of the project effort.

Section 7.0 - Manpower and Cost Planning

Presents the overall manpower and funding requirements for conduct of the project to a level that is commensurate with the data developed during the Phase B Definition Study.

Section 8.0 - Potential Problem Areas

Potential programmatic and technical problem areas are identified with recommendations as to their possible solution or minimization.

3.0 DEFINITION OF THE PRIME CONTRACTOR'S PROJECT

3.0 DEFINITION OF THE PRIME CONTRACTOR'S PROJECT

TECHNICAL DESCRIPTION

This section contains a description of the general approach to design of the MSS including a description of its configuration and the development requirements for ground support equipment and facilities.

Primary considerations in the design of the MSS include the requirements for a long-operating life; flexibility to conduct multidisciplinary experiments as well as an applications program in low-earth orbit; use of a "standard" module as a building block for an initial 6-man station with growth capability for a 12-man version; and, as a goal, adaptation of the "standard" module for use as a cargo module and a RAM.

The SD 71-215-2 MSS Project Preliminary Performance Specification defines the performance and design requirements for development of the MSS project flight and ground systems during Phases C and D.

INITIAL SPACE STATION CONCEPT

The initial MSS system consists of a cluster of four common station modules, two special modules (core and power), and a cargo module arranged in a cruciform configuration as shown in Figure 3-1, and with dimensional characteristics as shown in Figure 3-2. Each module of the system is capable of being transported to and from orbit internal to the space shuttle for on-orbit assembly.

The initial station system has the capability to support at least six crewmen, has a general purpose laboratory (GPL) capability, and has the ability to accommodate two attached or detached RAM's. The GPL capability includes two airlocks: one earth-oriented and the other zenith-oriented.

The MSS system is designed and sized for operation at an altitude of 240 n mi, and an inclination of 55 degrees. The basic flight mode is with the X-axis perpendicular to the orbit plane, the Z-axis along the local vertical, and the Y-axis opposite to the velocity vector (X-POP, Z-LV, Y-OVV). This mode will be flown at all times except for short periods of inertial flight for solar/stellar viewing, and shuttle approach and berthing/unberthing operations.

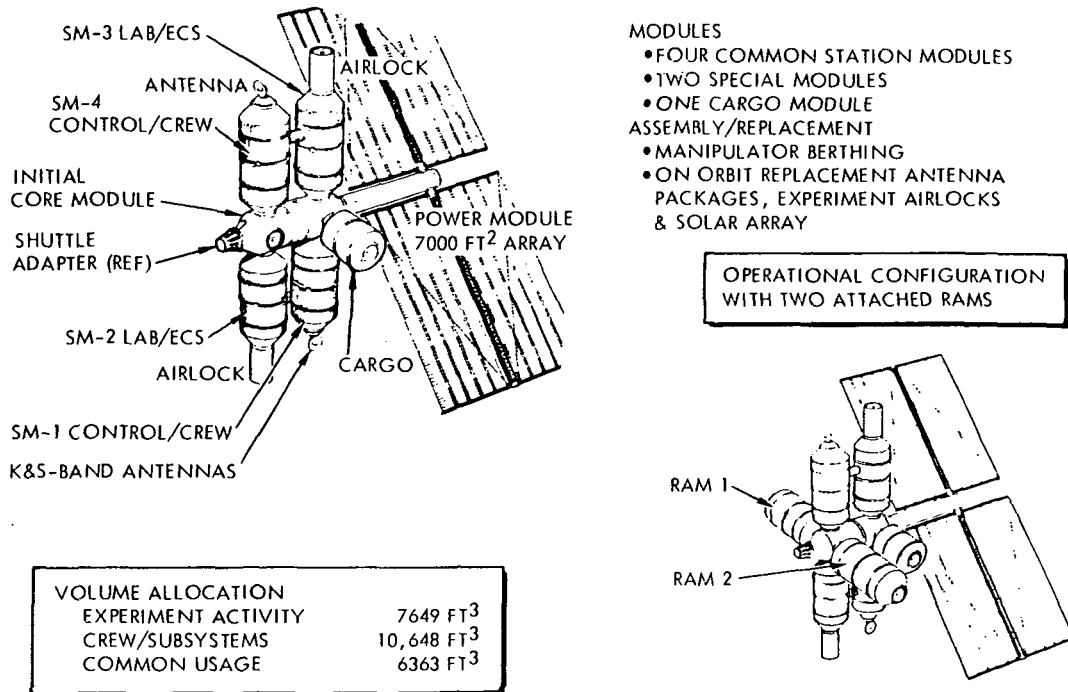


Figure 3-1. Initial Space Station Configuration

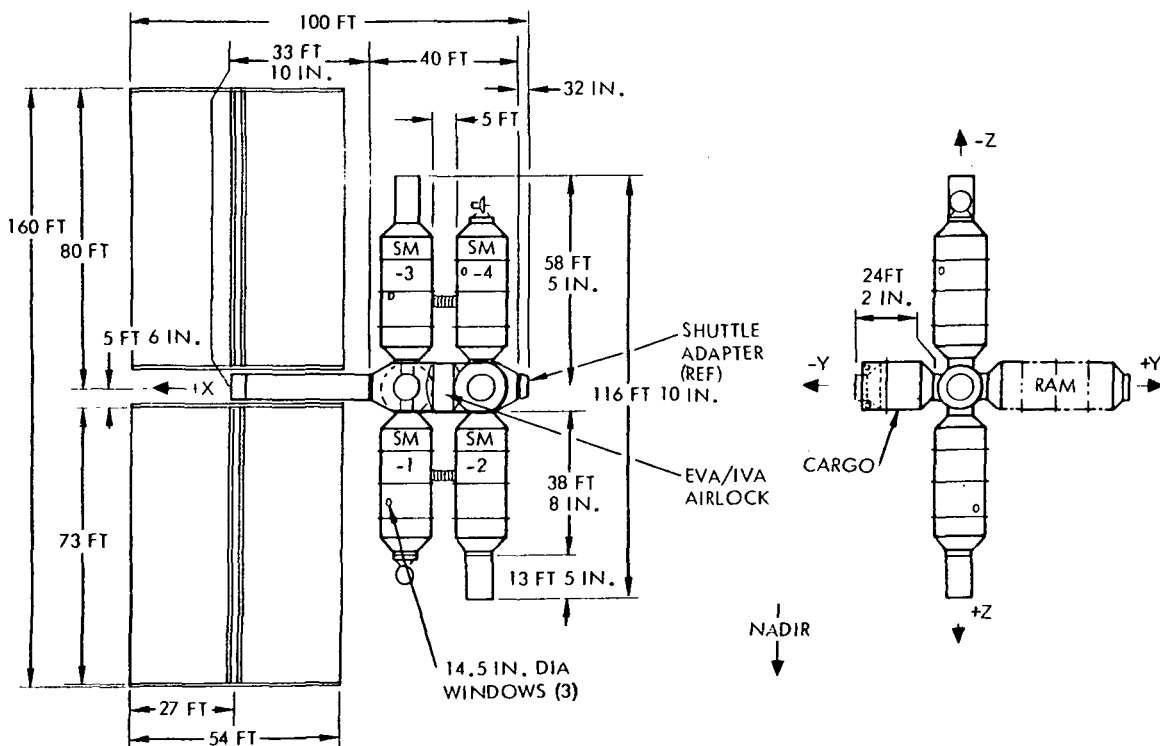


Figure 3-2. Initial Space Station Dimensional Characteristics

The system is capable of operating at altitudes between 240 and 270 n mi at an inclination of 55 degrees, in either a local vertical hold or inertial hold flight mode; however, the nominal mission is 270 n mi, 55 degree inclination, with the above basic flight mode.

Additional system characteristics are presented in subsequent paragraphs.

Initial System Modules

The modules comprising the initial MSS system consist of two special modules, four common modules, and a cargo module. These are described in the following paragraphs. A description of a cargo module concept is included; however, MSS preliminary design studies did not include the cargo module. It is therefore treated as a separate system in the technical documentation.

Initial Core Module

The initial core module (Figure 3-3) is 40 feet long between berthing interfaces and 12-foot 8-inches outside diameter. The 15-foot-diameter envelope intersects the edges of the side-berthing ports cluster. Light-weight skin (0.040-inch aluminum) and stringer construction is utilized. The eight side-berthing ports are spaced 20 feet apart; this allows a 5-foot clearance between the station modules. The four side ports are provided with thermal covers, with thermal control of the vertical ports provided during buildup with special insulation panels.

The installed subsystems are distributed between the V1 and V2 volumes separated by the EVA/IVA airlock. The airlock provides an equivalent floor of approximately 5 by 7 feet. All hatches open outward from the airlock. The EVA hatch (40-inch-diameter clear opening) is located at a 45-degree angle which provides the maximum clearance between attached modules. The guidance and control subsystem (G&C) optical reference and control moment gyros (CMG's) are located adjacent to the RAM berthing ports.

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

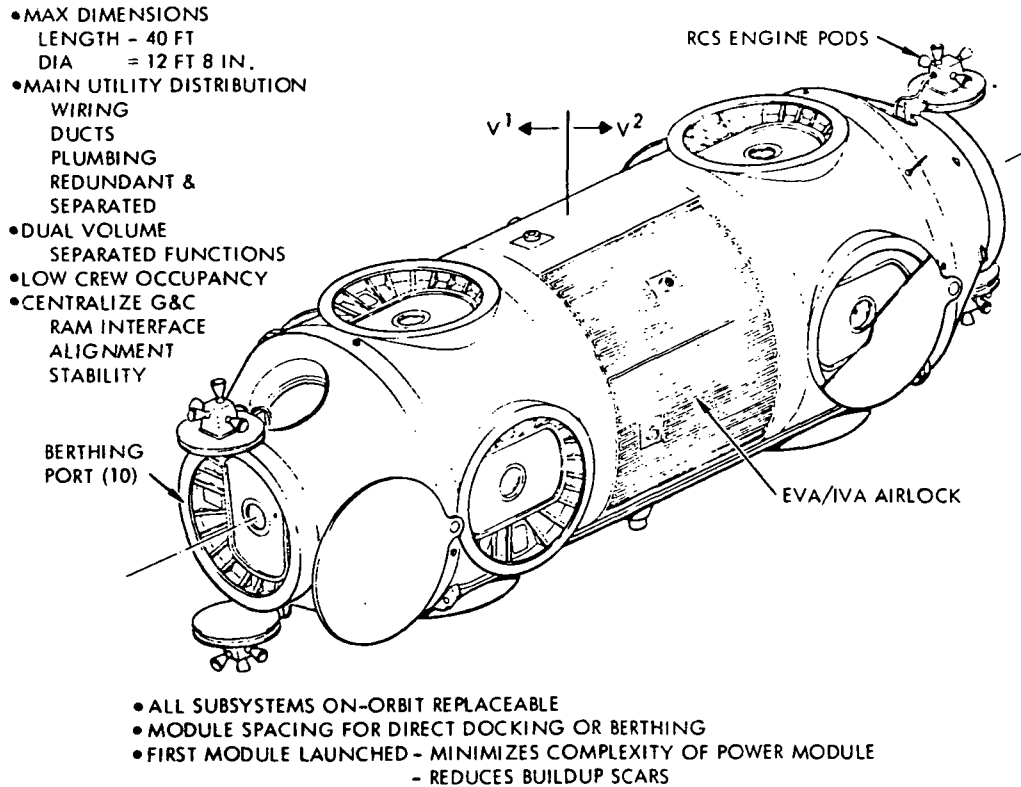


Figure 3-3. Initial Core Module

Power Module

The power module (Figure 3-4) consists of two assemblies: a power boom and a solar array.

The solar array assembly consists of the arrays and the orientation drive and power transfer mechanism. Shirtsleeve maintenance of the mechanisms is provided. The solar array assembly is replaceable and utilizes the standard berthing port.

The power boom has an 88-inch outside diameter and a length of 27 feet 6 inches. The 88-inch-diameter boom allows the solar array panels to stow within the 15-foot-diameter shuttle payload envelope. The boom is of monocoque construction utilizing 0.145-inch-thick aluminum, which increases its stiffness and consequently increases the natural frequency of the total space station assembly. High-pressure gas storage bottles for repressurization are placed in the boom. Shirtsleeve maintenance and replacement is provided even though the module is normally operated unpressurized.

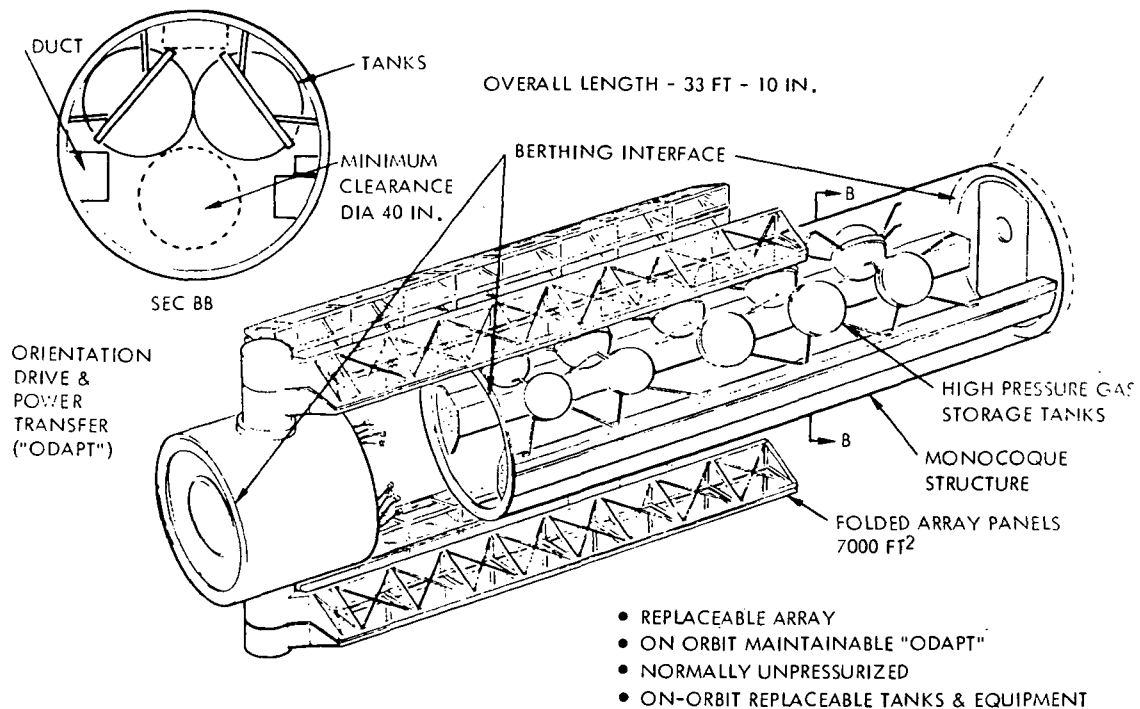


Figure 3-4. Power Module

Station Module Features

All of the station modules (Figure 3-5) are 38 feet 8 inches long between berthing interfaces and provide a 13-foot 8-inch clear inside diameter. The external frames and attach points extend to 15 feet. An active berthing port is provided at the core module interface and a passive port at the other end. The interface provisions across the berthing ports are identical. Each module contains four manipulator sockets for shuttle deployment and four shuttle bay attach fittings. Radiators cover the exterior of the cylindrical portion of the modules.

The longitudinal floor provides a single, structural component for mounting of equipment both above and below decks, greatly simplifying the manufacturing installation and design details. The longitudinal orientation also simplifies other ground operations of module assembly, checkout, and shuttle installation.

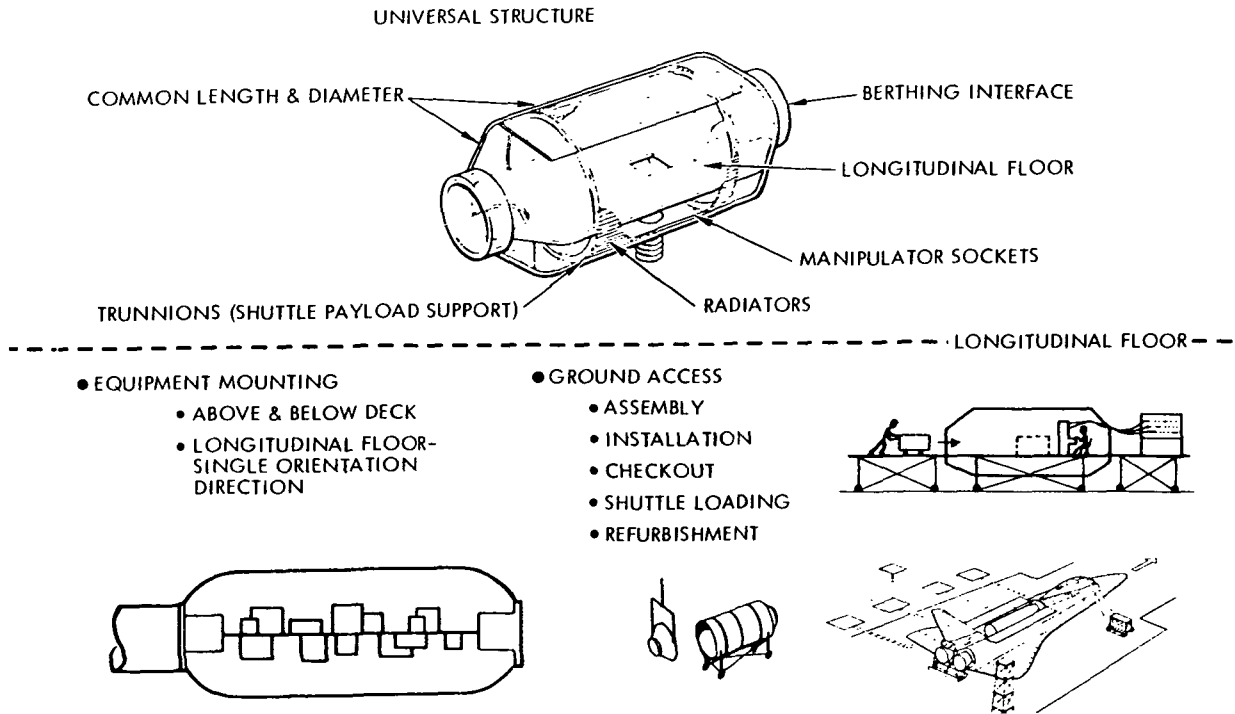


Figure 3-5. Station Module Features

Control/Crew Station Modules

The two control/crew modules (Figure 3-6) SM-1 and SM-4, have common functional allocations and equipment location. Each module performs a similar function in each of the two pressure-isolatable volumes of the station. Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

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

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

Laboratory/ECS Station Modules

The two laboratory/ECS modules (Figure 3-7) SM-2 and SM-3, are in different isolatable volumes of the station. Where backup functions are provided, they are located in similar areas in the module of the opposite volume.

The lower deck area of station modules SM-2 and SM-3 contain environmental control subsystem assemblies for air revitalization (CO₂ management and atmosphere control). Common installation arrangements provide easy access for maintenance and service. The remaining lower deck area is for storage of station and experiment supplies, and for installation of the RCS/ECLSS H₂ and O₂ gas accumulators.

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

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

Cargo Module

The cargo module concept (Figure 3-8) utilizes the MSS universal structure except that it is 24 feet in length compared to the station module length of about 39 feet. It is self-sufficient for 72 hours on orbit for six men when in the shuttle cargo bay. Up to 11,800 pounds of cargo can be carried with an up crew load of six passengers. Passengers would occupy the cargo module only during orbital periods, and transfer to the station would be accomplished through the orbiter. The 120 cargo containers, located as shown, provide sufficient, dry-cargo storage capacity to meet resupply and the 120-day storage capacity requirements. Five 48-inch-diameter tanks provide sufficient capacity for all anticipated liquid and gas resupply requirements. Should this requirement ever increase, up to nine tanks can be carried in the annular volume shown.

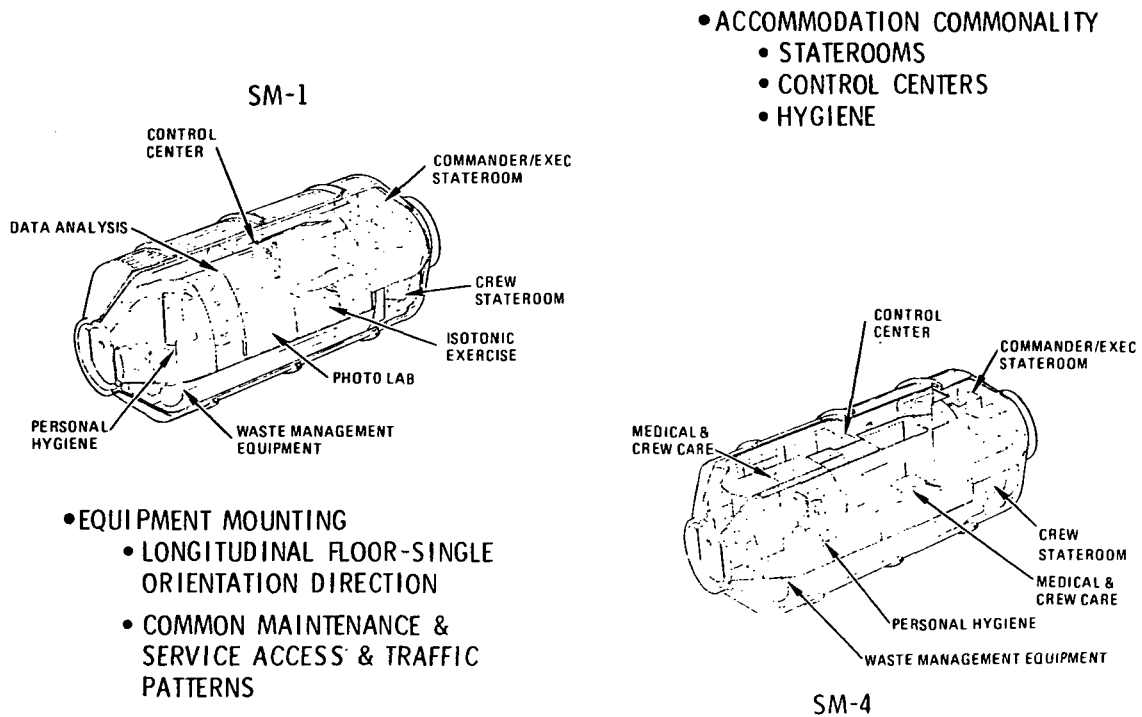


Figure 3-6. Crew/Control Modules, SM-1 and SM-4

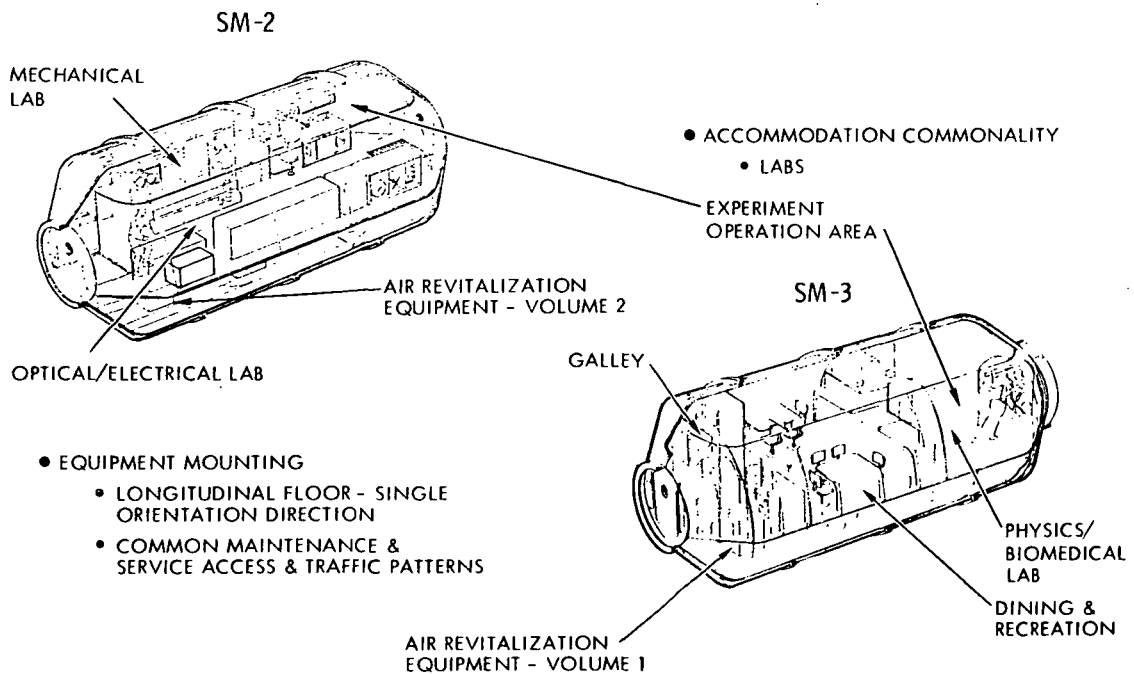


Figure 3-7. Laboratory/ECS Modules, SM-2 and SM-3

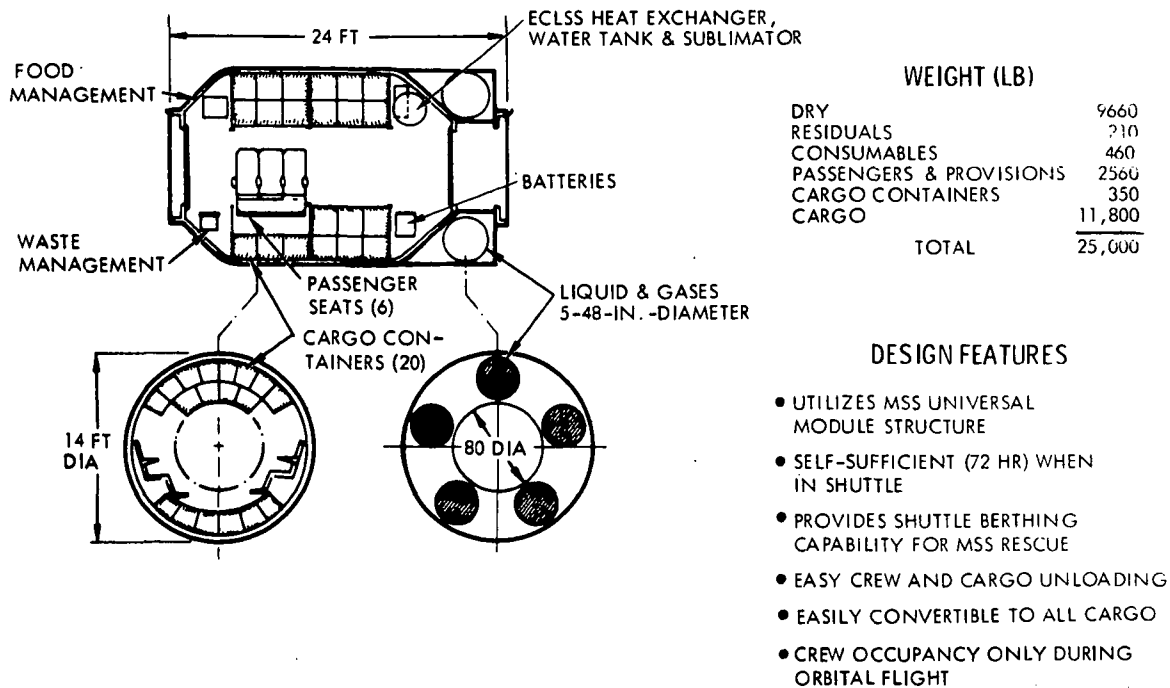


Figure 3-8. Cargo Module Concept

Space Station Subsystems

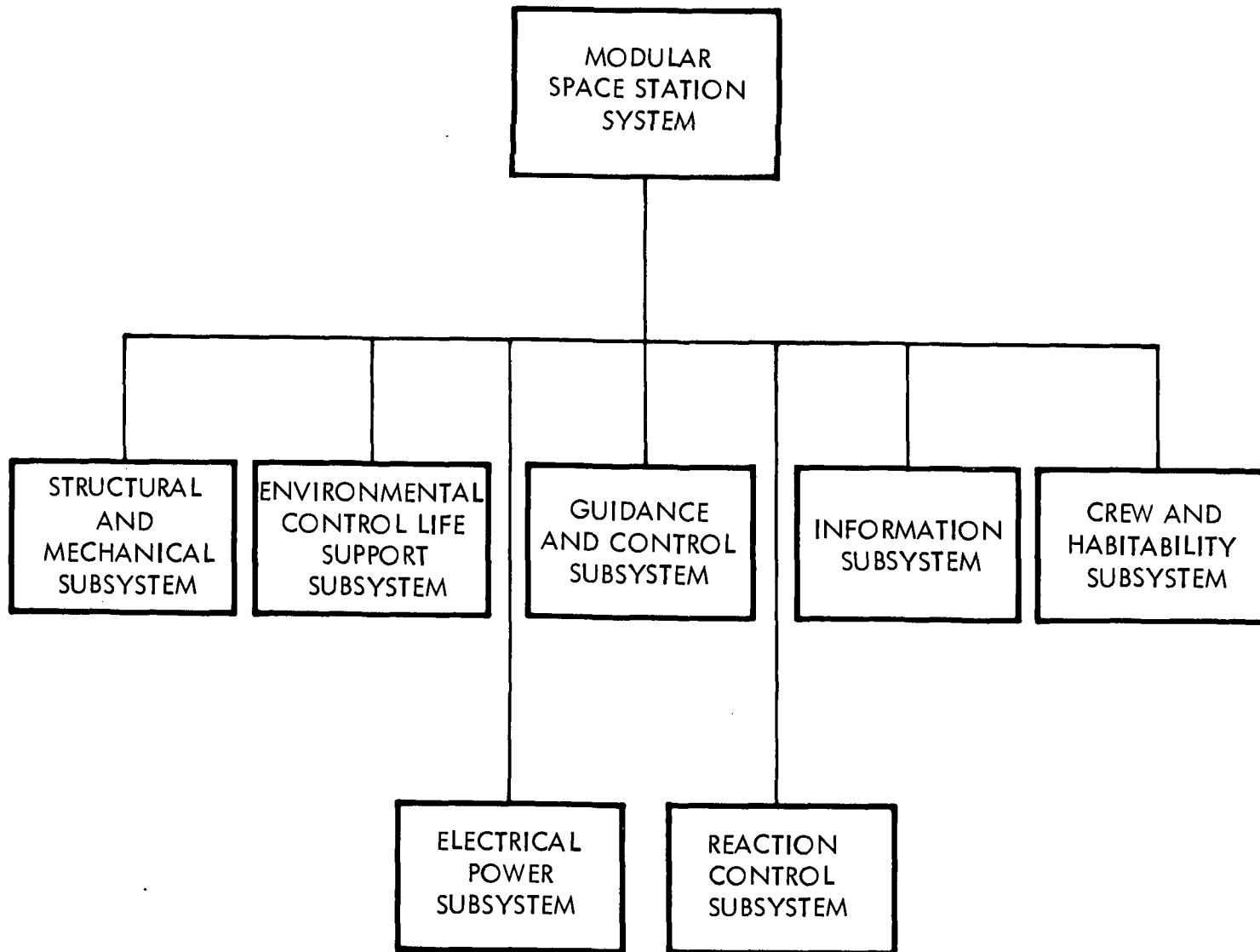
The space station system contains seven functional subsystems as shown on Figure 3-9. The following paragraphs give a brief functional description of these subsystems.

Structural and Mechanical Subsystem

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

Environmental Control Life Support Subsystem

The environmental control life support subsystem (ECLSS) provides essential atmospheric gases, temperature, pressure, and humidity control, food storage and preparation provisions, water and waste management, and personal hygiene facilities and materials for modular space station operation with a crew of six. The subsystem maintains thermal balance of the MSS as



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Figure 3-9. Space Station Subsystems

well as emergency reactant storage for the electrical power and reaction control subsystems. In addition, special life support capabilities are provided for emergency conditions.

