DECEMBER 1971

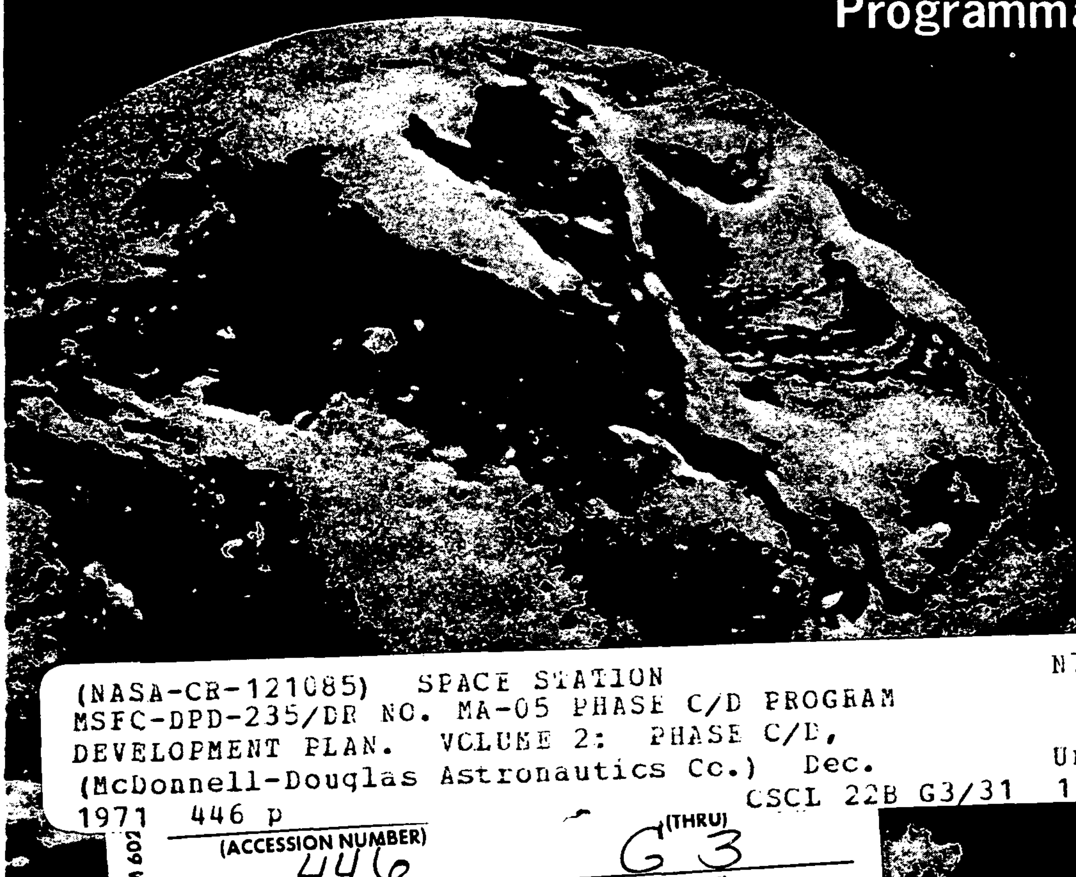
MDC G2539

SPACE STATION

MSFC-DPD-235/DR NO. MA-05
PHASE C/D
PROGRAM DEVELOPMENT PLAN

Volume II
Phase C/D
Programmatic Requirements

CONTRACT NAS8-25140



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VOLUME II
Phase C/D Programmatic Requirements

DECEMBER 1971 MDC G2539

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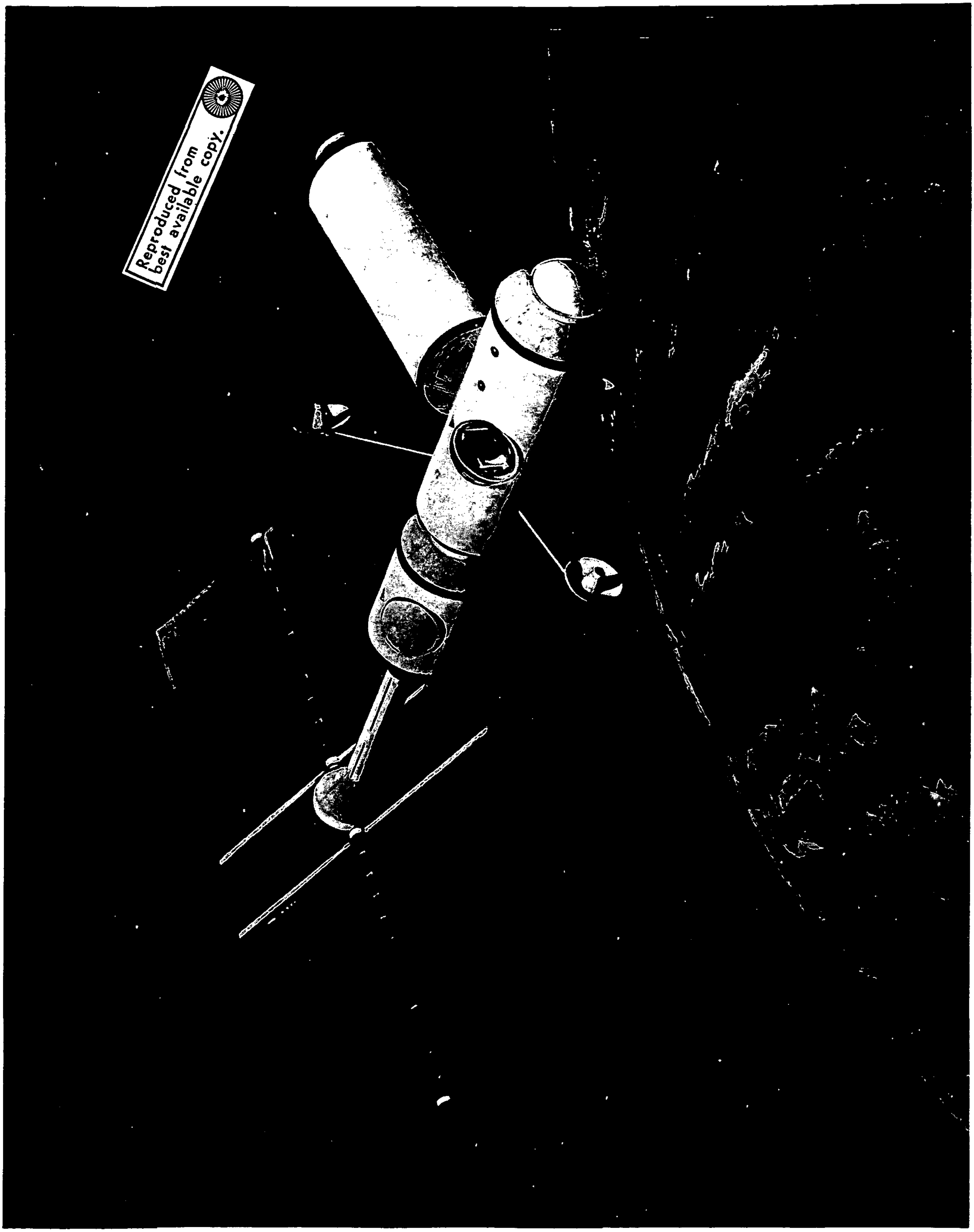

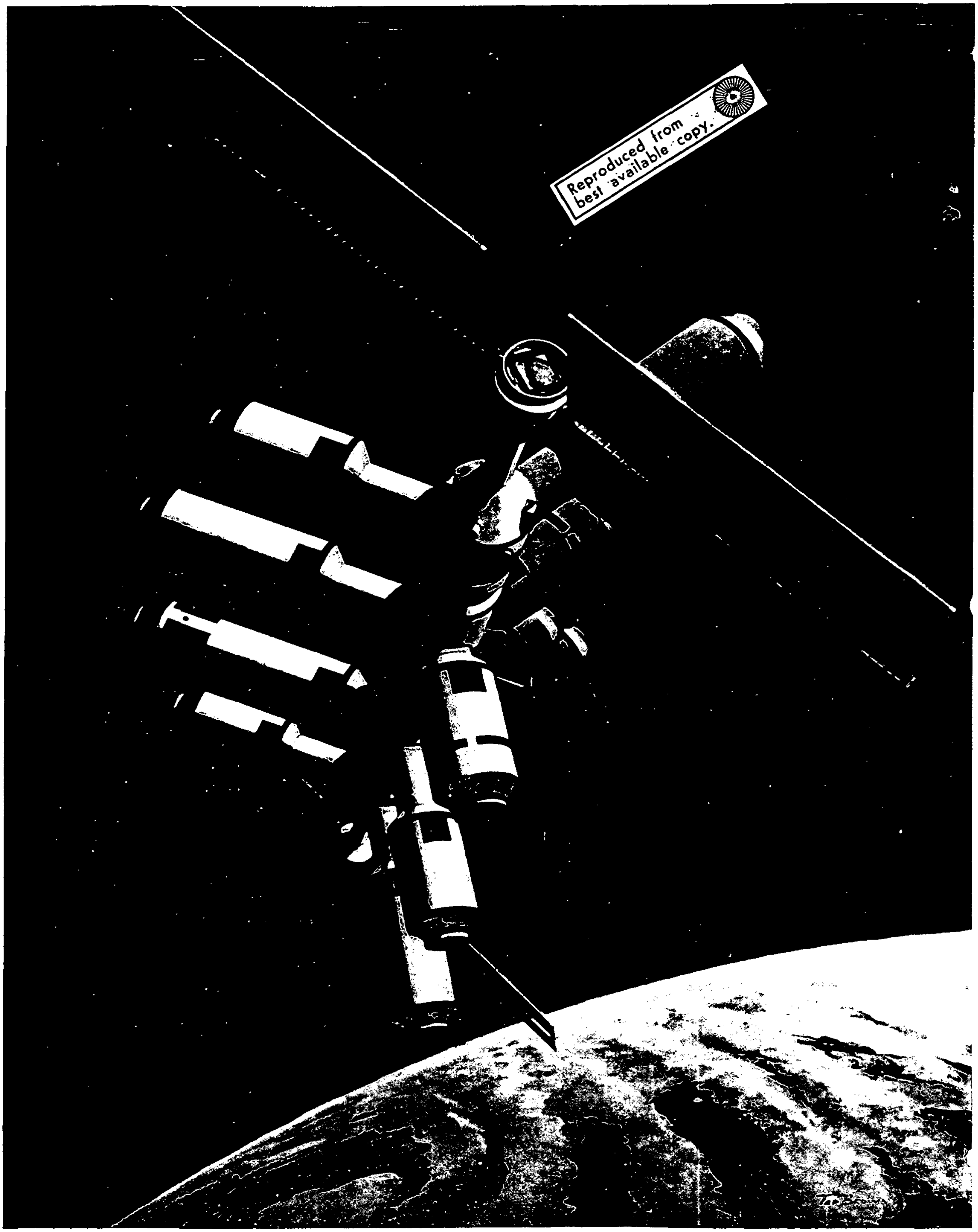

PREFACE

Work reported herein was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the Space Station Extension Period has been to perform the Phase B definition of the Modular Space Station. The modular program selected during the option period (low initial cost, incremental manning) was evaluated, requirements defined, and program definition and preliminary design accomplished to the depth necessary for exit from Phase B. The initial 2-1/2 month effort of the extension period was for analyses of the requirements associated with Modular Space Station program options. During this period, a baseline incrementally-manned program has been derived with attendant experiment program options. In addition, those features of the program that significantly affect the initial development and early operating costs were identified, and their impact on the program were assessed. This assessment, together with a recommended program, were submitted for NASA review and approval on 15 April 1971. The second phase of of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

This report is submitted as part of DRL No. MA-05 "Phase C/D Program Development Plan", which consists of the following volumes:

Volume I—Program Plan
Volume II—Phase C/D Programmatic Requirements

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

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

SUBJECT REFERENCE MATRIX

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

	CM				MA		MF	MP			SE								
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part I CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
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INTRODUCTION

BACKGROUND

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

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

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

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

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

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

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

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

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

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

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

SCOPE OF THIS VOLUME

The program plans in these volumes have been prepared in accordance with the Modular Space Station Program Definition (Phase B) Statement of Work, which requires the preparation of preliminary requirements plans for each of the major functional areas for the conduct of Phase C (design) and Phase D (development and operations). These plans have been prepared specifically for the Initial Space Station phase of the Modular Space Station Project. This Initial Space Station consists of the Power Module, Crew/Operations Module, General Purpose Laboratory Module and Logistic Module. The plans are keyed and coordinated to the Modular Space Station Work Breakdown Structure (illustrated in the Program Management Plan Requirements). They provide decision-making information at the project level as well as a functional baseline definition. Whereas the plans are complete in scope, covering the functional activities at the initiation of Phase C Design and continuing to the end of the 10-year operational phase, they are of necessity preliminary in depth. These plans address in detail the requirements for the development of the ISS, and its first five years of orbital activity. In addtion they provide for the general requirements associated with the GSS Phase (second five years of operation) in order to encompass the 10-year minimum design life of the Space Station. Some plans covering the more imminent period of time, such as design, and supporting research and technology, have been prepared in greater depth than plans covering the more distant time period, such as experiment integration and operations, logistics support, and crew training. Further definitization of these plans will be an evolutionary process relying on data from Modular Space Station definition studies, NASA in-house projects and related research and development work being done in the industry. Progressive development of these plans, and the supporting specifications, will satisfy the Phase B exit requirement of NASA Phased Project Planning.

It is most important to remember that these plans are requirements oriented, rather than solution or implementation oriented; the requirements identified in the plans are to be implemented in the preparation of detailed program plans for Phase C/D. The plans have been prepared from a NASA point of view and are intended to provide a suitable basis for NASA requirements incorporated in competitive solicitation for Phase C/D. The plans are oriented toward contractor activity and reflect the understanding of Modular Space Station Project functional performance requirements gained from the Phase B Definition Study. Consideration has been given to published NASA policies and procedures, and the applicable NASA documents are referenced in each program plan.

Three basic evaluation criteria have been systematically reflected in the definition of requirements found in each plan. They are:

- Maximum cost reduction from the NASA and contractor points of view.
- The one-of-a-kind nature of the Modular Space Station Program
- Ten-year program life in space.

These criteria appear in varying functional requirements such as:

- Use of off-the-shelf systems where performance requirements can be met within the state-of-the-art.
- Use of modularity in design to reduce complexity of maintenance.
- Elimination of fabrication practices requiring hard tooling of the type appropriate to production of more than one of a kind.
- Use or modification of existing facilities rather than requiring new facilities.

Recognition of these criteria as a requirement for all aspects of program planning will help assure that cost reduction will be built into the basic program plan.

MODULAR SPACE STATION
DESIGN PLAN REQUIREMENTS

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DESIGN PLAN REQUIREMENTS

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Section 1
INTRODUCTION

1.1 PURPOSE

The Design Plan Requirements defines the design implementation and control requirements for the Phase C/D of the Modular Space Station Project and specifically address the Initial Space Station (ISS) phase of the Space Station Program (Modular). It is based primarily on the specific objective of translating the requirements of the Space Station Program, Project, Interface and Support Requirements and preliminary Contract End Item (CEI) Specifications into detail design of the operational systems which comprise the Initial Space Station. This document has been prepared to guide aerospace contractors in the planning and bidding for Phase C/D.

The detail design requirements associated with the Phase C/D for the Growth Space Station (GSS) are to be established subsequently, encompassing any design functions required for modification of ISS elements, incorporation of new technology if appropriate, and providing GSS design integration. An additional objective of the design requirements defined herein is to assure that implementation plans consider the growth phase and provide for a cost-effective transition.

A detailed Design Implementation Plan will be prepared as a part of the proposals submitted by the competing aerospace firms for phase C/D defining their proposed methods and approach for meeting the requirements defined herein, providing specific planning for system design, design verification, interface engineering, detailed design, performance integration, and analysis and evaluation of development tests. Specific contractor policy relative to use of the Design and Development Implementation Plan will be required from the selected development contractor.

1.2 SCOPE

The definitions, requirements, and procedures contained in the design plan apply to the Initial Space Station system (consisting of the Crew/Operations, Power/Subsystems and General Purpose Laboratory Modules), the Logistics Module, and associated ground support equipment and facilities.

Specifications which establish the performance and design requirements related to the design plan are as follows:

Space Station Program (Modular) Specification - PS 02925
    Data Requirement CM-01
Space Station Project (Modular) Specification - RS 02927
    Data Requirement CM-02
Initial Space Station CEI Specification - CP 02929
    Data Requirement CM-03
Logistics Module CEI Specification - CP 02930
    Data Requirement CM-03
Interface and Support Requirements Specifications (RS 02928, RS 02933, RS 02934, RS 02935, and RS 02936)
    Data Requirement CM-04

The design baseline for the plan is described in Data Requirement SE-04, Modular Space Station Detailed Preliminary Design, as follows:

Volume	Book
Configuration	TBD
Environmental Control and Life Support	TBD
Electrical Power	TBD
Communications	TBD
Data Management	TBD
Onboard Checkout and Fault Isolation	TBD
Propulsion	TBD
Guidance and Navigation	TBD
Stability and Attitude Control	TBD
Structural/Mechanical	TBD
Crew Habitability and Protection	TBD
Experiment Support	TBD

This plan covers the period from the initiation of Phase C/D through five years of Initial Space Station operation, concentrating mainly on the early portion of the program, where design is a major task.

1.3 CONTROL

This plan is written in accordance with MSFC Standard Contractor Configuration Management Requirements (MM 8040.12) and Phased Project Planning Guidelines (NHB 7121.2)

Section 2
ORGANIZATION AND RESPONSIBILITIES

2.1 ORGANIZATION AND INTERFACE

2.1.1 Capability Requirements

It is required that the contractors design organization demonstrate adequate depth of capability in all applicable technical fields. As a minimum, the capabilities shall cover the key technical issues described in Section 6.

2.1.2 Contractors Organizational Interfaces

It is required that the contractor identify his approach to management of the design interfaces. The most important of these are:

A. The interface with the program integration activity, which shall exercise surveillance over the coordination of the designs of physical and functional interfaces with other projects and shall define interface requirements within the Modular Space Station Project.

B. The interface with the experiment integration activity, which shall coordinate the design of each experiment. Support to experiment integration shall include (1) the design of special experiment support hardware and software required to integrate experiment equipment and (2) experiment verification in the flight integration tool. (Reference the Verification Plan Requirements.)

C. The interface with the test activities in support of the test procedure and test article designs and the analysis of test results. This requires a direct assessment of the testing and closely coordinated interface with the testing organization.

D. The interface with manufacturing in support of the released drawings and other design documentation. Assessment of the hardware is required to assure that the system and detailed design requirements of the specifications have been translated to the end item.

E. The interface with the operations activity. The design activity shall provide engineering inputs for the selection of spare parts, establishment of detailed maintenance and training requirements, mission planning, and other operations functions.

2.2 ROLES AND RESPONSIBILITIES

It is required that the contractor's design organization specifically assign responsibilities for each of the system design and detailed design functions which are identified in subsection 4.3. In addition, it is required that the design organization assign technical responsibility for the configuration and each of the subsystem level functions described in Section 6. These functions are consistent with those described in the Work Breakdown Structure (WBS).

Section 3
DESIGN PROGRAM SCHEDULE

A separate schedule shall be provided for design and development activity related to each ISS performance function at the subsystem or assembly group level without regard to modular allocation.

Each detailed design schedule shall provide hardpoints such as design reviews, where specific design accomplishments are required to measure compliance conveniently. In addition to design reviews and engineering release hardpoints, interface definition milestones are required in each detailed design schedule. The relationship between incremental reviews shall be shown on the schedule.

Scheduling the design of the various modules is a supplemental process which shall be derived from the above schedules and presented at the module level.

Primary restraints which shall be considered relative to influence on design scheduling include the areas discussed in the following paragraphs.

3.1 INTERFACE DEFINITION

Each increment of interface definition upon which a design task is dependent requires schedule identity. This applies to both internal and external interfaces and to both software and hardware, recognizing that, as the project definition increases, interfaces must be more explicitly defined and scheduled.

3.2 PROCUREMENT--GOVERNMENT-FURNISHED EQUIPMENT LEAD TIMES

The design task involved with specification and definition of long-lead-time procurement items requires separate scheduling. Government-furnished equipment shall be treated as long-lead-time items.

3.3 TEST FLOW

The design schedule must recognize the requirement for a progressive flow in development and integration testing. Specifically, the sequence of development testing in the Space Station functional model (FM) will determine requirement schedules for hardware, software, and procedures as well as design of the functional model itself. The functional model and flight integration tool (FIT) test scheduling will in turn provide test results to the design function. It is required that the design schedule have sufficient milestones (such as a specific test analysis completion) to assure compatibility and close synchronization of design and test.

3.4 MANUFACTURING AND TEST FLOW

Engineering release shall be scheduled in relatively small packages, a functional assembly or structural section, primarily based on a convenient arrangement for planning and manufacturing control. The requirement to minimize manufacturing and test cost with a smooth flow shall drive design release schedules.

3.5 DESIGN REVIEWS

The design schedules which match the above requirements also must meet the requirement for formal reviews. The formal reviews provide one of the most important interfaces between the design activity and NASA, and are the most significant design milestones because of the specific review requirements that have been established. These requirements are summarized in following subsections.

3.5.1 Preliminary Requirements Review

The Space Station Preliminary Requirements Review (PRR) requires that the contractor present a conceptual design required to accomplish the following:

A. Assure that the rationale for selection of the configuration approach meets mission objectives.

B. Determine suitability of the selected configuration by reference to drawings, study reports, models, sketches, etc.

C. Determine suitability of the configuration to meet the required schedule.

D. Identify and review development tests required to select and substantiate design approaches.

E. Review operational requirements generated by the selected configuration and design concept.

3.5.2 Preliminary Design Reviews

3.5.2.1 Hardware Contract End Items (CEI's)

Each Space Station Preliminary Design Review (PDR) requires that the contractor present the basic design approach for each CEI under review (these may be combined in functional groups) as required to accomplish the following:

A. Establish the compatibility of the selected design approach with Part I of the Space Station CEI specifications.

B. Establish the compatibility of the Space Station interfaces. This includes functional and physical interfaces between Space Station CEI's as well as interfaces with the Shuttle Orbiter, Research and Application Modules (RAM's), etc. Interface compatibility includes interface review and mutual agreement on support requirements, schematic diagrams, layout drawings, envelope drawings, inboard profiles, etc.

C. Schedule preparation of detailed interface control documents.

D. Establish integrity of the selected design approach for the Space Station CEI's. Documentation is required to maintain traceability to the end-item-oriented system engineering which was accomplished in Phase B and to any trade studies or other system engineering which subsequently modify the Phase B output.

E. Identify the parts of the design which are subject to value engineering.

F. Establish the producibility of the selected design.

To accomplish the above, the contractor is required to present specific engineering documentation which can be formally identified as a product of the PDR.

3.5.2.2 Computer Program Contract End Items (CPCEI's)

The PDR for a CPCEI or group of CPCEI's is conducted after an approved Part I specification (including detailed interface definitions) is available. At a minimum, it is required that the following be accomplished:

A. Review all detailed functional interfaces with system equipment and communication links. Review word lengths, message formats, storage available within the computer, timing, and other considerations which were established in the Part I CPCEI specification. At PDR the interfaces between the CPCEI and hardware CEI's shall be defined at the subsystem level.

B. Review all interfaces with existing CPCEI's or CEI's external to the system. Analyze word formats, transfer rates, etc., for incompatibilities.

C. Review all functional interfaces between CPCEI's within the system.

D. Review the structure of the CPCEI as a whole with emphasis on the following:

1. Allocation of functions to individual computer program components (CPC's) and computer program functional flow.
2. Storage requirements and allocation.

3. Computer program operating sequences.

4. Design of the data base.

E. Analyze critical timing requirements of the system as they apply to the CPCEI to ensure that proposed CPCEI design will satisfy the timing requirements. Review estimated running time given by the contractor for compatibility with timing requirements.

F. Review the CPCEI interactions with the crew.

3.5.3 Critical Design Reviews

3.5.3.1 Hardware Contract End Items

Each Space Station Critical Design Review (CDR) requires that the contractor present the detailed design of the CEI under review. The CDR is accomplished when the design is essentially complete, and formally establishes specific engineering documentation which will be released for manufacture of the Space Station. The following shall be accomplished as part of each CDR:

A. Establish the compatibility of the CEI, as designed (Part II), with Part I of the detailed specification for the CEI.

B. Establish the system compatibility of the completed design. This shall be accomplished by comparison of the interface control drawings with the engineering drawings for the CEI.

C. Establish the integrity of the design by review of analytical and test data.

3.5.3.2 Computer Program Contract End Items

Critical Design Review of a computer program component (CPC) is held after program debugging. It is required that the following be accomplished during CDR:

A. Review design documentation, including flow diagrams that have been derived in the interim period between PDR and CDR.

B. Review a complete annotated listing of statements comprising the program will be reviewed. If higher-order languages are used in preparation of the program, listings in the higher-order language and in each lower-level language used in conversion to machine code shall be made available.

C. Present results of debugging runs and corrective coding steps taken. If the final debugging runs have not been performed in the operational computer and with resident executive control software under which the CPC is to be used, details of simulators, interpreters, and hardware/software tools used in debugging shall be reviewed. Differences between the simulation system and the operational system shall be presented, and potential effects of these differences shall be discussed.

D. Validate timing and storage requirements.

E. Review external simulation equipment and software. Verify and update interface requirements.

F. Present and discuss predicted effects on a CPC when operated in a processing environment which requires sharing of computer hardware with other CPC's.

G. Review preliminary documentation which is to be finalized and reviewed at First Article Configuration Inspection (FACI).

Section 4
DESIGN FUNCTIONS

The basic design function is to be carried out in Phase C/D under phased project planning (PPP) as described in NASA document NHB 7121.2, dated August 1968.

Design philosophy, specifications, and a design flow description identifying the major functional milestones and customer approval points are discussed in this section. These provide the guidelines and constraints for preparation of the Design and Development Implementation Plan.

4.1 DESIGN PHILOSOPHY

The design philosophy shall consist of those design policies that represent basic direction and are required for design management to (1) provide guidelines which are broader than specification requirements and (2) emphasize compliance with specifications in design implementation. Design philosophy must not be redundant nor in conflict with the program, project, and CEI specifications, and shall be implemented by a contractor-initiated system of design directive memoranda. In conjunction with the specification system, the design philosophy shall accomplish the following:

A. Establish standard design conditions, to the extent practicable, that can be applied to all units of the Space Station project. A rigid adherence to standard design conditions will minimize cost because it promotes commonality, standardizes interface configurations, and reduces the amount of development and qualification testing required.

B. Establish compatible, but separate design conditions where the standard design conditions are not the most effective or efficient— for example, as applied to manned versus unmanned vehicles, pressurized versus unpressurized compartments, airborne equipment versus GSE, etc. These design conditions shall be in consonance with the design and test environmental condition document.

C. Design for growth to GSS (or extensions such as Space Base, and other derivatives when ground rules are established). Allow for evolutionary growth by the use of modular concepts and standardized interfaces, materials, and hardware.

D. Provide hardware and software compatibility in all aspects of information management. This is a major cost reduction item in terms of data processing/conditioning interface hardware, initial programming time, and power/bandwidth economies.

E. Design to accommodate a flexible experiment program while retaining standardized interfaces. Electrical connections and characteristics, thermal conditioning, and mounting provisions shall remain fixed.

4.2 SPECIFICATIONS

The program and project (non-CEI) specifications provide performance and design requirements which apply to the hardware and software end items within the program or project. The Part I CEI Specifications provide the specific design requirements for hardware and software and are written in direct reference to the project specification. For many of the requirements, primarily in areas of operability, design, and construction, the CEI specifications provide only unique applicability on an "add or delete" basis. This requires that both the project specification and the CEI specifications be maintained in Phase C as the primary input to the design flow.

It is required that the contractor revise the preliminary specifications which are the product of Phase B to reflect the contracting arrangement for the project. Some required specification update activities which directly involve the design process are as follows:

A. Identification of CEI's and CPEI's, review, and specification "tree" update.
B. Interface and Support Requirement Specification review and update. These specifications are the instruments for identification of detailed requirements identified in the preliminary CEI specifications that are related to other projects or elements.
C. Rearrange derived performance requirements, primarily those which reflect the design approach, according to the subcontracting arrangement. Assembly-level performance requirements are defined from preliminary CEI Specifications and placed in lower-level specifications which are used for subcontracting or internal coordination between design groups. These lower-level specifications shall appear in the formal specification scheme only for engineering-critical components. It is required that all other significant assembly- or subassembly-level components have clearly delineated and documented performance and operation requirements. Contractor formats shall be acceptable, providing that the results of system design in requirement allocation is evident, and providing that these documents are made available for NASA review.

The results of the above shall establish direct design control at the highest practical level by simplifying the CEI specifications and removing implementation-oriented, low-level requirements from the formal change control process.

The basic product of the design task is the Part II CEI Specifications.

4.3 DESIGN FLOW

Figure 4-1 illustrates the required flow of basic design tasks, arranged in sequence but not time-scaled.

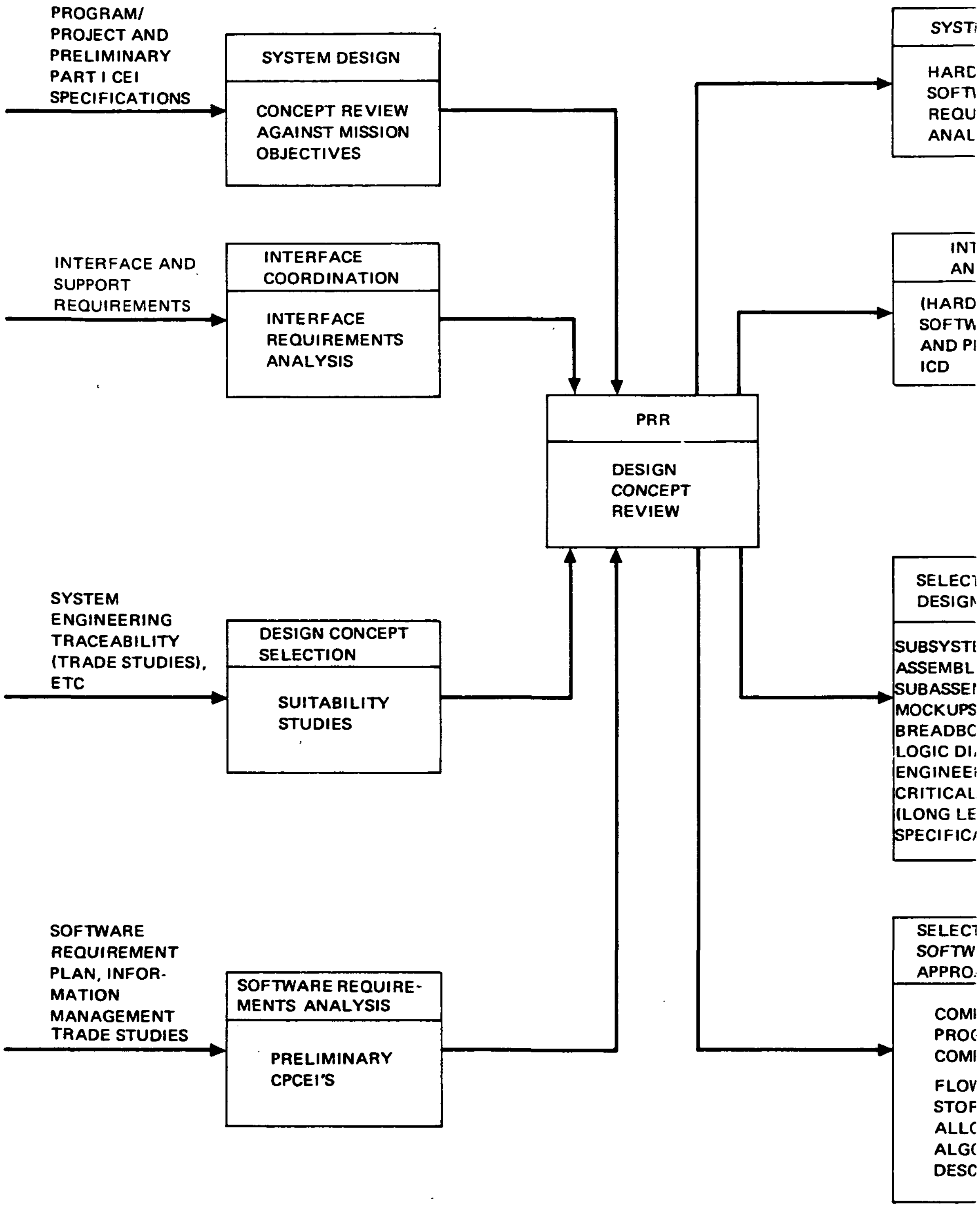
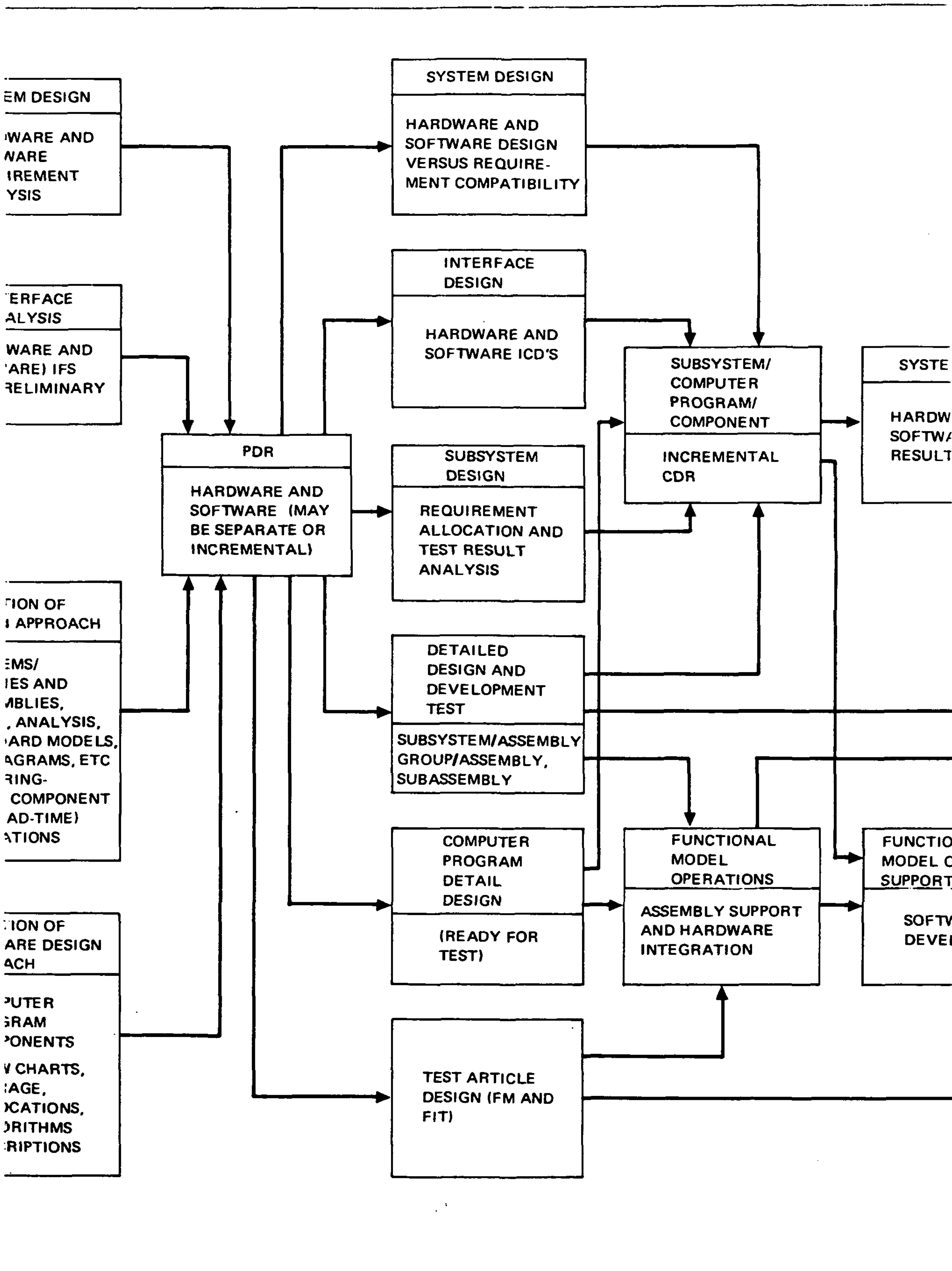
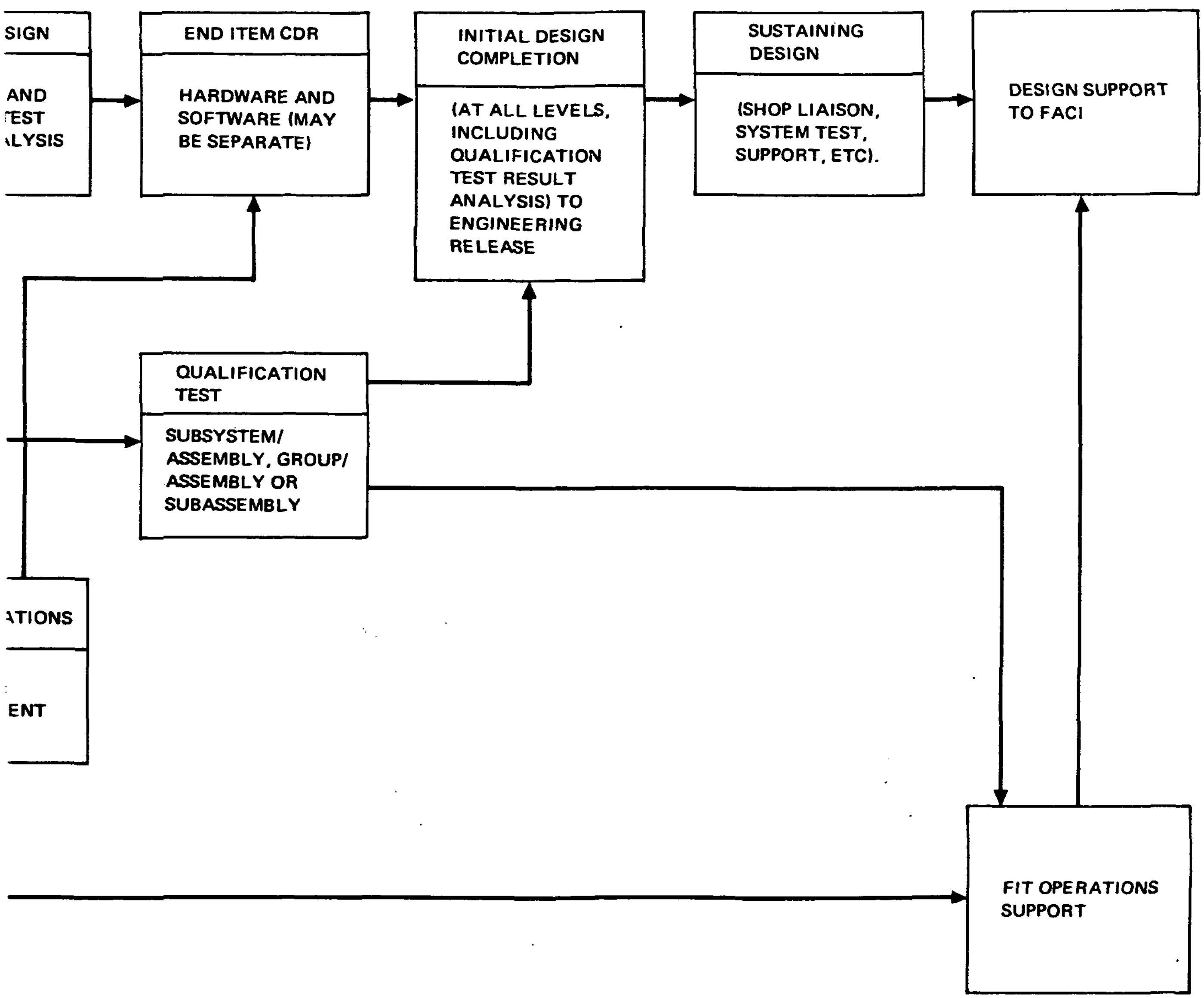


Figure 4-1. Basic Design Task Flow

FOLDOUT FRAME 1



FOLDOUT FRAME 2


SIGN
AND
TEST
LYSIS
END ITEM CDR
HARDWARE AND SOFTWARE (MAY BE SEPARATE)
INITIAL DESIGN COMPLETION
(AT ALL LEVELS, INCLUDING QUALIFICATION TEST RESULT ANALYSIS) TO ENGINEERING RELEASE
SUSTAINING DESIGN
(SHOP LIAISON, SYSTEM TEST, SUPPORT, ETC).
DESIGN SUPPORT TO FACI
QUALIFICATION TEST
SUBSYSTEM/ ASSEMBLY, GROUP/ ASSEMBLY OR SUBASSEMBLY
ATIONS
ENT
FIT OPERATIONS SUPPORT

From Phase B inputs, requirements analysis, and system design tasks culminate in a Preliminary Requirements Review (PRR), early in Phase C. The purpose of the PRR is to verify the compatibility of the contractor's design approach with the Program, Project, Interface, and End Item Requirements. After the PRR, the primary tasks which are performed in parallel (but not independently) are system design, interface analysis, and selection of specific hardware design approaches for all important subsystems, subassemblies, etc. A software design approach for each computer program element is correspondingly selected. This work is reviewed at the PDR. The hardware and software reviews may be separated and accomplished incrementally, as described in 3.5.2.

After the PDR, detailed design shall proceed at all levels, including design support of hardware development test, primarily at the assembly or subassembly level. Computer program detailed design shall be accomplished up to the point of test. During this time period, the system design function shall continuously verify the compliance of the detailed design, as it develops, against the requirements in the Part I CEI Specifications. Included in this shall be verification of the hardware and software interfaces as documented in the Interface Control Documents (ICD's). This work shall be reviewed at CDR. The hardware and software reviews may be separate and accomplished incrementally.

The test article shall be designed at this time and specifically limited to the design of the functional model (FM) and the flight integration tool (FIT). These are described briefly in subsection 6.4.

Design support to FM operations is required. The FM requires development hardware and computer programs in a buildup sequence. Generally, the first phase is for hardware integration and may be accomplished before or concurrent with the hardware CDR's. The computer program test and development phase is generally subsequent to CDR of the computer program components. The system design task shall include analyses of the test results of the FM operations, ensuring that proper system operation is obtained in the integration of hardware and software.

The design flow emphasizes the requirement for an end item CDR which summarizes the incremental CDR's and includes review of subsystem- and system-level test result analyses, primarily those resulting from the FM test and integration operations.

Qualification testing shall follow development testing, generally not restraining CDR but occurring before initial design completion at the engineering release milestone. Qualification equipment is required for construction. Sustaining design in direct support of manufacturing and test, and FIT operations support for the primary design activities required between Engineering Release (ER) and First Article Configuration Inspection (FACI).

Section 5
CONTRACTORS

The design requirements for contractors described herein assume that the project contractor will have the integration responsibility and shall be a reflection of all of the requirements of this plan. The depth of control and review is adjusted to an appropriate level that depends on the criticality and complexity of the contract item or group of items. It is required that each major subcontractor prepare a design plan which:

A. Recognizes the basic requirements as stated in procurement specifications.

B. Describes in detail the minimum-cost approach to hardware implementation. Emphasis will be placed on describing how existing design and test data may be used as a point of departure so that subsequent design and new development can be minimized and product confidence established.

C. Describes why drawing formats, design and construction standards, and other current practices which are different from the project standard are used.

D. Describes the requirements for reviews to be conducted by the integrating contractor and monitored by NASA.

E. Describes test design and test result analysis.

F. Describes separately the design approach for maintainability and reliability (probability of success).

G. Describes design documentation.

The objective of the above is to provide a set of contractor plans which reflect precise control of vital requirements, a thorough review of implementation, and visibility at all levels, but otherwise does not restrict the contractors in the interest of minimizing cost.

Section 6
DESIGN ACTIVITIES

This section identifies significant design requirements, critical design issues, and potential problems related to ISS systems and subsystems.

6.1 SYSTEM DESIGN

It is required that the contractor design for the Space Station be composed of systems which are balanced in design and performance to operate together in accomplishing the mission. To achieve this, the contractor shall make specific assignments and establish a tangible set of procedures to assure that design integration remains an active and recognizable part of the total Space Station design process throughout Phase C/D. It is required that the contractor shall:

A. Emphasize the requirement for functional integrity at the CEI level. For example, the environmental control and life support function is implemented in design with primary emphasis on orbital operation of the ISS module cluster.

B. Assure that the design fully considers the requirements of the orbital buildup.

C. Provide continued requirement analysis relative to the program, project and CEI specifications, conducting system-oriented reviews and changing performance allocations as necessary.

D. Assure that the interface coordination and design activities are consistent with the system design.

E. Design integrated tests, primarily the experiment integration tests to be performed in the FIT.

6.2 SPACE STATION MODULE SUBSYSTEM DESIGN

The following subsections provide brief descriptions of the subsystem and its design approach to introduce the identification of key issues and potential problems. It is required that the Design Plan shall emphasize detailed planning to establish confidence in each area, treating the issues identified from and others which evolve before Phase C/D. This will include a continuing assessment of the supporting research and technology results upon which the confidence in many designs depends (see Supporting Research and Technology Plan).

6.2.1 Environmental Control and Life Support (EC/LS) Subsystem

The EC/LS subsystem includes the equipment necessary to provide and control a 7×10^{-3} to 10×10^{-3} Kg/mm^2 (10 to 14.7 psia) O_2-N_2 atmosphere. The subsystem provides atmosphere purification, water management, waste management, IVA/EVA equipment, and thermal control. A wide diversity of technology is required to design and develop the EC/LS subsystem including high-pressure gas storage, atmosphere pressure and composition control, vacuum pumping, conventional atmosphere temperature and humdity control, atmosphere CO_2 control, membrane electrochemistry, urine and wash-water purification, fluid heat transport circuits, passive insulation systems, heaters, and thermal control coatings.

The key problems at the assembly level are the development of the solar collector, air evaporation equipment for urine H_2O recovery, reverse osmosis equipment for wash-water recovery, and pasteurization equipment for water sterilization.

The key subsystem-level design problem is that of integrating these many assemblies into the configuration with other subsystems such as power, propulsion, and structure, and making the subsystem as independent of configuration changes as feasible. Therefore, it is vital to complete an integrated EC/LS subsystem-level test with a simulated installation before final qualification of the assemblies.

In addition, this test will verify the automatic features of the EC/LS control systems as well as the autonomous fault isolation system. To the greatest extent practical, the interfaces with other subsystems such as propulsion will be simulated.

6.2.2 Propulsion/Reaction Control Subsystem

The propulsion subsystem provides the thrust impulse required to maneuver and position the Space Station in orbit. This subsystem is comprised of a high-thrust monopropellant (N_2H_4) system and low-thrust resistojet (CO_2) system. The high-thrust system provides the final orbit adjustments, maneuvers, scheduled distrubances, and backup attitude control. The low-thrust system provides the orbit-keeping and Control Moment Gyro (CMG) desaturation functions.

The requirements for a 10-year life with maintainable subsystem poses some new and severe requirements on the propulsion subsystem. In particular, contamination of external surfaces with exhaust products must be minimized, and maintenance provisions for toxic propellant systems and externally mounted thrustors must be developed.

The integration of the low-thrust (biowaste resistojet) system with the EC/LS subsystem is a new concept, and thus the control mode analysis, consumption schedule, and intersystem response characteristics require special attention. The mechanical design of the system, other than thrustors, is straightforward.

The high-thrust (N_2H_4) system design is largely within the state-of-the-art. Special emphasis must be placed upon surface contamination and thrustor life.

Development testing at the subsystem and assembly levels will be particularly significant in the propulsion subsystem design process. For example, test firings of thrustor modules under simulated altitude conditions will be required to verify adequate protection against heat soakback, thermal effects on adjacent structure, and exhaust contamination. Subsystem-level, non-firing, thermal-vacuum tests will be required to verify heater adequacy and electrical loads. Development of the high-thrust system requires a complete subsystem installation to be hot-fired for a series of duty cycles.

The low-thrust system development tests will be similar to those discussed for the high-thrust system. If practical, integration with the EC/LS system is desirable.

6.2.3 Guidance/Navigation and Stabilization/Attitude Control Subsystems

These subsystems provide Space Station navigational and attitude reference information to be used by experiment modules, experiments, logistics vehicles, etc. They provide Station attitude control with CMG's and generate commands for orbit keeping and maneuvers.

The guidance/navigation and control subsystems use several unique design approaches in sensing, computing, and control actuation which require both unique technical capabilities and special attention. Key items are: (1) drag accelerometer calibration, (2) GNC software development, (3) optical alignment monitor design, (4) maintainable CMG design, and (5) dynamic analysis.

The drag accelerometer must measure acceleration levels so low that calibration of the instrument may not be feasible on Earth. Therefore, the accelerometer requires analysis, indirect testing, and test facility development, and potentially may not be calibrated until it is used in the Station. On-orbit calibration is possible but will require development of special software.

Integration with the Data Management subsystem and development of the accompanying software to perform computation of attitude reference, navigation, rendezvous and traffic monitoring, Station attitude control, subsystem self-check, instrument calibration, etc., will require specialized technical capabilities in digital computer, interface, and software development and integration.

Optical alignment monitor design requires technical capability for design, integration, and test of devices for measurement of small angular misalignments between objects separated by large distances. Electro-optical instrument design and structural alignment capabilities must be combined.

Mechanical design concepts for maintainable CMG's are expected to be developed by supporting research and technology programs. Integration of CMG's with such design features will require special attention to installation location, access, maintenance procedure, and fault isolation.

6.2.4 Data Management Subsystem

The data management subsystem consists of all the necessary equipment to transfer, store, and process data to and from experiments and subsystems. It uses a data bus concept with modular multiprocessor computers and integrated multipurpose displays. It contains computation, data acquisition, data distribution, storage, and command and control elements. The development of special computation hardware requires a somewhat different approach than that accorded other equipment. Consideration must first be given to the software interface because hardware and software are interdependent in providing a functioning subsystem.

Although hardware and software design should proceed in a somewhat parallel fashion, definition of the hardware characteristics must first be established to allow software development. Characteristics such as (1) subsystem architecture, (2) operating and control procedures, (3) instruction repertoire, (4) parameters such as time delays, instruction word formats and lengths, and (4) instruction execution time, must therefore be firmly controlled to avoid invalidation of this development. This also implies that subsystem simulations and modeling activities required to develop characteristics such as queue lengths, time delays, and data rates must be performed at an early date.

As a result of this consideration, it was determined that computer hardware definition must be controlled at an earlier program stage than other equipment, and greater effort must be expended to achieve an equivalent design status.

The concept of a data bus, the dependence of the ISS on the distribution system, the magnitude of the number of devices, and the resultant composite data rates require additional verification of technique acceptability before and during Phase C/D.

6.2.5 Onboard Checkout Subsystem

The Space Station onboard checkout subsystem includes the equipment and software required to support in-flight checkout and fault isolation of Space Station subsystems and experiments. It is also used as the primary checkout and fault isolation tool during postmanufacturing and prelaunch operations. It consists primarily of remote data acquisitions units, processors, transmitter/receivers, data terminals, display control equipment, an independent caution and warning system, and some special test equipment.

The onboard checkout subsystem design must be planned for consonance with an orderly sequence of compatibility development tests conducted using the functional model. The functional model is the primary engineering tool for system-level hardware and software development. The testing culminates in the design of an operational checkout system which is then used to support other development testing, integration, and checkout software development activities. This critical issue is a development problem which is unique, based on the radical departure from the traditional AVE/GSE integration task.

6.2.6 Communication Subsystem

The Space Station communication subsystem provides:

A. Space Station-to-ground communication via data relay satellite
B. Direct Space Station-to-ground communications
C. Space Station-to-logistics vehicle communications
D. Space Station-to-experiment module communications

The communication subsystem consists of 2.44 M (8-ft) diameter, K_u-band and omni-directional antennas, amplifiers, receivers, transmitters with appropriate switching and multiplexing units, TV cameras, and an audio control center. The key issue in the design of the communication subsystem is the requirement for early, firm definition of interfaces, which are particularly intricate for this subsystem. These include the Shuttle, and the data relay satellite. The transmitter power output, receiver sensitivity, and antenna system gain are all affected by the performance requirements and characteristics of the other program elements. In addition, the interfaces and characteristics of the other vehicle subsystems will have to be firmly established. Hardware design is also a key issue. The mission requirements for the Space Station have imposed reliability levels on the communications subsystem which in many cases are several orders of magnitude greater than have been encountered previously.

The design requirements for the high-gain antenna system, which is located externally is a key issue. The high-gain positioner contains electromechanical and mechanical components which are quite susceptible to failure. In addition, the K_u-band tunnel diode amplifiers and mixers are located externally at the end of the antenna mast.

6.2.7 Electrical Power Subsystem

The electrical power subsystem includes a solar array/battery power source, energy management equipment, storage and regulation equipment, power conditioning equipment, and power distribution protection.

The key design issue is the development of the solar array and its deployment mechanisms.

The remaining electrical power subsystem assemblies are the transmission/conditioning/distribution assembly group, the energy storage assembly, and the power management assembly. These major elements are designed, developed, and tested as part of the FM and the FIT. One unique design function defined for these tests is that both steady-state and transient test conditions must be simulated, and a simulated or actual power load profile is desired to demonstrate the power management assembly design.

6.2.8 Structural/Mechanical Subsystem

The structural/mechanical subsystem includes:

A. The basic structure and all provisions for structural accommodation of the crew, the spacecraft subsystems, and an experiment program.

B. Mechanical equipment required for:

1. Docking with experiment or logistic modules, or the Shuttle orbiter.
2. Space Station access, including hatches, airlocks, and viewports.
3. Antenna deployment and drive.
4. Cargo handling and transfer.
5. Extravehicular activity support.

There are two areas of technical capability in the structural/mechanical subsystem that are required: structural analysis through computer redundant force analysis programs and mass property management. For structural/mechanical analysis, there is a requirement to apply a computer program which has a highly automatic capability for analyzing large complex structures using the force or displacement method. Such a program must provide a highly automated system for analysis of internal forces and deflections, critical loads and buckling modes, and resonant frequencies and vibration modes.

A cognizant mass property control and review capability with authority to implement the required mass property plans will be required to assure realistic and obtainable objectives and critical limitations. This control procedure will include integration of the experiments equipment and any items of carry-on equipment.

In addition, there are several structural/mechanical design tasks which will require special attention:

A. The environmental criteria and design constraints require investigations and special emphasis in three areas: dynamic seals, lubrication, and a structurally integrated meteoroid shield/radiator/insulation concept. Dynamic seals will be used to prevent or restrict loss of a gas or liquid across an interface subject to translation or rotation.

B. Dry lubricants have been used successfully in space for satellite operation; however, most of these applications have been for light loading conditions, intermittent operation, and short-duration missions. An investigation of lubricants and accelerated-life testing in a simulated space environment is required to assure high reliability and long life for operating mechanisms and components.

C. The search for efficient structural configurations has led to an integrated structural concept of a meteoroid shield/radiator/insulation system. The complex design and functional requirements for the three systems will require a system design approach and special attention to detail throughout the design phase to assure that the resulting concept is an optimum design.

6.2.9 Crew Habitability and Protection Subsystem

The crew habitability and protection (CH&P) subsystem consists of equipment, facilities, and supplies which comfortably and conveniently accommodate the crewmen and meet the Space Station mission requirements for sleep, food management, personal hygiene, recreation, exercise, trash management, medical and dental support, damage control, safety, pressure suit support, tools, restraints, and locomotion.

To develop provisions for the various aspects of crew habitability and protection which will be effective in zero gravity, a wide diversity of technology is required. The key problems at the assembly level are the development of items such as highly efficient and reliable microwave and infrared ovens; food freezers and refrigerators; diswashers and dryers; full-body showers; zero-g sinks; laundry washers and dryers; trash processor and compactor; devices for detection, warning, and repair of meteoroid damage; fire detection, warning, and extinguishing units; and dispensary equipment for the diagnosis and treatment of injuries, illnesses, and dental emergencies.

There are several aspects of the CH&P subsystem design which involve unique development testing requirements as a result of the high reliability levels imposed upon the electromechanical, electrical, mechanical, pneumatic, and hydraulic components that are usually susceptible to failure. In addition to individual assembly tests, extensive compatibility tests of various assemblies integrated with each other and with the EC/LS subsystem are required before final qualification of the CH&P assemblies and during the tests.

6.2.10 Experiment Support Equipment

This function provides the Space Station system with a General Purpose Laboratory (GPL) capability to:

A. Support the experiment program for 10 years.

B. Support the operation of the Space Station and its subsystems. These facilities will include shops and laboratories to repair, disassemble, assemble, and calibrate subsystem equipment.

This design task is complicated because the design requirements of the Space Station and its subsystems must be approved as a baseline defining the resources which will be available to the experiment contractors. To meet Space Station design schedules, much of the GPL will be based on preliminary experiment design containing state-of-the-art off the shelf equipment. Design, development, operator training, etc., related to special support items requiring development will remain within the responsibility of the experiments requiring their use.

Management of the tie-in between the Space Station GPL design and that of the individual experiments will be more critical and complex than has been the case on previous programs, and has been given special attention in the Experiment Integration Plan Requirements.

6.3 SPACE STATION GROUND SUPPORT EQUIPMENT

The Space Station GSE includes all equipment required to support the Station during factory checkout, handling, shipment, servicing, prelaunch and launch operations. Attention shall be directed to maximizing the use of the Onboard Checkout and Fault Isolation subsystem for functions normally accomplished by GSE. An overall objective of this program is the minimization of GSE required for development and operations. Development of key items of this equipment is accomplished in conjunction with development of the Functional Model (FM) and are used to support the FM throughout its program life.

Areas requiring special emphasis during the design and development phase will be integration of the GSE with the onboard data management and onboard checkout systems to achieve optimum ground operations capability. No qualification testing of GSE is required.

A set of Space Station GSE, for the Flight Integration Tool (FIT) and flight vehicle supports the FIT during factory checkout and integration. This equipment is then used to perform factory checkout of the flight vehicle. A set of module GSE will be shipped to the launch site with the flight vehicle modules and used to support prelaunch and launch operations.

Special emphasis is required on achieving optimum use of available launch site facilities and on integration with the mission management facility.

The Space Station GSE must be capable of supporting the FIT during its role as a configuration benchmark and integration vehicle.

6.4 TEST ARTICLES

The Space Station test articles are limited to the FM and the FIT.

6.4.1 Functional Model (FM)

The FM is a set of equipment used for integration of the Space Station subsystems and for development and integration of all onboard computer programs (onboard checkout, guidance and navigation, control, data management, etc.). It will consist of functional electronic subsystems with interfacing elements from other subsystems, plus software and general purpose, nondedicated computing capability.

The FM design is a direct derivation of the flight vehicle design. The FM design must provide a software development facility which is limited to the minimum capability that is rendered essential by the subsystem design and development effort. To minimize cost, the design will incorporate development test hardware to the greatest degree possible. The design documentation requirements are the minimum necessary to identify assembly and wiring on a laboratory basis. The drawing system requirements are for quick-reaction change control operated directly by the design group. A system which positively identifies incorporated change status is mandatory, on a reasonably informal basis.

6.4.2 Flight Integration Tool (FIT)

The FIT is a semicomplete, flight-configuration ISS system. It will contain all subsystems in their flight configuration, except for some items such as propulsion thrustors, electrical power sources, and thermal radiator panels which will be replaced by substitute items suitable for the ground test role.

The FIT is used initially to develop and verify the installation and operation of the subsystems. After the subsystems are operating, it will be used to verify the installation and interfaces of the integral experiments to be launched with the Space Station.

After launch of the Space Station, the FIT will continue to be used for integration of experiments and for checkout of Space Station modifications which are to be installed on orbit.

The design requirements for the FIT are to make a direct derivation from the flight vehicle design, establishing a design control system which will accommodate the requirement to maintain a limited flight-vehicle configuration in the FIT after the Space Station is launched.

Section 7
CONFIGURATION CONTROL

The basic configuration control requirements in design will be responsive to configuration management control as described in the Configuration Management Plan which will be prepared in accordance with Exhibit I of MM 8040. 12. The most significant configuration control requirements exerted on design are involved with the documentation which constitutes the Part II CEI Specifications, primarily drawings, and computer program documentation.

The contractor will define a formal drawing control system in accordance with MIL-D-1000. The objective of the drawing system and its change control system will be (1) to conclude design with documentation capable of supporting changes to the on-orbit Space Station, using the flight integration tool (FIT), and (2) to permit manufacture of the GSS or derivative Space Station with a minimum of design support.

Section 8
DATA/INFORMATION INTERCHANGE

It is required that the contractor provide NASA and other agencies or contractors those products of the requirement studies, trade studies, analyses, and design activities necessary to support the interface control documentation and to assure compatible designs. A data interchange system or matrix is required which will include key data exchange requirements according to schedule.

Section 9
DOCUMENTATION

The Design and Development Implementation Plan will identify the form and content of design documentation to be provided to necessary users throughout the time span of the Design Plan. This definition will be in agreement with the Statement of Work and the Contract Document Requirement List (CDRL), and will be further expanded for the contractor's internal utilization.

Section 10
REPORTING

The Design and Development Implementation Plan will identify the procedure and timing for reporting design status to NASA. This reporting plan will be keyed to the design schedule, taking into account major design milestones such as Preliminary Requirements Review (PRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Engineering (drawing) Release (ER), Qualification Test Complete, etc.

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MODULAR SPACE STATION

MANUFACTURING PLAN REQUIREMENTS

MANUFACTURING PLAN REQUIREMENTS

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MANUFACTURING PLAN REQUIREMENTS

Section 1

INTRODUCTION

1.1 PURPOSE

The Manufacturing Plan requirements have been prepared to guide contractor planning and bidding for Phase C/D. This document describes the policies and objectives of the Modular Space Station Project manufacturing activities, their application and the organization, and general operating controls/ procedures to be applied in preparing the Phase C/D implementation plan.

The plan is based primarily on the specific objective of translating the manufacturing requirements i.e., integration, test, tooling, facilities, production control, etc., into detail flow plans, method, and procedures required to manufacture and assemble the components that comprise the specific modules. An additional objective of this requirements plan is to assure that the manufacturing implementation plans consider the transition of the Initial Space Station (ISS) to the Growth Space Station (GSS) and to provide for a cost effective transition.

In response to the Agency RFP for Phase C/D, the aerospace contractors will prepare detailed manufacturing implementation plans defining the contractors methods and approach for meeting the requirements defined herein, providing specific fabrication flow plans, assembly flow plans, tooling, acceptance test plans, facility requirements, schedules, production intervals, manloading requirements, and logistic requirements.

1.2 SCOPE

The requirements and procedures contained in this plan apply to the Initial Space Station (consisting of the Power/Subsystem Module, Crew/Operations Module, and General Purpose Laboratory Module, the Logistics Module) and associated ground support equipment and facilities.

This plan covers the period from the initiation of the ISS phase C/D through five years of operational life, concentrating primarily on the early phase of the program where the manufacturing concepts and acceptance test concepts, and the manufacture of the required hardware are the major tasks.

1.3 CONTROL

The Manufacturing Plan shall comply with the MSFC Standard Contractor Configuration Management Requirement (MM8040.12). The plan shall be updated to reflect changes resulting from project review and as directed by NASA.

Section 2
ORGANIZATION AND RESPONSIBILITIES

The manufacturing plan shall present the management approach and the organization structure of manufacturing engineering and the associated production interfaces. The most important of these interfaces are:

A. The interface with the project integration activity, which shall exercise surveillance over the designs to ensure manufacturing feasibility and produceability of physical and functional interfaces with other modules and shall define manufacturing interface methods within the Modular Space Station Project.

B. The interface with design engineers to support the experiment integration shall include assistance in the design and manufacture of special experiment support hardware such as the Flight Integration Tool (FIT).

C. The interface with design engineering in support of the design requirements. Assessment of the design is required to assure that the system and detailed design requirements of the specification can be translated to the contract end item (CEI).

D. The manufacturing engineering interface with the test activities and test procedures which requires direct evaluation of the test procedures and activities. See Section 5 Product Acceptance Test.

It is required that the Manufacturing Plan define the roles and responsibilities of all line organizations and their detail functions. The description of a representative operations division organizational structure is depicted in Figure 2-1.

The organizations shall be matrixed in a manner analogous to current activities. Each of the divisions functional elements shall have a representative who shall report directly to the program office in all matters concerning the Space Station. Although these representatives shall be personnel working within their respective functional organizations, they shall be considered to be members of the program office. They shall report directly to the head of the program office on matters concerning the project. Conversely, it shall be through these representatives that the principle program shall flow to the various functional divisions for the accomplishment of the program objectives.

Section 3
MANUFACTURING

3.1 MANUFACTURING PHILOSOPHY

The manufacturing philosophy shall consist of those manufacturing policies that represent basic direction and are required for manufacturing management to (1) provide guidelines which are broader than specification requirements and (2) emphasize compliance with program, project, and CEI specifications in manufacturing implementation. The manufacturing philosophy shall accomplish the following:

A. Establish state-of-the art manufacturing conditions, to the extent practicable, that can be applied to all units of the Space Station Project. An adherence to state of the art will minimize cost and reduce the amount of development of manufacturing methods and research engineering and qualification testing required.

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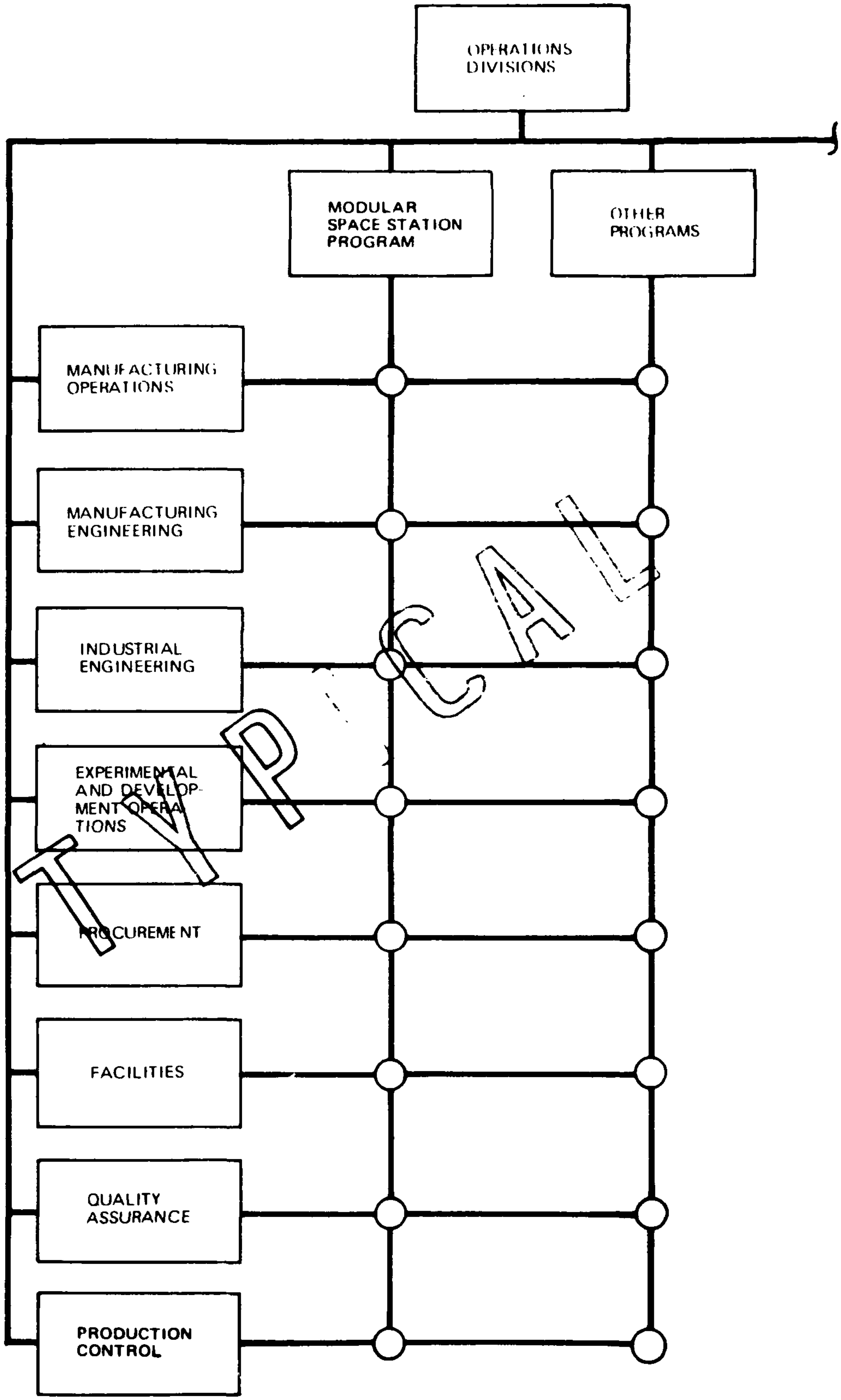

Figure 2-1. Program/Line Organization with Operations Division

B. Establish tooling and manufacturing commonality criteria that is capable of being used for separate design conditions; for example, the tooling and manufacturing criteria for the Crew/Operations Module and the Power/Subsystems Module could both use the same basic tooling. The use of universal tooling and the additions of low cost tooling aides and tooling adaptors for the manufacture of more than one module design will be cost effective and efficient.

C. The modular concept for the ISS and the GSS will be evolved into the conceptual manufacturing plans to insure a cost effective program. The philosophy must provide for the flexibility of incorporating or growing from ISS to GSS with minimum modifications to tooling and fabrication techniques.

D. Surveillance of design engineering during the early phases shall be a manufacturing philosophy to ensure produceability, matching interfaces of hardware, interchangeability, and a compatible philosophy between the design philosophy and the manufacturing philosophy.

E. Manufacturing plans shall be evolved for the manufacture of each component of the modules. These plans shall be comprised of but not limited to; fabrication flow plans, (see Figure 3-1), assembly flow plans (see Figure 3-2), tool lists, and capital equipment requirements. The man loading and production interval of the production line shall be established to ensure that adequate tooling, floor space, test requirements, and capital equipment requirements are identified. These plans and evaluations shall be included into the manufacturing plan.

F. Manufacturing plans shall address the acceptance of hardware from the receiving tests on components and materials to final factory verification of integrated modules using the FIT.

G. Manufacturing flows and transportation requirements must address logistics options (i. e., off-loaded items).

H. An evaluation of the manufacturing problem areas, the rationale of the problem areas, and the rationale of the proposed methods of solving these problems shall be provided in the manufacturing plan.