Electrical Power Subsystem

The electrical power subsystem (EPS) stores, generates, regulates, controls, and conditions electrical power required by the MSS for the full duration of the mission, including backup and emergency contingencies (except for emergency fuel cell reactants which are stored by the ECLSS). In addition, the electrical power subsystem shall be capable of transferring power to docked logistics vehicles, and research and applications modules through electrical interfaces. Besides power distribution, the electrical power subsystem provides the electrical distribution wiring of all subsystem interfaces, and provides for the general lighting needs throughout the interior and exterior of the space station.

Guidance and Control Subsystem

The guidance and control subsystem (G&C) determine the actual and desired station state vector, provides stable attitude for the conduct of experiment operations, and provides commands to the reaction control subsystem to maneuver the station to the desired state vector.

Reaction Control Subsystem

The reaction control subsystem (RCS), together with the torques supplied by the control moment gyroscopes, provides the forces and moments necessary for attitude control of the space station and those forces required for orbit altitude maintenance.

Information Subsystem

The MSS information subsystem (ISS) provides the effective acquisition, processing, distribution, and analysis of data. It serves mission planning and operations scheduling, command control, checkout, monitor and alarm, configuration control, inventory control, flight control, data management, support between MSS subsystems, the ground network, docked vehicles (space shuttle, RAM's, and cargo modules), integral experiments and the crew using communications, displays and control, data processing, software, and special support equipment.

Crew Habitability Subsystem

The crew habitability subsystem specifies metabolic, atmospheric, and habitability criteria; and provides food supplies, clothing and furnishings

necessary for crew comfort, well-being, and survival. The subsystem provides general equipment including tools, mobility aids, emergency O₂ masks and radiation monitoring devices for the crew. In addition, equipment is provided for crew recreation, exercise, and medical care. The subsystem also provides pressure suits, portable life support systems, and related equipment for EVA/IVA operations.

GROWTH SPACE STATION CONCEPT

In order to enhance low development costs for the initial station, the provisions for growth (scars) have been minimized. The two additional station modules (SM-5 and SM-6) utilized for growth (Figure 3-10) have taken maximum advantage of accommodation features developed for the initial station. The ECLSS water management and air revitalization accommodation features from the initial station laboratory/ECS-type modules and split-level, crew accommodation features from the control/crew-type modules have been integrated to provide two identical modules necessary for growth operations. Also, a short growth core module is included to satisfy the additional growth modules (two station plus one additional attached RAM) requirements.

A 10,000-square-foot solar array package is included to satisfy growth power needs. This package replaces the 7000-square-foot initial station solar array assembly and retains the power module boom structure.

As noted, this concept maintains a balanced V1 and V2 to satisfy safety requirements.

MSS GROUND SYSTEMS

The MSS ground systems provide the sites, facilities, equipment, and services necessary to support the development, production, and operational requirements of the MSS flight systems during the life of the MSS project. Details regarding ground system requirements are contained in the following documents:

SD 71-215-2 MSS Project Preliminary Performance Specification
SD 71-222 MSS Integrated Ground Operations
SD 71-223 MSS Program Operations Plan

The functions supported by the ground systems are listed below, and are discussed in general terms in the Summary Description of Key Events and Activities paragraph.

- Development test
- Fabrication

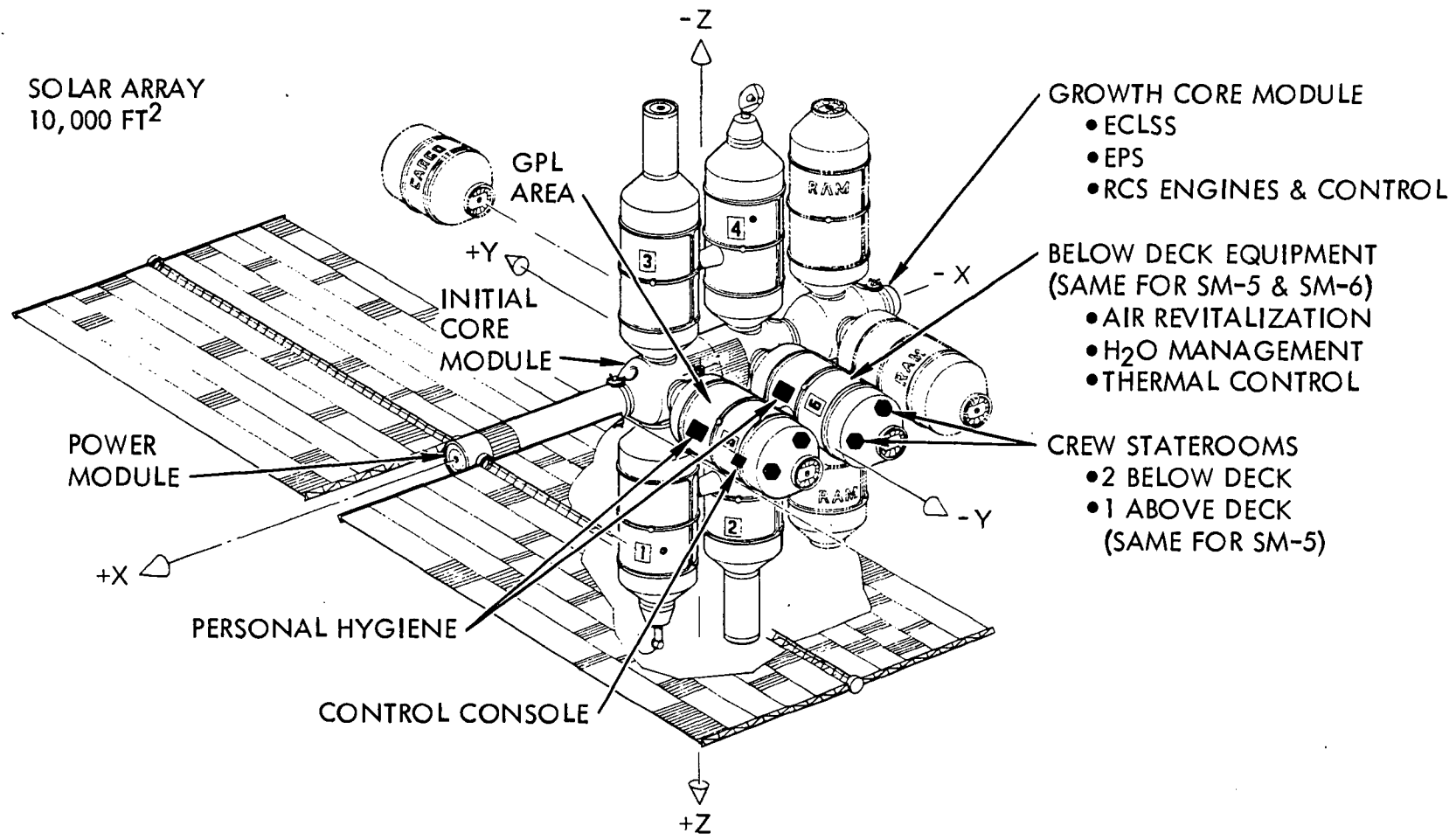


Figure 3-10. Growth Station Configuration

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- Assembly and installation
- In-process verification
- Individual module checkout
- Acceptance test
- Transportation and handling
- Servicing and support
- Mission planning
- Flight operations management
- Experiment operations planning
- Experiment operations management
- Logistics inventory management
- Tracking
- Communications
- Operations training
- Environment acclimation training

INTERFACES WITH OTHER PROGRAM ELEMENTS

The MSS has significant major interfaces with the space shuttle, the RAM's, and via communications with ground and space elements (Figure 3-11). The following paragraphs describe some of the operational characteristics that establish these interfaces.

Space Shuttle

The space shuttle provides the basic means of transporting station modules to orbit for assembly into the space station cluster during the buildup phase. Once the station is completely assembled and operational, the shuttle provides resupply support by transporting cargo modules to and from the station. It also serves as the vehicle for emergency rescue within 48 hours of alert notification. Additional details are contained in SD 71-221 MSS Shuttle Interface Requirements.

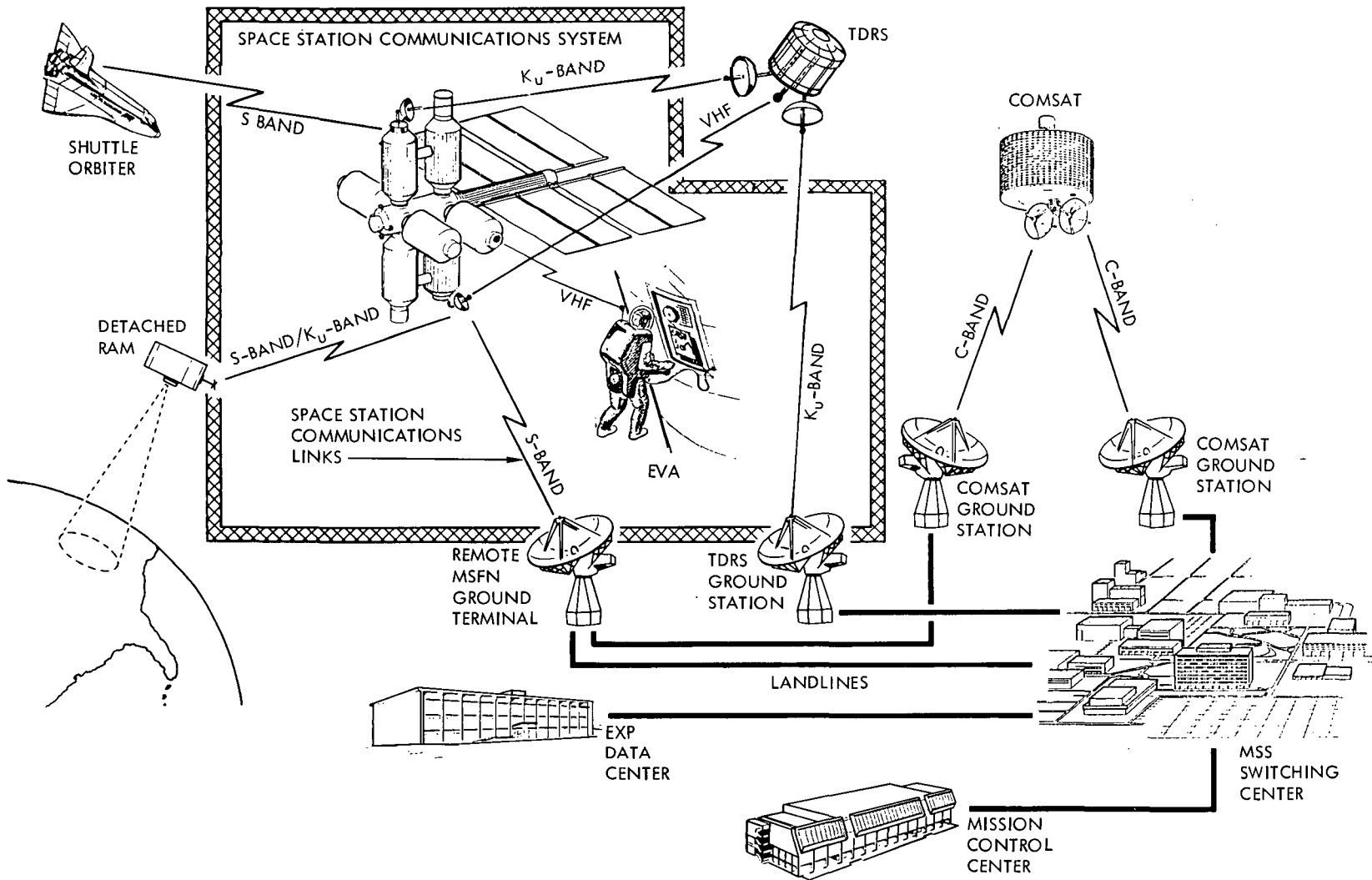


Figure 3-11. MSS External Communication Network

Experiment Modules (RAM's)

The space station has interfaces with attached and detached RAM's. The station provides electrical power, thermal control, and information transfer for attached RAM's, and for detached RAM's when berthed to the station. The station interface with detached free-flying RAM's consists primarily of a communication interface for command and control out to a distance of 450 n mi.

Communications

Direct communication from the space station to other program elements is accomplished through S-band equipment. Communication with relay satellites is via VHF and K-band equipment. The communication links consist of voice, video, and data.

SUMMARY DESCRIPTION OF KEY EVENTS AND ACTIVITIES

The NASA Earth Orbital Space Station Program, which was conceived as a logical outgrowth and continuation of the successful Apollo Lunar Program and the ensuing Skylab Program, is a significant increment in the development of man's capability for further exploration of outer space. The program is time-phased to support the overall NASA planning for future earth orbital space operations. The objectives with which current planning is involved are to place an initial 6-man MSS in earth-orbit during calendar year 1982, and to attain operational capability for a 12-man growth station in calendar year 1987. To accomplish these objectives, NASA has defined its program in terms of the projects shown in the program summary work breakdown structure, Figure 3-12.

In accordance with NASA direction, this plan addresses itself to the definition of the project for design, development, and operations of the MSS, its interfaces with other program elements, and associated activities. The project is described in the following paragraphs in terms of the major activities. The project is described in the following paragraphs in terms of the major activities and events as they occur in this time frame. The phasing and major products of each phase of project planning are depicted in Figure 3-13.

DESIGN

Phase C Design

The design approach adopted for the MSS is one that exhibits maximum cost effectiveness within the limits established by the project guidelines and constraints. This approach involves the use of a well-defined baseline; a planned design process; established design process interfaces; controlled constraints; recognized limitations; control of design quality; design for long life, maintainability, and commonality; and a balance of performance features. The initial baseline is defined in the preliminary performance specifications, and the planning process and design process interfaces are defined by the Phase C/D program plans. Constraints on design are provided through NASA direction and guideline documents, and design standards are provided through corporate operating policies. Design quality is provided through rigorous control of design prior to release; modularity, maintainability, commonality, reliability, safety, and standardization are provided through management direction and design review; a balance of performance features is provided through design trades.

NAS 9.9953
MODULAR SPACE STATION
WORK BREAKDOWN STRUCTURE

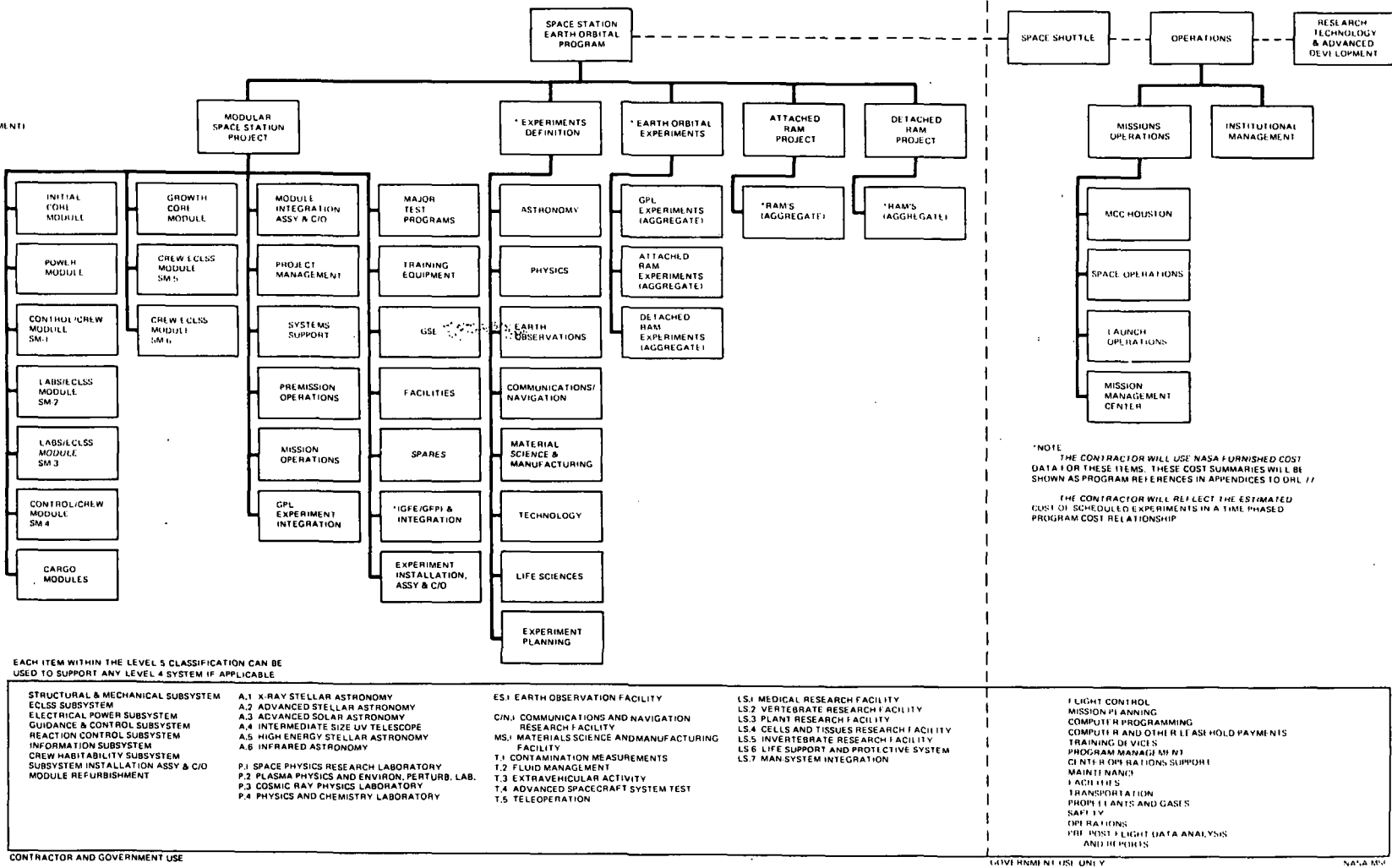
CONTRACTOR ONLY WBS

LEVEL 2 (PROGRAM)

LEVEL 3 (PROGRAM ELEMENT) (PROJECT)

LEVEL 4 (SYSTEM)

LEVEL 5 (SUBSYSTEMS)



*NOTE
THE CONTRACTOR WILL USE NASA FURNISHED COST DATA FOR THESE ITEMS. THESE COST SUMMARIES WILL BE SHOWN AS PROGRAM REFERENCES IN APPENDICES TO DRL //

THE CONTRACTOR WILL REFLECT THE ESTIMATED COST OF SCHEDULED EXPERIMENTS IN A TIME PHASED PROGRAM COST RELATIONSHIP

Figure 3-12. Program Summary Work Breakdown Structure

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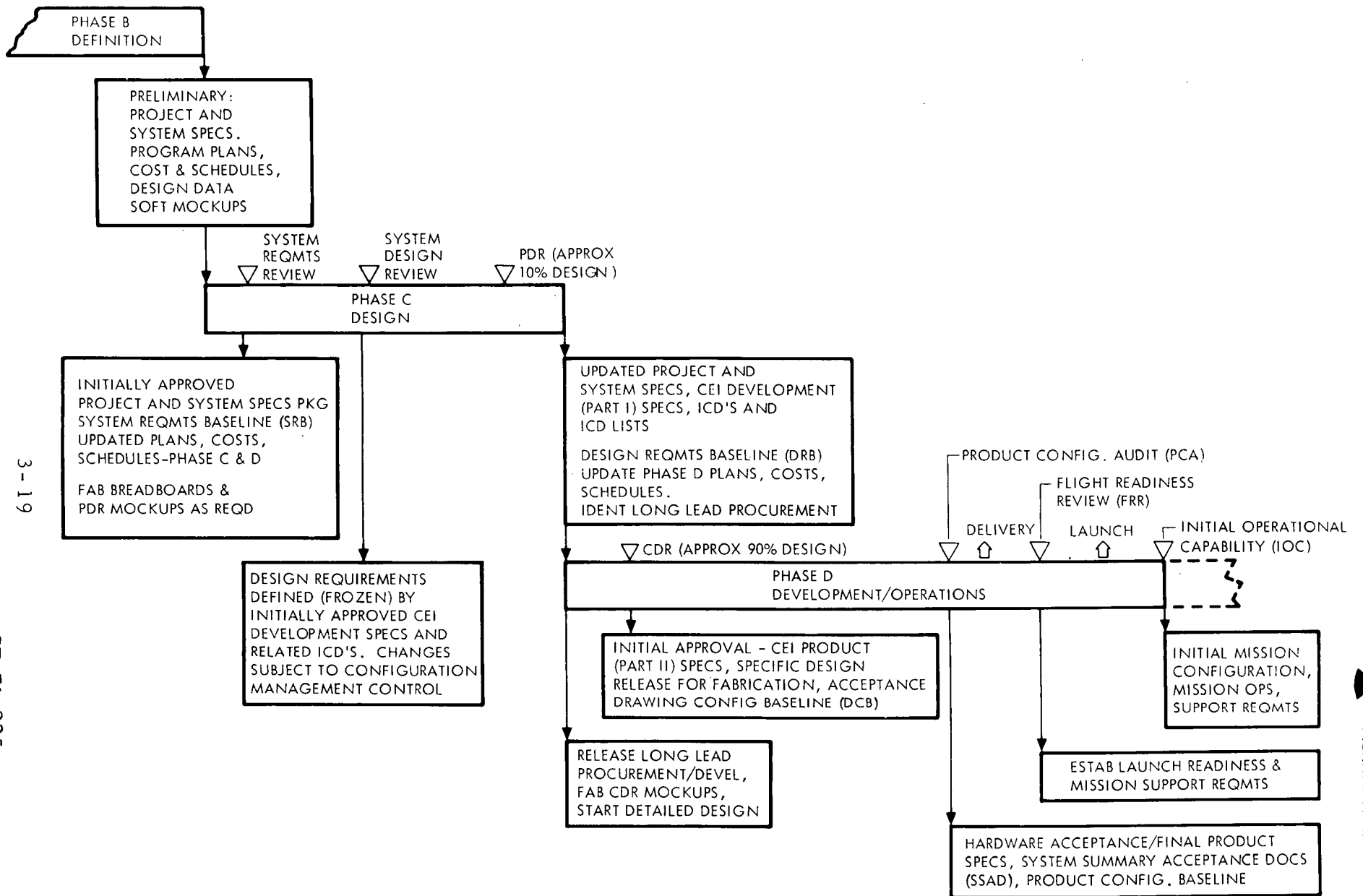


Figure 3-13. Project Phasing and Major Products

3-19

SD 71-225



Space Division
North American Form 1-11

Cost avoidance in the design process is accomplished by the selective use of interactive graphics (computer-aided design), numerical design, scientific computer programs, production drafting, and early application of change control and selection of materials and processes. Cost avoidance resulting from the design quality program is anticipated in materials, quality assurance, manufacturing, and test.

The first set of reviews in Phase C consists of the system requirements reviews (SRR's), which are conducted progressively on a functional basis by the customer. Three reviews are required to assess the system engineering documentation for the space station; the first is a review of the documentation for the mission performance function; the second is a review of documentation for the test and checkout function; and the third is a review of the supply and maintenance function documentation. The documentation prepared or updated specifically for these reviews includes the functional flow charts, project and systems specifications, functional baselines, operational analyses, development plans, trade-study reports, technical studies, and effectiveness criteria. Design products preparatory to these reviews are specified in SD 70-137 Space Station Design Plan. Other integral documentation updated during the period prior to the SRR includes the systems requirements preliminary interface identification, the contract end-item (CEI) identification, and the computer program contract end-item (CPCEI) identification.

A system design review (SDR) is conducted after definition has proceeded to the point at which the action items from the SRR's are closed, the project/systems specifications are approved, the design approach is defined to the extent that CEI's and critical items are described by initial development specifications, major interfaces and interface control document (ICD) lists are identified, and elementary schematics are developed. The SDR is performed in sufficient detail to ensure that technical agreement and understanding between NASA and the contractor are achieved before preliminary detail design is initiated.

A preliminary design review (PDR) is conducted by NASA for each CEI or group of functionally related CEI's to verify that the design approach satisfies the performance requirements. These reviews serve to determine the technical adequacy of the preliminary design and to verify compliance with the requirements established in the project or system specifications and other requirements documents. These result in formal concurrence or new technical direction from the customer regarding preliminary design efforts. They are also employed to establish the design requirements baseline (DRB) for subsequent detail design efforts by approval of CEI and CPCEI development specifications.

Prior to the PDR, a number of significant tasks are completed: preliminary design concepts are defined; all technologies and specialties are reviewed to assure that the state-of-the-art is adequate for detail design; producibility and operability of the design are analyzed from the layouts, schematics, and preliminary detail design; project and system specifications are updated; initial CEI development (Part I) and Government-furnished property (GFP) and Government-furnished equipment (GFE) performance-and-interface (P&I) specifications are prepared; quantities of pre-mission and mission ground support equipment (GSE) CEI's are determined; ICD contractual index and status reports are initiated with the preparation of key ICD's; and functional integrated schematics are initiated. Approximately 10 percent of the preliminary design, primarily related to long-lead-time critical items, is accomplished and released before PDR; long-lead-time procurement is identified; initial procurement specifications are prepared; preliminary selection of material and processes is made; breadboard testing is accomplished; PDR mockups are completed; and mockup requirements for critical design review (CDR) are identified.

Space station experiment provisions become firm design-to requirements at PDR and, therefore, impose constraints and limitations on the experiment program interfaces.

The experiment provisions and common use equipments (i.e., structures, docking interfaces, rendezvous interface, electrical power, environmental control, communications and control, etc.) are sequenced with constraints of volume, weight, electrical power, human factors, and trajectory. Consumables and resupply are analyzed, and ICD's necessary for space station experiment integration at CDR are identified and listed.

Phase D Design

Following PDR and approval of PDR results, detail design of test and production hardware and facilities is initiated. The detail design process produces the engineering documentation; e.g., initial CEI product (Part II) specifications, detail production drawings, assembly drawings, installation drawings, etc., required for production and review at the critical design review (CDR). During detail design, the requirements stated in the approved system and development specifications are reviewed, and top drawings and related ICD's are incorporated by reference.

Critical design reviews of CEI's, or groups of CEI/CPCEI's, are conducted to determine that the recommended detail design adequately reflects the requirements contained in the approved system and development (Part I) specifications; and that the design solution insures effective interfaces among the CEI's, CPCEI's, personnel, facilities, GFE, and GFP. System engineering documentation, especially interface control drawings (ICD's) governing the interface problem areas related to detail design, are approved by NASA and the participating contractors and included as appropriate in the development

or product specifications. These reviews are accomplished when the detail design is essentially complete; initial product (Part II) specifications are prepared; schematics, CDR mockups, or prototype hardware are reviewed; and fabrication drawings are readied for release to manufacturing. The product of the CDR is the acceptance of a specific design and approval of its release for fabrication. Documentation so approved constitutes a drawing configuration baseline (DCB) for the remainder of Phase D. Subsystem CDR's are conducted in advance of the CEI CDR's on an as-required basis. These reviews provide an advanced assessment of the major CEI CDR's.

During the development and fabrication following the CDR, but prior to product configuration audit (PCA), intermediate baselines are established as deemed necessary for control of product configuration; e.g., configuration freeze or qualification approval. A product configuration audit is conducted for designated CEI's, or groups of CEI's or CPCEI's, to obtain formal NASA acceptance of development and product specifications, drawings, hardware and software configurations, and acceptance test documentation. The PCA assures that the as-built configuration of a CEI matches its product configuration or that differences are reconciled, and verifies that the acceptance requirements prescribed by the documentation are adequate for acceptance of the CEI. Establishment of the product configuration baseline and the acceptance of the CEI or CPCEI's initiate the drawing and design maintenance activity (as contractually specified) for delivered products.

DEVELOPMENT TEST PROGRAM

The development test section of SD 71-222 MSS Integrated Ground Operations, establishes the basic development philosophy and checkout flow, identifies requirements for the utilization of existing and new test facilities, and serves as a guide for preparation of detailed development plans for the individual MSS subsystems and major test articles during Phases C and D. Also contained therein are descriptions of subsystem development issues, test requirements, checkout sequences, and checkout hardware and facilities requirements at the manufacturing and launch sites. A summary of key test program activities is presented in the following paragraphs.

Test Philosophy

The primary goal in all test activity is to acquire confidence that the equipment will perform its required functions in mission environment in a satisfactory manner. Even in the early development testing to validate concepts or selected components, the final goal is confidence in mission performance. Since an objective way to measure confidence has not yet been devised, test requirements are usually developed subjectively. The tendency is to test a great deal more than is really necessary and to lose sight of the end objective. The test becomes a test for tests sake rather than a building

block in the establishment of confidence. Recognition of the need for objective test evaluation has resulted in the creation of specialized test disciplines such as qualification, acceptance, prelaunch checkout, etc.

These test disciplines have evolved to the point that the need for them and their contribution to the overall confidence level is rarely questioned. For example, the approach to acceptance testing in most hardware programs has become one in which the passing of an acceptance test is the goal itself. A malfunction detected at that point results in a test failure and normally a complete recycle with the attendant wear and tear on the systems. A better approach is to consider the acceptance test as another link in the confidence chain. When a malfunction occurs, success has been achieved since a weak point has been exposed. A further extrapolation of this philosophy is to make use of the detected malfunction to exercise and evaluate the associated maintenance routines, thus gaining a bonus dividend in confidence that the planned isolation, mission continuation, and repair procedures are adequate. In no case should the subsequent recycle go any farther back than is necessary to re-establish the test configuration at the time of a malfunction.

A key factor in being able to apply this philosophy to modular space station testing is a rigorous test planning activity prior to the start of the test program. Each test in the program must be planned and phased with data utilization in mind. Each planned test must be assessed for its contribution to the overall confidence goal.

Ground Rule Summary

The ground rules for ground operations, as presented in SD 71-222, are designed to assure an integrated approach to test, manufacturing, ground support equipment, facilities, flight crew training, logistics support and prelaunch operations. The use of a common data base as the prime factor for integrating the several ground operations activities is a basic requirement for achieving launch confidence (Figure 3-14).

Cost avoidance is stressed by setting as a goal, maximum commonality of structures between like modules; and the commonality of subsystem assemblies, subassembly GSE, etc., between the MSS and the shuttle to the maximum extent possible. Additional cost avoidance is accomplished by integration of development, qualification and acceptance testing, and space operations.

The ground rules for test stress of the integration of requirements, procedures and data for development, qualification, acceptance, and launch operations as well as the use of the onboard checkout (OBCO) capability of the information subsystem (ISS) for acceptance and checkout.