I. Evaluation of technologies and current advancement of the state of the art shall be in the manufacturing plan for use during the C/D

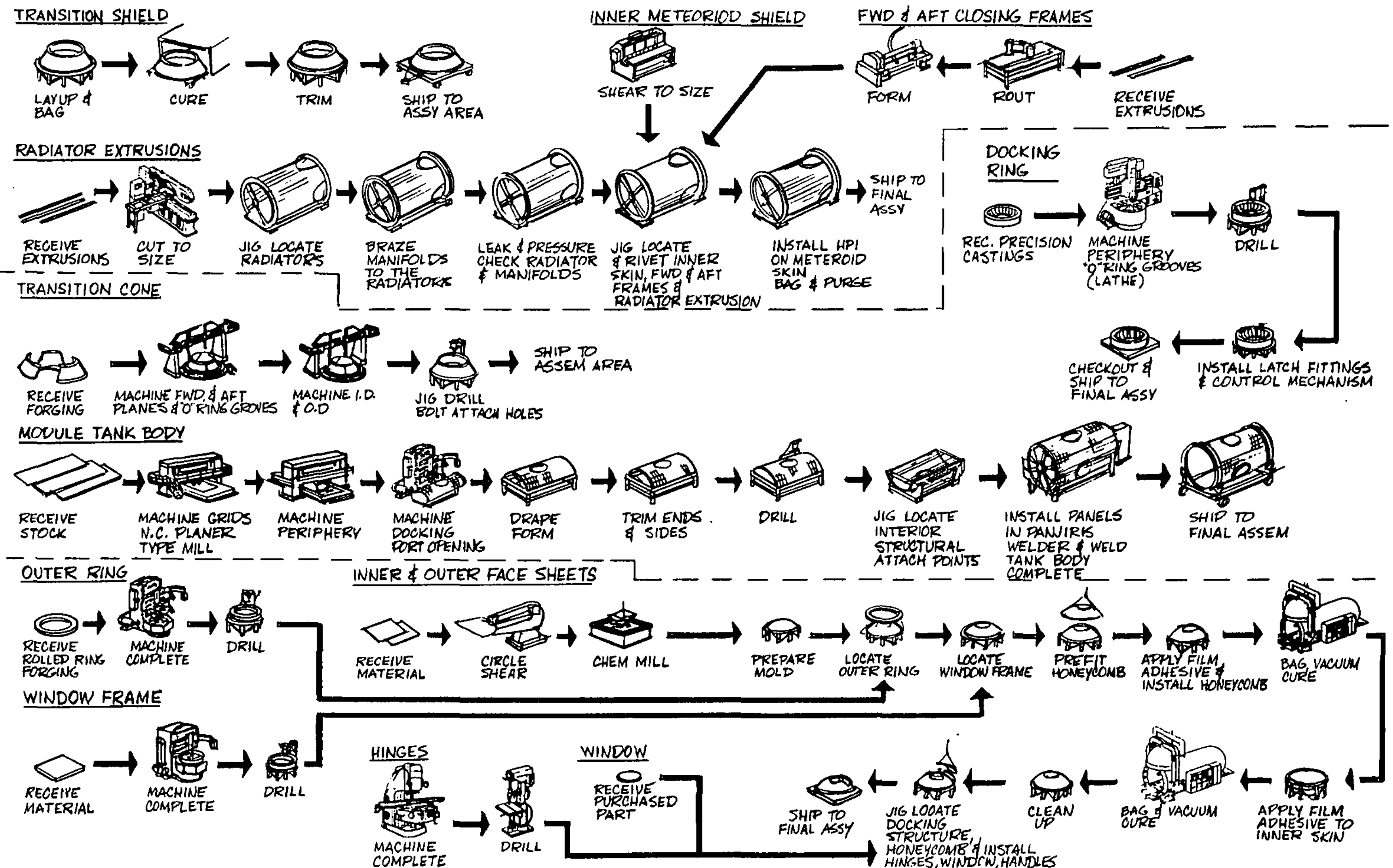

Figure 3-1. Typical Fabrication Flow Plan

FOLDOUT FRAME

FOLDOUT FRAME 2

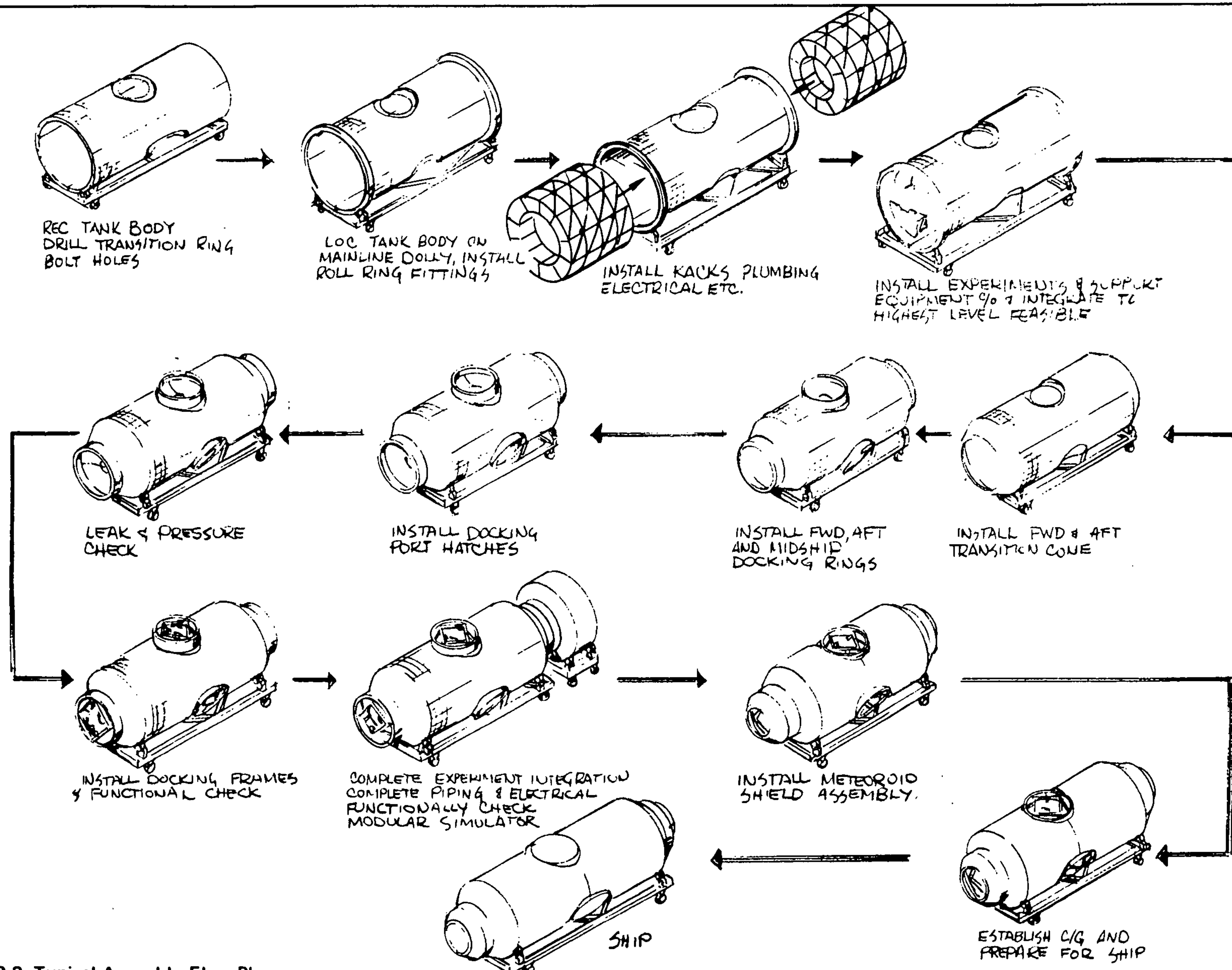

Figure 3-2. Typical Assembly Flow Plan

phase. Trade-off studies of state of the art, advanced state of the art, and new technologies shall be conducted and the results shall be included in the Manufacturing Plan.

H. Long-term life of the vehicle presents a manufacturing requirement that will necessitate a full evaluation of all the current manufacturing techniques. Trade-off studies, matrix's, and other evolutionary and problem isolating methods shall be used to establish the manufacturing criteria of the vehicle. The results of these trade off studies shall be included in the manufacturing plan.

3.2 HARDWARE CONFIGURATION

The major hardware configurations shall be identified and fabrication plans and assembly plans shall be implemented to ensure an orderly and feasible mode of manufacturing operations required to manufacture the current baseline. Figure 3-3 depicts a typical manufacturing engineering exploded view of the baseline vehicle and the pictorial sequence of assembly. The major structural components and manufacturing tasks that shall require manufacturing planning, fabrication flow plans, assembly flow plans, acceptance test plans are as follows:

- Structural Module
- Tunnel
- Bulkheads
- Pressurizable Cone
- Hatches and Docking Ports
- Docking Interface Structural Assembly
- Solar Array Drive and Orientation Mechanism
- Experiment Equipment Interface
- Meteoroid Shield and Radiator
- Equipment Racks and Component Structure
- Subsystems

Manufacturing criteria shall be established and implemented into the phase C/D manufacturing plan for each of the above noted major tasks. Each of these manufacturing tasks and the mode of implementation in the manufacturing plan is delineated under their individual heading in the subsections that follow.

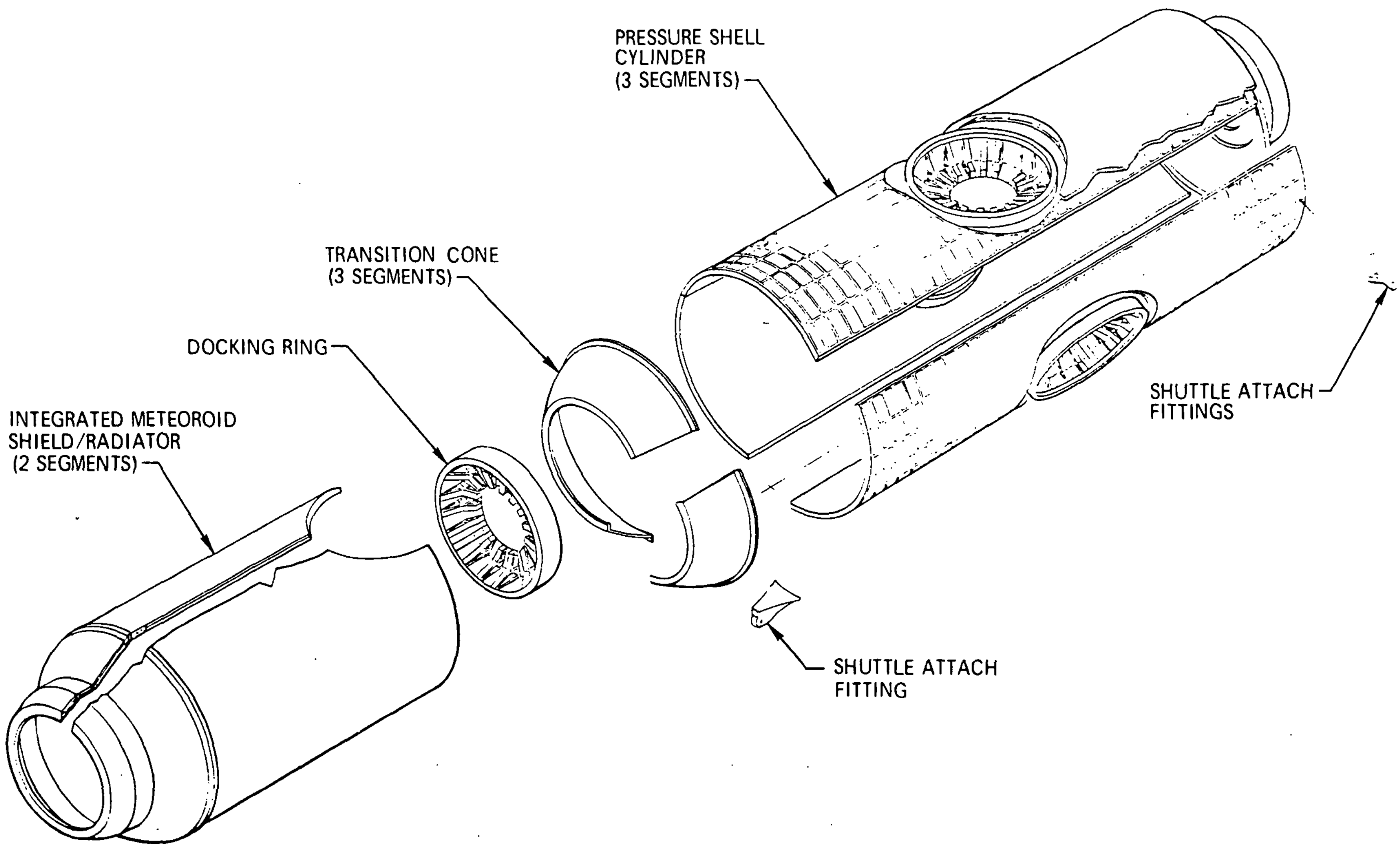

Figure 3-3. Space Station Modular Concept

3.2.1 Structural Module

The structural module is the foundation for the modular concept. The module has an ID of 13-ft 4-in., and will vary in length. The lengths of the structural modules are as follows:

A. 20-ft 8-in. for the logistics module

B. 58-ft for the power/subsystems module

C. 45-ft for the crew/operations module and for the general purpose laboratory module

The Manufacturing Plans shall establish compatible but separate manufacturing criteria where cost effectiveness and efficiency in manufacturing can be realized; for example the manufacturing criteria shall be evaluated for manned versus unmanned modules, pressurized compartments versus unpressurized compartments, etc. These tradeoff studies and the evaluated results shall be contained in the manufacturing report.

3.2.2 Tunnel

The tunnel is a pressurized monocoque aluminum structure that is 40 in. in diameter and is 279 in. in length. The tunnel is a structural component of the Power/Subsystems Module. The function of the tunnel is to provide access to the solar array deployment and orientation mechanism from the Power/Subsystems module. Manufacturing mechanical verification test requirements shall be evaluated and the results included in the plan. Simulated zero-gravity testing during verification testing of the tunnel and the solar array mechanism shall be evaluated and the results shall be included in the Manufacturing Plan.

3.2.3 Pressurizable Core

The pressurizable core is a monocoque aluminum structure of the Power/ Subsystem Module. Pressure testing and sequencing the pressurizable core structure into the manufacturing flow shall require a close interface between test engineering and product acceptance testing. An evaluation of testing the complete Propulsion Module including the pressurizable core or testing the pressurizable core as a separate entity shall be a manufacturing option. Trade-off studies shall be conducted and these studies shall be implemented in the Manufacturing Plan.

3.2.4 Hatches and Docking Ports

The hatches and docking ports are modular in concept and are common to all of the modules. The Manufacturing Plans for the manufacture of the hatches and docking ports shall include fabrication flow-plans, manufacturing flow plans, and product acceptance test plans. The Manufacturing Plans shall establish the baseline plans for the mode of manufacture for the hatches and docking ports. If the separate Manufacturing Plans are not compatible with the interrelated plans of the separate modules or, if the plans are not cost effective, individual plans for each of the structural module hatches, and docking ports will be initiated using commonality wherever applicable. Cost trade-off studies, and evaluations of the studies shall be made and shall be implemented into the Manufacturing Plan.

3.2.5 Docking Interface Structural Assembly

The docking interface structural assembly is a multi-use modular structure. Mechanical verification testing shall be a manufacturing requirement. Trade-off studies shall be conducted of the most cost effective modes of manufacture, i.e., sheet metal, forgings, closed die forgings, castings, etc. The evaluation of these trade-off studies and the results shall be included in the Manufacturing Plan.

3.2.6 Solar Array and Orientation Mechanism

The solar array and orientation mechanism shall require a manufacturing verification and test article during the development stages. An acceptance test program and an assembly plan shall be included in the manufacturing plan. A method of simulating zero gravity during manufacture will be a manufacturing requirement and the method evolved will be included in the Manufacturing Plan. The factors that will influence these evaluations and the results of these evaluations will also be included in the plan.

2

3.2.7 Experiment Equipment Interface

The contractor has the responsibility for the integration of the integral experiments located within the General Purpose Lab (GPL) during the manufacturing phase, and the integration of carry-on experiments that would be placed in the GPL at a later date. A simulated mock/up representing the experiment and a tool master with tooling interface holes, locators, reference points, etc., shall be a contractual requirement. Manufacturing engineering in conjunction with engineering design and procurement shall schedule and reflect in the manufacturing assembly flow plans the interface attaching sequence, the installation sequence, and the integration sequence of the equipment/experiments. These flow plans, tool lists, schedules, and the sequence of installation shall be included in the Manufacturing Plan.

3.2.8 Meteoroid Shield and Radiator

The meteoroid shield and radiator assembly is a sheet metal assembly comprised of extruded and roll-formed radiator tubes that are joined to the manifold and have a sheet metal inner skin riveted to the inner leg of the radiator tubes. The meteoroid shield and radiator are 360 degree segments and extend from midship to the forward or aft docking port transition rings. Each of the radiator assemblies is a separate entity with valving systems within the Space Station module. The meteoroid shield and the radiator are design requirements on the Crew/Operations Module, the General Purpose Laboratory Module and the Power/Subsystems Module. The methods of joining the radiator and manifold assemblies shall be evaluated and trade-off studies shall be conducted to evaluate the most cost effective mode of fabrication and assembly. The results of these evaluations will be included in the Manufacturing Plan. The installation of the high performance insulation (HPI) to the meteoroid assembly before installation shall be a manufacturing consideration. However, the possibility of puncturing the insulation, and the necessity of purging and bagging the insulation and meteoroid assembly will present manufacturing problems. Manufacturing options relative to the mode of assembly will be pursued and evaluated and flow plans will be included in the Manufacturing Plan.

3.2.9 Equipment Racks and Component Structure

Equipment racks and component structure requirements shall be evaluated for sequence of manufacture and installation. Ingress and egress will be a manufacturing consideration of major impact. Scheduling and correct installation sequencing will be a closely monitored manufacturing function. Rack provisions for vendor or subcontractor equipment shall be controlled by negotiated ICD's and prime contractor interface tooling. The requirements necessary to achieve an orderly installation, integration, and the maintenance of ingress and egress will be included in the plan through flow plans and scheduling.

3.2.10 Subsystems

Subsystems include attitude control, environmental control, communications, data management, and onboard checkout. Subsystems shall be manufactured in compliance with the design specifications and shall be product acceptance tested as outlined in Section 5. Ingress, egress, scheduling, integration, and checkout are major manufacturing considerations. Flow plans, acceptance test plans, integration sequencing, and scheduling requirements will be evaluated and the results will be included in the Manufacturing Plan.

3.3 FINAL ASSEMBLY METHODS

3.3.1 Assembly Sequencing

The mode of assembly of the Space Station modules comprising the ISS will be evaluated for the most compatible method of assembling the various configuration integration requirements. Master module simulators of docking interfaces, and integration simulators will be evaluated for feasibility and cost effectiveness. The results of these evaluations, final assembly flow plans, product acceptance test plans, required simulators and the tooling required to manufacture each of the ISS modules shall be outlined and included in the Manufacturing Plan. (Figure 3-2)

3.3.2 Interface Acceptance Tests

Components requiring a fluid interface shall be individually leak-tested upon installation. Systems shall not be operated until all affected components have been leak-tested and verified. Equipment shall be operated only to the extent needed to check the interface. These requirements will be included in the Manufacturing Plan.

3.4 ACCEPTANCE TESTING

The Manufacturing Plan shall reflect the acceptance philosophy established by the Verification Plan Requirements and satisfy the requirements specified therein. All-systems checkout of the flight modules, individual and integrated, shall be the responsibility of engineering. Manufacturing personnel shall support checkout operations as required.

3.5 PREPARATION TO SHIP

Requirements for this operation shall include cranes and hoisting fixtures to turn, weigh, and load the structural modules on the transporter. Surplus S-II and SIVB equipment shall be considered for this operation. After purging operations are completed and the monitoring and preservation equipment is attached, the shipping cover shall be installed. Shipping flow plans and the specific preservation methods will be included in the Manufacturing Plan.

3.6 ANTENNAS

Three high-gain antennas are mounted peripherially around an end docking structure transition ring for stowage during launch. After launch, the antennas are mechanically deployed below the mid point of the module and oriented as required. The fabrication of the antennas is currently within the state of the art. However, after installation, mechanical verification will be a manufacturing requirement. The mode of verification, the installation flow plans, and the tooling required will be included in the Manufacturing Plan.

3.7 GROUND SUPPORT EQUIPMENT (GSE)

Existing GSE from previous and current programs shall be used as applicable. A complete list of all modular Space Station GSE shall be provided. Tooling for new electrical/electronics GSE shall be minimized where possible. The low production rate and the high integration requirements are evaluations that will be made to determine the most cost effective approach. The results of these evaluations will be included in the Manufacturing Plans. Existing contractor and Government-owned assembly and test equipment shall be used for circuit card and wire-wrap as required. New Tooling and test adapters shall be provided only if not available from previous programs. Mechanical system GSE assembly rework and checkout shall be performed in existing contractor-owned clean rooms and bomb shelters. The new GSE Tooling and test requirements will be included in the Manufacturing Plan.

3.8 SPARES

Methods shall be defined, with alternates, to show the contractors approach to support prelaunch vehicle and ground equipment spares. Methods derived shall be compatible and shall refer to the Logistics Support Plan, and will be included in the Manufacturing Plan.

Philosophy for support of the 10-year operation of the Modular Space Station shall also be outlined and include alternates with recommended approaches. The alternates and the recommended approaches will be included in the Manufacturing Plan.

Section 4
TOOLING

4.1 DEFINITION

Tooling is defined as specific mediums required during the space station manufacturing phase by manufacturing. Typical examples of the mediums are:

A. Assembly jigs
B. Weld fixtures
C. Drill jigs
D. Mill fixtures
E. Lottie fixtures
F. Numerical control tapes
G. Handling dollies
H. Special test equipment

I. Templates

J. etc.

The manufacturing mediums are specific in nature and are generally custom built. Through the use of tooling, compliance with the design specification can be more efficiently achieved, interface fit-up of adjacent or mating, structures is controlled, and detail components can be premanufactured with tooling that is fabricated per a tooling program wherein all tools are interrelated and are compatible to each other.

4.2 TOOLING POLICY

Tooling shall be provided in accordance with the contractors existing policies and procedures.

The limited quantity of flight hardware in this program shall justify only minimum tooling to be provided by the contractor. Trade-off studies will be conducted to evaluate the feasibility and the schedule compatibility of having individual manufacturing and assembly lines, individual tooling and test fixtures for each of the proposed modules versus a single manufacturing and assembly line utilizing a multi-purpose tool in conjunction with adaptors and tooling aids to accommodate the manufacturing variables imposed by the modular differences. The results of these studies will be analyzed and the findings will be included in the manufacturing plan. No consideration will be made wherein the possibility of compromise to the integrity of the product is evident. The method of contractor control of tool masters, interface control tooling, prefit tooling, tool inspection, and periodic recheck shall be defined in the Manufacturing Plan.

4.3 INTERFACE CONTROL DOCUMENTATION

Support shall be provided by cognizant tooling groups in ICD negotiations whenever associate contractor and subcontractor hardware interfaces are contract requirements. Compatibility with subcontractors' capability and methods of assurance shall be evaluated before tooling and hardware fabrication.

Procurement and manufacturing engineering interfaces in conjunction with the contractors will establish tooling requirements necessary to accomplish interface control. These results will be included in the Manufacturing Plan.

4.4 MAJOR TOOLING REQUIRED

The Manufacturing Plan will consist of detailed fabrication flow plans, assembly flow plans, final assembly flow plans, and acceptance test plans; handling and shipping plans and man loading plans will be made to establish the production internal and the major tool requirements. Tool lists will evolve from these plans and will be included in the Manufacturing Plan.

Section 5
PRODUCTION TEST EQUIPMENT

5.1 INPLANT PRODUCTION TEST POLICY

Functional acceptance tests shall be performed on each and every end item delivered in the performance of the Space Station supply contract, and documented as evidence proving a line item condition of sell off. Acceptance tests shall also be performed on certain components and subassemblies of these end items as necessary. All functional acceptance tests shall be performed in accordance with engineering test requirements. Module acceptance test philosophies specified in the Verification Requirements Plan are summarized in the acceptance flow diagram depicted in Figure 5-1.

Three categories of in-plant acceptance tests are identified as follows:

(1) Receiving Tests - Normally performed at the time of receiving inspection of vendor, component, and major subcontractor items.

(2) In-Process/Assembly Tests - Performed at selected points in the assembly process to verify interface or subassembly integrity only when such a verification cannot be performed economically at the time of end item sell off.

(3) Final Acceptance Tests - Performed as a condition of end item acceptance, and to verify that all systems are functioning in accordance with the intent specified in the contract end item design specifications.

5.2 EQUIPMENT

All tests shall be performed with properly certified equipment calibrated to standards traceable to the National Bureau of Standards (NBS), using acceptance test procedures approved by Development Engineering and NASA if required.

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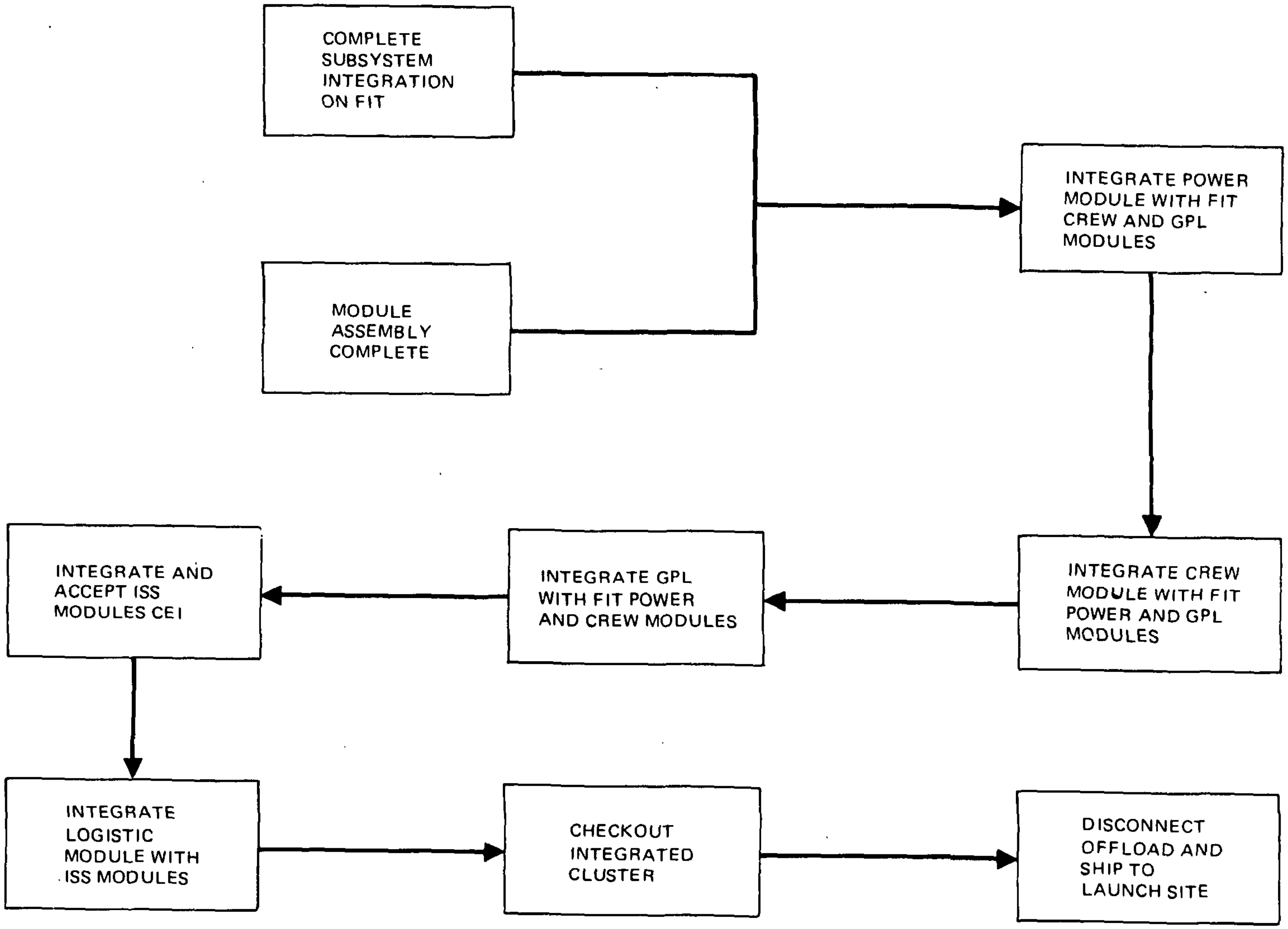

Figure 5-1. Space Station Module Acceptance Flow

Equipment used to perform acceptance tests shall be of the following types:

- Contractor owned available special and general purpose test equipment.
- Contractor furnished government owned non-deliverable in-plant production test equipment (PTE) and special test equipment (STE) unique to the space station*.
- Available space station end item ground support equipment (GSE).
- Associate/subcontractor furnished GSE.
- Government furnished GSE (GFP).
- Government owned contractor operated facilities.
- Existing PTE, STE, and GSE from other programs on a non-interference, rent-free basis.

Existing GSE from previous and current programs shall be used as applicable. A complete list of all GSE (existing and new) required for the space station shall be provided.

Tooling for new electrical/electronic GSE shall be minimal (tooling aids, etc.). Existing contractor and government-owned assembly and test equipment shall be used for circuit card and wire wrap manufacture as required. New tooling and test adapters shall be provided only if not available from previous programs.

Mechanical and pneumatic system GSE assembly/rework and checkout shall be performed in existing contractor-owned clean rooms and bomb shelters as required.

Due to the one-of-a-kind nature of the space station hardware, the contractor shall schedule new GSE availability for support of component and sub-assembly flight hardware testing where practicable, to avoid PTE duplication. The use of non-permanent test setups with existing bench equipment shall be employed unless justification is sufficient to permit fabrication of more elaborate production test equipment.

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*Equipment provided by the contractor and chargeable to the SS supply contract, shall conform to the NASA Procurement Regulation definitions of Material, Special Tooling, and Special Test Equipment.

The use of onboard checkout equipment for flight system tests shall be employed to the fullest extent to minimize specialized factory checkout equipment for this purpose. The contractor shall review and identify those items that are deemed to be of such a complex nature that a study to determine the most economical in-plant test approach will be required. Such studies will be detailed in individual test plans to show alternate methods considered, the necessary equipment for each, the operational steps involved, and a recommendation. A list of anticipated plans shall be included in the phase C/D documentation.

A list of major PTE consoles/complexes shall be provided with a brief description and justification. A typical listing might include:

- Hydrostatic proof test facilities for pressurized compartment tests.
- Gaseous nitrogen (GN_2) and gaseous helium (GHe) leak test set-up for pressurized compartment and propulsion components testing.
- Solar panel deployment equipment to facilitate zero-g deployment demonstration.
- Docking latch testing complex.
- Coolant flow conditioning and calibration equipment for cold plate and radiator panel testing.
- Integrated circuit module and circuit card test equipment

5.3 ALL SYSTEMS CHECKOUT AREA (IN-PLANT)

All systems checkout shall be performed before shipment of each CEI from the contractor's facility. In the case of the ISS modules, this checkout is performed by incrementally bringing each module on-line culminated by checking out the integrated modules. This is accomplished by substituting flight modules for FIT modules until the ISS configuration has been accepted. The area designated for FIT operations shall accommodate this all-systems acceptance as well as provide for the integration of the Logistics Module.

5.3.1 Area Activiation

Proposed area layouts shall be provided. Area buildup, including facility modifications, schedules, and post contract facility restoration shall be listed and briefly described. Major supplemental equipment required to support in-plant checkout (non-GSE) shall be identified with justification.

5.3.2 Facility Modifications

Contractor owned facility modifications chargeable to the space station supply contract necessary to support production checkout, shall be described with justification. In the event the contractor invests capital to accommodate major production test area deployment, and such activity is accomplished concurrently with construction chargeable to the space station contract, an appropriate method of cost segregation shall be identified with control and reporting techniques detailed.

Section 6
FACILITIES

Manufacturing facilities to accommodate final assembly and checkout may be selected from various existing Government-owned facilities, if applicable. Consideration shall be given to current program-shared facility usage (on a noninterference, rent-free basis), including modification and postdelivery restoration.

6.1 CAPITAL

Contractor capital improvements necessary to support Space Station module manufacture will be determined from the manufacturing requirements delineated in the Manufacturing Plan. The fabrication flow plans, assembly flow plans, final assembly flow plans, acceptance test plans, and packaging and shipping plans will be evaluated for the most cost effective method of achieving the capital improvements required. Trade-off studies will be conducted and the results of these studies included in the Facilities Utilization Plan.

6.2 CONTRACT

Required government-owned facility improvements or modification of capital property that are chargeable to the Modular Space Station Project shall be determined as required by the Manufacturing Plan. These requirements shall be delineated and briefly described relative to size, capacity, and function. Trade-off studies of the most cost effective method of achieving these improvements or modifications to government-owned facilities or capital property and the results of these studies will be included in the Facility Utilization plan

6.3 SEGREGATION OF COSTS

The contractor shall show the proposed method of cost segregation if capital and contract facility improvements are combined by one A&E.

6.4 CRITICAL FACILITIES

Critical facilities and the methods of control shall be defined. The design specifications, the Manufacturing Plan, the Facilities Utilization Plan will be evaluated to determine the critical facility requirements and the results of these studies will be included in the Facility Plan.

MODULAR SPACE STATION

QUALITY PLAN REQUIREMENTS

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QUALITY PLAN REQUIREMENTS

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QUALITY PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 GENERAL

This document has been prepared to guide contractor planning and bidding of Phase C/D. It defines the requirements and their application for the modular Space Station Project Quality Program; and the organization and general operating controls/procedures, policies, and objectives to be applied in preparing the Phase C/D Implementation Plan.

1.2 RELATION TO OTHER CONTRACT REQUIREMENTS

The quality program requirements set forth in this publication shall be satisfied in addition to all detail requirements contained in the statement of work or in other parts of the contract. Overlapping and interfacing contractual requirements, such as reliability, safety, and test, shall not result in duplication of contractor efforts. The quality program shall effectively complement and support functions required by other contract requirements.

1.3 ACTIONS AND PREROGATIVES OF THE GOVERNMENT

The operations and work of the contractor and his suppliers are subject to evaluation, review, audit, survey, and inspection by the procuring NASA installation and its designated Government quality representatives. Actions by or on behalf of the Government will determine that:

A. The contractor meets contractual requirements.

B. Materials, articles, and related services are of satisfactory quality and meet performance and design specifications.

Designated Government quality representatives may be assigned on a resident or itinerant basis at the contractor or supplier's facilities. The responsibilities and authorities delegated to these representatives will be defined by the NASA Contracting Officer.

The contractor shall provide the Government quality representatives with information, documents, records, inspection equipment, samples, materials, and reasonable facilities and assistance for the safety and convenience of the representative in the performance of his duties.

1.4 QUALITY PROGRAM DOCUMENTS

The contract will specify those documents to be submitted to the procuring NASA Installation and/or its representative for approval, review, or information. Government and contractor actions for submitted documents and their revisions are as follows:

A. Approval. Documents in this category require written NASA approval before use. Receipt by NASA shall occur within the time specified in the contract. Requirements for resubmission shall be as specified in letter(s) of disapproval.

B. Review. Documents in this category require receipt by NASA prior to use and within the time period specified in the contract. They are subject to evaluation by NASA or its designated representatives to determine contractor effectiveness in meeting contract objectives. When Government evaluations reveal inadequacies, the contractor will be requested to correct the documents.

C. Information. Documents in this category require receipt by NASA within the time period specified in the contract for the purpose of determining current program status, progress, and future planning requirements.

The contractor shall generate and use those documents necessary to meet cited requirements of the contract. These, and other contractor documents, shall be readily available to the procuring NASA Installation and its designated Government quality representative, and shall be submitted upon request.

1.5 GLOSSARY OF TERMS

Appendix A, "Glossary of Terms," defines selected terms used in this publication.

Section 2
QUALITY PROGRAM MANAGEMENT AND PLANNING

2.1 GENERAL

The contractor shall maintain an effective and timely quality program planned and developed in conjunction with all other contractor's functions necessary to satisfy the contract requirements. The program shall:

A. Demonstrate recognition of the quality aspects of the contract and an organized approach to achieve them.

B. Ensure that quality requirements are determined and satisfied throughout all phases of contract performance, including engineering design, development, fabrication, processing, assembly, inspection, test, checkout, packaging, shipping, storage, maintenance, field use, flight preparations, flight operations, and post-flight analysis, as applicable.

C. Ensure that quality aspects are fully included in all designs and are continuously maintained in the fabricated articles and during operations.

D. Provide for the detection of actual or potential deficiencies, system incompatibility, marginal quality, and trends or conditions which could result in unsatisfactory quality.

E. Provide timely and effective remedial and preventive action.

Objective evidence of inspections and tests shall be readily available to the procuring NASA installation and its designated representative.

2.2 ORGANIZATION

The contractor shall make functional assignments to implement each element of his quality program. Personnel performing quality program functions shall have sufficient, well-defined responsibility and the organizational freedom to assess problems and to recommend and/or effect solutions. The effectiveness of quality program functions and the ability of assigned personnel to assess, document, and report findings objectively shall be maintained during all phases of the contract work and shall not be reduced by other considerations, such as the influence of engineering changes, rework, or rescheduling. The contractor shall designate one individual responsible for directing and managing the quality program. He shall have direct, unimpeded access to higher management and shall report regularly to higher management on the status and adequacy of the program.

2.3 TRAINING

The contractor shall have trained and competent personnel for implementing the quality program. The contractor shall develop, maintain, and implement necessary training for engineering, fabrication, test, procurement, quality assurance, and other personnel who may have an effect upon or who are responsible for the determination of quality or to meet cited requirements of this publication. Training activities shall be documented and shall provide for:

A. Excellence of workmanship and personnel skills.

B. Careful and safe operations.

C. Maintenance and improvement, where necessary, of article and material quality.

Contractor personnel controlling selected processes and personnel performing selected operations shall be certified. Certification by the contractor may be reviewed or repeated by the procuring NASA Installation or its designated Government quality representative to verify the adequacy of such certifications. Certification of personnel shall be based upon objective evidence which includes training and testing. Certified personnel shall be given a card, badge, or similar evidence of certification.

Contractor personnel shall be recertified based on contractor or Government observation of unsatisfactory quality of articles or services; change in techniques, parameters or required skills; or interruption of work period as established for the process or operation involved. Recertification shall require retesting of the individual to the testing procedure to demonstrate continuing proficiency. Persons failing the retest shall not be permitted to perform these processes or operations until provided with additional training and required proficiency has been demonstrated.

Records shall be maintained of the training, testing, and certification status of personnel.

2.4 QUALITY INFORMATION

The contractor shall 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. Quality information shall be promptly disseminated to all concerned areas within the contractor's organization and to concerned suppliers to effectively implement quality program requirements and contract requirements.

2.5 QUALITY STATUS REPORTING

The contractor shall report the status of the quality program on a periodic basis, as specified in the contract. The report shall include, as required:

A. Organization and key personnel changes.

B. Significant program and article or material problems, their solutions and remedial and preventive actions.

C. Contractor performance, such as inspection and test activities and procurement activities relative to supplier selections, surveys, and procurement document reviews.

D. Supplier performance, such as acceptance and rejection rates.

2.6 QUALITY PROGRAM AUDITS

2.6.1 General

The contractor shall conduct audits of personnel, procedures, and operations which implenent the quality program. Each audit shall be performed by a team of contractor personnel familiar with all written procedures and standards applicable to the operation or work areas being audited and shall include personnel not having specific line responsibilities in those areas. Audits shall not require examination of all operations and documentation, nor examination of all articles and all materials, but shall include examination of articles and materials to verify the effectiveness of the contractor's efforts.

2.6.2 Unscheduled Audits

Random unscheduled audits shall be performed to effectively assess existing conditions and operations.

2.6.3 Audit Reports

The results of audits shall be documented in a report to contractor higher management with appropriate recommendations for correction of deficiencies. Action shall be taken to ensure effective correction of the reported deficiencies. Follow-up reviews shall be made to ensure that required corrections have been implemented.

2.7 QUALITY PROGRAM PLAN

The contractor shall prepare, maintain, and implement a Quality Program Plan which describes how the contractor will ensure compliance with cited quality requirements. The Quality Program Plan shall be submitted as required by the Request for Proposal or Contract. The plan format shall be readily identified with each cited requirement. The plan shall cover all quality program activities for the time period or phase authorized, be updated periodically and resubmitted, as specified in the contract, and serve as the planning and control document for the quality program.

The Quality Program Plan shall include:

A. Charts and narrative statements describing each element of the contractor's organization (e.g., procurement, engineering, reliability, fabrication, test, safety, and quality assurance) which implement the quality program and detailed statements of duties, functions, and responsibilities relating to each quality program task. The plan shall show the relationships of the individual managing the quality program with each element performing quality program tasks, including his authority to control and monitor cited tasks.

B. Narrative descriptions which describe the contractor's execution and management of each task. These shall be detailed in terms of when, by which organizations, and by which methods each task will be accomplished. Applicable contractor policies and procedures shall be references in the plan.

C. Identification of those elements of the planned program which will use the contractor's existing quality program documents and operations and identification of those requiring change. Proposed changes needed to meet cited requirements and the time schedule for implementing such changes shall be delineated.

D. Charts indicating inspection and test points of the fabrication and assembly operations.

E. A single plan shall be prepared to cover activities at all plants and sites, and all project phases from design through mission operation and shall identify activities at each major plant and site and shall describe significant differences in organization, requirements, and implementing procedures peculiar to a location or operation.

F. The Quality Program Plan shall be updated annually, and shall reflect the total remaining scope of the quality program. At each major plan revision, activities to be implemented during the immediate contract period shall be described in depth; planning for future activities shall be preliminary in nature and less detailed. Major revisions to the key milestones that mark significant changes in the nature of project activities and supporting quality assurance tasks shall be identified. Two such milestones are the beginning of hardware fabrication and the beginning of mission operations. Additions or modifications to the plan format shall be made as necessary to accommodate phasing of activities and sites.

Section 3
DESIGN AND DEVELOPMENT CONTROLS

3.1 TECHNICAL DOCUMENTS

The contractor shall establish, document, and ensure compliance with design control requirements and quality critieria during all phases of contract work. Contractor technical documents such as specifications, procedures, drawings, fabrication and planning documents, and process sheets shall be updated and/or developed and shall include, as applicable, the following information:

A. Characteristics and design criteria necessary for procurement, fabrication (including assembly), and inspection and test operations.

B. Characteristic tolerances.

C. Identification in accordance with Section 4, Identification and Retrieval.

Contractor quality assurance personnel shall conduct timely reviews of technical documents, and changes thereto. Reviews shall ensure that all necessary information has been included and that requirements are clear and unambiguous. The reviews shall be documented, deficiencies in the documents reported to responsible personnel, and action taken to ensure correction of the deficiencies prior to document release. These reviews shall be used in timely quality planning for subsequent procurement, fabrication, inspection and test activities.

3.2 QUALITY SUPPORT TO DESIGN REVIEW

Quality assurance personnel shall participate in design reviews to ensure that designs permit and facilitate producibility, repeatability, testing, and inspectability, and that related quality considerations are obtained.

3.3 CHANGE CONTROL

The contractor shall ensure control of all documents, and changes thereto, affecting the quality program. Documents shall be distributed to the proper points at the proper times, and obsolete documents removed from operating areas. The change control system shall be documented. The control system shall provide for initiation of document change requests. Changes which involve interface relationships or which affect articles not under design control of the contractor shall be coordinated with the affected parties. The contractor shall effectively integrate these requirements with other document control requirements of the contract.

The contractor shall clearly specify the effectivity point of documents and changes which affect materials, fabrication, or performance. The contractor shall ensure that: changes are accomplished on the affected articles or materials at the authorized point; changed articles are appropriately marked or identified; and associated documents are revised accordingly Provisions shall be made for inspection and test of changed articles or materials.

The contractor's method of implementation of these requirements shall be consistent with the configuration management provisions of the Program Management Plan.

Section 4
IDENTIFICATION AND DATA RETRIEVAL

4.1 GENERAL

The contractor shall develop and maintain an identification and data retrieval system for articles and materials to provide:

A. Identification to which procurement, fabrication, processing, inspection, test, and operating records can be related.

B. Means for locating articles and materials.

The contractor system shall be developed in conjunction with other contractor systems, such as engineering documentation control, configuration management, and logistics management. Common identification numbers and procedures shall be used among all systems.

Articles and materials need not be readily located by means of records except in special cases where traceability has been specified as an engineering requirement. Where special control of individual articles or lots of articles and materials is required, detailed identification methods and controls shall apply as indicated in subsections 4.2 and 4.3. The contractor shall select such items, based on mission criticality, limited life, or other considerations appropriate to Modular Space Station applications. The contractor's Reliability Plan shall establish the criteria for the selection of items and shall maintain the list of those items where such special controls are required. The contractor's Quality Plan shall describe the method of implementation.

4.2 IDENTIFICATION METHODS

Where control of individual articles or lots of articles or materials is required, one or more of the following detailed identification methods shall be used, as applicable:

A. Date Codes. Date codes indicating date of manufacture to identify articles or materials made by a continuous and controlled process and those which are subject to variations or degradation with age.

B. Lot Numbers. Lot numbers to identify articles or materials produced in homogeneous groups and where unique data are not required to be related to individual items. Heat, billet, or batch numbers are included in this category.

C. Serial Numbers. Serial numbers to identify individual materials or articles for which unique data are to be maintained or when other reasons exist for individual control.

D. Other Identification. Other identification methods, such as paint dots in lieu of or in addition to the methods specified herein, upon approval of their designated Government quality representative.

4.3 DOCUMENTATION

Method and location of part or type numbers and detailed identification on articles and materials shall be indicated on manufacturing drawings.

4.4 IDENTIFICATION CONTROL

Controls shall be established to ensure that detailed identification numbers for individual articles and materials or lots thereof are assigned in a consecutive manner. Records for articles and materials shall indicate applicable part or type numbers and associated detailed identification. This shall provide the capability of tracing backward to the material from which fabrication originated and forward to determine the location of like articles or materials within a level of process or assembly. Serial or lot numbers of scrapped articles or materials shall not be used for other similar articles or materials.

4.5 IDENTIFICATION LIST

Upon initiation of design activity, the contractor shall establish and maintain an identification list containing reference to contractor- and supplier-designed articles. This list shall indicate the part or type number for articles and materials and the applicable type of group or individual identification. The list may be initially prepared in generic terms; specific part numbers and related information shall be included as design progresses.

4.6 RETRIEVAL OF RECORDS

Contractor identification systems shall ensure that article and material procurement, fabrication, processing, inspection, and test records are related to the articles and materials specified in the identification list. It shall be organized so that these records and the related articles and materials may be located and retrieved in the event verification of, or removal of articles or materials becomes necessary.

4.7 RECORDS RETENTION

Records shall be maintained at the contractor's location for a period of two years after contract completion. These records are not to be released except through NASA approval.

Section 5
PROCUREMENT CONTROLS

5.1 GENERAL

The contractor is responsible for the adequacy and quality of all contractor-purchased articles, materials, and services.

5.2 SELECTION OF CONTRACTOR PROCUREMENT SOURCES

Contractor quality assurance personnel shall participate in the selection of procurement sources. The contractor's selection shall be based upon one of the following:

A. The supplier shall have a previous and continuous record of supplying quality articles, materials, or services of the type being procured.

B. A pre-award survey of the supplier's facility and quality system shall be conducted to determine if he is capable of satisfying procurement quality requirements.

C. When articles or materials are not fabricated specifically for contracts or subcontracts issued under NASA contracts and the contractor has no previous quality record of the supplier for such articles and materials, a pre-award survey of the supplier is not required. In such cases, a thorough inspection of the articles and materials shall be performed in accordance with technical documents.

5.3 PROCUREMENT DOCUMENTS

5.3.1 Review

Procurement documents which are issued at contractor plant sites and facilities, including other divisions or subsidiaries of the contractor, shall be reviewed by quality assurance personnel before release for adequacy of quality requirements. Such reviews shall be documented and shall include determination that:

A. Suppliers have been selected in accordance with subsection 5.2.

B. Applicable provisions of subsection 5.3.2 have been properly cited.

5.3.2 Contents

Procurement documents shall contain provisions for the following:

A. Supplier Quality Requirements. Supplier quality requirements shall be tailored to the specific procurement, with emphasis on avoiding unnecessary costs. Suppliers shall be required to comply with one of the following:

1. Subcontractors and major suppliers of Space Station subsystems, complex assemblies, and mission essential equipment shall be in accordance with this publication or applicable portions thereof.

2. Other suppliers shall be required to follow the Quality Program Requirements as specified in the contract.

B. Basic Technical Requirements. Procurements shall specify or reference technical requirements for articles, materials or services to be provided by a supplier. Applicable revisions shall also be indicated and documents provided.

C. Detailed Quality Requirements. The following detailed quality requirements, as necessary, shall be additionally included or technical documents containing these requirements shall be referenced. Applicable revisions of referenced documents shall be indicated and documents provided as necessary to the supplier.

1. Changes. The supplier shall be required to notify the contractor of any proposed changes in design, fabrication methods, or processes approved by the contractor, including changes which may affect the quality or intended end-use of the item, and obtain written approval of the change from the contractor before

making the change. Changed articles shall be identified differently from previous articles. When a proprietary item is procured by the contractor, the supplier shall be required to notify the contractor of changes.

2. Purchased Raw Materials. Purchased raw materials shall be accompanied with chemical and/or physical test results.

3. Raw Materials Used in Purchased Articles. Tests performed on specimens or detailed analyses of supplier's acceptance test results on all raw materials that are required to satisfy specification requirements and which are employed in the fabrication of articles purchased on this subcontract or purchase order shall be made available to the contractor upon request.

4. Preservation, Packaging, Packing, and Shipping. Requirements for preservation, packaging, packing, and shipping of articles and materials shall be specified or referenced.

5. Age Control and Life Limited Products. Records for articles and materials having definite characteristics of quality degradation or drift with age and/or use shall indicate the date and test time or cycle at which useful life was initiated, the life or cycles used, and the date and test time or cycle at which useful life will be expended. When appropriate, specify that the articles and materials exhibit similar information. The supplier shall ensure removal or rework of such articles and materials as required.

6. Identification and Data Retrieval. Identification and data retrieval requirements shall be specified.

7. Inspection and Test Characteristics. Characteristics to be subjected to inspections or tests by the supplier shall be specified.

8. Inspection and Test Records. Inspection and test records to be maintained by the supplier to provide evidence of supplier inspections and tests shall be clearly specified. Records to be provided to the contractor or his source inspection personnel shall be specified.

9. Resubmission of Nonconforming Articles or Materials. Nonconforming articles and materials returned to the supplier by the contractor and subsequently resubmitted by the supplier to the contractor shall bear adequate identification of such resubmission either on the article or material or on supplier records. Reference shall be made to the contractor's nonconformance document and evidence provided that causes for nonconformances have been corrected and actions taken to preclude recurrence.

10. Contractor Quality Assurance Activity at Source. When contractor quality assurance activity is required at source, the procurement document shall so indicate.

11. Government Source Inspection (GSI). When the Government elects to perform inspection at a supplier's plant, the following statement shall be included in the procurement document:

    "All work on this order is subject to inspection and test by the Government at any time and place. The Government quality representative who has been delegated NASA Quality Assurance functions on this procurement shall be notified immediately upon receipt of this order. The Government representative shall also be notified forty-eight (48) hours in advance of the time articles or materials are ready for inspection or test."

12. Procurements Other Than Those Requiring GSI. Procurements which do not require Government Source Inspection shall include the following statement:

    "The Government has the right to inspect any or all of the work included in this order at the supplier's plant."

13. Equipment Records. Detailed requirements for equipment records shall be specified.

D. New quality requirements shall not be imposed on suppliers of off-the-shelf items, or on suppliers of items used on other programs where quality requirements are at least as stringent as they are for the Modular Space Station.

E. Documentation and reporting requirements for subcontractors and suppliers shall be minimized, consistent with the requirements imposed on the contractor.

5.4 CONTRACTOR QUALITY ASSURANCE PERSONNEL AT SOURCE

The contractor may assign quality assurance personnel at subcontractor or suppliers' facilities. Personnel shall conduct appropriate quality assurance activities, including inspections, to ensure that the subcontractor or supplier complies with applicable requirements. Assignment of quality assurance personnel shall take place when one or more of the following conditions exist:

A. In-process or end-item controls have such an effect on the quality of the articles that the quality cannot be determined solely by inspection or tests of the procured articles at the contractor's plant.

B. Verification tests are destructive in nature and the quality cannot be verified solely by inspections or tests at the contractor's plant.

C. The environments or test equipment required cannot be feasibly and economically reproduced or made available at the contractor's plant.

D. Past performance or quality history of the subcontractor or supplier is marginal.

E. Qualification testing is to be performed by the subcontractor or supplier.

F. Articles or materials are designated for direct shipment from source to the procuring NASA installation or using site.

The contractor will provide a list of duties, responsibilities, and authorities of his assigned quality assurance personnel to the designated Government quality representative at the contractor's facility. When both Government source inspection personnel and contractor personnel are used at a supplier facility, the listing shall also be provided to the Government quality representative at the supplier's facility upon issurance of the procurement.

5.5 GOVERNMENT SOURCE INSPECTION

Source inspection performed by and for the convenience of the Government on procured articles or materials shall not, in any way, replace contractor source inspection or relieve the contractor of his responsibilities for ensuring their quality. The need for delegation of GSI will be determined by the procuring NASA installation or its designated Government quality representative.

5.6 RECEIVING INSPECTION SYSTEM

The contractor shall maintain a receiving inspection system which ensures:

A. That procured articles and materials indicate evidence of inspections and tests performed by the suppliers in accordance with purchase requirements and are accompanied with required inspection and test data.

B. That articles and materials or accompanying records exhibit evidence of contractor and GSI, as required.

C. That supplier inspection and test data is acceptable by conducting inspections and tests on criticality 1 and 2 items, and selected characteristics on criticality 3 hardware. As a minimum, receiving inspection and test shall include verification of characteristics and design criteria which have not been source inspected by the contractor and which can be verified without disassembly of the article. Particular emphasis shall be placed on those characteristics for which nonconformances may not be detected during subsequent inspection and test. Inspections and tests shall be accomplished in accordance with approved inspection and test procedures.

D. That periodic disassembly is accomplished as appropriate for more detailed verification of the specified requirements.

E. That identification and data retrieval requirements have been met and are maintained; that all required data and records are complete and correct; and that articles and materials can be directly related to applicable supplier records.

F. That appropriate inspection and test equipment and technical documents are available at the proper places and at the proper times to perform the test and inspections.

G. That supplier records for articles and materials having definite characteristics of quality degradation or drift with age and/or use indicate the date and test time or cycle at which useful life was initiated and the life or cycles used. The records shall be maintained and updated if life or cycle use occurs during receiving inspection activities. The receiving inspection system shall also ensure that the articles and materials, when required, exhibit evidence of initiation of useful life, the life or cycles used, and the date and test time or cycle at which useful life will be expended.

H. When required by specification or drawing, chemical analyses and physical tests are performed on test specimens submitted with purchased articles and materials.

I. That chemical analyses and physical tests are conducted on samples randomly selected from materials received.

J. That the quality status of articles and materials is maintained during receiving inspection and test operations. This shall include physical separation and identification of articles and materials according to the following categories:

   1. Items awaiting inspection or test results.
   2. Conforming items.
   3. Nonconforming items.

K. That articles and materials and their records clearly indicate their acceptance or nonconformance status when released from receiving inspection and test.

L. That articles and materials to be released are adequately controlled and protected for subsequent handling, storage or use.

5.7 RECEIVING RECORDS

Receiving inspection and test records shall be maintained for articles and materials to indicate, as a minimum: date of receipt; accomplishment of applicable requirements of subsection 5.6; results of inspections and tests; inspection and test procedures used; and disposition of the articles or materials. Records shall include copies of pertinent supplier documents received or an indication of the type of documents received and their location.

5.8 SUPPLIER RATING SYSTEM

Receiving inspection and test results shall be recorded to reflect on a continuous basis the qualitative and quantitative performance of individual suppliers and the quality histories of the supplier articles and materials. The contractor shall maintain a supplier rating system to aid in the selection of procurement sources based upon these results.

5.9 POST-AWARD SURVEY OF SUPPLIER OPERATIONS

The contractor shall schedule and conduct post-award surveys of suppliers based upon:

A. Criticality of items being procured.
B. Known problems or difficulties.
C. Supplier quality history.
D. Supplier fabrication and testing capability, and
E. Remaining period of supplier performance.

A schedule shall be prepared in matrix form to include all planned surveys conducted during the contract period. Supplier's of critical items shall be surveyed at least once a year in accordance with a suppliers quality program.

Each survey shall include examination of operations and documentation to determine compliance with established requirements as well as an examination of articles and materials to verify the effectiveness of the supplier's quality system.

A summary of survey results shall be documented, including problem areas discovered, with recommendations for timely correction and prevention of deficiencies; also recommendations for follow-up action.

5.10 COORDINATION OF CONTRACTOR-SUPPLIER INSPECTIONS AND TESTS

The contractor shall coordinate with selected suppliers to ensure compatibility of supplier inspections and tests with contractor inspections and tests of the procured article or material. The contractor shall provide technical assistance and training for suppliers as necessary.

The objective of the contractor's planning for control of one-of-a-kind hardware procured from subcontractors and suppliers shall be to receive and use such hardware with little if any additional inspection or testing. Close coordination and on-the-spot participation by cognizant contractor and subcontractor technical and quality assurance personnel shall be used to minimize documentation requirements and downstream assurance operations. Redundant inspections and acceptance tests of procured items by the contractor shall be avoided.

5.11 NONCONFORMANCE INFORMATION FEEDBACK

The contractor shall rapidly feedback to suppliers information concerning supplier-responsible nonconformances which are detected during contractor inspection, fabrication or assembly operations, or during test or use. The contractor shall ensure that the supplier takes prompt remedial and preventive action to preclude recurrence of nonconformances.

Section 6
FABRICATION CONTROLS

6.1 FABRICATION OPERATIONS

The contractor shall control fabrication, including assembly, operations to ensure that characteristic and design criteria specified in technical documents are obtained and maintained in all contractor-fabricated articles. Detailed fabrication documents shall be generated and utilized by personnel conducting fabrication operations. Fabrication documents shall include or reference:

A. Nomenclature and identification of the article to be fabricated.
B. Tooling, jigs, fixtures, and other fabrication equipment to be used.
C. Characteristics and tolerances to be obtained.
D. Detailed procedures for controlling processes.
E. Special conditions to be maintained such as environmental conditions or precautions to be observed.
F. Workmanship standards.
G. Contractor inspection and test operation to be performed during fabrication and assembly.

H. Specific cleanliness levels to be maintained by components, subsystems and systems.

I. Special handling equipment and protective devices.

J. Mandatory government inspection point.

The detailed fabrication control documents shall not be required where limited quantities are involved and where less costly means of fabrication control are adequate.

6.2 ARTICLE AND MATERIAL CONTROLS

Controls shall ensure that only conforming articles and materials are released and used and those not required for the operation involved removed from work operations. Articles having definite characteristics of quality degradation or drift with age and/or use shall be marked to indicate the date, test time, or cycle the critical life was initiated, and the date, test time, or cycle useful life will be expended. Data shall be recorded and maintained for such articles in accordance with documented requirements. Articles and materials to be fabricated or processed in a temperature-controlled environment shall be inspected and tested in a similar environment to the extent necessary to prevent quality degradation.

6.3 CLEANLINESS CONTROL

Fabrication, assembly, inspection, and test areas shall be controlled in accordance with documented cleanliness requirements for environments, work surfaces, tools, fixtures, handling, storage and shipping containers, and test and inspection equipment to prevent contamination. Technical documents shall include requirements to be implemented and the method for maintaining and measuring conformance to these requirements. Tests or inspections shall be performed to verify the cleanliness before initial use and at established intervals during use to ensure continued cleanliness.

Cleanliness requirements imposed by Space Station module operational considerations shall be included in applicable end-item specifications and ground operating procedures. Cleanliness requirements of manufacturing processes shall be imposed by applicable process specifications. Work areas include cleanliness control of the interior for the various Modular Space Station elements.

6.4 PROCESS CONTROLS

The contractor shall implement controls for those processes where uniform, high quality cannot be assured by inspection of articles alone. These processes include, but are not limited to, metallurgical and chemical processes, metal joining processes, bonding processes, plastics application, plating and coating processes, and surface treating processes. In addition, processes such as radiography, ultrasonics, liquid penetrant, and magnetic particle, shall be controlled to ensure that the results indicate the article or material quality levels.

Process Control procedures shall be prepared to implement applicable processing requirements and shall include detailed performance and control provisions. The procedures shall describe the preparation of the processing equipment and materials; the preparation of the articles or materials to be processed; detailed processing operations; conditions to be maintained during each phase of the process including environmental controls; the methods of verifying the adequacy of processing materials, solutions, equipment, environments, and their associated control parameters; and the required records for documenting the results of process inspection, test and verification.

The contractor shall provide for the certification of equipment for selected processes. Records certifying that tests have been performed and the results of such tests shall be maintained. Equipment shall be recertified as indicated by the results of quality surveys, inspections or tests, or when changes are made which may affect process integrity.

6.5 WORKMANSHIP STANDARDS

Where samples or visual aids showing acceptable workmanship are necessary, they will be jointly selected by the contractor and the procuring NASA Installation or its designated Government quality representative. Standards shall be reviewed and revised or replaced as necessary to satisfy current requirements.

Section 7
INSPECTIONS AND TESTS

7.1 GENERAL - VERIFICATION ASSESSMENT AND TEST

The contractor shall demonstrate as a part of the verification program that contract, drawing, and specification requirements are met. The program and its application to all phases of the contract shall provide maximum assurance that the quality inherent in the design is maintained.

Requirements of subsections 7.3, 7.4, and 7.5 for preparing and using inspection and test specifications and procedures will not be mandatory for one-time-only, lower-level inspections and tests performed under the direction of the cognizant engineer. Specifications and procedures shall be provided for inspections and tests of mission-critical items and repetitive items such as spares, and for final acceptance tests that will be repeated in mission checkout and planned maintenance operations.

7.2 INSPECTION AND TEST PLANNING

The contractor shall provide the necessary planning functions for the accomplishment of inspections and tests and an adequate documentation system which substantiates their accomplishment. The planning functions shall provide for:

A. Orderly and timely inspection and testing at the earliest opportunity and through all phases.

B. Coordination and sequencing of inspection and testing conducted at successive levels of assembly to ensure satisfactory articles and materials and to minimize unnecessary testing.

C. Economical and effective use of equipment, facilities, and personnel.

D. Availability of calibrated inspection and test equipment.

E. Coordination of inspections and tests conducted by the designated Government quality representative.

7.3 TEST SPECIFICATIONS

The contractor shall prepare and use test plans and specifications for each test to be performed as defined by the Verification Plan. Specifications shall be available to test and inspection personnel. Each specification shall include as applicable: test item nomenclature and identification; test objectives; quantity to be tested; reliability goal; test parameters and tolerances; acceptance and rejection criteria; environmental conditions; hazardous operations or situations; reference to applicable safety standards, rules, and regulations; allowable adjustment, repair, rework, or maintenance operations; requirements for data recording, analysis, retest, and reporting of test results; and disposition of test articles.

7.4 INSPECTION AND TEST PROCEDURES

For each inspection and test operation to be performed, the contractor shall prepare and utilize written procedures. These procedures shall be readily available to inspection and test personnel and shall be physically located at the applicable station at the time of inspection or test. Each procedure shall include, as applicable:

A. Nomenclature and identification of the test article or material.

B. Characteristics and design criteria to be inspected or tested, including values for acceptance and rejection.

C. Identification of characteristics and design criteria established for inspection or test by the designated Government quality representative.

D. Detail steps and operations to be taken in sequence, including verifications to be made before proceeding.

E. Cross-reference of characteristics with measuring equipment to be used, specifying range and type.

F. Details or instructions for operation of special data recording equipment, or other automated test equipment.

G. Layout and interconnection of test equipment and articles.

H. Hazardous situations or operations.

I. Precautions to comply with established safety requirements, ensure safety of personnel, and to prevent damage or degradation of articles and measuring equipment.

J. Environments and other conditions to be maintained.

K. Workmanship standards.

L. Constraints on inspection or testing.

M. Special instructions for nonconformances, anomalous occurrences, or results.

7.5 END-ITEM INSPECTION AND TEST SPECIFICATIONS AND PROCEDURES

End-item inspection and test plans and procedures shall be as required by the Verification Plan. Inspections and tests shall be conducted in a manner and under conditions which provide a valid measure of the overall quality of the end-item. The degree, duration, and number of tests performed on each end-item shall be sufficient to provide assurance that the end-item is capable of meeting contract requirements, and that the required quality and workmanship is present.

7.6 INSPECTION AND TEST PERFORMANCE

7.6.1 Inspections and Tests

Inspections and tests shall be established and performed to verify compliance with specifications and procedures. Inspections and tests shall be performed on procured and fabricated articles before their installation into the next higher level of assembly. The inspections also will include records review. The contractor shall ensure that each inspection and test operation (and to the extent practicable, each fabrication and assembly operation) is traceable to the individual responsible for its accomplishment.

To avoid unnecessary costs and excessive test time on limited-life items, the requirements for testing articles before their being installed in the next-higher level of assembly shall not be mandatory. The ease with which defective items can be replaced shall be considered in each specific case to determine whether postponing testing to higher levels of assembly is justified from the cost-effectiveness standpoint.

A. Control of Articles

1. Articles shall be inspected and tested in accordance with applicable technical documents.

2. Articles undergoing test shall not be adjusted, modified, repaired, reworked, or replaced except as specified in established documents, or in accordance with the requirements of Section 8.

B. Control of Inspection and Test Environments and Equipment

1. Environments shall be controlled to prevent compromising the quality of the article.

2. Equipment shall be controlled, maintained, and calibrated as specified in procedures for each equipment.

C. Criteria for Reinspection and Retest. Reinspection and retest may be required at any stage of contractor operations after accomplishment of remedial and preventive action whenever:

1. The article or material does not meet the contract or contractor specification requirements.

2. The inspection or test performed is not in accordance with test specifications or inspection and test procedures.

3. Equipment malfunctions occur.

4. Modifcations, repairs, replacements, or rework of the article or material occur after the start of inspection or testing.

5. The article or material is subject to drift or degradation during storage or handling. Periodic intervals for reinspection or retest shall be established.

6. Specified by Material Review Board (MRB). Retest shall be limited by consideration of remaining useful life and operating time for qualification.

7.6.2 Qualification Tests

Attention shall be given to assurance that flight hardware is qualified to meet specified space mission requirements. Such assurance may be obtained by ground operational and mission-duty cycle testing under simulated environmental conditions, by accelerated-life testing, by analytical techniques, and by combinations of these methods. Approval of the contracting officer is required for all qualification test criteria, plans, procedures, and reports. No qualification test program for flight hardware shall be considered complete until all final test reports have been approved by the contracting officer. All flight hardware in criticality categories 1, 1S, 2A, 2B or 3 (see Reliability/Maintainability Plan Requirements, Appendix A), shall be qualified at the component (black box) assembly level or at such higher assembly levels as deemed practical by one of the methods in the following subsections.

7.6.2.1 Test

Testing is the basic method to be used in the qualification of flight hardware. Such tests shall be used to determine that the hardware is capable of performing its required operational functions in the known or anticipated environmental conditions. These tests will be designed to subject flight configuration hardware to the worst case environments and stresses anticipated compatible with end item specifications.

7.6.2.2 Similarity

Qualification by similarity is acceptable provided all the following conditions are met:

A. Engineering evaluation reveals that design differences between the item being qualified and the previously qualified similar item are insignificant.

B. The previously qualified similar item was designed and qualified for equal or higher environmental stress levels and time durations than those known or anticipated for the item being qualified.

C. The item being qualified was fabricated by the same manufacturer as the similar item using the same processes, materials and quality control. Exceptions to this requirement may be granted on a case-by-case basis provided that a waiver request is submitted together with acceptable rationale to the contracting officer and that the manufacturer uses MSFC specified or approved process and quality control standards.

D. Documentation is provided which assures that qualification by similarity is adequate. The submitted documentation should include as a as a minimum, the test plans/test procedure/test report of the item to which similarity is claimed, a description of the differences between the items and the rationale for qualification by similarity.

7.6.2.3 Higher Assembly

Qualification of an item by test of a higher assembly will limit its usage to that assembly unless complete environment data is recorded for the particular item within the higher assembly. Qualification of an item by test of a higher assembly or module is acceptable provided the item being qualified is subjected to stress levels and time durations during the higher assembly test which are equal to or higher than the environmental qualification levels and durations specified for the item in the proposed application. Interractions between the various components and subsystems must be considered and evaluated when individual hardware items are qualified as part of a higher assembly test.

7.6.2.4 Analysis

This method of qualification is limited to those situations in which the hardware cannot be feasibly qualified by other methods as, for example, zero-g testing. Such analysis shall be documented to an extent sufficient to provide the contracting officer sufficient data to perform an independent verification of the results of the analyses. The following shall be available to the Government:

A. A qualification test requirements document defining the test objective, test environments, test levels, test durations, and test methods will be prepared for each item to be qualified.

B. Qualification test procedures will be prepared to assure that the objectives of the qualification test specification or requirements are achieved.

C. A final test report will be prepared upon completion of the qualification tests for all items subjected to qualification test.

D. Life-critical hardware requiring qualification by test, which is produced to identical design requirements by several manufacturing sources, shall be qualified, by test, for each source.

E. Previously qualified items shall be subjected to requalification, with the prior approval of the contracting officer when:

   1. Engineering evaluation determines that design, manufacturing, or quality control process changes have been made which affect its operation, function, or capability to withstand design conditions, and/or there has been an extended period of no production.

   2. New data indicate more severe environmental stress levels or time durations exist than those to which the item was originally qualified.

   3. The hardware assembly or manufacturing source is changed. Exceptions to this requirement may be granted on a case-by-case basis provided that a waiver request is submitted together with acceptable rationale to the contracting officer and that the manufacturer utilizes MSFC specified or approved manufacturing process and quality control standards.

F. Qualification test hardware will be selected from a normal production run. Test hardware shall have been subjected to normal inspection and acceptance tests. If first production items are selected, then all subsequent production items shall be produced identically to the selected test items.

G. Hardware items subjected to qualification testing shall be so identified and <u>shall not</u> be used as life critical flight hardware.

H. The number of qualification test specimens selected shall be sufficient to yield a significant level of engineering confidence, and one specimen shall be subjected to all anticipated environmental conditions.

I. A Certificate of Qualification (COQ) shall be prepared for each component of criticality 1, 1S, 2A, 2B or flight hardware in criticality 3 as specified in paragraph 7.6.2. Each COQ shall be approved by the contracting officer.

J. All documentation requiring review shall be submitted in sufficient time to permit thorough review by the contracting officer.

K. When failures or anomalies occur during qualification testing, the test shall be stopped until the failure cause is determined. Sufficient failures shall be immediately coordinated with the contracting officer before resuming the test.

L. Redundancy shall not affect the requirement for qualification testing.

M. A COQ shall be withdrawn from an "APPROVED" status and placed in a "QUESTIONABLE" status when:

   1. Design changes and changes in vendor's manufacturing processes occur.
   2. Significant component failures or anomalies occur during repeat qualification testing or during checkout and/or flight.
   3. Recurrent failures occur under circumstances not covered in item 2 above, such as repetitive failures occurring during acceptance inspection and testing.

   All such events shall be immediately reported to the contracting officer, and the COQ shall be retained in a "QUESTIONABLE" status until engineering investigations or analysis indicate whether the COQ should be returned to the "APPROVED" status or changed to an "UNAPPROVED" status.

7.6.3 <u>End-Item Inspections and Tests</u>

The contractor shall perform inspections and tests of the completed end-item intended for delivery under the contract. Nonconformances discovered before start of end-item testing shall be closed out in accordance with the requirements of Section 8. Nonconformances discovered during and after testing shall be closed out before succeeding operations, including shipping, in accordance with Section 8. The inspections and tests shall be performed in accordance with the end-item test specifications and procedures. In addition to determining contractual conformance, the contractor shall report immediately to the procuring NASA Installation and its designated Government quality representative any unusual phenomena, occurrence, difficulty or questionable condition, whose detection and correction is not specifically contained in the applicable requirements so that necessary actions can be initiated. The contractor shall stop testing when safety of personnel is in jeopardy or damage to the end-item or associated test equipment is possible.

7.6.4 End-Item Reinspection and Retest

Adjustments, modifications, repairs, replacements, or rework after completion of end-item inspections and tests shall require prior approval of the designated Government quality representative, if so authorized. The contractor shall evaluate the conditions involved and recommend to the representative the extent of reinspection and/or retest necessary.