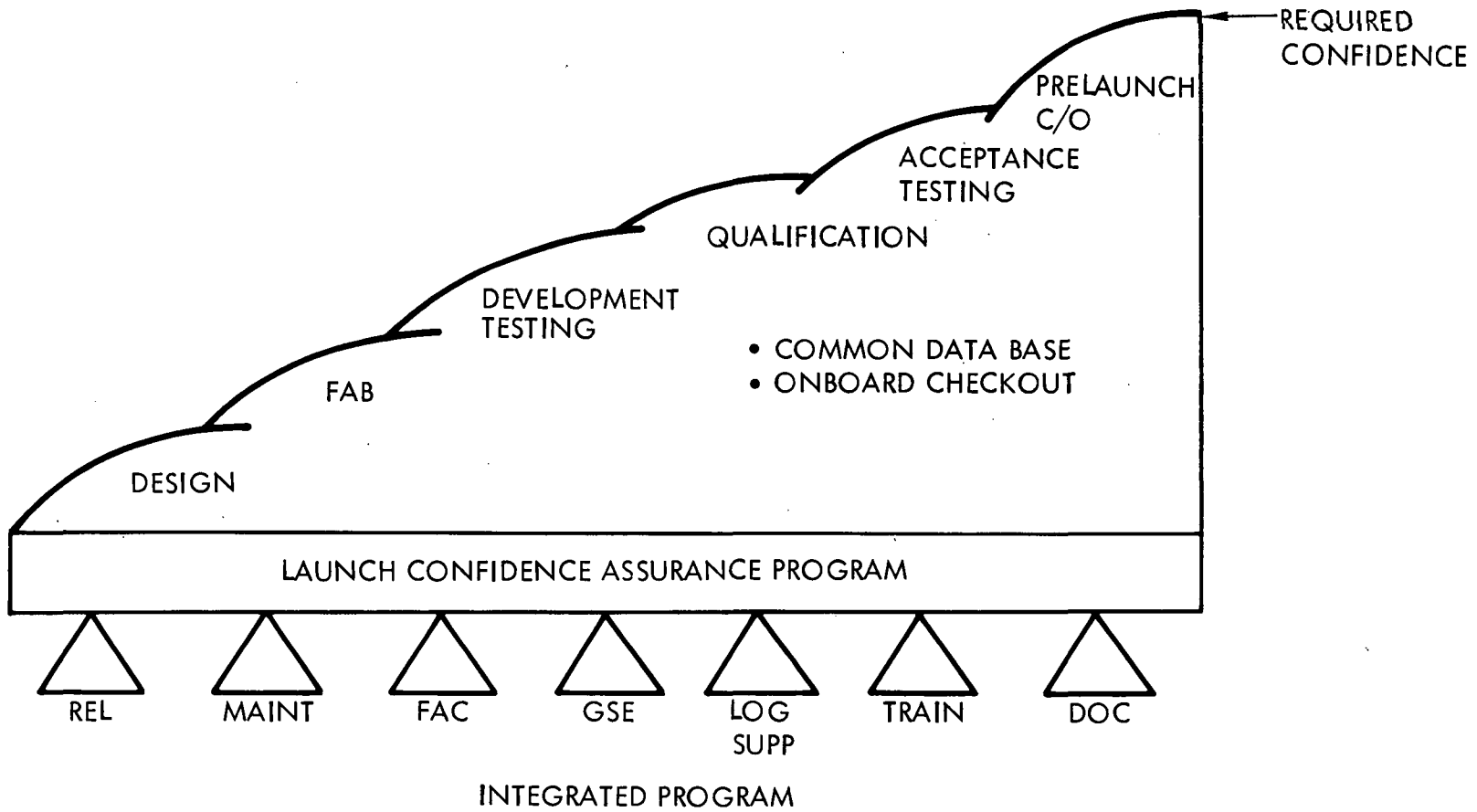


Figure 3-14. Integrated Program

Manufacturing ground rules provide for integration into the total ground operations by providing for:

1. Commonality of parts and processes to reduce tooling
2. Tying the production operations with other ground operations by use of the common data base
3. Utilizing the OBCO capability to the maximum extent possible for in-process testing

Ground support equipment (GSE) and facilities ground rules provide for:

1. A goal of shuttle-station GSE commonality
2. Minimizing the requirements for special-purpose GSE
3. Utilization of existing facilities with a minimization of rework

Ground rules for integrating crew training into the total ground operations suggest:

1. Crew participation in the checkout sequences
2. Use of the ISS capability to simulate operational situations
3. The need for dedicated training facilities to satisfy the continuing crew training requirement

Maintenance and logistics support ground operations ground rules provide for the following:

1. The ISS and the common data base provide the basis for configuration management and resupply requirements, program spares, and consumable inventories controlled by ground computer facility.
2. Development of maintenance procedures will be a requirement of the subsystems development programs.

Prelaunch and refurbishment ground rules state that:

1. Modules will be individually checked out using the mission support vehicle (MSV) to provide the intermodular functions.

2. Combined tests of those modules required to accomplish the basic station functions of multiple berthing, power generation, and subsystem control will be conducted prior to launch of the initial module.
3. The OBCO capability will provide primary prelaunch checkout functions.

Development Requirements Analysis

Development requirements analysis is the technique utilized for identifying and analyzing test issues. It involves analysis of the project elements and their subsystems in relation to functional requirements, trade studies, buildup concepts, design concepts, failure analysis, and crew tasks. Application of the test philosophy to the results of the development requirements analysis provides a logical determination of test article requirements. A summary of the major test articles required for the MSS project is given in Table 3-1. The major test hardware utilization logic is depicted in Figure 3-15. To minimize costs, multiple use of the hardware is made throughout the project.

MANUFACTURING

During Phase C, manufacturability criteria are established through producibility studies, and a manufacturing baseline document and the Manufacturing Plan are prepared using the background data generated during the Phase B study as a guideline. The manufacturing effort includes preplanning activity in all disciplines of the manufacturing cycle: initiation of long-lead-time procurement of raw materials and tooling; initiation of the manufacturing development programs where necessary to support the preliminary design requirements; and fabrication of mockups in accordance with engineering requirements to support the preliminary designs.

During Phase D, design of tooling, test equipment, and handling equipment is given final release for fabrication and procurement. Engineering drawings and specifications are received, planned, and released as manufacturing orders, tool orders, and material requisitions for shop and procurement action. Spares requirements are identified and authorized. Materials are ordered, received, stored, prepared, and staged for shop use. Firm plans, budgets, schedules, and directives are released and maintained. Fabrication, assembly, installation, test, and shipment of end-item hardware to the using site is accomplished according to schedule. Software and physical resources support to launch operations are provided promptly on demand before and after shipment of end-items. Efficient communication lines are maintained throughout this process to assure rapid dissemination of direction, information, and problem alerts, and to maintain general management

Table 3-1. Major Test Hardware Configuration

ARTICLE	UTILIZATION																											
	STRUCTURAL TEST							DYNAMIC TEST							COMPATIBILITY ASSESSMENT							ACCEPTANCE AND MSV						
	STR	ISS	RCS	ECS	EPS	G&C	C&H	STR	ISS	RCS	ECS	EPS	G&C	C&H	STR	ISS	RCS	ECS	EPS	G&C	C&H	STR	ISS	RCS	ECS	EPS	G&C	C&H
CORE 1							1**	.75	.75	.75	.75	.75	0	1**▲	1P	1P	1P	1P	1P	0	1		1					
CORE 2																					0	1F	1F	1F	1F	1F	1P	
CORE 3	1*	0	0	0	0	0																						
COMMON 1														1**▲	1P	0	8PR	1P	0	0	0	1F	0	1FR	0	0	1P	
COMMON 2	1*	0	0	0	0	0								(1)▲	8P	1P	8PR	1P	0	0	0	.7F	0	1FR	0	0	1P	
COMMON 3							1**	.75	0	.75	0	0	.75	(2)▲	1P	0	8PR	1P	0	0	0	1F	0	1FR	0	0	1P	
POWER 1	1*	0	0	0	0	0								(1)▲	1P	0	1P	1PR	0	0	0	0	0	0	0	0	0	
POWER 2							1**	0	0	1S	.95	0	0															
SUMMARY																												
TOTAL REQTS		STRUCT	ISS	RCS	ECS	EPS	G&C	C&H																				
CORE MODULE		3 PRI 2 SEC	1F 1P 0.7S	1F 1P 0.7S	1F 1P 0.7S	1F 1P 0.7S	1F 1P 0.7S	1P — —																				
COMMON MODULE		3 PRI 3 SEC	2.7F 2.8P 0.7S	— 1P —	3F 2.4P 0.7S	1F 3P —	— — —	— 3P 0.7S																				
POWER MODULE		2 PRI 1 SEC	— 1P —	— — —	— 1P 1S	— 1P 0.9S	— — —	— — —																				

CODES

▲	ENVIRONMENTAL SHIELD NIC	R	RADIATORS NOT USED FOR HEAT REJECTION
*	PRIMARY STRUCTURE	**	PRIMARY SECONDARY BERTH RING AND GPL FURNISHINGS
S	SIMULATED SUBSYSTEM	A	SOLAR ARRAYS NOT INSTALLED
F	FLIGHT-TYPE SUBSYSTEM		
P	PROTOTYPE SUBSYSTEM		
(1)	SECONDARY STRUCTURAL + BERTHING RING		
(2)	BERTHING ASSEMBLY ONLY		

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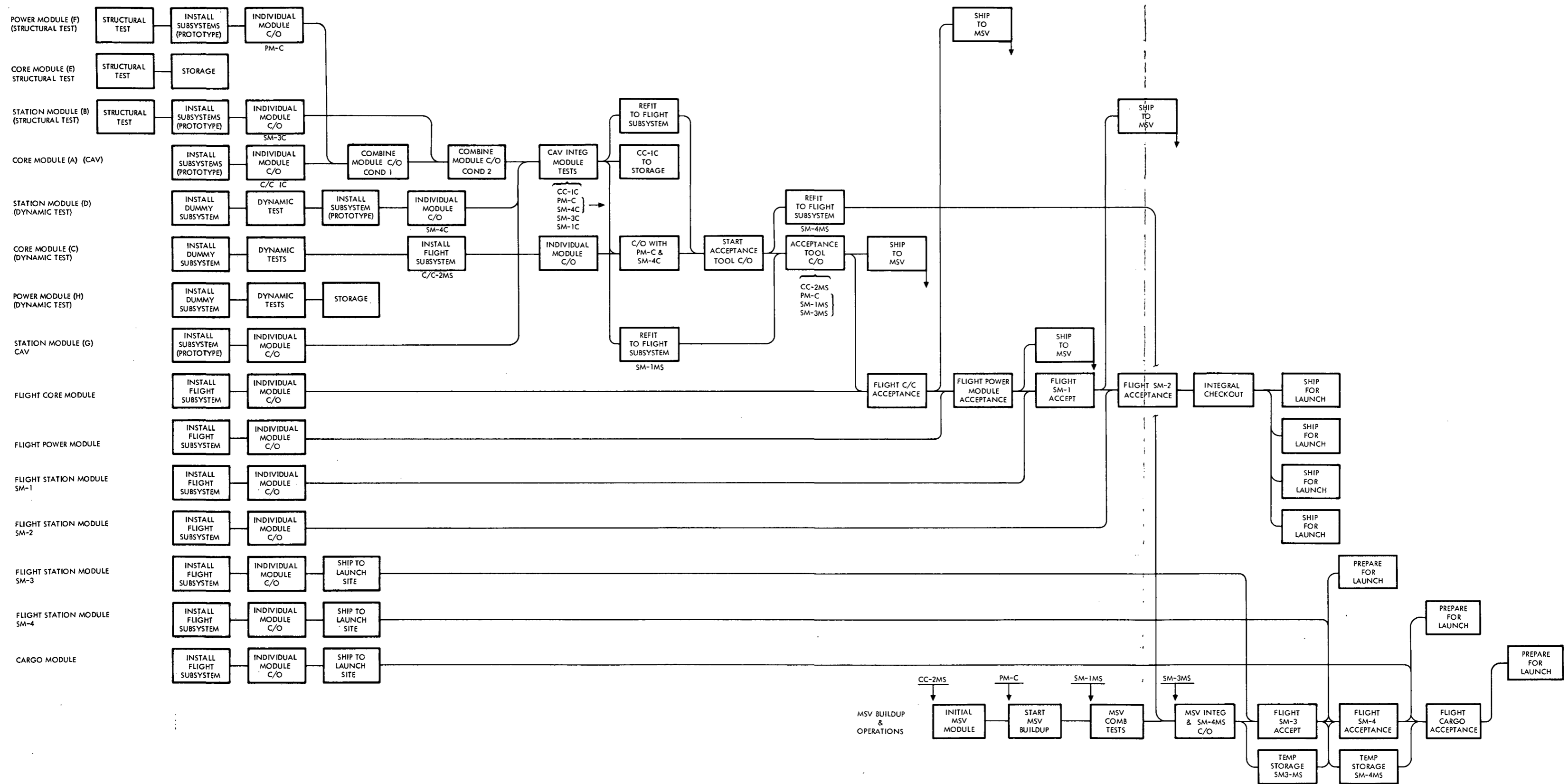


Figure 3-15. Major Hardware Utilization Logic

visibility. Figure 3-16 indicates the flow of the overall manufacturing process during Phases C and D.

The modular space station structural hardware can be produced within the current manufacturing state-of-the-art. No new special manufacturing techniques are anticipated. Major elements of the assembly sequence for a typical station module are illustrated on Figure 3-17. Additional information relative to detailed manufacturing requirements are contained in the SD 71-222 MSS Integrated Ground Operations document.

TRANSPORTATION AND DELIVERY

The primary objectives of the transportation and delivery activity are to ensure that reliability and functional capabilities of the hardware are not degraded and that maximum safety is provided in handling and movement of MSS hardware elements.

During Phase C and the early part of Phase D, plans and procedures are developed and finalized for transportation of the core, power, and station modules from the manufacturing and acceptance site to the shuttle launch site at Kennedy Space Center (KSC). Air transportation is designated as the mode of delivery for all modules in order to minimize packaging, handling, and transit time. Except for short distances, truck or rail shipment is not cost-effective due to considerations such as route clearance, raising of utility lines, tree trimming, roadway and bridge modifications, etc. Special transporters are used for movement of modules, in a horizontal position, from the acceptance site to the aircraft loading site, and from the shuttle landing runway at KSC to the Manned Spacecraft Operations Building (MSOB) for receiving inspection and other operations discussed in the Launch and Prelaunch paragraphs. During transit, alarm and recording systems and transducers and recorders for measuring in-transit shock are provided.

Figure 3-18 illustrates the sequence of movement of modules during the delivery phase; additional details regarding transportation are contained in the SD 71-222 MSS Integrated Ground Operations document.

PRELAUNCH AND LAUNCH OPERATIONS

Figure 3-19 represents the overall schedule of activity for prelaunch and launch operations, commencing with facility preparation and continuing through growth station operations. This includes GSE installation and check-out, buildup of the MSV, and the preparation for and launch, or relaunch, of all MSS modules. The schedule also provides for use of these capabilities in support of experiment/RAM operations.

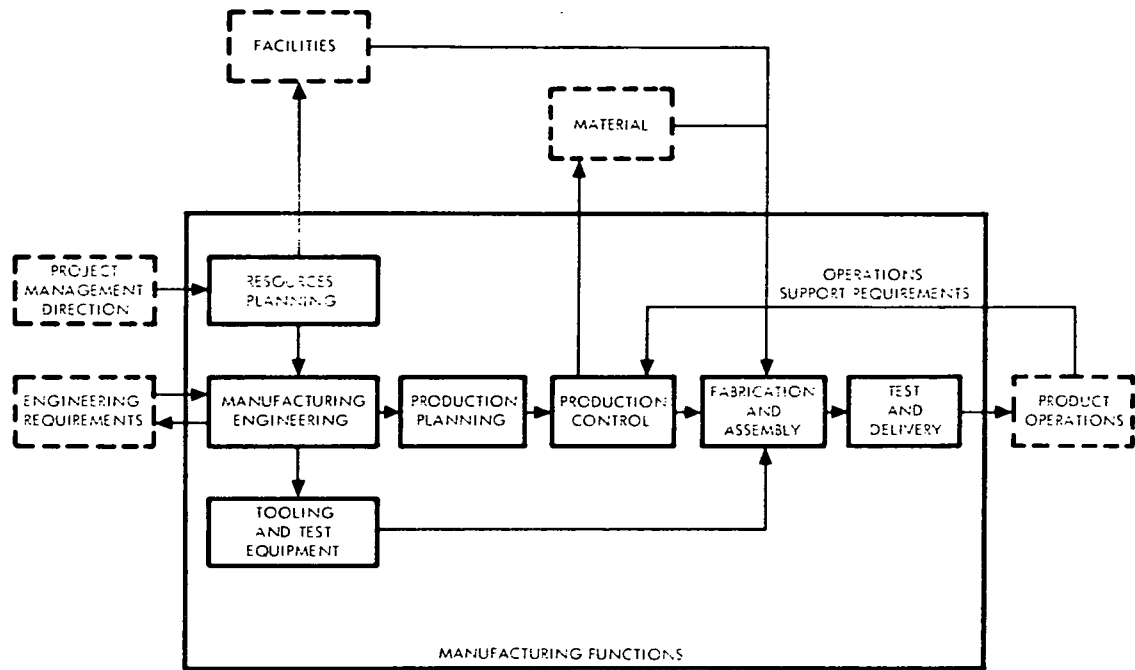


Figure 3-16. Manufacturing Process

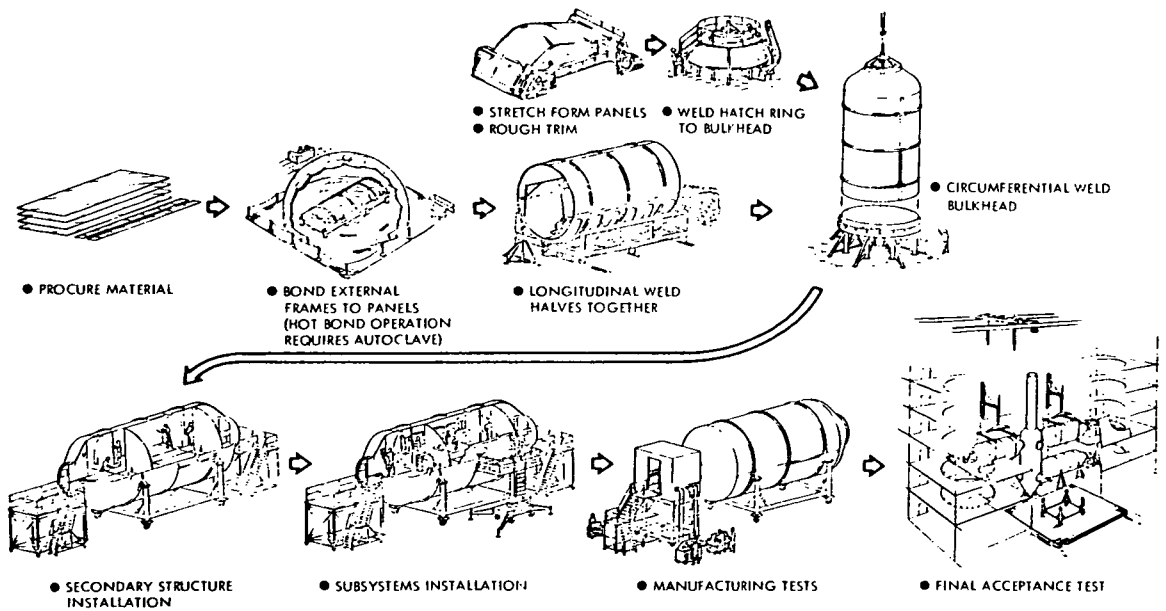


Figure 3-17. Station Module - Manufacturing Assembly Sequence

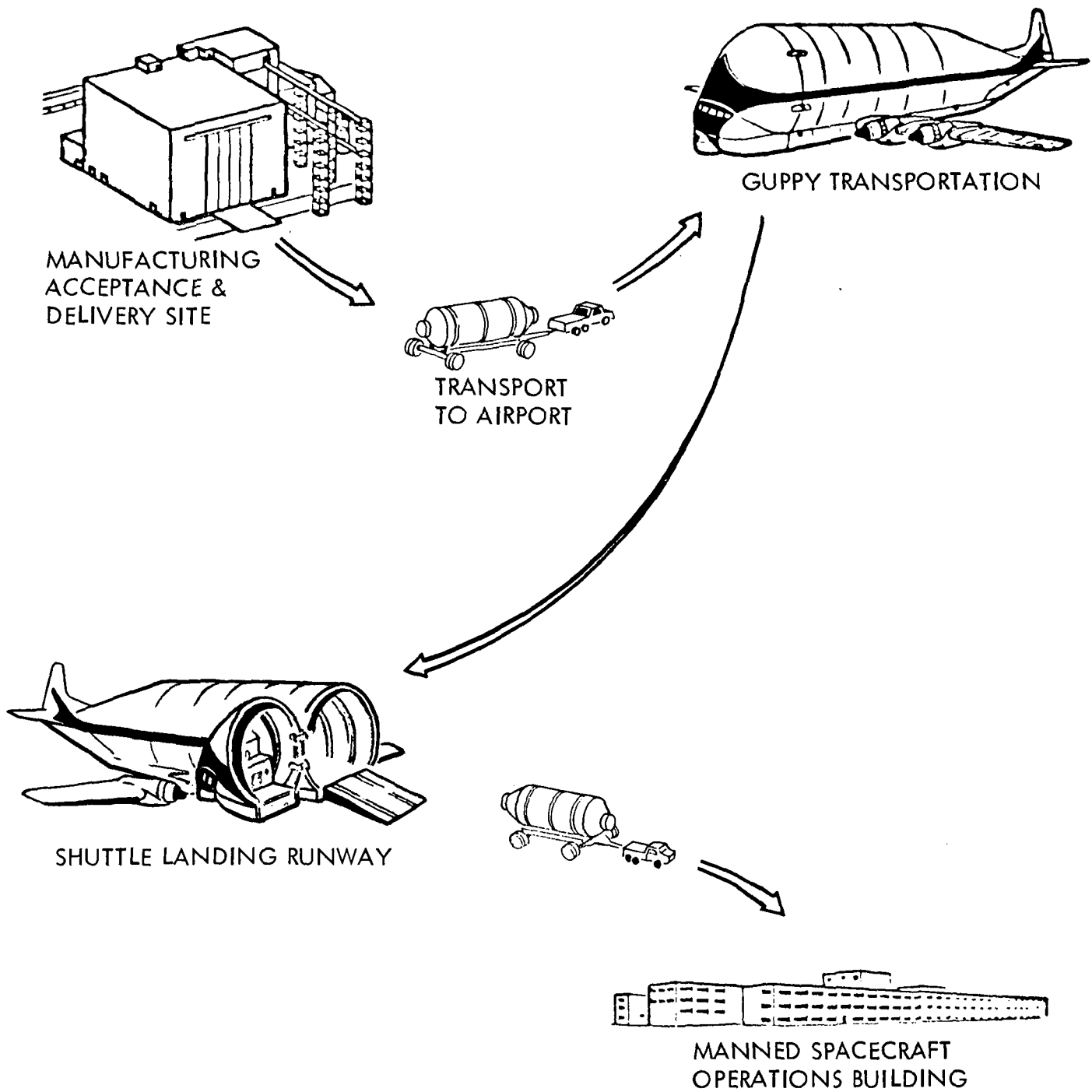


Figure 3-18. Transportation Flow - Space Station Modules

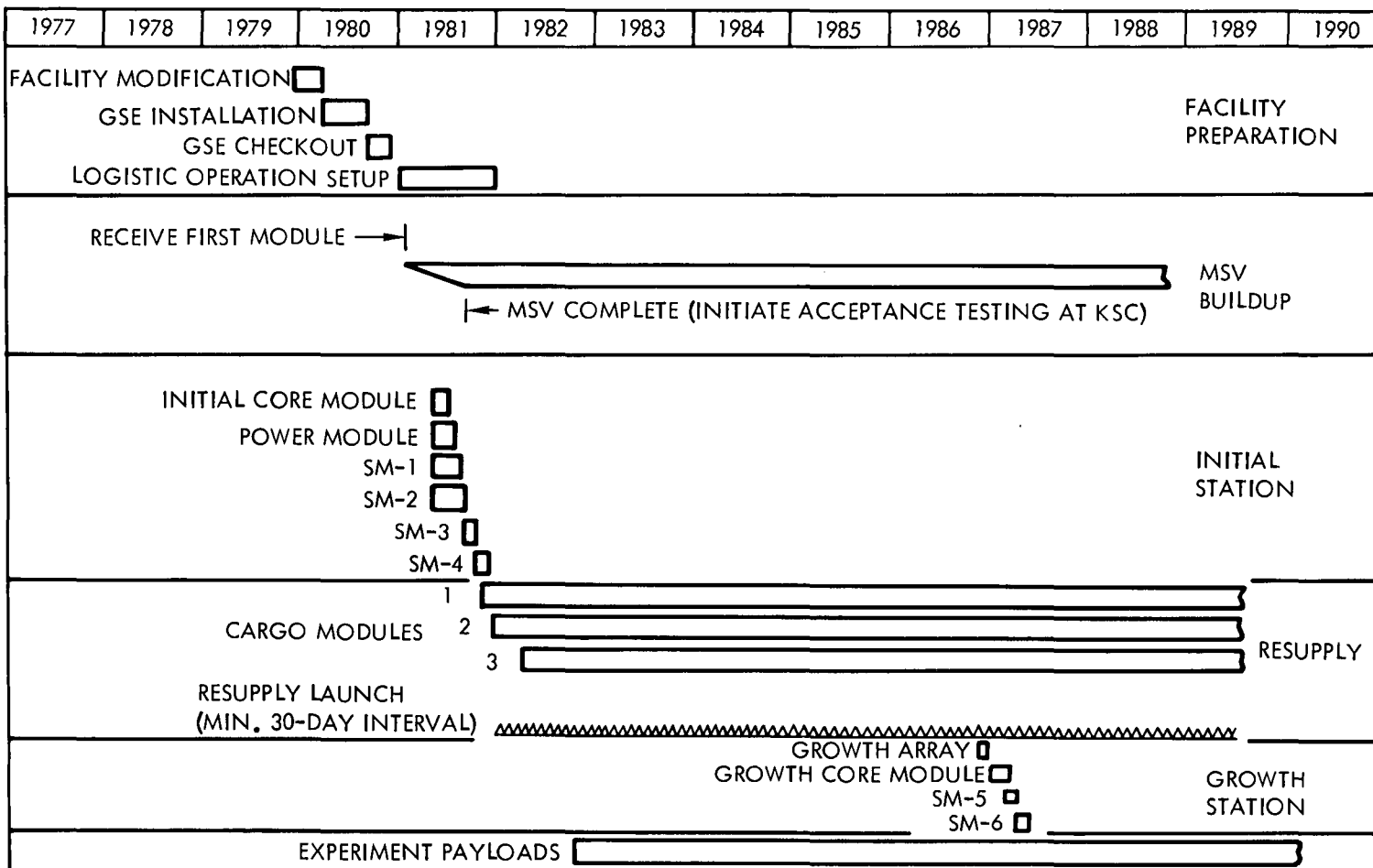


Figure 3-19. Launch Site Schedule

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On Figure 3-20, a typical flow path for modules is shown. Upon delivery from the manufacturing site, or upon return from orbit, the modules and their transporters arrive at the shuttle landing runway. New modules are transported directly to the MSOB, whereas cargo modules and RAM's returned from orbit are removed from the shuttle orbiter at the Vehicle Assembly Building (VAB), then transported to the MSOB for servicing. When ready for launch, or relaunch, all modules are installed in the orbiter at the VAB, and the mated orbiter/booster is transferred to the pad for launch operations.

New modules arriving at KSC fall into two categories: those that have had their acceptance tests performed at the factory, and those that will be accepted at KSC. The first four MSS modules (core, power, SM-1 and SM-2) are physically mated and receive integrated checkout and acceptance prior to shipment to KSC; therefore, prelaunch operations on those modules are limited to system verification type tests with the universal test equipment (UTE) provided by NASA. Acceptance capability is incrementally built up at KSC as MSV modules become available from the factory development test and compatibility assessment programs, and is fully established to support the arrival of module SM-3. Figure 3-21 shows the MSV installation in the MSOB.

The MSOB is the primary facility for conducting prelaunch operations on MSS modules and RAM's. This includes receiving inspection and servicing of new and recycled modules, system verification tests, berthing and module interface fit checks, and simulation and verification of physical and functional interfaces between the orbiting station and individual experiments, spare assemblies, and complete RAM's prior to their transport to orbit. The MSOB also provides a field-level capability for planned cargo module refurbishment.

After receiving inspection of a typical module and prior to mating with the UTE/MSV, an electrical interface verification is performed to determine the status of the module. Checks are made for continuity, resistance, and connector condition. The -X end of the module is then berthed, power and control cables are attached to the UTE/MSV, the module is activated, and functional verification of subsystems is conducted. A second mechanical berthing interface check is made between the +X end of the module and the orbiter, using an orbiter berthing simulator which provides electrical power and commands to the module when attached. This simulator is engaged by means of an overhead crane.

Upon completion of MSV interface operations, MSS modules and RAM's are transported directly to the VAB for loading into the orbiter at approximately 20 hours prior to shuttle rollout to the launch pad. Cargo modules are routed through the warehouse for loading of non-time-critical items. All modules are weighed and their centers of gravity determined prior to movement to the VAB.

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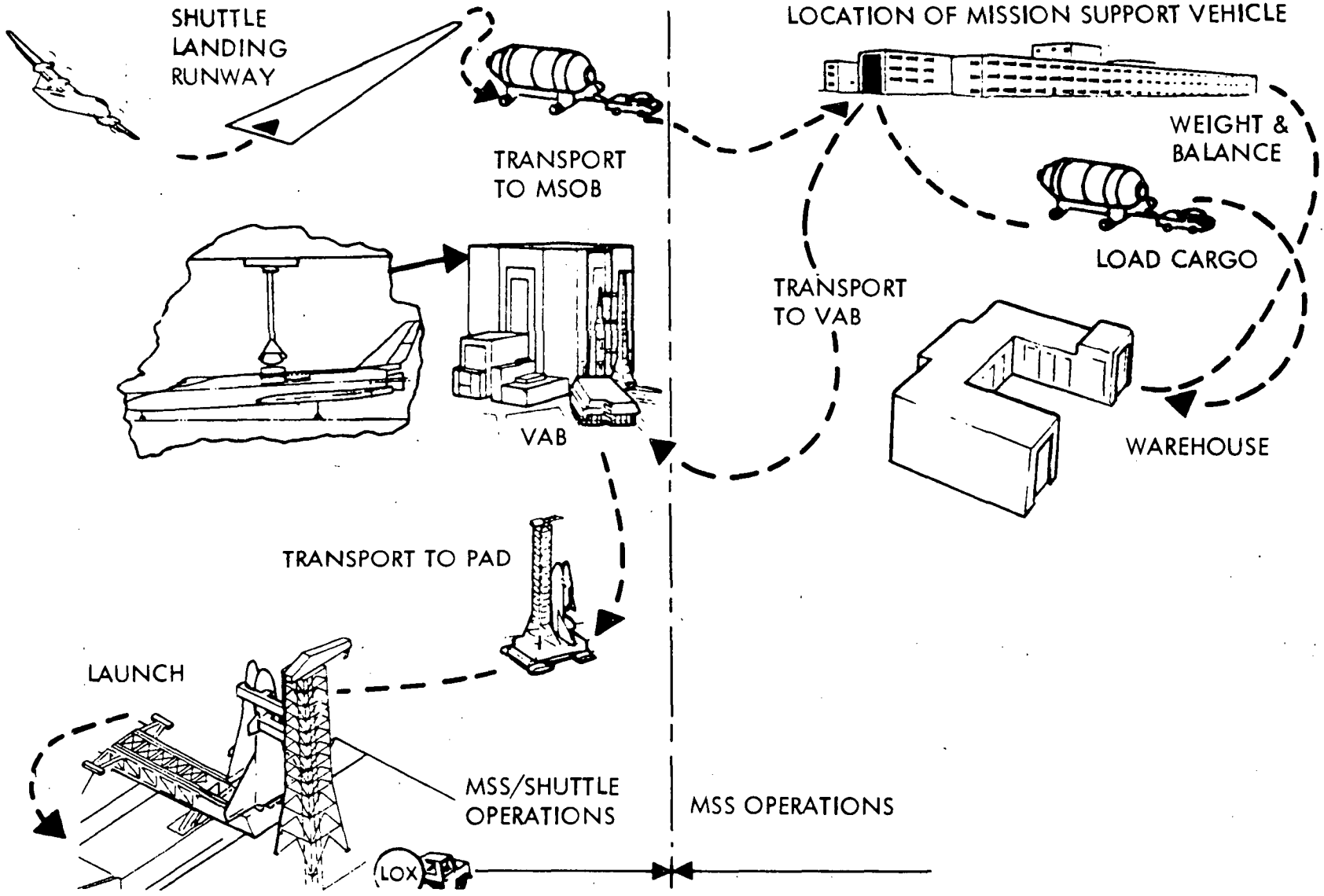


Figure 3-20. Typical MSS Module Flow at Launch Site

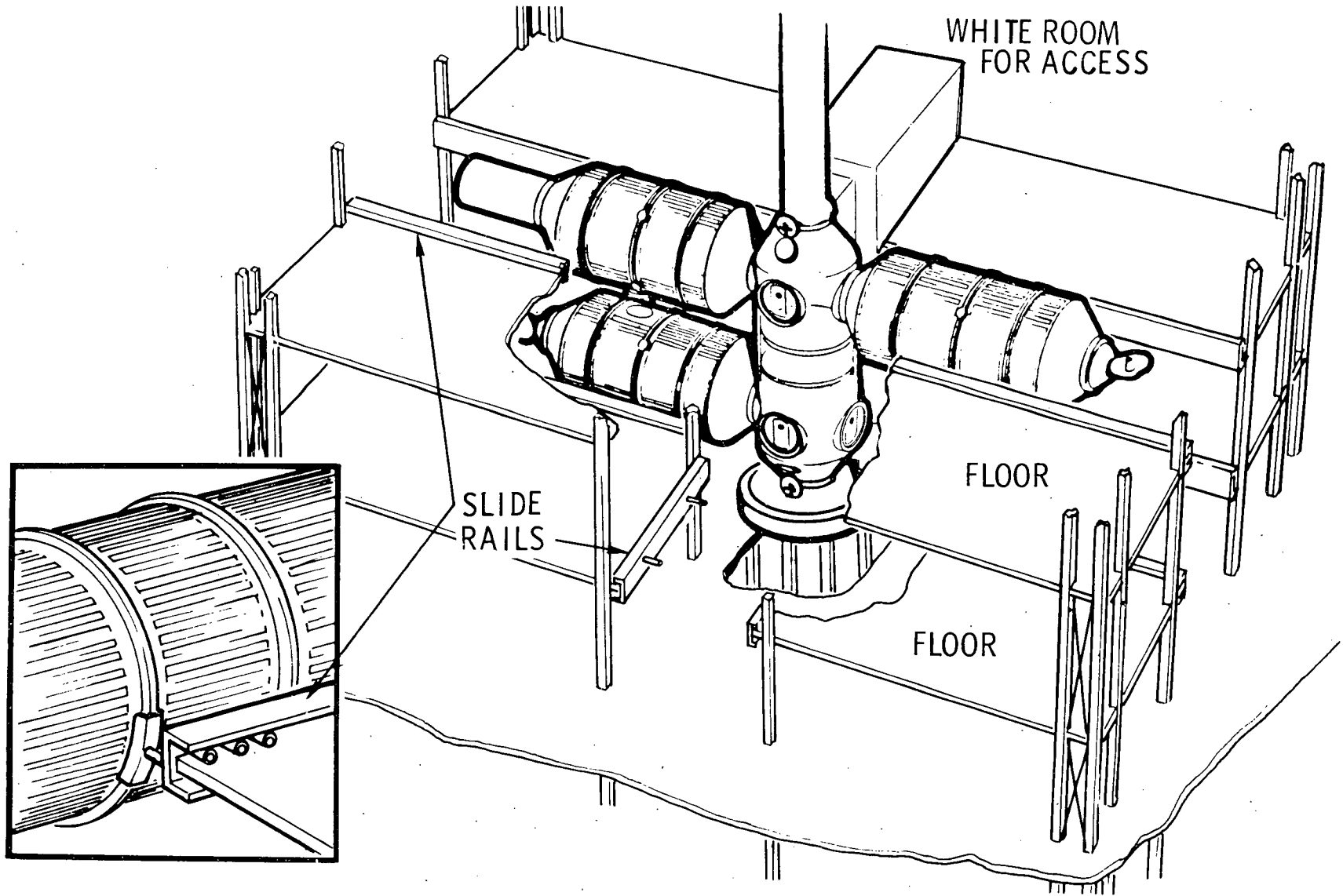


Figure 3-21. Mission Support Vehicle Installation—MSOB

At the VAB, the module is hoisted in a horizontal position above the orbiter and lowered into the cargo bay, the aft interface is established, and the orbiter cargo retainer and centering device is engaged. The crew in the orbiter cockpit makes all necessary checks of subsystem continuity and position indicators. Installation GSE is then removed from the cargo bay and the bay doors are closed.

The orbiter is mated to the booster in a vertical attitude, the shuttle is positioned on the launch umbilical tower (LUT), and transferred to the launch pad by the crawler-transporter. At the pad, the LUT is secured to the pedestals, shuttle-to-ground service connections are made, and the station/RAM modules are checked in preparation for the mission readiness test.

Launch operations are initiated with the loading of shuttle propellants, and time-critical consumables and cryogenics are loaded aboard cargo modules, when applicable. Flight personnel and/or station crews are brought on board, final system activation and countdown operations are performed, and the space shuttle is launched.

Further details regarding these launch site operations are contained in the SD 71-222 MSS Integrated Ground Operations document.

ORBITAL OPERATIONS

Assembly and Buildup Approach

All modules are launched with complete subsystems. This approach results in a design which minimizes the impact on station activation for normal subsystems operations.

With all subsystems installed at launch, with no internal connection breaks and with fluid lines filled, on-orbit assembly operations are reduced primarily to module-to-module interface connections, verification, and checkout. Other startup operations such as subsystem filling, purging, and recheck are eliminated.

The assembly and buildup approach is organized to allow only minimum system activation until permanent manning occurs. Only those subsystems required to maintain the station in a quiescent mode between launches are activated. Some subsystems are deactivated during quiescent operations; for example, the reaction control subsystem, most of the ECLS subsystem (except for atmosphere and thermal control), internal lighting, etc.

A wakeup receiver provides the communications link from ground or shuttle to the station, which has the capability of interrogating subsystem

status, turning quiescent systems on and off, and commanding attitude orientation and control, etc.

Initial Station Buildup

Figure 3-22 illustrates the buildup sequence of the initial MSS. Preferably, the initial module to be delivered to orbit has a minimum amount of scar equipment over and above that required for normal operations. Trade studies have shown that this objective was best achieved with the initial core module launched first, followed by the power module. These two assembled modules are flown in a gravity gradient mode at minimum (nearly quiescent) power between buildup launches.

A subsequent launch adds the first control/crew module (SM-1). The solar arrays are partially deployed and operated automatically with the now-present ISS. The configuration is now flown oriented about the principal axis and the regenerative segments of the fuel cells are activated. In subsequent sequence, the first lab/ECLSS module (SM-2), the second lab/ECLSS module (SM-3), and the second control/crew module (SM-4) are added at 30-day launch intervals.

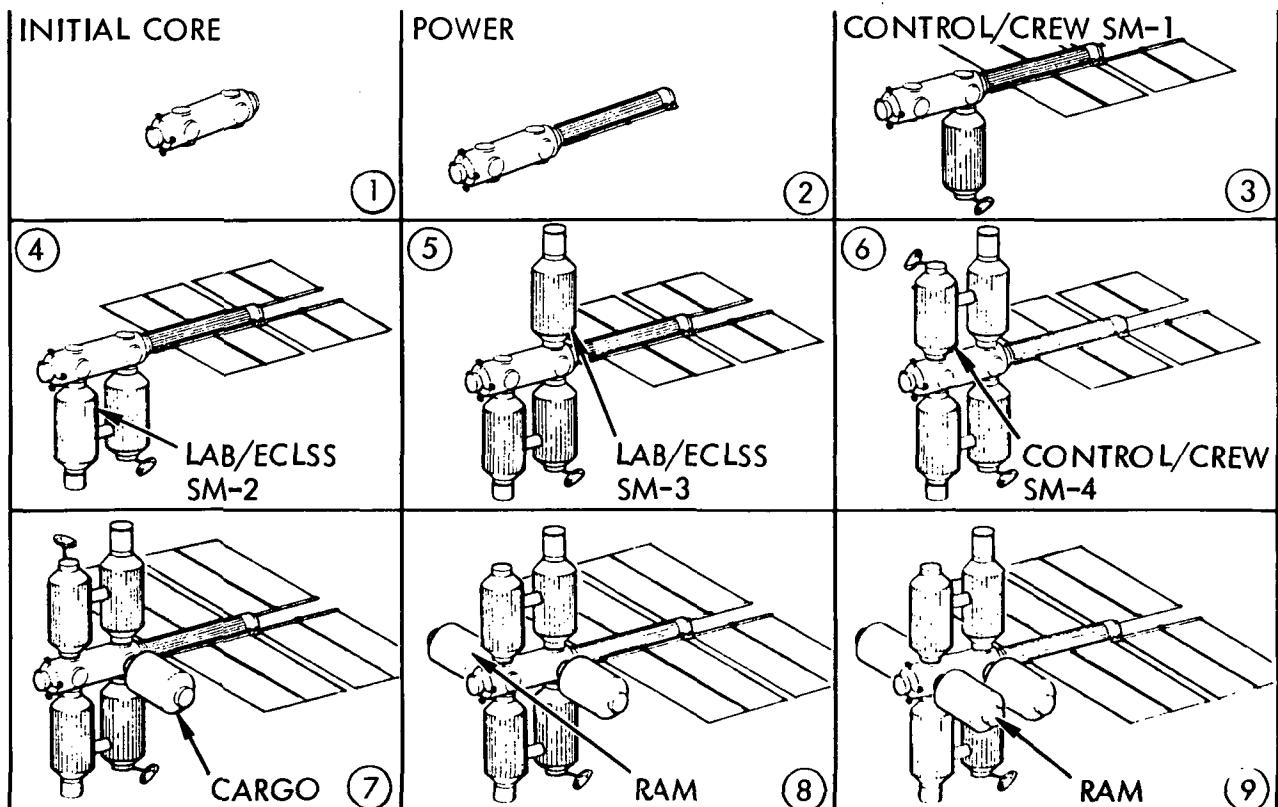


Figure 3-22. Initial MSS Buildup Sequence

Although Figure 3-22 indicates the numerical sequence of buildup, there are still station module alternate sequence variations that are viable options. An example, would be putting step ⑤ before step ④. This provides a more balanced configuration, but defers the early flexport assembly between SM-1 and SM-2 shown in step ④. Seven module launches are required to reach the initial operational capability (IOC) of the 6-man space station. Redundant subsystems in complete general purpose laboratories are available at this point to begin the program of experiment operations for a 6-man crew. Provisions are available for the subsequent addition of two RAM's, shown in steps ⑧ and ⑨ of Figure 3-22, during the initial space station operational period.

Typical Delivery Operations Sequence

The sequence of operations shown in Figure 3-23, is typical for the delivery of almost any station module, but is specifically directed to the first control/crew module since a significant amount of activation and checkout occurs at this stage of station buildup.

As illustrated, the shuttle containing the control/crew module activates the on-orbit core and power module cluster approximately 90 minutes prior to berthing the core and power cluster to the shuttle crew ingress/egress hatch. (An adapter is utilized between the core and shuttle to compensate for the different hatch envelope dimensions.)

Shuttle and station interface connections include caution and warning connections, core module TV hardwire connection, and air circulation ducts for humidity control and CO₂ removal.

As noted, suited crew ingress into the core module is performed for the functions listed prior to initiating the berthing of the control/crew module (SM-1). After berthing, two crewmen will normally work in a shirtsleeve environment to make all module-to-core fluid/gas/electrical connections and verification.

Following the control/crew module hookup and verification with the core module, the activation and checkout of many subsystem assemblies can proceed. The order of activation is as listed on Figure 3-23: (1) the information system in the control/crew module; (2) the fluid loops in the control/crew module external radiators; (3) deployment of the solar arrays; (4) power transfer from fuel cells to arrays; (5) initiation of regenerative fuel cell energy storage; and (6) startup of the control moment gyros.

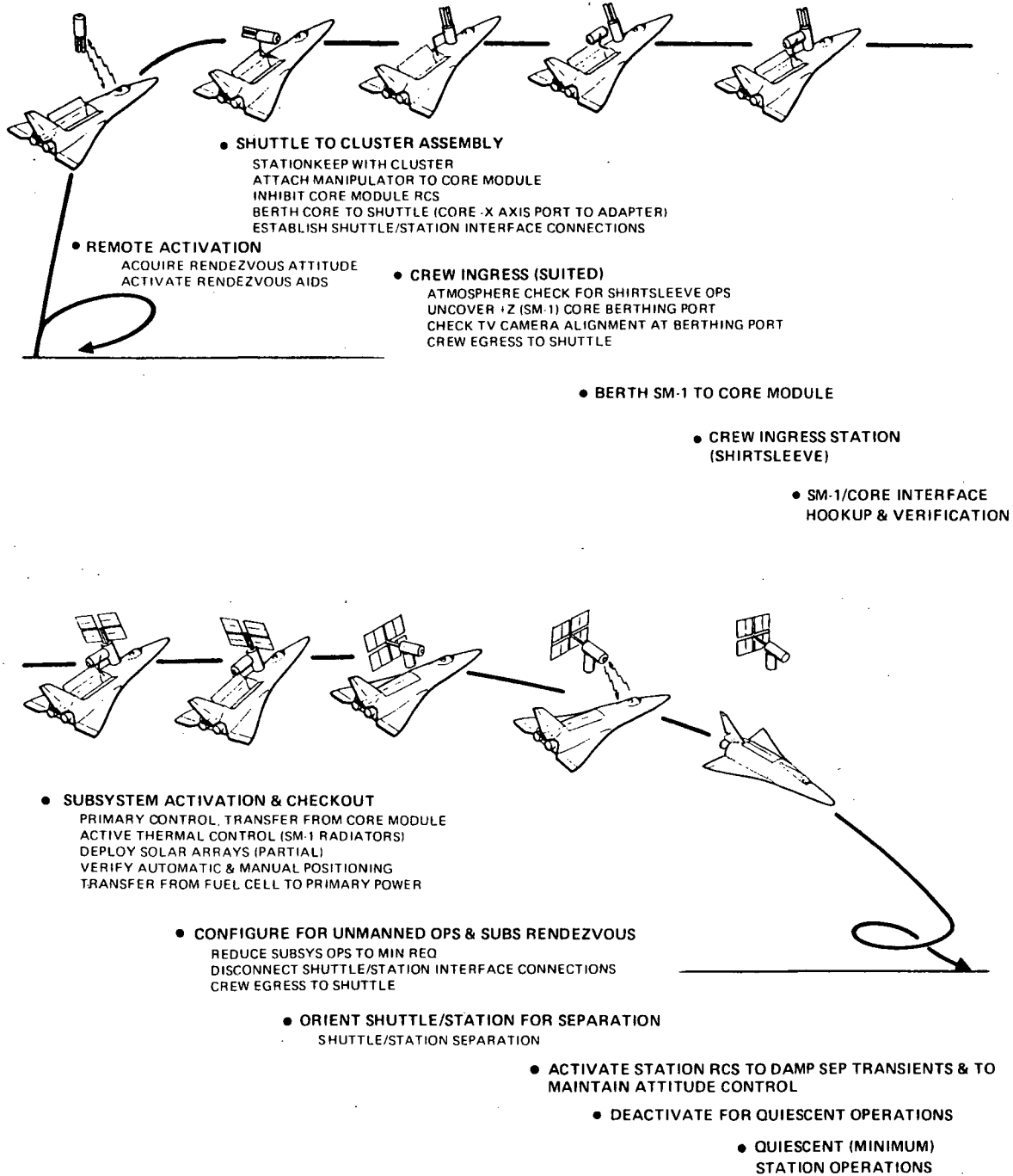


Figure 3-23. Typical Delivery Operations Sequence

After shuttle separation from the station cluster, the station maintains an orientation which minimizes RCS propellant expenditure. All major activated systems remain activated at this point in the buildup sequence. Some minor functions associated with manned operations are deactivated when the buildup crew leaves.

Flight Mode

The modular space station is capable of maintaining a local vertical hold and an inertial hold flight mode. This provides the basic stable platform mode for earth viewing and solar/stellar viewing instruments, respectively.

The reference flight mode orientation is illustrated on Figure 3-24. The X-axis is perpendicular to the orbit plane (toward the south), the Z-axis is along the local vertical (down) and the Y-axis is opposite the velocity vector. The flight mode acronym therefore is X-POP, Z-LV, Y-OVV. This mode will be flown at all times except for the short periods of inertial flight for solar/stellar viewing and shuttle approach and berthing/unberthing operations.

The X-POP flight mode is selected based on minimizing solar array shadowing by the station modules, best in-plane ground viewing, best orientation for combined orbit makeup, and control moment gyro desaturation.

Growth Station Buildup

Growth station capability is achieved by the addition of two station modules with crew quarters and life support, and by the addition of a short growth core module with added fuel cell and electrolysis equipment. The solar array is replaced with a 10,000-square-foot array. The growth station buildup sequence is shown in Figure 3-25. Crew buildup to the 12-man level is completed following step (14).

Mission Sequence Plan

The mission sequence plan provides the time phasing of the program elements with emphasis on the scheduling of experiments. The final mission sequence plan is described in detail in the MSS Preliminary System Design, SD 71-217, Volume II, and presents the experiment time phasing, accommodation mode, crew requirements, and logistics requirements. The resultant total orbital program, including initial and growth station buildup, and the conduct of one cycle of Blue Book experiments covers a time span of approximately 16 years.

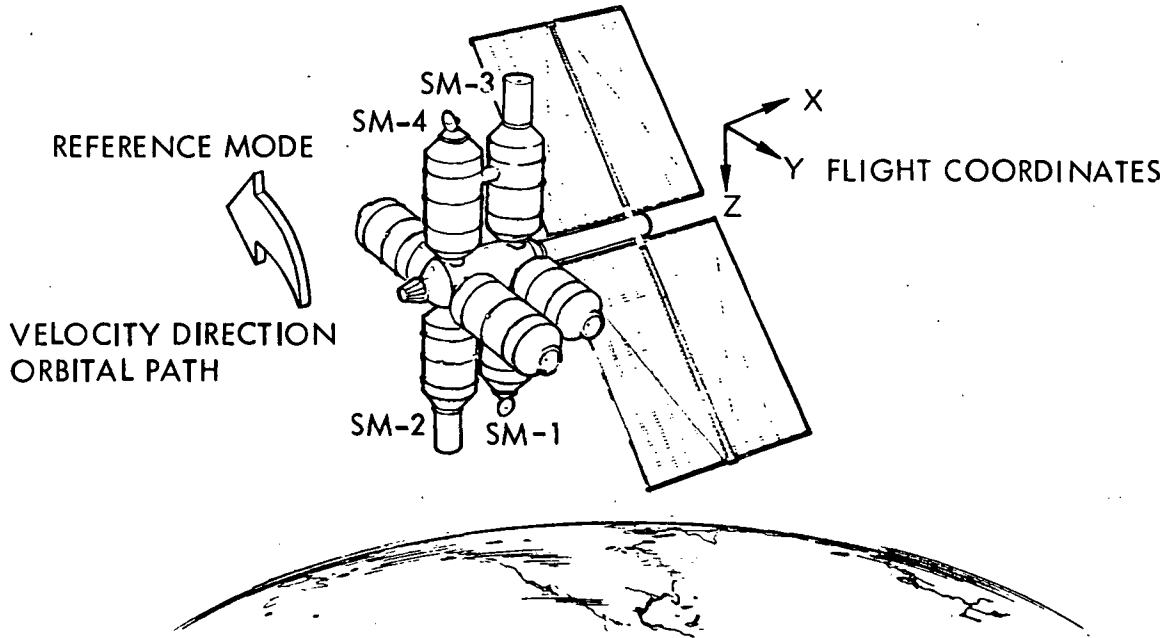


Figure 3-24. Reference MSS Flight Mode

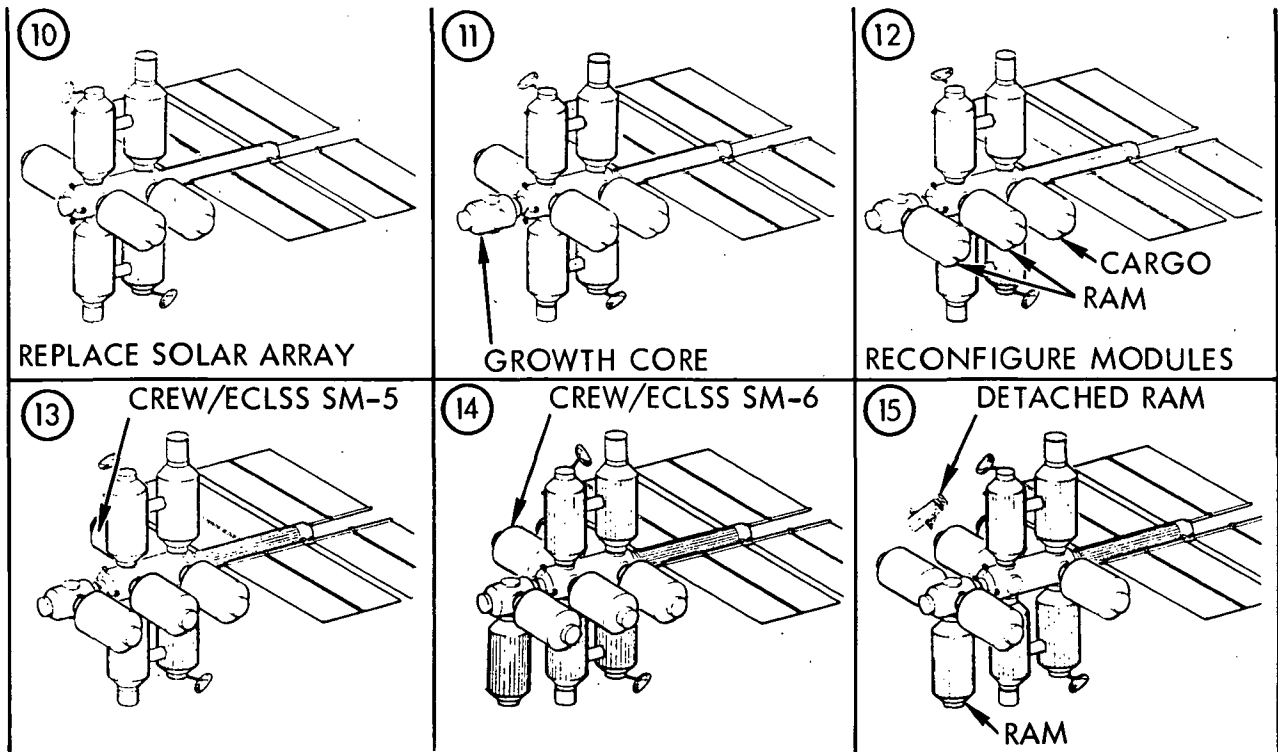


Figure 3-25. Growth MSS Buildup Sequence

The mission sequence plan and the associated experiment scheduling is intended to be representative of the operations of the modular space station. It is not intended to represent the experiment program which must be scheduled since the space station has the inherent capability and flexibility to accommodate alternate programs: e. g., one which emphasizes socio-economic benefits or one which emphasizes advancements in scientific knowledge. The mission sequence plan is intended to emphasize certain fundamental characteristics. For example, by defining an initial level of experiment activity (Level II), the majority of the functional program elements (FPE) can be accommodated early in the space station program while deferring some of the experiment equipment development costs until after the space station development peak annual funding. The Blue Book level of activity (Level III) is then deferred until the growth space station which provides a "facility capability" for accommodating the FPE's, as defined by the Blue Book. In this respect, the mission sequence plan illustrates the capability of the selected design concept to accommodate the Blue Book in a balanced program wherein all disciplines are represented throughout the program.

Crew Requirements

The basic crew requirements are divided into those requirements associated with station operations, experiment support operations, and experiment operations. The crew requirements for station operations and experiment support operations for the initial space station are on the order of 25 man-hours per day. These operations include the routine daily operations of the space station, routine and periodic maintenance, house-keeping, monitor and control of detached RAM's, etc. The experiment operations are those operations associated with the daily conduct of the space station experiments. Based on 25 man-hours per day for station operations and experiment support operations and a 10 hour work day, approximately 35 man-hours per day are available for experiment operations for the initial space station. The corresponding crew time distribution for the growth space station is approximately 30 man-hours per day required for station operations and experiment support operations leaving 90 man-hours per day for experiment operations.

Logistics Requirements

Approximately 1900 pounds of cargo per month are required for basic operations of the initial space station whereas 3600 pounds per month are required for the growth space station. Based on the experiment scheduling in the mission sequence plan, approximately 1000 pounds of cargo per month are required for operations of the initial space station experiments and 1800 pounds per month for the growth space station experiments.

are required for the delivery and return of RAM's and the support sections necessary for the operation of detached RAM's. For the experiment program (mission sequence plan) previously identified, only two support sections are required to support detached RAM operations. A third support section is provided for backup. RAM's and support sections are periodically returned to earth for refurbishment and redelivered to orbit for further utilization.

The resultant total shuttle support requirement is 134 flights: 35 flights for the initial space station, and 99 flights for the growth space station including the four shuttle launches for delivery of the station modules necessary for buildup to the growth space station. The resultant launch frequency is approximately one every eight weeks for the initial space station and one every six weeks for the growth space station.

Modular Space Station Disposition

Station disposition will be accomplished by the sequenced return of each module to earth. Experiment modules will be returned first, followed by disassembly of the growth space station in the reverse sequence used for buildup. The major exception to this sequence is that a cargo module (for gaseous propellants) will remain attached to the core module until all station modules and the power module are returned. Thus, the final return sequence will be: station modules, power module, cargo module, and core module.

Mission Support

Mission support operations are conducted throughout the space station program. During early and unmanned program phases, actual operational control is provided by the mission operations support system. During most manned phases, mission support activities consist of long-range planning and executive management of program operations. Mission support operations include mission management, ground tracking, communication, and crew training and conditioning.

PROJECT WORK BREAKDOWN STRUCTURE

The work breakdown structure (WBS) for the modular space station project is graphically displayed in Figure 3-27. It has been developed from the NASA-furnished program summary work breakdown structure shown in Figure 3-12. Only those categories of products (hardware, services, functions) of the program summary WBS that are a part of the MSS project have been developed to lower levels commensurate with that of the technical definition attained in this phase of the project. Space station flight modules are displayed to the subsystem level (Level 5); other project WBS elements are limited to the system level (Level 4). Further development of the WBS will be accomplished as future phases of the project enable more definition. (Refer to Section 5.0 of this plan.)

Descriptions of each item shown in Figures 3-12 and 3-27 are provided in the WBS dictionary contained in SD 71-226 MSS Program Cost and Schedule Estimates.

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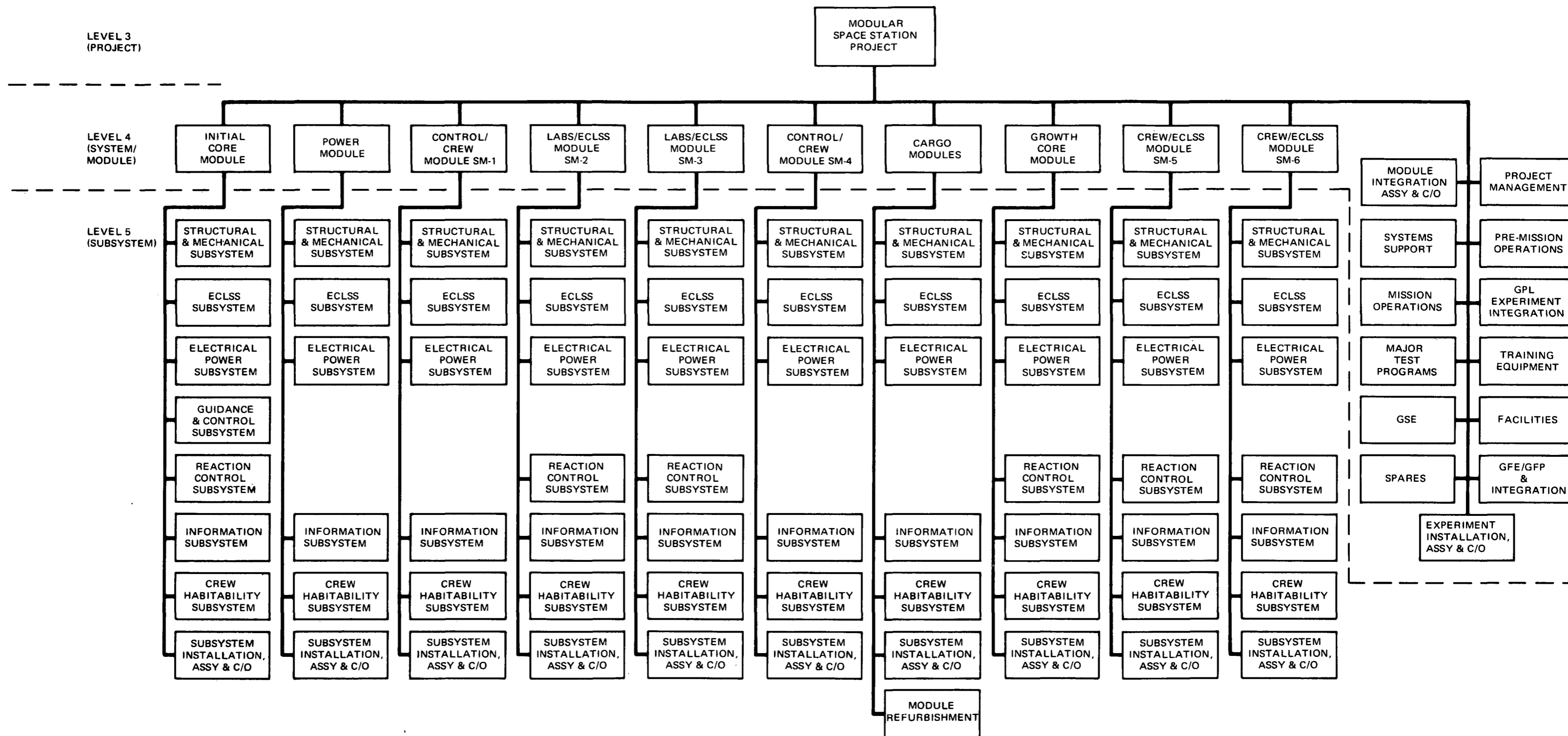


Figure 3-27. MSS Project Work Breakdown Structure

PROJECT MANAGEMENT NETWORK

Figure 3-28 is the logic network for the MSS Project. It depicts all major activities and events and their interrelationships, time-phased over the life span of the project. Key milestones are identified for both technical and administrative tasks, including formal reviews, major test program completions, and launches.

This network provides visibility into activity constraints, and will be one of the Program Manager's primary tools for assessing progress in achieving MSS project objectives. Requirements for its further development and application during Phases C and D are established in Section 5.0 of this plan.