7.6.5 End-Item Inspection and Test Report

The contractor shall prepare a summary type test report of each end-item required by the contract. The report shall include, but not be limited to, the following:

A. End-item nomenclature and identification.

B. Identification of articles removed and those replaced during end-item test.

C. Copies of approved requests for nonconformances requiring NASA Contracting Officer approval (see subsection 8.6).

D. List of authorized tests or retests not completed in accordance with approved procedures.

E. Summary of test data and results.

F. Listing of critical and limited life articles.

G. Total operating time/cycle records for each system and subsystem.

7.7 INSPECTION AND TEST RECORDS AND DATA

The contractor shall generate and maintain records and data of all inspections and tests performed. The records and data generated shall be appropriate for the particular type, scope, and importance of the inspection or test operation performed and sufficient in detail and extent to provide for complete verification and evaluation of the operations and objectives. Records shall disclose the status of articles and materials and evidence of inspections and tests performed, including the dates.

The contractor shall prepare, maintain and update the equipment records for each subsystem and system as a means of documenting its continuous history. Each record shall be identifiable to the pertinent equipment and shall be maintained in chronological order to account for all fabrication, assembly, inspection, and test operations, as well as idle periods (storage) and movements of equipment. Entries shall be complete, self-explanatory and signed, and should include or refer to details such as the following:

A. Configuration data: parts list, drawings, specifications, changes, and identification data.
B. Fabrication and assembly history: build-up and disassembly instructions, repairs, rework, modifcations.
C. Inspection and test records: specifications, procedures, results, variables data.
D. Nonconformance summary: initial review and MRB actions, remedial and preventive actions, Contracting Officer approvals.
E. Cumulative operating times or cycles.
F. Maintenance records.

The contract shall specify the equipment for which records shall be prepared, the level of assembly or operation at which they shall be initiated and requirements for submittal or shipment to equipment destination. Subsystem records shall be combined into system records. When a subsystem is operated or handled independently, including removal from its system, its record shall be maintained current.

7.8 CONTRACTOR QUALITY ASSURANCE ACTIONS

Before testing, the contractor's quality assurance personnel shall:

A. Verify that applicable inspection and test documents are available.
B. Ensure that requirements for selection and control of articles have been implemented and that test constraints have been resolved.

C. Verify that articles are identified.

D. Verify configuration of articles.

E. Verify that configuration of GSE is consistent with articles under test.

F. Verify that test equipment is calibrated and such calibration will be effective and sustained during the test period.

During testing, the contractor's quality assurance personnel shall:

A. Ensure that testing is accomplished in accordance with test specifications and procedures.

B. Ensure accurate and complete recording of data and test results.

C. Document rework, repair, or modification occurring during the test operation.

D. Document nonconformances and participate in their dispositions.

After testing, the contractor's quality assurance personnel shall:

A. Ensure proper disposition of articles.

B. Report any additional nonconformances and participate in their dispositions.

C. Ensure that remedial and preventive action has been accomplished relative to nonconformances.

D. Verify that test results and reports are accurate, complete, and traceable to the tested articles.

Contractor quality assurance actions in support of testing, as outlined above, shall not be mandatory for research and development type testing. Some actions may be performed on a selective or surveillance basis. The Quality Plan shall define the extent of the contractor's implementation of this requirement.

Section 8

NONCONFORMING ARTICLE AND MATERIAL CONTROL

8. 1 NONCONFORMING ARTICLE AND MATERIAL CONTROL

When an article or material does not conform to applicable drawings, specifications or other requirements, it shall be identified as nonconforming, segregated to the extend practicable and held for review action.

8. 2 NONCONFORMANCE DOCUMENTATION

The contractor shall:

A. Ensure documentation of nonconformance discovered by contractor, subcontractor, and supplier personnel and the designated Government quality representative, and maintain a control file giving a disposition históry.

B. Prepare and issue documents for each nonconformance comprising as a minimum:

1. A unique and traceable number.
2. The nomenclature and identification of the nonconforming article or material.
3. A description of the nonconformance and the required characteristic or design criteria.
4. Cause or reason for the nonconformance.
5. Remedial actions taken or recommended.
6. Disposition of the nonconforming article or material.
7. Initiator of the document.
8. Signatures of authorized personnel.

8. 3 REMEDIAL AND PREVENTIVE ACTION

The contractor shall:

A. Conduct appropriate analysis and examination of nonconforming articles, materials, or conditions to determine the cause or reason for the nonconformance. Nonconforming articles or materials shall be forwarded to the procuring NASA Installation as requested by the NASA Contracting Officer.

B. Conduct timely and effective remedial action to ensure the correction of the article or material.

C. Conduct timely and effective preventive action to prevent recurrence of the nonconformance including correction of technical documents, correction of other identical articles or materials at all locations, and the prevention of detrimental side effects.

D. Assign responsibility for follow-up of remedial and preventive actions to ensure accomplishment.

E. Notify responsible contractor or supplier organizational elements of nonconformances and the need for remedial and preventive actions.

F. Classify nonconformances as to criticality and process on a priority basis.

G. Closeout nonconformance documentation after verifying that effective remedial and preventive actions have been taken.

H. Appropriately document analyses, and remedial and preventive actions.

I. Notify the procuring NASA Installation of nonconformances, and their related remedial and preventive actions as established by contract.

8.4 INITIAL REVIEW DISPOSITIONS

Nonconforming articles or materials shall be reviewed initially by contractor quality assurance personnel and shall be subjected to one of the following dispositions:

A. Return for Rework or Completion of Operations. If the nonconformance is in the category of "return for completion of operations" or "return for rework to drawings, specifications or procedures," the article or material shall be returned for rework or completion using established technical documents and operations. During such rework, the article or material shall be resubmitted to normal inspection and/or test operations.

B. Scrap. If the article or material is obviously unfit for use, it shall be dispositioned in accordance with Government-approved contractor procedures for identifying, controlling, and disposing of scrap.

C. Return to supplier. When an article or material is found to be nonconforming on receipt, it may be returned to the supplier. The contractor shall provide the supplier with nonconformance information, and assistance as necessary, to permit remedial and preventive action.

D. Submit to Material Review Board. When the dispositions as described above are not appropriate, the article or material shall be submitted to the MRB for final disposition.

Articles and materials disposed of without referral to MRB may be subject to a review of each case by the designated Government quality representative to verify contractor decisions.

Initial review dispositions shall be recorded on nonconformance documentation.

8. 5 MATERIAL REVIEW BOARD

8. 5. 1 Membership

The MRB shall be comprised of one contractor representative whose primary responsibility is engineering, one contractor representative whose primary responsibility is quality, and the designated Government quality representative. Contractor members for the MRB shall be selected by the contractor on the basis of technical competence and shall have sufficient authority to make appropriate dispositions of the article or material involved. Contractor personnel designated for membership shall be approved by the Government representative.

8. 5. 2 Responsibility

The MRB shall:

A. Determine disposition of submitted articles of materials designated as nonconforming.

B. Ensure that effective remedial and preventive actions are documented on the nonconformance document prior to disposition.

C. Provide contractor recommendations to the Contracting Officer concerning nonconformance dispositions requiring his approval and verify implementation after approval is obtained.

D. Ensure that accurate records of MRB action are maintained.

8.5.3 MRB Disposition

Dispositions, other than scrap, require the unanimous agreement of the board members. In determining dispositions, the board shall: consider the effect of the nonconformance upon the intended use, review records of earlier review actions affecting the same article or material, and consider the recommendations of personnel acting in an advisory capacity. After the MRB has determined that an initial review disposition to submit a nonconforming article or material to the MRB is appropriate, the board shall specify on the nonconformance document one of the following dispositions:

A. Repair. When, in the opinion of the board, an acceptable repair is possible, repair action may be authorized. Procedures shall be established or approved by the MRB to perform this repair. Procedures shall include appropriate inspections and tests to verify the acceptability of the repair.

B. Scrap. If the article or material is unfit for use, it shall be dispositioned in accordance with Government approved contractor procedures for identifying, controlling, and disposing of scrap.

C. Use As Is. Nonconformances which do not adversely affect safety, reliability, durability, performance, interchangeability, weight, or the basic objectives of the contract may be accepted for use as is. The rationale for making a use as is disposition shall be documented on the nonconformance report.

D. Request NASA Contracting Officer Approval. Nonconformances which do adversely affect safety, reliability, durability, performance, interchangeability, weight, or the basic objectives of the contract shall be referred to the NASA Contracting Officer. (See subsection 8.6.)

8.6 WRITTEN REQUESTS FOR NASA CONTRACTING OFFICER APPROVAL

Contractor written requests for nonconformances for which the contractor recommends a disposition to repair or use as is must be submitted to the

NASA Contracting Officer when the nonconformance adversely affects safety, reliability, durability, performance, interchangeability, weight, or the basic objectives of the contract. Such requests require NASA Contracting Officer approval. Each nonconformance request shall be submitted through the MRB with written recommendations and proposed remedial and preventive action. Articles and materials shall be withheld from further processing until Contracting Officer approval is obtained.

8.7 SUPPLIER MATERIAL REVIEW BOARD

The contractor may, with approval of the procuring NASA Installation or its designated Government quality representative, delegate MRB responsibility to suppliers.

Section 9
METROLOGY CONTROLS

9.1 GENERAL

The contractor shall establish and use a documented metrology system to control measurement processes to provide objective evidence of quality conformance. Measurement standards and equipment shall be selected and controlled to the degree necessary to meet the requirements of this Section. Measurement processes shall be performed in accordance with established written procedures.

9.2 ACCEPTANCE

Before acceptance, the contractor shall ensure that all measurement standards and equipment are inspected and/or tested to ensure conformance with requirements. Documented results of the inspection and/or tests shall be maintained by the contractor.

9.3 EVALUATION

All special measurement standards and equipment (e.g., automatic test and checkout equipment) shall be evaluated under intended operating conditions to verify that:

A. When used in the intended measurement process, the standards and equipment measure the desired characteristics to the required accuracy and provide the desired indications or records.

B. Standards and equipment are compatible with the configuration of related hardware and environmental conditions.

C. Operating instructions are correct and complete. Documented results of the evaluations shall be maintained by the contractor.

9.4 ARTICLE OR MATERIAL MEASUREMENT PROCESSES

Random and systematic errors in any article or material measurement process shall not exceed 10 percent of the tolerance of the article or material characteristic being measured. Authorization for exception shall be requested from the procuring NASA Installation.

9.5 CALIBRATION MEASUREMENT PROCESSES

Random and systematic errors in any calibration measurement process shall not exceed 25 percent of the tolerance of the parameter being measured. Authorization for exception shall be requested from the procuring NASA installation.

9.6 CALIBRATION CONTROLS

A. Calibration. The contractor shall have his own or use the services of an outside facility for the calibration of measurement standards and equipment.

B. Traceability. All measurement standards shall be traceable to standards maintained by the National Bureau of Standards or their value(s) shall be derived from a controlled measurement process utilizing a fundamental constant of nature.

C. Handling, Storage, and Transportation. All measurement standards and equipment shall be handled, stored, and transported in a manner which shall not adversely affect quality nor result in hazardous conditions.

D. Identification and Labelling. All measurement standards and equipment shall be uniquely identified and labelled, tagged, or coded to indicate calibration status and due date of next calibration.

E. Calibration Intervals. Calibration intervals shall be established and periodically reviewed to maximize the availability of measurement standards and equipment without adversely affecting quality. Intervals shall depend upon the use, accuracy, type of standard or equipment, required precision, and other conditions adversely affecting the measurement process.

F. Recall System. All standards and equipment used in measurement processes shall be recalled and recalibrated at established intervals. Standards and equipment not recalibrated before the recall due date shall be removed from service or otherwise restricted from use. Authorization for exception shall be obtained from the procuring NASA Installation. Controls shall be established to ensure the immediate recalibration or removal from service of those found to exceed the established interval or which for any reason might have an adverse affect on quality.

The recall system shall, where practical, include centralized records and advance notification to using agencies, informing them when equipment is to be removed from service for recalibration. Where this is not practical, batch methods of recall or other suitable methods shall be used to assure that the equipment is recalibrated in accordance with established schedules.

G. Calibration Records. The contractor shall maintain individual records of measurement standards and equipment. These records shall include but not be limited to the following:

1. Identification of standard or equipment to be calibrated.
2. Identification of standard, equipment, and calibration procedure used in the calibration process.
3. Calibration intervals.
4. Dates and results of each calibration.
5. Due date of next calibration.
6. Individual(s) performing calibration.
7. Calibration facility.
8. Degree of nonconformance of standards or equipment received for calibration.

9.7 ENVIRONMENTAL REQUIREMENTS

Environmental characteristics (e.g., temperature, humidity, vibration, cleanliness) shall be compatible with the accuracy requirements of the article and material and calibration measurement processes.

9.8 REMEDIAL AND PREVENTIVE ACTION

Remedial and preventive action shall be taken relative to nonconforming measurement standards or equipment and to the article and material measured by the nonconforming standard or equipment.

Section 10
STAMP CONTROLS

10.1 STAMP CONTROL SYSTEM

The contractor shall establish and maintain a documented stamp control system, including written procedures, which provide for the following:

A. Stamps, decals, seals, torque wax, paints, signatures, etc., shall identify that articles and materials have undergone source and receiving inspection, in-process fabrication and inspection, end-item fabrication and inspection, end-item testing, storage, and shipment.

B. Stamps shall be traceable to each individual responsible for their use and records shall be maintained to identify individuals with specific stamps. Fabrication and inspection stamps shall be of different design.

C. Stamps shall be applied to records to indicate the fabrication or inspection status of associated articles and materials.

D. Stamps shall be applied to tags, cards, or labels attached to individual articles and materials or their containers, as appropriate.

E. Stamps indicating that fabrication, inspection, or test operations have been performed and may be applied directly to articles and materials except when this is impractical due to physical limitations of the article or such applications will compromise their quality.

F. Stamping methods and marking materials must be compatible with the articles and their use.

10.2 STAMP RESTRICTION

Contractor's stamps shall not contain the designation "NASA."

Section 11

HANDLING, STORAGE, PRESERVATION, MARKING, LABELING, PACKAGING, PACKING, AND SHIPPING

11.1 HANDLING AND STORAGE

11.1.1 Handling

The contractor shall protect articles and materials during all phases of fabrication, processing, and storage to prevent handling damage. Special handling instructions shall be forwarded to the receiving activities whenever the contractor's analysis has indicated that these instructions are necessary. Evidence of initial and periodic proof testing of handling equipment shall be maintained.

11.1.2 Storage

Articles and materials to be stored shall be protected against deterioration and damage. Articles and materials subject to age deterioration shall include on the container an indication of the date that the critical life of the article or material was initiated and the date at which the useful life will be expended. Procedures shall be generated and used to ensure the safety of personnel and the maintenance, positive identification, periodic inspection, and periodic test of articles.

11.2 PRESERVATION, MARKING AND LABELING, PACKAGING AND PACKING

11.2.1 Preservation

Articles and materials subject to deterioration, contamination or corrosion through exposure to air, moisture, or other elements during fabrication and storage shall be cleaned and preserved by methods which ensure maximum life and utility.

11.2.2 Marking and Labeling

The contractor shall ensure that appropriate marking and labelling for packaging, shipment, and storage of articles and materials are performed in accordance with applicable specification and/or contractual requirements. Critical, sensitive, dangerous and high-value articles shall be given special attention.

11.2.3 Packaging

Articles and materials shall be packaged to prevent deterioration, corrosion, damage, and contamination. Packaging procedures and instructions shall be used and provide for protection to articles and materials while at the contractor's plant, during transportation to destination, and upon arrival at destination. When maintenance of specific internal or external environments are necessary, these shall be included in the packaging and necessary environmental requirements shall be detailed on the exterior of the package or reference environmental procedures. When existing packaging specifications are not adequate to fully protect critical, sensitive, dangerous, or high-value articles, special packaging shall be designed, documented, and used.

11.2.4 Packing

The contractor shall provide for cushioning, blocking, bracing, or bolting, as applicable, to prevent rupture of flexible barriers, undesired free movement within containers, and physical damage due to transmission of shock and vibration. Tests shall be performed when necessary to ensure proper packing protection.

11.3 SHIPPING

11.3.1 Control

The contractor shall control all articles and materials shipped from his plant to ensure that:

A. All fabrication, assembly, inspection, and testing operations authorized and required to be performed at the plant or test site have been satisfactorily completed. This requirement may be waived depending on the nature of the end-item to allow out-of-position work at downstream locations, provided the omitted operations are clearly identified in the Government bill of lading (or DD-250) and properly scheduled in appropriate work orders for application at a later position, and if the omission is approved by the designated Government quality representative.

B. Accompanying documents have been properly identified as to inspection status by appropriate contractor's stamps.

C. They have been preserved and packaged in accordance with applicable procedures and requirements.

D. All articles and materials have been identified and marked in accordance with applicable procedures and specifications.

E. In the absence of packing and marking requirements in the contract or subcontract, packing and marking of articles and materials shall comply with Interstate Commerce Commission rules and regulations and shall ensure safe arrival and ready identification at destination.

F. Handling devices and transportation vehicles are suitable for the articles and materials involved so as to prevent damage.

G. The loading and transportation methods conform to applicable specifications and requirements.

In the event of any unscheduled removal of an article or material from its container, the extent of reinspection and retest shall be as authorized by the procuring NASA Installation or its designated Government quality representative. This shall apply only to deliverable items that have been previously inspected and approved by the Government and to Government-furnished equipment.

11.3.2 Documentation Package

The contractor shall include a complete documentation package with his shipment. This package shall contain documentation required to identify, maintain, preserve, and use the shipment and shall consist of those documents specified by the contract to be submitted with the shipment. Each shipping container shall identify the location of the documentation package.

Section 12
SAMPLING PLANS, STATISTICAL PLANNING AND ANALYSIS

12.1 SAMPLING PLANS

Sampling plans may be used when inspection or tests are destructive, or data, inherent characteristics, or the noncritical application of an article or material indicate that a reduction in inspection or testing can be achieved without jeopardizing achievement of quality, reliability, or design intent. When sampling techniques are to be employed, existing military sampling inspection documents will be used to the degree practicable. Sampling plans other than those contained in existing military documents may be used by the contractor. All sampling plans require the approval of the procuring NASA Installation or its designated Government quality representative.

12.2 STATISTICAL PLANNING AND ANALYSIS

Statistical planning and analysis may be used where such use will provide effective control over fabrication and inspection operations, especially in those areas where special processes and equipment are difficult to control. Charts shall be maintained at a location which will provide maximum use as a preventive action tool.

Section 13
GOVERNMENT PROPERTY CONTROL

13.1 CONTRACTOR'S RESPONSIBILITY

The contractor shall be responsible and account for all Government property supplied by the Government in accordance with the provisions of the contract, including property provided under such contract which may be in the possession or control of a supplier. The contractor's responsibility shall include, but not be limited to, the following:

A. *Upon receipt, examine to detect damage in transit.*

B. Inspect for quantity, completeness, proper type, size and grade as specified in the shipping documents.

C. Provide for the protection, maintenance, calibration, periodic inspection, segregation, and controls necessary to preclude damage or deterioration during handling, storage, installation, or shipment.

D. Maintain records which include:

1. Identification of the property
2. Dates, types, and results of contractor inspections, tests, and other significant events.

E. Functional test to determine satisfactory operation before processing or installation.

13.2 UNSUITABLE GOVERNMENT PROPERTY

The contractor shall identify, segregate, and report in accordance with Government procedures, any Government property found damaged, malfunctioning, or otherwise unsuitable for use as soon as the fact is known. Government property shall not be dispositioned, repaired, reworked, replaced, or in any way modified unless authorized by the contract.

Section 14

SOFTWARE QUALITY ASSURANCE

14.1 DEFINITION AND PLANNING

The contractor shall define and identify for NASA approval software end items of the Modular Space Station Project that (through their direct interface with Space Station Module hardware and immediate support of launch or mission operations) are sufficiently critical with respect to reliability or crew safety to warrant the providing of special assurances that they meet all specified requirements and are error free. These items may include ground and onboard computer tapes, checklists, or instructions that provide information to or which directly control, launch, or orbital operations, including onboard maintenance and checkout.

The Quality Program Plan shall include a separate section describing software quality assurance provisions. This section may summarize such provisions and reference other plans where further detail is provided, such as the Verification Plan, Software Integration Plan, Prelaunch and Launch

Operations Plan, Mission Operations Plan, Experiment Integration Plan, and Logistics Support Plan. Initial software quality assurance planning, while preliminary in depth, shall define the scope and applicability of such provisions. Method of implementation shall be defined in depth in the affected plan before scheduled need.

14.2 SOFTWARE CONTROLS

Control for selected Space Station Module software end items shall be equivalent to the controls imposed on Space Station hardware and services. Procured, as well as contractor-produced, software shall be covered. Methods shall include appropriate inspections and tests to verify software conformance to specified requirements and absence of erros. In addition, methods and procedures shall be established for control of software changes. Use of reference data, sample problems, error-detection programs, and operational and maintenance simulations using the Modular Space Station Flight Integration Tool (FIT) or mission simulator shall be considered as possible verification methods.

14.3 FINAL ACCEPTANCE

Provisions for documenting the results of acceptance inspections, tests, or operational simulations; turnover requirements; and procedures for continuing control of delivered software by NASA or the contractor shall be described in the contractor's plan.

Section 15
OPERATIONAL QUALITY ASSURANCE

15.1 DEFINITION AND PLANNING

The contractor shall define and identify module onboard orbital operations hardware installation, modification, repair, maintenance, and software operations where reliability or crew safety are sufficiently critical to warrant special onboard quality assurance provisions. Such operations may include the installation of carry-on experiment hardware, modification kits, and spares.

Operational quality assurance provisions shall be described in a separate section of the Quality Program Plan. This section may summarize such provisions and reference other plans where further detail is provided; for example, the Mission Operations Plan, Experiment Integration Plan, Logistics Support Plan, and the Reliability Plan. Initial operational quality assurance planning shall define the scope and application of such provisions while remaining preliminary in depth. Methods of implementation shall be defined in depth in the affected plan prior to scheduled need.

15.2 OPERATIONAL CONTROLS

Controls for selected onboard installation and maintenance operations shall provide assurance that equipment will not be damaged and that crew safety will not be jeopardized as a result of the work performed. The contractor shall review the controls imposed on similar work performed on the ground, and extrapolate the minimum controls to the module's operational environment. Constraints on personnel capability and available onboard inspection and test equipment shall be considered. Reliability degradation or safety hazards resulting from contamination or from the equipment being installed, repaired, or serviced shall be considered in establishing contamination detection and control provisions. Safe shutdown procedures for probable failures shall be established. Ground failures during testing and development will be used in the review process to assure that such procedures are available when the modules are manned in orbit.

15.3 PREOPERATION ACCEPTANCE

Final inspections, tests, and checkouts shall ensure that acceptance of the equipment for full operation will meet specified requirements. Crew organization and responsibilities for performing onboard quality assurance functions and preoperational acceptance shall be defined in the contractor's plan. Participation of ground crews in orbital quality assurance operations shall be considered, e.g., they will relay checkpoints, instructions, data points, telemetry readouts, ground simulation of problems and conditions, and will determine onboard corrective actions to the modules.

15.4 FIT AND FUNCTION TESTS

A fit and function test shall be performed on all Space Station Module equipment before use in orbit.

15.5 COMMONALITY

Quality assurance shall actively pursue commonality of hardware and software from system to part level. This effort shall be initiated during the design definition phase and continue through mission operation.

Section 16
DOCUMENTATION AND REPORTING

16.1 QUALITY DATA SYSTEM

The Quality Program Plan shall describe the contractor's system for recording the results of inspections and tests, for identifying areas needing improvement, and for evaluating corrective efforts. The product-related quality data requirements of subsections 2.4 and 7.7 shall apply except as modified herein.

Floor disposition of workmanship and damage problems involving one-of-a-kind Space Station Module hardware shall be handled by the most expedient means. Quality information relating to mission-critical items and critical spares shall meet all of the requirements of subsections 2.4 and 7.7 and provide for special identification and retrieval, if required, in accordance with Section 4. The possible use of production test data for reliability and maintainability purposes shall be considered and coordinated with the Reliability Program Plan.

A launch and mission support data-control system, with the continuing ability to research past data to solve current (e.g., in-orbit) problems, shall be described in the Quality Program Plan. The system shall provide for documentation of such problems and their solutions to help deal with possible recurrence. Reliability and maintainability data requirements shall be coordinated with the Reliability Program Plan.

16.2 QUALITY PROGRAM DOCUMENTATION

Quality program documentation to be generated by the contractor for use by NASA, associated contractors, and subcontractors, and for the contractor's internal use during Phase C/D, shall be described. Specific documentation provisions shall be incorporated throughout the plan.

The plan shall include a complete listing of documentation provisions, including for each provision a cross-reference to applicable plan subsections, status (submittal, review, information), schedule (with respect to pacing events), identification of primary originator and primary users and uses, limitations on scope or depth (categories of hardware, tests, etc.), a definition of each data item (to avoid redundancy and ambiguity), and a sample of each, illustrating proposed format with typical content.

In keeping with Modular Space Station cost-effectiveness objectives, quality program documentation shall be minimized. Emphasis shall be placed on direct communications of requirements and instructions. Formal documentation shall be prepared only where justified by planned subsequent functional use.

16.3 REPORTING AND INFORMATION EXCHANGE

The contractor's procedures for reporting passing information to NASA and other contractors as a function of time (progress reports) or as a function of particular events (test reports, failure reports) shall be summarized in this section of the plan. Reporting shall be limited to that required for necessary decision making or subsequent action by the recipient. Effective use shall be made of on-the-spot random audits and appropriate reviews at scheduled milestones to assure that quality assurance requirements of the project are being met. Submittal of costly formal documentation for program purposes shall be minimized.

The contractor shall use an innovative approach to minimize management and technical documentation and reporting provisions. Direct communication (telephone, teletype, fascimile) shall be employed wherever it can be more timely and cost effective. Quality progress, problems, and status reporting shall be integrated with overall project reporting provisions, and limited to problems or events with significant impact on project cost, schedules, or specified performance, but shall be a separate section clearly recognizable as a quality assurance output. Requirements for program management data reporting shall be coordinated with the Program Management Plan. Requirements for technical data reporting should be coordinated with other affected plans.

Provisions shall be described for affected agencies to interchange quality information resulting from Space Station Module(s) development, launch, and mission operations. This shall include the interchange of quality-related working data with associate contractors, shuttle and experiment module contractors (e.g., check-fixture dimensions to control hardware interfaces, and calibration data for multiple-use instrumentation).

Participation in cooperative programs concerned with interchange of data relating to reliability and qualification tests, failure rates, preferred parts, and failure occurrences (e.g., the Interagency Data Exchange Program and the NASA Alert Program) shall be described in the Reliability Program Plan. The Quality Program Plan shall reference applicable subsections of the Reliability Program Plan, identify interfaces, and describe related quality assurance provisions.

Section 17
SITE QUALITY ASSURANCE

17.1 GENERAL

This section of the contractor's plan shall encompass quality assurance activities at the launch site in support of Space Station Module launches and mission operations. Activities at other remote assembly, integration, test, and operational sites involved in the Modular Space Station Project shall be included. The provisions of this section shall be coordinated with the Prelaunch and Launch Operations Plan, the Mission Operations Plan, and the Logistics Support Plan.

17.2 SITE QUALITY PLAN

The intent of subsection 2.7, which requires that a separate site plan or a separate section of the plan be devoted to site activities, shall be met in the following manner. Where quality assurance functions performed at the site are similar to functions performed at the contractor's plant location and if they are adequately described elsewhere in the contractor's quality program plan, the applicable plan subsection shall be referenced. Where the method of implementation necessarily differs, these differences shall be identified as modifications, deletions, or additions to the referenced subsection. Additional plan subsections shall be provided to describe quality assurance functions peculiar to site operations.

Quality assurance functions that are a part of missions support tasks performed at the contractor's plant (such as sustaining engineering, manufacture of carry-on experiment hardware or modification kits, and manufacture or overhaul of spares) shall be described in other appropriate sections of the plan and/or implementation procedures. As the program progresses into the mission operations phase, sections of the plan devoted to plant operations shall be revised to reflect the new role of mission support.

17.3 AVAILABILITY OF QUALIFIED PERSONNEL

Because of the one-time-only nature of main-line Modular Space Station development and manufacturing activities, experienced trained personnel will be available from plant operations. Continuity of the quality assurance efforts shall be maintained, and experienced personnel will be effectively used during the transition from Space Station Module development to mission operations. The contractor shall plan for the transfer or temporary-duty assignment of key quality assurance personnal to the launch site for support of module launch and mission operations.

17.4 SERVICES

Quality-assurance-related launch site service contracts, such as metrology and cleanliness control, shall be described in appropriate subsections of the contractor's Quality Plan, with reference to the service contractor and his plan for providing the service.

Appendix A
GLOSSARY OF TERMS

Acceptance. The act of an authorized representative of the Government by which the Government assents to ownership of existing and identified contract items, or approves specific services rendered as partial or complete performance of the contract.

Analysis (Nonconformance). The study of a specific nonconformance, such as a failure, to determine the causes and to arrive at a course of remedial and preventive action.

Article. A unit of hardware or any portion thereof required by the contract.

Certification (Personnel). The act of verifying and documenting that personnel have completed required training and have demonstrated specified proficiency.

Certification (Process). A written statement based on objective quality evidence that a process conforms to specified requirements.

Characteristic. Any dimensional, visual, functional, mechanical, electrical, chemical, physical, or material feature or property; and any control element which describes and establishes the design, fabrication, and operating requirements of an article or material.

Configuration. The complete technical description required to fabricate, test, accept, operate, maintain, and logistically support an article.

Conforming. An article, material, or service which complies with specified requirements.

Contract. The prime contract executed by the Government and the prime contractor which, in addition to the terms and conditions thereof, includes by reference or otherwise, specifications, drawings, exhibits, and other data necessary to its proper performance.

Contract Schedule. That portion of a Government prime contract which describes the articles or services desired for that particular contract. Not to be confused with contract time-schedule or delivery schedule.

Contracting Officer. Any Government employee who is currently designated a Contracting Officer with the authority to enter into and administer contracts and make determinations and findings with respect thereto, or with any part of such authority. The term also includes the authorized representative of the Contracting Officer acting within the limits of his authority.

Contractor. The individual(s) or concern(s) who enter into a prime contract with the Government.

Contractor-Acquired Property. Property procured or otherwise provided by the contractor for the performance of a contract, title to which is vested in the Government.

Date Code. A symbol which indicates a specific date in code. A date code may consist of a series of numbers or letters that indicate day, week, month, or year.

Degradation. The deterioration of quality or ability to perform within established limits.

Delivery. The physical transfer of possession. The contract specifies the point and/time at which delivery takes place.

Designated Government Quality Representative. An individual designated by the procuring NASA installation to perform a specific function(s) relative to the contractor's quality assurance effort.

Effectivity. The point at which an action occurs to produce a desired result.

End Item. An aeronautical or space system or any of its principal system or subsystem elements, e. g. , launch vehicle, spacecraft, ground support system, propulsion engine, or guidance system. Also, articles covered by major subcontracts where this publication is invoked. Also, articles which will be delivered direct to a Government Installation or provided as GFP to a contractor.

Fabrication. The act of manufacturing or making; also, the building, assembly, or construction of articles and materials.

Functional Test. A test performed to demonstrate that the article operates as required.

Government Property. All property owned by or leased to the Government or acquired by the Government under the terms of a contract. Government property includes both Government-furnished property and contractor-acquired property.

Government-Furnished Property. Property in the possession of, or acquired directly by the Government and subsequently delivered or otherwise made available to the Contractor.

In-Process Inspection. Inspection which is performed during the fabrication cycle.

Inspection. The process of measuring, examining, gaging, or otherwise comparing an article or service with specified requirements.

Limited-Life Articles. Articles whose usefulness is limited to a specified time or cycle.

Material. The substrances of which an article is composed.

Measuring Equipment. Gages, inspection, measuring and test equipment, automated equipment, tools, jigs, fixtures, etc. which measure characteristics and parameters. Includes production tools incorporating an inspection, measuring or test function used for acceptance.

Measurement Processes. The application of standards, equipment, methods, environment and personnel to determine the magnitude of characteristics and parameters of articles, equipment, and standards.

Nonconformance. A condition of any article, material, or service in which one or more characteristics do not conform to requirements. Includes failures, discrepancies, deficiencies, defects, and malfunctions.

Preventive Action. Action to preclude or minimize the occurrence or recurrence of a nonconformance.

Qualification. Determination that an article or material is capable of meeting all prescribed design requirements.

Quality Assurance. A planned and systematic pattern of all actions necessary to provide adequate confidence that the end-item will meet all specified requirements.

Remedial Action. Action to correct a nonconforming article or material.

Repair. Operations performed on a nonconforming article to place it in usable and acceptable condition.

Rework. The continuation of processing of articles and materials that will make then conform to drawings, specifications, procedures, or contract.

Source Inspection (Government or Contractor). Inspection at the plant of the actual supplier of articles, materials, or services.

Subcontract. A contract or purchase order entered into under a Government prime contract by a supplier. May include orders to activities or subdivisions of the contractor.

Subcontractor. The individual(s) or concern(s) who enter into a purchase agreement under a Government prime contract.

Supplier. A subcontractor, at any tier, performing the services or producing the contract articles for the contractor.

MODULAR SPACE STATION
RELIABILITY PLAN REQUIREMENTS

RELIABILITY PLAN REQUIREMENTS

Outline

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RELIABILITY PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 SCOPE

This document has been prepared to guide contractor planning and bidding for phase C/D. It defines the requirements and their application to the Modular Space Station Project Reliability/Maintainability Program; and the organization and general operating controls/procedures, policies and objectives to be applied in preparing the Phase C/D Implementation Plan(s).

1.2 APPROACH

The reliability/maintainability program requirements herein require:

A. Definition of the major reliability tasks and their integration into the design.

B. Planning and evaluation of maintainability and hardware reliability (including effects of hardware/software interfaces) through a program of analysis, assessment, test, and review.

C. Timely status indication by formal documentation and other reporting, to facilitate control of the reliability and maintainability program.

1.3 RELATION TO OTHER CONTRACT REQUIREMENTS

Nothing in this publication shall be construed as a requirement for duplication of effort. Organizational responsibility for overlapping and interfacing functions such as quality assurance, safety, and test shall be clearly delineated in the Reliability/Maintainability Program Plan and cross-referenced in other pertinent technical program documents. Provisions stated herein should not be interpreted to preclude compliance with those which are invoked elsewhere in the contract. If conflict exists between the provisions of this document and those stated in the contract, the requirements set forth in the specifications and this document shall govern.

1.4 ACTIONS AND PREROGATIVES OF THE GOVERNMENT

1.4.1 General

Reliability/Maintainability work, data, and documentation generated during the contract effort by the contractor and major suppliers, are subject to examination, evaluation, and inspection at any time by the procuring NASA installation or its designated representatives. The contractor shall cooperate fully with such representatives, providing to them access to the contractor's and major supplier's facilities to permit performance of their designated function.

1.4.2 Separate Reliability Evaluations for NASA

NASA reserves the right to contract separately with contractors to function in the capacity of designated NASA representatives. Evaluation contractors usually will:

A. Provide technical advice to the procuring NASA installation.

B. Determine effectiveness of system and subsystem contractors' and suppliers' reliability programs, particularly with regard to potential sources of unreliability; and

C. Assess, evaluate, and recommend improvements in the reliability of the system hardware and software.

1.4.3 Inputs to Data Exchange Programs

NASA reserves the right to use portions of the reliability program data generated under the contract (particularly data on parts, devices, and materials), as inputs to various Government data exchange programs. Requirements for specific contractor effort will be specified in the contract.

1.5 RELIABILITY PROGRAM DOCUMENTS

Reliability documents called for in this requirements plan are required to be generated and available to the procuring NASA installation and its designated representatives unless expressly waived by the contract.

In addition, the contract will specify that certain of these documents be submitted to NASA for approval, review or information as follows:

1.5.1 Approval

Documents in this category require written NASA approval before use. Receipt by NASA shall occur within the time specified in the contract. Requirements for resubmission shall be as specified in letter(s) of disapproval.

1.5.2 Review

Documents in this category require receipt by NASA before use and within the time period specified in the contract. They are subject to evaluation by NASA or its designated Government representatives to determine effectiveness in meeting contract objectives. When Government evaluation reveals inadequacies, the contractor will be requested to correct the documents.

1.5.3 Information

Documents in this category require receipt by NASA within the time specified in the contract for the purpose of determining current program status, progress, and future planning requirements.

All contractor and supplier generated documents used to meet requirements of the contract, whether they are specifically cited for submittal or not, shall be readily available and shall be submitted to the procuring NASA installation and its designated representatives upon request (see also subsection 3.5). To facilitate Government and contractor evaluation of the reliability program, the contractor's filing system should be maintained in a manner to permit rapid identification, location, and retrieval of documentation pertinent to the reliability program.

1.6 GLOSSARY OF TERMS

For definitions of selected terms used in this publication, see Appendix A.

Section 2

RELIABILITY PROGRAM MANAGEMENT

2.1 ORGANIZATION

The contractor shall have one clearly identified organizational element which will be responsible for the planning and management of the contract reliability/maintainability program and for ensuring its effective execution. The individual designated as the head of this management organization shall have the necessary authority and resources to discharge this responsibility, shall devote full-time to the program, and shall report at a level having full responsibility for the contract effort. Although the accomplishment of many of the program tasks may not be the line function of the reliability management organization, that organizations shall have responsibility and authority to ensure that all reliability program tasks are accomplished effectively.

2.2 RELIABILITY PROGRAM PLAN

2.2.1 General

The contractor shall provide, maintain, and implement a Reliability Program Plan which describes how he will ensure compliance with specified reliability program requirements. The Plan shall be submitted as required by the RFP or contract. The plan shall cover all reliability program activities for the time period or phase authorized, and shall be updated periodically as provided for in the contract. This plan, together with the reliability program control reporting system (see subsections 2.3 and 2.4), shall serve as the master planning and control document for the reliability program.

2.2.2 Contents

The Plan shall include:

A. Charts and narrative statements which describe the organizational responsibilities and functions associated with the conduct of the reliability program and each task therein. This shall include for each task in the reliability program detailed statements of:

1. Duties of each organizational element (e.g., engineering, reliability, safety, fabrication, test, quality assurance) involved in its accomplishment or use of its outputs.
2. Delineation of interfaces in responsibilities and functions where more than one organizational element is involved.
3. The relationship of the reliability management organization to each of the other organizational elements performing reliability program tasks and reliability management's authority to control and monitor these tasks.

A summary (matrix or other brief form) shall be included which indicates for each reliability program requirement, the principal organization responsible for implementation and the specific organization responsible for generating necessary documents. In addition, the summary shall indicate each contractor organization which has approval or review authority relative to documents generated.

B. Narrative descriptions, time or milestone schedules, and supporting documents which describe in detail the contractor's plan for execution and management of each task in the reliability program. Directives, methods, and procedures shall be documented by the contractor to govern each task, and these documents shall be referenced in the Reliability Program Plan, be available, and be submitted on request.

C. Identification of these elements of the planned program which will use the contractor's existing reliability practices and documents and identification of these requiring changes. This shall include a description of the proposed changes needed to meet cited requirements and the time schedule for implementing such changes.

D. Identification of hardware or software items to be obtained by subcontract where the criticality and nature of the item is considered to warrant application of a formal reliability program. The plan shall contain or reference a detailed description of the reliability program requirements to be included in the subcontract for each such item. The degree of detail in these descriptions shall be in accordance with the phase of system development at which the reliability program plan is written. However, for each subcontract this description shall be updated in full detail before execution of the subcontract in question.

E. Reliability program effort at each remote test and launch site shall be addressed.

2.3 RELIABILITY PROGRAM CONTROL

2.3.1 General

The contractor shall devise a system for effective management control and audit of the reliability program. Insofar as practical, this system will use the reporting system prescribed for the overall contract effort, with supplemental provisions as agreed on with the procuring NASA installation. This sytem shall accomplish the following:

A. Identify each reliability task specified in the contractor's program plan with the organizational element responsible for its execution and include detailed time-phasing data and complete reliability milestone identifications.

B. For each reliability task, provide and periodically update a time phased listing (or listing by milestone interval) of planned, expended, and projected man-hours.

2.3.2 Reliability Program Reviews

A. The contractor shall conduct periodic reviews of his reliability program. These reviews shall evaluate progress and effectiveness and shall determine the need for adjustments or changes in the reliability programs. The reviews shall use techniques such as surveys, audits, and reviews of technical and management assessment documents from the reliability program and interfacing project areas. Reviews shall be conducted in conjunction with the PDR and CDR activity. Provision shall be made for participation of NASA personnel in selected portions of this contractor review activity at the discretion of the procuring NASA installation.

B. The schedule of reviews shall be included in the Reliability Program Plan, and reports of review results, and reports of verification of corrective action completions shall be documented by the contractor.

2.4 RELIABILITY PROGRESS REPORTING

2.4.1 General

The contractor shall report periodically on the progress of the reliability program. This reporting shall include pertinent information on the reliability programs of the suppliers identified in accordance with subsection 2.2. Reliability progress reporting shall comprise formal, scheduled written reports and/or a schedule of documented joint contractor-NASA reliability program management meetings. Schedules for reliability progress reports and management meetings shall be as specified in the Reliability Program Plan. Formal reliability progress reports may be submitted as a separate part of overall periodic progress reports for the contract.

2.4.2 Written Progress Reports

Periodic written progress reports shall include the following:

A. Technical progress of each reliability program task including significant accomplishments and milestones reached during the reporting period.

B. Reliability problem areas and proposed corrective actions.

C. Decisions and actions during the reporting period having impact on the reliability effort and description of their anticipated effect on hardware reliability.

D. Revised schedules for contract work and significant events in the succeeding reporting period.

E. Anticipated reliability program slippages and their effects.

2.4.3 Reliability Program Control Reports

The Contractor shall submit reliability program control data as a separately identified part of the periodic financial and management reports required by the contract.

2.5 SUPPLIER CONTROL

2.5.1 General

The contractor shall be responsible for ensuring that the reliability of system elements obtained from suppliers will meet the reliability requirements of the overall system. This applies to items obtained from any supplier whether in the first or any subsequent tier, or whether the item is obtained by an intra-company order from any element of the contractor's parent organization. The contractor shall provide guidance and controls to assure the adequacy of reliability programs and controls used by suppliers.

2.5.2 Reliability Program Requirements for Suppliers Required to Utilize Reliability Programs

Appropriate provisions of this publication shall be imposed by the contractor on subcontracts considered to require a reliability program, as prescribed in subsection 2.2. Appropriate provisions for such subcontracts shall at least include all provisions of this publication which:

A. Specifically require the contractor to impose that requirement on these suppliers.

B. Require the contractor to receive or to provide to NASA supplier data or documentation.

All such subcontracts shall also contain provisions for access of the contractor's personnel to the supplier's facilities as necessary to monitor and evaluate the supplier's reliability program and related activities.

2.5.3 Minimum Reliability Controls for Items not Requiring Reliability Programs

The reliability of all items obtained from suppliers who are not required to maintain a formal reliability program shall be controlled by the specifications, all elements within the OCS, as well as OCS self-test software, are then integrated.

Compatibility development testing with the FM will be continued in order to evolve integrated subsystem checkout software and the software required for acceptance testing for prelaunch checkout and for the mission.

As integral experiment computer programs are made available to the FM, these are also interfaced with the OCS and development tests conducted. Once the integrity of Space Station subsystems is established, the OCS experiment interface and checkout software development can occur in parallel with other FM activities.

B. Flight Integration Tool (FIT)—This test article has sometimes been called a "hard hot mockup." It is hard by virtue of strength and dimensional accuracy, since its structures (each module is represented) were built in the flight article tooling and will be initially used to develop tube and wire-tray runs. It will be hot (electrically and mechanically), since it will be modified by installing in it the hardware subsystems and software segments from the subsystem qualification program. Once the modification is complete, this unit represents the qualified flight article; in effect, this is tangible configuration management. The FIT, as shown in Figure 3-4, shall be used for the integration of qualified hardware, computer programs, and available experiments. Subsystem qualification may be completed on the FIT. Verification of the software shall be conducted, followed by the acceptance testing of the OCS and the integration of the General Purpose Laboratory Module experiments (see Figure 3-4).

Following the qualification of each module and of all three modules which have been functionally attached, the flight modules will be operated with the FIT. The reasons for these activities are twofold: (1) to check out each module before system level acceptance; and (2) to verify the FIT for its 10-year operational mission support functions.

The FIT will be used for continuing mission support to ensure that the orbital buildup is conducted satisfactorily and that the ISS cluster performs as specified. Further, it provides the capability of

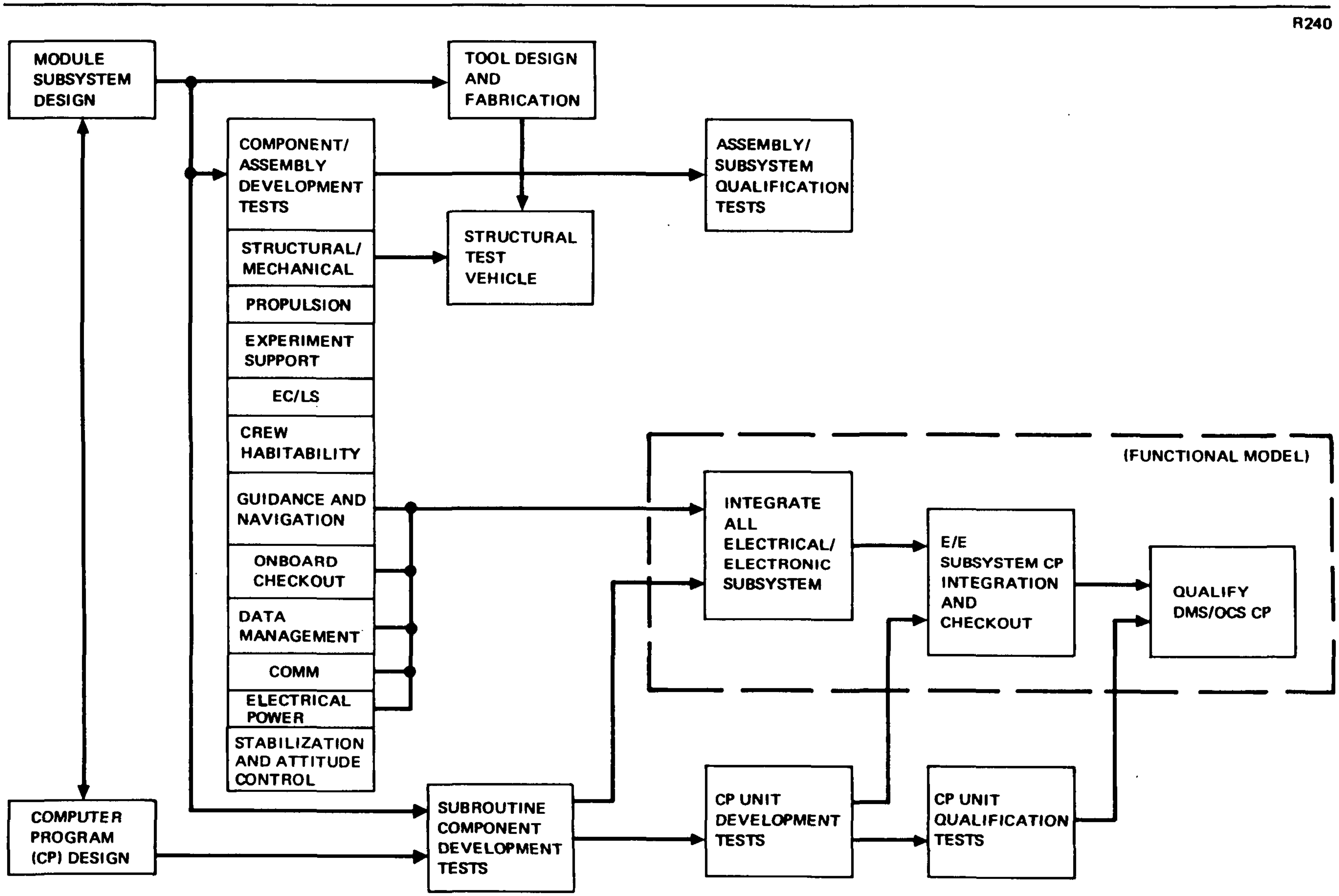

Figure 3-3. Integration Using Functional Model

on maintainability mockups. Data from other tests shall be used for maintainability verification. Thus, verification of maintainability shall primarily be an assessment by demonstration. A more detailed description of maintainability verification may be found in the Reliability/Maintainability Plan Requirements.

F. EMI Testing—EMI testing shall be applied throughout the test program to reduce the probability of obstacles in later checkouts.

The contractor shall identify in the General Verification Plan all anticipated significant subsystem test problems and delineate all tests in the detailed test plans prepared in Phase C/D. The key development items denoted in the Design Plan Requirements shall be addressed with special attention given to those items which may require an early ATP for Phase C/D.

3.3 INTEGRATION

Integration devoted to ensuring a viable 10-year experiment program must begin early in the Space Station development program and is the key to ensuring the integrity of the Initial Space Station (ISS). (Early use of mockups will benefit the experiment development community and aid the Space Station developer.) Engineering development tools will be used as integration devices wherever possible.

The contractor shall define the integration activities and controls to ensure minimum on-orbit buildup problems and maximum compatibility between the Space Station test facility, the experiment hardware, and the operating crew. This should be done using the following:

A. Functional Model—The FM as shown by Figure 3-3 shall be the primary engineering tool used for subsystem-level hardware and computer program development. Testing shall culminate in the establishment of an operational checkout system used to support other FM development testing, integration, and checkout software development activities.

   Following the establishment of the required Data Management System and control/displays capabilities, other elements peculiar to the On-Board Checkout System (OCS) are added. These elements include hardware and software required for checkout data acquisition, stimuli generation, and caution and warning. Interfaces of by testing for those intersects (e.g., development-reliability, qualification-man rating), but that these verification requirements shall be satisfied by use of data from other tests (assessment). System qualification and subsystem/system acceptance tests shall not include induced environment testing unless confirmed by the NASA.

A. Reliability Testing—All test data will be used to provide reliability confidence, and testing specifically designed for reliability data will be minimized. Reliability tests are conducted for the single purpose of increasing or establishing statistical reliability to assess safety and predictability of performance. The "commonality" and "replaceable unit design" concepts necessitate an emphasis on system safety analysis techniques rather than on statistical techniques.

B. Man-Rating Testing—The entire test program shall be designed to consider man's safety; therefore, all tests will supply man-rating confidence and no special testing for this purpose is considered necessary.

C. Component/Assembly/Subsystem Environmental Testing—These tests are performed under environmental stress upon individual hardware at a lower level than the system to ensure that safety and performance criteria are satisfied before testing at the next level. In recognition of the conservative design, this testing should be applied only to those components of a subsystem deemed critical because of operational or environmental stress. Further imposed environments at the system level may be completely avoided if environmental operation is verified at the assembly or subsystem level.

D. System Level Environmental Testing—The internal atmosphere of the Station makes testing of imposed environments (acoustics, vibration, thermal vacuum, etc.) unnecessary at the systems level. In addition, a habitable environment is not provided until the first two ISS modules are united in orbit.

E. Maintainability Testing—Tests which would be conducted solely for the purpose of gathering maintainability data to verify clearance for replacement of parts and use of tools on selected items are not considered necessary. This verification shall be performed primarily

Table 3-2

MINIMUM HARDWARE VERIFICATION

Verification Phases	Test Types								
			Imposed Environments						
	Reliability	Man-Rating	Component	Assembly	Subsystem	System	Flight	Maintainability	EMI
Development	x	x	●	●	●			●	●
Qualification	x	x	o	o	o	o		x	o
Acceptance	x	x	●	●	o	o		x	●
Integrated systems	x	x				o		x	
Prelaunch checkout	x	x						x	o
Mission operations	x	x						x	

● Test design point

x Test data use

o NASA confirmation required

Table 3-1

MINIMUM SOFTWARE VERIFICATION

Verification Phases \ Test Types	Software Levels					Integration	Adaptability	
	Subroutine	Component	Unit	Segment	Major Segment			
Development	●	●	●	●	●	●	x	Segment-level development performed on FM
Qualification			●	●		●	x	Segment-level qualification performed on IF
Acceptance			x	●	●	●	x	Unit-level acceptance implicit with segment acceptance
Integrated systems						x	x	
Prelaunch checkout				●	●	●	●	
Mission operations				●	●	●	●	

● Test design point

x Test data used

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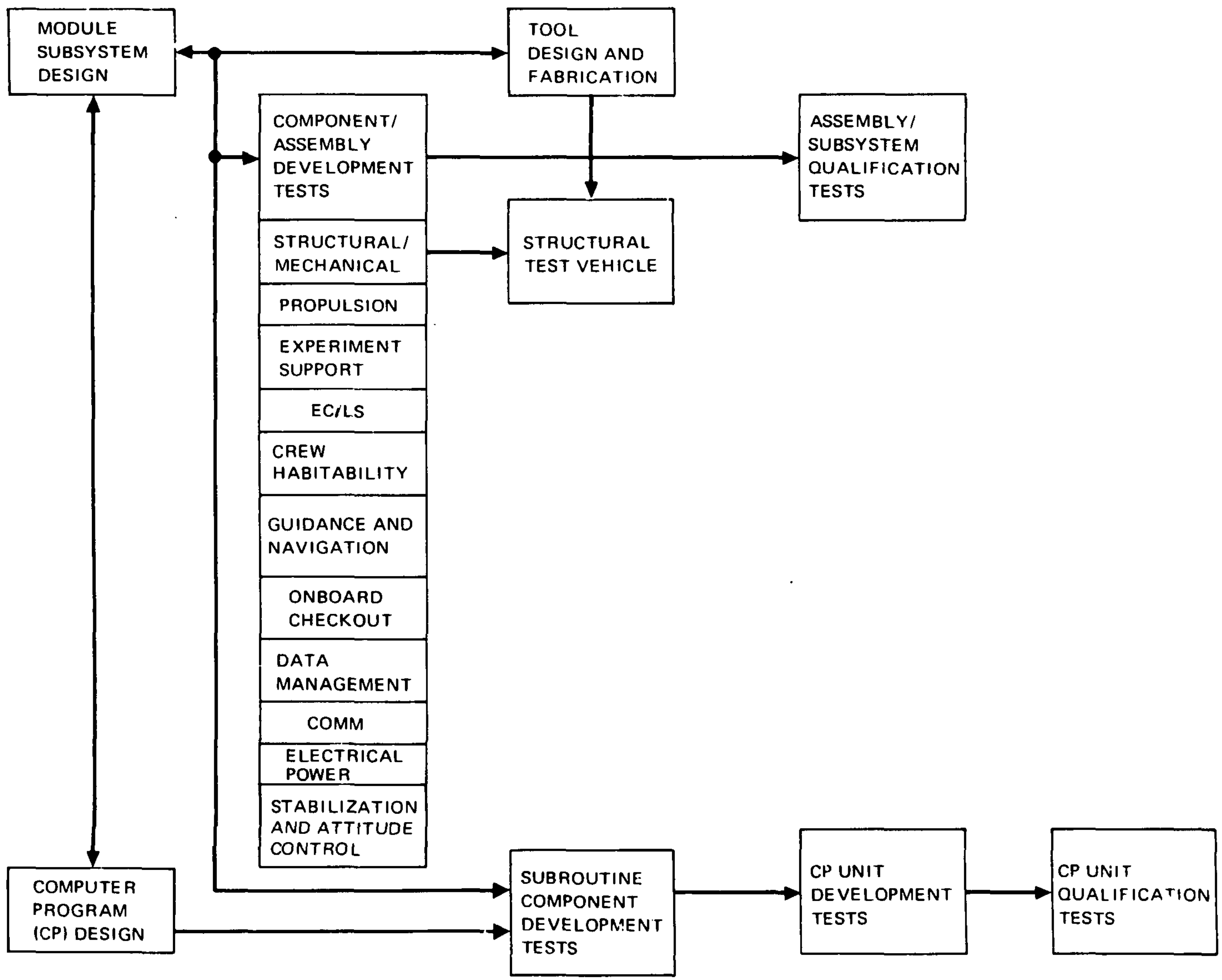

Figure 3-2. Computer Program Low-Level Development Qualification

C. All critical hardware will be tested at some level.

D. Test specimens will be required to undergo only one environmental test if appropriate.

E. System-level induced environmental acceptance testing is not required.

F. Environmental missions profile qualification testing shall be minimized.

G. The test program shall be planned and conducted for high correlation of test data between test types. Data from all test types shall be utilized for on-orbit verification.

H. Verification of a module or the cluster shall be limited to:

- Development of electrical/electronic subsystems and CPCEI on FM
- Qualification of integrated systems on FIT
- Acceptance of flight hardware on FIT
- Verification of orbital buildup sequences

3.1 COMPUTER PROGRAM (Figure 3-2)

Computer program (CP) verification ensures that the assembled codes and data tables meet the established performance requirements and that the program is operable and maintainable. Table 3-1 specifies the minimum CP verification to be described in the General Verification Plan. These tests have been formulated so that the proper software is available for hardware testing.

Subsystem development testing requires that the necessary computer programs be made available. This will cause the software to be developed at lower levels than the CPCEI. CP unit and CP segment level development will be performed on the FM.

Computer program acceptance will take place on the FIT before acceptance of flight modules.

3.2 SUBSYSTEM AND LOWER HARDWARE LEVEL TESTING (Figure 3-2)

The minimum testing to be considered in the General Verification Plan is presented in Table 3-2 and discussed below. Test design point designation implies that testing shall be explicitly performed for that purpose. Test data use simply menas that verification requirements will not be satisfied

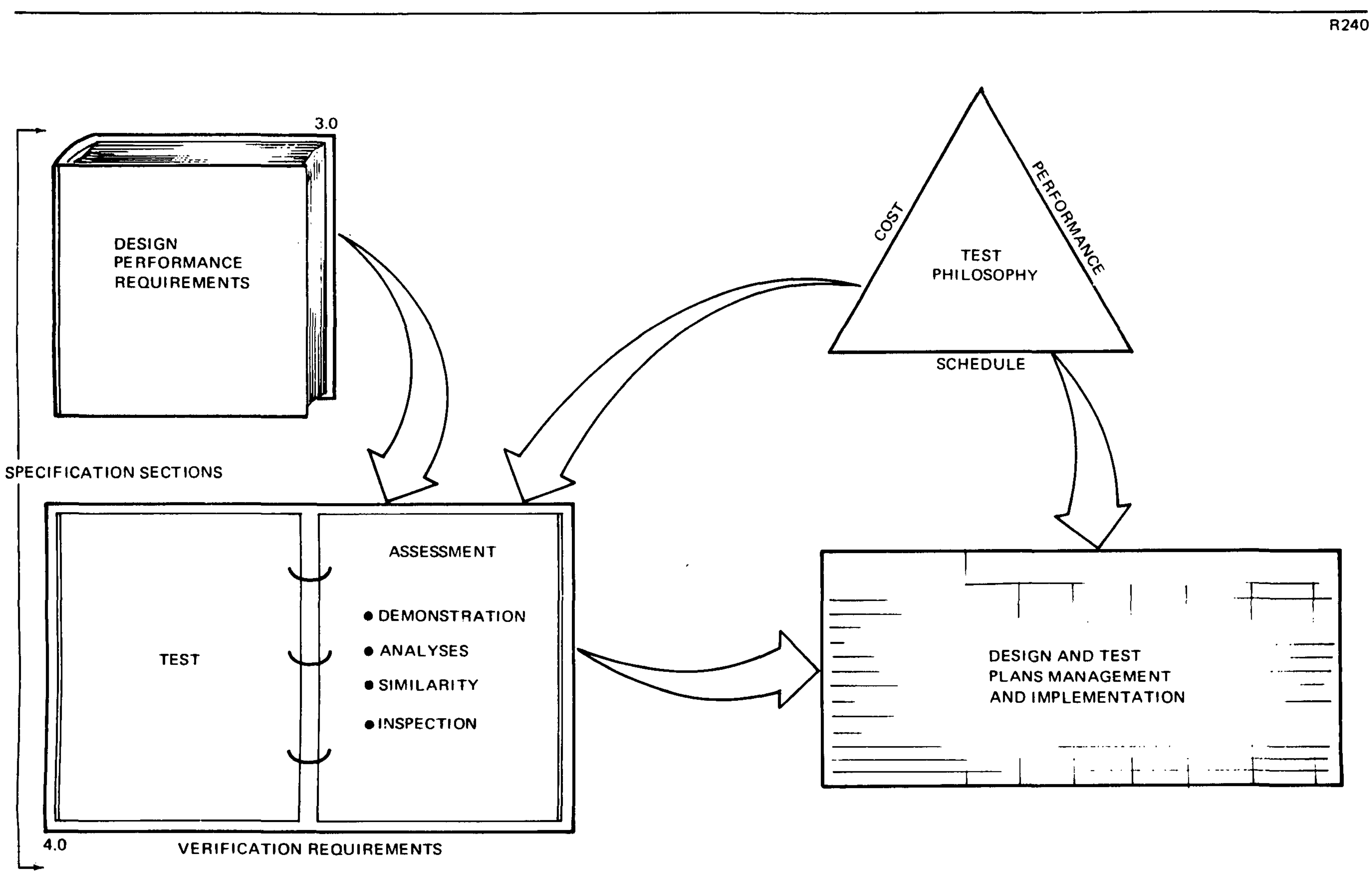

Figure 3-1. Test Philosophy

Section 3
VERIFICATION PHILOSOPHY

The Modular Space Station's 10-year life, room-ambient internal environment, resupply capability, subsystem commonality, maintainable design, and onboard fault isolation dictate that the concepts used in planning past verification programs be adjusted while maintaining equally high confidence in system performance. Although most problems are expected to result from subsystem development (e.g., the onboard checkout system and data bus concepts) and the integration of hardware/software/experiments, the program must address the one-of-a-kind design, commonality, modularity, multiple launch, orbital buildup, and incremental funding peculiarities of the Modular Space Station. The goal of a well-conceived verification program is to prove technical performance and to establish the confidence that a versatile, user-oriented orbital facility has been provided that is safe for personnel and maximizes mission return in the most cost-effective manner.

The approach taken toward verification has ramifications throughout the development of operational concepts and thus directly impacts design requirements. Figure 3-1 depicts the relationship of the test philosophy to the formulation of verification requirements and the implementation of a program to satisfy those requirements. As shown, test philosophy also impacts the implementation of design and test plans and therefore is presented herein.

The concepts upon which the test philosophy is based are summarized as follows:

A. Use of onboard systems for testing will be optimized to reduce test articles and GSE costs. To ensure the effectiveness of this use, component/assembly/assembly group/subsystem test instrumentation shall be planned so that data points and characteristics are common and compatible with the onboard systems.

B. Induced environment testing will be concentrated at the assembly/assembly group level (or lower).

C. Test Articles—items of system-level test hardware which may be deliverable. These articles need not consist of a complete system or any test specimen containing several subsystems. There are three test articles on the Modular Space Station Project; namely, Functional Models (FM) for both the Space Station modules and Logistics Module and the Flight Integration Tool (FIT).

2.6 CRITICALITY CATEGORIES

Categories of criticality are established for Space Station hardware to provide guidelines for determining test emphasis consistent with attaining the project objectives. The categories are defined as follows.

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

Criticality categories shall be defined for Space Station Module hardware at the generation level. They shall be determined in accordance with the Reliability/Maintainability Plan Requirements. Verification requirements for the various categories are specified in Section 4 of the Project/CEI Specifications.

Assembly	—Operators console, waste management, etc.
Component	—Relay, solenoid, valve, switch, printed card

This hardware tree is directly correlatable to the Project Work Breakdown Structure (WBS); the system is level 4, subsystem is level 5, etc. The WBS is shown in the Program Management Plan Requirements. Any difference from this tree must be specified in the General Test Plan.

2.4 LEVELS OF COMPUTER PROGRAM (CP) INTERFACES

Like the hardware tree, levels have been recognized for the parts of the overall CP. These levels shall be recognized in the Computer Program Contract End Items (CPCEI) and identified as to the correlatable hardware items; e.g., ECLS monitor subroutine relates to the ECLS subsystem.

The computer program tree shall be composed as follows:

CP Major Segment	—Onboard programs
CP Segment	—Data management, guidance and navigation
CP Unit	—Onboard checkout program
CP Component Subroutine	—ECLS monitor, sensor calibration

The Software Integration Plan Requirements presents an additional description for the computer program needs.

2.5 TEST SPECIMEN/MAJOR TEST ITEM/TEST ARTICLE

The management controls and the complexity of the Space Station development program dictate descriptions of test levels. These test levels are defined as follows:

A. Test Specimen—any object under test regardless of the hardware/ CP tree level.

B. Major Test Items—conglomerates of hardware which are used to develop assemblies and subsystems. Included in this definition are full-scale mockups, structural test vehicles, and electronic development fixtures.

The activities performed on the flight integration tool (FIT) to support the orbiting configuration, and to gain confidence that added modules will operate as designed when attached to the orbiting cluster, are considered to be this type of test.

2.2.5 Prelaunch Checkout

Prelaunch checkout is conducted at the launch site to verify that the integrated launch vehicle (payload, orbiter and booster) and its support equipment are ready for the launch phase. Prelaunch tests will repeat previous critical tests where essential. This is a combination of operational and management tools. It verifies that previously ascertained quality has not been degraded, confirms that launch preparations are correctly accomplished, and testifies that the launch vehicle is launch ready. The criteria for launch readiness shall be that all safe-to-man and all safe-to-launch items are "go".

The Space Station Module prelaunch requirements are covered in the Prelaunch and Launch Operations Requirements Plan.

2.2.6 Mission Operations

Mission Operation verifications consist of all those checkouts performed to determine the status of Space Station modules. This type includes assessments and tests performed to ascertain that each module(s) is safe to inhabit during the buildup, either from the ground or by means of the Shuttle, as well as those tests which are routinely performed to establish or measure system condition during the 10-year operational period.

The Space Station mission operations are covered in the Mission Operation Plan Requirements.

2.3 LEVELS OF HARDWARE ASSEMBLY

The hardware tree nomenclature used in the specifications and this document is as follows:

System level — ISS Space Station modules, Logistics Module, etc.

Subsystem level — Environmental Control/Lift Support, Data Management System, Guidance and Navigation processes, procedures, and natural or induced phenomena (as long as they are devoted to design application) to the most sophisticated tests used to ascertain that an end item will pass qualification testing. Development is a design tool and should remain within the control of design engineering. The development program also needs to be flexible and responsive to real-time needs. Therefore, it shall be the responsibility of the contractor to establish as well as implement development requirements. The NASA, by means of a Test Working Group, wishes to monitor the progress and results of these activities.

2.2.2 Qualification

Qualification is performed on hardware identical to the flight article or developed computer programs that have been accepted by the same tests and procedures as flight articles to verify that design and performance specifications have been met. When it is impractical to qualify flight-configured hardware (e.g. solar array structure deployment in a "g" field), deviations shall be identified, and rationale for this deviation presented.

2.2.3 Acceptance

Acceptance verifies that the hardware has been manufactured to the qualified design and meets the intent of that design and will properly perform during the mission as designed. In-process and receiving inspections to ensure quality of the end item are included in this category. Tests are performed at the CEI level and lower. Acceptance tests of the CEI are not intended to explore or confirm the operational envelope, but rather to indicate that the hardware is like that hardware which qualifies the design. Environmental acceptance testing shall be considered only on an "exception" basis, requiring specific approval from NASA.

2.2.4 Integrated Systems

Integrated systems verification is conducted to ensure the compatibility of system level (and higher) interfaces and to ensure interelement performance. The requirement that the orbiting station be self sufficient and provide automatic fault isolation, the presence of integrally launched experiments and the Modular buildup/initiation makes this verification a key to the success of the mission.

have negligible effect on qualification. Similarity shall pertain to characteristics such as material, configuration, and functional element or assembly, and may be applied selectively for applicable environments.

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

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

D. Demonstration—Demonstration shall be used to verify end-item features such as service and access, maintainability, transportability, or human engineering features. This method shall be used in lieu of test, when possible, to verify crew restraints and habitability performance requirements.

2.1.2 Test

Testing is the aggregate of those empirical activities required to verify that the hardware/software meets the performance requirements of the specification.

2.2 PHASES OF VERIFICATION

2.2.1 Development

Development is conducted to determine and evaluate the feasibility of the design approach and to acquire data to support the design and development process. Development hardware/software is representative of, but not necessarily identical to, production hardware or operational computer programs. Development covers the gamut from empirical investigation of

1.3 CONTROL

Appropriate NASA and other Government requirements have been reviewed, and the portions applicable to the Modular Space Station Project have been incorporated in this document. When there is a conflict between the requirements in this document and other documents, the appropriate specification will take precedence.

1.3.1 Approval

This document shall be approved by the NASA.

Section 2

DEFINITIONS

Verification is the process by which it is determined whether or not a design satisfies the requirements for that design. This process includes two methods by which, either singly or jointly, this determination may be made—assessment and/or test. To ensure a commonality of usage and a common basis for implementation, this section presents definitions that shall be used in preparing verification plans.

2.1 METHODS OF VERIFICATION

2.1.1 Assessment

Assessment is the engineering evaluation of existing data and observation of actual performance. Assessment may be made using the following techniques.

A. Similarity—Qualification testing may be waived if the end item is similar or identical in design and manufacturing processes to another article that has previously been qualified to similarly stringent criteria and it can be demonstrated that the dissimilarities

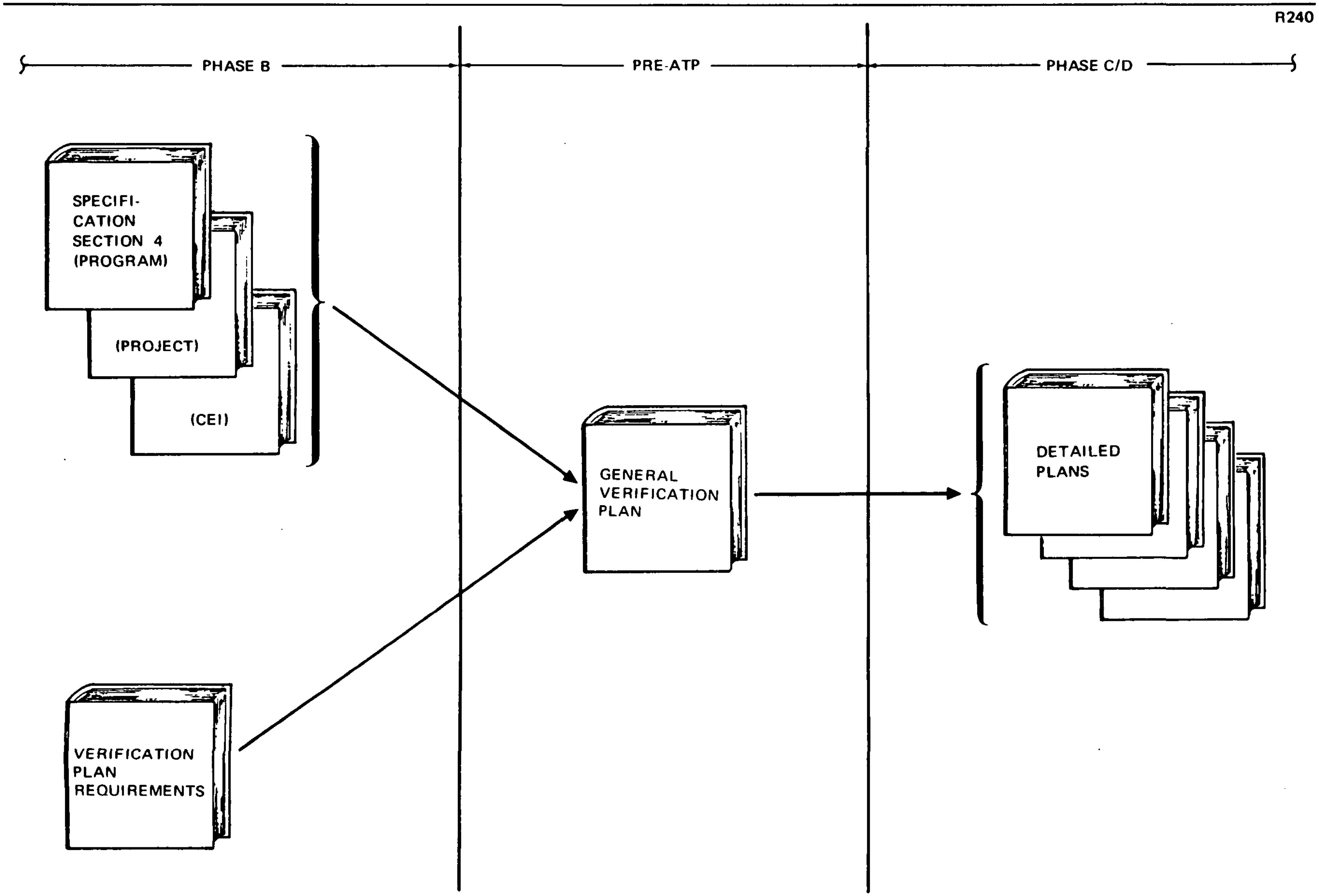

Figure 1-1. Verification Plan Requirements Relationships

VERIFICATION PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

The Verification Plan Requirements have been prepared to guide contractor planning and bidding for Phase C/D. This document describes the policies and objectives of the Modular Space Station Project Verification Program, their application, and the organization and general operating controls/procedures to be applied in preparing Phase C/D implementation plans. More specifically, this document describes a General Verification Plan which shall state how the contractor will satisfy the Section 4 Verification requirements of the Program, Project, and CEI Specifications in conducting the verification program in Phase C/D.

It sets forth the basic project/system managerial and technical requirements for hardware and computer program testing; provides guidelines for the preparation and implementation of detailed plans for Phase C/D; and provides descriptive information on the function of verification and its impact on other functions of the project/program to establish reasonable boundaries and limits for the verification program.

1.2 SCOPE

The definitions, requirements, and procedures specified are applicable to the verification of Modular Space Station hardware, software, and associated support functions with major emphasis upon the Initial Space Station (ISS) phase and the planning, conduct, evaluation, and reporting of test operations. It is limited to Phase C/D, and although the breadth of testing is discussed, it remains only preliminary so the contractor may employ his own technical and managerial ingenuity. The plan covers the period from the requirements baseline, established after Phase B, through development and the ISS operational life. Figure 1-1 depicts the relationships of this document to other Phase B documentation and the General Verification Plan which will be submitted in the Phase C/D proposal.

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VERIFICATION PLAN REQUIREMENTS

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8.4 AUDIT REPORT

The contractor will periodically audit the Modular Space Station system safety program against the approved system safety program plan. Activities not proceeding in accordance with the plan will be reported to the procuring activity, and a description of the actions being taken to bring the program into control will be given.

Paragraph 3110 of NHB 1700. 1, Volume III, dated 12 December 1969, and include (but are not limited to):

A. Risk levels in terms of risks being assumed.

B. Rationale for assumption of these risks, including the special controls invoked to minimize the probability of hazardous conditions occurring, and the alternatives that were considered.

C. Waivers to safety criteria, standards, or requirements that were granted.

D. System safety activities that are behind schedule and have not been completed.

8. 1 HAZARD REPORTS

The contractor will prepare a hazard report for each critical or catastrophic hazard that is identified and has not been adequately controlled at the date of the report. As a minimum, this report will contain:

A. A description of the hazard.

B. The method of detection.

C. The person responsible for elimination or control of the hazard.

D. The suspense date for completion of safety action.

8. 2 ACCIDENT-INCIDENT REPORT

The contractor system safety organization will investigate Space Station mishaps where death, damage, or personal injury has resulted. The techniques described in Chapter 9, NHB 1700. 1 (Volume I), dated 1 July 1969, will be used. The findings, conclusions, and recommendations will be documented and given to the appropriate action agencies within the contractor's organization and to the NASA procuring activity. The contractor will be prepared to provide technical assistance to boards investigating mishaps that occur within his jurisdiction.

8. 3 PROGRESS REPORT

The contractor will periodically report progress in accomplishing the safety tasks, as shown in the task matrix described in Section 2. 2. Reporting formats shall be developed by the contractor and approved by NASA before submittal of safety reports.

Section 6
DATA AND INFORMATION EXCHANGE

Safety data provided by the procuring activity and pertinent to the Modular Space Station design will be used to prevent repetitive design deficiencies. Safety data generated by completing the safety analysis task (Section 4.2) shall be reflected in the contractor data requirement list (NASA Form 1106). All safety data developed on the Modular Space Station Program shall be filed, maintained, and made available for review and use upon request by authorized representatives of the procuring activity.

Section 7
DOCUMENTATION

All significant safety efforts and the results of the efforts shall be documented, and the documentation shall be placed in a safety data file. This file will include but not be limited to:

A. Safety criteria, standards, and requirements.
B. Special safety study reports.
C. Progress and activity reports.
D. Safety analysis reports.
E. Safety analyses.
F. Hazard reports.
G. Accident-incident reports.
H. Audits

Section 8
REPORTING

A safety analysis report (SAR) will be prepared in support of each major program accomplishment. The requirements for the SAR are contained in safety devices, warning systems, and special procedures will be provided by the contractor to assure safety during tests and operations associated with the Modular Space Station project. System safety engineers will be provided for analysis, hazard identification, and corrective action recommendations concerned with abnormal conditions that occur during flight operation.

5.5 EXPLOSIVE ORDNANCE SAFETY

Special precautions are required in the analysis of explosive and ordnance systems associated with the Space Station Modules to assure that the explosives and ordnance systems are designed with adequate safety criteria. Special care will also be taken in reviewing procedures associated with explosive and ordnance system marking, packing, storage, transportation, and testing.

5.6 GROUND HANDLING AND TRANSPORTATION

Analyses will be performed to identify and reduce or eliminate the safety hazards associated with handling and transportation of all equipment, subsystems, and systems that are a part of the Modular Space Station Project.

5.7 FACILITIES

Safety standards, criteria, and requirements will be provided for facility design or modification, review and analysis of design to identify and reduce or eliminate hazards, and monitoring the use of the facility.

5.8 TRAINING AND CERTIFICATION

All Space Station Module personnel certification requirements and ground and flight training activities will be reviewed to assure that safety instruction is an integral part of the overall training program. The system safety organization will provide appropriate inputs to the training materials. A thorough knowledge of the safety aspects of the Modules activities will be a requirement for flight and ground crew certification.

5.2 ENGINEERING DESIGN

Paragraph 4.3 of OMSF Safety Program Directive No. 1, Revision A (SPD-1A), dated 12 December 1969, states the design procedural sequence precedence for system safety that will be followed in design. In support of this effort, a closed-loop problem identification and corrective action system will be provided to assure that system safety is given adequate consideration by the design groups. All proposals for engineering design changes will be analyzed for their impact on safety to assure that the level of safety in the Space Station Module systems is not degraded.

5.3 PROCUREMENT AND FABRICATION

To provide assurance that procurement, fabrication, assembly, or manufacturing test does not result in residual hazards being incorporated into the Space Station Module systems, the following actions are required:

A. System safety criteria and requirements will be provided in the procurement documents for use in critical material procurement.

B. System safety reviews will be performed in planning the manufacturing of critical systems.

The system safety organization shall also provide the quality assurance organization with inspection requirements for safety items and with information on safety-critical characteristics. The problem identification and corrective action system (Section 5.2) will assure that the safety organization receives rapid notification of safety discrepancies. The system safety organization will coordinate with the industrial safety and public safety efforts to ensure an effective and integrated total Modular Space Station Project safety effort.

5.4 TESTS AND OPERATIONS

The system safety organization will analyze all test and operation procedures to identify and reduce or eliminate hazards. The analysis will determine safety requirements for personnel, procedures, and equipment used in installation, maintenance, support, testing, buildup, operations, emergency, escape, egress, rescue, and crew training. Appropriate design changes,

4.3 PROGRAM REVIEWS, INSPECTIONS, AND CERTIFICATIONS

System safety will be an integral part of program reviews, inspections, and certifications which are key checkpoints oriented to the hardware design, development, fabrication, test, and mission phases of the program. Safety input will be relative to the risks being assumed, with rationale for acceptance and the status of hazard resolution.

System safety will be an integral part of PDR's and CDR's. Recommendations for resolving any identified deficiencies must be included in the review documentation.

4.4 SAFETY SURVEILLANCE

Potentially hazardous operations and the associated procedures shall be reviewed to assure compliance with safety regulations, criteria, requirements, standards, and check lists. The degree of monitoring will depend on the nature of the operation, the history or experience associated with the operation, and the quality of technical data available.

Section 5
SAFETY ACTIVITIES

In additional to the primary system safety effort of identification and elimination of hazards from the Space Station Module systems, the aerospace contractor's safety organization shall participate in all overall program activities related to system safety.

5.1 ENGINEERING ANALYSES

The contractor's system safety organization will review safety-related engineering analyses and trade studies that are being accomplished by other engineering groups. The required system safety inputs will be determined, and the inputs will be provided to the appropriate engineering group.

B. Analysis of the design to identify new safety requirements and to eliminate or reduce hazards. Review rationale for acceptance of residual risks (this should include a review of the special controls imposed to minimize the probability of hazardous conditions occurring).

C. Participation in trade studies and design review to assure that safety concerns are covered. Ensure that design requirements, released engineering drawings, as-built hardware, software, test specifications, and criteria and procedures are compatible and safe.

D. Survey and monitor system operation. Provide safety status and reporting through program. Assist and/or serve on accident/ incident investigation boards as required.

4.1 SAFETY CRITERIA

Results of the safety analyses and experience from Phase B of the Modular Space Station Program and other programs will be used to develop safety criteria and requirements. The contractor shall develop a method to assure that:

A. System safety criteria and requirements are implemented in the design and procedures.

B. These criteria and requirements are evaluated on an iterative basis to assure accomplishment of original intent.

4.2 SAFETY ANALYSIS

System safety analyses are conducted to identify, classify, and provide information for reduction or elimination of hazards in the Modular Space Station Project design. The system safety analysis techniques described in NHB 1700.1, Volume III, Chapter 2, dated 6 March 1970 will be used, as appropriate, in the most effective sequence to produce useful safety information in performing system safety analysis of the modules. Maximum use of prior analysis will be made in Phase C/D.

D. Resolve conflicts between agencies, organizations, and contractors in areas related to safety.

E. Augment the safety staff as required in emergency action.

2.2 ROLES AND RESPONSIBILITIES

A matrix chart of Space Station Module safety roles and organizational responsibilities for accomplishment of system safety tasks will be provided by the contractor. The tasks will be listed in detail, and a narrative description of each task indexed to the chart, will be provided. The chart will also show schedule start and completion dates for each task listed.

2.3 JOINT OPERATION PLANS AND AGREEMENTS

The system safety inputs to any safety-related joint operating plans of agreements between associate contractors, will be provided in an appendix to the System Safety Plan. The contractor will update the appendix as necessary to reflect current methods of operation.

Section 3
SYSTEM SAFETY SCHEDULES

System safety program milestones will be clearly defined and interrelated with other Modular Space Station Program activities. These safety milestones will be compatible with the overall Modular Space Station Project milestones and will include start and completion dates. The contractor will periodically record and report the status of progress toward meeting the milestones.

Section 4
SYSTEM SAFETY FUNCTIONS

The system safety function encompasses the following steps:

A. Preparation and dissemination of system safety criteria, requirements, and standards to the engineering design, manufacturing, testing, prelaunch, and flight operations groups.

C. A single Modular Space Station Project focal point for system safety, having immediate access to the project manager with primary responsibility for coordinating all system safety efforts.

D. Formal, published, procedural directives and policies for implementing the System Safety Plan.

E. System safety effort controls to evaluate plan implementation, correct deficiencies, redirect the effort as required, and evaluate the extent to which the system safety effort contributes to overall Modular Space Station Program effectiveness.

2.1 ORGANIZATION AND INTERFACES

Overall system safety requirements are specified by the NASA Project Office in OMSF Safety Program Directive No. 1, Revision A (SPD-1A), dated 12 December 1969. The contractor's system safety requirements are specified in this document. The contractor is expected to translate these requirements into tasks and activities in the System Safety Plan.

2.1.1 Contractor Organization

The System Safety Plan shall contain a detailed description of the contractor's system safety organization and its interfaces with associated contractors; subcontractors and their functions of reliability, human engineering, maintainability, and quality assurance; and system safety working groups. The system safety organization will be designed and properly integrated into the overall project organization to eliminate overlap and conflict.

2.1.2 System Safety Working Group

Contractor personnel will participate in a system safety working group (SSWG) established by NASA to:

A. Review the system safety effort to establish system safety program requirements and to recommend action to correct deficiencies.

B. Review the results of safety analyses and studies as well as the action taken on safety recommendations.

C. Provide guidance and recommendations for establishing safety criteria and design requirements.

D. System Safety Plan (Industrial Operations), MM 1700.2, dated 12 March 1968 (as a reference only).

E. NASA Handbook, Phased Project Planning Guidelines, NHB 7121.2, dated August 1968.

F. MSFC-DRL-160, Item 13-III, Appendixes G, OMSF Safety Program Directive No. 2, Personnel Certification; H, MMI 1710.6, Personnel Certification; and I, MMI 1711.2, Accident/Incident Reporting.

1.5 DEFINITIONS

The system safety terms used in this document are defined in Paragraph 3.0 of OMSF Safety Program Directive No. 1, Revision A (SPD-1A), dated 12 December 1969.

Section 2
ORGANIZATION AND RESPONSIBILITIES

The Modular Space Station system safety effort shall be conducted to ensure that:

A. Safety will be designed into system equipment, procedures, and facilities.

B. Appropriate system safety techniques will be used to achieve an acceptable level of safety.

C. System and facility operations will be accomplished with the use of safe procedures.

D. The system safety effort will be documented and reported.

E. The safety effort will be scheduled to be compatible with the overall Modular Space Station Program milestones.

Appropriate management principles will be applied to all aspects of the system safety effort to accomplish the following objectives:

A. Planning to establish an orderly, effective, logical, and timely system safety effort.

B. A safety organization to implement the approved System Safety Plan.

This document is prepared to guide contractor planning and preparation of proposals for Phase C/D.

1.2 SCOPE

The definitions, requirements, and approaches to the system safety effort specified herein are applicable to the planning, organization, coordination, direction, and control of the Modular Space Station Project safety effort. This system safety effort will be applied to the Modular Space Station Project facilities, equipment, and procedures; relates to Work Breakdown Structure (WBS)* Level 3 and below; and is limited to Phase C/D. The time period governed by this plan extends from the implementation of Phase C to the end of the 10-year operational life.

1.3 CONTROL

The Modular Space Station Program, Project, and CEI Specifications are the governing requirement documents for initiating Phase C. The NASA system safety requirement documents listed in the documents tabulated in Section 1.4 have been reviewed, and requirements pertinent to the Modular Space Station Project have been extracted, tailored to Module requirements, and incorporated in this plan. The plan will reflect all deviations or exceptions to established NASA documents.

1.4 APPLICABLE DOCUMENTS

The following documents contain the NASA System Safety requirements and are applicable to the extent noted herein:

A. NASA Safety Manual, Volume I, Basic Safety Requirements, NHB 1700.1, dated 1 July 1969.

B. NASA Safety Manual, Volume III, System Safety, NHB 1700.1, dated 6 March 1970.

C. OMSF Safety Program Directive No. 1, Revision A (SPD-1A), dated 12 December 1969.

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*Ref: DR CM-01 Space Station Program (Modular) Specification PS 02925
DR CM-02 Space Station Project (Modular) Specification RS 02927.

SYSTEM SAFETY PLAN REQUIREMENTS

Section 1
INTRODUCTION

A system safety approach in which safety deficiencies are identified and corrected after the fact is not acceptable for the Modular Space Station Project. Considering today's accelerated technological pace and space system complexity, such an approach would have an unacceptable impact on NASA space programs. Consequently, the concept of planned system safety will be followed on the Modular Space Station Project.

This concept is designed to preclude the occurrence of hazardous events, reduce safety-related program delays, and eliminate unsafe facilities and their operation. This will be accomplished by application of special safety emphasis in a positive program for hazard identification, hazard elimination, control of residual hazards, and risk management techniques throughout Phase C/D of the program. In this manner, NASA can expect safety risk to be held to a minimum within the constraints of operational effectiveness, time, and cost. This document, therefore, specifies system safety requirements that are to be reflected in a Modular Space Station Project Safety Implementation Plan to be prepared by the contractor.

1.1 PURPOSE

This document provides system safety requirements for the Modular Space Station Project which will be used in the preparation of the Phase C/D implementation plans. The system safety requirements herein are specified with respect to:

A. Preparation of the System Safety Plan for Phase C/D.

B. Technical and managerial requirements for conduct of the system safety effort.

C. Interfaces with other activities within the project.

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SYSTEM SAFETY PLAN REQUIREMENTS

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Subcontract. A contract or purchase order entered into under a Government prime contract by a supplier. May include orders issued to activities or subdivisions within the contractor's organization.

Supplier. A subcontractor, at any tier, performing the contract services or producing the contract articles for the contractor.

System. One of the principal functioning entities comprising the project hardware, software, and related operational services within a project or flight mission. Ordinarily, a system is the first major subdivision of project work. Similarly, a subsystem is a major functioning entity within a system. (A system may also be an organized and disciplined approach to accomplish a task, e.g., a failure reporting system).

Reliability. A characteristic of a system, or any element thereof, expressed as a probability that it will perform its required functions under defined conditions at designated times for specified operating periods.

Reliability Apportionment. The assignment of reliability subgoals to subsystems and elements thereof within a system which will result in meeting the overall reliability goal for the system if each of these subgoals is attained.

Reliability Assessment. An evaluation of reliability of a system or portion thereof. Such assessments usually employ mathematical modeling, directly applicable results of tests on system hardware, estimated reliability figures, and nonstatistical engineering estimates to insure that all known potential sources of unreliability have been evaluated.

Reliability Demonstration. Statistically designed testing, with specified confidence level, to demonstrate the degree to which a system or element thereof meets the established reliability requirement.

Reliability Prediction. An analytical prediction of numerical reliability of a system or element thereof similar to a reliability assessment except that the prediction is always quantitative and is normally made in the earlier design stages where very little directly applicable test data is available.

Software. The combination of nonhardware items associated with hardware that are used to govern its design, handling, test, and use. Typical items of software are drawings, specifications, computer programs, plans, instructions, and procedures.

Single Failure Point. A single element of hardware, the failure of which would result in loss of objectives, hardware, or crew, as defined for the specific application and/or project for which the single point failure analysis is performed.

success of the system's mission. Critcalities are usually assigned by categories, each category being defined in terms of a specified degree of loss of mission objectives or degradation of crew safety.

Maintainability. The quality of the combined features of equipment design and installation which facilitates the accomplishment of inspection, test, checkout, servicing, repair, and overhaul necessary to meet operational objectives with a minimum of time, skill and resources in the planned maintenance environments.

Milestone. Any significant event in the project life cycle or in the associated reliability program which is used as a control point for measurement of progress and effectiveness or for planning or redirecting future effort.

Nonconformance. A condition of any article or material, or service in which one or more characteristics do not conform to requirements. Includes failures, discrepancies, deficiencies, defects, and malfunctions.

Overstress. A value of any stress parameter in excess of the upper limit of the normal working range or in excess of rated value.

Part. One piece or two or more pieces joined together which are not normally subject to disassembly without destruction of design use.

Qualification. Determination that an article or material, with its associated software, is capable of meeting all prescribed design and performance requirements as stated in pertinent specifications.

Qualification Test. A test or series of tests conducted to determine whether an article or material, with its associated software, meets qualification requirements.

Redundancy (of design). The use of more than one means of accomplishing a given function where more than one must fail before the article fails to perform.

Design Specification. Generic designation for a specification which describes functional and physical requirements for an article, usually at the component level or higher levels of assembly. In its initial form, the design specification is a statement of functional requirements with only general coverage of physical and test requirements. The design specification evolves through the project life cycle to reflect progressive refinements in performance, design, configuration, and test requirements. In many projects the end-item specifications serve all the purposes of design specifications for the contract end-items; for articles not designated contractually as end-items, design specifications provide the basis for technical and engineering management control.

Designated Representative. An individual (such as a NASA plant representative), firm (such as an assessment contractor), DOD plant representative, or other Government representative designated and authorized by NASA to perform a specific function(s) for NASA. As related to the contractor's reliability effort, this might include evaluation, assessment, design review participation, and/or approval/review of certain documents or actions. (However, NASA approval or review authority will not be delegated to a non-Government organization.)

Device. A combination of parts and structure, usually less complex than a component, which performs a specific function within a component or subsystem. Devices frequently are capable of disassembly, and may combine several types of functions such as electro-mechanical, electro-physical, or electro-chemical. The same type of article may be considered a device in one assembly and a component in another, depending on such factors as complexity and relative importance in the particular system. Some examples of devices are: valves, relays, small motors, bearings, gyros, batteries, thermocouples, strain gauges, and connectors.

Failure Mode, Effect, and Criticality Analysis. Study of a system and working interrelationships of its elements to determine ways in which failures can occur (failure modes), effects of each potential failure on the system element in which it occurs and on other system elements, and the probable overall consequences (criticality) of each failure mode on the

Category	Potential Effects of Failure
1S	Applies to Safety and Hazard Monitoring Systems. When required to function because of failure in the related primary operating system(s), potential effect of failure is loss of life of crew member(s).
2A	Immediate mission flight termination or unscheduled termination at the next planned earth landing area. (Can also include loss of primary mission objectives.)
2B	Launch scrub
3	Launch delay or loss of secondary mission objective
4	None of the above

When considerable analysis and expense are required to discriminate between criticality categories, the more critical category will be assigned. Other criticality categories that are compatible with the above may be used provided a cross-reference is defined.

Nonconformances encountered shall be classified according to the potential effect at the most critical period of countdown and/or flight. The following guidelines shall be used in nonconformance criticality category assignment:

A. Criticality determination is not affected by the nature of the checkout where the current problem was discovered. Criticality is based on the potential effect at the most critical period of countdown and/or flight of the mission. Criticality applies to the hardware failure mode.

B. Criticality categories are also applicable when a Failure Mode and Effect Analysis (FMEA) does not identify the particular hardware or failure mode, but sound engineering judgment dictates that the problem could fit the above definitions (that is, structural or electrical cabling problems involving critical components.)

C. When a nonconformance is reported against hardware used in multiple applications, it shall be classified based on the most critical application.

D. Launch scrub (as distinguished from launch delay) is defined as a delay long enough to require retanking of propellants and/or reschedule of the launch to a later date.

K. Identify crew skills and special training requirements.

L. Location.

M. Contingency (steps) time.

N. Criticality.

5.10 EVA MAINTENANCE

EVA maintenance tasks shall be identified. Data resulting from tradeoffs against other methods of maintenance or design option shall be provided. Each maintenance task shall be analyzed for safety hazards.

Appendix A
GLOSSARY OF TERMS

The following definitions apply to terms as used in this publication.

Component. A combination of parts devices, and structure, usually self-contained, which performs a distinctive function in the operation of the overall equipment. A "black box" (e.g., transmitter, encoder, cryogenic pump, star tracker).

Contract. The prime contract executed by the Government and the prime contractor which, in addition to the terms and conditions thereof, includes by reference or otherwise, specifications, drawings, exhibits, and other data necessary to its proper performance.

Contractor. The individual(s) or concern(s) who enter into a prime contract with the Government.

Criticality Categories: Established equipment classifications into which individual items of flight and ground support hardware are ranked according to specific potential effects of failure on the flight or ground crews and mission. Categories established for Modular Space Station Program hardware are:

Category	Potential Effects of Failure
1	Loss of life of crew member(s) (ground or flight)

5.7 DESIGN CHANGES

The organization responsible for approving engineering design changes shall notify the maintainability organization of the proposed changes. The maintainability organization shall review the proposed changes to determine the impact on maintainability and maintenance implementation and shall notify the approval organization of the impact.

5.8 SUBCONTRACTOR AND SUPPLIER CONTROL

The system contractor shall be responsible for ensuring that the maintainability and maintenance of system elements obtained from subcontractors and suppliers will meet the maintainability and maintenance requirements of the overall system. This applies to items obtained from any supplier, whether he be in the first or any subsequent tier. All subcontracts shall include provision for review and evaluation of the subcontractor's maintainability and maintenance effort by NASA or its representatives as prescribed in subsection 1.4.2.

Appropriate provisions of this publication shall be invoked by the contractor on all major subcontracts and on suppliers of all major components used in the system.

5.9 MAINTENANCE ANALYSIS

Maintenance analysis shall be performed for each subsystem to define the planned replaceable level. Analysis shall provide:

A. Items to be maintained.
B. Spare Weight and Volume.
C. Spares.
D. Tools and equipment.
E. Method of fault isolation/test.
F. Requirements on logistic systems.
G. Allowable downtime.
H. Predicted maintenance time/repair (corrective/preventive).
I. Input to redundancy requirements.
J. Recommendation for improved life.

5.2 MAINTAINABILITY ASSURANCE PLAN

The contractor shall identify and define essential tasks required to assure optimum maintenance capabilities during the mission and shall describe how the contractor will assure compliance to maintainability requirements. The requirements of subsections 2.3 and 2.4 shall also apply for the maintainability section.

5.3 MAINTAINABILITY DESIGN CRITERIA

The contractor shall periodically update general and detailed maintainability design criteria as defined in the specifications.

5.4 MAINTAINABILITY ANALYSIS

A maintainability analysis of the critical items (Category 1 and 2) shall be performed in sufficient depth to assure compliance of each system, subsystems, assembly, and/or component to maintainability design requirements. The analysis shall be used during design, design review, development, and test to evaluate the degree of achievement of these requirements and as a basis for design improvement feedback. Trade-offs shall be documented with the rationale provided for modifications or waiver of maintainability design requirement.

5.5 DESIGN REVIEW

Maintainability requirements shall be a parameter at each design review at the system, subsystem, and/or major component level. Maintainability personnel shall participate in all design reviews, sign all design review reports to indicate concurrence with the review and with the actions to be taken, and follow up on all action items affecting mission maintenance.

5.6 SUBCONTRACTOR SPECIFICATION

The provisions of subsection 5.5 shall be imposed on suppliers required to have formal reliability programs (see subsection 2.2). Provisions shall be made for participation of appropriate representatives of the contractor at his discretion, and for attendance of NASA personnel as observers at all supplier formal design reviews.

known potential sources of unreliability have been evaluated. Assessments shall consider the qualification status of each component, subsystem and system, as well as appropriate revision of failure mode, effect and criticality analyses (see subsection 3.4) as necessary to incorporate newly available test results and to reflect design changes and refinements.

4.4 RELIABILITY INPUTS TO READINESS REVIEWS

The reliability organization shall ensure that all pertinent reliability data necessary to support each project milestone review or buyoff occuring after prerelease design review is provided in complete form and in a timely manner. This shall include all pertinent data on supplier-furnished articles which are a part of the specific hardware assembly to which the readiness review pertains.

4.5 RELIABILITY EVALUATION PROGRAM REVIEWS

At appropriate milestones scheduled in the Reliability Program Plan, the contractor shall review his reliability evaluation effort (see subsection 4.2). This review shall be conducted as a part of the contractor's overall reliability program review activity prescribed in subsection 2.3. In these reviews of reliability evaluation effort, pertinent test results will be examined to determine that completed portions have adequately evaluated the pertinent system elements in terms of the reliability objectives. After each review, the contractor will provide the procuring NASA installation a written report of results of the review including actions to be taken, and responsibility therefor. Results of these reviews will also be considered and acted upon in contractor-NASA reliability program management meetings (see subsection 2.4).

Section 5
MAINTAINABILITY ASSURANCE

5.1 GENERAL

The contractor shall establish and maintain an effective maintainability program which is responsive to the maintainability requirements identified in the Program, Project, and CEI Specifications.

controls shall be designed to prevent use in the system of parts, devices, or materials which may be in a questionable condition. They shall also be designed to prevent degradation of parts, devices, and materials due to environments or faulty manufacturing or assembly techniques.

3.10.9 Parts, Devices, and Material Failure Analysis

The contractor's parts, devices, and materials organization shall participate in investigating the cause of, and in devising remedial and preventive actions for each part, device, or material failure that causes a nonconformance in higher levels of assembly (see subsection 3.7). The significance of the failure as related to like parts or materials used elsewhere in the system, and the possibility of the occurrence of additional failures shall be determined and documented.

Section 4
RELIABILITY EVALUATION

4.1 GENERAL

The contractor shall establish and conduct a program directed toward evaluating reliability of the system and its elements throughout the project life cycle. The reliability evaluation program shall be designed to produce objective data necessary for assessing the degree of system conformance to mission requirements and contractual reliability requirements.

4.2 RELIABILITY EVALUATION

As a part of the Reliability Program Plan, the contractor shall prepare a section identifying how he will conduct reliability evaluation. The initial version of this section shall be updated at program milestones specified in the Reliability Program Plan.

4.3 RELIABILITY ASSESSMENT

At milestones specified in the Reliability Evaluation Section, the contractor shall assess system reliability. These assessments shall utilize test results, mathematical analyses and engineering analyses to ensure that all necessary parts, devices and materials as early in the project life as possible. The project lists should be complete (with the exception of a few items) and be submitted to the procuring NASA installation before initiation of detailed design of the hardware; completeness should include qualification at part, material, and device levels. After initial submittal of the lists, candidate additions shall be submitted with specification, qualification, and application information to the procuring NASA installation before their inclusion in the lists. Contractor parts/devices/materials lists shall be updated and submitted as specified in the contract.

3.10.7 Parts, Devices, and Materials Application Review

To ensure proper applications of parts, devices, and materials in the system design, the contractor (or supplier, if appropriate) shall conduct thorough parts, devices, and materials application reviews on the design of each component ("black-box") at appropriate milestones during its design and development. In these reviews, each application of each part, device, and material shall be examined in light of its rated capabilities in comparison to the design requirements of that application. In ascertaining application adequacy, consideration shall be given to anticipated life requirements, functional and environmental usage stresses, and historic and current failure experience (i.e., results of analyses of parts, devices, and materials failures which have occurred in higher level assemblies on the same system or project). Special attention shall be given to any parts used which are not selected from the project parts list, and the review output documentation shall include or reference justification for each such usage. The contractor shall take immediate action to correct identified deficiencies. Application reviews shall be documented in detail in application review reports. These reports shall be a required item of input documentation to formal design reviews at the component level (see subsection 3.6). Within 15 days of the completion of each application review (or as otherwise specified), the review documentation shall be available as specified in the contract.

3.10.8 Parts, Devices, and Materials Handling

The contractor shall specify minimum requirements for control of stocking and installation procedures for parts, devices, and materials. These

3.10.4 Parts, Devices, and Materials Specifications

Adequate specifications shall be used as a basis for description and control of all parts, devices, and materials to be used in the contract hardware. Where adequate specifications do not exist (as determined jointly by the contractor and the procuring NASA installation), the contractor shall prepare them. Specifications shall be responsive to applicable requirements (reliability and quality requirements as well as part, device, or material capability) and shall be expressed in terms of conformance to readily measurable criteria.

3.10.5 Parts, Devices, and Materials Qualification

Where adequate qualification data are not available (as determined jointly by the contractor and the cognizant NASA installation), the contractor shall be responsible for the design and conduct of qualification tests on parts, devices, and materials to determine their adequacy in meeting specification requirements and for development of criteria to be used in acceptance testing. The contractor shall generate test specifications for those parts, devices, and materials which he will subject to qualification testing. Requalification of parts, devices, and materials shall be conducted as necessary to ensure continued control over design, materials, manufacturing processes, and quality controls after initial qualification. The contractor shall keep a file of qualification data for all parts, devices and materials used on the project, and shall indicate the qualification status of each item on the project parts, devices and materials lists (see subsection 3.9.6). He shall also report status of those items requiring qualification or requalification as a part of periodic progress reports (subsection 2.4) and shall prepare a report for each part, device, or material qualification test.

3.10.6 Parts, Devices, and Materials Lists

Based on the above efforts, the contractor and suppliers having a formal reliability program (see subsection 2.2) shall prepare and maintain project parts, devices, and materials lists for use in design of the contract hardware. Because these items are a limiting factor on the reliability of the design and hardware, every effort shall be made to select and qualify all

All standards and practices (including process specifications) shall be subject to action by NASA (e. g. , approval or review, and control of changes) as specified in the contract.

3.10 PARTS, DEVICES, AND MATERIALS PROGRAM

3.10.1 General

The contractor shall implement a program covering selection, reduction in number of types, specification, qualification, application review, analyzing failures, stocking and handling methods, installation procedures, and establishing other reliability and quality requirements for parts, devices, and materials to be used in the contract hardware.

3.10.2 Parts, Devices, and Materials Organization

The contractor shall use a group of qualified specialists to act as advisors to the design groups on the selection and application of parts, devices and materials and to develop and conduct the parts, devices, and materials program.

3.10.3 Parts, Devices, and Materials Selection

The contractor and suppliers shall select parts, devices and materials for the contract hardware on the basis of suitability for their application(s) and proven qualification of each to the requirements of its specification. Initial selections may be based on good performance in prior comparable uses or its presence on an existing list, whether NASA-furnished or from another source. Wherever practicable, items selected shall be already qualified to pertinent specifications, and selection shall minimize the number of styles of each generic type. When selecting items previously qualified, the contractor shall devote particular attention to currentness of data, applicability of basis of qualification and adequacy of specifications. The results of the selection effort will determine requirements for additional qualification testing and will be the basis for the parts, devices and materials lists for the system (see subsection 3.9.6).

the ALERT Coordinator. Beginning 30 days prior to each mission Flight Readiness Review (FRR) and continuing through launch, expedited communications (such as TWX, telecommunication, visit, handcarry, memorandum) will be utilized for distribution of advance copies of ALERTS. During these time periods the contractor will expedite ALERT closures through the resident Government agency. Following the expedited closure, formal closeout correspondence to the contracting officer will be initiated. The responses will indicate or provide (1) confirmed, suspected, or no usage of the problem item, (2) problem analysis, recommendations, or corrective action accomplished to resolve the problem, and (3) identification of issued nonconformance reports, as applicable.

D. Contractor Initiated ALERTS. When the contractor encounters a significant problem with a part of material which may affect equipment and for which there is no known ALERT, the contractor will initiate an ALERT and submit it to the ALERT Coordinator for review, publication, and distribution.

3.9 STANDARDIZATION OF DESIGN PRACTICES

The contractor shall maintain a continuous effort to standardize and control design practices and fabrication processes. He shall formalize the results of this effort in manuals for use of his personnel, such as those working in design, drafting, fabrication, processing, and inspection. The contractor shall use his existing standards and specifications insofar as practicable, modifying them as necessary to meet the reliability, quality, and other requirements of the contract. To the extent prescribed in the contract, NASA design or processing standards shall be incorporated in the contractor's design standards system and the contractor shall impose a similar requirement on appropriate suppliers. The contractor's reliability organization shall be responsible for reviewing design and process standards to be used for the contract effort to ascertain their adequacy in meeting reliability requirements of the contract.

The contractor shall review for adequacy the standards and design practices of all suppliers required to use a reliability program (see subsection 2.2).

5. Identification of hardware (or software) item affected, including serial or lot number where appropriate and drawing/part numbers (with revision identification).
6. Identification of end-item if known.
7. Brief description of problem.
8. Status of analysis and closeout actions, including projected dates for completion of these actions.
9. Identification of formal documentation changes supporting close-out (e.g., engineering order number or procedure modification number).

Each status summary shall contain clear identification of its scope, including time span, data exlusions (e.g., supplier data, in some cases), and hardware covered (part numbers and serial numbers).

3.8.3 Reporting of Selected NASA Parts and Materials Problems (ALERT)

Problems with parts, materials, or equipment which are of mutual concern to the procuring activity, other NASA centers, and associated contractors are reported through the NASA ALERT system. The contractor shall establish a systematic approach to evaluate and respond to all NASA ALERTS (NASA Form 863) to investigate, resolve, and document parts problems in accordance with DR No. RA-13.

A. Investigation. Upon receipt of a problem ALERT, the contractor will initiate an immediate investigation to determine the use and significance of the problem item identified by the ALERT in his inhouse program and in that of his subcontractors and suppliers.

B. Resolution. Subsequent to the start of acceptance testing, when investigation discloses known use of the item identified in the ALERT, a nonconformance report will be issued against each element of program equipment using the item. The report will be prepared, and the nonconformance resolved, and closed out in conformance with program procedures.

C. Documentation. The contractor will provide a documented response on each ALERT investigation and resolution to the contracting officer within 30 days after receipt of the ALERT, with copies to format between the treatment of problem/failures of each criticality and functional category. The description shall clearly spell out ground rules for:

1. Categorizing the reporting problem/failures.
2. Reviewing correctness of categorization decisions (e. g. , to ensure against categorizing problems as being less critical than they are).
3. Prescribing levels of technical management judgement and review in the closure procedures for each problem/failure category.
4. Referral of recurrent nonconformances from other nonconformance reporting systems to the problem/failure reporting system (see subsection 3. 7).

This description shall reference that portion of the Quality Program plan covering nonconforming article and material control and clearly show the complementary interface in responsibilities, procedures and practices in this area between the quality program and the reliability program. If a single system is used for reporting of both functional and nonfunctional nonconformances and problem/ failures, the system shall be described only once in either the Reliability Program Plan or the Quality Program Plan and shall be referenced in the other.

B. Cumulative status summaries covering each reported problem/ failure shall be submitted as a part of the periodic reliability progress reports (see para. 2. 4) or as otherwise prescribed in the contract. The status summaries shall list each problem/ failure report as a separate line item and provide the following data:

   1. Identifying serial number of the problem/failure report and source (prime or subcontractor) of the report.
   2. Test and site where problem/failure occurred.
   3. Criticality category.
   4. Problem/failure occurrence date and closeout date (target or actual).

J. For hardware problems, all functions of the problem/failure reporting system shall become fully applicable at the time of first application of power (or first test usage for mechanical items) at the lowest level of assembly (above part level) of qualification or flight-configuration hardware. For software problems, operation of the problem/failure reporting system shall begin with the first application or signoff (whichever occurs first) of the software item.

K. Where special functional models or prototypes (thermal model, vibration model, etc.) are tested as a part of qualification of the flight hardware design, the problem/failure system shall apply to testing of these models.

L. Provide for timely dissemination of problem/failure reports to appropriate elements of the contractor's organization and shall provide for rapid retrieval of information, including closure status, on each reported problem/failure. Reports originated at remote test and launch sites shall be distributed to appropriate organizations at the plant sites.

M. Require that individual problem/failure reports generated under subcontracts designed in accordance with par. 2.2 be submitted to the prime contractor as a part of the regular distribution at the time these reports are generated.

N. Reporting and data processing aspects of the contractor's system shall be devised to provide necessary data in the form and manner required by the procuring NASA installation for timely follow-up of problem/failures, for use in pertinent milestone and readiness reviews, and for other reliability data requirements.

3.8.2 Information to be Submitted

The contractor shall submit the following information relating to his problem/failure reporting system as well as those used by suppliers required to have a formal reliability program:

A. Description of the problem/failure reporting system as a part of the Reliability Program Plan (see subsection 2.2). This shall include a description of the format and system of numbering of reports and show clearly all differences in procedure, responsibilities, and organization will participate, as appropriate, in the analysis of reported part, device, or material failures (see subsection 3.9).

E. Provide for categorizing problem/failures by criticality and for differentiating between functional and nonfunctional nonconformances.

F. Recurrent nonconformances from other nonconformance recording systems used under the contract shall be referred to the problem/failure reporting system. Such recurrent nonconformances shall include those of a nonfunctional nature and those of a functional nature that occur during in-process testing (i.e., during fabrication) which are recurrent to the extent defined in the Reliability Program Plan (see subsection 3.7.2a) or in Material Review Board procedures (see NHB 5300.4(1B), paragraph 1B804). Such referred items shall be subject to analysis and closure requirements for other reported problem/failures.

G. Provide for accomplishment and documentation of remedial and preventive actions.

H. Provide for a review of each problem closeout on each reported problem/failure by the reliability organization and by higher levels of technical management appropriate to the criticality category of the problem/failure involved.

I. Provide for closeout of each problem/failure within time periods prescribed in the contract. Closeout shall at least require that:

   1. Remedial actions have been accomplished.
   2. Necessary preventive design and software changes have been devised and accomplished.
   3. Necessary design or computer program changes have been verified in test.
   4. Effectivity of preventive actions has been established.
   5. The preventive action has been made in existing identical items of hardware to which it is pertinent,
   6. The closeout document has been signed off by the appropriate management authority to indicate technical review and by the reliability and/or quality organization to certify completion of all closeout actions.

equipment directly involved in mission operations, and checkout equipment as defined in the Reliability Program Plan. Software items covered shall include test specifications, test and checkout procedures, operating and handling instructions, and computer programs for use in:

1. Test, checkout, and launch of mission hardware.
2. Operation of on-board mission equipment.
3. Test, execution, and post-mission analysis of mission operations.

If a separate system is employed for software deficiencies, its procedures and controls shall conform to appropriate requirements of this subsection; also, its governing procedures shall be referenced and its interface with the problem/failure reporting system shall be defined in the Reliability Program Plan.

B. Cover all observed nonconformances of a functional nature, as well as suspected nonconformances of a functional nature. The latter shall include:
   1. Unusual conditions occurring in test or handling which are suspected to have an effect on the hardware.
   2. Transient malfunctions and suspected malfunctions.
   3. Observed deviations from previous performance (e.g., parameter drift).
   4. For the software items cited in item A, it shall cover nonconformances, deficiencies, and ambiguities which are considered potential contributors to improper operation of the hardware or failure of the hardware or mission.

C. Provide for reporting of each problem/failure within time periods stated in the contract.

D. Provide for investigation and engineering analysis of each reported problem/failure, followed where appropriate by laboratory analysis of failed hardware. The investigation shall be adequate to assess causes, mechanisms, and potential effects of the problem/failure and serve as a basis for decisions on most efficient remedial and preventive actions. The investigations and their conclusions shall be documented. The contractor's parts, devices and materials

3.7.2 Trade-Off Studies

A control system shall be established to ensure that reliability is considered when design considerations are subjected to trade-off analysis. An analysis of the effect on reliability shall be conducted on the proposed design change. The analysis shall consider such factors as failure modes deleted and added, additional testing requirements and changes to reliability and quality control practices and procedures.

3.7.3 Engineering Design Changes

Each engineering design change made after the engineering documentation in question has been placed under formal design change control shall be submitted for review, analysis, and concurrence of appropriate members (including reliability personnel) of the design review group (or change control board if established). Where the nature of the change warrants a formal design review, the review will be conducted in accordance with accepted procedures (see subsection 3.6.1) before release of the change. Where the acceptability of design changes is ruled on by change control boards, their membership shall include representation from the reliability organization as well as other groups normally represented on design review teams and be subject to concurrence by the procuring NASA installation.

3.8 PROBLEM/FAILURE REPORTING AND CORRECTION

3.8.1 Requirements of the Activity

The contractor shall employ a controlled system for identification, reporting, analysis, remedy, and prevention of recurrence of functional nonconformances and suspected nonconformances of a functional nature which occur throughout specified portions of the contract effort. Hereafter this is called the "problem/failure reporting system." This system shall be consistent with applicable requirements for nonconforming article and material control as stated in Chapter 8 of NHB 5300.4(1B), and shall also satisfy the following requirements:

A. Cover the hardware and software as specified below, the interfaces between the hardware and this software, and the interfaces between hardware or software and testing or operating personnel. Hardware shall include all flight-configured hardware, ground

3.6 ELIMINATION OF HUMAN-INDUCED FAILURE

The contractor shall provide for elimination of potential sources of human-induced failures from basic design through operational use. Special emphasis shall be applied in this area to hardware and software involved in ground support, in mission operations, and in flightcrew operations. Features to eliminate potential human-induced failures shall be given careful consideration in design reviews.

To minimize human-induced failures, a systematic effort shall be directed toward making proper and safe use of the convenient hardware and software and toward making improper or unsafe use inconvenient or extremely difficult. This effort should enhance the system's capability to be fabricated, handled, maintained, and operated with maximum facility and minimum hazard to life and equipment. The effort shall cover the design of the equipment, analysis, and elimination of reported problems and failures, and all operational and instructional material and training associated with its handling, storage, transportation, checkout, and use.

3.7 DESIGN REVIEW PROGRAM

3.7.1 Design Reviews

The contractor shall establish and conduct a formal program of planned, scheduled, and documented design reviews as identified in the program development plan. Design reviews shall be conducted on each critical item with interdepartmental participation, including personnel from the contractor quality and reliability organization as well as NASA representation, at the discretion of the cognizant NASA installation. FMEA's are to be available at design reviews. The contractor's reliability organization and other participating elements of the contractor's organization shall sign all design review reports to indicate concurrence with the completeness of the review and actions to be taken. Assignment of followup actions as a result of design reviews shall be documented to include the responsible individual's organization and the steps taken to complete satisfactorily the assigned action(s). These provisions shall be invoked on all subcontractors, whose item or components have been determined to be critical items (Category 1 or 2) or limit-life items.

on the FMEA. This criticality determination shall be performed on each critical item based on the items applicable failure mode, the system loss probability from the failure effect analysis, failure frequency ratio, and the items unreliability. (Use Part II of MSFC Drawing 10M30111A as a guideline for performing the criticality analysis).

NOTE: When the FMEA is performed to the part level, the criticality analysis shall also be to the part level.

3.4.3 FMEA and Criticality Analysis Completions

Preliminary FMEA and criticality analysis will be completed before Preliminary Design Review (PDR). Final FMEA and criticality analysis will be completed 30 days before Critical Design Review. Update will be commensurate with other program milestones and shall be defined in the Reliability Program Plan.

3.5 WEAROUT AND AGEOUT MODE EFFECTS ANALYSIS (WAMEA)

The contractor shall conduct a Wearout and Ageout Mode Effects Analysis on each item covered by the FMECA to identify critical end of life failure modes and effects of ageing and wear. A limited life (time/cycle and age) items list shall be compiled and maintained. Operational life estimates and performance degradation detecting techniques are to be provided in accordance with guidelines provided by NASA.

The contractor shall ensure that controls are imposed on all time/cycle and age sensitive items identified by the Wearout and Ageout Mode Effect Analysis. Drawings, specifications, and procurement documentation shall reflect the proper control and documentation requirements, including recording of data, maintenance of records, and transmittal of the information with the hardware.

Based on the results of the FMEA the contractor shall compile a critical item list. The list shall include:

A. Single Failure Points—Single items of hardware, preferably at the component level, failure of which will lead directly to a condition described by categories 1, 1S, 2A, (structural members which perform no function other than providing structural integrity are excluded).

NOTE: A component is a part, assembly, or combination of parts, subassemblies, or assemblies (usually at the replaceable items level and usually self-contained) which performs a discrete function in the operation of the overall equipment.

B. Launch Critical Components—Components not listed under single failure points, but whose failure can result in a Launch scrub, i.e., a delay sufficiently long to require retanking of propellants and/or reschedule of launch to a later date.

C. Critical Redundant/Backup Components—Redundant components whose next failure results in a condition described by categories 1, 1S, and 2A. This list shall include components of operational backup systems.

D. Ordnance System Components—(Pyrotechnics only).

The critical item list shall be accompanied with the failure consequence of each critical item and with the rationale for retention or corrective action.

For each critical item, the contractor shall perform an FMEA which identifies all piece parts (resistors, diodes, connectors, etc.) failure modes and their effects on the critical item. Based on the results of this analysis, a critical parts list shall be compiled. The critical parts list shall include all parts whose single failure results in loss of a critical item's function. The critical parts list shall be by critical item and shall include part number, part name, and manufacturer.

3.4.2 Criticality Analysis

The contractor shall perform a criticality analysis to the part level which estimates the probability of occurrence of failure mode effects identified

3.4 FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSES

3.4.1 Failure Mode and Effect Analysis (FMEA)

The contractor shall perform an FMEA to identify all failure modes and their effect on higher level hardware, the launch, the mission, and the crew. (For lower tier hardware contracts, if effect on mission and crew cannot be determined, the effect on other systems shall be identified to the highest level possible). The analysis shall include the following:

A. A functional description of each major system under analysis.

B. A logic block diagram that identifies functional relationship between all elements. (Refer to MSFC Drawing 10M30111A, for guidelines).

C. Within each system, the name of each component, part number, functional description, and quantity used.

D. Component failure modes, considering that they may result in any of the four general failure types:

1. Premature operations.
2. Failure to operate at a prescribed time.
3. Failure to cease operation at a prescribed time.
4. Failure during operation.

Typical examples of failure modes are: no output, fail open, fail closed, short, leakage, etc.

E. Failure effect on subsystem, other systems (interfaces) launch, mission, and crew safety. (For lower tier hardware contracts, if effect on mission and crew cannot be determined, the effect on other systems shall be identified to highest level possible).

F. Criticality classification in accordance with Appendix A.

G. The failure mode and its effect for each mission phase.

H. Recommendation for each failure mode, e.g., design change, quality control methods, maintenance provisions, checkout capabilities, operating procedures, possible alternate methods for accomplishment, etc.

I. The effect of loss of any input furnished by equipment not included in this analysis, but required for operation of the equipment being analyzed; for example, loss of electrical power or thermal control furnished by hardware whose design responsibility is that of another contractor or government agency.

(or periodically) on an overall basis. The documentation of individual design specification reviews shall be used as inputs at design reviews of components and subsystems, and the overall summaries shall be used as inputs at subsystem and system level design reviews and in program status reporting.

Although design specifications are primarily the responsibility of the design and systems engineering organizations, it shall be the function of the reliability organization to require their revision when they are found to be functionally out of date or otherwise deficient. Design specifications and their revisions shall be subject to NASA action as specified in the contract.

3.3 RELIABILITY GOALS

The contractor shall review reliability requirements established in the program, project, and CEI specifications, to assure that established reliability goals for the program are clearly stated and accompanied with a definition of the conditions which constitute achievement of these goals. The goals shall be feasible requirements which can be incorporated into the design and evaluation of the hardware. Examples of goals are as follows:

3.3.1 Design Goals

A. No single failure shall abort the mission.

B. Failure occurring within a subsystem shall not propagate across the interface between the subsystem and other subsystems.

C. Maintenance can be performed within the allowable systems downtime.

3.3.2 Test and Evaluation Goals

Prior flight and/or ground test will have demonstrated that systems elements are capable of meeting reliability/maintenance requirements.

NOTE: Numerical reliability goals will be stated only when the method of determining accomplishment is defined.

drawings and other technical documents which include pertinent qualification, test and inspection requirements.

2.6 RELIABILITY OF GOVERNMENT-FURNISHED PROPERTY (GFP)

Where the overall system includes components or subsystems furnished by NASA, the contractor shall be responsible for obtaining via the procuring NASA installation adequate reliability data on these items for use in performing required reliability tasks for the system. Where examination of these data or testing by the contractor indicate inconsistency of the reliability of Government-Furnished Property with the reliability requirements of the overall system, the procuring NASA installation shall be formally and promptly notified for appropriate action.

Section 3

RELIABILITY ENGINEERING

3.1 GENERAL

Reliability engineering consists of a number of interrelated tasks and is considered an integral part of the project activity. The level of effort in individual reliability engineering tasks varies with the phase of the project life cycle which the task in question supports; e.g., tasks supporting design peak at an early time, while those supporting test activities peak later. This Section describes the basic reliability engineering tasks.

3.2 DESIGN SPECIFICATIONS

The contractor's reliability organization shall review for concurrence all design specifications or shall ensure that they are independently reviewed prior to their release. This review shall ensure that the set of specifications covers all items of hardware at the appropriate levels, that each is complete in its contents, and that each is functionally (and physically) consistent with interfacing design specifications. These reviews shall also be conducted whenever individual specifications change; they shall be documented individually as they occur and shall be summarized at milestones

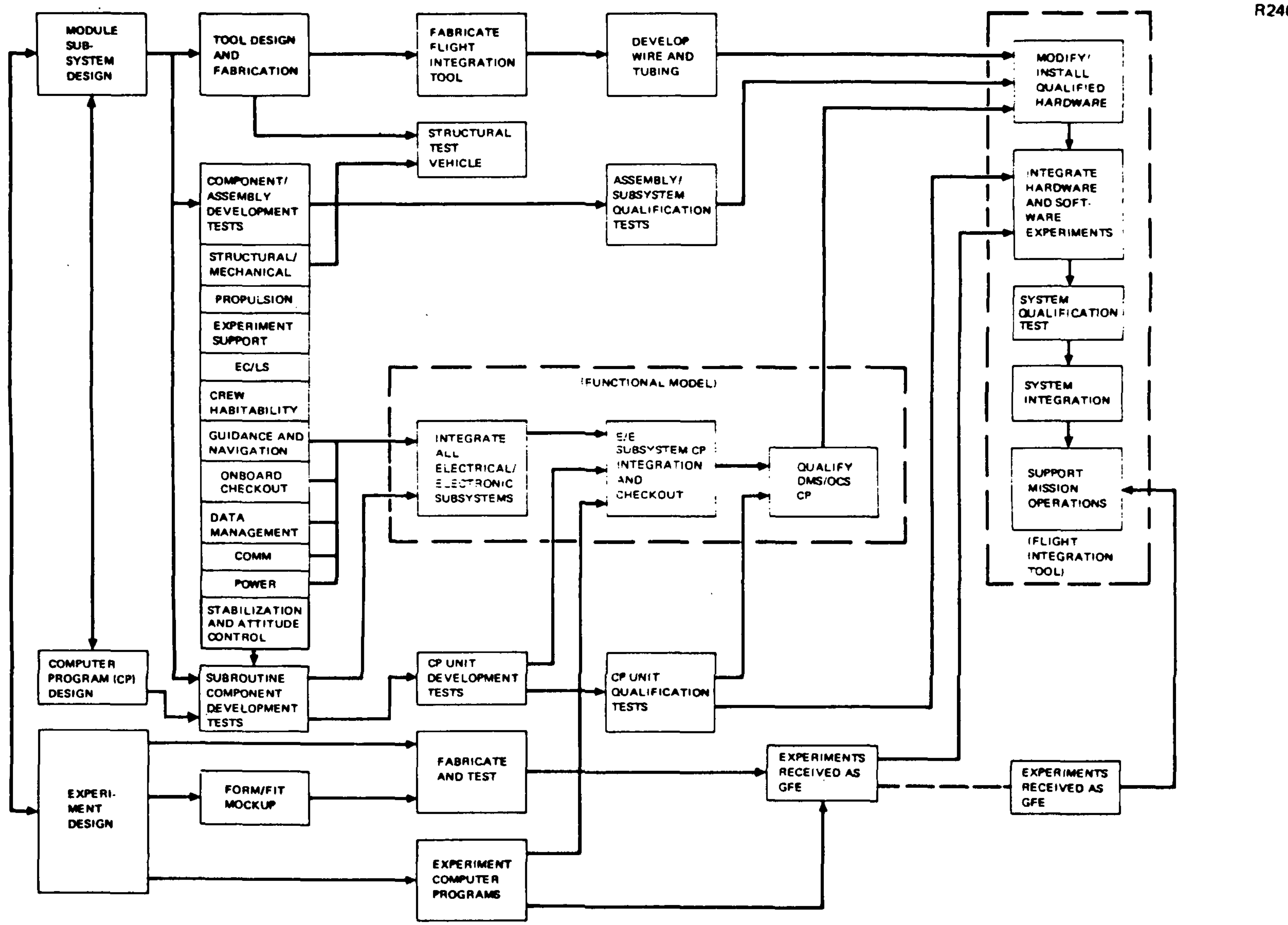

Figure 3-4. Integration Using Flight Integration Tool

checking out RAM project modules and integral experiments during the ISS phase as well as the added Space Station modules to achieve GSS.

During the life of the program, the lower level hardware will change, if only because of the unavailability of originally qualified replacements; e. g., the part is out of production or the manufacturer is out of business. The replacement item will be qualification tested and the qualification specimen installed on the FIT, maintaining its integrity for operations support and configuration management. It is expected that similar confirmations with regard to compatibility with the logistics system would be accomplished.

C. Crew Integration—The flight crew will be at the contractor's site through flight module production as a minimum. The contractor shall identify those tasks for which the participation of the flight crew is required. Additionally, maximum use shall be made of these personnel to ensure compatibility with the flight hardware and software.

3.4 ACCEPTANCE

These verifications occur during receiving inspections, in-process tests and inspections, acceptance of new or modified GSE, and checkout (Figure 3-5). Receiving inspections and in-process tests shall be performed in accordance with the Quality Plan Requirements and the contractor's inhouse control documents. As a minimum, this type testing shall include the following requirements:

A. Receiving tests and inspections shall be conducted on all levels of hardware upon receipt at the contractor's plant or using site.

B. In-process tests and inspections, although minimized by the absence of a production run, shall be performed at points of assembly where further assembly will reduce the capability to perform a complete functional test or inspection of the item.

Final acceptance of new and modified GSE shall be accomplished, when possible, after the GSE has been mated with its interface; compatibility testing will be accomplished to ensure interface operations.

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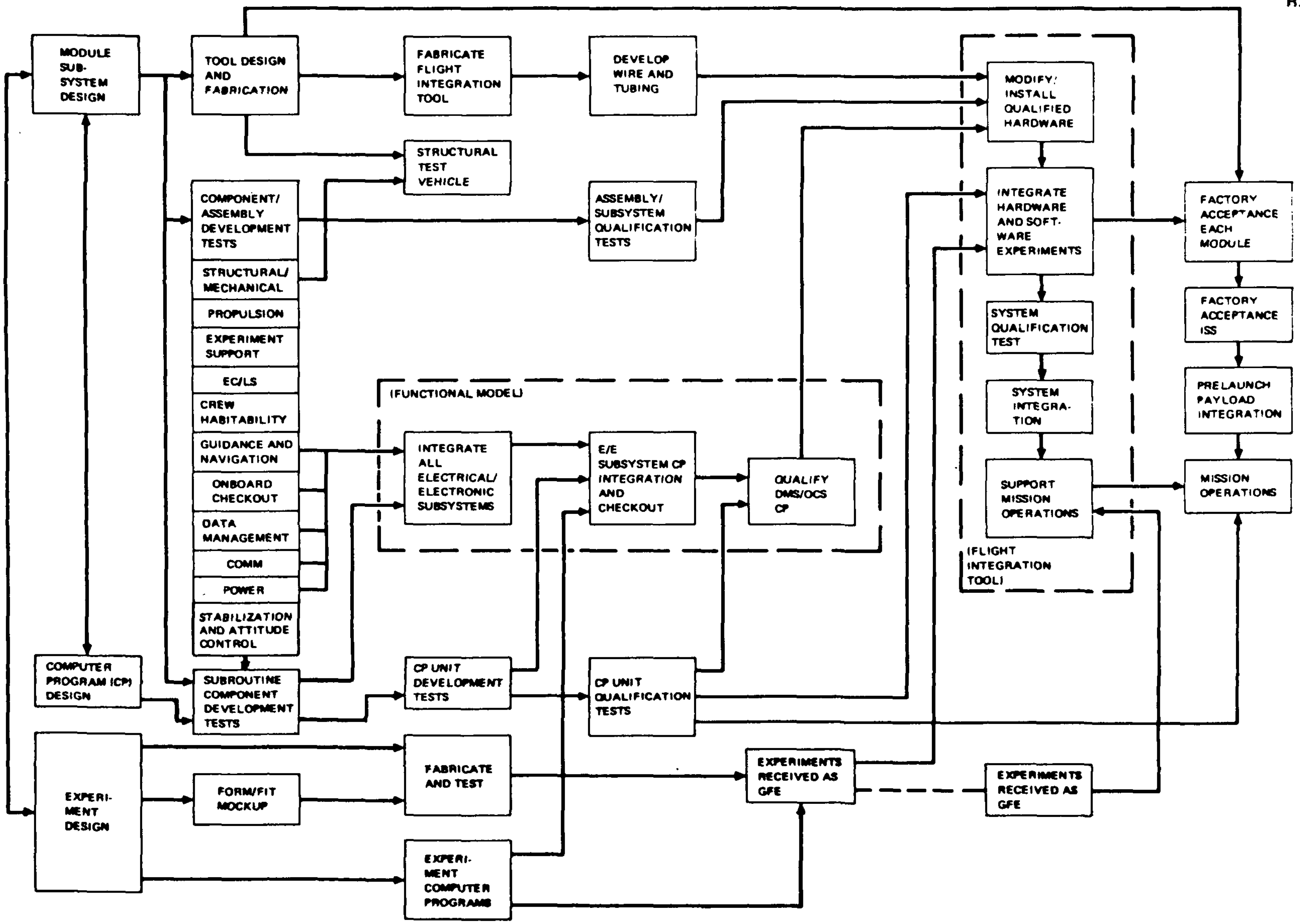

Figure 3-5. Acceptance, Prelaunch, and Orbital Operations

Acceptance of the ISS Modules shall be conducted separately and collectively using the accepted OCS with the executive computer program. Included in the final flight module checkout will be EMI testing. These tests shall proceed by bringing each module outline, using the FIT and GSE and adding modules until all modules are operating collectively. When the Initial Space Station Modules/Space Station CP Major Segment has been accepted, the system level acceptance is complete. Acceptance of Logistics Modules shall maximize the use of interface simulators and minimize additional project GSE. The payload weight restrictions imposed by the orbiter may necessitate offloading items (e.g., expendables and CMG's) after acceptance testing and transport to orbit by subsequent modules. Additional acceptance testing of such offloaded items is not considered necessary.

At the time the two additional modules are built for the GSS phase, acceptance will take place in orbit or by using the FIT. This decision is not necessary for the planning of ISS testing.

3.5 PRELAUNCH CHECKOUT

Prelaunch checkout (Figure 3-5) encompasses all operations at the launch site. These activities fall into the following three separate types of tests: (1) checkout of each module to ascertain its integrity following transport; (2) module/orbiter interface tests following installation of the payload in the Orbiter cargo bay; and (3) final confidence checks on pad to ensure that servicing and the move to the pad have not degraded flight readiness.

The Prelaunch and Launch Operations Plan Requirements specifies readiness for these test operations.

3.6 MISSION OPERATION TESTING (Figure 3-5)

Whereas previous spacecraft have been launched integrally, the in-orbit buildup of the Modular Space Station has implications on both ground tests and orbital operations. Ground testing must be planned as to provide the greatest confidence in the Station's capabilities prior to transport from the factory. Integral Systems testing described above will verify within all practical limits the buildup and orbital operations, but the crux of this verification must take place in orbit. Figure 3-6 depicts an example of the verifications

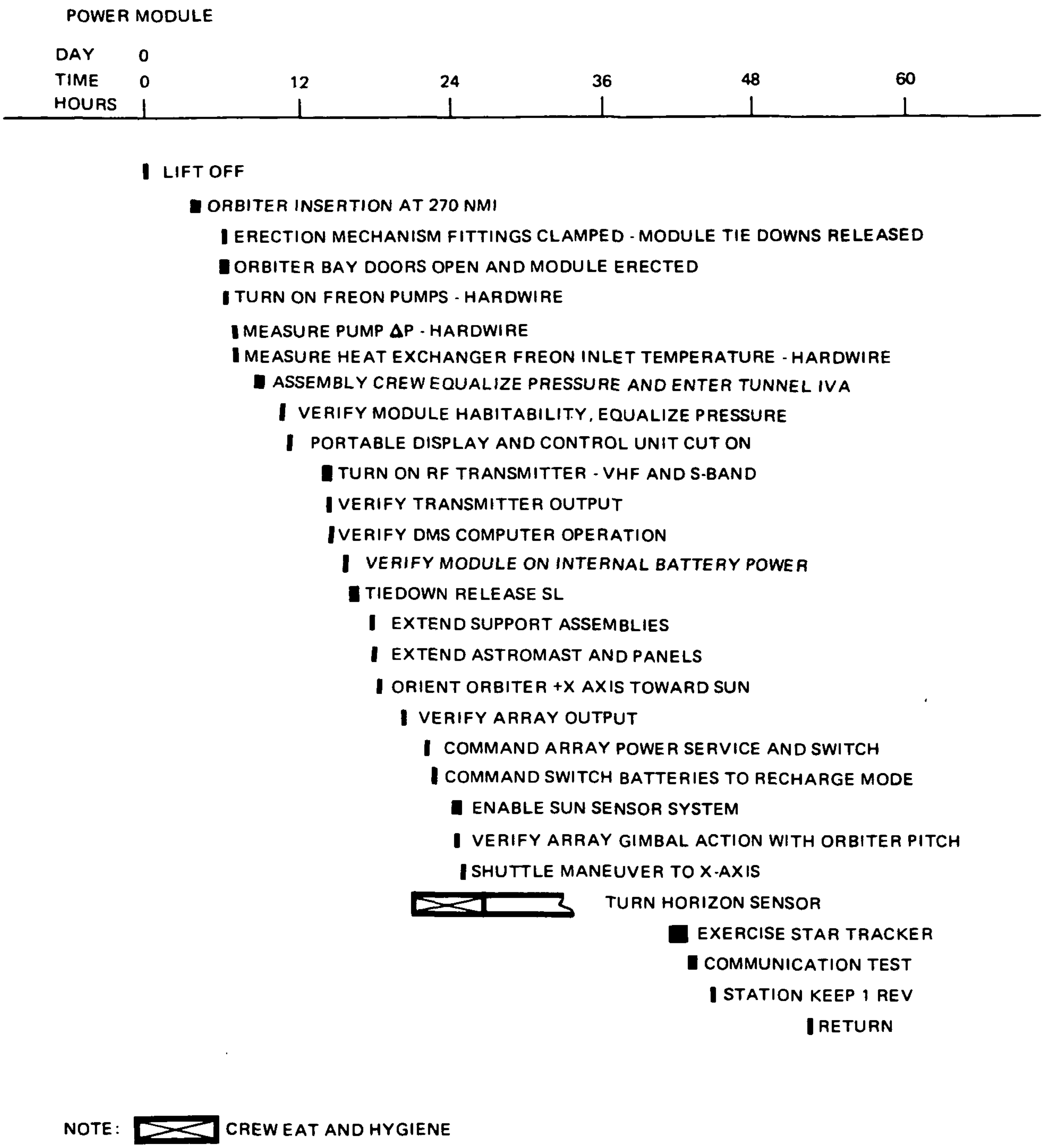

Figure 3-6. Power Module Activation Sequence

that might be performed during the activation of the Power/Subsystems Module. Similar procedures will be developed for the remainder of the activation sequence. The culmination of the buildup verification will be a total system test to ascertain the operation of onboard and ground systems for initiation of sustained operations. The completion of this test shall constitute IOC.

Additionally, the Onboard Checkout System, which will have been the primary tool for buildup testing, routinely conducts tests to establish Station status by automatically monitoring specific data points. This operational capability shall also influence test planning so that test data from component level testing is compatible with these data points.

The Mission Operations Test Plan shall specifically address those tests or checkouts that will be performed in orbit in accordance with mission plans to establish the status of the Space Station whether in buildup or in an operational mode.

During a 10-year mission, it is expected that a part/CP component, etc., may fail that was procured from a vendor who has subsequently gone out of business. In such a case, a replacement part will have to be qualification/acceptance tested before being ferried to the Space Station for replacement. These tests are not to be considered mission operations tests and hence are not within the purview of the Mission Management Complex. The contractor shall address this problem and provide for this type of support.

Section 4

ORGANIZATION AND RESPONSIBILITIES

Verification Program objectives shall be met by taking the following approach:

A. Establish verification management system emphasizing working level participation.

B. Identify and control Section 4 requirements rigorously.

C. Define and enforce interfaces for smooth integration.

D. Confine testing to CEI/CPCEI requirements or increased confidence.

E. Provide contractual flexibility to incorporate test result impact.
F. Provide overall visibility for more sound test program.

4.1 ORGANIZATIONS AND INTERFACES

As shown in Figure 4-1, verification management for the Modular Space Station Project is to be at three levels: the Space Station Project Office, NASA centers having direct project responsibilities and/or support responsibilities (including the CEI Manager), and the Contractor.

4.1.1 Program Office

The Program Office by means of the Program Specification will establish overall verification policy. This policy shall specify program verification requirements which, in addition to verifying the Level 1 performance, design, and interface requirements, will establish the management principles and technical guidelines to structure a cost-effective test program.

4.1.2 Project Office

The Project Office and CEI Manager will define requirements consistent with policies established at the Program Office and shall ensure that verification plans and methods are consistent with these policies and requirements. Project and CEI verification requirements are specified in Section 4, Verification, of the appropriate specification.

4.1.3 Resident NASA Office

Although test programs should be developed for a minimum of NASA daily participation in the working-level activities, there are some activities which must be reviewed and approved before activities are started; e.g., qualification tests, and acceptance buy-off. Authority and responsibility will be delegated to resident NASA representatives by the Program or Project Office to facilitate a quicker approval cycle and test program flexibility and responsiveness. The General Verification Plan shall address this relationship and make recommendations for the accomplishment of these goals.

4.1.4 Contractor

The contractor shall translate Program and Project Office policies/ requirements into requirements for verifying CEI performance/design solutions, including CEI-to-CEI interface requirements. The verification

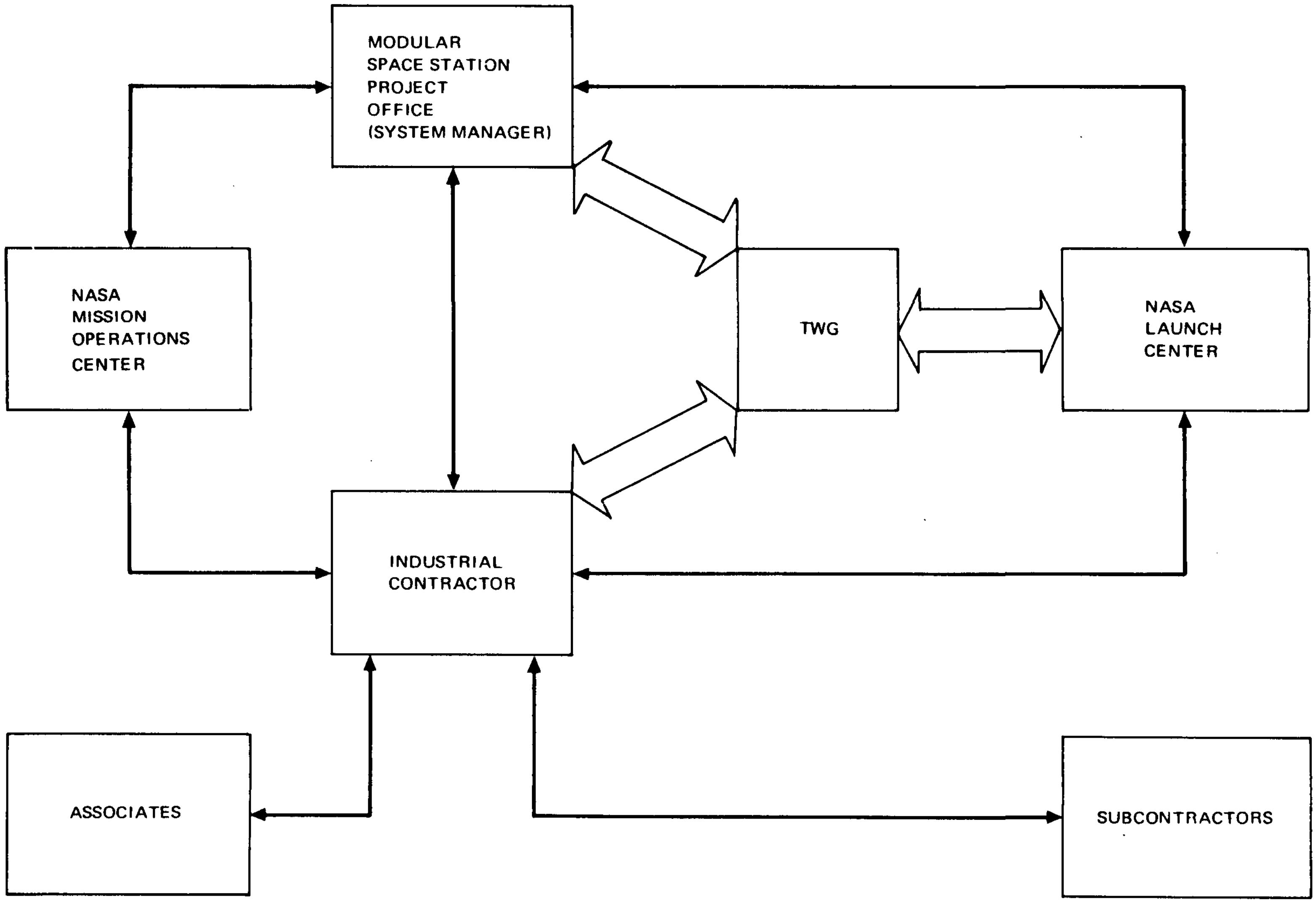

Figure 4-1. Modular Space Station Project Test Interfaces

program shall be implemented at the working level through test plans which shall be under the cognizance of the contractor and CEI manager. The contractor must, however, substantiate that these plans satisfy CEI and project specification requirements.