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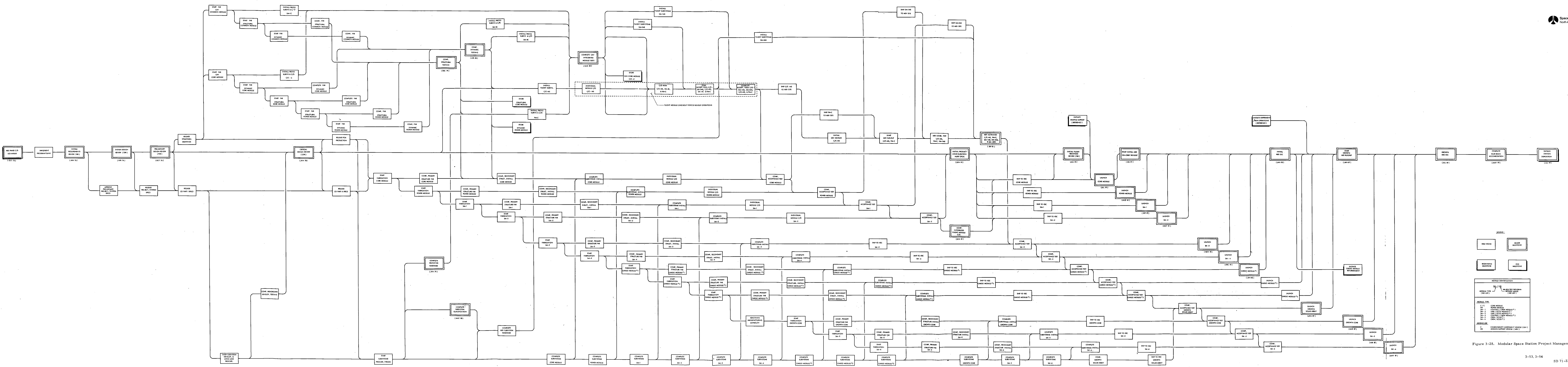


Figure 3-28. Modular Space Station Project Management Network

PROJECT MASTER SCHEDULE AND KEY MILESTONES

A summary of all program elements involved in the NASA Space Station Earth Orbital Program and the time-phased relationship and interaction among the elements is presented on Figure 3-29. A detailed schedule covering all program elements is contained in SD 71-226 MSS Program Cost and Schedule Estimates; however, only the modular space station project is detailed herein. The dotted lines corresponding to the "end funding projections" milestone indicate the limit to which funding for each project is forecast in SD 71-226, and is repeated herein for reference only.

APPROACH

The approach to preparation of the MSS project master schedule includes the following:

1. Establishment of ground rules and assumptions.
2. Consideration of schedule data from the NASA Apollo, Skylab and space shuttle programs.
3. Application of schedule data from the contractor's hardware programs.
4. Extraction of applicable data from technical analyses conducted during the Phase B Definition Study.
5. Preparation of a preliminary hardware tree reflecting the MSS design to ensure that all systems, subsystems, and components are considered for development analysis.
6. Preparation of a project WBS identifying the hardware, software, services, and tasks that must be considered in preparing a master schedule.
7. Determination of the number and purpose of prototypes, mockups, test articles, and flight hardware.
8. Preparation of a list of key project milestones arranged in chronological order.

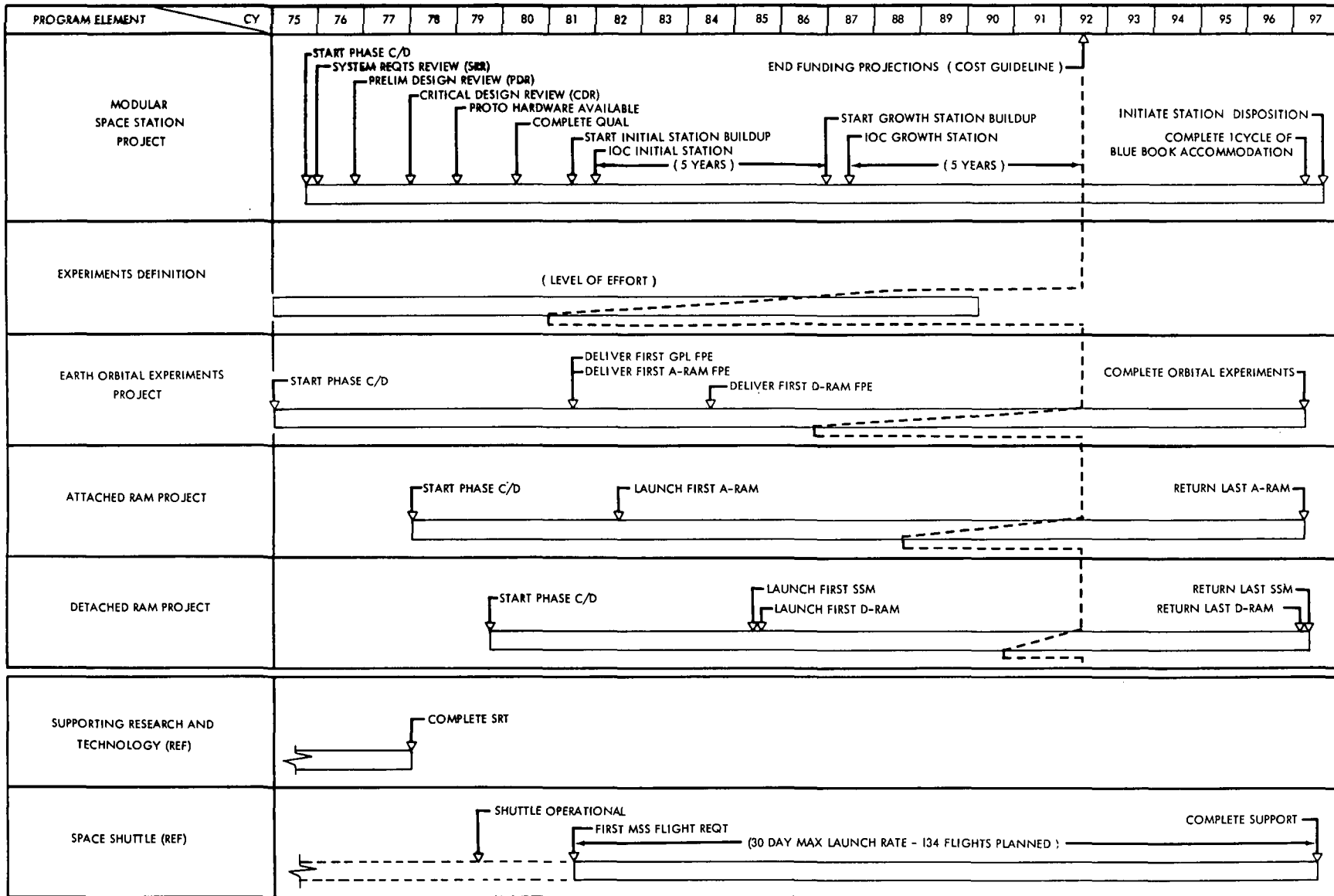


Figure 3-29. Program Summary Phasing Schedule

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9. Preparation of a project management network that establishes sequence and interdependency of events.
10. Analyses of the previous information and translation of the systems and subsystems requirements into development requirements.
11. Construction of the master schedule through an iterative process that takes into account all of the preceding factors.

GROUND RULES AND ASSUMPTIONS

The following ground rules and assumptions were established to provide a common baseline and frame of reference for preparation of the MSS project master schedule:

1. An integrated schedule is required for all MSS project effort from the initiation of Phase C through completion of mission requirements.
2. The MSS Phase B study has defined the MSS configuration and established requirements for its development.
3. Phase C and Phase D will be continuous and cover the span from October 1975 through completion of support for the experiment program.
4. All MSS module launches will be made from the Kennedy Space Center via the space shuttle, at a frequency no greater than once every 30 days. Launches will support the mission sequence plan provided in SD 71-217 MSS Preliminary System Design.
5. Air transportation will be utilized for shipment of modules from the manufacturing site to KSC.
6. Existing contractor and Government facilities will be utilized; requirements for modified or additional facilities and related equipment will be kept to the minimum.
7. The first four MSS modules will require concurrent, integrated checkout and acceptance prior to shipment and launch of the first module.



8. Capability for complete module acceptance testing will be provided at KSC at the earliest practicable time, by incremental buildup of the MSV from development hardware. KSC systems verification capability will be initiated prior to arrival of the first flight module from the acceptance site.
9. One set of major assembly tools for special modules (core and power) and one set for "common" (station and cargo) modules will be available.
10. Manufacturing time spans will be based on a one-shift, 5-day workweek, with spot overtime as required.
11. Primary structure fabrication is to be continuous and uninterrupted for all initial MSS modules including the three cargo modules required for support of the initial station; growth module fabrication will be deferred until the in-work need date. Subsystem procurement and/or fabrication will be initiated only as required to support launch requirements.
12. The project master schedule will define an orderly, economical evolution of events leading to the realization of overall program objectives. The phasing of the project will not be considered as fixed, except for the initiation of Phase C and meeting the operational capability dates.

SCHEDULE HIGHLIGHTS

Figure 3-30 is the master schedule for the MSS project. It portrays an integrated set of activities that depict the evolution of the MSS through the phases of design, development, delivery, and launch; achievement of the 1982 IOC at the 6-man level; achievement of the 1987 IOC for the 12-man growth station; and operations through accommodation of one cycle of Blue Book experiments.

Each element of the project WBS has been scheduled to a depth commensurate with the level of technical definition attained during this phase of the project.

As shown, the Phase C/D effort is initiated on October 1, 1975. At this time, planning baselines are verified and work authorized as outlined in Section 5.0, and the Phase C/D program plans, described in Section 6.0, are implemented as soon as possible. Three months later, on January 1, 1976, the system requirements reviews (SRR) are held to review the initial MSS system specification package and establish an initial system requirements baseline (SRB). Three months later, on April 1, 1976, a system design

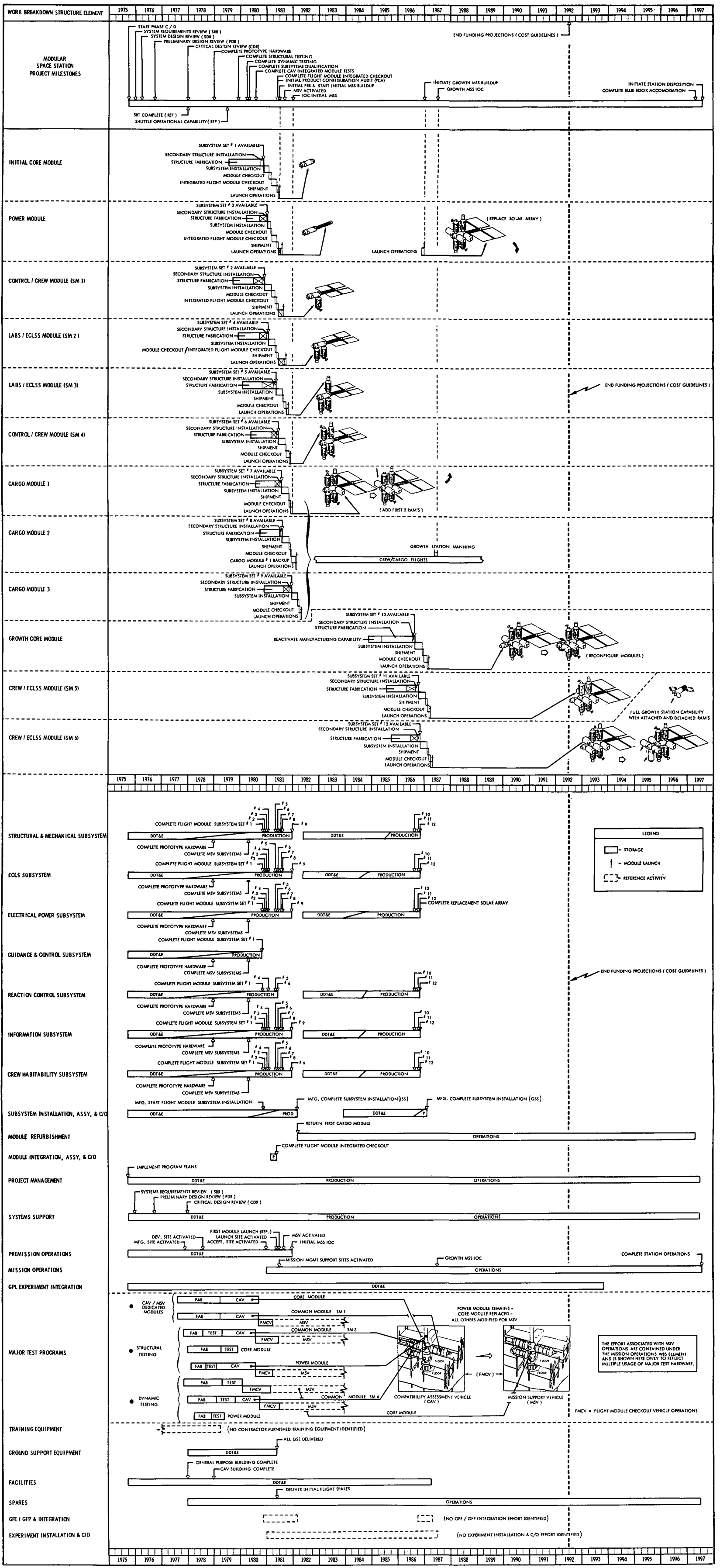


Figure 3-30. MSS Project Master Schedule

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review (SDR) is held to establish the project requirements baseline (PRB) based on initial (partial) CEI development (Part I), and GFP and GFE performance and interface (P&I) specifications. Critical long-lead subsystem development procurement specifications are released at this time.

After the SDR, engineering begins preliminary design, and manufacturing initiates fabrication of required soft mockups. On October 1, 1976, preliminary design reviews (PDR) are conducted to confirm technical requirements and the contractor's engineering approach. The systems specifications are updated and the CEI and CPCEI development (Part I) specifications are formally approved by NASA, thus establishing the design requirements baseline (DRB). Long-lead procurement requirements are identified and critical procurement is initiated as required.

Detail design and subsystem development is initiated subsequent to PDR, preliminary make-or-buy requirements are determined, supplier surveys are conducted, and the remaining long-lead time materials and development procurement specifications are released. The release of structural detail drawings and detailed subsystem drawings occurs as necessary to support the subsystems development and module structure fabrication effort.

On January 1, 1978, a critical design review (CDR) is held to conduct a technical review of the detail design and CEI product (Part II) specifications. At this time, approximately 90 percent of the detail, assembly, and installation drawings are ready for release. The specific design is accepted and released for production, and the drawing configuration baseline (DCB) is established.

During the period from CDR to August 1, 1980, prototype subsystems are acquired, development and qualification test programs are completed, flight module primary structure fabrication has been initiated, and the initial flight subsystems have undergone compatibility assessment and are ready for installation in the flight modules.

On October 1, 1980, subsystems installation begins in the first (initial core) module. The next three flight modules are also begun in series, the four modules receive individual acceptance tests, and the required integrated checkout of all four modules is accomplished during the month of May 1981, in parallel with the initial product configuration audit. The four modules are shipped to KSC on June 1, 1981, initiating prelaunch operations.

Following prelaunch activities in the MSOB, the core module is installed in the shuttle orbiter at the VAB and launched to orbit on July 1, 1981. All remaining initial station modules are launched at 30-day intervals, achieving IOC on January 1, 1982 with the launch of the first cargo module and a crew of six.

In parallel with the foregoing operations, buildup of the MSV at KSC has been initiated in February 1981 and completed on September 1, 1981, allowing module SM-3, and all subsequent modules, to receive final acceptance test at KSC.

Growth station module production, checkout, and prelaunch operations are shown, leading to the launch of the growth solar array package on January 1, 1987, and the achievement of growth station IOC on July 1, 1987, and the achievement of growth station IOC on July 1, 1987 with a crew of 12 on board. Growth station operations are completed, the last operational crew complement is returned to earth, and station disposition is initiated on July 31, 1997.

Not shown on the MSS project master schedule, but previously summarized in Figure 3-26, are the logistic support launches (crew and cargo) and RAM launches planned during the life of the initial station and following the achievement of the growth station IOC.

PROJECT SCHEDULE BASELINE

This MSS project master schedule, Figure 3-30, provides the framework for development and preparation of detail schedules for all Phase C/D project activities at the functional and work package levels. It will be maintained and controlled at all times to ensure that only the latest planning data are utilized by all Project activities. A chronological summary of key project milestones is as follows:

• Start Phase C/D	10-1-75
• System Requirements Review (SRR)	1-1-76
• System Design Review (SDR)	4-1-76
• Preliminary Design Review (PDR)	10-1-76
• Critical Design Review (CDR)	1-1-78
• Complete Prototype Hardware	1-1-79
• Complete Structural Testing	12-1-79
• Complete Dynamic Testing	4-1-80
• Complete Subsystems Qualification	5-1-80
• Complete CAV Integrated Module Tests	8-1-80
• Complete Flight Module Integrated Checkout (first 4 modules)	6-1-81



- Initial Product Configuration Audit (PCA) 6-1-81
- Initial Flight Readiness Review (FRR) 7-1-81
- Start Initial MSS Buildup (Launch Initial Core Module) 7-1-81
- Launch Power Module 8-1-81
- Launch SM-1 9-1-81
- MSV Activated 9-1-81
- Launch SM-2 10-1-81
- Launch SM-3 11-1-81
- Launch SM-4 12-1-81
- IOC Initial Station (Launch First Cargo Module) 1-1-82
- Start Growth MSS Buildup (Launch Growth Solar Array) 1-1-87
- Launch Growth Core Module 3-1-87
- Launch SM-5 4-1-87
- Launch SM-6 5-1-87
- IOC Growth Station 7-1-87
- Complete Blue Book Accommodation 5-1-97
- Initiate Station Disposition 7-31-97

4.0 ORGANIZATION

4.0 ORGANIZATION

APPROACH

The organizational concept that will be utilized for the modular space station project is one that integrated a project-oriented organization with the product-oriented work breakdown structure. Responsibility for functional performance is assigned to project functional managers and responsibility for product performance is assigned to WBS element task managers, both reporting directly to the Program Manager.

Implementation of this organizational concept occurs in varying degrees, commensurate with project phasing requirements. As an example, the effort to be performed during the design phase is largely engineering and only cadre representation is required from other functions. As the project progresses into the development phase, increased emphasis must be placed on functions such as manufacturing, test, and quality assurance, resulting in appropriate expansion and buildup of these functions. As hardware activities begin, the function of the WBS element task manager assumes increasing importance. With further progress into operational phases, the roles of test site operations and logistics become dominant and other functions become supporting activities. Thus a modular space station project organization is achieved that is flexible, dynamic, and completely adaptable to the ever-changing requirements of program activity.

ORGANIZATION STRUCTURE

The generic organization for future phases of the MSS project is shown in Figure 4-1; the organization and WBS integration concept is portrayed in Figure 4-2. The activation or implementation of specific functions will be accomplished in accordance with the concept expressed in the preceding paragraphs.

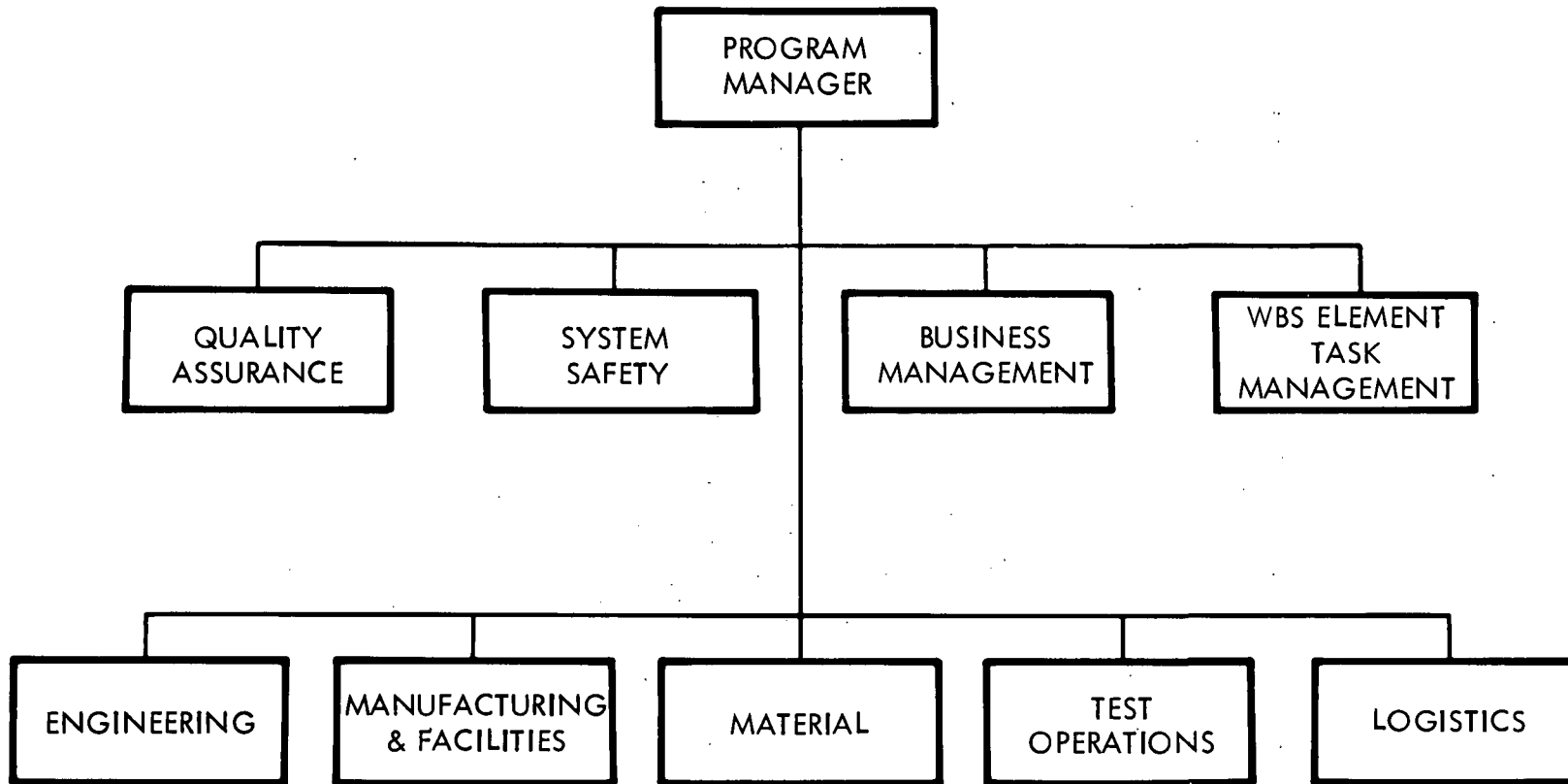


Figure 4-1. Generic Project Organization

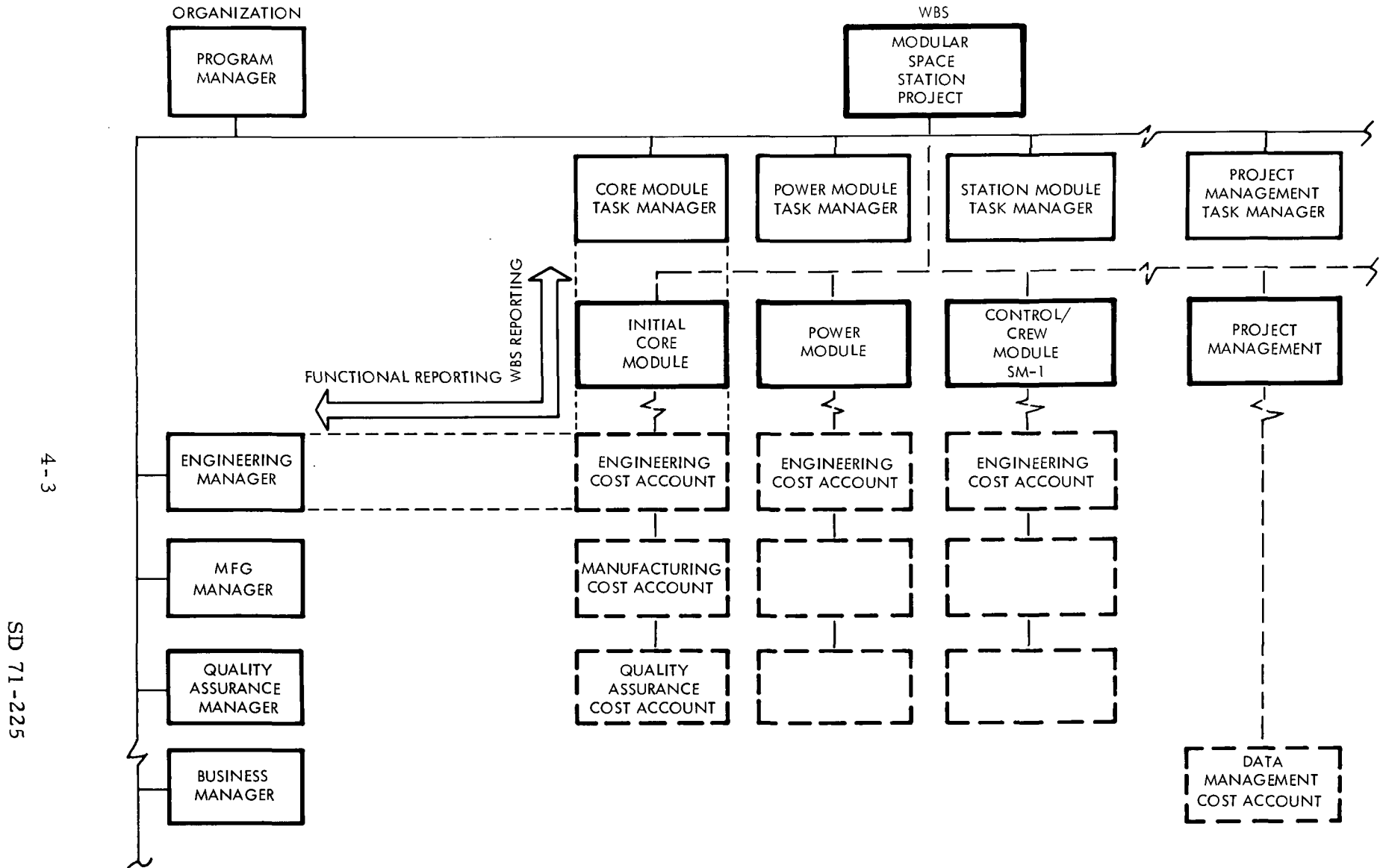


Figure 4-2. Organization/WBS Integration

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AUTHORITY AND RESPONSIBILITY

PROGRAM MANAGER

The Program Manager derives full authority for conduct of the MSS project from the NR Space Division President. His overall responsibilities include:

1. Meeting the cost, schedule, and technical performance requirements of the contract
2. Establishing and approving project directives, program plans, schedules, and specifications
3. Allocating and controlling all project funds
4. Controlling contacts with the customer regarding project matters
5. Assessing performance versus plans and directing appropriate corrective action on deviations
6. Providing visibility on project status, progress, and problems to appropriate company and customer management

PROJECT FUNCTIONAL MANAGERS

Project functional managers operate under authority delegated by the Program Manager for the performance of all project effort within their functional organizations. They are directly responsible to him for meeting the following programmatic responsibilities and the specific functional responsibilities shown in Table 4-1:

1. Accomplishing all assigned project tasks within the designated requirements for cost, schedule, and technical performance
2. Assuring that the Program Manager is fully informed on the status of the project effort for which they are responsible
3. Within the limits of their delegated authority, initiating appropriate corrective action for all functional problems within their designated areas

Table 4-1. Responsibilities of Project Functional Activities

Project Functional Activity	Responsibility
Business Management	<p>Implements and operates project business management systems; provides project direction and guidance on performance management, cost reduction management, data management, associate contractor interface management; establishes and maintains the program master plan, work breakdown structure, and master schedule; provides visibility on project status and progress; monitors and evaluates overall project performance; coordinates and integrates the project planning and controlling function. Implements and operates the budget allocation system; develops cost-accumulation structure in accordance with the project work breakdown structure; provides project visibility on cost performance, status, and trends; plans and controls manpower loading; monitors and reports headcount and overtime utilization; provides property management function. Reviews functional budget requests and provides recommendations to the Program Manager. Acts as primary interface with customer's contracting organization on all contractual requirements; verifies contractor compliance with provisions of the contract; prepares, coordinates, and transmits change proposals to customer; conducts negotiation of all contract changes; and administers provisions of contract.</p>
Engineering	<p>Provides overall systems engineering and technical management of the project; determines and integrates all design requirements, develops and integrates design and evaluates all hardware and software products; establishes technical performance standards and test requirements; performs technical performance measurement and evaluation; operates cost-effectiveness evaluation system; provides visibility on technical status, progress, and problems; and implements in design the results of technical specialty studies such as system safety, reliability, maintainability, and thermal control. Insures that the engineering drawings and specifications as released meet the terms of the contract. Operates the project reliability management system.</p>
Quality Assurance	<p>Establishes and maintains an effective and timely quality program necessary to verify that all deliverable items meet the quality requirements of the company and customer; provides visibility on quality trends and related activities; establishes and maintains a system for identification of quality problems and correction of deficiencies; inspects to contractor engineering drawings and specifications to insure that terms of contract are met. Implements the quality assurance and configuration management systems on the project.</p>
Material	<p>Establishes, implements, and directs all project procurement and subcontracting activity, procures all required material for project usage; provides visibility on status, progress, and problems of the material procurement function; monitors and evaluates performance of subcontractors; advises in make-or-buy decisions. Insures that subcontractor performance meets contract specifications and requirements. Provides interface between customer/contractor and subcontractors.</p>
System Safety	<p>Establishes and implements the safety management system and activities that will assure achievement of project safety goals; provides continuous safety risk visibility to enable economic management decision-making; assures incorporation of safety considerations in system design; monitors project operations to assure compliance with safety requirements; provides visibility on safety performance; establishes and maintains a closed-loop system for detection and correction of safety defects.</p>
Manufacturing & Facilities	<p>Defines and implements all manufacturing effort in support of project requirements; provides total project facilities support, provides visibility on status and progress of manufacturing activity; identifies manufacturing problems and determines cost effective solutions; monitors manufacturing performance and initiates corrective action for deviations from plan. Operates the project interdivision work authorization system.</p>
Test Operations	<p>Develops and implements all test plans for development test, post-manufacturing acceptance test, and offsite tests in accordance with requirements established by Engineering; provides visibility on status and progress of all test operations; directs and controls test site operations; provides maintenance and upkeep of all project test facilities and equipment.</p>
Logistics	<p>Provides for test site logistics support; based on engineering criteria and historical data, determines and provisions required quantities of spare parts, in-flight replaceable units, and support equipment; develops and conducts technical training; provides visibility on status and progress of all logistics activities; develops integrated logistics support concepts; develops maintenance, modification, overhaul and repair concepts; controls overhaul and repair program; provides for installation of test site equipment and site activation.</p>

WBS ELEMENT TASK MANAGERS

WBS Element task managers operate under the delegated authority of the Program Manager for assuring proper performance of project effort related to their assigned WBS element. They are responsible for ensuring a completed project within the specified requirements for cost, schedule, and technical performance. They maintain total cognizance of all functional activities, status, performance and problems pertaining to their WBS elements, and provide the project interface with the customer on such matters. They are responsible for the following specific actions:

1. Assure that all functional plans relative to their assigned WBS elements are mutually supporting and, when executed, provide adequate visibility of status, performance, and problems
2. Assist functional managers in establishing the required budgets and resources to accomplish those tasks related to their assigned WBS elements
3. Provide and present to the Program Manager properly analyzed cost, schedule, and technical performance data with appropriate explanation for variances and forecasts of future performance with respect to their assigned WBS elements
4. For potential or actual problems that affect their assigned WBS elements, coordinate all resolution activity with affected functional managers and provide consolidated reporting to the Program Manager.

5.0 MANAGEMENT

5.0 MANAGEMENT

MANAGEMENT APPROACH

Utilizing the organization described in Section 4.0, this contractor will plan and control MSS project activities through the operation of existing management systems prescribed in the Space Division Policy Manual, augmented and supported by functional manuals and integrating documents.

The Policy Manual, through a series of individual interfacing directives, prescribes requirements for management of the Space Division and its programs. The directives individually and collectively reflect requirements established by the Company, its customers, and Federal, State, and local laws. Recognizing that it is a virtual impossibility to direct all activities at all levels of management in the details of their jobs, this directive system has applied the principle that "all is permitted except what is restricted." This permits standardization of diverse activities in an environment that encourages initiative and creativity.

As shown in Figure 5-1, the Policy Manual represents the top level directive document of the Division, and provides the policy and requirements to which supporting functional manuals and integrating documents are responsive. Functional manuals contain statements of functional direction, procedure, and methods that provide "how to" information relative to specific functions. Integrating documents provide requirements for specific actions or processes that must be imposed on business systems of several functions in order to accomplish management tasks requiring special emphasis, such as performance management, configuration management, data management, etc.