The General Verification Plan shall contain a definition of the detailed verification organization and its test interfaces with associate contractors, subcontractors, and project working groups. The organization shall incorporate features which reflect the above management principles and the program management objectives stated in the Program Management Requirements Plan.

4.1.5 Test Working Group

A Test Working Group (TWG) shall be established, consisting of NASA center and contractor test program personnel from the working level to make recommendations as a group on the test plan and schedules. The TWG shall be co-chaired by a NASA representative and a contractor representative, each empowered to speak for his management. The membership shall have test-organization representation. The primary responsibilities of the TWG are as follows:

A. Establish criteria and constraints for the project test program from component development through prelaunch checkout of the modules.
B. Review test concepts.
C. Ensure test requirement conformance and traceability with design/performance by continuous test-plan reviews.
D. Establish test interface control requirements.
E. Resolve technical test problems.

This group shall constitute the major working level test interface between the Modular Space Station Project Office and the industrial contractor. Its activities shall be conducted on an orderly basis with well-documented minutes and agenda. Any questions of a contractual nature shall be directed to the formal organization for resolution.

4.2 ROLES AND RESPONSIBILITIES

The Space Station Program Roles and Responsibilities document of the Space Station Program (Modular) Plan, (DR Number MA-05, Vol. I), shall be used as a guide in identifying and describing the roles and responsibilities at the project level and how they will be accomplished.

The General Verification Plan shall include the definition of interfaces for assessment and test within the company structure, as well as for associate and subcontractor. It shall define these organization interrelationships so that the responsibility for any task (i. e., plan, procedure, test, or report) is not divided, there are no gaps or redundancies, and the performer of the task is certain for what and to whom he is obligated.

4.3 JOINT OPERATING PLAN/AGREEMENTS

The contractor shall establish in the General Verification Plan the methods and procedures envisioned to provide for a smooth flow of test hardware, software, and test support equipment (fixtures, instrumentation, GFE, STE, and GSE) and timely use of facilities and support services. These methods shall address the requirements contained in the Interface and Support Requirement documents with special emphasis on "Exchange Hardware and Delivery Dates" and "Exchange Services and Performance Periods" requirements.

Section 5
SPECIFICATIONS AND REQUIREMENTS

Project and CEI Specifications contain verification requirements which have been established to specify responsibilities, verification methods, management review relationships, test operations, and constraints on the verification program. The methods of identifying and controlling these requirements provide great opportunities for significant project cost savings. Past programs have contained tests that have arisen from other than CEI Section 3 requirements. The contractor shall define the verification program so that testing is performed in direct response to a verification requirement and that these requirements are compatible and consistent with performance requirements of the Program, Project, and CEI Specifications. Development test requirements must be continually screened to ensure technical and program relevance.

5.1 IDENTIFICATION AND CONTROL OF VERIFICATION REQUIREMENTS

5.1.1 Identification

Using a systems engineering approach, the contractor shall define verification requirements consistent with the Program and Project Specifications and compatible with the System Safety, Reliability, and Quality Plans. As shown in Figure 5-1, four decisive steps define a verification program:

Step 1. Translates the performance requirements into verification requirements and is delivered as Section 4 of the Part I CEI Specification. This translation has been accomplished using the following logic:

- Identify method of requirement verification, i.e., analysis, inspection, demonstration, and test.
- Analyze verification requirements in terms of test types, facilities, personnel, data, etc.
- Optimize the test approach by conducting tradeoffs in terms of performance, schedule, design risk, test results, severity of environment, and cost effectiveness.
- Identify interfaces and constraints imposed by the other program/project elements, such as facilities, software/hardware, training, and subcontracts.
- Document the selected test approach in the CEI/CPCEI Specification.

Step 2. This is the primary concern of this document and results in a plan for each verification phase. This step is continually performed to "fine tune" the verification program to reflect design changes and test results.

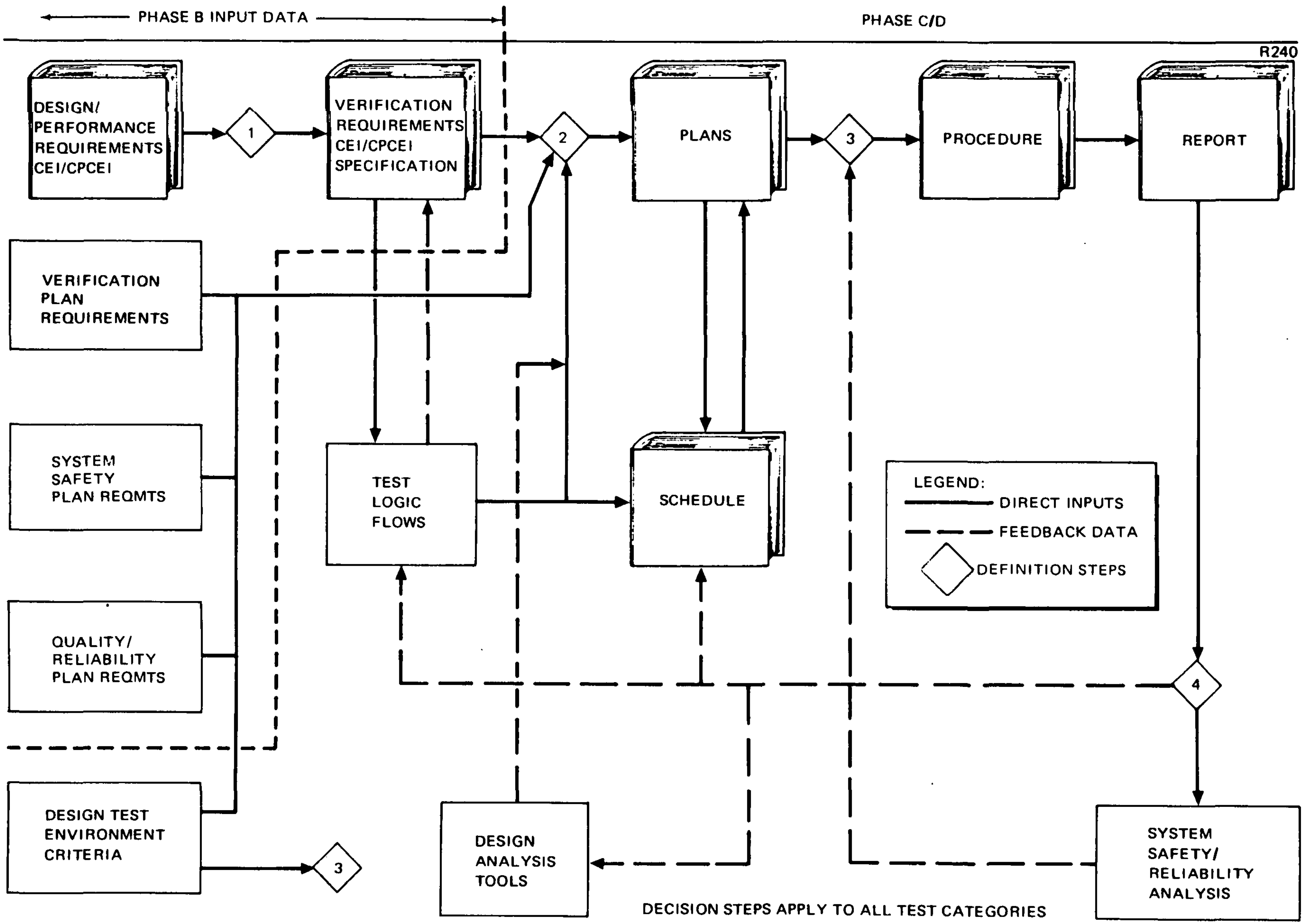

Figure 5-1. Test Identification Decision Process

The first pass through this step is critical because care must be taken to ensure that real requirements are being planned. A preliminary set of plans and schedules, along with Section 4 of CEI/CPCEI Specifications, will be reviewed and approved at Preliminary Requirements Review (PRR).

Step 3. This step results in the working level documents which direct the verification. Care should be taken here to check the requirements for the test.

Step 4. This step is the analysis of verification data and is most critical to the achievement of verification program objectives for the following reasons:

- Test status/results are compared against the plan.
- Test result impact on the design analysis tools and subsequent test plans and procedures.
- Failures and anomalies are explained or corrected.
- Test data are analyzed to gain system safety and reliability confidence.

5.1.2 Control

In the General Verification Plan, the contractor shall define a rigorous system for controlling test requirements. This system shall be implemented upon the initial agreement of test requirements at Preliminary Requirements Review (PRR) and shall continue through the 10-year mission life. The four purposes of this control system should be to:

1. Maintain constant awareness of the source of test requirements.
2. Ensure compliance with CEI/CPCEI Specifications.
3. Restrict tests to those absolutely required for this compliance.
4. Provide flexibility to incorporate design changes.

5.2 SUPPORT REQUIREMENTS

After identifying the requirements, the contractor shall identify demonstration and test facility/equipment, support software, personnel, procedures, and safety requirements. These requirements shall be summarized in the associated plans and described in the appropriate test procedures. The summary shall provide the NASA with a correlation of the item with the verification and a plan for activation and operation.

5.2.1 Test Article/Item/Specimen

The contractor shall identify and describe the test article/major test items/ specimens required to support the verification program. Maximum use shall be made of mockups, trainers, and integration fixtures. When a particular article/item/specimen is used for more than one activity or at more than one test location, this shall be identified as such. In developing these items, the contractor shall maximize use of previously tested hardware, the relocation of an item to reduce program costs, and the continuing use of these items for integrating or training activities throughout the mission duration.

5.2.2 Test Facilities/Equipment

The guideline of imposed environment testing at the component/assembly/ subsystem level and none at the system level minimizes the need for any new test facilities. Test facilities and equipment already in existence shall be used to the maximum extent. Reference should be made to NHB 8800.5, Technical Facilities Catalog, in planning tests. Specific attention shall be given to the requirements of integrated systems testing. Test equipment and GSE needed to simulate inputs/outputs to subsystems must be compatible with the Onboard Checkout System as well as other subsystems. GFE and GSE shall also be identified. The contractor shall functionally checkout all test equipment and GSE to ensure that no damage or degradation of the test specimen is introduced into the test hardware or that results will not include test equipment error. (Refer to NHB 5300.2.)

5.2.3 Special Test Computer Programs

Subsystem and integration testing will require complete or interim versions of deliverable scheduled computer programs or portions thereof. However, in the conduct of most tests, additional, nondeliverable computer programs are needed to control the specimen or test environment as well as to simulate interfaces. The contractor shall establish policies for designing and coding to ensure that these computer programs are compatible with project software and consistent with the appropriate CP segment logic.

5.2.4 Experiment Integration

The contractor shall define requirements for the integration of integral experiment software and hardware. The principal investigator shall comply with these requirements, when applicable, so that his experiment will be available for integration and checkout. These requirements shall reflect the use of the FIT to verify interfaces prior to transport to the cluster.

5.3 QUALITY ASSURANCE/RELIABILITY REQUIREMENTS

The contractor shall provide for the control of hardware/software configuration, explanation of test failures/anomalies, test specimen history, and the proper corrective action by implementing the Quality and Reliability/Maintainability Plans Requirements. The contractor shall describe his system for using all test data to ascertain system effectiveness. The Quality and Reliability/Maintainability Plan Requirements specifies the content of this system.

5.3.1 Configuration/Part Number

The test planning shall provide for the traceability required to satisfy the requirements of Quality Plan Requirements pertaining to critical items and limited operating-life items. The interfaces between hardware and computer programs while they are being tested shall be considered. In addition, the use of the FIT as an "as-built" configuration control and sources of spares shall be included.

5.3.2 Failure/Retest

The contractor shall define and implement a rationale philosophy of failure and retest which will contribute to ensuring a reliable system at a minimal cost. This philosophy shall be compatible with the design philosophies, long-life assurance, and quality assurance and reliability. The Reliability/Maintainability Plan Requirements developed in Phase C/D shall contain methods and procedures to explain all failures and distinguish between specimen failures, test procedure failures, human failures, and test equipment failures. In addition, policies and procedures for controlling the quality and reliability of computer programs and associate software shall be defined.

5.4 SAFETY

The contractor shall refer to the System Safety Plan Requirements, and relevant industrial safety codes and practices in planning and conducting the test program. Specific identification and description of safety programs shall be made of those testing activities involving human subjects or radioactive materials.

5.5 DESIGN/TEST ENVIRONMENT CRITERIA

The contractor may find it of some value to prepare a Design/Test Environment Criteria document to guide the preparation of test plans and procedures in Phase C/D. These criteria shall be compatible with design criteria specified in Section 3 of the Project and CEI Specifications and reflect the capability of existing test facilities and equipment. Regardless of whether this document is prepared, the contractor shall describe the method of confining test environments to environmental design requirements.

5.6 VERIFICATION CONDUCT AND CONTROL

The contractor shall implement the verification program at the working level. The individuals directing and participating in the verifications shall be aware of the objective, requirements, project interfaces, and contractual obligations. The contractor shall provide assurance to the Government that the checkout crew is proficient and qualified to conduct verification. The contractor shall further ensure that each verification is conducted in accordance with the policies and procedures specified herein. This may be accomplished by the establishment of a centralized requirements/management organization made up of representatives from the working level and Test Project Office.

5.7 DATA ACQUISITION/DISPOSITION

The contractor shall plan the verification program to optimize the use of data during all project phases. It shall be compatible with the following requirements:

A. Data shall be acquired in a manner which provides a compatibility with methods used during FM and FIT activities.

B. Data acquisition equipment and data points shall be used which best simulate the On-Board Checkout System (OCS) and Data Management System (DMS) specifications to ensure compatibility and optimized use.

C. Test data shall be maintained by the contractor until the TWG determines that it may be disposed of.

D. Test data shall be made available to the Mission Management Complex to facilitate mission operations analysis.

5.8 MANAGEMENT REVIEWS

The test program shall be reviewed in conjunction with other project tasks on a formal basis at (1) Preliminary Requirements Review (PRR), (2) Preliminary Design Review (PDR), (3) Critical Design Review (CDR), and (4) First Article Configuration Inspection (FACI). The detailed requirements for these reviews are specified in the Design Plan Requirements, and Section 4 of the Project Specification. Active participation by test management is required at each review. This participation is specified in the Program, Project, and CEI specifications.

Section 6
SCHEDULES

The contractor shall develop and maintain detailed schedules to the CEI/CPCEI level for verification activities. As shown in Figure 5-1, these schedules should evolve from logic flow diagrams which are prepared during pre-ATP and shall be included in the General Verification Plan, but shall be maintained throughout Phase C/D. These activities and schedules shall relate to and be consistent with the Program and Project Specifications, schedules, and milestones, and reflect the following activities and requirements:

A. Significant development tests.

B. Fabrication of test hardware and substitutes.

C. Development of special test computer programs.

D. Interrelationships of software and hardware verification.

E. Subsystem/CP segment and system/CP major segment integration activities.
F. Hardware/software interchange.
G. Support equipment/facilities/GSE/use.
H. Hardware configuration and flow to emphasize multipurpose usage.
I. Major constraints arising from the test plan or imposed upon it; e.g., PRR, PDR, CDR, and other reviews.

Internal working schedules shall be prepared and maintained by the contractor for testing activities at hardware and software levels lower than the CEI. These schedules shall be prepared in the contractor's own format and should be realistic working schedules. The scheduling system shall be reported in the appropriate plans.

6.1 SCHEDULING GUIDELINES

The Modular Space Station Project schedule identifies the major milestones for the project and overall program milestones based upon the Phase B Study. In preparing the schedules specified above, the contractor should use the program/project schedules, together with the verification philosophy and integration logic shown in this document, tempered by the following guidelines:

A. It is desirable to have all design and hardware conceptual development completed by the end of Phase C.
B. Development at levels lower than the system should be completed by the Critical Design Review (CDR).
C. Development hardware and software should be used for development integration activities when possible.
D. Structural/Mechanical CDR must occur sufficiently early to permit the assembly of Flight Integration Tool (FIT) structure at the end of project PDR.
E. On-Board Checkout System (OCS) PDR must occur sufficiently early to support the integration of electrical/electronic subsystems and computer programs.

F. Qualification testing of subsystem/CP segment and lower levels should be accomplished before flight vehicle installation.

G. Qualification test hardware shall be installed in the FIT and modified computer programs shall control its operation.

H. The FIT shall be used to verify the operational modules for a 10-year mission and conversely, the FIT must be verified for its 10-year mission support role.

I. Operational module acceptance testing shall be conducted using an accepted OCS. This requires prior acceptance of the applicable software.

6.2 TEST STATUS

The status of Space Station test activities, actual versus planned, shall be identified and maintained for all activities specified above. Although only status reporting at the CPCEI/CEI specification level is required, the contractor shall provide means of reporting status at the lower levels. These lower level schedules and status reports will be major tools of the TWG.

Section 7
DATA/HARDWARE/SOFTWARE INTERCHANGE

Informal interchanges will be required to integrate the various hardware, software, and experiment activities leading up to and taking place during the integrated and checkout verifications. The exchange of hardware design information to the computer program writer, the provision of experiment definition to the core module engineer, etc., have great implications upon this integration.

The contractor shall address this interchange in all requirements and specification documents and shall implement a communication system to provide the desired end. Every managerial component that has the need for these data shall be provided with it. Specifically, the General Verification Plan should define those methods to be used by the contractor in verifying the design solutions (Interface Control Documentation) against the requirements of the Interface and Support Requirements document.

Section 8
DOCUMENTATION AND REPORTING

The contractor shall prepare and maintain verification program documentation in sufficient detail to ensure (1) meeting the objectives of planning and tracking for visibility and traceability, (2) requirement identification and control, (3) procedure preparation and control, and (4) test performance status, while remaining consistent with absolute need and cost effectiveness as specified in the Program Management Plan Requirements. This can be accomplished by restricting the preparation of documents to only those required for planning, conduct, and control.

Table 8-1 specifies the suggested verification documentation for the Modular Space Station Project. As stated above, it is the contractor's responsibility to prepare and maintain documentation in sufficient detail to provide visibility to the NASA; therefore the General Verification Plan shall identify the extent of documentation necessary to accomplish these goals. The contractor may require additional documentation to meet the above objectives. The data requirements list proposed by the contractor shall be established in the Contract Statement of Work and shall be identified as line items on the Contractor Data Requirements List (CDRL), NASA Form 1106. These line items shall be defined by Data Requirements Description (DRD), NASA Form 1107. These documents shall be consistent and compatible with other project/program documentation. Furthermore, they shall be prepared so that changes are reviewed, approved, and incorporated with minimal revisions and cycling time.

8.1 SPECIFICATIONS

The verification program shall have basis in the verification requirements specified in Section 4 of each end-item specification and cross referenced to the design/performance requirements of Section 3. The verification plan is established directly from the interpretation of these verification requirements, the Design/Test Environmental Criteria Document, and other plans which may guide the contractor in his implementation of Program and Project Specifications. These specifications shall be revised as necessary to reflect directed project changes and shall be the touchstone for all testing activities.

Table 8-1

MODULAR SPACE STATION PROJECT

SUGGESTED VERIFICATION DOCUMENTATION

Description	Category*
Design/test environment criteria	(IV)
General verification	I
Development plan	(IV)
Qualification plan	(I)
Integrated Systems plan	(I)
Acceptance plan	(I)
Prelaunch and checkout plan**	
Mission operations test plan**	
Test procedures	I
Reports (verifying)	I
Reports (non-verifying)	IV
Test progress report	IV
Test requirements drawings	I

( ) Not individually mandatory - may be combined in other Plans/ Specifications

* Documentation Types:

Category I — NASA Review/Approval
Category IV — Available at contractor site but not delivered to NASA

** Refer to appropriate requirements plans

8.2 VERIFICATION PLANS

The contractor shall define the Modular Space Station Project Verification Program as described by this document, in the General Verification Plan. This plan shall identify requirements, specific tests and assessments, schedules, responsibilities, and all other requirements specified or referred to herein as being in the verification plan. The plan shall describe verification in all phases and methods for each CEI as deemed necessary by the contractor with significant tests being discussed in detail. As it becomes necessary, in Phase C/D development, qualification, acceptance, integrated systems, and prelaunch verification and significant verification methods shall be further defined in appropriate plans or by expansion of the General Verification Plan. The latter is perfectly acceptable and is actually preferred, as long as the objectives of visibility and completeness are met. Software verification documentation requirements are specified in the Software Integration Plan Requirements.

8.3 VERIFICATION REPORTS

The contractor shall be responsible for the preparation of reports covering all completed verifications. Reports which contain data to accomplish a Section 4 verification requirement shall be approved by NASA. Other reports shall be made available to NASA by individual request.

8.4 TEST PROGRESS REPORTS

The contractor shall be responsible for providing to NASA periodic test progress reports to identify major accomplishments, major problems and their planned corrective actions, and the plan for the next reporting period. These reports shall be consistent with project management instructions and those stated herein.

8.5 CORRECTIVE ACTION/FAILURE CORRECTION REPORTS

The contractor shall apprise the Modular Space Station Project Office of all failures and subsequent corrective action occuring on hardware and software classified in Criticality Categories 1 and 2. This appraisal shall be submitted in accordance with the Quality and Reliability/Maintainability Plans Requirements.

MODULAR SPACE STATION
FACILITY UTILIZATION PLAN REQUIREMENTS

FACILITY UTILIZATION PLAN REQUIREMENTS

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FACILITY UTILIZATION PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

This document has been prepared to guide contractor planning and bidding for Phase C/D. It defines the facility requirements and their application for the Modular Space Station project, the organization and general operating control/procedures, and policies and objectives to be applied in preparing the Phase C/D Implementation Plan(s).

1.2 SCOPE

The Implementation Plan will cover both contractor-owned and Government-owned facilities required for engineering, manufacturing, assembly, test prelaunch, launch, and mission support. The plan shall encompass the Phase C/D time span. Significant facility milestone dates shall be defined in a Master Phasing Schedule. Other program plans that have facility requirement inputs or relationships are the Design, Manufacturing, Verification, Prelaunch and Launch Operations, Program Management, Software Integration, Crew Training, and Logistic Support Plans.

This plan shall (1) identify the facility requirements peculiar to the Modular Space Station Project, including new facilities and modifications to existing facilities; (2) identify the significant milestones in acquiring and activating facilities; (3) identify documentation requirements related to Modular Space Station facilities; and (4) recognize interrelationships with other elements of the national space program.

1.3 CONTROL

This plan will be published, revised, and distributed in accordance with the instruction contained in the Contractor Data Requirement List (CDRL).

Section 2
GENERAL REQUIREMENTS AND CONSTRAINTS

A description of the Modular Space Station configuration will be found in DR SE-04, "Modular Space Station Detailed Preliminary Design."

2.1 FACILITY APPROACH

To reduce costs, maximum effort will be made to use existing facilities or to require only minimum-cost modifications. It will also be necessary for the Modular Space Station Program to share facilities with other elements of the NASA space programs. This means that close control must be maintained over all utilization schedules to prevent intolerable interference.

2.2 OPERATIONAL SITES

2.2.1 Contractor Sites

The contractor will provide facilities for design, fabrication, assembly, and test of Modular Space Station systems components and assemblies. The contractor will also be required to provide special facilities, such as those required for propulsion system testing, or handling or test of other toxic or hazardous materials.

When contractor facilities are inadequate or otherwise unsuitable and would require the expenditure of funds for new facilities, the use of Government-owned facilities will be considered, and candidate sites identified.

2.2.2 Government-Owned Facilities

Government-owned facilities will be provided for Space Station prelaunch and launch activities and for mission support. The contractor shall identify facility requirements necessary to accommodate his activities in support of these functions. Government-owned facilities will be made available within the limitations of existing procurement practices and with due regard to existing program schedules. Existing Government facilities will be modified, or additional facilities will be constructed, as indicated by project requirements and as justified by trade studies.

2.3 FACILITY CONSTRAINTS

2.3.1 Costs

The contractor will expend maximum effort to assure that facility costs are kept at the practical minimum. New construction or modifications to existing facilities will be approved only when no satisfactory alternative solution can be found.

2.3.2 Specified Facilities

Kennedy Space Center (KSC) will provide the launch facilities for the Modular Space Station project.

2.3.3 Common Usage

The Space Station Project will share the facilities at KSC with other elements of the space program in the same time frame. Facilities selection will take facility requirements of other programs into consideration. No modifications will be allowed that would permanently destroy current capabilities.

2.3.4 Clean Work Areas

Specification clean rooms will not be provided except where an absolute requirement can be shown.

2.3.5 Schedules

A Space Station Project milestone schedule and a facility activation plan will be generated. Major milestones will include A&E design Critical Design Reviews (CDR's), Beneficial Occupancy Dates (BOD's) and operational readiness dates. A typical milestone schedule is included in Figure 3-1.

Section 3
CONTRACTOR FACILITIES

3.1 ENGINEERING AND DEVELOPMENT

The contractor shall provide the areas for engineering, computing, reproduction, library, files, etc., required to support design and development of the Space Station Modules. An area will be required for a full-sized

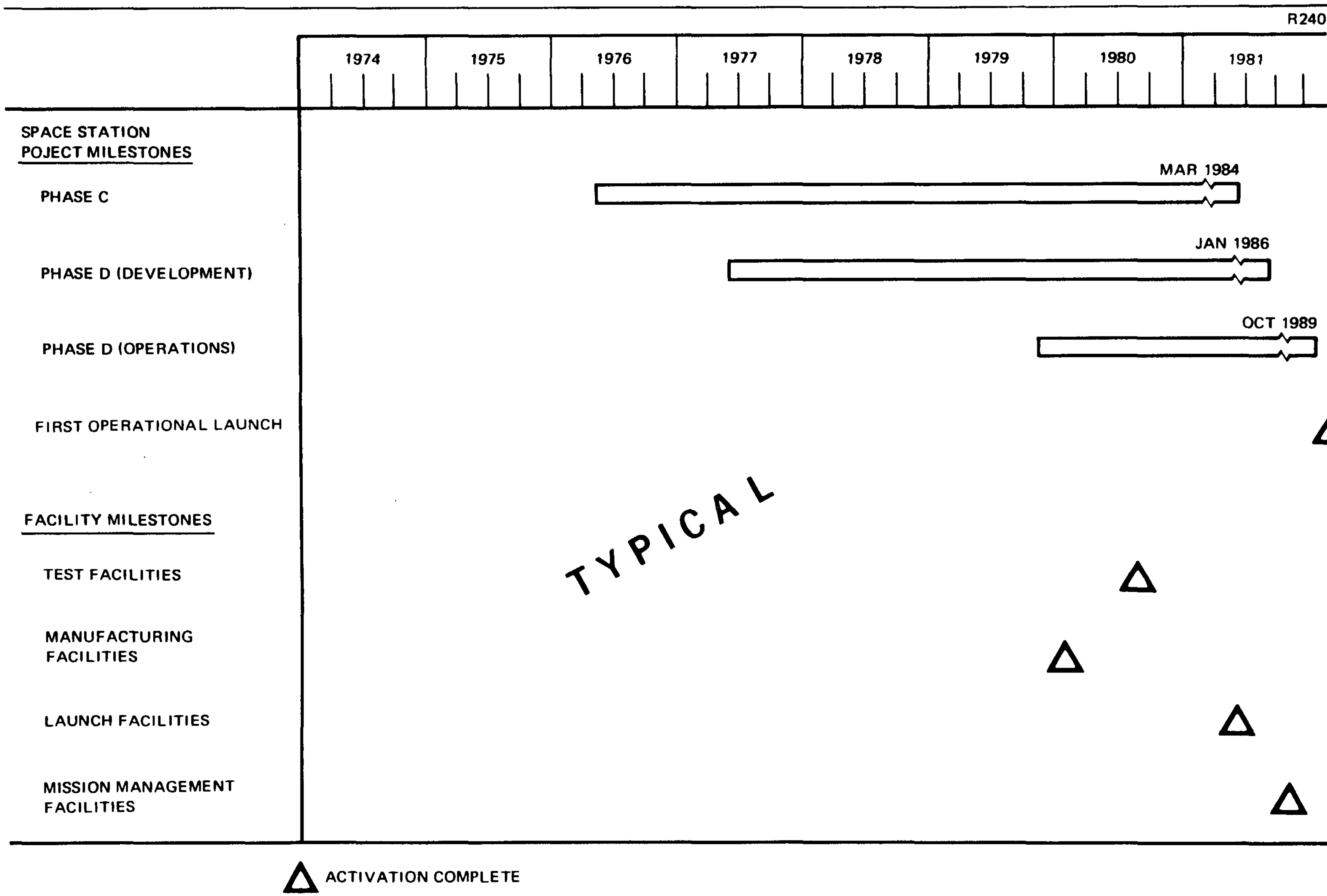

Figure 3-1. Space Station Project Milestones

Modular Space Station mockup. During early development phases, space will also be required for full-sized module structures that will serve as integration fixtures. This includes the functional model and the flight integration tool as described in the Verification Plan Requirements.

3.2 FABRICATION AND SUBASSEMBLY

The contractor shall provide suitable facilities and equipment for fabrication and subassembly.

The contractor shall identify facilities and equipment required for fabrication operations, which will include:

A. Sheet metal working equipment, including skin mills, brakes, and rollers.
B. Boring mills.
C. Heat-treating equipment.
D. Chemical milling equipment.
E. Anodizing equipment.
F. Precision welding equipment.
G. Cleaning equipment.

The contractor will also identify all special tooling, special test equipment, and special environments required for fabrication and subassembly operations.

The Manufacturing Plan Requirements provides additional information on manufacturing flows and forms the basis for definition of the requirements for manufacturing facilities.

3.3 DEVELOPMENT AND PRODUCTION TESTS

The contractor shall provide the facilities required for development and production testing, including:

A. System development and test laboratories.
B. Hydrostatic test facilities.
C. Hazardous test facilities.
D. Structural test facilities.
E. Wind tunnels.
F. Space Station functional models.

In the event that test requirements exceed the contractor's facility capabilities, consideration will be given to the use of Government-owned facilities, such as those at Seal Beach, California; Michoud, Louisiana; Tullahoma, Tennessee; Huntsville, Alabama; and Houston, Texas. When necessary, Government-owned facilities will be made available on a rent-free, noninterference basis.

Thermal-vacuum testing of the individual modules or the assembled Space Station is not considered a baseline requirement.

Further discussion of test requirements appears in the Verification Plan Requirements.

3.4 FINAL ASSEMBLY

The contractor shall provide an area suitable for final assembly, test, and preparation for shipment of the Space Station basic assemblies. The final assembly area will require the following:

A. A clear ceiling height of approximately 50 ft (15.24 m).
B. An area of approximately 10,000 ft^2 (929 m^2).
C. A 10-ton crane with minimum 40-ft (12.19 m) hook height.
D. Environment control.
E. Accessibility for module transporter and prime mover.
F. Over-the-road access to an ocean dock.

Section 4
GOVERNMENT-OWNED FACILITIES

4.1 KENNEDY SPACE CENTER

Kennedy Space Center (KSC) facilities and resources will be used to support receiving, inspection, assembly, integration, checkout, and launch operations. In addition to the Shuttle launch complex, other facilities will be provided for Space Station and logistic operations. The Implementation Plan will include identification of other facilities required as illustrated in the typical list in Table 4-1.

Table 4-1

LAUNCH SITE SUPPORT FACILITIES

Administrative	Technical
Offices	Mechanical-electrical GSE maintenance area
Conference and briefing rooms	Machine shop and welding shop
Supply storage	Fluids laboratory (hydraulic test)
Safe storage facilities	Calibration and standards laboratory
Waste repositories and disposal facilities	Chemical, biological, and physiological laboratories
Mail services	Communications and electronic equipment maintenance area
Packaging and packing	X-ray laboratory (radiographic)
Reproduction facilities	Vacuum test area
Badge and lock facilities	Telemetry systems maintenance area
Parking facilities	Screen room
Technical library	Photographic laboratory
Telephone, Datafax, and TWX services	Optical, materials, and acoustics laboratories
Leased lines	Computers
Fire protection	Gas and hypergolic analysis facilities
Safety surveillance and equipment	Guidance system laboratory
Security guards and control services	Heat-treating laboratory (small items)
Cafeteria	Meteorological forecast services
First aid and emergency treatment facilities	

4.1.1 Shuttle Landing Strip

Space Station components will be transported by air from airports near their manufacturing and test locations to the Shuttle landing strip. In the event of schedule conflicts, the skid strip at Cape Kennedy Air Force Station is available for use as backup.

4.1.2 Roads

Upon arrival at the Shuttle landing strip, the Space Station Module will be individually transported to the Vertical Assembly Building (VAB) low bay. Upon completion of receiving inspection and flight servicing operations, the modules will be transported to the Shuttle maintenance hanger adjacent to the VAB.

4.1.3 Vertical Assembly Building (VAB) Low Bay

The Space Station Modules will be located in a VAB low bay for flight servicing operations.

4.1.4 Shuttle Orbiter Hangar and VAB

The Space Station Modules will be loaded in the orbiter cargo bay in the orbiter hangar. They will remain in the cargo bay for all Shuttle operations in the VAB and during transport to the launch pad.

4.1.5 Shuttle Launch Pad

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

4.1.6 Launch Control Center

The launch control center specified by the Shuttle program will be used for (1) controlling integrated Shuttle Space Station operations, (2) maintaining and monitoring range safety, (3) monitoring countdown operations and initiating launch, and (4) coordinating resupply payload integration.

Space Station control and monitoring GSE will be installed in the launch control center as specified by the Shuttle program.

4.1.7 Manned Spacecraft Operations Building (MSOB)

The MSOB will provide support, prelaunch, and launch activities as required.

4.1.8 Central Instrumentation Facility (CIF)

The CIF will provide instrumentation support for the Space Station during launch pad operations.

4.1.9 Ordnance Storage Facility

The ordnance storage facility will be used for storing Space Station ordnance that is to be installed in the Space Station after its removal from the VAB.

4.2 MISSION MANAGEMENT (Program Support Operations)

Mission management will support mission control functions that include ground-based Onboard Checkout System (OCS) backup, monitoring of Space Station guidance and navigation, analysis of long-term trends, initial checkout and activation of the Space Station, launch support, crew assistance during initial manning and activation of the Space Station during high-activity periods, flight crew training and mission simulation, and mission planning.

4.2.1 Flight Operations

This area will support the functions of flight direction, trajectory support, communication control, ground support system operations, and booster systems support.

4.2.2 Mission Analysis and Planning

This area will support mission integration planning, logistic planning, resource utilization planning, experiment planning, trajectory planning, and operation and procedure development and modification.

4.2.3 Experiment Operations

This area will support the experiment data base, physical data receiving laboratory, experiment analysis laboratory, special-purpose displays, data processing and storage, information retrieval, and special-purpose experiment processing.

4.2.4 Crew Training and Simulation

This area will support the Space Station Module simulator(s), experiment simulators, simulation director, simulation controller, system specialists, and experiment module operators.

4.2.5 Crew Accommodations

Crew accommodations will be required to provide a live-in capability for flight crew personnel during final preparation and training for transfer to the Space Station, and for returning crew members who are undergoing observation, readjustment, and debriefing. Crew accommodation can be located in a standard-type building consisting of living quarters and sanitary, dining, physical conditioning, medical, and flight-suit donning facilities. These facilities will have a high degree of self-sufficiency during periods of isolation before flight.

4.2.6 Logistic Support Operations

Logistic control will maintain centralized surveillance, control, and management of Space Station logistic support elements during the station's ten-year orbital lifetime. Consideration should be given to locating this function at the Shuttle launch site, preferably in the MSOB and the Supply Shipping and Receiving Building adjacent to the MSOB.

4.2.7 Inventory Control

Inventory control will maintain centralized control over activities dealing with Space Station inventory resupply, including the logistic vehicle cargo constituents, procurement, control of inventory item quality, and preparation of the resupply cargo for flight. The inventory center will contain a data and control facility and a cargo-storage resupply and shipment-preparation facility. Consideration should be given to locating this function at the Shuttle launch site, preferably in the MSOB.

4.3 MANNED SPACE FLIGHT NETWORK

Designated tracking stations will be used to support Space Station flight operations. The MSFN tracking stations assumed to be available for this purpose include the KSC launch area and Bermuda 30-foot (9.14 m) antenna sites. Goddard Space Flight Center will provide MSFN configuration control and Tracking Data Relay Satellite System (TDRSS) management control. Existing MSFN capabilities will be used on a time-shared basis without modifications.

4.4 TRACKING DATA RELAY SATELLITE SYSTEM (TDRSS)

The TDRSS will consist of a series of geosynchronous satellites operating in conjunction with a ground station to provide communications to the orbiting Space Station. The ground station will be a standard-type building having attached or remote data relay satellite-oriented antennas.

The ground station will provide the ground terminal for RF transmission to and from the Data Relay Satellite (DRS). The ground station will receive data and relay it as necessary to the mission management center.

4.5 EASTERN TEST RANGE (ETR)

During prelaunch, launch, and early ascent, the ETR will provide range safety support.

4.6 TRANSPORTATION

The Super Guppy will be provided for transporting the modules from the manufacturer's facility to KSC (Section 4.1). Other components and supporting equipment will be shipped on Government Bill of Lading (GBL) via surface vehicle or aircraft.

Section 5

DOCUMENTATION

The contractor shall prepare and submit facility-related documentation as specified in the Phase C/D data requirement list. The data will include:

A. An expanded facility utilization plan based on this document and the specified DRD.

B. A list of all facilities, contractor or Government-owned, to be used in support of the Space Station Project.

C. Preliminary Facility Contract End Item (FCEI) specifications for new or modified facilities.

D. Preliminary cost estimates for new or modified facilities.

E. Preliminary facility activation plan covering new or modified facilities.

F. Identification of major machine tools and Special Test Equipment (STE).

MODULAR SPACE STATION
PRELAUNCH AND LAUNCH OPERATIONS
PLAN REQUIREMENTS

PRELAUNCH AND LAUNCH OPERATIONS PLAN REQUIREMENTS

Outline

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PRELAUNCH AND LAUNCH OPERATIONS PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

The Prelaunch and Launch Operations Plan Requirements define the requirements necessary for the preparation of the Phase C/D Implementation Plan(s). This shall include: (1) a description of the policies and objectives of prelaunch and launch operations; (2) identification of the application, organization, and general operating controls and procedures to be applied in its implementation; (3) descriptive information on the functions of prelaunch and launch operations; and (4) description of the impact on other functions of the program. Specifically, the Prelaunch and Launch Operations Requirements Plan:

A. Defines NASA and Modular Space Station contractor and other program contractor relationships and responsibilities at the launch site.

B. Defines the flow and objectives of prelaunch and launch operations.

C. Defines flight-crew participation requirements in prelaunch and launch operations.

D. Serves as a guide for the subsequent NASA and contractor planning of Phase C/D.

1.2 SCOPE

The Prelaunch and Launch Operations Requirements Plan covers requirements for hardware and software items of the Modular Space Station project involved directly in prelaunch and launch operations. The Logistics Module ground operations are an integral part of the logistics operations and are covered in subsection 4.4 of the Logistics Support Plan Requirements. Prelaunch operations will comprise all operations performed at the launch site necessary to make the Space Station modules ready for launch. Shuttle operational requirements shall not be included in this plan, although they may be referenced to provide continuity to the Space Stations operations. Specific interface requirements are covered in the Interface and Support Requirements documents. All preparation requirements shall be included, such as site activation, Space Station module servicing and checkout, installing the Space Station in the Shuttle, and ground personnel staffing and training activities.

Launch operations will comprise the activities directly related to launching the vehicle and leading to lift-off of the space vehicle. Requirements for post launch operations directly affecting the launch site will also be included in the plan. The plan will be limited to Phase C/D. It will reflect an understanding of the prelaunch and launch function for the Modular Space Station Project, and the significant requirements, critical issues, and potential problems associated with it. The plan shall exclude all requirements activities concerned with the logistics support of the Space Station on orbit (covered in Logistics Support Plan Requirement) and mission support ground operations after launch (covered in Mission Operations Plan Requirement).

1.3 CONTROL

The plan is to be consistent with NASA policies, procedures, and organization; and the program, project, and CEI specifications. The plan must be approved by NASA. All changes will be submitted through that same office. The relation to other Government agencies and associate contractors shall be supplied by that office.

1.4 SUMMARY

Modularization of the Space Station, and use of the Shuttle as the launch vehicle (LV) have resulted in a prelaunch and launch operations concept considerably different from past and present concepts. The nature of Shuttle operations requires that the payload be fully checked and flight ready before it is installed in the orbiter cargo bay; requiring little access thereafter (except for hazardous servicing). This is in contrast to existing concepts where a number of payload tests can be accomplished after mating with the LV. Mating of modules on orbit to create the operational Space Station requires that the modules be verified for compatibility and integrated operation prior to launch. This plan must take into account the possible growth to a Growth Space Station (GSS) configuration. This would be done in two steps with buildup accomplished by adding modules to the Initial Space Station (ISS) group of three modules. The GSS would be achieved by the addition of two modules launched at a later date, Power/System and Crew/ Operation. Integration and verification of the modules is accomplished before prelaunch and launch operations, hence, the individual modules are received at the launch site in an essentially flight-ready condition. Checkout and servicing activities are kept to a minimum as a result.

Section 2
ORGANIZATION

2.1 OPERATIONAL REQUIREMENTS AND FUNCTIONS

Test and operations activities at the launch site for any given Space Station module will be considerably less than the activities of current manned space flights. Nevertheless, it will be necessary to provide an organization, with suitable management techniques and control, to implement Space Station prelaunch and launch activities. A typical organization is shown in Figure 2-1. Daily launch operations meetings will be conducted by the Space Vehicle Test Supervisor to provide hardware and software status, scheduling of required support, and problems and potential resolution of problems. The appropriate NASA and contractor personnel will attend. The Space Station contractor shall organize a task team (similar to that shown in Figure 2-2) to implement Space Station operations. A briefing, to be held at least 2 days before each major operation, will be scheduled and conducted by the launch contractor. Any support requirements not satisfied for the operation shall be identified. Particular emphasis shall be placed on identifying hazardous operations, safety considerations, and required safety support procedures. A readiness certification statement shall be provided by applicable participants. The briefing participants shall review equipment configuration and appropriate interfaces to ensure that there are no problems that would affect results or compromise objectives.

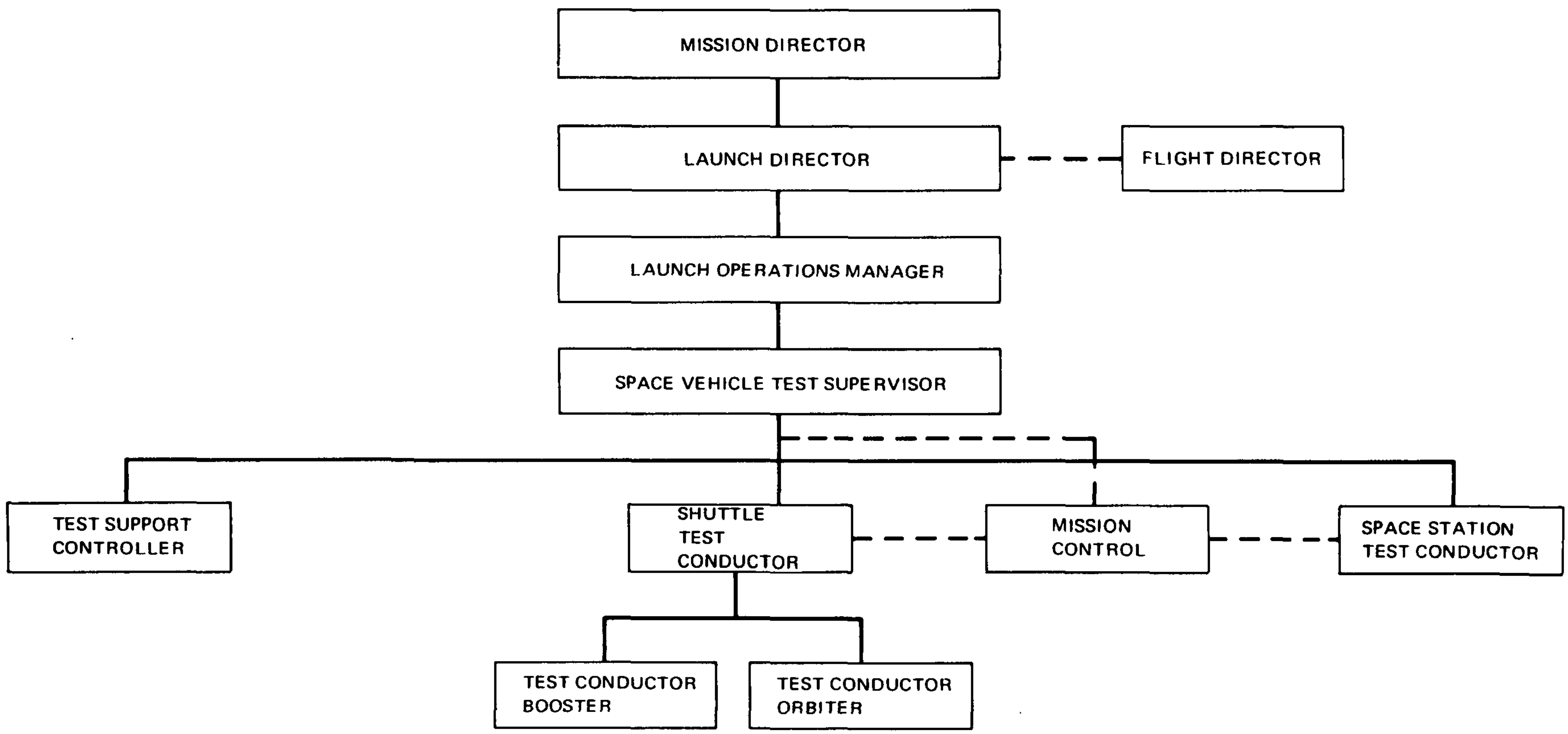


Figure 2-1. **Typical Launch Organization**

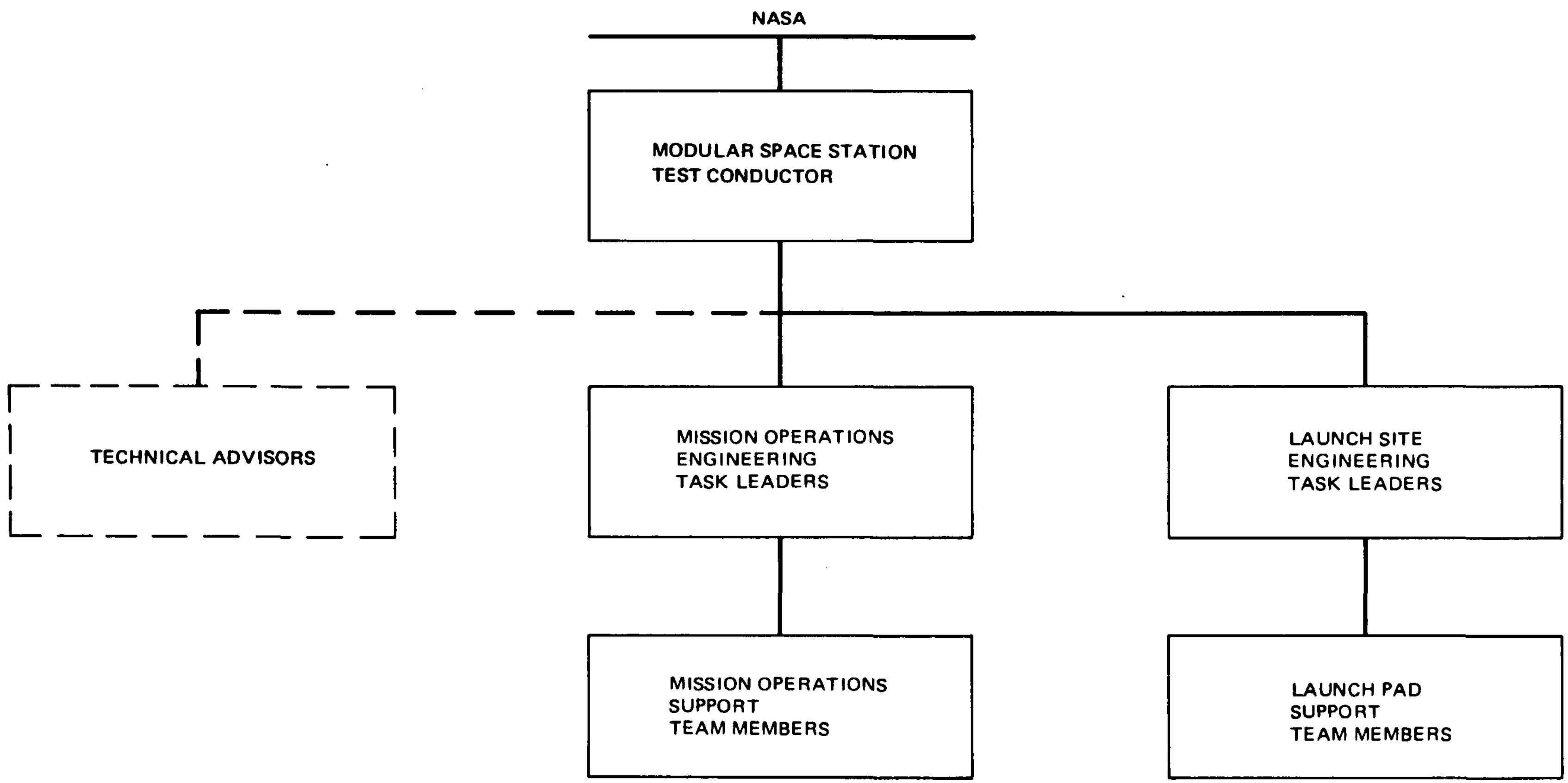


Figure 2-2. Typical Test Team Organization for Space Station Systems

2.2 ROLES AND RESPONSIBILITIES

Specific roles and responsibilities shall be assigned to assure adequate accomplishment of prelaunch and launch operations, and to provide management visibility of progress. A matrix shall be prepared, as shown in Table 2-1, defining the roles and assigning the specific responsibilities. The matrix shall be determined jointly by NASA and the Space Station contractor.

2.3 GROUND OPERATIONS WORKING GROUP

A Space Station Ground Operations Working Group (GOWG) will be established early in Phase C. The GOWG shall ensure accomplishment of all Space Station objectives at the launch site by (1) participating in the detailed prelaunch and launch operations planning as required to resolve problem areas; (2) reviewing all expanded objectives and requirements for adequacy; (3) recommending additions or deletions to fulfill the objectives efficiently; (4) planning for facility acquisition and modification equipment installation and activation; (5) participating in the planning of module integration and verification of on-orbit compatibility before delivery to the launch site; and (6) other functions that may be involved and are necessary to ensure successful prelaunch and launch operations. The GOWG shall be composed of senior representatives of the contractors and NASA organizations that will ultimately be involved in launching the Space Station. GOWG meetings shall be scheduled on a regular basis as determined in Phase C.

Section 3

INTEGRATED PRELAUNCH AND LAUNCH OPERATIONS

3.1 SCHEDULE

Prelaunch and launch operations developed according to this plan shall begin when the first shipment of GSE is installed at the launch site, and continue through completion of postlaunch operations after the final module launch. The Modular Space Station project schedule details are discussed in the Space Station Master Phasing Schedule.

Table 2-1

TYPICAL ROLES AND RESPONSIBILITY MATRIX

Function or Activity	Responsible Agency or Organization				
	NASA Launch Site	NASA Other (Specify)	Space Station Contractor	Shuttle Contractor	Other (Specify)
Overall direction and management of prelaunch and launch operations, assurance that all facets are ready for launch (Launch Director)	Δ		S	S	
Management and technical execution of all tasks (Launch Operations Manager)	Δ		S	S	
Test plans, schedules, and their implementation (Test Planning Manager)	Δ		S	S	
Checkout and countdown of the Space Vehicle, assurance that all launch complex GSE and support requirements are met (Space Vehicle Test Supervisor)	Δ		S	S	
Successful completion of Shuttle activities (Shuttle Conductor)	M		I	Δ	
Successful completion of Space Station activities, coordination with NASA and other contractors (Space Station Test Conductor)	M		Δ	I	
Direction and utilization of support crews, assurance that all requirements and objectives are met, and that anomalies are reported and documented (Engineering Task Leader)	M		Δ	S	
Accomplishment of tasks per release procedure (support crew)	M		Δ	S	
Technical assistance in making real-time decisions regarding Space Station and internal experiment status (technical advisors)	S		Δ	S	

Key: Δ = Prime responsibility; S = Supporting; I = Interfacing; M = Monitoring.

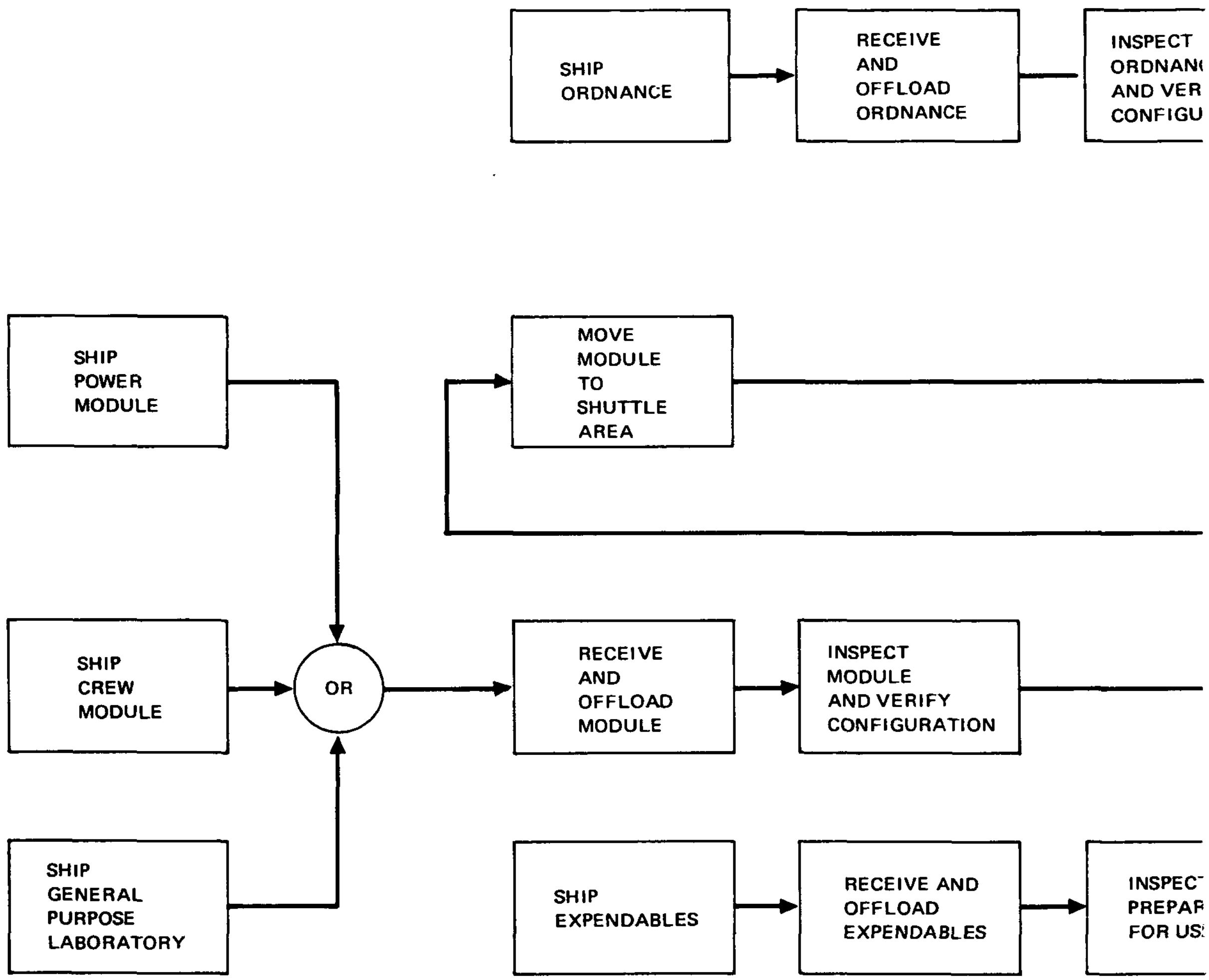
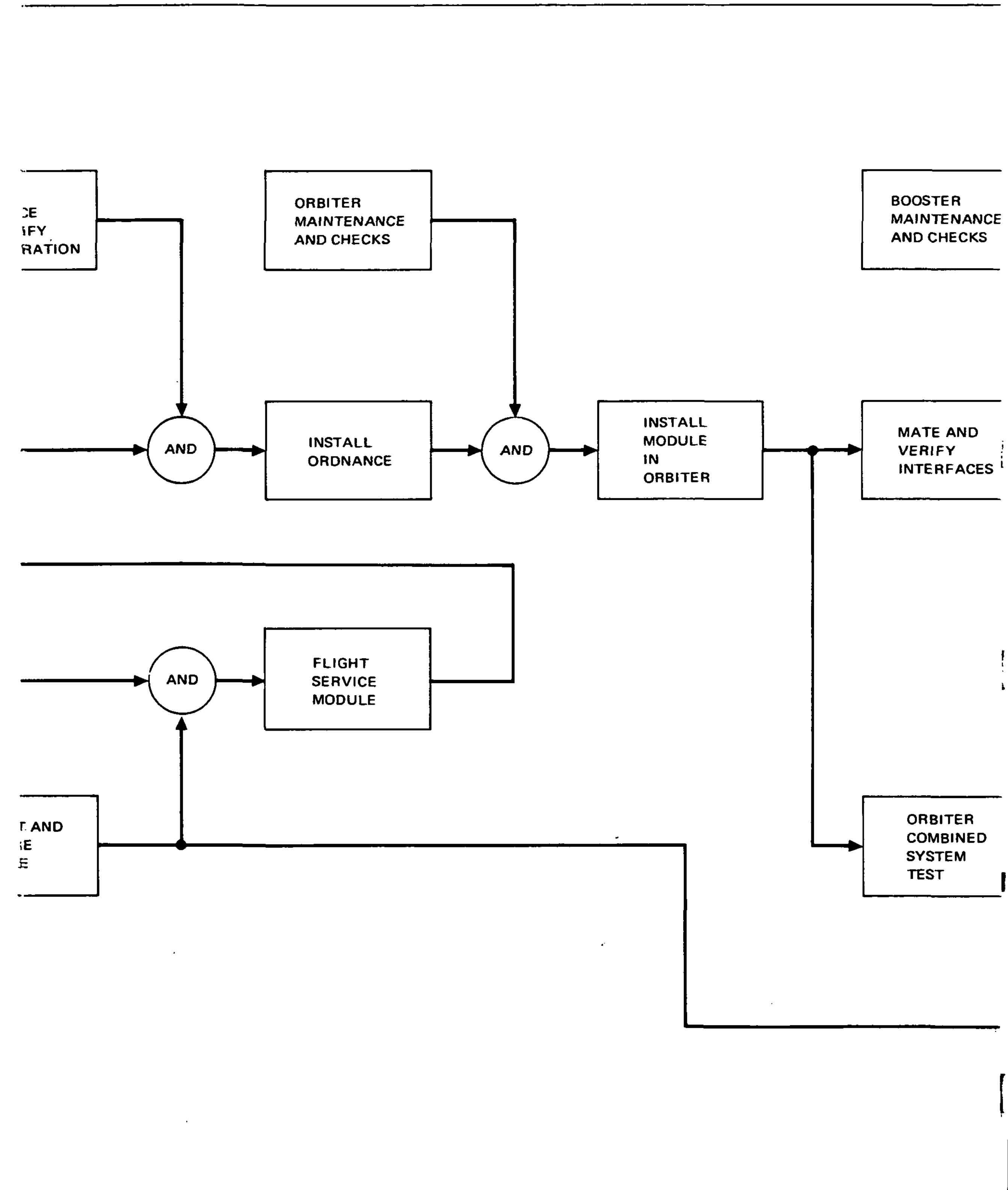
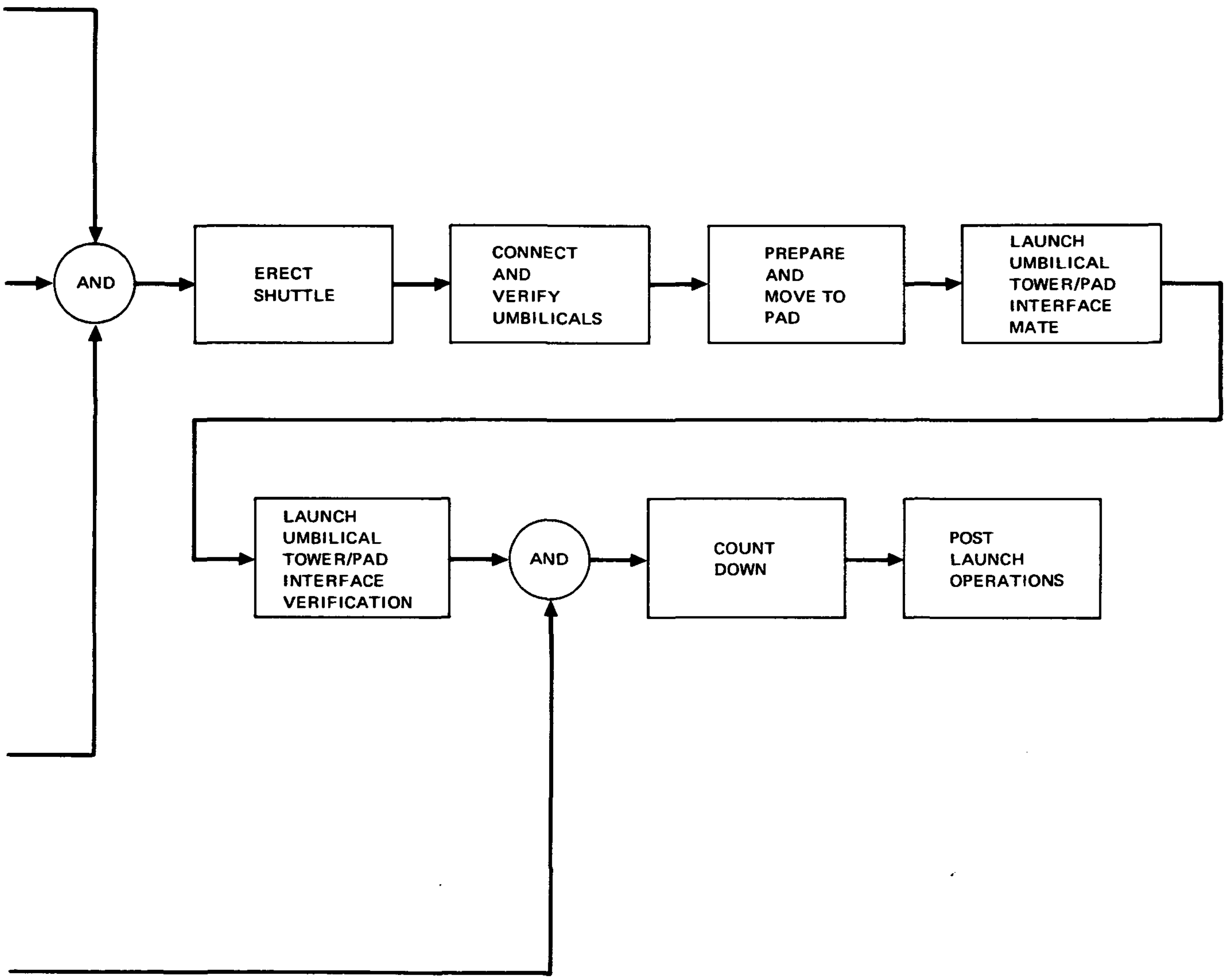


Figure 3-1. Typical Module Operational Flow

FOLDOUT FRAME 1



FOLDOUT FRAME 2


AND
ERECT SHUTTLE
CONNECT AND VERIFY UMBILICALS
PREPARE AND MOVE TO PAD
LAUNCH UMBILICAL TOWER/PAD INTERFACE MATE
LAUNCH UMBILICAL TOWER/PAD INTERFACE VERIFICATION
AND
COUNT DOWN
POST LAUNCH OPERATIONS

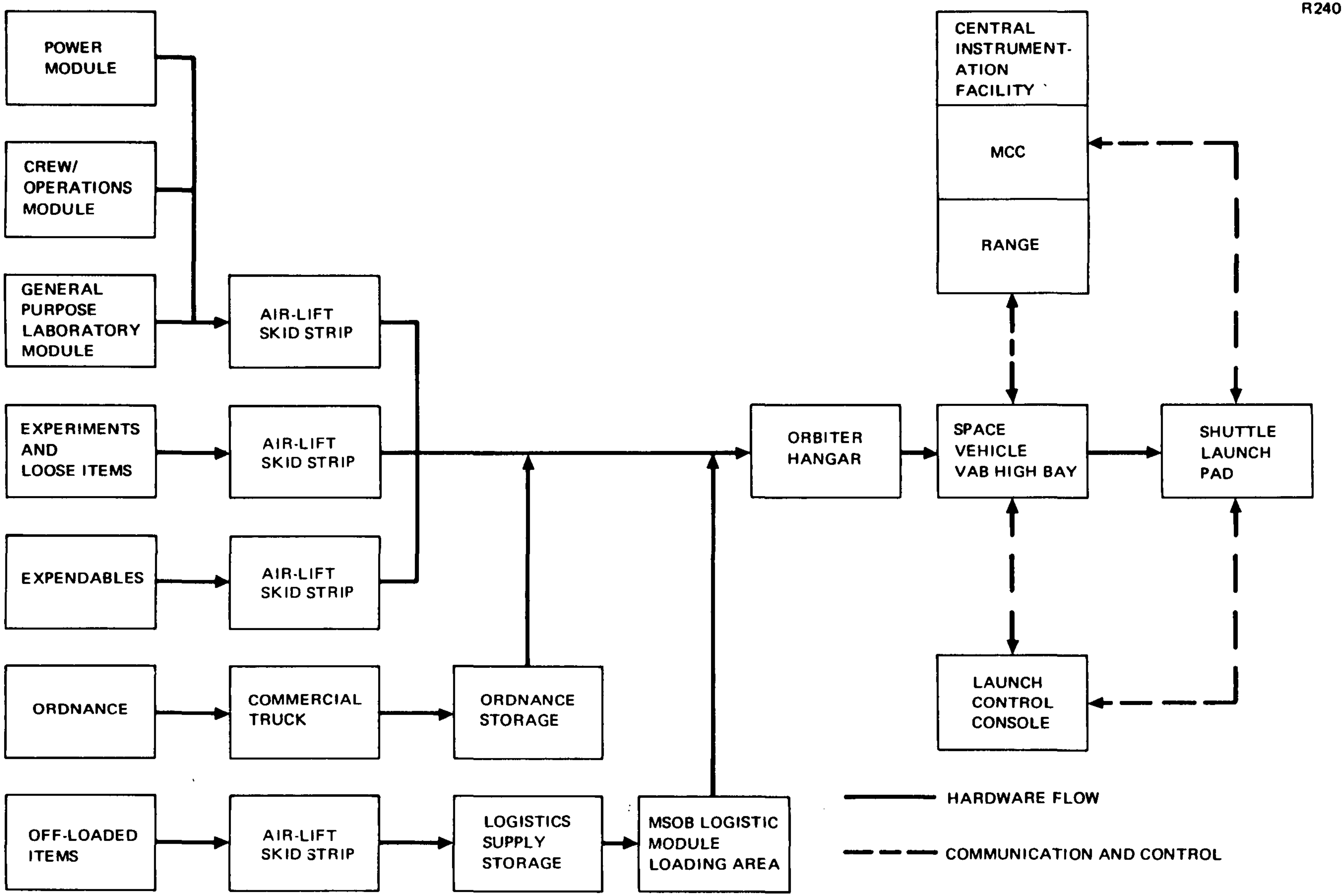


Figure 3-2. Space Station Operational Flow Through the Launch Site

3.2 SITE ACTIVATION

A detailed plan for site activation task accomplishment and acceptance shall be generated, including schedules showing lead time to meet launch schedule. Facility modifications and GSE installation shall be accomplished without impact on, or interference with, other programs in progress at the same time. The down time of activities and equipment common to Space Station and other programs shall be scheduled in coordination with other users. Acceptance of modification and installations shall be accomplished incrementally (i.e., when a given task is complete).

3.3 SPACE STATION OPERATIONS

3.3.1 Checkout and Launch

Detailed plans for the accomplishment of checkout and launch for each module shall be prepared by the contractor. Overall operational flow developed during Phase B (Figure 3-1), and to be documented in detail in the plan is shown for reference and shall be followed in the development of these detailed plans.

Major objectives and functional requirements for the prelaunch and launch operations identified in the flow shall be as delineated below. The contractor shall expand these requirements to a level that will allow detailed design of the ground system to progress, ensure compatibility of Space Station detail subsystem design with ground operations, and divide the major operational activities into smaller operational packages that form a basis for detailed design of operations and generation of procedures. The expanded operational descriptions shall be included as a part of this plan. The main operations, as listed in the flow chart in Figure 3-1, are briefly defined as follows:

A. Receiving and Offloading of Space Station Modules and Support Elements—Removal of the various elements arriving at the launch site from their respective modes of transportation and moving them to the proper receiving inspection area, as indicated in Figure 3-2.

B. Receiving Inspection and Configuration Verification—To ascertain the condition of each item as received at the launch site, and to document transportation damage. Inspection differs for different elements; in particular, interior inspection of the Space Station Modules is delayed until internal access can be established.

C. Space Station Flight Servicing

1. To hook up GSE.
2. To service Space Station systems.
3. To load all cargo and expendables on the Space Station Module except hazardous commodities to be launched with it.
4. To remove GSE and close up the Space Station to make it ready for flight, including final leak checks of hatches, etc.

D. Move Module to Shuttle—To move the module from its test and operations area to the Shuttle.

E. Installation of Space Station Ordnance—To install ordnance devices in the Space Station that will be required for such activities as releasing solar arrays, releasing and deploying antennas, etc. The vehicle assembly building shall be cleared in the proximity of these operations.

F. Install Module in Shuttle—To remove the module from its transporter, lower it into the Shuttle orbiter cargo bay, and secure it in position.

G. Mate and Verify Interfaces—To mate any module/orbiter functional interfaces and verify proper mating.

H. Erect Shuttle—This is basically a Shuttle operation during which the Space Station module is a passive participant. Shuttle operations including closing and securing the cargo bay door, performing a combined systems test of the orbiter, erecting the orbiter and mating it with the previously erected booster, verifying the booster/orbiter interface, and connecting orbiter umbilicals.