The program master plan and subsidiary program plans provide the medium for defining and integrating specific requirements imposed contractually by individual customers. These plans are further discussed in Section 6.0.

In the following paragraphs the specific requirements for management tasks, that will be given special emphasis during conduct of the MSS project, are provided: These requirements will be implemented through the use of existing company business systems, supplemented as necessary by appropriate program implementing instructions and functional procedures.

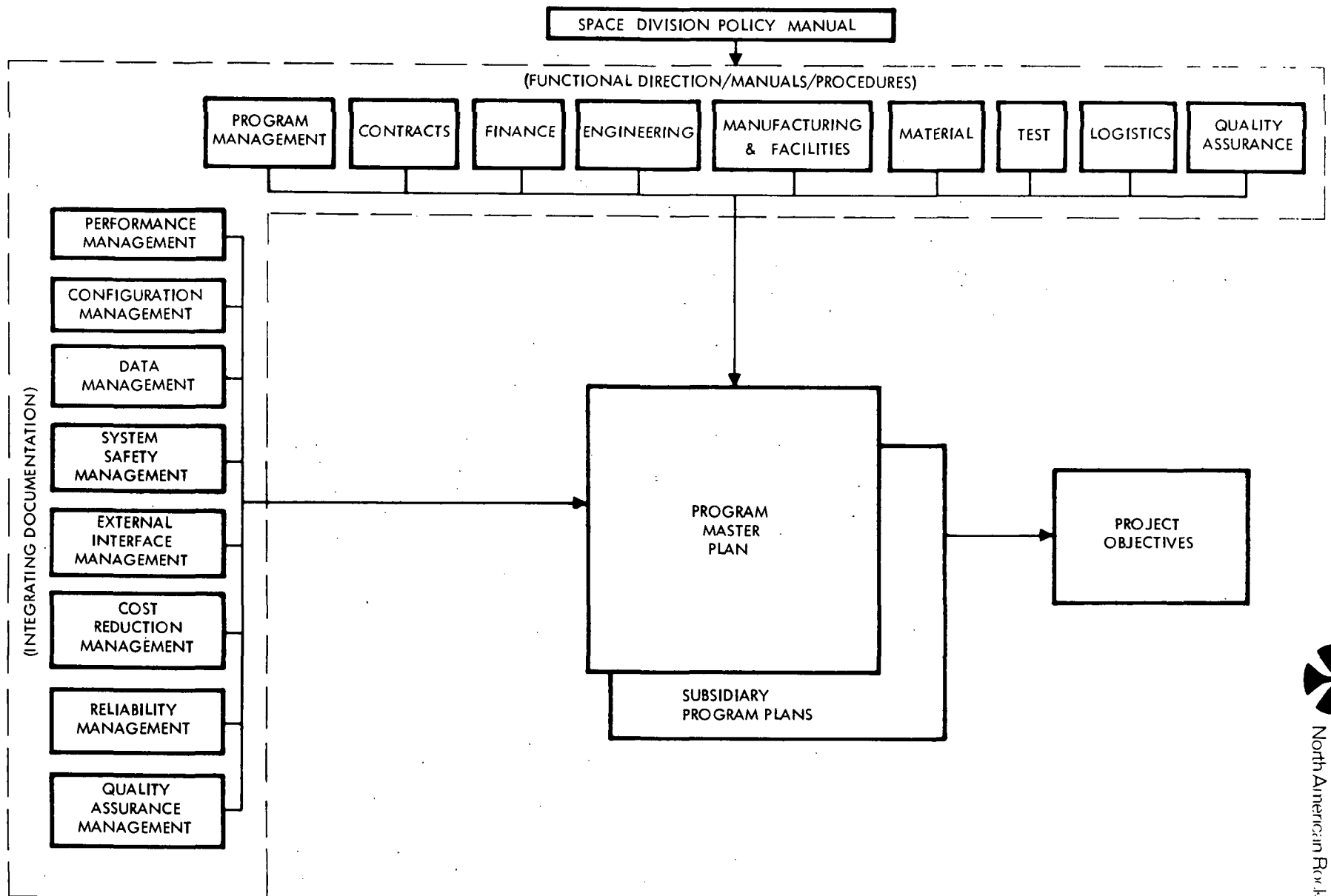


Figure 5-1. Space Division Management Concept

PERFORMANCE MANAGEMENT

The performance management system provides the Program Manager with formal procedures to plan the MSS project, authorize the work, and determine project status. The end result is a means of controlling costs, maintaining schedules, and assuring proper technical achievement. The system is carried out within the framework of a negotiated contract that established targets for costs, schedules, and technical performance. The overall requirements for the performance management system are:

1. Prepare and maintain a performance management plan as prescribed in Section 6.0
2. Establish and maintain time-phased records of negotiated contract value
3. Establish and maintain records of negotiated contract milestones
4. Establish and maintain records of technical performance measurement parameters selected from the negotiated contract specifications
5. Periodically compare cost, schedule, and technical performance to plan
6. Isolate factors causing deviations from plan
7. Initiate corrective action
8. Provide continuing visibility of status, progress, and future requirements
9. Control changes

The tasks involved in fulfilling the above requirements, and assignments of responsibility for their accomplishment, are shown in the matrix of Table 5-1. Additional details of system requirements are provided in the subsections that follow.

PLANNING

Planning provides both the contractor and the customer with an overview of the total project, and indicates the programmatic route for achieving prescribed objectives. It provides for: gathering all available

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Table 5-1. Performance Management System—Responsibility Assignment Matrix

System Activity		Project Management								
		Program Manager	Business Management			Engineering	All Functional Departments	Work Package Managers	WBS Element Task Managers	
			Contracts and Pricing	Planning and Control	Financial Management					
Planning	General	WBS	Approve project WBS	Issue customer WBS	Prepare, coordinate, publish, and maintain project WBS	Review and support preparation and maintenance of project WBS	Review and support preparation and maintenance of project WBS	Support preparation and maintenance of project WBS	Review and support preparation and maintenance of project WBS	
		Baselines	Approve all baselines	Define contract baseline	Define schedule reporting and performance baseline	Define cost reporting and performance baseline	Define technical reporting and performance baseline			
		Organization/product	Approve project organization structure		Prepare project organizational structure. Define organization/product relationship	Review project organizational structure	Review project organizational structure	Prepare function organization to support WBS products		
		Logic	Approve project logic		Prepare, coordinate, and publish project logic		Support preparation of project logic	Support preparation of project logic		
		Plans	Approve program plans		Prepare, coordinate, and publish master plan. Coordinate and integrate all program plans	Prepare and coordinate program financial plan. Support preparation of master plan	Prepare technical plans. Support preparation of master plan	Prepare functional plans. Support preparation of master plan	Review program plans	
	Detail	Schedule	Approve master schedule		Prepare, coordinate, publish, and maintain master schedule. Coordinate supporting schedules	Review master schedule	Review master schedule. Prepare supporting schedules	Support preparation of master schedule. Prepare supporting schedules	Prepare supporting work package schedules	Review master schedule and supporting schedules for assigned task
		Cost	Approve functional budgets		Prepare subdivision of functional budget	Prepare, coordinate, issue, and maintain functional budgets. Review and coordinate sub-budgets	Prepare subdivision of functional budget	Prepare subdivision of functional budgets	Prepare work package budgets	Review budgets for assigned task
		Technical performance	Approve technical performance parameters	Support negotiation of technical parameters. Incorporate in contract	Support preparation of technical parameters	Review technical performance parameters	Prepare and maintain technical performance parameters. Negotiate technical agreement with customer	Support preparation of technical performance parameters	Prepare technical performance parameters for work packages	Review technical performance parameters for assigned task
		Work packages	Approve cost account/work package managers		Coordinate and support preparation of work statements and schedules for work packages	Coordinate and support preparation of work package budgets. Assign cost accounts	Coordinate and support preparation of technical performance parameters for work packages. Approve functional work packages	Coordinate, support, approve and issue functional work packages	Prepare and coordinate work packages	Review work packages for assigned task
		General Order		Prepare, coordinate, issue, and maintain general order	Support preparation of general order	Support preparation of general order	Support preparation of general order			
Authorizing	Program Directive	Approve program directive		Prepare, coordinate, and issue program directive	Support preparation of program directive	Support preparation of program directive	Support preparation of program directive			
	Subdivision of Work Authorization Document			Review and approve schedules for SWAD's	Review and approve budgets for SWAD's	Review and approve technical performance parameters for SWAD's	Review, approve, and issue functional SWAD's	Prepare and coordinate functional SWAD's	Review and coordinate SWAD's for assigned task	
	Work Order						Support preparation of work orders	Prepare, coordinate, and issue work orders		
	Subcontract	Approve subcontracts		Coordinate schedule reporting requirements for subcontractors	Coordinate cost reporting requirements for subcontracts	Coordinate technical performance requirements for subcontracts	Support preparation of subcontracts. <u>Material:</u> Prepare, coordinate, and negotiate subcontracts		Review and support subcontracts for assigned task	
	Inter-Divisional Work Authorization	Approve major IDWA's		Coordinate schedule reporting requirements for IDWA's	Coordinate cost reporting requirements for IDWA's	Coordinate technical performance requirements for IDWA's	Support preparation of IDWA's. <u>Manufacturing:</u> Prepare, coordinate, and negotiate IDWA's		Review and support IDWA's for assigned task	
	Measurement and analysis	Review performance at project level		Monitor overall performance. Perform analysis of schedule performance	Monitor overall performance. Perform analysis of cost performance	Monitor technical performance and perform analysis	Monitor and analyze functional performance	Monitor and analyze work package performance	Monitor and analyze overall performance for assigned task	
Controlling	Corrective action	Approve corrective action at project level		Initiate, coordinate, and monitor corrective action at project level	Recommend corrective action at project level. Initiate corrective action at function level	Recommend corrective action at project level. Initiate corrective action at function level	Recommend corrective action at project level. Initiate and monitor corrective action at function level	Recommend corrective action at functional level. Initiate corrective action at work package level	Recommend corrective action at project level. Initiate corrective action for assigned task	
	Control of changes	Approve changes to baselines	Prepare, coordinate, submit and negotiate changes to contract	Initiate and coordinate changes to schedule reporting and performance baseline	Initiate and coordinate changes to cost reporting and performance baseline	Initiate and coordinate changes to technical and performance baseline	Evaluate, coordinate, and implement approved function changes. <u>Material/Manufacturing:</u> Coordinate subcontractor/IDWA changes	Initiate changes in work packages. Implement approved changes	Review, evaluate, and recommend changes to baselines	
	Customer reporting	Approve all formal reports to customer	Prepare, coordinate, and submit contract reports to customer	Maintain status displays in MIC. Coordinate MIC data with customer. Prepare and coordinate schedule reporting	Prepare and coordinate financial status reporting to customer	Prepare and coordinate technical status and progress reporting to customer	Support preparation of customer reports. Support operation of MIC	Support preparation of customer reports. Support operation of MIC	Review and coordinate customer reports for assigned task	

information pertinent to the project; sorting and identifying the significant factors in this information; interpreting and/or formulating basic assumptions; clarifying basic objectives; developing action for achieving objectives; assigning responsibility for accomplishing defined tasks; allocating resources; and establishing a schedule for accomplishment. Systematic planning before initiation of effort serves to prevent costly false starts and performance of unnecessary effort. Total planning is performed in two phases: general planning and detailed planning. General planning provides the basis for initially directing the conduct and course of the project. Detail planning is developed progressively to support actual implementation of work. Both aspects of total planning are discussed in the following paragraphs.

General Planning

Work Breakdown Structure.

A product-oriented work breakdown structure (WBS) is prescribed as the means of subdividing the contract effort into lower level, manageable segments of work. The contractor's WBS is a development of the customer-supplied WBS to lower levels that are appropriate for managing program costs, schedules, and technical performance. As the main management vehicle for integration of all project tasks, it provides a consistent and visible framework that facilitates the following:

1. Performing effective program planning
2. Assigning management and technical responsibilities for project performance
3. Integrating the functions of scheduling, budgeting, work authorization, and cost accumulation with the contractor's organizational structure
4. Maintaining positive control of project effort, resource allocation, expenditures, and procurement actions
5. Providing meaningful reporting of project progress and status

Baselines

Performance management activities are conducted within the framework of the WBS. It is therefore necessary to relate these activities to the WBS. Respective levels of the WBS are selected as the level at which specific performance management activities take place. These selected levels are referred to as baselines, shown on Figure 5-2, and the following discussions prescribe the planning requirements to be implemented at each of the various baselines.

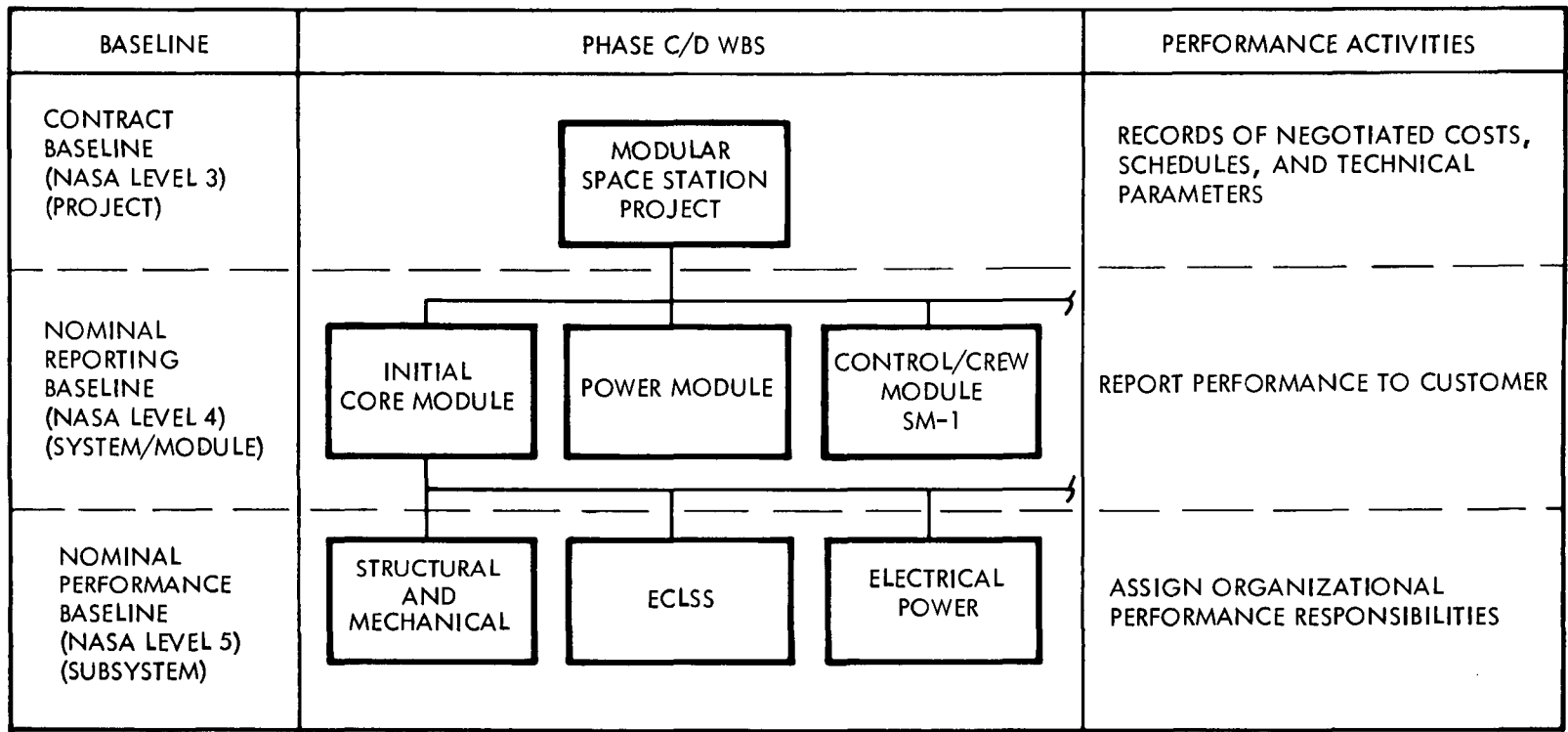


Figure 5-2. Baseline/WBS Relationships

1. Contract Baseline - the WBS level at which the contractor establishes and maintains records of the negotiated costs, milestones, and selected performance measurement parameters.
 - a. The contract baseline will reflect formal contractual requirements.
 - b. The planning will assimilate contractually authorized changes in a timely manner.
 - c. A schedule baseline will be maintained and will typically contain contract end item delivery schedules and milestones that constrain or control other major program events.
 - d. A cost baseline will be maintained and will consist of a single dollar amount for each contract line item as derived from the negotiated contract value.
 - e. The cost baseline for each line item will be time-phased by the Government fiscal year for planned duration of the contract.
 - f. A technical performance baseline will be established and maintained consisting of a record and identification of those technical parameters used for formal technical performance measurement.
 - g. Contract baseline planning will be conducted at Level 3 of the WBS.
2. Reporting Baseline - the level at which performance is reported to the customer.
 - a. The reporting baseline will be established at those levels of the WBS at which the customer's Project Office will control the project. The level will be established within the contract and will nominally be at Level 4 (system/module level).
 - b. Detail planning will be summarized to the reporting level to provide a yardstick for measuring performance.
 - c. Planning will be both functionally oriented (engineering, manufacturing, etc.) and product-oriented (WBS element) in order that progress can be measured in both activities.

3. Performance Baseline - the lowest WBS level at which organizational responsibilities for performance are assigned.
 - a. Budgets will be assigned at the performance baseline level for each functional organization. The performance baseline is subdivided within functional activities through the use of cost accounts.
 - b. The Program Manager will clearly delineate the subdelegation of responsibility for budget and schedule allocation and control, status reporting, and baseline definition within the project organization down to the cost account level.
 - c. Planning to the cost account level will be provided for that period into the future required for further detailed planning. Beyond this period, planning may be grouped by cost accounts, provided each such grouping applies to work within one functional organization and one WBS element.
 - d. Individuals responsible for measuring performance at the cost account level will be identified. These individuals are referred to as cost account managers.
 - e. The contractor will maintain work packages containing budgets, schedules, and technical performance milestones. The work package budgets are the detail resource allocations that comprise the cost accounts.
 - f. Planning at the performance baseline will be completed for at least the remainder of the current fiscal year when firm funding targets have been supplied by the customer.
 - g. For the succeeding fiscal year, and during any period when funding targets have not been established, performance-baseline-level planning will be performed for approximately 6 months ahead.

Organization/Product Relationship

Management of a project is carried out by the Program Manager through a project organization. Project products are a result of the functional activities within the project. It is therefore necessary as a part of the project management process to measure functional performance as well as performance related to products. The combined use of functional managers, WBS task element managers, cost accounts, and work packages provides the means by which both product and functional performance can be measured.

Figure 5-3 shows the relationship between products and functional organizations. The relationship principle can apply to varying organization and WBS concepts. In all cases the following general requirements will be met.

1. The Program Manager will delegate appropriate authority and responsibility to functional management for control of cost accounts and subordinate work packages.
2. The Program Manager will delegate appropriate authority and responsibility to WBS element task managers for managing total product performance. Individuals so assigned will monitor the progress against the product related work packages assigned to functional managers.
3. WBS element task managers will also be authorized to make direct contact with the customer and associate contractors concerning their assigned WBS elements.

Logic

The project logic defines the essential and logical order of primary phases, activities, and events required to accomplish the project. It is used to ensure that event and activity schedules are consistent with the necessary chronological ordering and interconstraining effects.

The project logic will:

1. Be developed at the project summary level and at selected supporting levels
2. Define the interrelationships of major products and objectives
3. Be compatible with the WBS
4. Be developed to a level of detail necessary to identify high risk areas in all phases of the contractor's project
5. Define constraints and control milestones appropriate to all levels of schedules and plans
6. Be periodically updated to validate schedules, to define impact or problems, and to develop alternate solutions
7. Be constructed in a manner that will facilitate use of determining the impact of actual or proposed changes

The preliminary project logic for the MSS is shown on Figure 3-28 in Section 3.0.

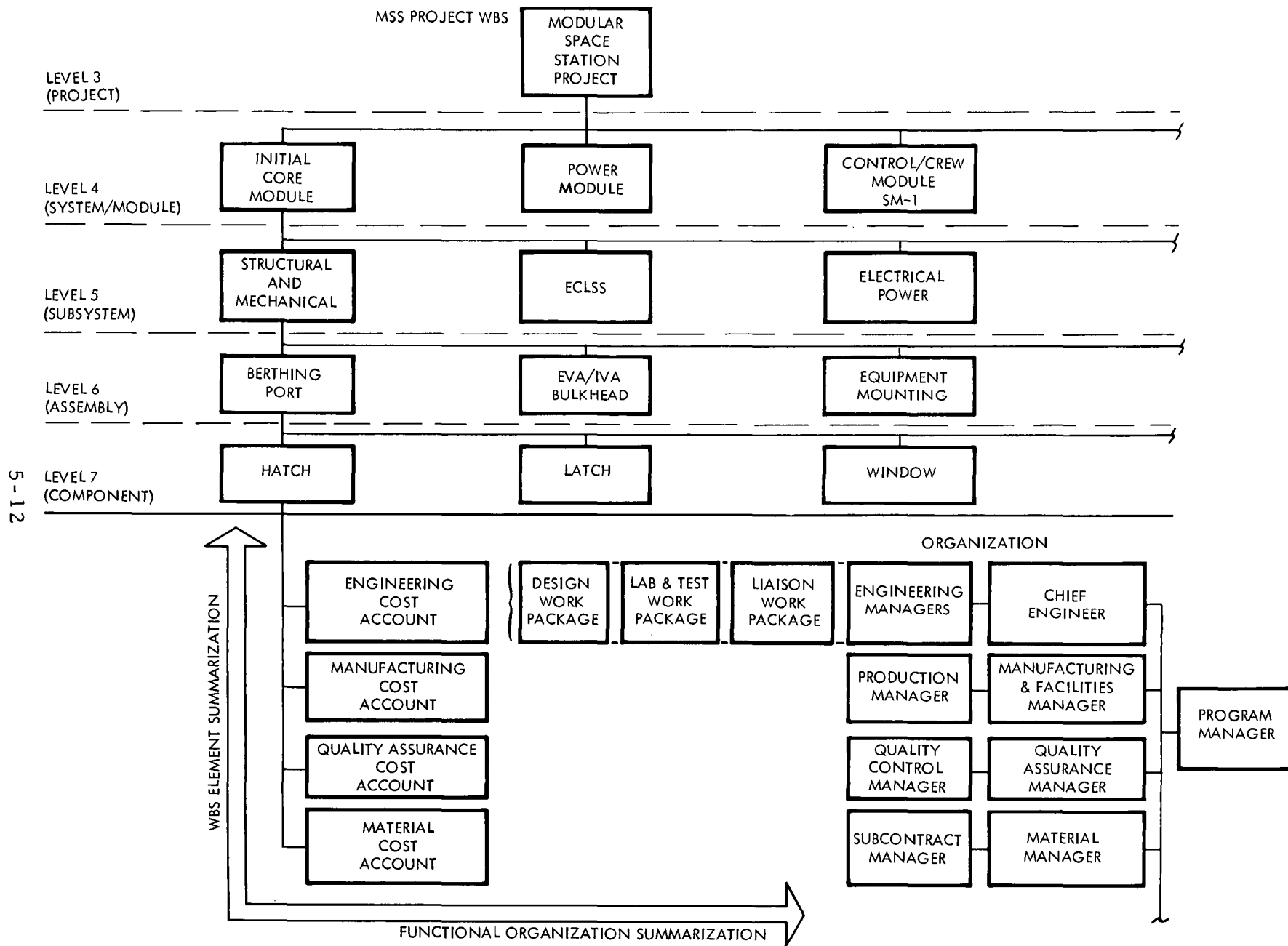


Figure 5-3. Relationship of Products and Functional Organizations

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Plans

Plans are required to ensure that the approaches used for implementation of the MSS project functions and activities are complete and integrated. They are also necessary to establish the customer's understanding and concurrence with respect to what the contractor will do and how he will perform certain significant project functions and activities. The contractor's plans system provides the following:

1. A single-point function be designated for preparation of the program master plan and for integration of all subsidiary plans.
2. Each plan will define the organization, functions, logic, interfaces, process timelines, and other data required for planning and control of the function.
3. Plans will be top-level descriptions of how the particular function/discipline will be planned, executed, and controlled.
4. Plans will make reference to internal company/project documentation that will be used for implementation, such as functional manuals, integrating documents, procedures and program implementing instructions.
5. Plans are updated as necessary to reflect changes in planning baselines.

Identification of essential MSS project phase C/D plans is provided in Section 6.0 of this document.

Detail Planning

Detail planning is developed from information that properly identifies schedules, costs, and technical parameters. In this section, the basic cost, schedule, and technical requirements are covered first, followed by the requirements for content, frequency, and traceability of work packages.

Schedule

Schedule planning time-orientates the project work represented by the WBS in conformance with the order and constraints shown by the project logic. Schedules are used to establish the correct timing and order of performing tasks and to provide a basis for measuring schedule performance. Schedule planning will be performed as specified below:



1. A master schedule for Phases C and D of the modular space station will be prepared, using the schedule shown on Figure 3-30, Section 3.0, as a baseline.
2. The master schedule will be used as a basis for establishing the negotiated contract schedule baseline.
3. The final master schedule will be available for customer review, concurrent with preliminary design review (PDR) or upon final contract negotiation, whichever occurs first.
4. The master schedule will be consistent with, and related to the WBS, and will identify contract milestones and significant project summary milestones.
5. A schedule control system that ensures compatibility between the master schedule and lower-level-detail schedules will be established and maintained.
6. The schedule control system will further ensure that authorized project changes are promptly incorporated into the master and baseline schedules.
7. WBS element schedules will be correlated to reporting level schedules.
8. Major functional organization milestones within cost accounts and their correlation to supported WBS element schedules will be identified.
9. Scheduled events or indicators of planned volume of work versus time will be identified in a manner that provides an objective measurement of work.
10. Relationship between work volume measurement milestones or indicators and supported cost account milestones will be identified. This identification will be contained in the work package documentation.

Cost

Cost planning divides and time-phases the total contract value by elements of cost, by function, and by products. Actual expenditures are compared against these planning estimates to monitor cost performance

and to locate accurately the cause of significant variances. In developing cost planning data, the contractor will:

1. Prepare and maintain a total project financial plan in consonance with the negotiated contract
2. Time-phase the financial plan by quarter for the ensuing four quarters and thereafter by Government fiscal year
3. Subdivide the financial plan by element of cost
4. Assure that the financial plan contains direct budget allocations by function, i. e., engineering, manufacturing, logistics, test, quality assurance, etc.
5. Maintain the plan for the duration of the contract by incorporating authorized contract changes
6. For the performance baseline planning period, establish budgets for all contractually authorized work to the cost account level with separate identification of cost elements (labor, material, etc.)
7. Identify level of effort in cost accounts which are planned and controlled by time-phased budgets established for this purpose. Only that effort which cannot be identified as discrete work packages or as apportioned effort will be classed as level of effort
8. Identify undistributed budget consisting of internally unauthorized (future) work package budgets and level-of-effort budgets within cost accounts
9. Provide that the sum of all work-package-level budgets within a cost account equals the cost account budget
10. Summarize direct budgets from cost accounts into the WBS without allocation of a single cost account to two or more WBS elements
11. Summarize direct budgets from the cost accounts into the contractor's functional organizational structure without allocation of a single cost account to two or more organizational elements

12. Identify the methodology for establishing the budgets for apportioned effort
13. Identify the indirect budgets and method for allocation to the contract

Technical Performance

The technical performance measurement (TPM) system provides a tool for determining and assessing technical performance, and for early identification of technical problems and resulting cost and schedule impacts to the project. The requirements for technical performance planning are:

1. Technical performance planning at the reporting baseline level will be effected through a technical performance measurement system that is an integral part of the engineering process.
2. The TPM system will be implemented at PDR and will be demonstrated within a reasonable time thereafter as directed by the contracting officer.
3. System performance parameters will be selected from the applicable contract end item (CEI) specification.
4. TPM plans will be prepared for selected parameters. These plans will identify and define specific verification events that will permit the assessment of progress against the selected parameters.
5. Verification events will reflect the verification methods listed in the CEI specification, that correspond to the selected performance parameters.
6. Selected performance parameters will be related to the project WBS, and verification milestones will be identified within subordinate schedules.
7. Technical performance values will be measured at the planned level at the planned frequency, and results will be submitted to higher levels of contractor engineering and project management.

Work Packages

1. Planning. Work package planning provides detailed working level instructions that divide all work in a manner, sequence, and

chronology to support the higher levels of contract planning.
Work package planning requirements are:

- a. All near-term contractual effort will be planned, budgeted, and controlled at the work-package level.
 - b. Planning that exists at the cost account level will be planned in more detail as the contract work is defined in greater depth.
 - c. Detail planning at the work package level will be performed for as long a period into the future as is practical.
 - d. The work package will contain budgets, schedules, and technical performance parameters that constitute the plan against which the work package manager assesses and controls the working level tasks.
 - e. When all work packages within a cost account have been planned, the sum of their assigned budgets must not exceed the total cost account budget.
2. Work Package Criteria. Work packages will be developed to meet the following criteria:
- a. Be representative of a unit of work at the level where work is physically performed
 - b. Provide a clear distinction of work content from all other work packages within the parent cost account
 - c. Be assignable to a single cost account and organization element
 - d. Have clear start and completion dates that are representative of physical accomplishment
 - e. Have budget expressed in terms of dollars, man-hours, or other measurable units
 - f. Be limited in size and duration such that the total number of work packages in a cost account is a manageable quantity
 - g. Generally, be no longer than one year nor less than 3 months in duration

- h. Have internal indicators that enable measuring objectively the volume of work accomplished relative to the total work content of the work package
3. Work Package Traceability. Traceability from the work package to the contract baseline is required to ensure that planning is in conformance with the tasks defined by the contract statement of work and the WBS dictionary. The requirements for work package traceability are:
 - a. Provide that each successive level of planning is derived from, and reconcilable to, its immediately preceding level
 - b. Provide that all immediately succeeding levels of planning are identified at each planning level
 - c. Provide that effects of contract changes on planning are reflected in the relevant elements at all planning levels and are incorporated in a timely manner

AUTHORIZING

A work authorization system provides the means of ensuring that appropriate resources have been allocated for work to be performed, and that all work has been contractually authorized and properly planned before it actually begins. The contractor's work authorization system, as shown in Figure 5-4, satisfies the following requirements:

1. Provides that the work to be done and responsible organizational elements have been defined and identified before work is authorized to begin
2. Assures that schedules, budgets, and technical performance requirements established for the work to be authorized are in consonance with the contract baseline
3. Provides documented authorization for commencement of work, including traceability to the contract baseline.
4. Assures that work packages that have been closed are not reopened. For any changes in opened or unopened work packages there must be a recorded explanation of budget and effort that is to be modified.