I. Connect Umbilicals and Verify

1. To connect module umbilicals (through Shuttle access doors provided for the purpose), and verify proper connection.
2. To participate to the extent necessary in the Shuttle integrated system test.

J. Preparations and Move to Pad—Basically a Shuttle Operation:

1. To prepare the space vehicle and launch umbilical tower for movement to pad by performing final inspection, disconnecting vehicle assembly building equipment, bringing crawler or transporter to the assembly building, etc.
2. To move the tower to pad.

K. Launch Umbilical Tower and Pad Mate and Interface Verification—Basically a Shuttle operation:

1. To connect the launcher with pad facility services and GSE.
2. To verify the mechanical alignment of the launcher.
3. To verify the functional operation of the interface between the tower and the pad.

L. Countdown

1. To perform final preparations and launch a Space Station Module, including final activation of space vehicle systems, propellant loading, Space Station Module checks and monitoring, and terminal countdown in parallel with Shuttle operations.
2. To secure pad after lift-off and control damage (a Shuttle operation).

M. Postlaunch Operations

1. To secure equipment dedicated to the Space Station and prepare for the next module launch.
2. To assess pad and launcher damage, and to effect repairs (a Shuttle operation).

3.3.2 GSE and Facilities

GSE requirements are contained in Section 2.8.4 of "Integrated Mission Management Operations", MP-03. Additional requirements (or deletions) shall be added and explained as they become apparent as a result of expanding the descriptions of major activities. Facilities in which the major functions shall be accomplished are identified in Figure 3-2. The Facilities Utilization Plan contains an explanation of facility usage.

3.3.3 Space Station Module Access

Space Station Module interior access control and safety will be of prime importance at the launch site. The general guidelines outlined below shall be used to determine detailed access requirements.

A. Only personnel trained for Space Station Module interior operations shall be allowed access to the Space Station Module interior.

B. Only personnel attired for Space Station Module interior operations shall be allowed access to the Space Station Module interior.

C. Only personnel required to perform specific tasks in accordance with approved procedures shall be allowed access to the Space Station Module interior.

D. Only material and equipment requirements identified on the approved list determined in accordance with the Design Plan shall be allowed in the Space Station Module interior.

E. All material items entering the Space Station Module shall be accounted for.

F. A monitor shall be located at each Space Station Module interior access point to control access, verify training of entering personnel, check their outer attire, and determine their requirement for entry. The monitor shall log all items and personnel in and out of the Space Station, and ensure that all items are on the approved list.

General access to the module exterior will not be possible after the module has been installed in the Shuttle orbiter cargo bay. Such access will be limited to those areas of the module that can be reached through the cargo bay door, or through the small access doors provided in the Shuttle skin for umbilical connections.

3.3.4 Safety

All activities shall be governed from a safety standpoint as indicated in NHB 1700.1, Volume I, NASA Safety Manual, and in KMI 1710.1A, the KSC Safety Program.

3.3.5 Test Procedures

All tests and operations shall be performed in accordance with approved procedures. Flight software and the onboard checkout system (OCS) are not fully operational for single modules. However, they should be used whenever possible for performing ground tests.

3.4 EXPERIMENT OPERATIONS

Experiment operations covered by this plan shall be limited to those associated with the integral experiment equipment launched with the Space Station General Purpose Laboratory (GPL) module and which were installed at the factory. These operations shall be under overall control of the Space Station contractor. However, the experiment contractor shall furnish procedures for operating and testing experiment equipment and shall assist in performing operations. The operations shall be limited to housekeeping and experiment health monitoring; no functional checks of integral experiments shall be performed at the launch site. Prelaunch and launch operations planning for other (nonintegral) experiment equipment are excluded from this plan.

3.5 FLIGHT CREW OPERATIONS

There will be no flight crew participation required in Space Station Module prelaunch and launch operations at the launch site. Their participation shall be scheduled only during the Space Station integrated testing before delivery to the launch site and in the flight integration tool (FIT). In general, only the activation crews and first permanent crews (operational) will have the benefit of particpating in integrated testing of the flight modules. Training operations included within the framework of prelaunch and launch operations (for crew and logistics module launches) shall be specified during Phase C/D. Training operations shall be coordinated with the Crew Training Plan.

3.6 INTERFACE REQUIREMENTS

Prelaunch and launch operations interface with other facets of the overall program. The detailed prelaunch and launch operations plans shall be compatible with the plans listed below. The interfaces with these plans shall be developed in detail during Phase C/D.

A. Design Plan
B. Manufacturing Plan
C. Quality Assurance and Reliability/Maintainability Plans
D. System Safety Plan
E. Verification Plan
F. Facility Utilization Plan
G. Program Management Plan
H. Crew Training Plan
I. Logistics Support Plan
J. Experiment Integration Plan
K. Program Integration Plan
L. Software Integration Plan

Section 4
SUPPORT REQUIREMENTS

4.1 MISSION CONTROL

The mission management center shall participate in tests designed to verify the ground space vehicle interface in the countdown. Powered flight operations are the responsibility of the Shuttle, with Space Station mission management center monitoring module status. The mission management center shall take over responsibility for the module during activation on orbit. The role of the mission management center in each test and operation shall be described in detail in the expanded operational requirements (subsection 3.3).

4.2 GROUND DATA MANAGEMENT

Requirements shall be determined for prelaunch and launch data acquisition, processing, reduction, and distribution. Requirements shall also be determined for interfacing with mission data management.

4.3 GROUND CREW STAFFING AND TRAINING

Space Station ground crew personnel shall be drawn from existing complements of launch site personnel familiar with launch operations, and from experienced personnel who have had on-the-job training through participation in factory checkout and integrated checkout of the modules. The selected personnel participating in factory and integrated checkout shall accompany the Space Station Modules through all checkout operations, and shall operate critical man-machine interface functions at the launch site. Personnel who have been responsible for Space Station design, test procedure generation, and inputs to flight crew handbooks shall also assist in checkout at the launch site. A training plan shall be formulated, specifying the detailed requirements (such as lectures on Space Station Module design and operations for launch site personnel, and lectures on launch operations for temporarily assigned personnel) and ensuring that all personnel possess the required expertise by participating in simulated operations, integrated testing, factory testing, etc. Ground crew Space Station responsibilities shall be temporary; that is, personnel traveling with a given module shall return to their original locations at the conclusion of launch; launch site personnel shall prepare for the next launch or return to their previous area of responsibility. Module egress under emergency conditions shall be a part of the training. The Space Station Modules will be designed for occupancy with standard safety operating procedures being used. It is expected that the level of hazard associated with launch operations and test will not exceed present levels of hazard associated with Apollo spacecraft operations and test.

4.4 LOGISTICS

Expendable procurement requirements for accomplishing prelaunch and launch operations shall be determined, including type, quantity, quality, and schedule for procurement. Requirements shall be coordinated with the Logistics Support Plan.

4.5 OTHER

The Interface and Support Requirements Documents will form the basis for operational support required for Space Station activities at the launch site. Operational support from within the launch site Launch Operations organization will be obtained through the daily status meetings and internal support request forms. Operational support from outside the launch site organization shall be obtained through a formal request and response system, the requirements document/support directives systems. Support requirements shall be prepared and requested in a format which will fit an automated system currently under development. Support requirements shall be developed in detail during Phase C/D.

Section 5
DOCUMENTATION

The form and content of data to be provided to NASA, associated contractors and subcontractors, and for the contractor's internal use throughout Phase C/D shall be specified.

Section 6
REPORTING

Procedures for a contractor to report to NASA or to other contractors, as a function of time (progress reports), or as a function of particular events (test, accident reports, etc.), shall be proposed by the contractor. The frequency and milestones to which these reports will be assigned shall also be specified.

Section 7
DATA AND INFORMATION INTERCHANGE

Requirements for the collection, transmission, and processing of data or information during development, test, and prelaunch and launch operations shall be determined by the contractor and included in his implementation plan.

MODULAR SPACE STATION
MISSION OPERATIONS PLAN REQUIREMENTS

MISSION OPERATIONS PLAN REQUIREMENTS

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MISSION OPERATIONS PLAN REQUIREMENTS

Section 1
INTRODUCTION

This plan presents the requirements for mission operations planning for the Modular Space Station operational phases. This requirement plan provides guidance to the contractor proposing for the development contract. During Phase C/D, the Mission Operations Plan will be prepared and encompass all aspects of the Space Station mission operations, including certain requirements relating to the experiment project since they will impact Modular Space Station requirements when the experiments are on-orbit and become operationally dependent on the Modular Space Station project. The requirements presented herein cover the Initial Space Station (ISS) operations of the Modular Space Station project. These requirements supplement those presented in detail in the Space Station Program, Project and I&SR specifications.

1.1 PURPOSE

The purpose of this plan is to define the Modular Space Station flight operations baseline from which missions will be performed during the ISS operational phase of the program. This plan identifies project operational requirements, their application, the organization and general operating control/procedures, policies and objectives that must be considered in preparing the Phase C/D Missions Operations Plan.

1.2 SCOPE

The mission operations of the Modular Space Station project begins with the ATP of Phase C/D. The first activity of the contractor in Phase C/D shall be to develop a Missions Operations Plan covering those activities required prior to IOC and continuing through the flight operations of the mission. The scope of this document covers all elements of the Modular Space Station project, including those interface and supporting functions required throughout the Space Station Phase C/D.

The plan identifies the rationale for the Phase B operations requirements to assist the Phase C/D contractor in the development of the Mission Operations Plan. Overall success of the Phase C/D Mission Operations Plan will be highly dependent on the ability of the contractor to identify the interdependancies between hardware and mission planning in the 10-year operational program, and the inherent capability of the plan to provide sufficient mission flexibility within the framework of the established mission management organizations. This requirements plan will identify those interdependancies and mission organizations defined in the Phase B study to provide maximum operations visibility to the Phase C/D contractor.

1.3 CONTROL

The implementation plan shall be revised as required during Phase C/D under the authority of the NASA. This plan, following initial approval, will be released and controlled by the Space Station Program Director's Office.

Following initial release of this plan, and until cancellation, revisions may be made by the assigned NASA Program Manager, except when a revision involves a change in the identified Space Station Program baseline. For such a revision, the requirement revision shall be approved by the controlling office identified above.

1.4 IMPLEMENTATION

A preliminary Mission Operations Plan for implementation of the Space Station program shall be prepared and submitted with the Phase C/D proposal. The final Mission Operations Plan shall be available at the time of the Space Station CDR. It shall be revised (as presented in subsection 1.3) as required from that time forward.

This Mission Operations Plan will:

A. Provide a project-level planning tool to contribute to all program mission operations activities.

B. Establish the operational requirements, guidelines, constraints, responsibilities, interfaces, support, and time-phasing of milestones or major events required to accomplish the total operations for the conduct and support of the mission.

C. Document the integrated results of all project operations analysis and requirements into a mission program plan to effect optimum mission operations in accomplishing established objectives.

D. Establish and define lower-level operations documentation (plans and procedures, such as experiment operations, logistics vehicle operations, Tracking Data Relay Satellite (TDRS) operations, and crew training) required to implement missions operations.

E. Provide a means to plan and document changes to mission operations resulting from such inputs as program changes and mission objective additions or deletions. The Mission Operations Plan will provide the direction for lower-tier documents required to implement mission operations throughout the 10-year program.

1.5 ROLES AND RESPONSIBILITIES

Within the Space Station Program, a Space Station Project Office will be established. The contractor shall provide the operations engineering, analysis, coordination, liaison, and documentation required by this office to develop the Space Station Mission Operations Plan. The contractor shall also look to this office for guidance of the contractor versus NASA roles within the mission operations organization for the implementation of the plan. Until the tasks identified within the Mission Operations Plan are specifically assigned by the NASA, the contractor shall be assigned the responsibility of revising and maintaining the plan.

Section 2
MISSION

The Modular Space Station mission definition is presented in DR MP-01 "Space Station Program (Modular) Mission Analysis Document." A cursory description is presented below. The Missions Operations Plan shall be developed using these mission descriptions, the Program, Project and I&SR

specifications. Any deviation from this by the contractor shall require NASA's written consent. In the event of discrepancies between this document and the Specifications, the specifications shall prevail.

2.1 MISSION OBJECTIVES

The primary mission objectives of the Modular Space Station program is to provide and maintain a manned earth-orbital laboratory to conduct a variety of scientific and engineering activities. These activities, accomplished in 90-day mission cycles (see Section 4.1) are to be conducted in an earth orbit of 55-deg inclination and 242-nmi (448 KM) orbital altitude (referenced to the equator). The detailed objectives of the Space Station shall be continually changing throughout the operations phase, as the national objectives, scientific objectives, and space operational priorities are revised. For this reason, "mission flexibility" will become the singular most important characteristic of the end product of the Mission Operations Plan.

2.2 MISSION DESCRIPTION

The summary mission profile is presented in Figure 2-1. As shown, the Space Station is scheduled to begin flight operations in 1980 with the launch of the first Space Station module (the power subsystems module). The Space Station will primarily operate in an unmanned mode until the first two sustained operations crewmen arrive withthe logistics module at completion of the Initial Space Station (ISS) buildup operations (launch number 4).

During the ISS buildup, two Space Station crewmen, accommodated as Space Shuttle passengers, will accompany each module to orbit. These two crewmen will be used on-orbit, while the Space Shuttle remains attached to the payload module, to perform physical mating of interfaces and Space Station systems checkout on-orbit. Following completion of these activities, the two crewmen will return to Earth in the Space Shuttle.

As a result of the unmanned operations of the Space Station and the obvious critical nature of buildup, a group of flight operations support personnel will be required for flight control during the buildup operations. Those personnel must also be provided the capability to communicate with and command the orbiting unmanned vehicle.

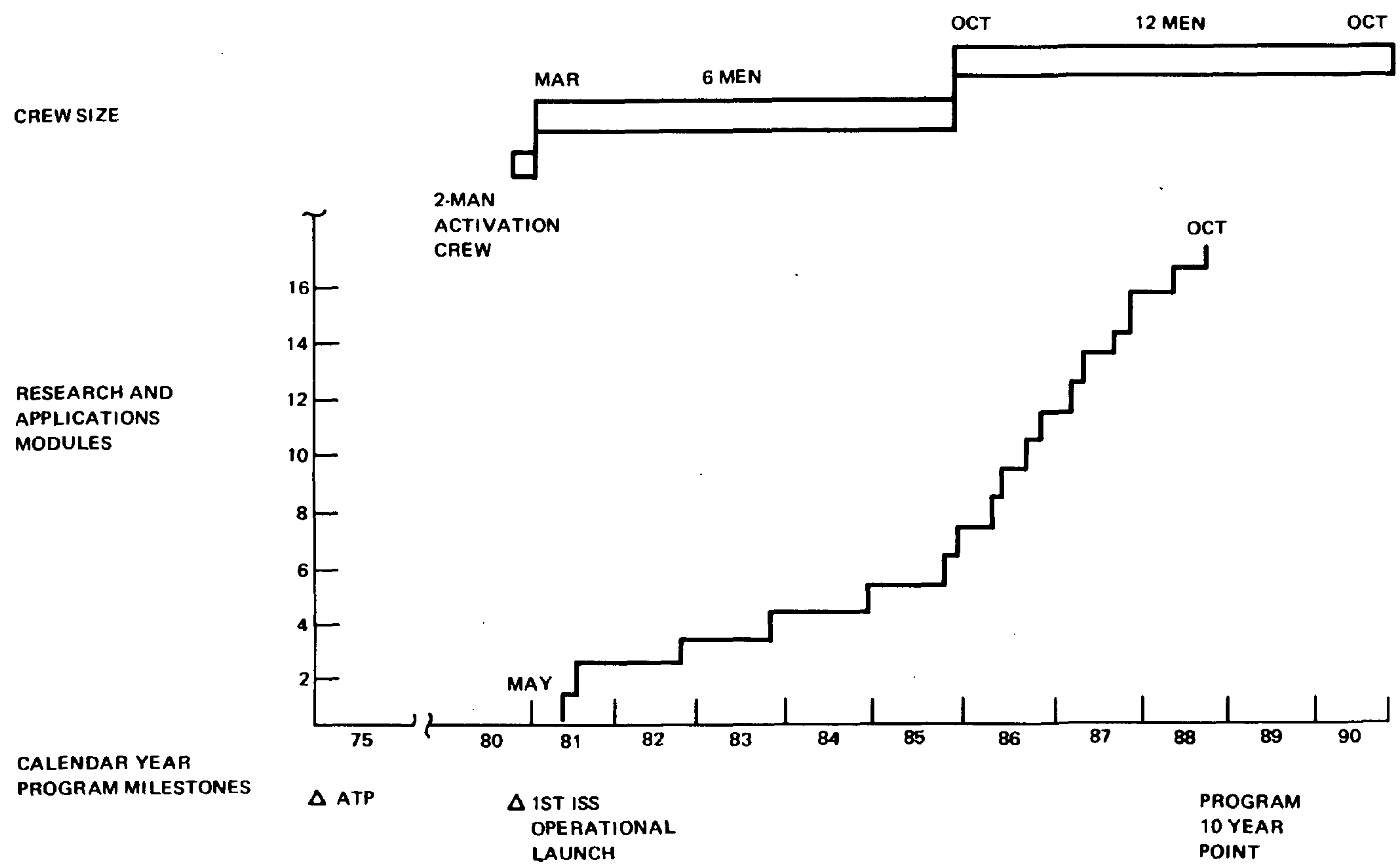

Figure 2-1. Space Station Program Schedule

Following completion of the buildup operations, the Space Station will perform operations on-orbit for a period of no less than 5 years with an average of 6 crewmen. During this 5-year period the Space Station compliment of experiments will be continually changing as the logistics module will provide the delivery capability (with the Space Shuttle) for resupply, replacement, and rotation of consumables, equipments, and the crew, respectively. The baselined experiment operations schedule is presented in Figures 2-2.

Following 5 years of ISS operations, the Space Station mission capabilities will be increased with the addition of one power module, one crew/operations module, and six additional crewmen. This growth will be accomplished with a corresponding growth of the experiments on-orbit.

2.3 MISSION CONFIGURATION

The ISS configuration will be continually changing throughout the mission as experiment modules (RAM) are delivered to orbit and returned to Earth. In addition, as each Logistics Module is delivered to the Space Station with the new supplies, it will be docked to one of the two docking ports assigned for logistics, and a Logistics Module with depleted supplied docked at another docking port will be returned to earth.

Figure 2-3 presents a typical orbiting vehicle configuration profile for the ISS phase of the Space Station mission. As shown, six docking ports are provided, four for experiment modules and two for Logistics Modules.
Figure 2-4 presents the typical configuration during the GSS mission. As shown, 11 docking ports are provided: two for free-flying RAMS, three for logistic vehicles, and six for attached RAMS.

2.4 MISSION MANAGEMENT

The Phase B Study identified the significance of mission management within the complex set of relationships between the program elements (such as Space Station, Space Shuttle, Logistics Vehicle, and the Experiment Project) required to allow the 10-year operations to be accomplished with the necessary precision required and in a cost-effective manner. The Mission

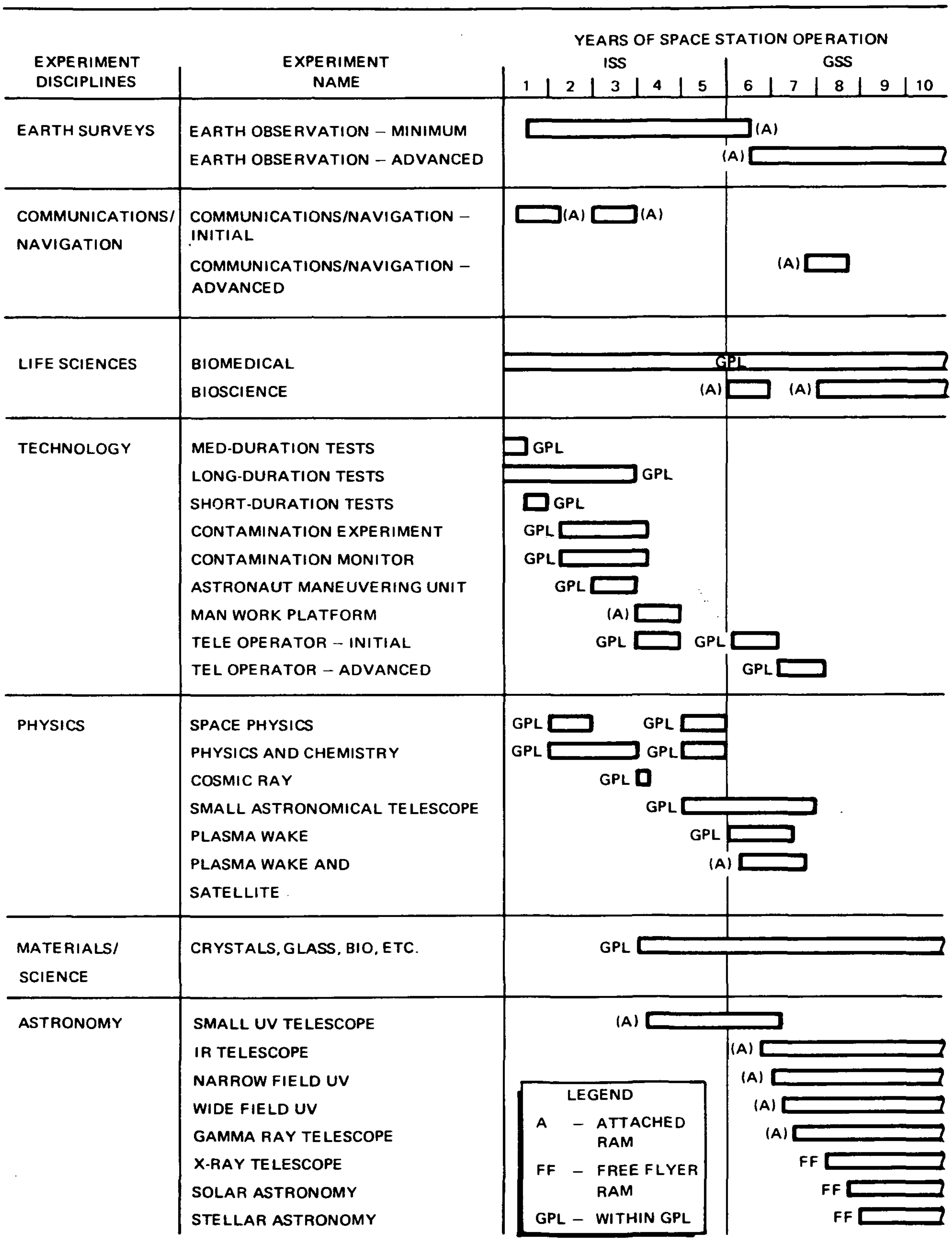

Figure 2-2. Baseline Research and Applications Programs

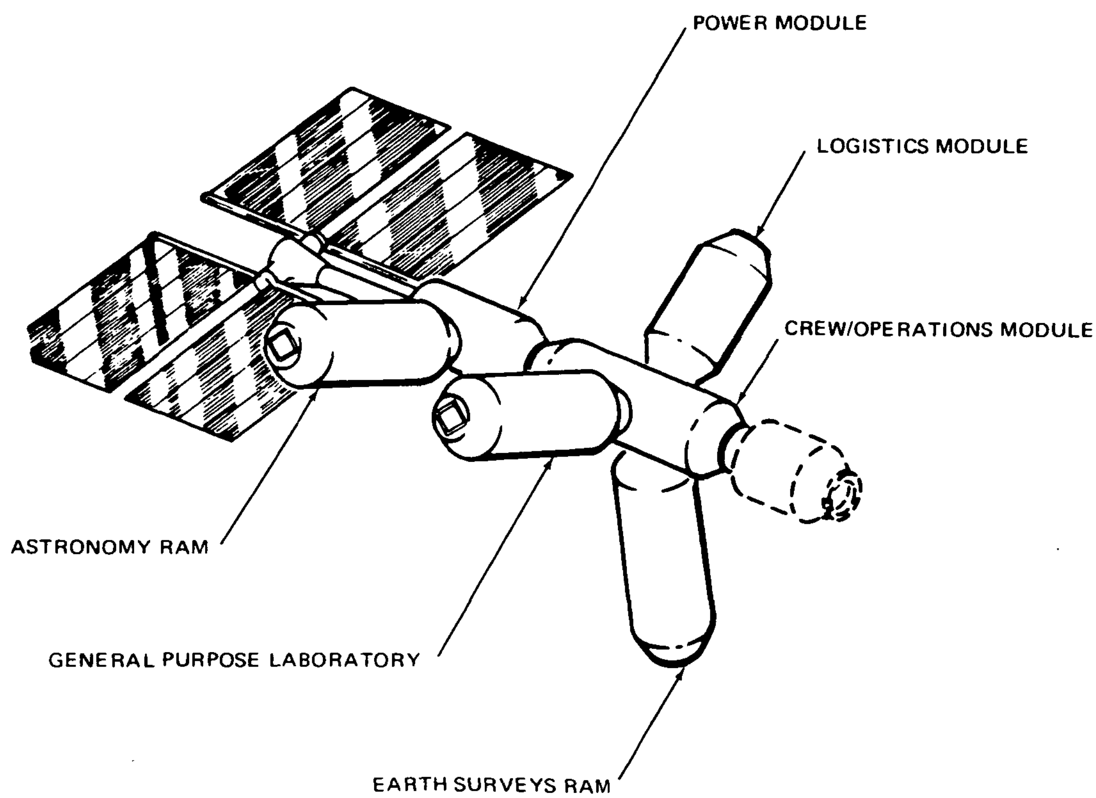

Figure 2-3. ISS Configuration

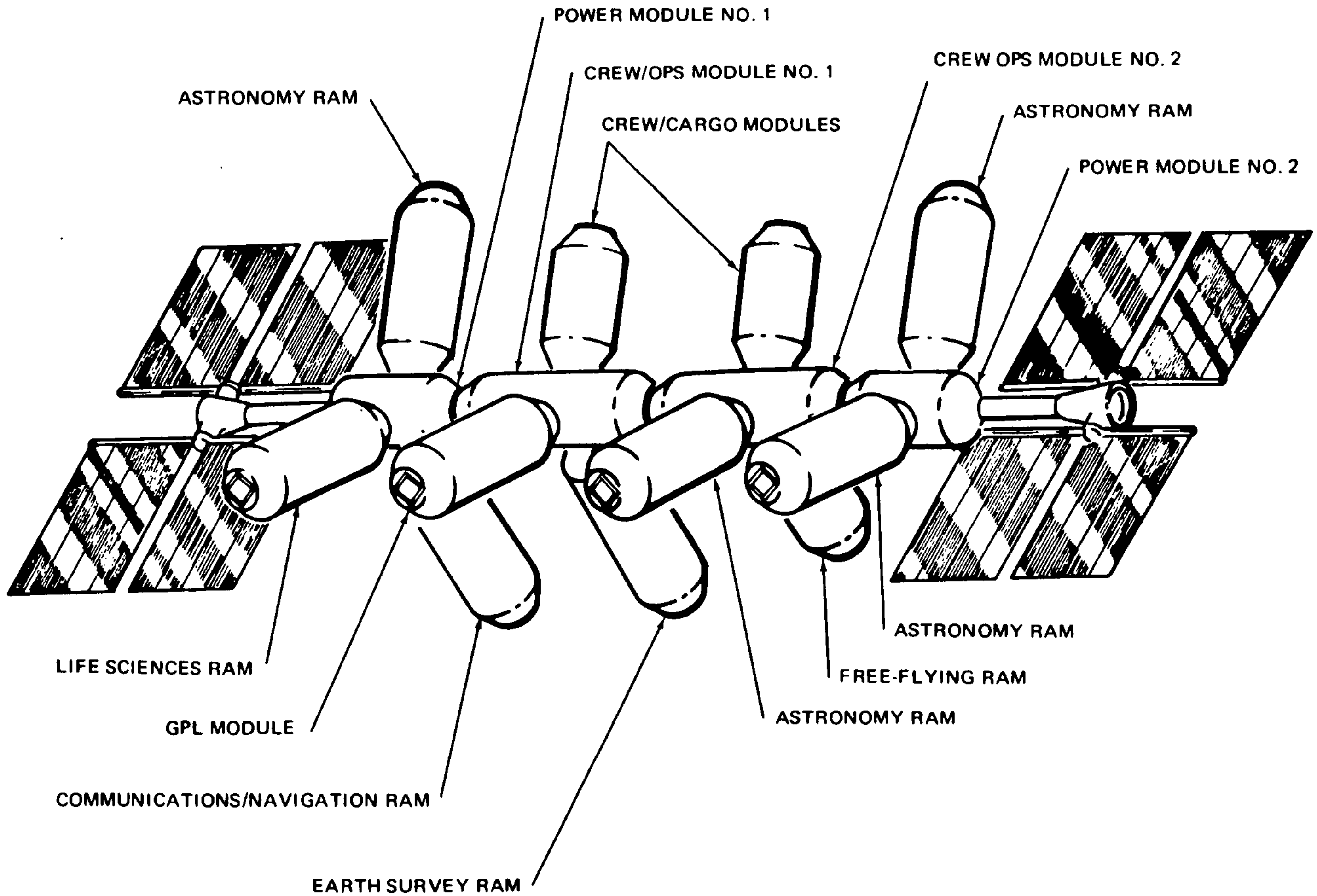

Figure 2-4. GSS Configuration

Operations Plan will be required to pay particular attention to the organization of these projects and their functions to insure proper mission planning, preparation, and execution.

The functional allocations shown in Figure 2-5 were identified for the Phase B Study as the primary requirements for Mission Management. These activities will be further identified in Section 4 of this Plan. The Phase C/D Mission Operations Plan shall detail the specific organization, relationships, and schedules required to establish the mission management required to fulfill these functional requirements. The plan shall accomplish this within the existing framework of on-going NASA activities and responsibilities, and shall detail the necessary contractor effects required in support of the overall Program Management.

The resultant Mission Operations Plan shall be used to plan and document the operations of mission management to provide the planning flexibility, accuracy, and integration required to efficiently support operations in the open-ended 10-year space program.

Section 3
FLIGHT OPERATIONS

The flight operations of the Modular Space Station project are described in detail in DRD 235-MP-01 "Space Station Program (Modular) Mission Analysis Document." The information presented in this section of the plan is intended to highlight those key operations identified in the Phase B Study which must be included within the planning for the Mission Operations Plan implementation.

3.1 INITIAL SPACE STATION

The Space Station buildup occurs over a period of 90 days. The Space Station modules, primarily designed for manned operations will be operated during these 90 days in an unmanned mode using flight operations support personnel and facilities on the ground.

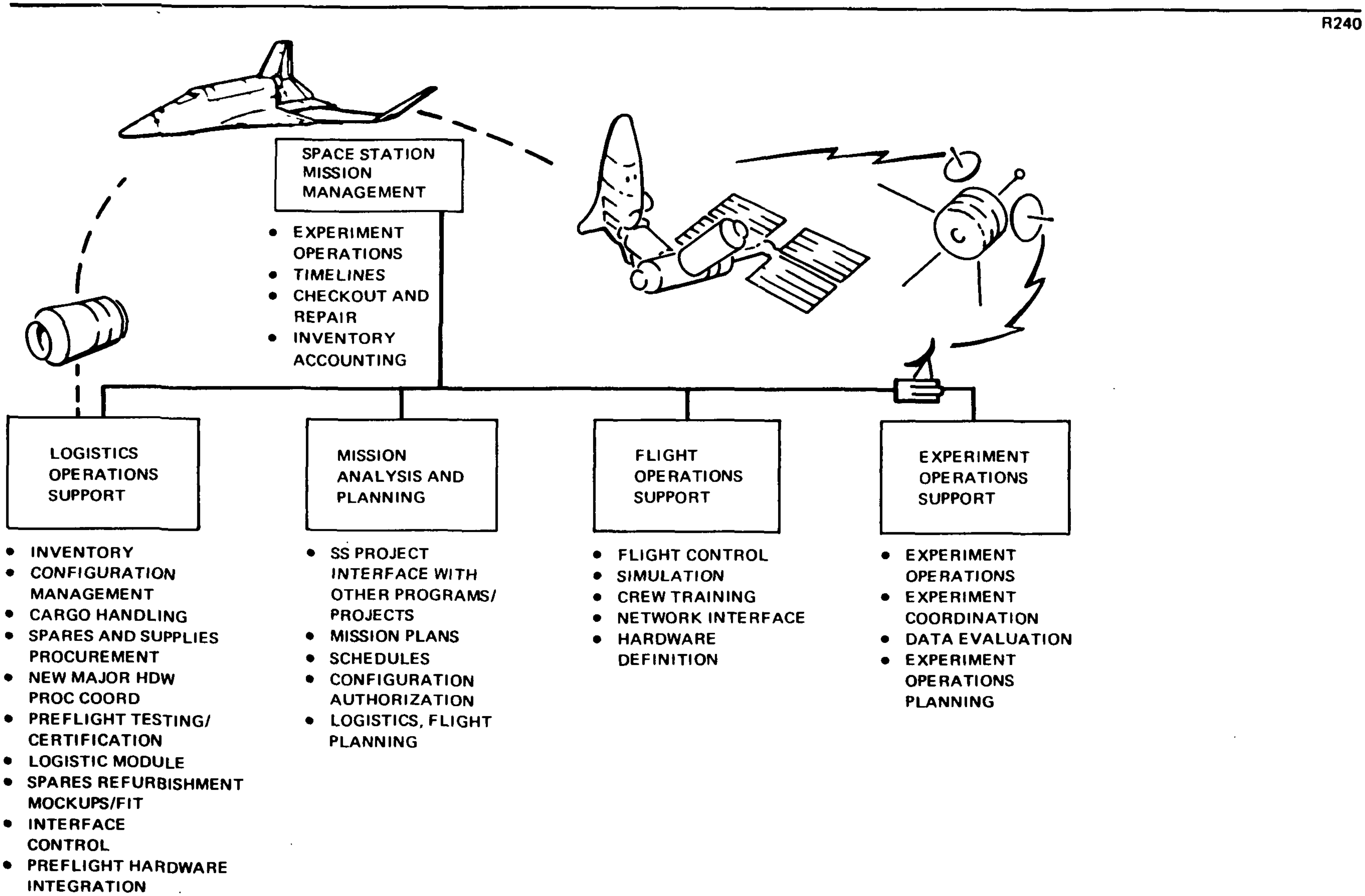

Figure 2-5. Space Station Mission Management Operational Functions

Without the capability for on-orbit daily maintenance and repair, these flight operations support personnel must be equipped with complete interrogation and command capability with the orbiting vehicle. In addition, these personnel will require extensive premission analysis and training to prepare them for their flight-control activities during this period. With the finite probability of systems failures on-orbit, these personnel must also be provided the capability to revise the next scheduled flight crew activities and logistic inventory for required repairs on-orbit. In addition to these functions, the final operation certification of the orbiting configuration will be a function of these personnel. The Mission Operations Implementation Plan shall include the provisions for those special functions during the Initial Space Station buildup phase of the mission.

3.2 INITIAL SPACE STATION OPERATIONS

The sustained Space Station operations will be designed for maximum use of the on-orbit resources to optimize the scientific return of the mission. This will be accomplished within the funding constraints imposed on the Space Station program; however, the overall operations will have this target objective as one of the primary drivers on the program.

During the Phase B Study, the complexity of combining various activities within given resource constraints was identified as one of the more critical problems confronting the Modular Space Station program, since this program would not be one which could be timelined out second-by-second, for the 10-year duration. As a result, a concept was derived which would provide the on-orbit crew with a general 90-day flight plan, supplemented by a 30-day activity plan, further supplemented by a continually updated 48-hour crew plan. The 90-day flight plan was based on a 6-man crew to be rotated with a new crew every 90 days. The 30-day activity plan was based on a 6-man crew to be rotated with a new crew every 90 days. The 30-day activity plan was based on 2 crewmen being rotated every 30-days with Space Shuttle flights. And finally, the arbitrarily-set 48 hour, continually updated, crew plan was designed to account for the various resource availability, exemplified by the following list:

A. Targets of opportunity

B. Logistics available

C. Power available
D. Crewman availability
E. Crew skill availability
F. Sun angle
G. Cloud cover
H. Common equipment availability
I. Etc.

The Mission Operations Plan must provide a technique to account for the changing configuration, its available experiments, and the varying resource constraints throughout the 10-year mission to provide to the ISS operations a maximum mission flexibility.

3.3 GROWTH SPACE STATION (GSS) BUILDUP

The Phase B Study identified a stepped growth from a six-man ISS to a 12-man GSS. This growth, would be accomplished with the addition of another power module and another crew operations module to the orbiting configuration. This Mission Operations Plan should account for this contingency growth in all areas of concern, including the analysis and assessment of its impact on sustained ISS operations.

3.4 GROWTH SPACE STATION OPERATIONS

The GSS operations will be an extension of the ISS operations with the exception of free-flying experiment RAMS being included in the GSS. The Mission Operations Plan must provide for this contingency growth in mission, configuration, and operations complexity.

3.5 SPACE SHUTTLE INTERFACES

As defined, the Modular Space Station relies on the Space Shuttle for support in the build-up and sustained operations. During buildup, the Space Shuttle provides the crew habitability accommodations for the two assembly crewmen for a maximum of 5 days on-orbit time. During this buildup, the Space Shuttle will also provide the attitude control and stabilization for the configuration whenever it is docked to the Space Station; along with the special maneuvers which are required for orbital checkout of subsystems. In addition, the Space Shuttle will supply the atmosphere control, power, and communication subsystem support.

During sustained operations, the Space Shuttle will transport the Space Station crewmen to and from orbit as passengers in the Shuttle, supplying 14 man-days of crew support for this function. The Mission Operations Plan must provide for the interface planning and integration to insure compliance with the Modular Space Station Project requirements on the Space Shuttle Program during the 10-year mission.

3.6 ATTACHED EXPERIMENT MODULES

Figure 2-2 presents the on-orbit operation schedule for a typical Space Station set of experiments. As shown, during the ISS phase of the mission, several attached experiment modules (RAMS) will be operated in conjunction with the Space Station as integral parts of the Space Station. These RAMS will be dependent on the Space Station for subsystem (power, environment control, data, logistics scheduling, etc.) support in addition to the crew support for operations. The Mission Operations Plan will include the requirements for mission planning integration between the Modular Space Station Project and the RAM Project, and provide an effective means of long-range scheduling for delivery and return of these RAMS within the basic constraints of the Space Station and Space Shuttle Programs.

Section 4
MISSION SUPPORT OPERATIONS

The mission support operations, consisting of mission analysis and planning, experiment operations support, logistics operations support, and flight operations support, will be required to perform functions necessary for the sustained operations of the Modular Space Station project over the 10-year mission duration. The Phase B Study identified those functions shown on Figure 2-5 as required on the ground for support of the ongoing mission.

The Mission Operations Plan must provide for these functions, allocating responsibilities between the NASA and the contractor personnel. The information presented below expands on these required functions and the rationale which resulted in their inclusion in the mission support operations.

4.1 MISSION ANALYSIS AND PLANNING

The Modular Space Station project will require project planning, and analysis, efforts in excess of any previous space program. These efforts will comprise the nucleus of preflight and premission operations preparations. The analyses will include the on-orbit resource scheduling, ground resource scheduling, training, training support, and the real-time operations support documentation. Due to the functional complexities of the program, including Space Station, RAMS, the Space Shuttle, the Ground Network, and the various operations support agencies, a large amount of project-integrated planning will also be required.

The analyses and planning efforts will respond to the program directives and program objectives as identified by the Program Management organization. These efforts will be charged with the responsefulness of the conduct of the mission throughout the 10 years.

As envisioned in the Phase B Study, the ISS will not be autonomous, but rather, will operate within the boundaries of preselected mission constraints and objectives identified by the analyses and planning efforts. In order that these on-orbit ISS operations are carefully preplanned and effectively performed, these analysis and planning functions will be concerned with each project element within the program.

Because of the anticipated changing experiment role of the ISS in the space program, it will be required that the Space Station be equipped with the capability for real-time redirection of its resources in response to equipment anomalies. The ISS cannot afford a period of nonproductivity resulting from a lack of scheduling flexibility on-orbit. For this reason, the ISS will require the capability on-orbit to redirect its near real-time (24 to 48 hours) activities, within the Space Station resources available for maximum return of scientific data.

The Mission Operations Plan will include the establishment of the group to respond to the requirements for mission planning and analyses within the established NASA-allocated roles and responsibilities in these areas. The plan will also identify the necessary interface areas which must be included to insure successful and timely execution of these required functions.

4.2 EXPERIMENT OPERATIONS SUPPORT

The primary functional objective of the ISS is the support and operation of the experiments to be performed. As shown in Figure 4-1, the anticipated scientific orbital program will include experiment activities outside the Modular Space Station project. The amount of total scientific data anticipated during the Space Station time-frame, along with the requirements for analyses, storage, and dissemination of these data, indicates the requirement for an Integrated Earth Orbital Program. The Integrated Earth Orbital Program will perform the detail scientific analyses; however, a limited amount of experiment analyses supporting the mission planning and flight operations evaluation will be required in the Modular Space Station Project to assess the ongoing mission activities. In addition to this functional requirement, the continual additions and revisions to existing experiment hardware onboard the ISS will require integration and operations analyses to assure the operational interfaces between the experiment support requirements and the Space Station provided services are compatible.

The Mission Operations Plan will identify those required interfaces between the Integrated Earth Orbital Program and the ISS project, and define those specific functions to be performed as experiment operations support within the Modular Space Station project, including the experiment scheduling activities and development of software scheduling techniques required by the Space Station mission management.

4.3 LOGISTICS OPERATIONS SUPPORT

The logistics requirements of an open-ended, 10-year Space Station project will differ significantly from any previous space program logistics requirements. Problems associated with configuration management of the orbiting

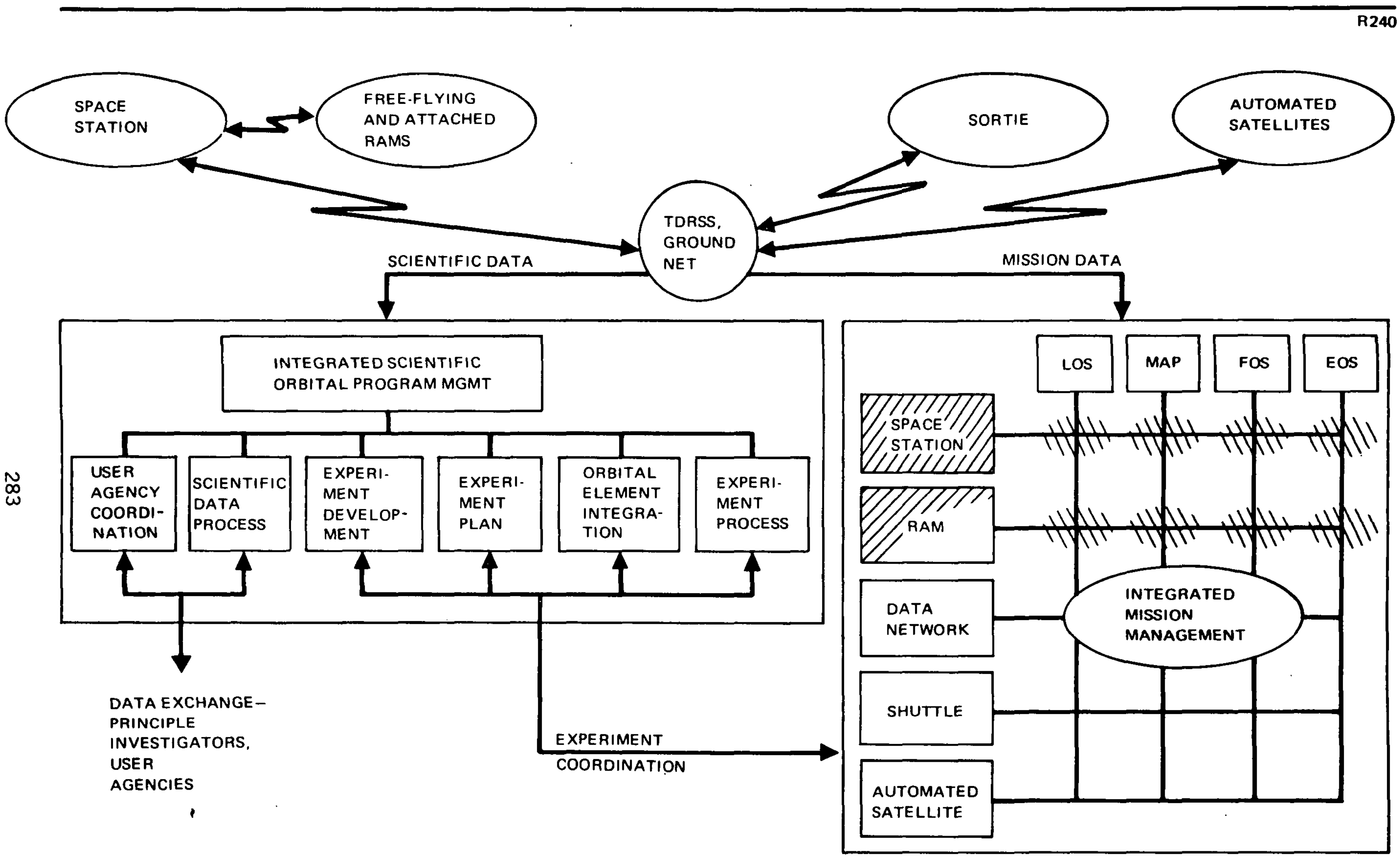

Figure 4-1. Support Elements of an Integrated Earth Orbital Program

vehicle, cargo handling of a continually-resupplied vehicle, and sustained space procurement are new to the NASA. The requirements for this type of activity are presented in the Logistics Plan. Requirements must be defined in detail in the Logistics Plan.

The Mission Operations Plan will include the establishment of the logistics operations activities, and insure that the requirements, as specified in the avove document, are integrated within the overall operations planning for the ISS.

4.4 FLIGHT OPERATIONS SUPPORT

The Modular Space Station project will require daily NASA and Contractor support for the on-orbit operations of the ISS, during ISS buildup, and thorughout the 10-year mission. With the advent of an on-orbit scheduling capability (discussed in subsection 4.1) for the ISS crew, and the design objectives for subsystem maintenance on-orbit, the function previously known as flight control will change in emphasis. The historical "control" will change to a new "support" role; however, during ISS buildup the primary function of the operations support efforts will be to flight control the unmanned orbiting vehicle.

The Modular Space Station project will require that both the flight crews and ground crews be trained using classroom and simulation techniques to develop proficiency in their mission activities. These requirements are covered in the Crew Training Plan. The Mission Operations Plan contractor shall be required to use existing facilities and equipment in performing these functions; the responsibility of flight crew training and flight readiness is a NASA responsibility. The contractor will, however, be required to support these activities by documenting the Phase D hardware and its operation to some degree. The Mission Operations Plan will identify the limit of the contractor effort in this area.

The total grouping of mission support functions will be highly dependent on the interface with the ground network providing the Space Station data. The Mission Operations Plan will identify this functional interface and the related dependancies to provide sufficient visibility into the planned network functions within the Modular Space Station Project. As in the area of crew training, the ground network operation is clearly a NASA responsibility; however, the Mission Operations Plan is required to identify any contractor or contractor/NASA interface with this network which is critical to the successful execution and/or completion of any mission support operation.

Section 5
DATA AND SOFTWARE INTERCHANGE

The data and software interchange shall be one of the items critical to the successful operations of the Space Station. The information interchange associated with operations and operations support shall be required to begin as early as possible within the program, and to continue until program completion. Starting with design information (which will later be used for the generation of procedures), the information flow required shall be continuous between the various operation activities of the project. All physical interfaces shall require operations information exchange as well as interface control documents to manage the hardware compatibility.

The contractor shall identify in the Mission Operations Plan all areas of information exchange that will be required for preflight preparation, and concurrent with the mission for mission support. The plan shall establish the controls required to insure proper information flow, and establish a set of project standards for use and compliance by all project elements. These standards will be required throughout the life of the project and shall include, but not be limited to, such items as a set of Cartesian coordinate systems, measurement systems, and environment standards. All of these established standards shall be designed primarily to aid in communications and shall be in agreement with the program standards.

Section 6
DOCUMENTATION

Documentation, being the primary product of preflight mission operations and a key part of the program mission operations during the execution of the mission, shall receive particular attention in the Mission Operations Plan. The plan shall be designed to direct all lower-tier operations documentation required to implement mission operations throughout the 10-year program.

In initial development of the Mission Operations Plan, the contractor shall follow the requirements listed below to develop the implementation philosophy of the Mission Operations Plan:

A. The plan shall be prepared and published under the direction of NASA.

B. All mission operations tasks shall be traceable to a mission objective.

C. All interface planning functions shall be referenced to their detailed parent planning document.

D. The plan shall be consistent with the approved version of DR CM-01, 02, 03, and 04.

E. Mission planning shall concentrate on developing the highest possible degree of Space Station autonomy with minimum and cost-effective ground support.

F. The plan shall show the logical flow of all inter-related functions required to achieve Space Station program objectives.

G. The Plan shall be designed to provide the framework for detailed subtier planning. It shall be used as a mission management tool rather than a detailed operational definition document.

H. The plan shall define and outline all subtier plans and procedures, and methods of control and tracking.

Section 7
REPORTING

The contractor shall include in the Mission Operations Plan the requirements, techniques, procedures, and anticipated schedule for reporting the status and results of Phase C/D Mission Operations and Mission Support Operations to the NASA. The contractor shall pay particular attention to expediency in the development of the reporting activities.

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MODULAR SPACE STATION
PROGRAM MANAGEMENT PLAN REQUIREMENTS

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PROGRAM MANAGEMENT REQUIREMENTS PLAN

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PROGRAM MANAGEMENT PLAN REQUIREMENTS

Section 1
INTRODUCTION

The Modular Space Station program involves the development of an earth orbiting Modular Space Station configuration which supports a 10-year program of space experimentation and exploration. The magnitude, duration and complexity of this program presents a significant challenge to provide technical management practices which must be simple and effective. The Space Station Phase B Definition Studies have evolved a management methodology capable of controlling and assessing large, complex programs. The technique provides:

A. A mechanism for the identification of performance and its measurable characteristics.

B. Assurance that both NASA and the Contractor have management visibility over all facets of the program, and can exercise technical and administrative control to minimize cost.

C. Systematic program framework for the development of cost and schedule data and to detect the sensitivity of performance, cost, and schedule to planned or unanticipated change.

Management policies and associated decision making processes will be supported by several management techniques developed for the space station program which reduce the complexity of management and technical development functions. These management techniques are briefly discussed in the paragraphs that follow to clarify their identity, function, and relationships.

The definition studies have evolved and tested a program Work Breakdown Structure which relates management responsibility to the development activities, and permits the allocation of performance, from the allocate, cost, and schedule, total program down to the deliverable end-item level. It also provides the capability for selective assessment and control of the subsystem level in instances where subsystem performance and development may be critical to subsystem success. The Work Breakdown Structure (WBS) to be applied in this development program is illustrated in Figure 1-1. The WBS shall be used and expanded, as necessary, to structure and identify program performance cost and schedule status during subsequent phases of detail design development, design verification, and operations.

Figure 1-2 identifies the various levels of technical requirements, and is directly relateable to the WBS. These requirements are documented in specifications, at the Program, Project, and System/Contract end item, (CEI) level, and define program performance and performance verification requirements for each item at each level. Interface and Support Requirements (I&SR's) at each level are similarly documented. These I&SR's define, performance, design, interface and support and services required of agencies or contractors on both sides of the interface. Interface control documents (ICD's) perform this function at the hardware level. Phase C/D development will be initiated with and shall be responsive to these specifications and the performance requirements defined therein. As performance is developed and expanded at lower levels these documents shall be expanded and updated.

A definitive relationship has been established between performance requirements (Section 3.0 of the Specifications) and verification requirements (Section 4.0) at each level. It is this relationship which will be applied in quantitatively assessing both contractor and equipment performance.

This Management Plan Requirement is supported by the additional plans identified in this document. This Requirements Plan package identifies the plans required of the contractor by NASA during the Program Implementation Phase. These plans that have been derived from the specifications described above and expanded through systems engineering techniques to

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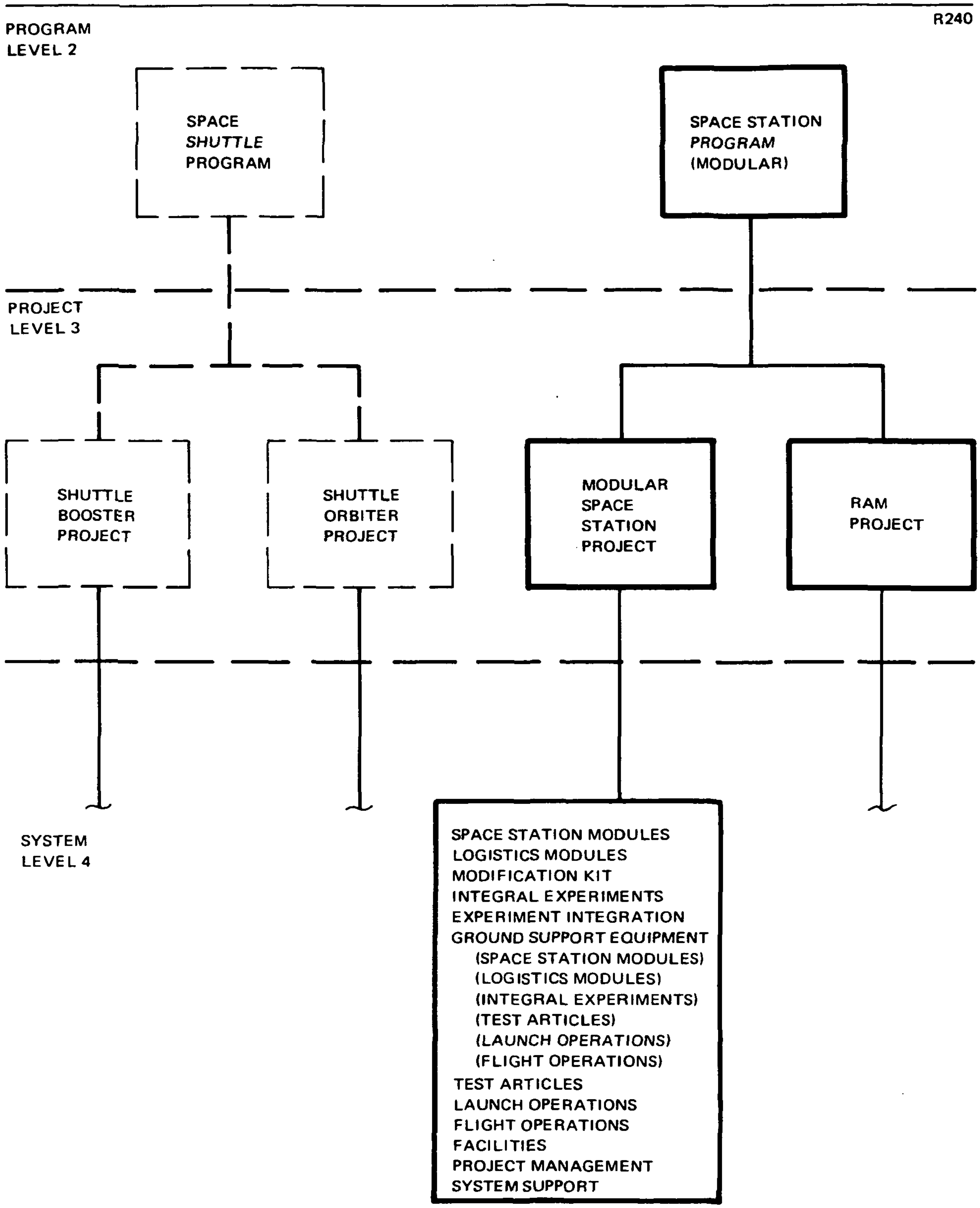

Figure 1-1. Work Breakdown Structure for Space Station Program (Modular)

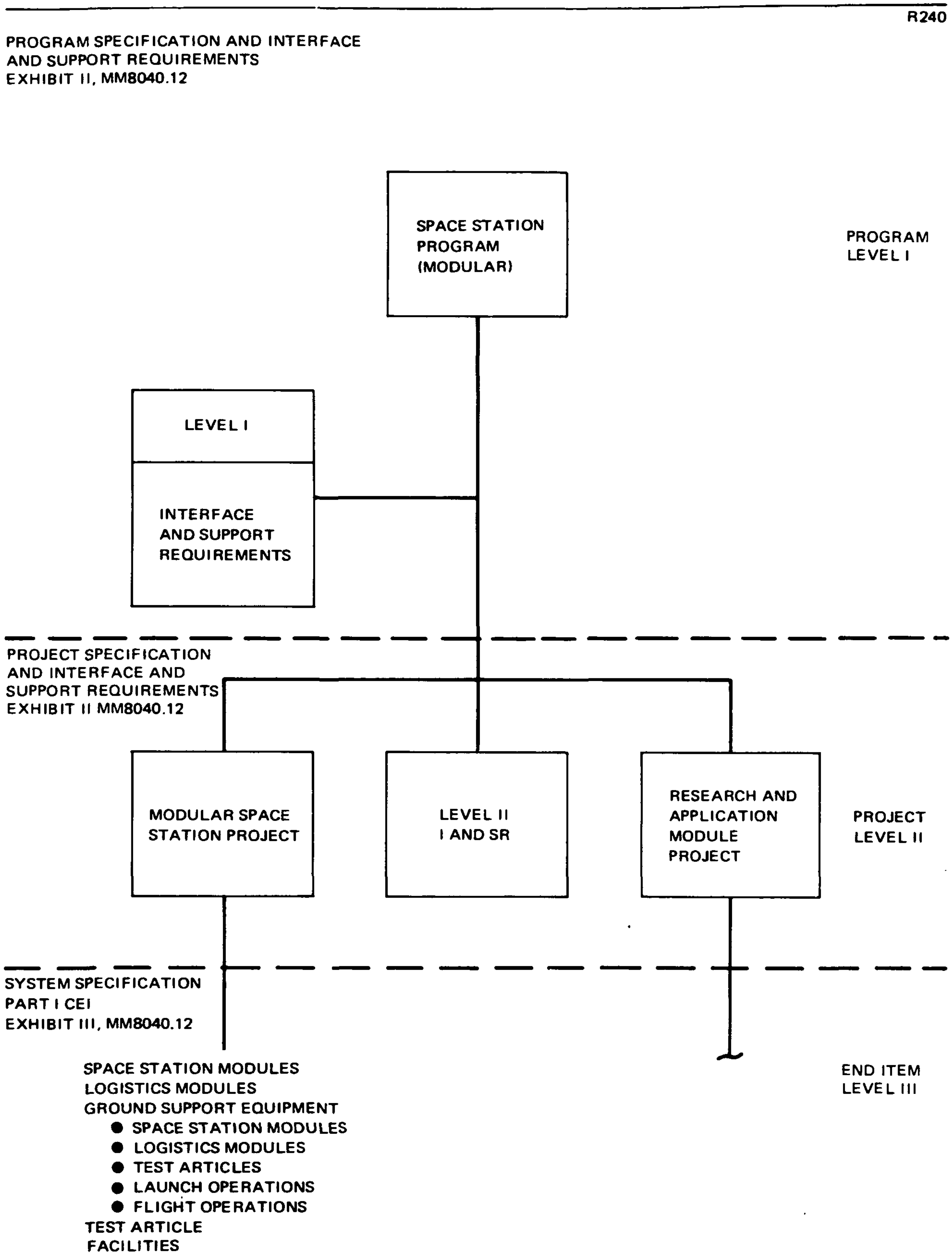

Figure 1-2. Space Station Program (Modular) Requirements Structure

provide the information necessary to conduct total program technical development and management. These requirement plans are tabulated below:

1. Design
2. Manufacturing
3. Quality
4. Reliability/Maintainability
5. System Safety
6. Verification
7. Facility Utilization
8. Prelaunch and Launch Operations
9. Mission Operations
10. Crew Training
11. Experiment Integration
12. Logistic Support
13. Supporting Research and Technology
14. Program Integration
15. Software Integration

The contractor shall prepare these implementation plans in accordance with the Plans Requirements before the initiation of the development phase.

Using the established relationship of the WBS to the Performance Requirements structure described and illustrated above, and the program development plan, the contractor shall develop and interelate program management networks for the accomplishment of the tasks embodied in the Requirement Plans. Within each plan, management networks must be organized for each level of development. The complexity of each network should be minimized and kept consistent with the level it supports. Key events (PRR, PDR, CDR, FACI) should be identified and related to the accomplishments required by each plan.

The contractor shall, as a part of the Program Management Plan, utilize the techniques developed for the Space Station Program (i. e., Performance Requirements/Verification Relationships), to establish his methods for reporting program status, and quantifying the relationship of system performance to costs and schedules. This technical measurement structure must be relatable to the WBS and all management networks at appropriate levels and milestones.

The concept of "a 10-year useful life cycle" is a significant departure from past single mission space systems planning and management. The management approach developed for the Space Station Program embodies this philosophy, and involves major shifts in emphasis in technology areas and design/test philosophy. It recognizes the emphasis that must be placed on the management of systems that will require on-orbit maintenance and replacement, multiple redundancy, and planned long-term logistic support. The contractor's Management Plan shall explicitly define his concepts and experience, a management process for controlling design and exploiting a long life-cycle system in terms of configuration maintenance and the associated requirements of long-term logistics planning and technological response.

The purpose of this plan is to identify those management and organizational requirements which permit the achievement of the following goals:

A. Development and operational costs within fixed budget forecasts.
B. A design concept within the state of the art but maintainable and flexible for future technological adaptability.
C. Low-risk, multiple-redundant operation.
D. Identifiable configuration and logistics management.
E. Optimized experiment and crew support facilities.
F. Minimum development risk, high-commonality concept which offers the potential of rapid-change impact analyses.
G. Minimum Test—Qualification of lowest level of assembly.

The requirements in this plan are applicable to Phase C/D of the Modular Space Station Project of the Modular Space Station Program and are directly correlated to the NASA-approved Space Station Project WBS shown in Figure 1-1; the WBS cannot be changed without NASA approval. The requirements shall be reflected in all other Space Station program and project plans where appropriate. The requirements within this plan shall be used in the preparation of the phase C/D Program Management Implementation Plan. Figure 1-3 depicts key milestones as they relate to the baseline requirements and functions of the Space Station project.

Section 2
FUNCTIONS AND RESPONSIBILITIES

The contractor shall define his management organization and the roles and responsibilities of its subgroups. He shall establish interface control techniques and procedures, and define his methods for determining adherence to performance, cost, schedule and goals. The organization shall be under the direction of a project director who will be directly responsible for project accomplishment. The organization shall be structured to include the functions of program development and engineering, fiscal management, manufacturing, quality control, procurement, launch and mission operations, configuration management, safety, reliability, and data information management.

Brief descriptions of the above functions and related responsibilities are presented in subsection 2. 1.

2. 1 CONTRACTOR FUNCTIONS AND RELATED RESPONSIBILITIES

2. 1. 1 Program Development and Engineering

A program development and engineering function shall be performed. This function will embody the technical responsibility for assuring that total project requirements are incorporated in technical decisions. This technical function consolidates system development, and project engineering. The system development function shall interface with NASA to define system contract requirements, provide management methodology, techniques, plans,

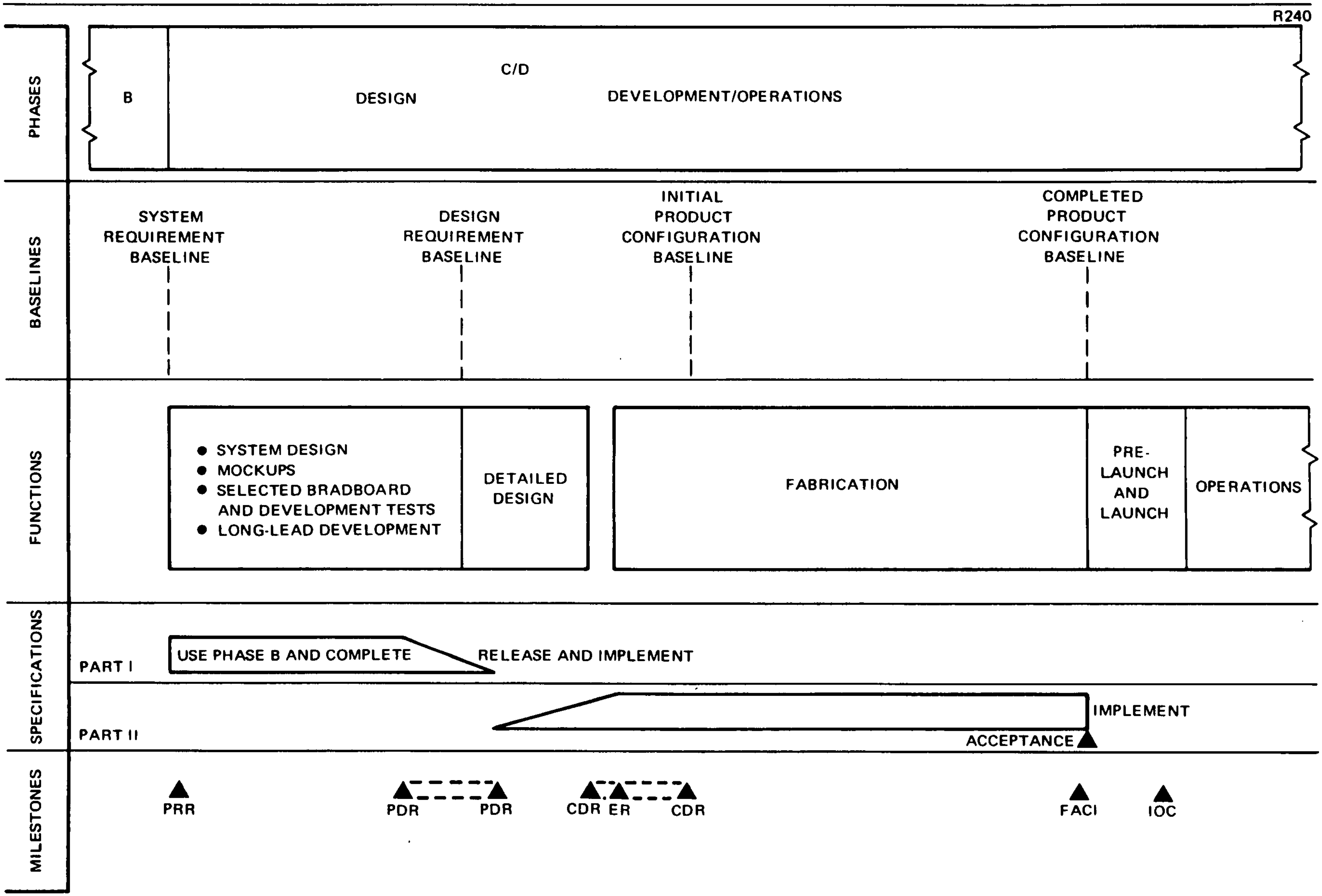

Figure 1-3. Project Milestones Versus Project Baselines and Functions

cost and schedules, perform program integration, identify and define the tasks necessary to support the project, and assure that design/development and activities are responsive to system requirements. Project engineering shall be functionally oriented by technology and be responsible for engineering design, test, checkout, and the technical effort of the subcontractors.

2.1.2 Fiscal Management

Fiscal management, in consonance with the contractor's established fiscal policy shall perform the four basic functions of budgeting and cost control, program control, contracting, and reporting for the Space Station project. These functions shall be organized to fulfill the project requirements of pricing, cost management, data management and financial planning and control.

2.1.3 Manufacturing

Manufacturing a "one-of-a-kind" vehicle indicates the need for a streamlined manufacturing organizational concept. Functional elements of fabrication, manufacturing engineering, planning, tooling, inspection and test, and facility engineering shall be integrated to the extent that emphasis is directly oriented to the production of the end item. Interface relationships with support functions (e.g., procurement, quality control) shall be similarly organized. The manufacturing organization shall perform fabrication, assembly, checkout, and delivery of the end items.

2.1.4 Quality Control

A separate and distinct quality control organization shall be established. This organization shall be the prime interface with NASA for the establishment and implementation of the quality assurance and reliability assurance requirements of the contract. As with the manufacturing organization, it should be structured to consolidate functions that emphasize the one-of-a-kind concept, including the interface with the Government inspection agency. This organization shall be responsible for all quality control functions at the contractor's plant, subcontractors' locations, and the launch site.

2.1.5 Procurement

The procurement organization shall direct all major subcontract and material procurement. It shall reflect the contractor's modified procurement policy directed to the procurement of highly sophisticated singular items and shall be organized to interface effectively with the engineering, manufacturing, and quality control organizations. Organizational requirements shall also be placed upon subcontractors to streamline their organizational structure to stress the development of a unique end item.

2.1.6 Launch and Mission Operations

During the development phases, the launch and mission operations organization shall act as a support body to NASA for prelaunch, launch, and mission planning activities. Direct interfaces with design engineering and experiment integration functions shall be emphasized to ensure mission operational inputs in the early design and planning stages. When the project moves into the operational phases, this organization shall become the basis from which the contractor will expand his efforts, relative to this function, to support the NASA at the mission operational site.

2.1.7 Configuration Management, Safety and Reliability, and Data and Information Management

Management organizations for such functions as configuration management, safety and reliability, and data and information management shall be established as staff-oriented functions under the contractor's project director. To avoid excessive cost, emphasis shall be placed on performing these functions with a small but highly skilled staff. The nature of these functions necessitates mandatory interface responsibilities with NASA to manage and control numerous detailed requirements. A directly parallel functional relationship with NASA shall therefore be stressed. Responsibilities for configuration management and for data and information functions are further delineated in Sections 7 and 8.

2.2 NASA/CONTRACTOR INTERFACE

Close working group relationships will exist between NASA and contractor technical communities relative to system engineering and preliminary design and development necessary for successful review milestones, i.e., PRR, PDR, CDR, and FACI. NASA emphasis will be to concentrate on user requirements, i.e., safety, reliability, maintainability, and operational and functional characteristics, whereas the contractor will concentrate on developing the definition and preliminary design to a level of confidence adequate to meet the NASA requirements.

The Program, Project, CEI, and I&SR Specifications shall be the vehicles for technical direction of the contractor by NASA. The agency will utilize these documents to assess the adequacy of the contractor design and verification results in meeting program mission objectives and for monitoring the contractor's progress.

In addition to Technical Direction Meetings, NASA/contractor working group sessions will include discrete events such as quarterly reviews PRR, PDR, CDR, FACI, or acceptance review and flight readiness review. The PRR shall be conducted at the earliest feasible point after ATP, and will encompass both technical and management review of the contractor's plans for meeting program requirements. The contractor shall be responsible for providing clear and adequate project program reports and briefings to ensure that NASA has visibility over the contractor's implementation plans. Control of NASA/contractor technical interface will be maintained by the NASA project office and the contractor program development and engineering function to ensure maintenance of the respective roles and responsibilities described above. The contractor will be responsible for providing clear and complete inputs in support of all program activities.

2.3 CONTRACTOR INTERFACE CONTROL

Interfaces at all levels of management are defined in the Interface and Support Requirements Documents (I&SR). The contractor shall be responsible for maintaining the appropriate I&SR's.

Section 3
SCHEDULES

All schedules generated by the contractor for the Space Station project shall adhere to the following principles:

A. Project constraints and milestones shall be emphasized.

B. Maximum emphasis shall be on the control of start and termination points, for all activities that are critical to the development, fabrication, test, and operation of the elements comprising the modular space station.

C. Schedules shall be designed with inherent flexibility and visibility to adjust at the detailed level while maintaining firm program milestones.

D. Schedules shall relate to the WBS and management networks and be end-item oriented.

3.1 PROJECT SCHEDULE

The contractor shall prepare a Master Space Station Project Schedule which shall be based upon and be compatible with the Space Station Program Master Schedule and the Space Station Project WBS. Using this Project Master Schedule, the contractor shall develop a project management logic network of activities and events in direct relation to the WBS, and in sufficient density to depict planning, implementation, and other milestone-type information that will provide NASA a clear understanding of the contractor's plan for accomplishing the requirements of the Phase C/D work statement. A description of each logic network event and activity shall be included to define clearly the work involved in the accomplishment of the event. Contractor-initiated changes to the Master Space Station Project Schedule which affect the Space Station project management logic network or project costs shall be submitted to NASA for approval. Where changes to the project management logic network dictate changes to the Master Project Schedule or result in increased costs, such changes will be approved by NASA. In those cases where changes cut across projects, the contractor's project integration activities shall assure their reflection in the project baseline documents and I&SRS, interface control documents (ICD). The contractor shall identify key program milestones, i.e., major engineering, manufacturing, and test activities, key program reviews, delivery dates, and launch.

3.2 CONTRACTOR INTERNAL WORK SCHEDULES

Internal schedules shall be prepared in accordance with a jointly agreed to format. These schedules shall be controlled internally by the contractor's normal control system and shall reflect the specific way the work will be done. As a part of his proposal, the contractor shall identify for review and approval the scheduling system he will use, including sample formats and control and issuance procedures. Schedules at the subsystem level and below will be classified as Type IV data available for NASA review at the contractor's facility, except in instances where a subsystem may be deemed critical either in terms of development time, performance, or cost.

Section 4
FINANCIAL, COST/SCHEDULE PERFORMANCE MEASUREMENT AND CONTROLS

4.1 GENERAL REQUIREMENTS

Using the management approach developed for the Space Station Program, the contractor shall interrelate all facets of the program (functional, programmatic, technical, and indirect activities) together and illustrate his approach for assessing technical performance against cost and schedule. The reporting system shall relate to the approved work breakdown structure and Performance Requirements Structure. The contractor shall make use of his own information systems to the maximum extent possible. The system shall provide visibility and control of technical performance test results, schedule relations, and direct and indirect costs and labor. It is the intent that the contractor use a single management reporting system for program technical status, the allocation and control of both direct and indirect costs and labor, and that separate reports and management systems not be prepared for the government. The management information system shall include provisions for periodic update to reflect changes in plans, implementation, accomplishments, etc., including recommended reviews and working sessions with interfacing organizations. The contractor shall describe the criteria and ground rules for updating or changing the management information system.

The contractor shall establish a technical status/cost/schedule measurement, and control system which will:

A. Report technical progress (design status/test results) and budget in accordance with the WBS at the subsystem level (e.g., EC/LS, data management, etc.).
B. Track and schedule, report, and verify actuals at the subsystem level.
C. Relate comparable performance status between all WBS items for which he is responsible.
D. When problem areas develop, have the capability to control and report at selected levels of the WBS below the subsystem level. Control and reporting at these levels shall be requested only by the contractor project management or the NASA project director.
E. Produce a technical capability/cost/schedule assessment system compatible with the project WBS.
F. Provide administrative controls needed to comply with "use and change" cost elements when such actions involve Government-furnished facilities.

The contractor shall specify the frequency of update of the master file for each category of information (financial, schedule, test information, failure data, unsatisfactory condition reports, corrective action etc.) and shall specify the ground rules and criteria to be followed in the update.

4.2 REPORTING

The contractor shall submit technical and financial management reports based on the project WBS and Program, Project, I&SR and CEI Specifications. These reports will include cost reporting to the level as specified or negotiated in accordance with the requirements contained in subsection 4.1 and will relate to agency code accounts.

Section 5
CONFIGURATION MANAGEMENT

Configuration management practice shall apply to program documentation (specifications, plans, procedures, reporting formats) as well as design drawings, hardware/software, and spares. The maintenance of on-orbit configuration control over a 10-year cycle is a peculiar problem requiring special attention. If substantial reductions are to be attained in the costs for programs of this scope, it is mandatory that configuration management processes and associated change control techniques be simplified and made functionally effective.

Since the Modular Space Station Project involves one-of-a-kind hardware, simplification of configuration management during the development/ production phase can be achieved. This is reflected in the following requirements:

A. A small configuration management organization shall be established to direct the function within the technical organization. Ultimate change responsibility is vested in the project manager.
B. The flight integration tool (FIT) is a ground-based duplicate of the on-orbit Space Station and shall be used for configuration reference and control.
C. Formal configuration management shall meet the requirements of MM8040.12, as modified by NASA-contractor agreements.
D. The contractor shall be responsible for verifying that Part I CEI Specification requirements have been met.
E. Government-directed changes affecting hardware design and performance will be incorporated into the appropriate levels of specifications as requirements.
F. The specifications are the basis for determination of in-scope and out-of-scope requirement changes.
G. Configuration control shall be divided into two phases:
Phase I shall start at Phase C/D ATP and continue through to that time when all Class I changes, emanating from CDR have been approved. During that time, all changes shall be internally controlled by the contractor, with the exception of those Class I changes

that affect the approved CEI Specification. The contractor's internal control system shall include change review and approval at the project management level and shall demonstrate that decision making information is documented, and that identification, traceability, and verification data are collected and maintained. The exception, those changes affecting the approved CEI Specification, shall be controlled by formal configuration management procedures (MM 8040. 12).

Phase II will start at the end of Phase I and will continue until the end item is delivered to NASA by an approved DD Form 250. During this time all changes shall be internally controlled by the contractor (as defined above) with the exception of Class I changes affecting the approved CEI Specification requirements, which shall be controlled by formal configuration management procedures (MM 8040. 12). All Class I and Class II changes shall be submitted to the government for review, and all government-directed changes shall be incorporated into the CEI Specification.

As an active participant in integrated mission management (See section 7 below), the contractor will support NASA in configuration control disciplines at the mission operations site.

Where changes affecting the Modular Space Station during Phase C/D require hardware design, acceptance test, or qualification test effort, NASA shall notify the contractor of the effect of the change relative to form, fit, function, and performance requirements.

H. All Class II changes shall be controlled internally by the contractor (as defined above) and shall include change review and approval at the project management level.

I. At the time of end-item delivery, the contractor shall supply a configuration identification index (CII) and a Configuration Status Accounting Report (CSAR).

Section 6

DATA MANAGEMENT AND RELATED INFORMATION EXCHANGE

6.1 DATA MANAGEMENT

An efficient and cost-effective data management program shall be developed. Requirements for original data must be determined carefully and specified only in those areas where the contractor's internal data will not suffice. Summary-level data in management decision-oriented format will be directed wherever it will adequately serve project needs. Two underlying features are indispensable to a "low-cost" data and documentation plan:

A. NASA and the contractor must reach mutual agreement in establishing summary-level data requirements.

B. Bulk data shall remain at the contractor's location, available for review.

The Data Management Plan, which the contractor shall prepare and maintain, shall adhere to the following requirements:

A. Only the "master project documents (e.g., Program and Project Specifications, CEI Specifications, and Program/Project Plans) shall be considered Type I data.

B. Data shall be limited to that which is absolutely necessary for the contractor to develop, manufacture, test, and deliver the end item.

C. The applicable data requirement descriptions (DRD's) will be designated by NASA and should consider the contractor's recommendations.

6.2 RELATED INFORMATION EXCHANGE

The contractor shall define an information exchange system which will provide real-time and off-line information and information processing. Emphasis shall be placed on summary-level information which shall be prepared and processed on standardized formats to allow for compatibility of operation between NASA and contractor project directors. Consideration should be given to the adoption of automation, such as video control rooms at the NASA center and at the contractor's plant. The objective is that the same summary-level data, oriented to support management decisions, shall be available both to NASA and the contractor project management at the same time.

Section 7
INTEGRATED MISSION MANAGEMENT

To perform mission management in a cost-effective and precise manner, the relationships between the operations elements (e. g. , logistics, experiments, mission control, mission planning) over a 10-year period will require a high degree of coordination among the Modular Space Station Project, other projects, and NASA. An integrated mission organization will be established to provide a strong central control for mission operations.

In Phase C/D, the contractor shall establish a technical and management organization (subsection 2.1.6) which will support NASA in planning the mission operational functions of flight support, experiment support, logistic support, mission analysis and planning, and Shuttle launch support as they relate to the Modular Space Station project. Cost-effectiveness dictates that the Phase C/D analysts and planners shall form the nucleus of the contractor's staff which will support NASA in the aforementioned mission operation functions at the NASA mission operations site during Phase D. Selection of this staff during Phase C must include consideration of the Phase D assignments.

In the latter stages of Phase C and during Phase D, the contractor will actively support NASA as the Modular Space Station project member of the mission operations team. To reduce to a minimum the number of interfaces, the contractor's team shall consist of a consolidation of his associate, second-level, and support contractors. This participation will consist of the following:

A. Flight Support Operations—Prelaunch and launch, simulation and training, mission control, and ground network control.
B. Experiment Support Operations—Scientific data control, experiment program management, and experiment support center.
C. Mission Analysis and Planning—Mission definition, mission scheduling, flight scheduling, and trajectory and orbit analyses.
D. Logistic Support Operations—Inventory control, configuration management, ground facility maintenance, and procurement.
E. Shuttle Launch Operations—Mission coordination, schedule coordination and up- and down-cargo coordination.

The contractor shall develop a Space Station mission operation plan which will will outline the operational requirements, guidelines, constraints, responsibilities, interfaces, and time phasing of major milestones or events required to fulfill those functions iterated above.

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MODULAR SPACE STATION
CREW TRAINING PLAN REQUIREMENTS

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CREW TRAINING PLAN REQUIREMENTS

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CREW TRAINING PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

The purpose of this document is to define the crew training requirements for the Modular Space Station and their application; and, the organization and general controls/procedures, policies, and objectives to be applied in preparing the Phase C/D Implementation plan. This document has been prepared to guide contractor planning and bidding for Phase C/D.

1.2 SCOPE

This Crew Training Plan Requirement covers all aspects of flight and ground crew training required for operation of the Modular Space Station project. The Implementation Plan shall be limited to Phase C/D. It will reflect an understanding of the training function in the Modular Space Station Project, significant training requirements, and the critical issues and potential problems associated with training.

Crew Training will be accomplished by NASA. To perform these functions, hardware and software available within both the Modular Space Station and Shuttle Programs will be used.

1.3 CONTROL

This plan will be developed in accordance with NASA Handbook NOD. 1, NASA Safety Manual Volume I, Basic Safety Requirements NHB 1700.1, Dated 6 March 1970; Handbook 1700.2, NASA Safety Manual Volume III, System Safety, NHB 1700.1, Dated 6 March 1970; Handbook 7121.2, Phased Project Planning Guidelines, dated August 1968; the Phase C/D Statement of Work; and the Program and Project Specifications.

The Crew Training Plan will describe the way in which the plan is approved, how it may be changed, relationships to other Government agencies and associate contractors, and the single point of NASA contact for final direction.

Section 2
ORGANIZATION AND RESPONSIBILITIES

2.1 ROLES AND RESPONSIBILITIES

The roles and responsibilities of all contractors and agencies will be identified and described. The responsibilities discussed in the following paragraphs have been identified to date.

NASA will be responsible for all crew training activities, but contractors (including experiment contractors and principal investigators) will be responsible for defining the requirements for training, i.e., the knowledge and skills required by crewmen to accomplish their functions. In addition to maintaining overall responsibility for all crew training, NASA will select and train members of the operations crew in the operation and maintenance of the systems and subsystems. NASA will direct cross-training in scientific or research duties required of the operations crew, but this may be accomplished by experiment contractors or principal investigators.

NASA will select the principal investigators for each functional program element (FPE) or experiment. The initial selection of experiment crewmember candidates will be made by the principal investigators. NASA will review these selections and impose additional selection criteria relating to space flight qualifications that will be used in the final selection of experiment crew members.

The principal investigator or experiment contractor shall train the experiment crewmen in scientific disciplines and the operation of experiments, but NASA will provide indoctrination and training in space-peculiar operations, operation and maintenance of space vehicle subsystems, and emergency and safety provisions and procedures.

Since the docking maneuvers are the responsibility of the Shuttle, crew training associated with these maneuvers is not a responsibility of the Modular Space Station Program. Thus this plan will not address training associated with this activity.

Detailed plans for each area of responsibility will be developed. These will be integrated into the overall training plan and will include reports to be submitted, the approval cycle, coordination meetings between interfacing areas, and status-reporting procedures.

2.2 ORGANIZATION AND INTERFACE

The contractor's organization and the responsibilities of the organization's various elements will be defined, and the interfaces with other contractors and customer agencies will be identified. The following represents, as a minimum, the interfaces between various organizations having training responsibilities that must be analyzed in greater detail and redefined in the training plan.

The plan will define the interface between the prime contractor and NASA in relation to the contractor's establishment of training requirements and NASA's implementation of a training program to meet these requirements.

The interfaces between the prime contractors and any subcontractors who develop subsystems must be defined since the subcontractors will be responsible for providing information concerning the operation and maintenance of subsystems. The prime contractor, therefore, must integrate the requirements for training on these subsystems into overall training requirements.

The plan will define the interfaces among the prime contractor, the experiment contractors, and the principal investigator, who will develop training requirements and plans for experiment operations, so that a plan and schedule for training crewmen in space-peculiar operation can be established by the prime contractor and implemented by NASA.

The plan will define the interface between the Modular Space Station contractors and the logistic vehicle contractors so that any requirements for training or indoctrination related to crew or cargo transfer by the crew can be integrated into the total crew training plan.

The interface between NASA and the principal investigators, who will make the initial selection of (and provide scientific training to) experiment crew members, will be described, even though the prime contractor will not be directly involved in the interface, since these activities must be integrated and scheduled into the overall training plan.

Section 3
REQUIREMENTS

3.1 REQUIREMENT ANALYSIS

A training requirement analysis will be conducted to identify all functions to be performed by the flight and ground crews in the operation of the Modular Space Station. This will include preflight, launch, on-orbit, deorbit, and recovery operations. It will include experimental activities as well as the activities involved in the operation and maintenance of the various Modules. In addition, ground crew training requirements will be defined and skills established for the performance of ground activities such as Logistics Support, including Log M refurbishment, mission support, mission planning and analysis.

For the on-orbit phases of operation, certain activities will be analyzed to identify and describe in detail the functions to be performed by crew members. These descriptions will include the conditions under which the functions must be accomplished, quantitative measures of accuracy of performance, and any time limitations imposed upon performance. The activities to be analyzed will include, as a minimum, the activities involved in maintaining the health and well-being of the crewmen, such as eating, sleeping, personal hygiene, housekeeping, recreation, and exercise; the activities involved in the operation, maintenance, and repair of the modules, such as navigation and guidance, orbit keeping and attitude control, rendezvous and docking, cargo transfer and storage, subsystem checkout, module equipment maintenance and repair, experiment module maintenance and support, communications and data transmission, and extravehicular and intravehicular activities; the activities involved in performing the basic mission of the Modular Space Station (research); and the activities involving safety and emergency procedures.

3.2 SKILL ANALYSIS

Each of the functions defined in Section 3.1 must be analyzed to determine the precise skills required for its accomplishment. Each task function will be analyzed to determine the knowledge and motor skills required. An analysis of the functions to be performed in relation to the skills required will be accomplished to synthesize individual crew requirement descriptions, including both primary and secondary skill requirements. This analysis can be accomplished only when the precise nature (i.e., detailed design characteristics) of the subsystem has been determined and a detailed definition of maintenance and repair procedures has been developed. Consequently, little detail about skill requirements can be identified at this time. However, the operation and maintenance philosophy upon which the design and development of the Modular Space Station will be based will yield some insight into the area. The Modules and their subsystems will be designed for maximum automation of all routine functions, both in operation and maintenance, so that crew members, including the operational crew, can devote the major portion of their time to performing the primary mission of the Station (research). Onboard checkout and monitoring of subsystems will be accomplished with maximum automation, and with replacement of equipment at the highest possible level consistent with the logistic capability. Maintenance technicians (in the usual sense), are therefore not required. To ensure maximum use of Space Station time in orbit, however, the crew will be trained to accomplish fault isolation and repair or modification at the lowest possible level in emergencies. This means that the crew members must completely understand all details of the design and operation of subsystems. Consequently, the operational crew must be trained as highly skilled, multidisciplined engineers. Moreover, since a significant portion of their time will be available for research, they must be trained in scientific skills so that they can effectively participate in these operations.

Each member of the experiment crew, in like manner, must possess the skills of a true scientist, not a technician, since the crew will work as scientists, making decisions on the basis of analyses of data obtained in orbit, and altering experimental procedures or apparatus to maximize the benefits from their research. They must possess expertise in the design and operation of their scientific apparatus so that they will be able to adjust, repair, and modify it as required to maximize the return of scientific data.

3.3 SELECTION REQUIREMENTS

On the basis of the above analyses and descriptions, criteria for the selection of the various crew members will be developed. These criteria will specify educational background, length and type of experience, physical requirements (such as age, height, and weight limitations), aptitudes, sensory and motor capacities, intellectual requirements, and personality characteristics. Procedures to be used in selecting crew members will be specified. Special attention will be given to the procedures used in selecting scientific personnel, particularly in relation to any role that elements of the scientific community would play in this selection process.

Criteria for the selection of operations crewmen will be developed by the Modular Space Station contractor(s). NASA will use these criteria (with additions or deletions) to make the selections. However, since these crewmen will also engage in research activities, the principal investigators whose experimental programs will use these crewmen will specify the scientific capacities that such crewmen must possess. These criteria will therefore be incorporated into the total package used by NASA in selecting the operational crew.

The principal investigators will make the initial selection of candidates for experiment and scientific crewmen, and will establish the scientific criteria for these selections. Such criteria will be approved by NASA prior to use in the selection process. In the final selection of the scientific crewmen, the candidates will be further screened by NASA, using criteria pertaining to suitability for space operations, including consideration of launch, long-term orbital operation, and reentry and recovery.

3.4 TRAINING REQUIREMENTS

The relationship between skill requirements and selection criteria will be analyzed to determine the additional training that each selected crew member will require. These training requirements will include both the acquisition of additional information and the development of manipulative skills and procedures. Techniques to be used in providing the required training will be specified and described. Included will be type, length, and content of classroom courses; requirements for training in the performance of simulated tasks and procedures; and requirements for team versus individual training and practice of proposed functions and duties.

The specific training required will, of course, depend upon the specific skills to be developed. These (as noted above) cannot be identified until more detail is available concerning system and subsystem design and operation. In view of the philosophy of operation and maintenance noted earlier, however, it is obvious that the crewmen must be provided with a complete understanding of the design and operation of every subsystem so that repairs can be effected in emergencies. This will require training in the fundamentals of various engineering disciplines, space physics, and orbital mechanics as well as training on the specific subsystems. In like manner, training for experiment operations will require a thorough understanding of the fundamentals of the scientific discipline involved, as well as an understanding of the purpose and operation of the specific experiments and associated apparatus.

The procedures to be used in qualifying personnel for assignment to space operations will be defined. Here, again, any requirements for participation by elements of the scientific community in qualifying scientific personnel will be noted.

The Modular Space Station contractor(s) will develop tests of performance proficiency, which will be used by NASA in partially qualifying operational crewmen. The principal investigator will develop tests of performance proficiency for scientific activities. The principal investigator's tests will be reviewed and approved by NASA and then administered by the principal investigator in initially qualifying scientific crewmen. Both types of crewmen will be subjected to qualification tests administered by NASA to determine suitability for long-term operations in the space environment.

3.5 TRAINING FACILITIES AND EQUIPMENT

The activities and products associated with the identification, selection, and development of training facilities and equipment will be defined.

Equipment and facilities will include simulation equipment, prototypes, mockups, system hardware, and development fixtures. In general, elaborate simulation facilities such as those required for training Apollo crews are not considered essential for the Space Station crewmen at this time. Maximum use of part-task simulators or subsystem simulators to demonstrate subsystem operation or for use in training crewmen for maintenance and repair is anticipated. These simulators can be studied independently of each other, however, and a total system simulator is not required.

Other provisions that will be required are mockups for learning emergency procedures, and means of zero-gravity simulation such as water immersion facilities and zero-gravity aircraft flights.

The most cost-effective method and schedule for satisfying the above requirements will be identified.

3.6 SCHEDULE

A comprehensive schedule will be prepared which will define the time when major training phases must occur so that appropriate flight crew personnel with the prescribed training will be available. A review of the schedules of existing NASA and Air Force facilities will be made to assure availability for the Modular Space Station Program. The schedule will be coordinated with crew rotation and experiment program plans.

3.7 TRAINING MANUALS

Training manuals will be developed for major operations. The manuals will encompass Space Station operations and maintenance; experiment operations and maintenance; cargo module interfaces; and prelaunch, launch, and post-flight procedures.

Section 4
DATA AND INFORMATION INTERCHANGE

The techniques and procedures to be employed in the exchange of data and information among the appropriate contractors and agencies will be defined.

Task analysis information will be available, for example, from other contractor tasks, while NASA will provide detailed information, as required, regarding existing training programs, equipment, and facilities.

Section 5
DOCUMENTATION

A documentation schedule will be developed and will identify all formal reports and plans required to complete this task. It will show data input and output requirements and interfaces.

Section 6
REPORTING

Reporting responsibilities will be established in conjunction with the contractual status-reporting requirements (such as monthly, quarterly, and other progress reports) and the report outline and format.

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MODULAR SPACE STATION

EXPERIMENT INTEGRATION PLAN REQUIREMENTS

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EXPERIMENT INTEGRATION PLAN REQUIREMENTS

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EXPERIMENT INTEGRATION PLAN REQUIREMENTS

Section 1
INTRODUCTION

Support of the Modular Space Station experiments will be provided through NASA by various user agencies (HEW, Agriculture, Interior), the scientific community, and cooperative internationals.

NASA, together with the Space Station contractor, will assess and schedule the Earth-orbital experiment program and identify the modes of accommodation for the experiments. The scientific community and cooperating internationals will define, design, develop, and procure the experiment instrumentation for those experiments to be flown on the Modular Space Station. Experiment-peculiar GSE will be under the control of NASA interface requirements. The Space Station contractor, will be responsible for integrating the experiments into the station.

1.1 PURPOSE

This document develops the experiment integration requirements necessary to accommodate those experiments in the General Purpose Laboratory (GPL) Module which is part of the Space Station Module Project. Attached and free-flying experiments are addressed under the RAM project and are not part of this plan.

The initial experiments will be launched in the GPL Module. Later onboard experiments (carry-on experiments) will be transferred on-orbit to the GPL via the Shuttle Orbiter by means of the Logistics Module. The Experiment Integration Plan should emphasize integration and operations techniques that will materially improve effectiveness and reduce the integration and operation costs of the program. Potential approaches include minimizing functional and compatibility testing of the experiment instruments, minimizing documentation, and appropriate use of automation in conjunction with onboard assessment by scientific personnel.

This plan defines the experiment integration requirements and their application for the Modular Space Station Project, and the organization and general operating controls/procedures, policies and objectives to be applied in preparing the phase C/D implementation plan.

1.2 SCOPE

The Experiment Integration and Implementation Plan shall address the following:

A. Support to be provided to NASA in preparation of the Part I CEI Specifications for the GPL Module experiments.

B. Definition, design, development, procurement, interface definition, and integration of the experiment common mission support equipment for using experiments onboard the GPL Module.

C. Methods for verification of interfaces and certification of the operability of the experiments.

D. Identification of experiment integration test requirements to be incorporated in Section 4.0 of the appropriate CEI Specification, and coordination and incorporation of these tests into the Modular Space Station Test Plan in accordance with the Modular Space Station development and operational schedules described in the Program Plan. (DR MA-05, Volume I)

E. Coordination of onboard and support experiment configuration management with Modular Space Station configuration management to assure physical, functional, and personnel compatibility with the Space Station Modules throughout its operational life.

After initial operations of the GPL, integration verification of the carry-on experiments will be accomplished using the Flight Integration Tool (FIT).

Figure 1-1 indicates major functions which must be addressed in the Experiment Integration Plan. This flow offers two paths for integration of experiments into the GPL Module. The preferred path envisions an acceptance test of the experiment at the experiment contractor's facility. This acceptance test would verify the operability and compatibility of the experiment with the GPL through the use of an interface simulator. After this

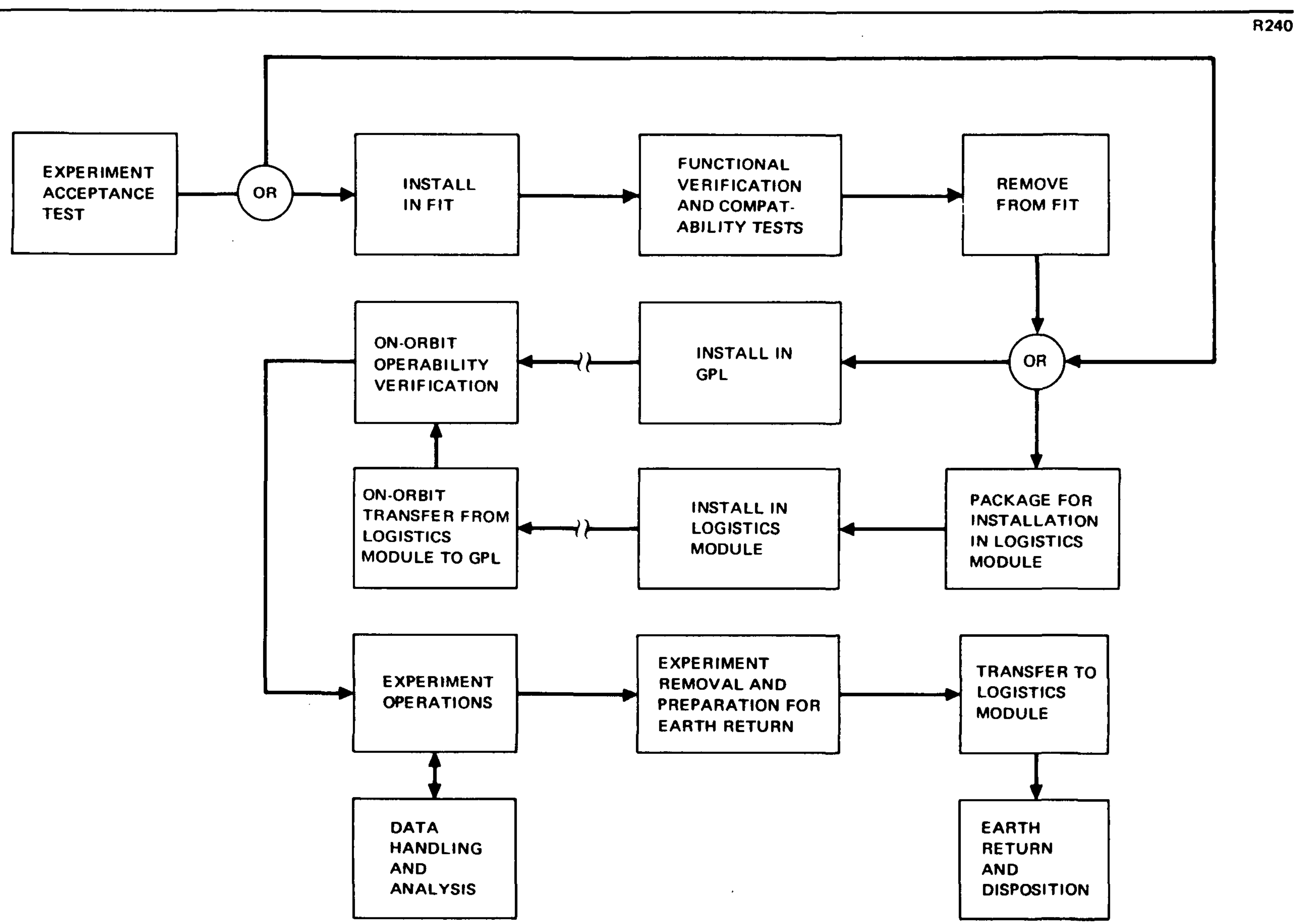

Figure 1-1. Experiment Integration and Operations Flow

interface verification, the experiment would be packaged for transfer to the GPL in the Logistics Module. In instances where experiment complexity or operational needs are such as to require more comprehensive acceptance, flow through the flight integration tool has been identified. It is anticipated that initial experiments may also have to follow this path, but as the program matures, the experiment integration flow should become increasingly oriented around the preferred path. The Experiment Integration Plan must also define the initial categories of experiments to be accommodated by each path, and must describe the methods to be used in directing subsequent experiment integration activities.

1.3 CONTROL

This plan shall be written in accordance with the Modular Space Station Program, Project, and CEI Specifications. It shall be governed by the requirements identified in those specifications and shall be compatible with the CEI specifications for experiments that are to be accommodated in the GPL Module.

Section 2
ORGANIZATION AND RESPONSIBILITIES

2.1 ORGANIZATION AND INTERFACES

The Experiment Integration and Implementation Plan shall be prepared by the Modular Space Station contractor and, upon approval by NASA, will serve as the planning document for the integration and operation of all experiments that are in the GPL. This plan, to be submitted by the contractor in response to the Phase C/D request for proposal, shall contain a definition of the experiment integration activities and their interfaces with related Space Station Module activities, i.e., Space Station Module assembly and test, configuration management, and logistic support. This plan shall further recommend methods to be followed in scheduling and controlling the receipt of flight-qualified experiments.

2.2 ROLES AND RESPONSIBILITIES

NASA will schedule and support all selected experiments. The Modular Space Station contractor's Experiment Integration Plan shall provide proposed definitions of the roles and responsibilities of the Space Station contractor and in performing the experiment integration functions shall define the interfaces between NASA, the user, and other organizations and agencies.

Two levels of interface relationships must be addressed specifically.

A. Interfaces between the experiment integration activity (NASA and contractor) and organizations outside the Modular Space Station project. Examples of these organizations include the experiment hardware manufacturers, users or principal investigators, and the Space Shuttle program.

B. Interfaces between the experiment integration activity and other elements of the Modular Space Station project, such as Space Station Module manufacturing, logistic operations, and mission operations.

The Experiment Integration Plan will, in each instance, identify functional and procedural interfaces and responsibilities.

The Modular Space Station contractor shall also be responsible for developing, as a part of the Experiment Integration Plan, a user's handbook describing and detailing the capabilities of the GPL to accommodate experiments. This handbook shall include information specifying power (types and quantities), volume, telemetry channels (type, frequency, and bandwidth) and such other information as may be necessary to constrain the principal investigator and experiment designer in the definition of experiment hardware. It is anticipated that this handbook will serve as a guideline document for the design of experiment hardware.

2.3 JOINT OPERATING AGREEMENTS AND PROCEDURES

As a part of the Experiment Integration Plan, the contractor shall recommend joint operating agreements (JOA's) and joint operation procedures (JOP's) as applicable to the experiment integration and operation activities that will be implemented during Phase C/D. These JOA's and JOP's will establish organizational responsibilities for the flow of hardware and software across organizational lines and will be keyed to the hardware and software defined in the Modular Space Station Project and CEI Specifications.

Section 3
EXPERIMENT SCHEDULES

3.1 EXPERIMENT INTEGRATION SCHEDULE

Figure 1-2 typifies Modular Space Station Program and Project milestones that are significant to experiment integration activities and is to be used in conjunction with the schedules presented in DR MF-01 "Space Station Program (Modular) Cost Estimates." Together with the experiment flow illustrated in Figure 1-1 these data are to be used as a guide in the preparation of an experiment integration schedule that depicts the sequence of the integration activities for accommodation of all onboard experiments (integral and carry-on). Typically, this schedule should establish the required dates for delivery of all experiments, the sequence of operations occurring after experiment receipt, and the scheduling of carry-on experiments to be accommodated aboard the GPL Module and Logistic Module.

3.2 EXPERIMENT OPERATIONS SCHEDULE

The contractor shall develop schedules for operation of the experiments aboard the GPL. The requirements for the development of the scheduling capability is covered in the Mission Operations Plan Requirement.

Section 4
EXPERIMENT INTEGRATION REQUIREMENTS AND ANALYSIS

4.1 EXPERIMENT SPECIFICATION REQUIREMENTS

The contractor shall, as a part of the Experiment Integration Plan, define the assistance required of NASA, the user, and all contractors and subcontractors in preparation of the individual CEI Specifications for the GPL experiments and any ground support equipment needed for GPL experiment integration or for ground support of experiment operations on orbit. The Modular Space Station Program and Project Specifications will establish guidelines for the contract team, the experiment principal investigators, and their subcontractors.

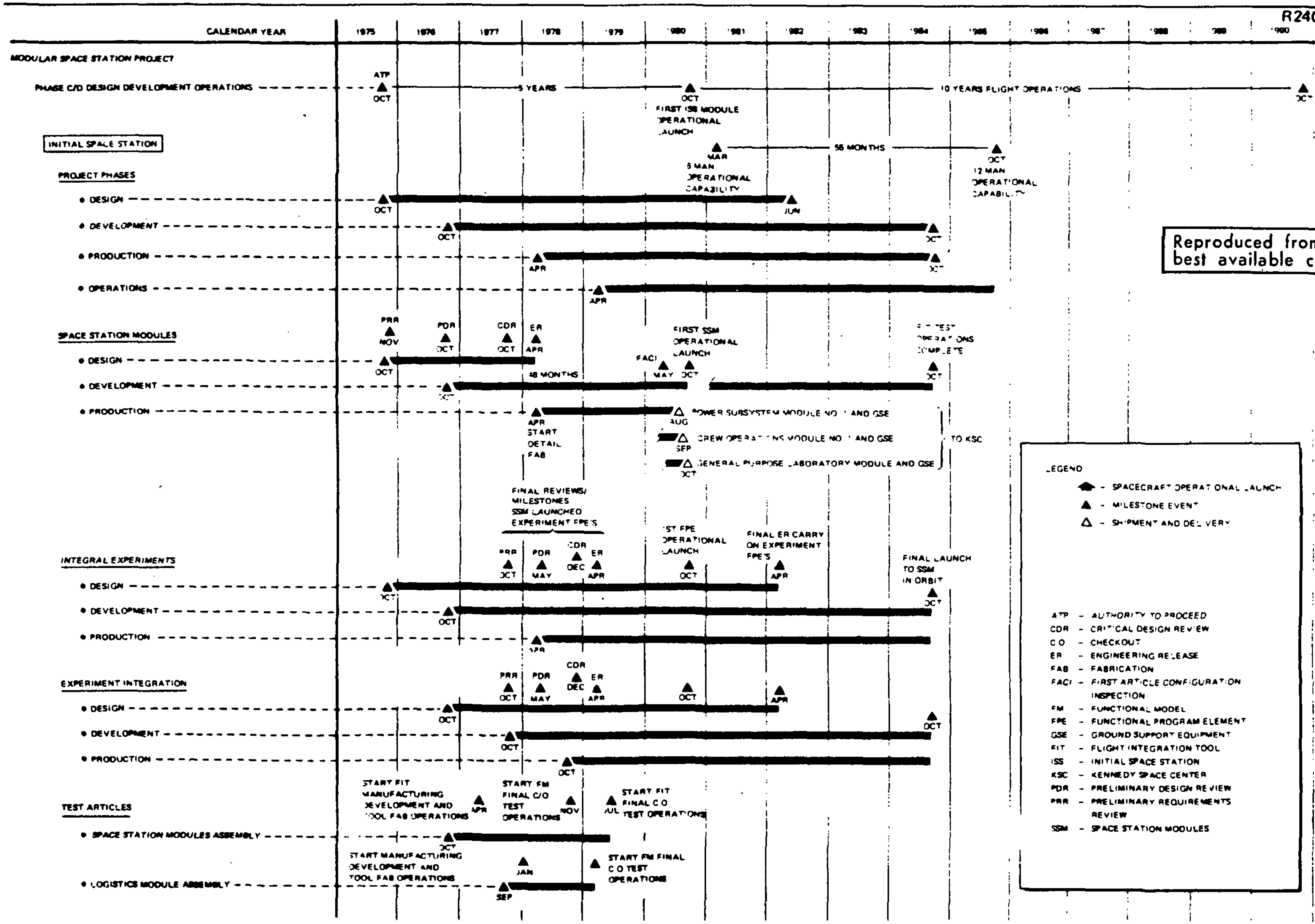

Figure 1-2. Experiment Integration Events

Cost savings are to be emphasized in preparation of this plan. Areas in which cost savings can be realized are:

A. Reduce qualification testing of experiments to flight loads only.

B. Reduce backup hardware by spares provisioning.

C. Use existing commercial laboratory equipment as appropriate.

D. Minimum documentation. Avoid duplication and control distribution of all documents only to parties with need to know.

4.2 EXPERIMENT SPECIFICATION

The experiment integration task includes preparation of end-item specifications, performance of preliminary requirement review, and obtaining approval of end-item specifications. Experiments must follow end-item specification constraints and interfaces as detailed by the Program, Project, CEI, and Interface and Support Requirements Specifications.

4.3 EXPERIMENT INTERFACES

The experiment interfaces shall include a set of interface control documents. These documents shall be prepared for each experiment, and will include drawings of connectors, bolt-hole circles, shielding straps, etc., together with schedules, signoff logs, and validation procedures.

To avoid overcontrol (and excess costs) as evidenced on other programs, an objective is a simpler system based on:

A. Reducing the number and type of interfaces requiring separate handling.

B. Using agreements (JOA's) between contractors, within contractual requirements, to minimize involvement by all parties.

Section 5

EXPERIMENT INTEGRATION AND OPERATION ANALYSIS

5.1 EXPERIMENT ANALYSIS

Experiment analyses will be carried out by members of an experiment integration group to assist in the preparation of experiment operation plans and to establish baselines for experiment operational activities on orbit.

These personnel will attend meetings of potential contractors, review solicited and unsolicited submittals, prepare preliminary NASA integration documents (experiment requirements analyses, ERA's and experiment requirement documents, ERD's), and provide reports to management with appropriate recommendations.

5.2 EXPERIMENT DESIGN

Interface control documentation (ICD's) procedures, and schedules are to be prepared as part of the design reviews. Activities will include completion of design drawings, preparation of interface control documents, preparation of detail test plans (including development, qualification, and acceptance test plans) as required by the verification plan, design and fabrication of training hardware, conduct of development tests, and definition of spares and maintenance requirements. This phase of activity ends at the completion of the critical design review (CDR) for each experiment.

5.3 FABRICATION

Documentation of common procedures is to be reviewed and disseminated by the integration contractor.

5.4 TEST AND OPERATION

A test philosophy shall be developed to maximize the use of existing facilities and minimize repetitious tests. Integration testing should be limited to system-level tests and shall be minimized as consistent with the integration philosophy described in subsection 1.2.

Section 6
DATA, HARDWARE, AND SOFTWARE INTERCHANGE

The contractor shall recommend all data and information required from the project for support of the experiment.

Section 7
DOCUMENTATION

The contractor shall recommend the form and content of data to be provided to NASA associates and subcontractors, and to the contractor's internal organization for use through Phases C/D. This includes reports, specifications, plans, requirement documents, resource warrants, status reports, spares requirements, configuration management documents, and operation, maintenance, and handling procedures required to implement the experiment integration and operation functions of Sections 4 and 5. Functions of each document will be defined with the objective of combining documents where savings are apparent.

Section 8
REPORTING

The contractor shall identify the procedure for passing information to NASA or other contractors as a function of time (progress reports) or a function of particular events (design reviews, tests, etc.). The contractor shall specify the frequencies of these reports and the milestones with which they will be associated.

MODULAR SPACE STATION
LOGISTICS SUPPORT PLAN REQUIREMENTS

LOGISTICS SUPPORT PLAN REQUIREMENTS

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LOGISTICS SUPPORT PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

This plan defines the logistics support requirements for the Space Station Project, and their application; and, the functions and general operating controls, policies, and objectives to be applied in preparing the logistics Phase C/D Implementation Plan. The Implementation Plan will include (1) a general organizational structure, (2) identify support for diversified experiments, and (3) description of interfaces with major Modular Space Station Program functions.

This document has been prepared to guide contractor planning and bidding for Phase C/D.

1.2 SCOPE

Logistics support requirements for hardware and software falling under the control of the Modular Space Station Project, either as a development requirement or as an operational responsibility are specified by this document. It is limited to Phase C/D application and covers the full spectrum of support requirements through a 10-year operational life. Figure 1-1 depicts the principal logistics functions, interface relationships, and related responsibilities and dependencies.

1.3 CONTROL

The general concepts and practices found in NHB 7500.1, Logistics Requirements Plan; NHB 7500.2, Operational Maintenance Plan; and NHB 5300.6, Parts and Material Program Plan shall be used as the basic guidelines and constraints for the logistics support applicable to the Modular Space Station Project.

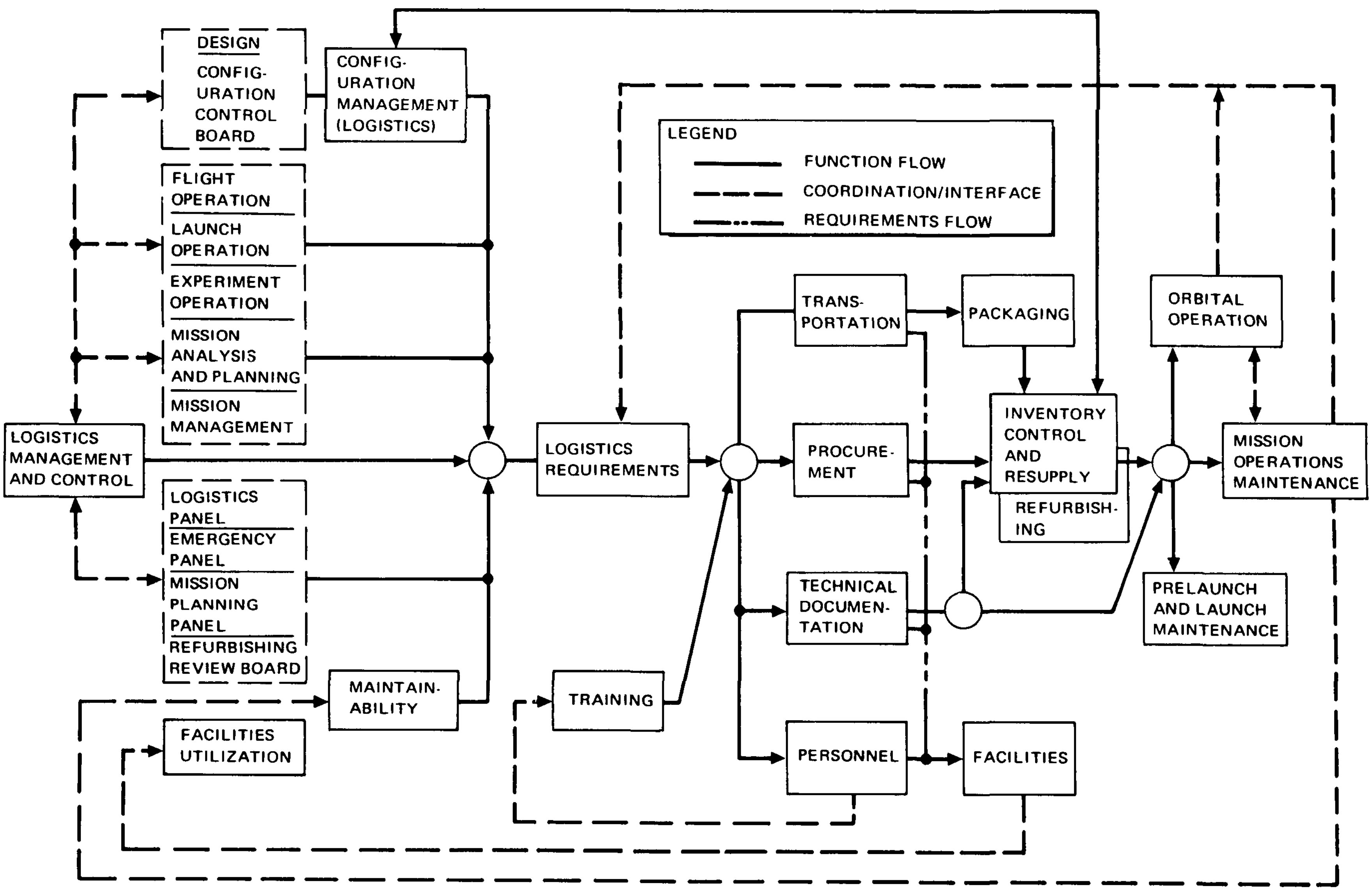

Figure 1-1. Space Station Logistics Function and Interface Flow

The requirements of this plan are compatible with Modular Space Station Project objectives established by Modular Space Station Project management. The plan shall be subject to review and revision as the program is further defined during Phase C.

Section 2
CATEGORIES AND OPERATIONS

The contractor shall prepare a plan presenting his approach to logistics support for the Modular Space Station Project. The proposed methods for meeting the general requirements delineated in subsequent paragraphs of this plan shall be included.

2.1 LOGISTICS SUPPORT CATEGORIES

Logistics support will be divided into two categories: (1) that required to support prelaunch and launch operations, and (2) that required by the Space Station in orbit. NASA logistics support practices will serve as guidelines for this implementation plan. Application of these concepts shall be constrained to the lowest cost-effective level commensurate with the single launch of a unique vehicle. Support provided for the manned orbiting station shall extend for a 10-year period, and new concepts will be implemented where required to maintain the resupply service and experiment delivery support.

2.2 LOGISTICS SUPPORT OPERATIONS

Logistics Support Operations, working in conjunction with Mission Analysis and Planning, Experiment Operations, and Flight Operations, will be the primary influencing force for support of system operation. The logistics effort will encompass the orbital system (the Space Station Modules, and carry-on experiments), Research and Application Module (RAM) support, logistics modules, ground systems and support elements such as the Flight Integration Tool (FIT), training devices, handling and access equipment, and maintenance equipment.

Section 3
LOGISTICS CONTROL AND MANAGEMENT

Logistics operations support will be organized and geographically located to meet the time critical resupply needs of an orbiting Space Station with the limited number of Shuttle resupply flights available. Project activities shall provide major management control points for inventory control and resupply procurement, packaging and transportation, maintenance engineering and services, configuration management, technical documentation, logistics personnel training requirements, data management, and refurbishment and distribution. Each activity shall be responsive to requirements of interfacing activities, including mission analysis/planning, training, maintainability, design engineering, and facility utilization.

Logistics activities supporting prelaunch and launch operations and preparation for orbital support must provide cohesive support. A functioning logistics operation is required before the first Space Station Module launch to assure an uninterrupted flow of cargo to support the sustaining mission.

3.1 REPORTING

The status of logistics support functions shall be periodically reported to the Logistics Manager, Modular Space Station Project. The information will disclose current posture, real and anticipated problems, and a forecast of future activities. Special attention will be given to critical impact areas in schedules and performance.

3.2 PERFORMANCE REVIEW

A Modular Space Station Program Logistics Review Board comprised of NASA and prime contractor representatives from Mission Management and Logistics will convene periodically to review logistics activities, objectives, and effectiveness. Management will provide comprehensive and detailed reports for the reviews.

Section 4
INVENTORY CONTROL AND RESUPPLY

An inventory control and resupply function shall be developed which is capable of maintaining support for the orbiting Space Station and related ground equipment including the Logistics Module. The function will include an inventory management system, automated inventory data management system, resupply planning, Logistics Module staging activity, and refurbishment and disposition control. The function will commence with the Initial Space Station provisioning and procurement and continue to project completion.

4.1 INVENTORY MANAGEMENT

Inventory management shall provide surveillance, accountability, and on-line reporting for all assets under Space Station control. Assets will include common spares and supplies, equipment in repair or refurbishment cycle, logistic modules, experiments in impound for launch including RAM modules, and crews quartered for flight. A capability to adjust inventories as assets are depleted shall be integral to the system. On-orbit inventory utilization and logistics feedback data reported through Flight Operations shall allow ground surveillance of inventories and requirements for logistics planning and resupply. Stock replenishment and the scheduling of experiments and crews shall be included in inventory management.

4.2 DATA MANAGEMENT

An automated inventory data management system will be provided that has the capability to receive, store, and maintain input data; and to generate reports of available assets, utilization, and other related information. The system shall be on line and have full data-selection capability.

4.3 RESUPPLY PLANNING

Logistics planning will be conducted on a continuing basis to identify long-term requirements for each resupply mission. Requirements for each next-scheduled resupply launch will be firmly established through evaluation of priorities and crew requests, Logistics Module capacities, and Space Station storage capabilities. Life and mission sustaining resources in the ground inventory will be restored to a 120-day minimum level immediately after each resupply mission. The Logistics Module loading sequence shall be determined on the basis of predicted resource utilization and removal from the module when integral to the Space Station. The availability of materials selected for each resupply mission shall be firmly established, and quantities shall be allocated for processing into the Logistics Module a minimum of 30 days before launch, only emergencies excepted.

4.4 LOGISTICS MODULE GROUND OPERATIONS

After the initial receipt of the Logistic Modules, the logistic module operations become a closed operational cycle with the launch of each module, a period in orbit functioning as a storage compartment for Space Station supplies, and a subsequent return to the ground for refurbishment and launch (Figure 4-1). The implementation plan shall describe the detailed functions illustrated in this figure. The resupply staging and refurbishment/ disposition requirements are described in the following subsections.

4.4.1 Resupply Staging

A staging area will be provided for the preparation and loading of the Logistics Module for launch, and for the receipt and disposition of materials returned from the Space Station. A mock loading of all planned materials shall precede actual loading, and the sequential unloading routine identified for space environment will be validated. Flight personnel shall participate in the unloading practice. Final loading sequence and load factors (center of gravity, container selection, etc.) shall be predicated on mock-operation results. Maximum loading shall occur in the staging area. Resupply materials and Logistics Module servicing operations that are not compatible with extended storage, such as cryogenics, shall be loaded as part of launch preparation. Live experiment cargo and flight personnel shall also be boarded late in the launch preparation sequence.

4.4.2 Refurbishment and Disposition

Logistic Modules returned from the Space Station shall be unloaded in the staging area, and all materials dispositioned and distributed. Special handling and storage will be provided for hazardous materials and for experiments and experiment data. Refurbishment for the Logistics Modules

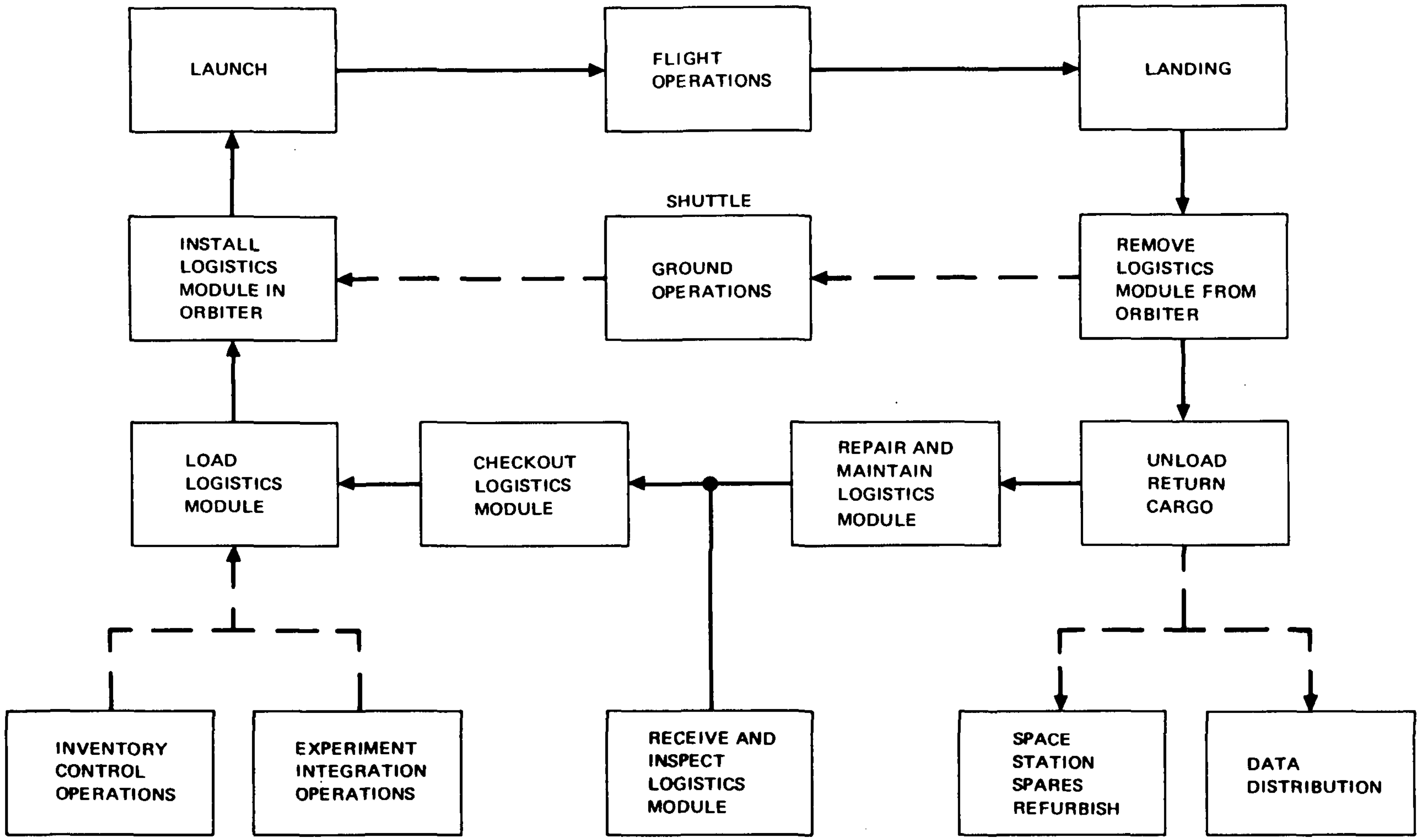

Figure 4-1. Logistics Module Operational Flow

will be accomplished in the staging area unless the module has sustained significant structural damage. In this event, the module may be recycled to the contractors facility.

4.5 INVENTORY CONTROL FOR GROUND EQUIPMENT

Inventory control for ground equipment and systems supporting Space Station operations will be an integral part of the requirements stated in Sections 4.1, 4.2, 4.3, and 4.5 (as appropriate).

Section 5
CONFIGURATION MANAGEMENT

Compatibility shall be maintained at all times between equipment and software configurations and supporting spares, maintenance procedures, transportation requirements, and other areas of logistics responsibility. An automated accounting system compatible with the inventory data management system shall be established to provide on-line identification of inventories and procedures. Proposed changes to equipment under Space Station inventory control, including scheduled experiments, will be reviewed during the evaluation cycle and logistics impacts will be defined. The impact to resources onboard the Space Station will receive special consideration. Implementation of equipment changes using the kit technique shall be applied to equipment and inventory items simultaneously. Modification instructions shall be validated and hardware fit and function verified for all on-orbit and critical ground equipment changes prior to implementation. Orbital equipment modifications shall use the Flight Integration Tool (FIT) for validation.

The configuration of spares, software, and other resources supporting prelaunch and launch phases shall be controlled through a system supporting that required for the operational phase. Transition from one phase to another shall not constitute requirements for unique configuration management.

The configuration management function will be performed by the Modular Space Station Project contractor under the direction and approval of NASA. This function will be accomplished as a part of the integrated mission management concept described in DR MP-03 "Integrated Mission Management Operations." As noted above, the FIT will serve as the ground-based reference model for configuration control of the on-orbit Space Station and its experiments. The methods and procedures for accomplishing this configuration management shall be developed by the Space Station contractor as a part of his Logistics Implementation Plan.

Section 6
PROCUREMENT

Initial procurement of an adequate range of spares and supplies shall be predicated on minimum-contingency quantitative criteria and shall satisfy projected use for an established period of initial equipment operation; for example, 6 months. Mission protection (insurance) items peculiar to a one-of-a-kind system shall be included in the initial procurement. After the initial equipment-operating period and continuing through Modular Space Station Project duration, replenishment to appropriate stock levels shall in general be determined from consumption rates and individual mission objectives. Procurement of support for hardware and software change packages affecting orbital and ground systems shall be time-phased to operational implementation and shall provide minimum support levels.

6.1 SPARES AND SUPPLIES STOCK REPLENISHMENT

Procurement of initial spares and supplies for Space Station Modules, Logistics Module, and associated ground equipment shall be based primarily on logistics analyses. Special emphasis will be placed on securing long-lead-time items and items requiring extensive processing (critical testing, packaging, etc.) after delivery. The initial procurement of spares and supplies for experiments will follow recommendations of the experiment contractor. Receipt of such assets, however, will be compatible with Space Station operation and logistics schedules.

Stock replenishment will be based on inventory control levels, current and historical use factors, updated logistics analyses, and crew recommendations. Replenishment for experiments will also consider recommendations from the experiment contractors and principal investigators. Production facilities for spares and supplies will not be maintained over the Space Station operational period (10 years) solely to ensure source availability. Items of low and intermittent usage shall be obtained from various sources as the need arises, and procurement restrictions for standard items will be eliminated. Procurement practices for peculiar prelaunch and launch support equipment will be austere; surplus and manufacturing assets will be appropriated whenever possible. Analyses covering only critical parameters will be conducted for logistics support of prelaunch and launch operations.

6.2 RESUPPLY VEHICLE

The program management function will provide the single control point for scheduling shuttle flights to support routine resupply launches. Resupply launches that are not routine, such as emergencies and NASA directed priorities, will be coordinated with affected Modular Space Station Program organizations and internally scheduled.

6.3 EXPERIMENTS

The transition of experiments from the respective contractors to Space Station inventory for subsequent transport to the orbiting Space Station shall be achieved through the program management function. The physical receipt of such experiments at a Space Station controlled facility prior to Logistic Module loading will be affected only as required to facilitate logistics operations. Availability, however, will be firmly established, and interfaces will be validated, using the FIT or other support equipment as required. Figure 6-1 illustrates the possible flow paths for experiments from acceptance testing and receipt from the experiment contractor through orbit operations and return. Additional details are covered in the Experiment Integration and Operations Plan Requirement.

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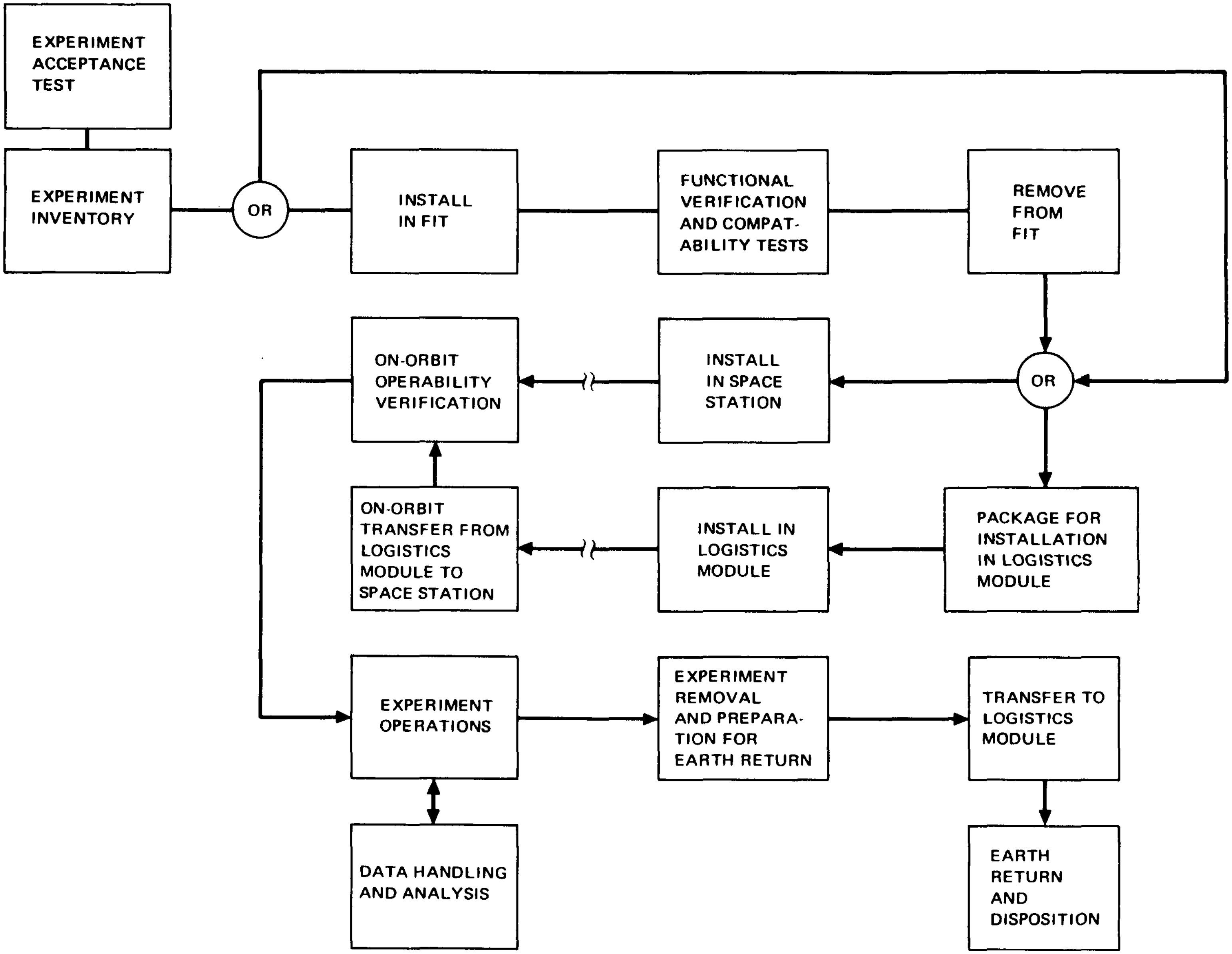

Figure 6-1. Integral Experiment Flow for 10-Year Operations

Section 7
PERSONNEL

Training requirements for each logistics function will be identified to assure availability of the necessary skills on orbit and on the ground. Flight crews will be instructed in such tasks as maintenance, onboard inventory control, return-cargo packaging and loading, and cargo handling. Ground personnel requirements will include inventory management, procurement, logistics module staging, critical packaging, and other responsibilities. The identification of training equipment and preparation of courses rest with the training function and are covered by the Crew Training Plan.

Section 8
MAINTENANCE

Preventive and corrective maintenance requirements will be developed for the Space Station Project, and its constituent system. Requirements will also be developed for the prelaunch and launch mode. These requirements will be based on maintenance and maintainability analyses developed under the policies contained in the Reliability/Maintainability Plan, and the project-peculiar concepts stated in subsequent paragraphs of this document. (The Reliability Plan discusses guidance in maintainability analysis.) Maintenance functions applicable to the Space Station Modules and Logistics Module in an operational or other critical mode shall be evaluated through test demonstrations.

8.1 PREVENTIVE MAINTENANCE

Preventive maintenance will be conducted onboard the orbiting Space Station to the level demanded by design; extravehicular activity will not be required for preventive maintenance. The preventive maintenance performed on the Space Station during prelaunch and launch operations shall be limited to that required to supplement checkout functions and to ensure maxiumum equipment reliability. In each case, Space Station preventive maintenance shall be incorporated into normal operational and checkout tasks.

The Logistics Modules will be maintained in a flight-ready condition through continued preventive maintenance while grounded. Preventive maintenance for the Logistic Module in the space environment will be restricted to essential requirements and shall be performed as a planned Space Station operation.

Ground equipment supporting the Space Station subsequent to launch and Logistics Module operations shall be maintained through a formal preventive maintenance program in a manner commensurate with equipment utilization. The preventive maintenance requirements and implementation practices for GSE supporting prelaunch and launch operations will be in keeping with minimum support policy; and existing analysis data, documentation, and scheduling information will be utilized to the maximum extent practical.

8.2 CORRECTIVE MAINTENANCE

Corrective maintenance requirements for the Space Station shall be based initially on analytical data. Replacement levels and repair functions shall reflect compatibility with the Onboard Checkout Subsystem (OCS), which provides the principal fault detection and isolation tool during orbital and ground operations. The technical laboratories within the Space Station will be considered a primary repair facility for routine and contingency corrective maintenance on orbit. Corrective maintenance for the Logistics Module, when attached to the Space Station will also use the laboratory capability.

Repair and replacement levels for ground equipment supporting Space Station and Logistics Module operations will be planned to a level that ensures maximum required availability with greatest economy. For GSE supporting prelaunch and launch requirements, the level of repair will complement available spares with minimum additional procurement, and existing documentation and procedures will be utilized wherever launch reliability is not compromised.

8.3 REFURBISHMENT—LOGISTICS MODULES

The Logistic Modules will be refurbished after each flight and returned to the configuration required for next flight assignment. Planned repair and replacement levels for the Logistic Module subsequent to refurbishment will not necessitate extensive checkout.

8.4 BENCH REPAIR

The control applied to repair of replaced assemblies will be commensurate with assembly application. Space Station and Logistics Module items will meet or exceed original manufacturing specifications and will be flight-certified. Items from ground equipment will meet original requirements to the extent authorized variations have not been established.

Section 9
TECHNICAL DOCUMENTATION

9.1 TECHNICAL DATA

Operating and maintenance instructions and procedures will be developed for the Space Station Modules and Logistics Modules for both the orbital and ground environment. Each procedure developed for an orbit application shall be fully verified and validated through actual performance on the FIT. Similar documentation will be prepared for supporting ground equipment, training devices, and special items such as the FIT and Logistics Module. Standard refurbishment, loading, and launch preparation procedures are required for the Logistics Module. The methods of documentation for on-orbit application shall be compatible with data management and communications subsystem design and should consider microfilm, aperture cards, ground link data-display system, and handbooks. Documentation supporting ground operations will normally be in handbook form.

9.2 MANAGEMENT DATA

Logistics support management and procedural documentation that recognizes each logistics function shall be developed. Logistics schedules covering all facets of the operation (Logistic Module refurbishment to parts delivery) shall form a part of this documentation.

Section 10
PACKAGING AND TRANSPORTATION

10.1 PACKAGING

The requirements for preservation, packaging, packing, and marking of Space Station equipment and resupply items shall be established and will provide a basic criteria for transportation. Requirements for terrestrial shipments and storage shall be in accordance with MSFC-STD-343. Requirements for spares and supplies transported to the orbiting Space Station shall assure item survival during launch, ascent, and transfer, and shall facilitate space storage and unpacking in a weightless environment. Packaging will be standardized to conform to the Logistics Module design configuration and space limitations, and will consider repackaging constraints imposed by the space environment for items being returned from the Space Station. Special environmental requirements (heat, refrigeration, etc.) beyond that provided by the Logistic Module shall be integral to the packaging. Requirements impacted by or attendant to experiments, including living creatures and biomedical specimens, will be coordinated with the experiment project through the Program Logistics Panel.

10.2 TRANSPORTATION

Transportation planning and support shall be provided for all Space Station Modules (Crew/Operations Module, Power Module, General Purpose Laboratory Module and Logistics Modules) and ground equipment (orbital support equipment, flight integration tool, training devices, prelaunch and launch equipment, etc.) from point of manufacture or delivery to the operational or staging areas. Conventional transportation modes shall be employed, with innovations developed as necessary to cope with physical, environmental, and sensitivity constraints created by equipment design. Maximum feasible use will be made of existing equipment and systems using modifications and adaptations when economically advantageous. Special requirements will be identified for hazardous materials. Handling techniques will be developed for spares and supplies identified as resupply cargo to support Logistics Module preparation and delivery for launch. Transportation capabilities provided under the experiment project for live cargo and hardware will be evaluated and supplemented as necessary to assure adequate support when cargo is under Space Station cognizance.

Section 11
FACILITIES, EQUIPMENT, AND SUPPORT

Facilities, equipment, and support required for the extended (10-year) logistics support of the Space Station shall be predicated on the concept of centralized operations. Facilities requirements will be based on the logistics functions, such as control and management, inventory procurement and storage, maintenance, and housing for the data management computer complex. Equipment needs beyond those developed specifically for the project will be based on the necessity for sophisticated data processing, inventory movement, transfer of expendables, storage of perishables, and limited autonomous maintenance activity. Logistics support will include the normal elements of base support, special assistance from on-site maintenance services, technical laboratory services, and Logistics Module handling during transfer from staging to the launch area. The policies and practices to identify specific facilities, equipment, and support are contained in the Facility Utilization Plan.

7

MODULAR SPACE STATION

SUPPORTING RESEARCH AND TECHNOLOGY

PLAN REQUIREMENTS

SUPPORTING RESEARCH AND TECHNOLOGY PLAN REQUIREMENTS

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SUPPORTING RESEARCH AND TECHNOLOGY PLAN REQUIREMENTS

Section 1
INTRODUCTION

A Modular Space Station supporting research and technology (SRT) plan for Phase C/D must be defined to solve the problems associated with the selection and development of hardware. The successful accomplishment of this SRT will minimize the development risk during Phase C/D. This plan establishes initial guidelines for the implementation of the required SRT. The purpose, scope, and methods of implementation are discussed in the following paragraphs.

1.1 PURPOSE

This plan presents a preliminary SRT plan for the Modular Space Station project development and 10-year operational life period. This document:

A. Provides the framework and guidelines around which a detailed plan can be prepared.

B. Highlights the SRT items that are recommended for the Modular Space Station Program.

C. Provides a method for the implementation of the SRT items to assure that these items are accomplished within schedule and funding constraints.

D. Defines methods for handling key interfaces between the contractor and NASA.

E. Defines the roles and responsibilities of the contractor and NASA.

F. Establishes schedule and documentation constraints.

G. Provides a definition of the assessment methods and factors for all SRT items, and the procedure for continual assessment of presently identified or ongoing SRT.

1.2 SCOPE

The scope of this document encompasses the SRT required to implement the Modular Space Station Project Phase C/D (development and operations). All

SRT applicable to the Modular Space Station project as identified in SE-10, "Supporting Research & Technology Document", will be the subject of this plan. A list of these Space Station project recommended items, that has been defined to date, is shown in Table 1-1. The Technology Category and technology panel columns are discussed in Sections 3.1 and 3.2, respectively.

This Phase C/D preliminary plan covers the SRT that is applicable for the initial launches of the Initial Space Station (ISS) as well as those items required for Growth Space Station (GSS) whose development lead times would require initiation prior to ISS IOC.

This preliminary SRT plan is contractor-activity-oriented, but prepared from NASA's point of view, with consideration of NASA's policies, procedures, and organization.

1.3 CONTROL

The SRT plan is written in accordance with NASA Document NHB 7121.2, August 1968. Additional documents which constrain the performance of SRT tasks will be specified by NASA, if required. This plan shall be recommended by the Modular Space Station Program Office and/or technology panels prior to proceeding into Phase C/D. All changes to the plan will be handled through the same process. All contractor or NASA agencies associated with the plan are to be advised of any revision to the plan.

The final direction for the plan and its implementation rests with the Space Station Project Office, whereas the single point of contact for the SRT contractor is the applicable NASA contracting agency.

Section 2
ORGANIZATION

This section defines the roles and responsibilities, interfaces, and implementation requirements for the SRT necessary for the Modular Space Station project.