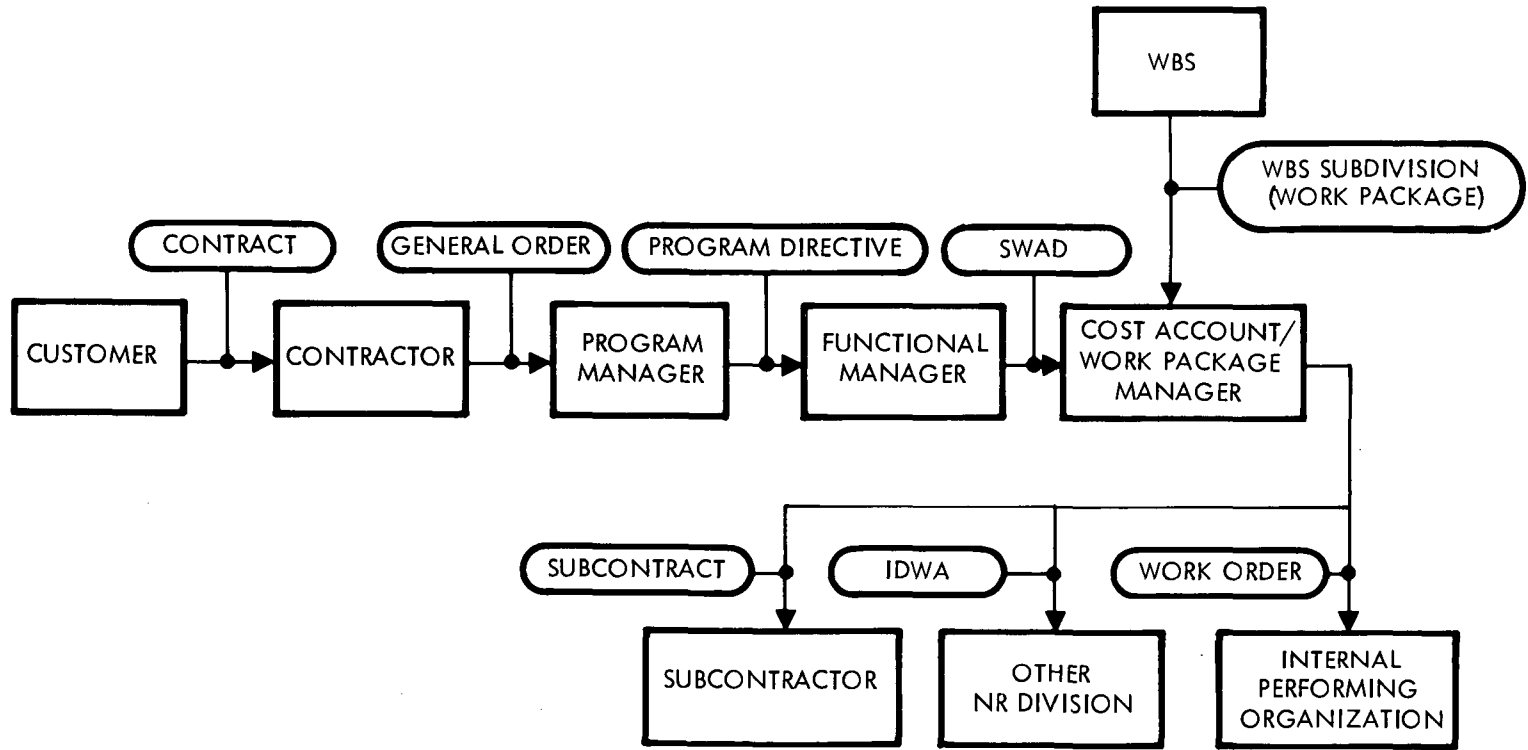


Figure 5-4. Work Authorization System

General Order (GO)

The general order is the contractor's internal document, issued to the Program Manager by the company contracts organization, authorizing him to accomplish the effort specified in the contract statement of work. It provides funding, funding limitations, allocation of direct and indirect labor hours by functional category, material dollars, travel dollars, and the amount of contract funds set aside for use as a management reserve. It specifies the general cost, schedule, and technical performance requirements of the contract. The general order also specifies the cost accounting structure to be used in fulfilling contract requirements.

Program Directive (PD)

The program directive is the document issued by the Program Manager to the project functional managers authorizing the performance of effort specified in task assignments. It provides time-phased budget allocation and establishes schedule and technical performance requirements.

Subdivision of Work Authorization Document (SWAD)

The SWAD is the document issued by functional managers to specific individuals authorizing the accomplishment of subdivisions of the total functional effort. It provides a time-phased allocation of funds, prescribes the schedule and technical performance parameters for the effort, and assigns the cost account for accumulation of costs. The individual to whom the SWAD is issued is designated as the cost account/work package manager.

Work Order

The work order is the document issued by the cost account/work package manager to a performing organization authorizing the performance of effort. It assigns budget and schedule for the effort prescribed.

Subcontract

The subcontract is a bilateral agreement between the prime contractor and an external company for the performance of effort in accordance with specified schedule, cost, and technical requirements. It is issued by the material function in compliance with decisions of the MSS project make-or-buy committee. Reporting requirements are also specified consistent with both the contractor and subcontractor performance management systems.

Interdivisional Work Authorization (IDWA)

The IDWA is a document similar to a subcontract used in authorizing effort to be performed by another division of the contractor's company. It includes specification of task, schedule, cost, technical, and reporting requirements. Major IDWA's are approved by the Program Manager based on decisions of the project make-or-buy committee. Minor IDWA's are approved by functional managers, and used to equalize manpower loading or to utilize special capabilities of other company divisions.

CONTROLLING

Controlling is the activity of performance management that provides the measurement and analysis of performance, the determination and initiation of corrective action, the control of changes, and continuing visibility of current performance. The primary objectives of this activity are to place in the hands of management timely information that permits early detection of performance deviations from plan, and enables initiation of corrective action before major problems develop.

Measurement and Analysis

The contractor's measurement and analysis system provides for recording actual costs, actual schedule performance, actual achievement of technical goals, and comparing them with planned values. Comparisons of planned values of work accomplished (PVWA) and actual costs (AC) show whether completed work has cost more or less than was originally planned and budgeted. Comparisons of planned value of work accomplished (PVWA) and planned value of work scheduled (PVWS) show whether work completed was accomplished ahead of or behind the original plan. A graphic portrayal of these comparisons is shown in Figure 5-5.

Analyses of these differences reveal factors contributing to the variances and enable management to initiate appropriate corrective action. These variations may be the result of errors in initial estimates, technical factors that require a different application of resources, uncontrollable changes in cost of labor or materials, unpredicted variations in personnel efficiency, or a combination of such reasons.

The contractor's measurement and analysis system provides that:

1. Applied direct costs are recorded in a formal system that is controlled by the general books of account.

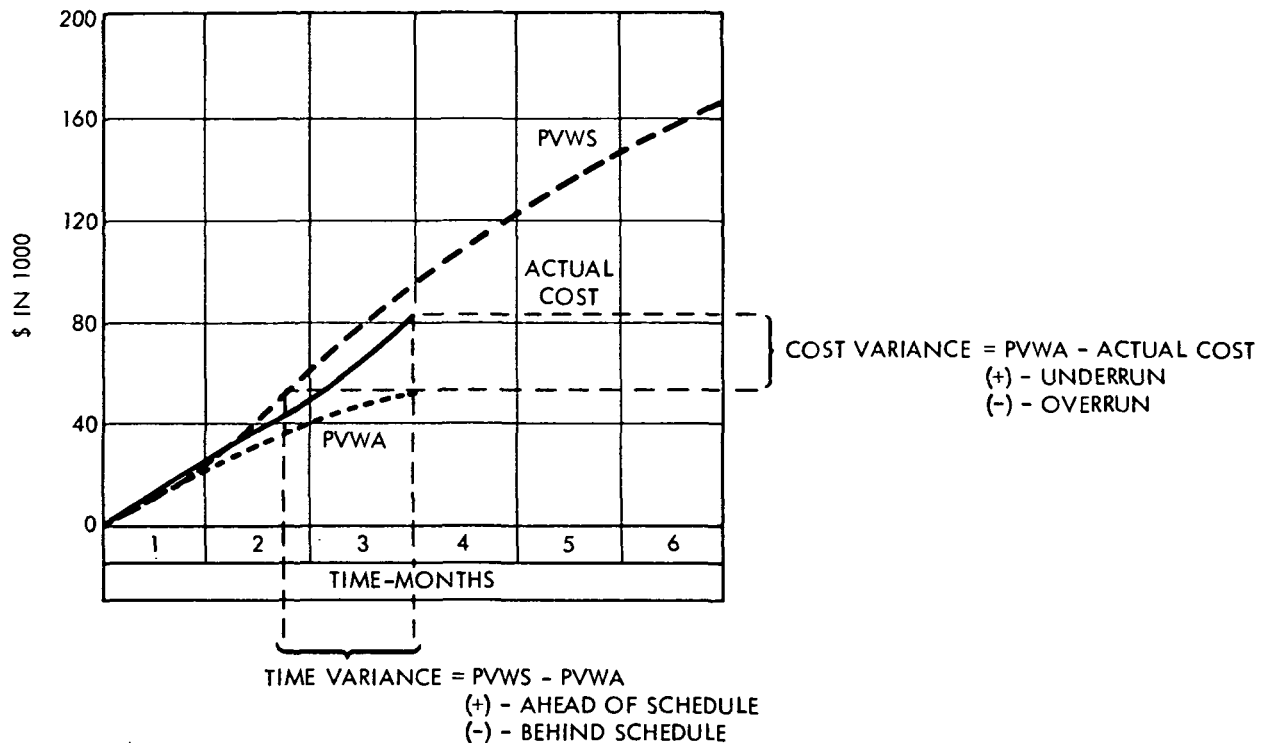


Figure 5-5. Cost/Performance Relationship

2. The amounts charged to work completed and in process during the reporting period are entered in the books of account
 - a. When labor, material, and other direct resources are actually consumed
 - b. When material resources are withdrawn from inventory for use
 - c. When material or subcontract software and other non-recurring resources are received, provided they are uniquely identified to the contract
 - d. When major components or assemblies are received on a line flow basis that are specifically and uniquely identified to a single serially numbered end item

3. Major material items that are initially entered in an inventory cost account, are transferred to operating cost accounts at point of usage.
4. Material or component items used for test, spares, etc.; or dispositioned as scrap, unanticipated test quantities, etc., are charged to that task or items of the project for which it was used.
5. Government-furnished materials are accounted for at point of usage.
6. Costs are accumulated in a manner that identifies recurring unit and equivalent unit costs and/or lot costs.
7. Applied direct costs are summarized from the cost account through the WBS, without allocation of a single cost account to two or more WBS elements.
8. Applied direct costs are summarized from the cost account through the contractor's functional organization without allocating a single cost account to two or more organizational elements.
9. All direct cost is collected from the cost account level by cost element, direct cost is summarized through the organizational and WBS structure at the cost account level, and indirect cost is summarized to the total contract level.
10. Retroactive changes to records pertaining to work performed, that will change previously reported amounts for applied direct costs or indirect costs, are prohibited except for correction of errors and routine accounting adjustments.
11. The following, at the cost account level, are identified on a monthly basis using data from, or reconcilable with, the accounting system:
 - a. Planned value of work scheduled and planned value of work accomplished
 - b. Planned value of work accomplished and applied direct cost for the same work
 - c. Variances resulting from the aforementioned comparisons, classified in terms of labor, material, or other appropriate elements together with the reasons for significant variances



12. Total planned and actual indirect costs allocated to the contract at the total project level are identified on a monthly basis.
13. Performance data are summarized at the total project and reporting level and variances are determined from the performance baseline. Significant differences between planned and actual schedule accomplishment and planned and actual technical performance are identified on a monthly basis, together with reasons for any variations.
14. Technical performance measurements and projected system performance values are analyzed.
15. Managerial actions to be taken as a result of analysis of performance are identified.
16. Revised estimates of cost at completion for WBS elements at the contract baseline are developed at quarterly intervals and compared with the fiscal-year budgets, the negotiated contract price, and the latest statement-of-funds requirements reported to the Government.

Corrective Action

When variances occur between planned and actual performance, timely management action is required to prevent serious downstream effects on project objectives. The contractor's corrective action system provides a formalized process that enables a manager to utilize his own initiative and judgment in resolving the variations from plan. This process involves identifying the problem, conducting trade studies of the integrated effects of alternative solutions, developing plans for corrective action, selecting a course of action to pursue, observing the action, and replanning as required to ensure successful problem resolution. The contractor's closed loop corrective action system provides the following:

1. The analyses of variances in cost, schedule, and technical performance are promptly referred to appropriate levels of management for review.
2. Responsibility for corrective action is assigned to specific organizations and individuals.
3. Problems identified as potentially critical to project success are referred to top program management for resolution.

4. Courses of action are defined which consider cross-effects on cost, schedule, and technical aspects of the solution.
5. Continuous monitoring, evaluation, and display of progress toward problem resolution is provided in the management information center.
6. Evaluation and closeout of completed corrective action is accomplished.
7. Follow-up action in the form of replanning is provided.

Control of Changes

Control of changes to performance management baseline documentation will be provided through the configuration change control system described in the Configuration Management Subsection of this plan. The use of this system will ensure that all changes resulting from corrective actions are reflected in related schedule, budget, and technical performance documentation.

Customer Reporting

The successful attainment of project objectives is a mutual responsibility of both contractor and customer management. Visibility of performance status and progress is a key to successfully fulfilling this responsibility. The contractor's customer reporting system ensures that the essential information utilized by the contractor for management of the project is provided on a regular and timely basis to the customer. It establishes and maintains a continuing point of reference for programmatic discussions between contractor and customer. The contractor's system provides the following:

1. The customer is furnished a single-source document covering the elements of cost, schedule, and technical performance including integrated analysis, on a periodic basis mutually agreed to at contract go-ahead.
2. Charts, graphs, and narrative analysis are used to communicate status and program performance at a practical management level.
3. Specific problem areas and special situations are highlighted on a by-exception basis, using in-depth detail data normally used by functional departments in performing their regular management functions.

4. Supplementary data, such as computer runs, accounting data, and similar material are made available as appropriate.
5. A management information center (MIC), as a tool for contractor and customer management use, is established and maintained for status reviews, briefings, and coordination meetings.
6. Current information on progress and control of the project for each area of management interest is displayed in the MIC.
7. Basic control data in the form of planned performance baselines, status against the baselines, and actions taken to correct deviations is maintained in the MIC.
8. Data displays are appropriately identified to facilitate maintenance of equivalent data displays by the customer at his control center.
9. Rapid and accurate changes to data displays are made to reflect the current situation.
10. A method for communicating data is provided that permits update of the data displays at the customer control center simultaneously with changes made to the contractor's displays.
11. All data requirements of the contract are submitted in a timely manner and in prescribed format.

CONFIGURATION MANAGEMENT

Configuration management is the element of project management which assures that technical documentation, by which a system or product is identified, controlled, and recorded, is in conformance with contractual agreements, and that its technical integrity is maintained from concept through completion. By its nature, configuration management imposes specific restraints on a broad spectrum of project management functions and interfaces. These restraints or requirements must be optimized within business systems and procedures, and in the interest of cost-effectiveness, applied only to the extent necessary to accomplish the management task. This approach has governed the selection of requirements used in the following paragraphs to describe the MSS project configuration management system.

ORGANIZATION

The configuration management office for the MSS project is established as an entity of the quality assurance function and is responsible for ensuring:

1. A Configuration Management Operating Plan is prepared and maintained as prescribed in Section 6.0.
2. Contractual configuration management requirements are fully implemented.
3. An effective interface with the customer configuration management organization and configuration control board (CCB) is established and maintained.
4. Configuration audits of deliverable end items are conducted.
5. Configuration baselines are established and maintained.
6. Records on hardware and software requiring traceability are maintained.
7. An efficient control system for planning, authorizing, and implementing configuration changes is established and maintained.

CONFIGURATION IDENTIFICATION

All technical documentation that defines the functional and physical characteristics of deliverable products and the products themselves will be identified by unique configuration identification numbers. This requirement ensures a common means of communication, regarding the items, between contractor and customer, and facilitates the manufacture and acceptance of these items or parts to the correct configuration requirements. Progressive configuration identification will be accomplished by establishing formal configuration baselines at phased project milestones and managing identified changes to these baselines. Configuration baselines are established through formal customer reviews which verify the accomplishment of contract technical requirements for the current phase and establish contract technical requirements for the succeeding phases of the project. The formal customer reviews that will be conducted for the MSS project are as follows:

- System Requirements Review (SRR)
- System Design Review (SDR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Product Configuration Audit (PCA)
- Flight Readiness Review (FRR)

System Requirements Review (SRR)

The system requirements review verifies the initial system specification package and by customer approval, establishes the contractual baseline for conduct of the design phase of the project.

System Design Review (SDR)

The system design review is conducted when the definition effort has proceeded to the point where design requirements are defined by customer-approved project and systems specifications and related interface control documents. This review establishes the system requirements baseline and initiates configuration management control.

Preliminary Design Review (PDR)

Preliminary design review is held after the technical requirements and engineering approach is established. The PDR reflects customer approval of the project specification update and the Part I CEI development specifications, and establishes the design requirements baseline for Phases C and D.

Critical Design Review (CDR)

Critical design review is accomplished when detail design is initially complete and fabrication drawings are ready for release to manufacturing. The CDR is a technical review of the detail design of an end item or selected group of items in relationship to the development specifications that constituted the design requirements baseline.

Product Configuration Audit (PCA)

The product configuration audit for designated contract end items (CEI's), or groups of CEI's, is conducted upon completion of acceptance testing. It provides formal customer acceptance of development and product specifications, drawings, and hardware and software configurations. The PCA assures that (1) the as-built configuration of a CEI matches that same unit's product configuration identification or that differences are reconciled, and (2) the acceptance testing requirements prescribed by the documentation are adequate for acceptance of the CEI. This establishes the product configuration baseline.

Flight Readiness Review (FRR)

The flight readiness review, as appropriate to unmanned shuttle payloads, is conducted by the customer prior to each launch. This review is technical and verifies that all changes or assembly and checkout activities completed since product configuration audit have been incorporated into the total system or components thereof, and that documentation and configuration are in complete agreement.

CONFIGURATION CONTROL

The contractor's change management system provides the means to control changes to the established baselines through formal control procedures and appropriate management level change authorizations.

1. Changes to a baseline are identified, processed, and approved through a uniform system that provides a complete definition of the change in terms of the following:
 - Reason for the change
 - Effect on specifications
 - Effect on drawings
 - Effect on interfaces
 - New and old part numbers
 - Configuration item serial number effectivity
 - Change implementation schedule
 - Cost of change by each CEI
 - Revisions to assigned WBS element or work package (task, schedule, cost)
2. All proposed changes to baseline documentation are classified as either a Class I or a Class II change.
3. Any change to a baselined document that affects stated requirements (i. e., performance, design, reliability, maintainability, interface, test, interchangeability, or configuration), delivery schedule, the contract WBS, contract cost, or commonality, is defined as a Class I change.
4. Class I changes are approved by the customer CCB, or if so delegated, by the local customer representative.
5. Any change that is below the level of requirements definition in currently baselined documents is defined as a Class II change.
6. Changes to baselined documents to correct errors (i. e., typographical, missing dimensions, etc.) are also defined as Class II.
7. Class II change documentation is approved by the contractor. Copies of Class II changes are provided to the local customer representative on request.

8. Each change proposed against a baseline is assigned a unique change identification number.
9. The assigned number is used to "package" the complete change identification.
10. All change documents used to propose, approve or disapprove, and to implement an approved change use the same change number for identification.
11. A current record is maintained by a single function that identifies the authorized configuration documents (including changes/ revisions released for production and/or test).

CONFIGURATION ACCOUNTING

The contractor's configuration accounting system audits, records, processes, and reports configuration data to both the contractor and customer. This system provides the information necessary for planning and controlling product configuration.

1. The configuration accounting system will provide a means of identifying all documents that define the configuration baseline. The system will record manufacturing and inspection data to identify the product hardware configuration and installation verification.
2. All changes to the design configuration baselines will be recorded. Status reports of change implementation will be provided during the life cycle of project hardware.
3. The contractor's reporting system will be based on the concept that the principal provisions and report usage will be identification of a requirement.
4. Reports will be provided that satisfy common requirements for both contractor and customer configuration, identification, or status information.
5. Comparative (as-designed and as-built) configuration data will be furnished to satisfy acceptance data requirements for delivery of contract end items.

INTERFACE CONTROL DOCUMENTS

Establishment of system interface control requires identification and definition of interfaces, scheduling, preparation, approval, release, and control of formal interface control documents (ICD's).

1. The ICD's for the modular space station will be used to record the design agreements between associate contractors, as authorized by the customer; and will, with production drawings, facility construction drawings, and specifications, provide a means to control design parameters at the interfaces between system segments.
2. Interface control drawings will be based initially upon the requirements of the Part I development specifications which contain the interface requirements.
3. Engineering change proposals originated by an associate contractor, and that affect an interface, will be reviewed by the prime contractor for certification of technical agreement prior to submittal to the customer.
4. When the prime contractor and associate contractor cannot agree on resolution of an interface problem, specific direction must be requested from the customer.
5. Changes initiated by the customer will be reviewed by the prime contractor for interface impact and resolution of any identifiable interface problems.

SUBCONTRACTOR CONFIGURATION MANAGEMENT

1. Requirements established for the modular space station prime contractor will be applied to subcontractors and suppliers to the extent necessary for configuration control of the product being procured.
2. Subcontractors will be required to maintain a systematic approach to configuration identification, drawing preparation and release, change management, and configuration status accounting. Design reviews will be scheduled and conducted to support project milestones. Physical configuration audits will be conducted on all development items procured.

CONFIGURATION MANAGEMENT AUDITS

1. Audits of configuration management-related systems will be conducted for validation of effectiveness in meeting configuration management requirements.
2. Audits will be performed internally to verify the adequacy of system interfaces between functional elements.
3. Major subcontractors will also be audited to establish conformance to requirements.

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DATA MANAGEMENT

Specific attention to the management of data is required to ensure the timely delivery, currency, proper initial distribution, and retrievability of all data. Business management will direct the application of the contractor's data management system on the MSS project.

To achieve innovative approaches and cost reductions in the production and management of data, the contractor will selectively identify project data requirements necessary for performing management surveillance of the project. These data will normally be the same data required by the contractor for internal control.

GENERAL

The contractor will prepare and maintain a data management and documentation control plan as described in Section 6.0.

DELIVERABLE DATA

The contractor's system for management of deliverable data will meet the following requirements:

1. All contract data will be prepared as directed by the contract data requirements description (DRD). The contractor's existing format and document numbering systems will be used to the fullest extent. Responsibility for preparation of each data item will be identified to a specific accountable manager.
2. Preparation and delivery schedules for contract data will be identified in project schedules. Scheduled milestones and events planned to provide visibility on the progress of data items will be identified.
3. Internal and external distribution of each data item, including records of such distribution, will be controlled. Records will also be maintained of specific documents approved by NASA.
4. Incorporation of approved changes into the affected data items will be accomplished in a timely manner. Definition of changes to data items as an integral part of the change description contained in documents authorizing changes will also be accomplished.



5. Data retention and storage, in accordance with contractual requirements, of all pertinent prime and subcontract documentation will be provided for.

GOVERNMENT-FURNISHED DATA

The contractor's system for management of Government-furnished documentation supplied for the contractor's internal use will conform to the following requirements:

1. A record of request and receipt will be maintained.
2. Internal distribution will be made only to contractor personnel in need of the data. Records of such distribution will be maintained for the purpose of updating in the event of superseding changes.
3. An appropriate place for storage will be provided, and a system of indexing and retrieval will be maintained.
4. Final disposition will be made in accordance with contract requirements.

SYSTEM SAFETY MANAGEMENT

The contractor's system safety program will be managed by the system safety function and effective during the design, development, and operations phases of the modular space station project. It will ensure that all potential hazards are identified as early as possible and that corrective action is taken.

The contractor's program will meet the following general requirements:

1. Establish a distinctly identifiable system safety organization reporting to one person who has direct access to the Program Manager. Clearly defined responsibilities, functions, authority and relationships between line, staff and top management will be provided.
2. Prepare and maintain a system safety plan as described in Section 6.0.
3. System safety criteria will be included in engineering, test, maintenance, and operations documents.
4. Identified hazard classifications and hazard reduction precedence sequences will be as agreed upon between the customer and the contractor. These guidelines, criteria and requirements will apply to all contractor and subcontractor activities.
5. System safety analyses, including system logic diagrams, systems hazard analyses, operations hazard analyses, design change assessment, and failure mode effects analyses (FMEA's) will be used, where appropriate, to identify potential hazards.
6. A hazards list will be maintained throughout the life of the project to list identified potential hazards and their classification and status relative to corrective actions.
7. Hazard data collection and flow processes will be identified in established system safety procedures.
8. Safety personnel will participate in design reviews, customer acceptance reviews, and in accident/incident investigations and reviews.



9. In-house, off-site, and subcontractor system safety audits, inspections, and reviews of locations will be conducted periodically. Results of these activities will be available for customer review.
10. Safety personnel will review all test, checkout and operational procedures and classify and monitor those that are safety critical. System safety personnel will participate in each launch readiness decision.
11. System safety requirements will be imposed on major subcontractors appropriate to their activities and products.
12. A vigorous safety training and safety awareness program will be conducted and its progress will be reported to the customer on a regular basis.
13. System safety deficiencies and actual or potential problems will be reported to project management for evaluation and processing through the corrective action system.

EXTERNAL INTERFACE MANAGEMENT

The prime contractor plans and controls his external interfaces with subcontractors, other company divisions, the customer, and associate contractors to ensure that:

1. Responsibilities and authority of interfacing organizations are accurately defined and clearly understood.
2. Reports and communications provide the type and level of information required for efficient management.
3. Working level information between interfacing organizations will be freely exchanged within the confines of established limits.

SUBCONTRACT MANAGEMENT

The prime contractor utilizes a subcontract management system that provides effective planning of prospective subcontracts, definition of procurement requirements, establishment of make-or-buy criteria, conduct of source selection, award of subcontracts, and auditable measurement and visibility of subcontractor performance. The project material function operates the subcontract management system and fulfills the following requirements:

1. Prepare and maintain a subcontract management plan as described in Section 6.0.
2. Participate in the development of the hardware utilization list and the establishment of make or buy criteria.
3. Develop a make-or-buy program that will assure maximum technological, economic, and schedule benefits to the customer through equitable distribution of effort between internal and external sources.
4. Conduct a long-lead-time item analysis to identify items and determine optimum cost-effective procurement award dates.
5. Ensure compatibility of subcontract awards with prime contract requirements and project objectives.

6. Conduct proposal evaluation, source surveys, and selection of subcontractors.
7. Develop subcontract milestones and schedules that reflect significant events compatible with the project master schedule.
8. Manage subcontract effort in the areas of change authorization, performance measurement, corrective action initiation, and technical and management direction.
9. Obtain periodic subcontract progress reports on cost, schedule and technical performance.
10. Coordinate and control all interface activities between the customer/prime contractor and subcontractor organizations.

INTERDIVISION WORK MANAGEMENT

In making primary make or buy decisions the Program Manager, as chairman of the Project Make or Buy Committee, takes into account all factors that affect quality, reliability, safety, schedule, cost, and technical performance of the required product. In addition, he gives full consideration to the products and services of other divisions of the company on the basis of:

1. Special products, facilities and capabilities
2. Minimal flow time capability
3. Effective utilization of total company resources
4. Minimal cost in achievement of project objectives

For management of all work authorized to be performed by other divisions of the company the contractor utilizes an integrated system that treats the effort in a manner similar to subcontracted effort.

This system provides procedures for authorization and management of the work which will assure timely, accurate, and auditable measurement of cost, schedule, and technical performance. The system is operated by the Manufacturing function which coordinates and controls all interface activities, meetings, correspondence, and technical direction in support of the Program Manager.

CUSTOMER INTERFACE MANAGEMENT

The accomplishment of project objectives to the mutual satisfaction of both contractor and customer requires a close but disciplined interface relationship between the two. The primary responsibility for ensuring this relationship rests with the top representatives of each activity, i. e., the Program Manager for the contractor and the Program Manager for the customer. All interface relationship between the contractor and customer will be authorized and controlled through their delegations of authority. The following general categories of interface relationship are defined and responsibility for control established.

Contractual Interface

This interface involves all matters associated with the contract, its negotiation, changes, administration, interpretation, and reports of compliance. The contractor will interface with the customer contracting officer through the designated project contracts and Pricing representative. The only binding agreements on the company will be effected through this interface.

Administrative Interface

This interface results from formal communications between the contractor and the customer. It involves a review of all incoming correspondence, including that electrically transmitted, to ensure that responsible project management is informed promptly and that timely action is taken when required. The project business management function is responsible for implementing, operating, and controlling this interface with the customer.

Technical Interface

This interface involves the interchange of technical information between the contractor and the customer. It encompasses both informal and formal communications which are related to technical conduct of the project but which do not alter contractual baselines. The project chief engineer is responsible for implementing, operating, and controlling this interface with the customer.

ASSOCIATE CONTRACTOR INTERFACE MANAGEMENT

Contractors having prime contracts with the same customer, for products that have mutual physical and/or functional interfaces, hold an associate contractor relationship to each other. Effective teamwork among

such associate contractors dictates that their mutual interfaces be formally defined and controlled. To accomplish this function the contractor will take the following action:

1. Establish an associate contractor interface management function under Project Business Management to coordinate the managerial and technical interfaces with other MSS program contractors designated by the customer as associate contractors.
2. Develop, negotiate, administer, and maintain documented agreements with associate contractors, subject to customer approval, that prescribe operating and control procedures for all mutual interfaces relating to the MSS program.
3. Support the establishment and operations of an interface control working group (ICWG) as directed by the customer, for the resolution of interface problems.
4. Establish design agreements with associate contractors through the development of interface control documentation (ICD).
5. Coordinate the exchange of ICD's, design data, schedules, and plans with associate contractors.
6. Ensure continuous follow-up on ICWG action items in accord with customer direction.
7. Ensure that contractual action is initiated for implementation of required interface activities.



COST REDUCTION MANAGEMENT

Cost reduction management has as its objective the performance of a job with reduced cost, or the performance of a better job for the same cost, without sacrificing quality of product, service, or scheduled delivery to the customer. Through continuing management attention and utilization of established company systems for conservation of resources, value control of functional processes, and operational analyses, a major impact can be achieved in reducing costs of the project. The following actions will be taken by the contractor to attain a cost-effective project:

1. Place management emphasis on cost reduction and cost avoidance.
2. Provide systematic analysis of functions and evaluation of alternatives with the objective of obtaining the greatest product value with respect to technical performance, schedule, and cost.
3. Provide improved utilization of resources through the reclamation and reduction of waste.
4. Conduct continuing examination and analysis of requirements for hardware, software, or services to eliminate or modify those that do not contribute to effectiveness of the product.
5. Implement cost reduction programs that encourage employees and subcontractors/suppliers to initiate cost savings ideas in all operation areas.

The cost reduction management system will be implemented by all MSS project functions, under the direction and guidance of project business management.

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RELIABILITY MANAGEMENT

The contractor's reliability management system, operated by the engineering function, ensures control and accomplishment of all reliability tasks in a cost-effective manner during design, development, and operations of the modular space station. It provides the methodology to satisfy the following requirements:

GENERAL

1. Prepare a reliability program plan, as described in Section 6.0, that defines the project requirements and identifies the implementation methods.
2. Provide a single-point function within the project organization with the responsibility for planning, implementing and controlling the reliability function.
3. Assign a head of reliability who will devote full time to the reliability effort and report at a level appropriate to the fulfillment of his contract responsibilities.
4. Monitor all reliability tasks to assure that they are effectively accomplished and that project reliability requirements are met.
5. Establish supplier reliability controls which assure that procured hardware is compatible with project reliability requirements.
6. Provide visibility of project reliability status, effectiveness, resource expenditure, and identified problem areas to the customer.

DESIGN SPECIFICATIONS

1. Generate and maintain appropriate design specifications/product control documentation to ensure their adequacy in support of project reliability objectives.
2. Revise specifications when they become obsolete or out of date.
3. Conduct independent reliability review of selected project specifications.



RELIABILITY EVALUATION

1. Provide procedures which ensure that all designs selected for station usage have appropriate reliability evaluation through qualitative and, as applicable, quantitative analysis techniques.
2. Utilize evaluation techniques that identify potential problem areas and assure compliance of each configuration with project criteria.

FAILURE MODE EFFECTS ANALYSIS

1. Perform detailed failure mode effects analyses (FMEA's) on candidate configurations early in the design phase.
2. Identify deficiencies or needs, such as single failure points (SFP's), potentially hazardous conditions, critical items for emphasis, need for redundancy, etc.
3. Perform a continuing effort to eliminate or minimize the effect of single failure points throughout the project.

MAINTAINABILITY

1. Provide maintainability features in designs developed by the contractor that are based on reliability experience and analytical studies.
2. Identify those components, considered in the design, which will require frequent removal because of known limited life or age-sensitive characteristics, as well as hardware with unique maintenance and adjustment problems.
3. Conduct maintenance planning which reflects project reliability experience with an optimum mix of both preventive and curative measures.

DESIGN REVIEW

1. Establish a formal program of engineering management evaluation of all proposed designs.
2. Conduct design reviews at the system, subsystem, assembly, subassembly, and component levels which provide comprehensive critical audits of all pertinent aspects of the designed hardware and software that affect reliability requirements.



3. Identify and document potential design problems to ensure that appropriate action is taken to achieve reliable designs.

PROBLEM REPORTING AND CORRECTION

1. Evaluate technical problems associated with hardware and software (such as failures, discrepancies, nonconformances, etc.) to ensure a continual upgrading of the system configuration.
2. Implement a controlled problem reporting system for reliability, quality, and safety disciplines commencing at the hardware development phase of the project.
3. Provide a closed-loop problem reporting and correction system that identifies, verifies, tracks, and documents correction of quality, reliability, and safety hardware problems as well as associated software nonconformances.
4. Ensure that problem definition/status/closeout data is compatible with the customer problem data bank requirements.
5. Provide maximum emphasis on a resolution of deficiencies that could affect personnel safety, mission success, or cost-effective module operation.

PARTS AND MATERIALS PROGRAM

1. Provide a parts and materials program which consists of selection, specification, application, and qualification controls.
2. Provide a parts selection program which minimizes the number of part types used.
3. Develop a project preferred and standard parts list and materials program requirements and ensure its use by all project agencies.
4. Maintain an accountability system that identifies the location of Modular Station parts and materials.
5. Identify data requirements and screening activities for off-the-shelf hardware that will eliminate potential reliability problems.



TEST

1. Establish controls for a planned program of testing and application analysis which will ensure that equipment used on the Space Station Project is capable of performing within all anticipated environments and use conditions.
2. Utilize techniques that identify risks and potential problems and assure certification rigor compatible with the project reliability objectives.
3. Provide a certification program along with an acceptance test program to minimize known fabrication problems.



QUALITY ASSURANCE MANAGEMENT

Establishment of an effective and timely quality assurance program in consonance with NHB 5300.4(1B) requires implementation of specific quality assurance tasks and management controls. The Contractor's Quality Assurance Management System implements the following requirements. As described in Section 6.0, a detailed MSS project quality program plan will be prepared to define the quality program implementation.

QUALITY ASSURANCE MANAGEMENT ORGANIZATION

A single-point function will be established within the project organization which has the responsibility for planning, controlling, and implementing quality assurance requirements of the project. One individual will be assigned the responsibility for directing and managing the quality assurance program, and he will report directly to the Program Manager, with specific responsibility to the Vice President of Quality Assurance.

QUALITY ASSURANCE PROCEDURES

Effective and timely quality assurance procedures and control documentation, tailored to the applicable phase of the project, will be developed and implemented. Unscheduled audits will be performed on personnel, procedures, operations and associated documentation which affect the quality program.

QUALITY INFORMATION

Quality Assurance will provide for the collection, processing, analysis, and recording of quality information resulting from the design, procurement, fabrication, test, inspection, and usage of articles and materials procured and produced. Appropriate quality information will be promptly disseminated to concerned areas within the contractor's organization and to concerned suppliers to effectively implement quality program requirements and contract requirements.

DESIGN CONTROL

Quality Assurance will establish quality criteria and implement a system to ensure their incorporation in the contractor's technical documents such as specifications, procedures, drawings, fabrication and planning documents, and process sheets. Quality Assurance will participate in design

reviews to ensure that designs permit and facilitate producibility, repeatability, and inspectability and that related quality considerations are defined and incorporated in applicable technical documentation. The contractor's Quality Assurance organization will be responsible for control of all quality-generated documents and changes thereto and will verify that changes are accomplished as authorized on affected articles or materials.

PROCUREMENT QUALITY CONTROLS

Quality Assurance will ensure that procured materials and services meet specification requirements and quality criteria. This assurance will be obtained by review of applicable documents, effective selection of sources, technical assistance and training, assignment of surveillance personnel, and receiving inspection.

FABRICATION QUALITY CONTROL

Quality Assurance will provide quality surveillance of fabrication and assembly operations to ensure that characteristics and design criteria specified in technical documents are included and maintained in all contractor-fabricated articles.

INSPECTION AND TEST

Quality Assurance will conduct an inspection and test program which demonstrates that contract, drawing, and specification requirements are met to provide maximum assurance that the quality inherent in the design is maintained.

NONDESTRUCTIVE EVALUATION

Quality Assurance will use nondestructive evaluation techniques to determine the integrity of structures during manufacturing and to support prelaunch and on-orbit operations. Specific methods will be established to substantially reduce inspection time during manufacturing. Where necessary, on-board nondestructive evaluation methods will be established to provide a timely data readout of structural integrity to support maintenance operations.

NONCONFORMANCE CONTROL

Quality Assurance will establish a nonconformance and corrective action system that provides for the identification, recording, review, and disposition of materials and articles that do not conform to applicable drawings and specifications. The system will include a material review board and will ensure that appropriate corrective and preventive actions are initiated and resolved upon identification of adverse quality trends.

METROLOGY

Quality Assurance will implement a metrology system to control measurement processes to ensure the accuracy of hardware conformance to design requirements. Measurement standards, gauges, and measuring, inspection and test equipment, including production tooling and automated equipment, will be selected and controlled to the degree necessary to meet project requirements.

STAMP CONTROL

Quality Assurance will implement a stamp control system to ensure that stamps are applied to articles and materials (and related records) to indicate fabrication and inspection status, that traceability is provided to responsible individuals, and that stamping methods and marking materials are compatible with the articles and their use.

HANDLING AND STORAGE

Articles and materials will be suitably protected, marked, labeled, and packaged to protect them from deterioration and damage during all phases of fabrication, processing, and storage.

STATISTICAL TECHNIQUES

Quality Assurance may use statistical techniques such as sampling plans, statistical planning, and analysis to provide effective and efficient control over fabrication and inspection operations.

GOVERNMENT PROPERTY CONTROL

The contractor will be responsible for, and account for all Government property provided under the contract.

6.0 PROGRAM PLANS

6.0 PROGRAM PLANS

PURPOSE AND SCOPE

The purpose of program planning documents is to establish courses of action for achieving project objectives and to communicate these courses to all concerned activities. The program plans described in this section are essential to management and conduct of Phases C and D of the Modular Space Station Project. They provide a basis for developing realistic schedules and cost estimates and ensure integration of the various activities of the project. Total program plan requirements are identified in SD 70-166 Space Station Program Phase C/D Data Requirements.

The scope of the planning activity for the MSS project encompasses all project management and technical functions including business management, systems engineering and design, manufacturing, test operations, facilities logistics support, system safety, configuration management, reliability, and quality assurance. Program plans will be developed and prepared for each of these activities in Phase C, based on the requirements established during the Phase B Definition Study. These plans will be updated as required to reflect major project changes and resultant replanning at primary milestones, such as the PDR and CDR.

DESCRIPTION OF PHASES C AND D PLANS

Brief descriptions of the essential program plans for Phases C and D are provided in the following paragraphs. Supplementary plans will be developed, as needed, to meet additional project requirements.

1. The Program Master Plan, the contractor's top planning document, provides the baseline for conduct of all contractor effort during Phases C and D. It defines project tasks, prescribes the project organization, assigns responsibilities, establishes the master schedule, provides the developed WBS, and defines requirements for supporting program plans. This plan is an update of the Program Master Plan (SD 71-225) prepared during Phase B.
2. The Performance Management Plan defines the business systems and control disciplines that will be utilized for planning and control or project operations during Phases C and D. It describes in detail, the application of the cost, schedule, and technical



performance measuring systems and assigns organizational responsibilities for their implementation. The plan implements the requirements established in Section 5.0 of SD 71-225 Program Master Plan.

3. The Configuration Management Operating Plan defines the organization, responsibilities, methods, procedures, and processes that will be used to meet the configuration management requirements imposed by the customer. It ensures that the technical documentation by which the MSS Project hardware is identified, controlled, and recorded will maintain its technical integrity throughout the project. It implements the requirements defined during Phase B, summarized in Section 5.0 of this document, and detailed in SD 70-141, Appendix A, Configuration Management Requirements Plan.
4. The Data Management and Documentation Control Plan defines the organization, responsibilities, procedures, and processes that will be utilized in complying with the contractual data requirements of the MSS Project. It implements the requirements defined during Phase B, summarized in Section 5.0 of this document, and detailed in SD 70-141, Appendix B, Data Management Plan.
5. The Subcontract Management Plan describes the organization and management processes that will be utilized in planning and controlling all subcontracted effort required for the project during Phases C and D. This plan implements the requirements established in Section 5.0 of SD 71-225 Program Master Plan.
6. The Engineering Management Plan, as the top technical plan, provides the guidelines for conduct of all technical aspects of the MSS Project. It defines technical objectives, scope and depth of engineering tasks, and schedule of accomplishment. It establishes an engineering organization and defines overall responsibilities in the disciplines of systems, design, test, and logistics engineering. It describes the systems to be used for controlling the technical effort and provides the basis for development of all supporting technical plans. It implements the requirements defined during Phase B and documented in the SD 70-137 Design Plan.
7. The Test Plan defines the integrated test process for development and qualification of the Modular Space Station. It delineates the optimum programmatic approach with respect to cost, schedule, project objectives, system interfaces, organization, facility utilization, and test software. It provides instructions for subsequent detail test plans and procedures. This plan is an update of Section 2.0 of SD 71-222 MSS Integrated Ground Operations prepared during the Phase B definition study.

8. The Facility Plan defines both contractor and Government facilities required for the project. It identifies existing facilities that will be utilized, new or modified facilities, time-phasing requirements, and planning for obtaining new facilities and modifications. This plan is an update of Section 5.0 of SD 71-222 MSS Integrated Ground Operations, prepared during the Phase B definition study.
9. The Logistics Support Plan defines the organization and procedures that will be implemented to provide logistics support for the project. The logistics support includes spares provisioning and supply support, maintenance analysis support, transportation and handling, operational support, site activation, refurbishment, technical manuals, and training. This plan is an update of Section 7.0 of SD 71-222 MSS Integrated Ground Operations, prepared during the Phase B definition study.
10. The System Safety Plan describes the safety tasks to be carried out during the MSS Project and the techniques and methods to be used in assuring the application of system safety principles throughout all phases of the project. It identifies organizational task assignments and responsibilities associated with the conduct of system safety. It provides a systematic method for identifying, analyzing, eliminating, or controlling and categorizing hazards. This plan implements the requirements defined during the Phase B definition study, summarized in Section 5.0 of this document, and detailed in SD 70-133 System Safety Plan.
11. The Manufacturing Plan defines methods and procedures to produce, functionally test, and deliver acceptable end-items of the Modular Space Station on schedule with minimum cost. It provides a manufacturing organization, a master phasing schedule, and a plan for acquiring raw material with appropriate lead times for completing all subsequent operations in accordance with the master phasing schedule. It prescribes procedures for production control, indicates plant layout with sequence flow charts, and defines tooling philosophy. It defines necessary skills and total manpower required to perform the manufacturing effort. This plan is an update of Section 3.0 of SD 71-222 MSS Integrated Ground Operations, prepared during the Phase B definition study.
12. The Quality Program Plan defines the organization and methods for ensuring compliance with all quality requirements of the project. It defines quality assurance procedures for all phases of the project, including inspection, test, checkout, packaging, shipping, storage, maintenance, field installation, and prelaunch



and orbital operations. It provides methods for early and prompt detection of actual or potential deficiencies, system incompatibility, marginal quality, and trends or conditions that could result in unsatisfactory quality. This plan implements the requirements defined during the Phase B definition study, summarized in Section 5.0 of this document, and detailed in SD 70-130 Quality Program Plan.

13. The Reliability Program Plan defines the organization and methods for meeting the reliability requirements of the MSS Project. It includes a detailed time-phased description of all tasks to be performed and the procedures for implementing, monitoring, and controlling these tasks. This plan implements the requirements defined during the Phase B definition study, summarized in Section 5.0 of this document, and detailed in SD 70-129 Reliability Program Plan.

7.0 MANPOWER AND COST PLANNING

7.0 MANPOWER AND COST PLANNING

INTRODUCTION AND SUMMARY

This section presents an overview of the manpower and financial requirements for the Modular Space Station Project. These requirements have been developed on the basis of performing the effort defined by the MSS Project Work Breakdown Structure shown on Figure 3-27 and to the schedule established on Figure 3-30. In general, a parametric method of costing was utilized that derived cost data from NR, NASA, DOD, and industry sources. In-house trade studies were conducted to evaluate alternative program requirements, objectives, and candidate concepts. Based on iterative cycling of the data developed throughout the definition study, the costs for conduct of the MSS project through 5 years of growth station operations are estimated to be \$2.373 billion in GFY 1972 dollars with a peak manpower requirement of 16,800 equivalent direct personnel occurring during GFY 1979. These data were derived from, and are compatible with, the total MSS Program Cost and Schedule Estimates, SD 71-226.

ASSUMPTIONS AND GROUND RULES

The manpower and financial requirements for the MSS project were developed on the basis that the following assumptions, ground rules, and rationale are effective:

1. Cost estimates are intended for budgetary and planning purposes only.
2. Cost estimates reflect the configuration definition and mission profile contained in SD 71-215-1 Initial MSS Systems Preliminary Performance Specification, and as generally described in Section 3.0 of this plan.
3. Costs reflect 1972 dollars and include all elements of cost through the general and administrative (G and A) level.
4. Non-recurring costs include design and development, major test programs, initial tooling and special test equipment, ground support equipment, facilities, site activation, and miscellaneous other costs in direct support of DDT&E.

5. Recurring production costs include material procurement and manufacturing of flight hardware, acceptance test, maintenance of tooling and special test equipment, and miscellaneous costs in direct support of production.
6. Recurring operations costs include spares, launch and mission support site operations, cargo module refurbishment, and in-plant effort in support of launch and flight operations.
7. Costs that are specifically excluded from the MSS project are: space shuttle development, investment, and operational costs; costs of experiment definition, experiments and attached and detached RAM projects; and consumables, foods, medical and dental supplies, clothing, personal gear, space suits, EVA equipment, and other MSS GFE/GFP.

FUNDING AND MANPOWER

The estimated total cost of the MSS project is shown in Figure 7-1, as a requirement for funding allocation by Government fiscal year. The peaking of DDT&E, along with the rapid buildup of production and the start of operations, cause the peak loading of approximately \$580 million in GFY 1979.

In Figure 7-2, cost estimates have been converted to manpower requirements showing the peak manpower requirement of approximately 16,800 that will occur in GFY 1979. This figure includes all prime and subcontractor personnel and is based upon \$35,000 per equivalent direct man-year for DDT&E, and \$32,000 for production and operations, measured in GFY 1972 dollar values. These values are based on historical experience adjusted for inflation to 1972 dollar values.

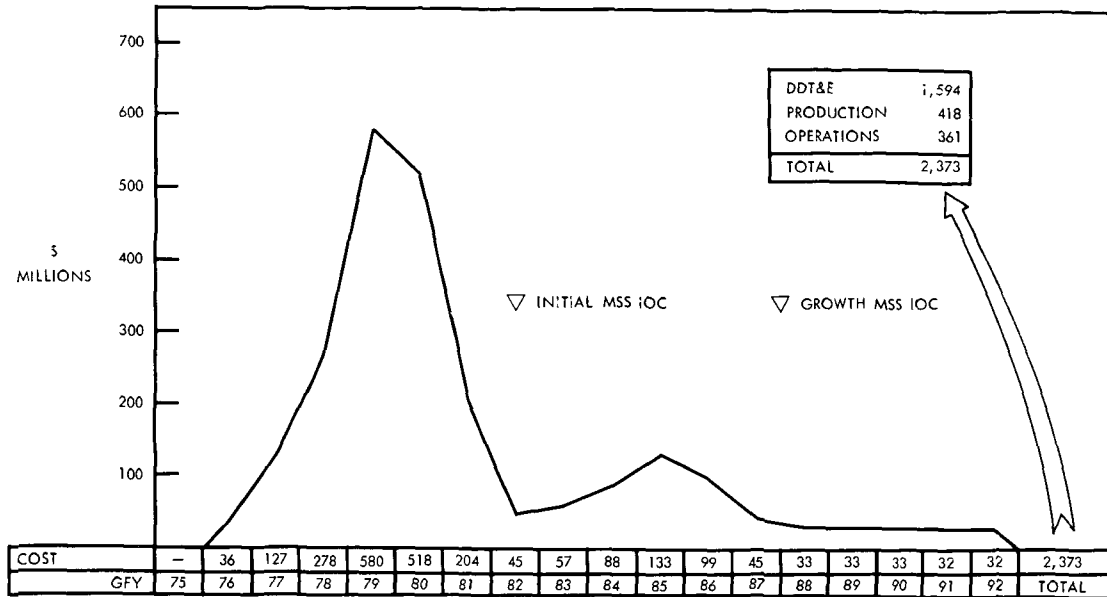


Figure 7-1. MSS Project Funding Projection

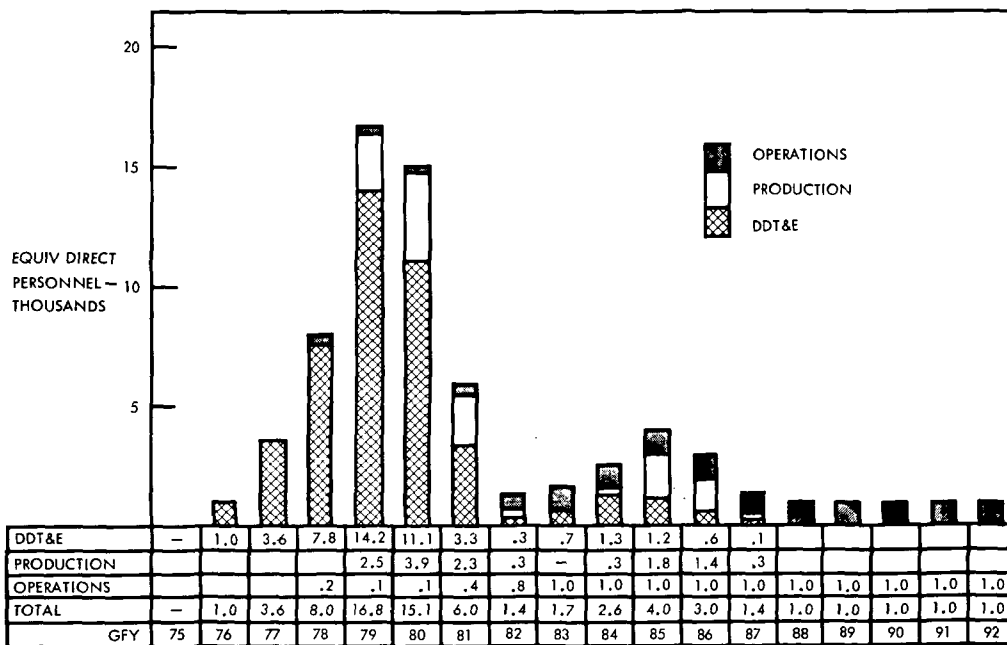


Figure 7-2. Project Manpower Requirements

8.0 POTENTIAL PROBLEM AREAS

8.0 POTENTIAL PROBLEM AREAS

TECHNICAL

The technical problems involved in producing a modular space station are not severe. The approach to the program has been to incorporate low cost concepts requiring a minimum of technology advancement, and to leave wide margins for the weight, volume, and performance changes that inevitably occur. The key to maintaining the program in a high-confidence, low-cost posture is to systematically conduct a supporting technology program that brings key elements to full technology readiness in a timely manner.

The key technical areas of concern in the modular space station program are: (1) integrated subsystem control and (2) module-to-module interface complexity. A third key technical area of concern is equipment reliability and life, but the criticality of this has been considerably reduced by a "forgiving" station design and nearly 100 percent maintenance capability.

The concern over integrated subsystem instrumentation and control stems from the basic reason-for-being of the space station; that of applying maximum crew time to performing research and applications tasks. This requires computer-controlled automation of subsystem operation and major computer assistance in fault isolation and on-board checkout. The degree of electrical and mechanical integration required is well beyond current practice in ground utility systems (power, telephone, water supply, etc.) with the added space station requirement of maintenance of a habitable environment. The major technical recommendation of the study is that the Government should include such integration as major elements in space station supporting research and technology.

The second key concern, module-to-module interface complexity, stems from the buildup approach whereby each module is placed in orbit one at a time, 30 (or perhaps 60) days apart. Attention to this area during preliminary design has mitigated the problem somewhat by minimizing the activation of subsystems during station buildup, and by simplifying the interaction of one module with another. Nevertheless, the core module, designed as a manned, maintainable element of an integrated space station, must operate as if it were an unmanned spacecraft for approximately 6 months. In addition, it was not practical or even possible to attain complete module independence; the interfaces between modules are still physically and functionally complex.

Again, this complexity is primarily related to buildup since, once assembled, the station modules are very seldom disconnected or moved. There is no specific single technology recommendation addressed to this problem; rather, it should be considered in all subsystem technology developments where there is a module-to-module interaction within the subsystem. In addition, higher level integration tasks such as the one mentioned in the preceding paragraph should include module-to-module integration aspects.

During the course of the study, a large number of lower level but nevertheless important technology areas were identified. These are shown in Table 8-1 and have been discussed with the NASA for possible inclusion in supporting technology programs. Many are currently underway; the others could be added to these or started as new projects. As previously mentioned, continuing timely technology development is the key to keeping the space station program a low-cost, low-risk endeavor.

Table 8-1. Modular Space Station Technology Requirements

NR MSS CONCEPT NEEDS			
EPS	Lightweight solar array (Lockheed technology) Solid state circuit breakers Inverters EPS/ISS control, monitoring, fault detection/isolation Regenerative fuel cell EPS computer simulation Power switching on solar array	Information Management System	Higher order language compiler for subsystem management OBEO syntax OBEO module software specification Station central processor simulation Station central processor procurement (enr eval model) Man-machine interaction evaluation tests Wide-band tricolor facsimile
ECLSS	Solid polymer water electrolysis Hydrogen depolarizer (CO ₂ removal) Vapor compression water reclamation Fire detection & control Water purity monitoring Atmosphere contaminant monitoring Instrumentation reliability ECLSS/ISS control, monitoring, fault detection/isolation Long duration manned integrated testing		Low-noise uncooled S-band receiver High-power solid-state S-band transmitter Station data bus evaluation tests Dynamic scheduling algorithm Station central processor executive program File security techniques IFRU signature analysis Optical/bubble storage breadboard K-band transponder evaluation tests RE communications switching through TDRS Interpretive displays (situation, decision-aids, etc.) Interactive query language (operations)
RCS	Engine igniter assembly Engine development Engine quad maintenance Instrumentation reliability Interface connections	Materials & Structures	Proof-test criteria to assure service life Development of in-orbit structural repair techniques Berthing mechanics Utilities quick disconnect fittings Seals Characteristics of polymers in space environment Characteristics of lubricants in space environment Thermal control coatings for window assemblies Thermal insulation panel
		Space Medicine & Human Research	Habitability criteria verification Re-entry stress following prolonged exposure to weightlessness Control of micro-organisms Evaluation of techniques to prevent cardiovascular deconditioning
ADDITIONAL CANDIDATES (Alternatives, Back-up, Program-Sensitive, Common With Other Program Elements)			
EPS	NiCd battery (100-300 AH) Pulse battery charger techniques	Information Management System	High density data storage Plasma displays
ECLSS	Heat pipe technology Heat pipes, heat exchangers User equipment delta requirements analyses Coolant fluid Single fluid concept ECLSS atmospheric control equipment compatibility Reverse osmosis water reclamation Regenerative charcoal	Materials & Structures Space Medicine & Human Research	Most are common to cargo module, RAM, & sortie Artificial gravity assessment
RCS	Biowaste resistojets Long-term cryogenic storage Cryogenic liquid zero-g transfer Zero-g liquid & cryogenic gaging		

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PROGRAMMATIC

It is the opinion of the contractor that the Level 3 MSS project, as defined herein, can be accomplished within the prescribed time-frame provided that funding is available at the levels projected in Section 7.0. Should specific fiscal constraints be imposed which undersupport resource requirements, and assuming that current technical guidelines and systems definition remain unchanged, then funding becomes the programmatic driver and operational timing would be revised accordingly.

There are several related studies which have been concluded or initiated during this MSS Phase B Definition Study and which will have definite influence on the Space Station Earth Orbital Program, as currently baselined. Typical of these are the sortie missions, RAM definition, shuttle configuration and payload alternatives, and "common" module design and producibility studies. Program changes will undoubtedly impact the MSS project. The contractor recommends, therefore, that key Phase B documents such as this MSS Program Master Plan be maintained current with those developments in order to preserve continuity and to enhance the capability for initiating Phase C in a timely, effective manner.

APPENDIX

APPENDIX

DEFINITIONS

The criteria contained in this document for the contractor's performance management system are to be interpreted according to the following definitions and regulations.

APPLIED DIRECT COST (ACCRUED COST)

The amounts recognized in the period associated with the consumption of labor, material, and other direct resources, without regard to the date of commitment or the date of payment. These amounts are to be charged to work in process in the period that any of the following takes place:

1. When labor, material, and other direct resources are actually consumed
2. When material resources are withdrawn from inventory use
3. When material or subcontract software and other nonrecurring resources are received that are uniquely identified to the contract and scheduled for use within 60 days
4. When major components or assemblies are received on a line-flow basis that are specifically and uniquely identified to a single serially numbered end item.

APPORTIONED EFFORT

Effort that by itself is not readily divisible into work packages but is directly related to existing work packages.

AUTHORIZED WORK

The effort (1) that has been negotiated and definitized by supplemental agreement and (2) for which firm contract prices have not been agreed to, but for which written contract instructions have been received to proceed with work.

BUDGET

The resources (measured in dollars, man-hours, or other definitive units) that are formally assigned by the contractor for the accomplishment of a specific task or group of tasks.

CONTRACT BASELINE

The time-phased values of the total project at WBS Level 3 as identified in Section 3.0, Figure 3-27. The baseline total must equal the contract cost as defined below. It represents the sum of direct effort and allocable indirect work budgets and management reserves for the original contract and budgets for government authorized changes. If work is authorized before it is definitized, interim budgets will be used for authorized work until it is definitized.

CONTRACT COST

The total contract value, excluding fee or profit, consisting of the sum of definitized costs and costs for all government-authorized work not yet definitized.

COST ACCOUNT

The focal point within the contract WBS at which applied direction costs are accumulated and summarized by WBS and functional organization and the lowest required level at which planned value of work accomplished is compared with planned value of work scheduled and applied direct costs. It is also the WBS level where costs are accumulated for performance measurement purposes. The cost account will normally be further subdivided into work packages and will contain separate identification of cost elements (labor, material, etc.). The cost account will have the following characteristics:

1. A clear definition of work to be performed
2. A specific budget and schedule
3. A designated manager with complete responsibility for completing the assigned work within all performance measurement constraints
4. Be restricted to a single functional organization
5. Apply to a single WBS element

DEFINITIZED CONTRACT COSTS

Negotiated costs that are formalized in a contractual document such as a Supplemental Agreement.

DIRECT COSTS

Any cost that can be identified specifically with a particular cost objective. Direct costs are not limited to items incorporated in the end product as material or labor. Costs identified specifically with the contract are costs of the contract and are to be charged directly thereto.

ESTIMATED COST AT COMPLETION (EAC)

Applied direct costs and indirect costs allocable to the contract, plus the estimate of costs for authorized work remaining.

INDIRECT COSTS

A general group of indirect expenses such as those generated in manufacturing departments, engineering departments, tooling departments, general and administrative departments, and indirect costs accumulated by cost centers within these general groups. Included are general groups of expenses such as general administration and general expense, maintenance and operation of physical plant, library expenses, and use charges for building equipment. Indirect costs derived from overhead cost pools that are added to applied contract costs are to be allocated and controlled by government-approved accounting procedures.

LEVEL OF EFFORT

That activity that cannot be associated with a quantitatively measurable end product or result and is controlled by time-phased budgets established for that purpose.

MANAGEMENT RESERVE

The total contract cost less the summed value of all the budgeted effort. This cannot be a negative value.

ORGANIZATIONAL ELEMENT

A unit of the contractor's organization.



PERFORMANCE BASELINE

The distribution of time-phased costs from operating organizations to the cost account level. This level will serve as the formal baseline for schedule and cost performance measurements. The sum of work budgets allocated to cost accounts plus management reserves must equal the time-phased budgets and reserves in the contract baseline.

PLANNED VALUE OF WORK ACCOMPLISHED (PVWA)

The sum of the budgets for completed work packages and completed portions of open work packages, plus budgets for level of effort and apportioned effort activity completed.

PLANNED VALUE OF WORK SCHEDULED (PVWS)

The sum of the budgets representing the cumulative financial plan from inception to the current report period, including the amount of level of effort and apportioned effort.

REPORTING BASELINE

The level of reporting to NASA that should typically be at Level 3 of the WBS for total project data and at WBS Level 4 for each primary organizational function, except when lower levels of the WBS are of significant importance to warrant their inclusion.

SIGNIFICANT VARIANCES

Variances or differences from plan that are great enough to require further review, analysis, or action.

UNDISTRIBUTED BUDGET

A budget that has been identified and set aside for a specific future task or set of tasks in support of the contract, but that has not been distributed to a specific operating organization.

VARIANCE MEASUREMENTS

Budget Variance

Difference between the planned value of work scheduled (PVWS) and actual recorded costs. A negative variance indicate actual costs are in excess of planned budget (PVWS); conversely, a positive variance indicates actual costs are less than planned budget (PVWS).



Cost Variance

Difference between the planned value of work accomplished (PVWA) and actual costs. A positive variance indicates an underrun of planned cost, i. e., work is being accomplished at a lower cost than planned. A negative variance indicates an overrun of planned cost, i. e., work is being accomplished at a higher cost than planned.

Schedule Variance

Difference between PVWA and PVWS in the order stated. A positive variance (PVWA is greater than PVWS) indicates the category reported is ahead of schedule and in a favorable position. A negative variance (PVWA is lesser than PVWS) indicates the category reported is behind schedule and in an unfavorable position. By plotting cumulative PVWA and PVWS dollar value curves on a time scale and identifying the PVWA dollar value for the current report period on the PVWS curve, it is possible to measure the difference between PVWA and PVWS (schedule variance) in terms of calendar time.

WORK BREAKDOWN STRUCTURE (WBS)

A product-oriented family tree division of hardware, software, and services, and other work tasks that organizes, defines, and graphically displays the products to be produced as well as the work to be accomplished in order to achieve the specified product. The following criteria must be satisfied:

1. The WBS must be used to allocate all resources to fulfill contract project requirements and must accommodate the accounting structure for budget and cost purposes and the project organizational structure for responsibility definition.
2. The contractor will structure the WBS from the NASA-provided level (normally to the system level) downward to at least the cost account.
3. All subcontracting and major procurement effort will be included at the proper level of the WBS.
4. The WBS must be integrated with the contractor's functional organization in a manner that permits performance measurement for WBS and organizational elements assigned to the contract effort beginning with the cost account level.

WORK PACKAGES

Detailed short-span jobs (or purchased material items) identified by the contractor and controlled by him is assigning work within his organization and accomplishing work to complete the contract.