Table 1-1

MODULAR SPACE STATION SRT

	SRT Category, Number, and Title	Technology Panel
A.	Advance Technology	
M1.	Solar Array Degradation	P
M2.	Interconnection and Operational Techniques for Multicomputer Systems	IS
M3.	Magnetic Bubble Storage Techniques for Bulk Digital Data	IS
M4.	Dynamics and Control of Flexible, Multi-Body Structure	C
M5.	Docking Dynamics Procedure and Techniques	C
M6.	Navigation Sensor and Software	C
M7.	Physical Conditioning in Hypodynamia	B-RES
M8.	Man-Machine Interface for Astronomical Instruments	B-ENG
M9.	Contamination Effects on Experiments	EI
B.	Advanced Development	
M10.	Integrated System Development - Solar Arrays, High Capacity Batteries and the Modular Space Station	P
M11.	Array Orientation/Drive System	P
M12.	High-Capacity Battery Evaluation	P
M13.	Charge/Discharge Control Technique	P
M14.	Random Load Cycling Effects on Batteries	P
M15.	Power Management by Computer Techniques	P
M16.	Power Regulation System Evaluation	P
M17.	Modular Inverter System Development	P

Table 1-1

MODULAR SPACE STATION SRT (Continued)

	SRT Category, Number, and Title	Technology Panel
M18.	Solid-State Switching for High Voltage and High Current	P
M19.	High-Level Power Transfer and Connector Development	P
M20.	Optical Image Processor	IS
M21.	Analog Image Processor	IS
M22.	Image Processing Executive Program	IS
M23.	Computer Simulation of Model of Image Processing System	IS
M24.	High-Density Magnetic Recording	IS
M25.	Multipurpose Displays	IS
M26.	Integrated Display Techniques	IS
M27.	Laser/Holography Storage Technique for Bulk Data	IS
M28.	Checkout Parameter Sensing and Associated Calibration Techniques	IS
M29.	High Gain Antenna System Maintenance	IS
M30.	High Gain Antenna Acquisition and Tracking	IS
M31.	Advanced Electronic Packaging and Installation Techniques	IS
M32.	Software Reliability	IS
M33.	Long Life Pressure Cabins	MS
M34.	Long Life Pressure Tanks	MS
M35.	Dynamic Seals	MS
M36.	Docking Systems	MS

Table 1-1

MODULAR SPACE STATION SRT (Continued)

	SRT Category, Number, and Title	Technology Panel
M37.	Meteor Impact on Biaxially Stressed Materials	MS
M38.	Adaptive Controller	C
M39.	Onboard Sensor Alignment, Calibration and Maintenance	C
M40.	Rendezvous Sensor Improvement	C
M41.	Solar Cell Energy Wheel System	C
M42.	Solar Panel Dynamics	C
M43.	Biowaste Resistojet (Engine and System)	C
M44.	Monopropellant Thrusters (N_2H_4)	C
M45.	Maintenance, Resupply, Propellant Transfer	C
M46.	Optical Fine Pointing of Manned Space Experiments	C
M47.	Waste Collection and Sampling	B-RES
M48.	Early Detection of Infectious Disease	B-RES
M49.	Environmental Microbiology	B-RES
M50.	Body Composition and Fluid Balance Methodology	B-RES
M51.	Potable Water Monitoring and Contamination Control	B-RES
M52.	Low-Level Environmental Stress	B-RES
M53.	Atmosphere Constituent Requirement	B-RES
M54.	Decompression Sickness Empirical Model	B-RES
M55.	Wash Water Criteria	B-RES
M56.	Biological Specimen Container	B-RES

Table 1-1

MODULAR SPACE STATION SRT (Continued)

	SRT Category, Number, and Title	Technology Panel
M57.	Crew Task Allocation - for Data and Experiment Operations	B-ENG
M58.	Quantification and Measurement of Habitability	B-ENG
M59.	Accommodations for Female Astronauts	B-ENG
M60.	EVA Requirements (Manned or Remote)	B-ENG
M61.	On-Orbit Crew Performance Assessment	B-ENG
M62.	On-Orbit Maintenance	B-ENG
M63.	Cargo Handling, Packing and Storage	B-ENG
M64.	Mass Determination Devices	B-ENG
M65.	Physiologic Monitoring Equipment	B-ENG
M66.	Availability Prediction Method Verification	B-ENG
M67.	Water System Bacteriological Control and Monitoring	B-ENV
M68.	Low Partial Pressure CO_2 Removal	B-ENV
M69.	Atmosphere Leak Location	B-ENV
M70.	Reverse Osmosis for Wash and Condensate Water Recovery	B-ENV
M71.	Solar Collector	B-ENV
M72.	Radiator and Solar Collector Coating	B-ENV
M73.	Non-Venting Fecal Collector	B-ENV
M74.	Trace Contaminant Control	B-ENV
M75.	Orbital Calibration/Active Figure Control Techniques	EI
M76.	Liquid-Handling Apparatus for Bio-Experimentation	EI

Table 1-1

MODULAR STACE STATION SRT (Continued)

SRT Category, Number, and Title		Technology Panel
M77.	Automated Positioning and Retrieval of External Experiments	EI
M78.	On-Orbit Cleaning, Recoating, Servicing and Calibration of Optical Elements	EI
M79.	Cryogenic Systems for Space Experiments	EI
M80.	General Systems Technology	MT
C.	Supporting Development	
M81.	Ku-Band Low Noise Receiving System	IS
M82.	Volatile Liquid Pressurization	C
M83.	Bellows Expulsion Tankage	C
M84.	Bio-Analytical Instrumentation	B-ENG
M85.	CO_2 Conversion	B-ENV
M86.	Water Electrolysis Unit Development	B-ENV
M87.	Photographic Film for Space Experiments	EI
M88.	Film Processor	EI

LEGEND:

P	Power	B-ENG	Bio-Engineering
IS	Information System	B-ENV	Bio-Environment
MS	Materials and Structure	EI	Experiment Integration
C	Control	MT	Management Techniques
B-RES	Bio-Research		

2.1 ROLES AND RESPONSIBILITIES

The roles and responsibilities for each SRT item are required to establish specific responsibilities as to implementation, monitoring, and support functions. This is necessary to (1) assure the adequate accomplishment of the SRT, (2) allow management and organizational visibility, and (3) stipulate a means for illustrating who should provide programmatic assessment data necessary for continual reassessment of all ongoing SRT. Table 2-1 shows a typical example of a role-and-responsibility matrix of the type which must be prepared for all SRT. NASA, in conjunction with the hardware contractor, will prepare these matrixes following approval of the items by the technology panels.

2.2 INTERFACES

The interfaces between the hardware contractor and (1) the applicable NASA agency, and (2) the contractor performing the SRT are defined in Figure 2-1. The prime interface between the Modular Space Station project hardware contractor and NASA will be through the Technology Panels. Definition of the roles and responsibilities will provide a basis for the interface identification.

This plan will interface with other SRT Phase C/D plans for other projects within the Modular Space Station program and other programs. The Technology Panels, aided by the hardware contractor, will define these interfaces, especially those between the Modular Space Station project SRT and the Research Applications Module (RAM) Project SRT plan. There is also an interface with the Shuttle SRT plans which should be identified to eliminate possible duplication or combine similar SRT which could reduce costs. The NASA Modular Space Station Project Office, in conjunction with Technology Panels, will define the interfaces.

Additional interfaces exist between the Modular Space Station project and the Skylab project. This plan shall identify SRT that the Skylab can perform in support of the Modular Space Station. The appropriate NASA centers will aid in these determinations.

Table 2-1

SRT ROLE-AND-RESPONSIBILITY MATRIX
(Typical Example)

SRT Number and Title	Applicable NASA Center	SRT Contractor	Agency/Contractor: Technology Panel	OSSA	OART	OMSF	MSFC Program Office	MSC	Langley	LERC	Hardware Contractor
Reverse Osmosis for Wash and Condensate Water Recovery	MSFC	MDAC/ Chemtric Inc.	M			▲ M	M	S			-
Docking Dynamics Procedures and Techniques	MSFC	MDAC	M		▲ M		M	S	S		-
Ku-Band Low Noise Receiving System	MSFC	Radiation Inc.	M			▲ M	M	S			M S
Dynamics and Control of Flexible Multi-body Structure	MSFC	MDAC	M		▲ M		S	S			-
Biowaste Resistojets	MSFC	TRW/ MDAC	M			▲ M	M		S		M S
Analog Image Processor	MSFC	IBM	M			▲ M	S				M S
Modular Inverter System Development	MSFC	Westinghouse	M			▲ M	M			S	M S
Power Management By Computer Technique	MSFC	MDAC	M			▲ M	S				-

▲ Primary Responsibility—The task of prime responsibility of assuring that SRT is accomplished on time and within funding.
S Support—A task of providing support in the form of information or assistance to the organization(s) with primary responsibility.
M Monitor—A task of monitoring activities to assure that implementation of SRT is accomplished.

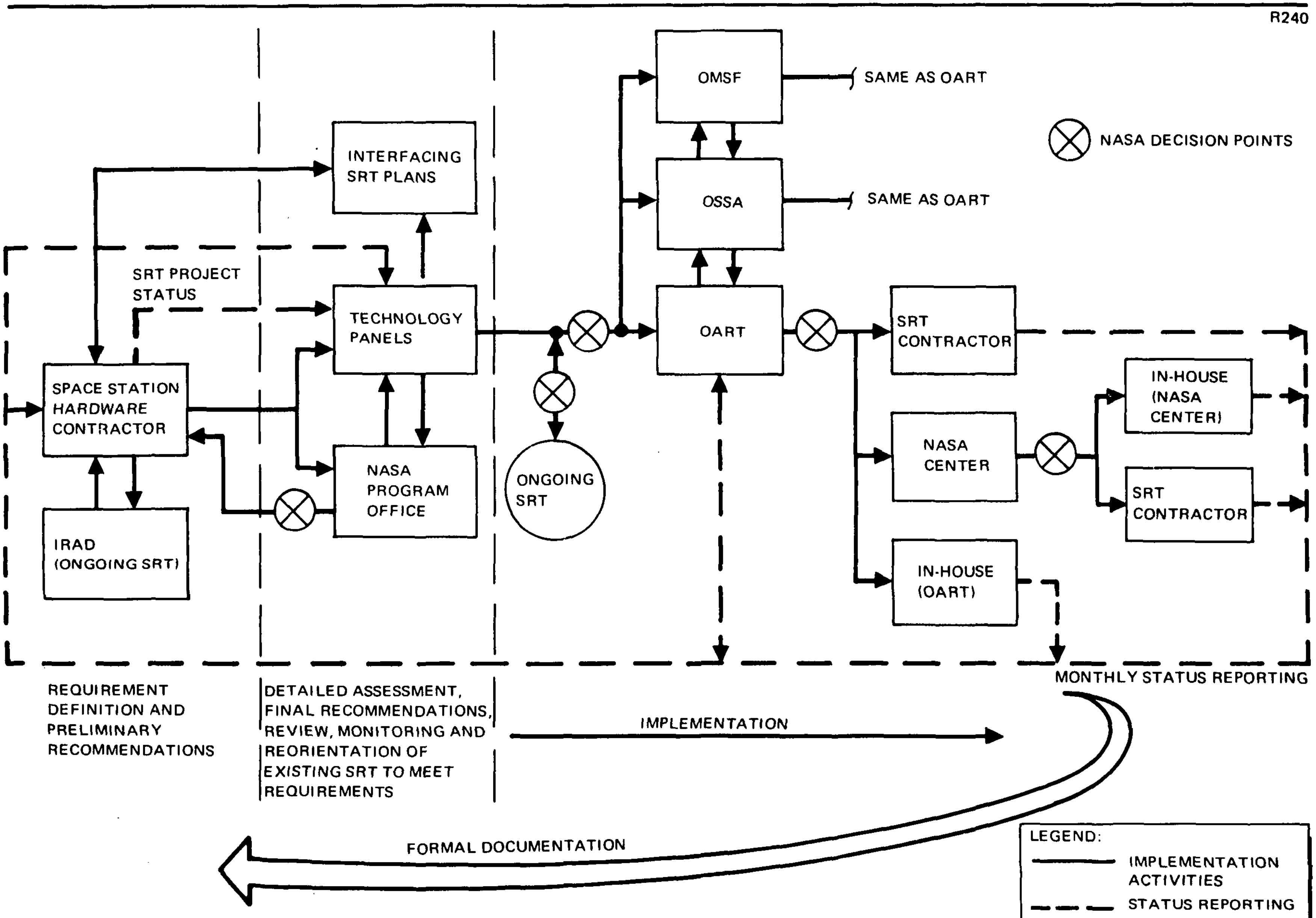

Figure 2-1. Interface/Implementation/Data Flow

2.3 IMPLEMENTATION

The SRT implementation will be performed under the cognizance of a NASA agency and in accordance with the role-and-responsibility matrix defined in Section 2.1. The implementation flow of the recommended SRT is shown in Figure 2-1. Implementation is normally performed by (1) the Office of Advanced Research and Technology (OART), (2) the Office of Manned Space Flight (OMSF), and (3) the Office of Space Science Applications (OSSA). OART generally performs the research and advanced technology activities; OMSF, through the program office, normally performs the advanced development and supporting development categories; and OSSA handles scientific-type SRT in the research and advanced technology categories. NASA determines which agency provides the implementation for various SRT items. NASA also provides the hardware contractor with the name of the SRT contractor and the key individuals responsible for performing the SRT.

In the process of implementation, the existing technology base (ongoing SRT) provided by the NASA laboratories and industry will be drawn upon to supply the needed technology requirements for the Modular Space Station project. It is the primary responsibility of the technology panels, supported by the other NASA agencies (i.e., OART, OMSF, and OSSA), to match these ongoing SRT efforts with the Modular Space Station requirements and reorient or supplement them with new SRT tasks as applicable to satisfy the requirements. These NASA agencies are also responsible for seeing that the SRT will satisfy the Modular Space Station project requirements and is accomplished within funding and schedule constraints. The NASA Program Office is responsible for determining which SRT should be incorporated into Space Station design. Figure 2-1 also shows the major points at which NASA must make various decisions to implement the SRT items. These decisions include (1) what ongoing SRT can be used by the Modular Space Station project, (2) which should be reoriented or combined to better meet the Space Station requirements, (3) which NASA agency should have prime responsibility for which SRT items, and (4) who should perform the new SRT tasks. The definition of the role-and-responsibility matrix will establish the responsible NASA agency.

Implementation progress is controlled and monitored by the documentation requirements contained in Sections 6, 7, and 8.

Section 3
SRT CATEGORIES, TECHNOLOGY AREAS, AND DATA REQUIREMENTS

The contractor must categorize all SRT required for the Modular Space Station into the existing SRT categories, group them into the technology areas (NASA panels), and satisfy certain data requirements. These data must be available before any detailed assessment. The definition, type of analysis, and equipment included in each category and technology area/ panels, as well as the type of data required for each SRT item, are discussed in the following paragraphs.

3.1 CATEGORIES

The following definition of SRT categories was obtained from NHB 7121.1, Attachment C, dated 28 October 1965.

3.1.1 Research (R)

Research is the activity directed toward an increase in scientific and engineering knowledge. When this SRT category has a programmatic implication, it is applied rather than basic research and addresses only the conceptual phase (A) of phased project planning.

3.1.2 Advanced Technology (AT)

Advanced technology is the activity of advancing the state of the art in the field of methods and techniques through the application of science and engineering. Any associated hardware effort does not go beyond that required to demonstrate the validity of the advanced method or technique. The AT category of SRT isprimarily concerned with the conceptual phase and has only a secondary concern with the definition phase (B).

3.1.3 Advanced Development (AD)

Advanced development is the activity of developing systems, subsystems, or components which are recognized as having long development times, prior to Phase D approval of the project in which they will be used. The product of the activity shall be a set of specifications, within the then-current state of the art, which describes the hardware that was the subject of the advanced development activity. The AD category of SRT is concerned with both the definition phase (B) and the design phase (C).

3.1.4 Supporting Development (SD)

Supporting development is the activity of developing (1) backup or alternate systems, subsystems, and components, and (2) fabrication, cost, and evaluation techniques. Advances in the state of the art may or may not be incorporated as appropriate. The products of this activity are hardware or techniques suitable for replacing their primary counterparts in the major development effort being supported. The SD category of SRT is concerned with the design phase (C) and early phase(D).

The selection of the proper category for each SRT item is a function of the type of SRT required and the state of development of the SRT activity to be performed.

3.2 TECHNOLOGY AREA/PANELS

The contractor must categorize the SRT items into technology areas. The areas included in this plan are equivalent to the technology panels established by NASA for the Modular Space Station program. These panels and their respective areas of responsibility are discussed in the following paragraphs.

3.2.1 Power Panel

This category includes the production(source), conversion, conditioning, control, and distributionof electrical power. Included are all subsystems and components that pertain to power systems, i.e., solar array, power conversion, etc.

3.2.2 Information System Panel

The subsystems and technologies associated with this category are communication, data management, onboard checkout and fault isolation, and controls and displays. Included are all components of these subsystems, i.e., centralized multiprocessors, data bus, multipurpose central and local displays, VHF and S-band, etc.

3.2.3 Materials and Structures Panel

This category includes items pertaining to materials technology, including chemical analysis, the mechanical design/hardware associated with the station and manufacturing and assembly techniques. Included in the areas are basic structure, docking system, pressure shells, tankage, seals, radiators, meteoroid shield, welding techniques, radiation effects and shielding, thermal control features of the structure, external contamination, etc.

3.2.4 Control Panel

The subsystems and techniques associated with this category are stabilization and attitude control, guidance and navigation, propulsion (reaction control), dynamics, and flight mechanics.

3.2.5 Bio-Research Panel

This category pertains to scientific investigation and equipments used to advance the technology in the areas of space medicine, hygiene, and health. This includes experimental equipment and techniques to assess man's capability to function normally in space for long periods of time and instrumentation to assess the effects of the Space environment on man and man's capabilities to perform work in space. Biology is also included in this category.

3.2.6 Bio-Engineering Panel

The areas of interest for this category are man-machine integration, habitability, teleoperators, bio-instrumentation, and maintainability.

3.2.7 Bio-Environmental Panel

This category includes items pertaining to food, water, and waste management; atmosphere generation, storage, and control and contaminant monitoring and control; atmosphere purification; integrated life support systems and protective systems, including thermal control equipment; and measurement and instrumentation. Also included in this category is crew equipment/systems.

3.2.8 Experiment Integration

This technology area covers the equipment development, activities, procedures, and techniques required to perform the integration of the experiments into the Modular Space Station. The area is system level oriented rather than subsystem and requires the knowledge of the Space Station Configurational Design and Operations. It is not currently identifiable with any of the jurisdictional areas of the panels noted in 3.2.1 through 3.2.7.

3.2.9 Management Techniques

Management techniques is a technology area and covers the development of management systems, procedures, techniques, and methodologies required to effectively manage the large and complex systems. Increased emphasis must be directed to the definition of more effective management approaches if space program costs are to be materially reduced. Currently, no panel has been identified with this responsibility.

3.3 DATA REQUIREMENTS

Before detailed assessment and recommendation of SRT items, certain data pertaining to the item must be provided by the originator of the item. A sample of the required data is presented in Section 3.4. These data should be of sufficient depth to determine priority and provide the assessment data needed to support an adequate justification for the incorporation of the items into the plan.

Each SRT item has been given a permanent number so that any additions or deletions will not affect the publication of revised SRT lists. If an item is removed from the list, the word deleted will be substituted for the title of the item. Numbers from 1 to 500 have been designated Space Station Program items, including all projects. The letter "M" behind each number indicates Modular Space Station Program to differentiate them from the original Space Station items.

3.4 SRT DATA REQUIREMENTS (TYPICAL EXAMPLE)

A. Item: Reverse osmosis for wash and condensate water recovery.

B. SRT Category: Advance development

C. SRT Technology Area/Panel: Bio-environment

D. Status: The reverse osmosis unit is in the developmental prototype stage. A unit is being fabricated and tested by Chemtric Incorporated under Contract to NASA-MSC. This effort is intended to produce an engineering prototype for the Space Station Prototype Program (SSP).

Additional programs are being jointly sponsored by NASA and the Office of Saline Water (OSW) to develop better performing membranes. This effort is being directed largely to develop membranes which perform well at pasteurization temperatures (165°F).

E. Justification: Reverse osmosis has the potential to recover condensate and wash water at very low weight and power penalties. Multi-filtration, which is the major competitor, with reverse osmosis, requires large amounts of expendables if high quality recovered water is desired. On the other hand, small amounts of expendables are needed with reverse osmosis and the pumping power is low. Because reverse osmosis has the potential for low vehicle penalty, it is recommended as an SRT effort.

F. Technical Plan:

Objectives—The objective of this SRT effort is to develop a reverse osmosis prototype and verify its long term performance in an integrated life support test. Recovery rates of 90 percent will be the design goal so that the penalty for water recovery from the residuum can be minimized. Maintaining a sterile system is a major objective of the effort since in the past bacterial growth within the wash water system has been a problem.

Technical Approach— The proposed effort consists of two distinct paths: (1) development of suitable membranes, and (2) development of an integrated reverse osmosis unit. Both tasks are currently being performed under NASA and OSW Contract and no change to the current effort is being recommended. The membrane development task is concentrating on developing membranes which will operate satisfactorily at 165 F. This operating temperature is necessary to prevent bacteria growth within the reverse osmosis unit. Performance of state-of-the-art membranes degrade at pasteurization temperatures. Pasteurization is favored because biocides can cause skin irritations and they do not act sufficiently fast.

Development and testing of the prototype unit is necessary to determine if the membranes can be successfully integrated into a hardware package. The unit should be tested in an integrated life support test using crew produced wash water and condenstate to create valid test conditions.

G. Resource Requirements:

Manpower (man years)	fy 1973 4	fy 1974 6	fy 1975 4
Funding	$200,000	$300,000	$200,000
Engineering	100,000	100,000	100,000
Equipment and Materials	$300,000	$400,000	$300,000

Section 4
SRT SCHEDULE AND PHASING

Figure 4-1 shows the SRT phasing which is consistent with the development schedule for the Modular Space Station baseline program and establishes schedule constraints for each SRT category. Research and advanced technology efforts are related to Phases A and B, and substantial results from these efforts are needed prior to or during Phase B. To minimize development risk to the program, no research can be permitted, and the advanced technology effort must be completed by the end of fy 1975. Advanced development should contribute to pre-Phase C, but would be useful if received in Phase C. Advanced development will start in January 1973 (fy) and must be complete by March 1977 (fy) to minimize risk. Decision to go into supporting development activities will not be made until Phase C, and the latest possible decision action will occur several months before engineering design

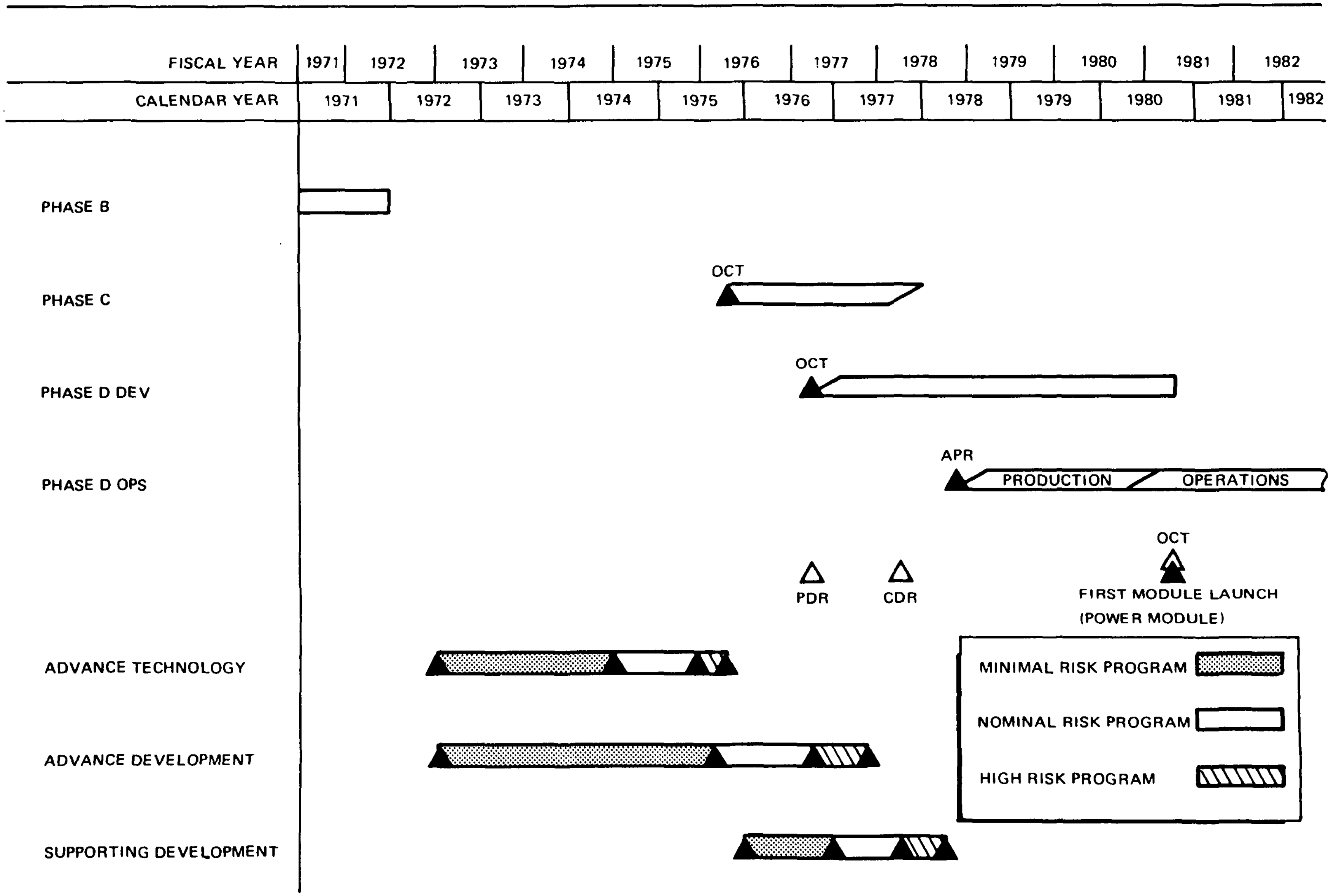

Figure 4-1. SRT/Modular Space Station Development Schedule Interrelationships

is complete. This effort will begin in June of 1976 (fy) and be complete in March of 1978 (fy) to minimize risk. The advanced development and supporting development efforts are keyed to the PDR and CDR activities, and high risk in the SRT effort can jeopardize the accomplishment of these reviews.

The SRT constrained by the schedule in Figure 4-1 pertains to that needed for the Space Station to accomplish the October 1980 (calendar) launch. SRT will also continue throughout the 10-year program, especially in the experiment areas. However, the continuing SRT for the Modular Space Station project will be limited to carry-on experiments and possible upgrading of key subsystems.

Section 5
SRT ASSESSMENT

All SRT items that are to be candidates for incorporation into this plan must be assessed programmatically. Once the SRT items have been recommended and incorporated into the program, they must be continuously reassessed, since schedule, funding, and priorities are subject to change. During the assessment or reassessment of SRT activities, the schedule implications resulting from these assessments must be described and evaluated. The initial assessments are made by the applicable study contractor, while final assessment and recommendation are provided by the NASA Technology Panels described in subsection 3.2.

5.1 ASSESSMENT OF NEW ITEMS

A gross programmatic assessment should be made by the applicable study contractor as described in Space Station MSFC-DRL-160 Line Item 18, Space Station Program Definition Volume IV "Integrated SRT Plan". This will be updated to include all additional or new items that may result from follow-on Phase B and Phase C activities. Final assessments and recommendations will be provided by the NASA Technology Panels. The technology panels will take the gross assessments and recommendations of the study contractor and perform a more detailed assessment utilizing data described in subsection 3.3. Data used in this assessment will include requirement for SRT, SRT status and justification, objective and technical approach, detailed cost and schedules, and any other factors deemed necessary for ranking and recommending required SRT.

5.2 REASSESSMENT OF ONGOING SRT

The Modular Space Station contractor will continually reassess the ongoing and presently defined SRT. This is required to determine if the SRT being performed is satisfying the appropriate phases of the program. Changes in past SRT assessments may result from further design definition, addition of new items, grouping of existing items, justification for priority changes, schedule and funding problems, etc. The reassessment will be performed as described in subsection 5.1.

5.3 SCHEDULE IMPLICATIONS

The Modular Space Station contractor and/or the technology panels will analyze the schedule implications associated with the addition of new SRT items, the recategorization or reassessment of existing items, or other factors which may affect the Modular Space Station development schedule. Schedule risk will also be analyzed in conjunction with these changes to determine effects on program milestones.

Section 6
DATA AND INFORMATION INTERCHANGE

There is a need for a precise and well-coordinated flow of information from the contractor performing the SRT to (1) the Modular Space Station project hardware contractor and (2) NASA (primarily the technology panels, which are the focusing area). This flow will ensure that the SRT is being accomplished as required and that the cognizant agencies and contractor are aware of any problem areas. The flow shown in Figure 2-1 illustrates how these data interfaces operate. This figure indicates that:

A. The status reporting will go directly to the hardware contractor, applicable technology panel, and contracting agency, i.e., OART for monitoring, review, and programmatic assessments. This procedure allows for quick response to problem areas.

B. The hardware contractor's status reporting to the MSFC program office will be through the technology panels.

C. Formal documentation will be accomplished through a path which is the reverse of the contracting procedure.

NASA and the hardware contractor will further define the data flow in follow-on activities.

Section 7
DOCUMENTATION

The contractor or agency performing the SRT tasks must provide formal documentation on the final results of the tasks. The SRT documentation shall include as a minimum the type of data shown in outline form in Table 7-1.

This outline must be expanded by NASA and the hardware contractor during follow-on activities. Documents shall be submitted within one month of the task completion date. Distribution of these documents will be the responsibility of the NASA Project Office (hardware contracting agency) in conjunction with the Technology Panels.

Section 8
STATUS REPORTING

The hardware contractor for which the SRT is ultimately being performed needs status data on all SRT applicable to his hardware. Therefore, the

Table 7-1

PRELIMINARY OUTLINE OF SRT DOCUMENTATION

1.0 Introduction and Summary

2.0 Background Data

Discuss background data leading to SRT effort, including requirements for the SRT and any applicable SRT efforts used in conjunction with or as background for the present effort. Include SRT data sheets as described in Section 3.3. Discuss schedule and how well it was met during task accomplishment.

3.0 SRT Task Description

Describe tasks performed during the effort.

4.0 Results

Discuss results of SRT tasks, including major problem areas.

5.0 Conclusions and Recommendations

Describe conclusions as a result of performing task and discuss recommendations for future effort, i.e., tasks to be performed as part of the follow-on categories (advanced development, etc.)

---

contractor performing the SRT tasks must provide various status data at prescribed intervals. This is particularly critical with SRT items which are program-or project-critical. Two types of status reports are required, as illustrated in Figure 2-1:

A. A status report from each contractor performing an SRT task. This shall include a discussion of (1) key results to date, (2) problem areas and possible solutions, including alternate approach if applicable, (3) schedule data (is task on schedule, and if not, why?), and (4) future efforts for the next reporting period.

These status reports will be sent directly to the hardware contractor, with copies to the appropriate technology panel, and shall be on a monthly basis with telephone conversations, followed by records of discussion, as applicable to resolve problem areas.

B. A quarterly status report from the hardware contractor to the NASA Program Office. This report shall be a compilation of all SRT tasks applicable to the Modular Space Station project. In addition to the above data, in summary form, this report shall include (1) a determination of how well the SRT tasks being performed are fulfilling the requirements, and (2) a discussion of alternates being considered if SRT is not successful or is too far behind schedule to be incorporated.

Detailed outlines of these reports shall be provided by the hardware contractor. All status reports will utilize the technology panels as the point of focus, and these panels, along with the applicable hardware contractor, will review, monitor, and perform programmatic assessments as to schedule implications, funding, etc., based on these data.

MODULAR SPACE STATION

PROGRAM INTEGRATION PLAN REQUIREMENTS

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PROGRAM INTEGRATION PLAN REQUIREMENTS

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PROGRAM INTEGRATION PLAN REQUIREMENTS

Section 1
INTRODUCTION

The Modular Space Station Program integration effort is concerned with the generation of program requirements program/project/CEI management, systems development, baseline definitions, interface data, verification criteria, plans resource estimates/constraints, and mission operation aspects. The Modular Space Station Program must manage interface responsibilities and requirements with all elements of the Space Station Program, related programs and government agencies including the following: RAM Project, Shuttle Program including Shuttle Orbiter and Booster Projects, Space Skylab Program offices, SRT Agency, and the Launch and Flight Operations Centers. The requirements for the integration of NASA and contractor efforts culminating in successful mission operations are imposed by the Modular Space Station Program, Project and CEI Specifications, Interface and Support Requirements Specifications, and the related program and project plans.

1.1 PURPOSE

This plan defines the policies, objectives, and requirements of the Modular Space Station Program Integration Plan; describes the application of the plan together with the organization and general operating controls and procedures required for its implementation; and provides descriptive information on the function of the plan and its impact on other functions of the program.

The synthesis of the Modular Space Station is the general objective of the Space Station Program integration effort. Specific objectives leading to this are:

A. Early identification and detailed evaluation of external constraints on the Modular Space Station Program which may have an impact on the management, schedule, or development of the Space Station.

B. Hardware, software, and functional definition and control that guarantee the customer and associates interface knowledge and assure compatibility during the development of the Modular Space Station Project.

C. Operational capabilities of the individual elements of the Modular Space Station Program that are compatible with the changing missions for the 10-year operational life of the Space Station.

1.2 SCOPE

This plan covers the program integration activities associated with hardware and software items of the Modular Space Station Project, Modular Space Station Program support, and related program interfaces. The plan covers the period from the requirement baseline through a 10-year operational life. After Space Station launch, the scope of activities will focus on integration of flight hardware changes and effects of related programs. The plan reflects understanding of the integration function of the Modular Space Station Project, significant requirements, and associated critical issues and potential problems.

1.3 CONTROL

The implementation plan will be written in accordance with the applicable portions of NASA documents "MSFC Standard Contractor Configuration Management Requirements," MM8040.12. It shall reflect the requirements of the "Space Station Program (Modular) Specification," PS02925 the "Space Station Project (Modular) Specification," RS02927 the "Interface and Support Requirements" RS02928 et al, and the Program Management Plan. How the plan is approved, how it may be changed, relationships to other government agencies and associate contractors, and the single point of contact for final direction will be supplied with the Phase C/D statement of work.

Section 2
ORGANIZATION AND RESPONSIBILITIES

2.1 ORGANIZATION AND INTERFACE

Where appropriate, the program integration function shall be delegated to the project or systems organizations when it can be assured that the integration activities can be more effectively accomplished. The organization must be structured so that the flow of authority and lines of communication can be clearly demonstrated. The placement of the integration function must allow for (1) visibility of external constraints on the program, (2) identification of and issuance of implementation direction for changes to system interfaces, and (3) flow of integrated mission operations information between the Modular Space Station Program and all affected agencies.

The plan shall identify the principal internal integration and support functional groups which will implement the integration activities. The Space Station inegration organization must have the capability to interface with the RAM Project contractor, the Shuttle Spacecraft Projects (Orbiter and Booster) contractor, the flight crew, the NASA Skylab Program office, the supporting research and technology agency, NASA Management agencies, and the launch and flight operations centers. The Phase C/D plan must identify the contacts in each of the above areas.

2.2 ROLES AND RESPONSIBILITIES

Space Station functional roles and responsibilities are found in the Program Management Plan. Typical integration roles and responsibilities are depicted in Table 2-1 with key activities listed under each task. The contractor shall expand the matrix to identify both internal and external responsibilities that meet the integration requirements of this plan.

2.3 JOINT OPERATING PLAN AND AGREEMENTS

Integrated contractor activities are controlled by the Program, Project System Specification, I&SR's, and plans. The contractors shall mutually establish the necessary joint operating plans (JOP's) and agreements (JOA's) consistent with Interface and Support Requirements (I and SR) and Interface

Control Documents (ICD) to carry out the integration activities. These JOP's, JOA's, ISR's, and ICD's, shall define responsibilities, interchange mechanisms, and working relationships.

Section 3
PROGRAM INTEGRATION SCHEDULES

Based on the Modular Space Station Program schedule, key events shall be depicted on a schedule which must include the major interrelated milestones of system and project design development and test events interface documentation due dates, integrated test milestones, and key inputs required from related programs. Figure 3-1 depicts some typical events and their relationships with the program milestones.

Some primary considerations in the integration schedule are:

A. Early definition of interface requirements. To minimize design changes, all interface requirements must be defined and documented in the CEI system specifications before the preliminary design reviews of affected end items. Interface control drawings can then be prepared to meet the system design flow schedule. As changes are identified in the development phase, a system engineering approach can be taken to assess design impact and to provide the most economical interface design changes.

B. Early definition of joint operating agreements, CEI design, development and test planning requirements for exchange hardware. The system development and verification and impact on other flow schedules will depend on program/project schedules and planning. These provisions must be provided so that formal contractual direction can be given to affected contractors.

C. Receipt of planned information from the Skylab and supporting research and technology programs. If this information is not obtained in time to key into the design flow for the Space Station, the development schedules and cost of the Modular Space Station Programs will be impacted.

Table 2-1

TYPICAL ROLES AND RESPONSIBILITIES

	Task / Contractor Agency	Space Station Project (Contractor)	Space Station Program (Agency)	RAM Project (Contractor)	Space Shuttle Program (Contractors)	Flight Crew	Supporting Research and Technology (Agency)	Skylab Program (Agency)	Launch Operations Center (Agency)	Flight Operations Center (Agency)
	Activity									
A.	Project Management and System Support									
1	Update Space Station Program Specification	P	A	S	S					
2	Update Space Station Project Specification	P	A	S	S					
3	Update Interface and Support Requirements	P	A	S	S				S	S
4	Update Experiment Module Project Specification	S	A	P	S					
5	Update Space Station Program Plans	P	A	S	S					
6	Update Space Station Project Plans	P	A							
7	Evaluate Supporting Research and Technology Schedules	P	S				S			
8	Evaluate Skylab Program Experiment Implementation	P		S				S		
B.	Engineering Design and Development									
1	Prepare Space Station Module Interface Control Documents	P	A	S	S					
2	Analyze Space Station Module System Interface Design	P		S	S	S				
C.	Fabrication Assembly, and Checkout									
1	Direct Acceptance Testing, Space Station Module	P	A	S						
2	Analyze Interface Tooling Requirements	P		S	S					

Legend
Responsibilities:
P - Prime
S - Support
A - Approve

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 2-1

TYPICAL ROLES AND RESPONSIBILITIES (Continued)

	Task / Contractor Agency	Space Station Project (Contractor)	Space Station Program (Agency)	RAM Project (Contractor)	Space Program (Contractors)	Flight Crew	Supporting Research and Technology (Agency)	Skylab Program (Agency)	Launch Operations Center (Agency)	Flight Operations Center (Agency)
	Activity									
D.	<u>Test Operations</u>									
1	Analyze System Test Results from FIT	P		S	S	S				
2	Analyze Test Results from FM	P								
E.	<u>Facilities</u>									
1	Prepare Joint Agreements for Common Use of Facilities	P	A	S	S					
F.	<u>Launch Operations</u>									
1	Direct Space Station Activities	S	P	S	S				S	
2	Direct Launch Vehicle Activities	S		S	S				P	
G.	<u>Flight Operations</u>									
1	Prepare Mission Timeline	P		S	S	S			S	S
2	Analyze Modification Kit Requirements	P		S	S	S			S	S
3	Define Operational Software Constraints	P	S	S						S

Legend

A = Approve

P = Prime

S = Support

FOLDOUT FRAME 1

FOLDOUT FRAME 2

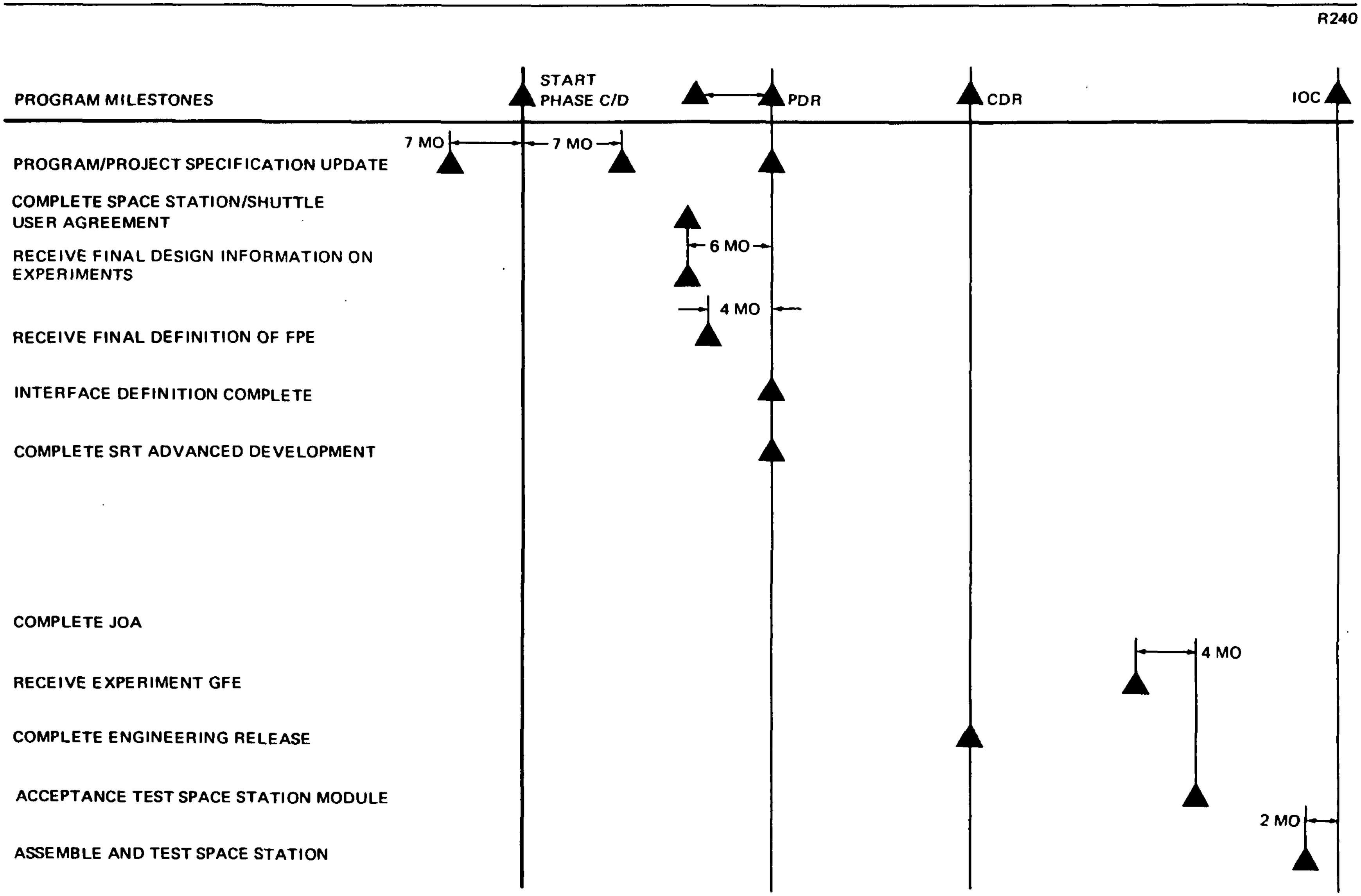

Figure 3-1. Typical Key Integration Milestones

Section 4
PROGRAM INTEGRATION FUNCTIONS

The integration functions of the Space Station Program shall include those disciplines which will contribute to a workable combination of a complex system of flight hardware, software, crew, and supporting ground equipment and personnel.

4.1 PROGRAM REQUIREMENT DEVELOPMENT

Program requirement development during Phases C/D shall consist of maintaining and expanding specifications; providing a continually updated baseline program/system definition; identification and analyses of resource/external factor constraints and the performance of system support functions. The function of program requirements is to maintain the objectives, missions, performance requirements, inputs and constraints for the Space Station Program.

4.1.1 Specifications

The specification section encompasses the program specification, the Space Station Project Specification, I&SR's, hardware CEI specifications and software CPCEI specifications.

4.1.1.1 Program Specification

The program specification will be the controlling document for the program. Inputs to the specification will be accomplished in accordance with MSFC MM8040.12.

4.1.1.2 Project Specification

The Project Specification developed in Phase B shall be updated in Phase C/D to reflect design and Development impacts and program specification changes. The specification will be maintained in accordance with MM8040.12 requirements (design, performance, and support). Allocations and criteria from the program specification shall be expanded during Phase C/D and reflected as revisions in the project specification. The project specification shall be the controlling document for the technical effort at the Project Level.

4.1.1.3 Interface & Support Requirements (I&SR's)

All I&SR's will be updated in the same manner prescribed for the Program and Project Specifications.

4.1.1.4 Contract End Item Specification

The contract end-item specifications shall be reviewed for consistency with the requirements and criteria of the program and project specifications. This effort will be continual throughout the specification development phase. Changes to the specifications after customer approval will be considered as a part of the change effort.

4.1.2 Baseline Definition

The baseline definition shall consist of maintaining a summary extract of the program and project definitions; updating and expanding the experiment program definition; maintaining a current definition of all Modular Space Station Project systems as well as significant end items. The function of the baseline definition is to provide program visibility to all elements of the program and to provide a means for identifying alternative approaches.

4.1.2.1 Program/Projects

A summary extract of the current program/project definition shall be maintained at all times.

4.1.2.2 Experiment Program

The current experiment program definition, with the identification and schedule of all FPE's to be accommodated, will be maintained at all times.

4.1.2.3 System/End Items

The current definition of all Modular Space Station Project systems and end items will be maintained.

4.1.3 Resource/External Factor Constraints

The Modular Space Station Program contractor(s) shall review the external resource constraints on project(s) and shall reflect these constraints through the specification and as inputs to program plans. Major constraints shall include the supporting research and technology requirements, facility resources, available funding and related programs such as Skylab and Shuttle. This function must be concentrated during the design phase but will continue through the operational phase as new requirements are identified for experiments and their related Space Station modification kits.

4.1.4 System Support Functions

The requirements for the system support functions at work breakdown structure (WBS) Level 3 shall be analyzed for project consistency, verification philosophy, cost avoidance, and implementation feasibility. The requirements for each work package at WBS Level 3 must sum up to the whole of the requirements reflected in the project specification and project plans. The basic requirements identified in Phase B and expanded in Phase C/D by each functional element must be played back against the project and program specifications and plans. Change requirements shall be identified and implemented through the controlling documents.

Requirements are a key to cost avoidance techniques. Each new or expanded requirement identified at any level shall be analyzed through a trade study for a cost avoidance possibility as well as to determine feasibility for the implementation of the requirement. The make-or-buy structure shall be accomplished at the time of requirement identification to ensure a total program economy in cost and schedule.

4.2 INTERFACES

4.2.1 Hardware-Software Interfaces

System engineering for the Space Station Program is defined as the effort to review and approve all functional and physical interfaces between the Space Station module/integral experiments and the attached or free-flying modules, logistic module, crew cargo module (GSS only), Shuttle spacecraft, and ground or space support facilities during the design phase. All ECP's will be reviewed and approved as a part of the ECP package before implementation during the phases from design through operation. System engineering review will be performed on all major changes affecting cost, schedules, or performance which occur after the design phase.

4.2.2 Support Interfaces

Joint operating agreements (JOA's) and Interface and Support Requirements covering contractor, customer, and agency will be developed for the areas of exchange hardware, software, and data; common support facilities; and system support to cover the period through design, fabrication, and acceptance testing. The JOA's and, interface control documentation shall provide detailed relationships within the constraints of the project specifications and program plan.

4.3 SYSTEM EVALUATION

4.3.1 Design Reviews

An evaluation of the compliance of the design with program, project and CEI specification requirements for interfaces, allocation, and system criteria shall be presented at the formal preliminary design review (PDR) cirtical design review (CDR) and first article configuration inspection (FACI). Program integration activity shall provide the criteria and documentation requirements necessary to control and evaluate design reviews.

4.3.2 Verification

All verification processes and results associated with Space Station activities will be reviewed by program integration and the analyses will be evaluated against the project specification performance requirements. The results of verification functions shall be managed by processes defined in the quality plan and reviewed for specification compliance by program integration at designated critical milestones.

4.3.3 Performance/Cost/Schedule Measurement

On a semiannual basis, a complete evaluation of the Space Station Program progress shall be prepared, and recommendations for realignments for future planning shall be made. The progress assessment shall include the technical progress versus the system performance related to the schedule and cost at the appropriate WBS level. The periodic schedule and cost progress reports required by the Program Management Plan and technical progress reports required by the Design Plan shall be used as the basis for formulating the Project Management Assessment Report. This activity shall be under the direction and control of program integration.

4.4 OPERATIONS

4.4.1 Functional Analysis

The contractor shall perform functional analysis to the depth required to support design and interface operations for the orbiting vehicle configuration. The elements shall include the flight crew, Space Station module, attached module, free-flying module, crew cargo module (GSS only), logistic module and the Shuttle spacecraft (orbiter). The analysis shall include the RF link between the orbiting vehicle, data relay satellite, and the ground station. Functional flow block diagrams shall be used only as internal contractor documentation to support the PDR and detailed ground and mission operations.

4.4.2 Orbital Flight Operations

The Space StationProgram contractor shall perform analysis of the orbiting vehicle operations to produce a baseline mission timeline. The analysis shall be supported by the RAM Project, the Shuttle Spacecraft (orbiter) project, and necessary ground support agencies. The analysis shall include the crew interface and the ground support interface requirements. These requirements will be detailed and refined throughout Phase C/D to recognize changing missions. The timeline shall be updated periodically on a 90-day basis through the design phase and must bs consistent with the Space Station Program and Project Specifications, the Space Station Program Plan, Ground and Mission Operations Plan.

4.5 PROGRAM PLANNING, COSTING AND SCHEDULING

4.5.1 Program/Project Plans

The Space Station Program plans will be analyzed to evaluate the consistency of the approaches planned for design development and verification as well as compliance with the specifications. The effort shall include revisions to the Phase C/D System plans as necessary.

4.5.2 Supporting Plans

Supporting plans from other projects and programs will be analyzed as they interface with the Modular Space Station Program. The analysis is to define management methods or scheduling which could be changed or altered to effect a cost saving to the program. This effort will be primarily concerned with plans for manpower, facilities, and funding.

4.5.3 Resource Estimates

Resource estimates consisting of cost, schedules, manpower, funding and facilities will be provided for trade studies, evaluation and planning purposes. Those data will also be used to provide management visibility.

4.5.3.1 Cost

All cost estimates will be traceable to a WBS item or a proposed derivation of the WBS. Strict adherence to the latest NASA Cost Analysis guidelines will be required. Traceability will be maintained between the cost estimates CER (Cost estimating relationship) and the technical characteristics of the appropriate performance specification.

4.5.3.2 Schedules

Updated schedules will be available at all times. All schedules will be traceable to a WBS item or a proposed derivation thereof. Traceability between NASA's milestones and any schedule will be readily visible.

4.5.3.3 Manpower

Manpower requirement/projections will be maintained in an updated state.

4.5.3.4 Funding

Funding distributions will adhere to the latest NASA Cost Analysis guidelines. All funding distributions will be traceable to a prior cost estimate and schedule.

4.5.3.5 Facilities

Facility projections and use will be provided.

Section 5
PROGRAM INTEGRATION ACTIVITIES

5.1 ENGINEERING ANALYSIS

Space Station Program integration shall perform analysis of functional requirements identified in the Space Station Program Project and Systems (CEI) Specifications. These analyses shall be in sufficient depth to establish the prelimimary compatibility of the hardware contract end items (CEI's) with functional requirements at the preliminary design reviews scheduled in the Design Plan. The functional requirement analysis and allocation of software requirements will follow an approval and implementation cycle as required by the Software Integration Plan.

The contractor shall continually analyze standard design conditions established and documented as outlined in the Design Plan for internal use on the Space Station Program. All conditions which will be applicable to other contractors shall be added to the standard design criteria documented in the Space Station Specifications during Phase B. Figure 5-1 depicts the flow of data and the controlling agencies for the specification upgrading. These standards shall be used in the design of all Space Station elements.

Trade studies shall be performed as new requirements are identified during the engineering analysis. Trade studies shall be limited to those identified requirements which have been approved by the program.

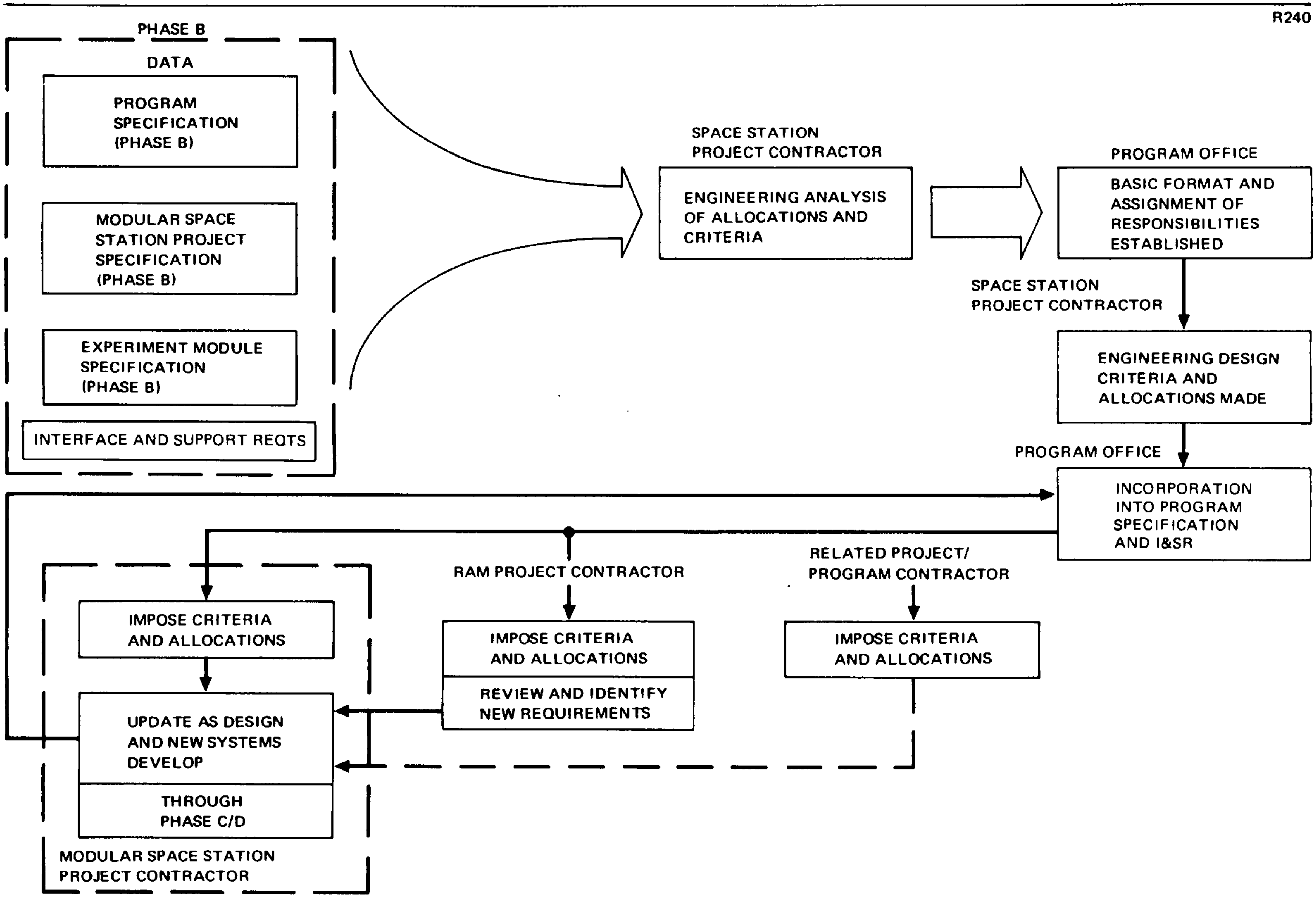

Figure 5-1. Integration Engineering Analysis Flow

Analysis shall be performed to amplify performance requirements, ISR's and ICD's identified in the Space Station Program, and CEI Specifications. The contractors shall identify all interfaces with other contractors and shall use the system developed for the Space Station Program to track, and allocate responsibility for definitive interface control. The interface Control Documentation shall be defined at the CEI level.

Space Station Program integration shall perform operational analysis to develop the baseline timeline for the operational phase. Timelines must be updated on a periodic basis to reflect design development and operational status. The analysis shall cover all of the activities in the daily operation of the Space Station, including the control of the Shuttle spacecraft (orbiter) within a specific radius of the Space Station, the operation of the experiments or logistic modules, and the transmission of all data. The contractor shall perform this activity for the first activation of the Space Station with a specific update for each Shuttle resupply of crew, cargo, or experiments.

5.2 ENGINEERING DESIGN

Program and project specifications and plans shall be updated as design evolution dictates. The design progress is constrained by the specifications and the JOA/JOP's. If the design changes affect these documents, a deviation is required and must be approved by NASA. The flow of design requirement documentation is shown in Figure 5-2. The project and CEI specifications are the specifications that are affected by design evolution and the requirements changes wil be primarily in the areas of operability, design, verification and construction. The orderly progression of design for the program must be constrained to provide an economical design and development of all related project and program elements. To ensure that the requirement documentation flow supports the Design Plan, program integration shall maintain the capability to update the program and project specifications and circulate changes in a timely manner. Contractors shall identify in an expanded plan constraints from the program schedule that would impact the design phase. These items will include definition of other project elements and supporting research and technology, as well as early

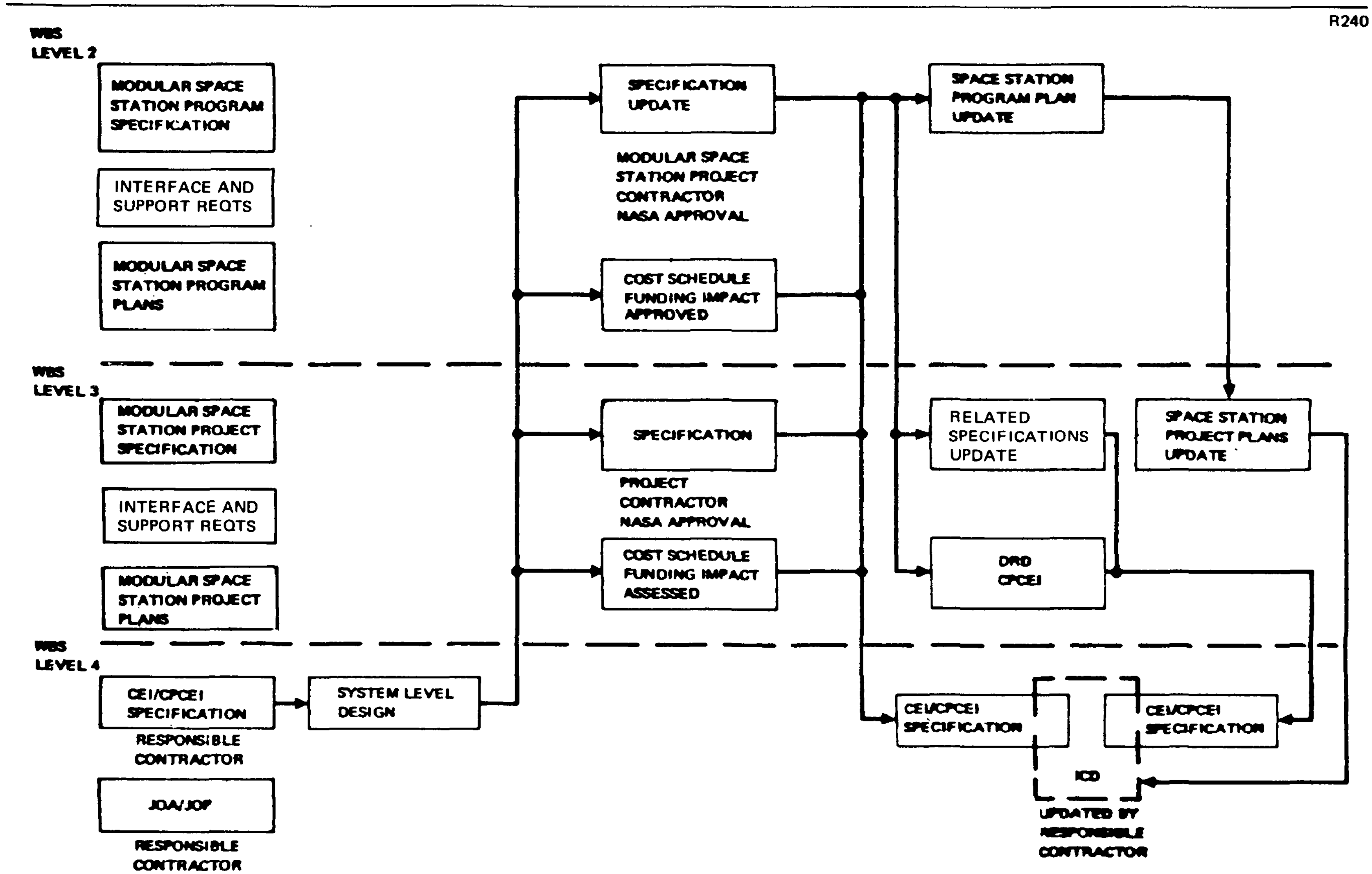

Figure 5-2. Integration Flow of Design Change

release of development items within the project. These items will be an integrated effort and will be reflected in the Design Plan.

The hardware interfaces identified in the Phase B study shall be expanded during Phase C/D, and interface control documentation (ICD's) shall be developed for interfaces at the end item level which is the responsibility of different contractors. The ICD's shall reflect the requirements in the project specification. The ICD's shall be available for the Critical Design Review.

Exchange hardware and software shall be identified, and joint operating procedures shall be written as part of the ICD during the Phase C/D effort to ensure availability of the applicable items.

The analysis of design changes and plans for impact on the Space Station Program Elements shall be a continuing effort through the design phase. Changes which affect the design information in related plans shall be highlighted immediately to the customer.

5.3 FABRICATION

The contractor shall maintain change control over all hardware fabrication in accordance with NHB 8030.2 and Modular the Space Station Project Manufacturing Plan. The interfaces shall be controlled by ICD's and by master exchange tooling. The exchange of hardware and delivery of interface tooling shall be strictly controlled during the fabrication phase.

5.4 ACCEPTANCE TESTING

Acceptance testing shall be conducted to verify system compliance with the project/system specifications. System acceptance verification shall be based on acceptance of the Space Station modules. The testing acceptance activity shall be compatible with the verification plan and quality assurance plan. The contractor shall maintain a viable system to integrate system testing whenever studies show a need based on functional, hardware, or economical considerations.

5.5 STORAGE

The Space Station Program (except for logistic module operations) as envisoned, does not include a storage requirement at the launch site. Thus to account for program contingencies, the contractor must provide storage capability for the modules at the final assembly point. The storage would occur after customer buy-off (DD-250).

5.6 TEST OPERATIONS

The compatibility of the hardware and software shall be verified on the functional model. Comparisons shall be made of the requirments defined in the specifications and requirements for software performance. Integration of the complete system of hardware for the orbiting vehicle shall be verified on the Flight Integration Tool. These verifications shall be consistent with the Verification Plan and the Software Integration Plan.

5.7 FACILITIES

Program Integration shall review the facilities outlined in the facility Utilization Plan for common usage between other projects or programs. This review shall assure adherence to project master schedule requirements and shall initiate actions to eliminate utilization overlaps and uneconomical delays.

5.8 FLIGHT OPERATIONS

Program integration shall coordinate hardware and functional requirements of the Space Station Program during mission operations in support of the mission management team. As new modification kits or operations are identified, the interfaces between contractors shall be identified and controlled through the program, project, I&SR's, and CEI specifications. Timelines will be published to support each mission operation plan. Mission operational effectiveness data shall be analyzed to determine potential impact on Space Station hardware and software. This requirement permits responsiveness to NASA-initiated requests and project management recommendations for improved mission operations.

Section 6
DATA/HARDWARE/SOFTWARE EXCHANGE

6.1 DATA AND INFORMATION INTERCHANGE

The data and information interchange shall be managed through one central agency in each project. Identification and scheduling of data and information requirements will be included as part of the Program Management Plan and the Design Plan.

6.2 HARDWARE/SOFTWARE

The exchange hardware/software items shall be identified during Phase C/D as required to meet program objectives and schedules. Responsibility for each item will be identified as a separate item in the responsibility tabulation sheet.

Section 7
DOCUMENTATION

Program/Project Integration shall be responsible for developing and revising, as necessary, the baseline documents of program, project, I&SR's, and CEI specifications and the individual Program/Project Plans. The constant evaluation of change and performance operation data feedback, as indicated in Figure 7-1, is essential to assure the accomplishment of Modular Space Station Project objectives in an economical and timely manner.

Section 8
REPORTING

The contractor shall supply to NASA, contractors, and other using agencies, applicable program integration information. This includes information required as a function of time (progress reports), events and problems. Such information shall be limited to that essential to decision making.

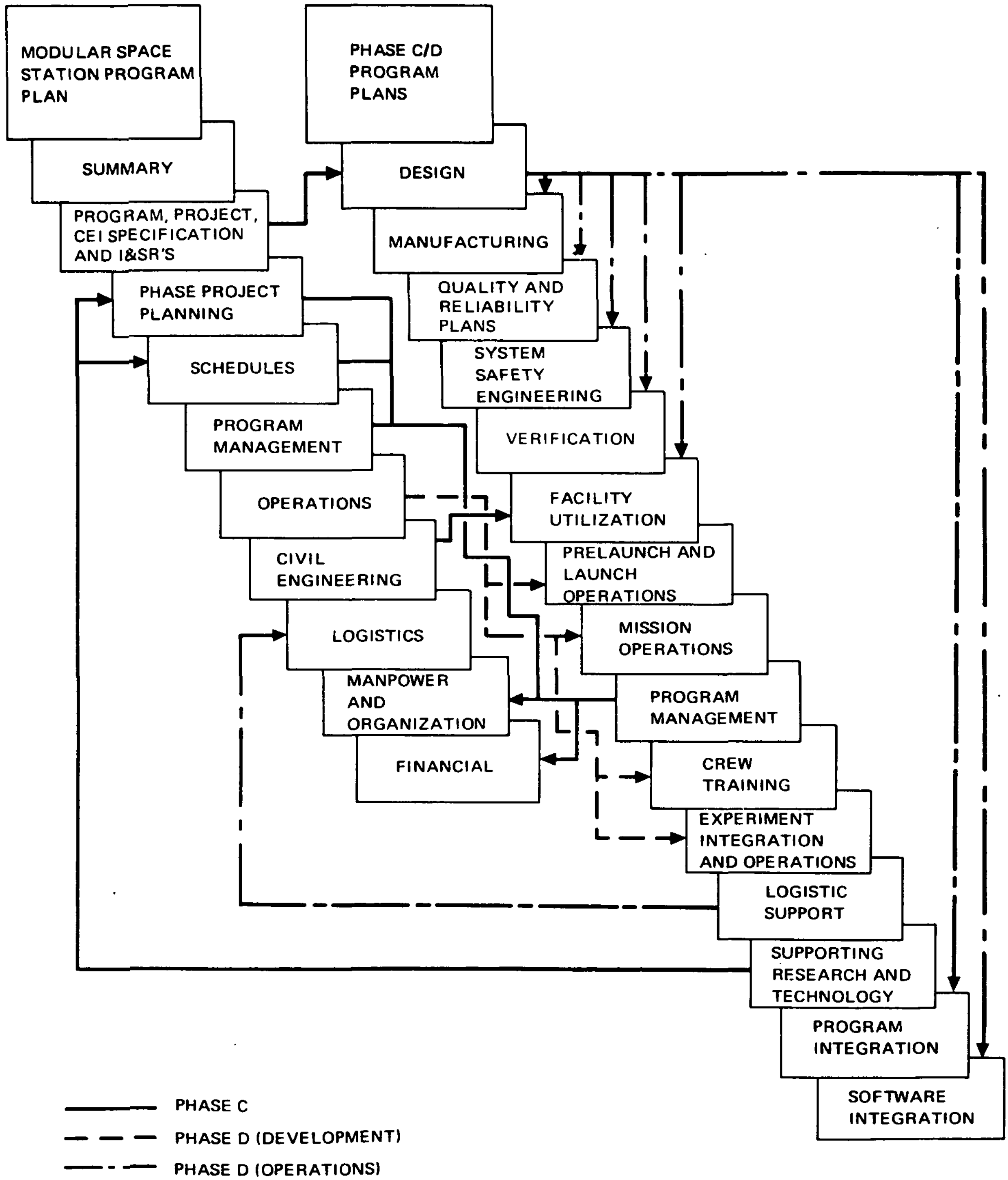

Figure 7-1. Modular Space Station Project Baseline Documentation Relationship

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MODULAR SPACE STATION
SOFTWARE INTEGRATION PLAN REQUIREMENTS

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SOFTWARE INTEGRATION PLAN REQUIREMENTS

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SOFTWARE INTEGRATION PLAN REQUIREMENTS

Section 1
INTRODUCTION

1.1 PURPOSE

This plan defines the software requirements and their application to the Space Station Project; and, the function and general operating controls/procedures, policies, and objectives to be applied in preparing the Phase C/D Software Integration Plan. This document has been prepared to guide contractor planning and bidding for Phase C/D.

The contractor shall develop an integrated set of software requirements for the Modular Space Station Program.

1.2 SCOPE

This plan is applicable to all deliverable software produced in support of the Modular Space Station Project. Deliverable software will include existing software that is determined to be applicable, either directly or with modifications, and newly developed software identified in each of the areas noted above, i.e., operations, maintenance, and support.

These requirements shall encompass the three functional areas of maintenance, operations, and support and will span the development and operational life of the Modular Space Station Program.

1.3 SOFTWARE GUIDELINES

The requirements allocated to computer programs are developed primarily from the operational requirements and from the design requirements for the equipment. In many cases, trade studies must be made to determine the applicability of a hardware versus a software solution.

For the Space Station Modules, computer program design and operation will be predicated on meeting the objectives and design approach identified for the Station: primarily long-duration, autonomous flight operations, and centralization of data collection, processing, and dissemination. The onboard Space Station Module computer programs shall:

A. Be highly user-oriented.

B. Be capable of being rapidly modified.

C. Possess alternate means of operation in the event of equipment malfunction or computer program errors.

D. Provide control for data routing and processing under varying loading conditions, including maximum load.

E. Provide for fully automated operations to the extent feasible and practical, with minimal human intervention required.

F. Generate output messages in a form that is readily interpreted by human operators.

G. Be compatible with launch site processing system (LSPS).

The ground station computer programs shall:

A. Provide for semiautomated operations, allowing human intervention and optional processing mode selection.

B. Possess alternate means of operation in the event of equipment malfunction.

C. Provide control for data routing and processing under varying loading conditions, including full load.

D. Generate output messages in a form that is readily interpreted by human operators.

E. To the extent feasible and practical, duplicate the structure and logic of the onboard programs.

Requirements peculiar to the design and operation of computer programs for the Modular Space Station Program are allocated in terms of functional performance requirements, design requirements, and information transfer. The requirements are applicable to both onboard and ground processing and satisfy processing tasks required to support research and scientific activities, maintenance and checkout operations, daily mission operational activities, training, and communications.

1.4 APPLICABLE DOCUMENTS

NASA documents applicable to this plan are:

NASA Document	Title
NHB 8040.12	Configuration Management Manual
DR CM-01	Space Station Program (Modular) Specification-PS 02925
DR CM-02	Space Station Project (Modular) Specification-RS 02927
DR CM-03	Initial Space Station CEI Specification-CP 02929
DR CM-04	Interface and Support Requirements
DR MA-05, Volume II	Modular Space Station Verification Plan Requirements
DR MA-05, Volume II	Modular Space Station Design Plan Requirements

Section 2
SOFTWARE ORGANIZATION

2.1 FUNCTIONAL REQUIREMENTS

Three classes of computer programs are identified as being required to accomplish both onboard and ground data processing tasks for the Modular Space Station Program. These classes are maintenance, operational, and support. Figure 2-1 shows this categorical arrangement. Requirements allocated to each class are presented in this section.

2.2 MAINTENANCE PROGRAMS

Maintenance programs shall consist of a set of computer programs designed to operate in the onboard and ground data processors. They shall be designed to verify system and equipment operation and support maintenance operations. The programs shall provide computational techniques and control to satisfy the overall program requirements for autonomous operation and system availability. The computational techniques shall include performance monitoring, test and excitation, diagnostics, and inventory management.

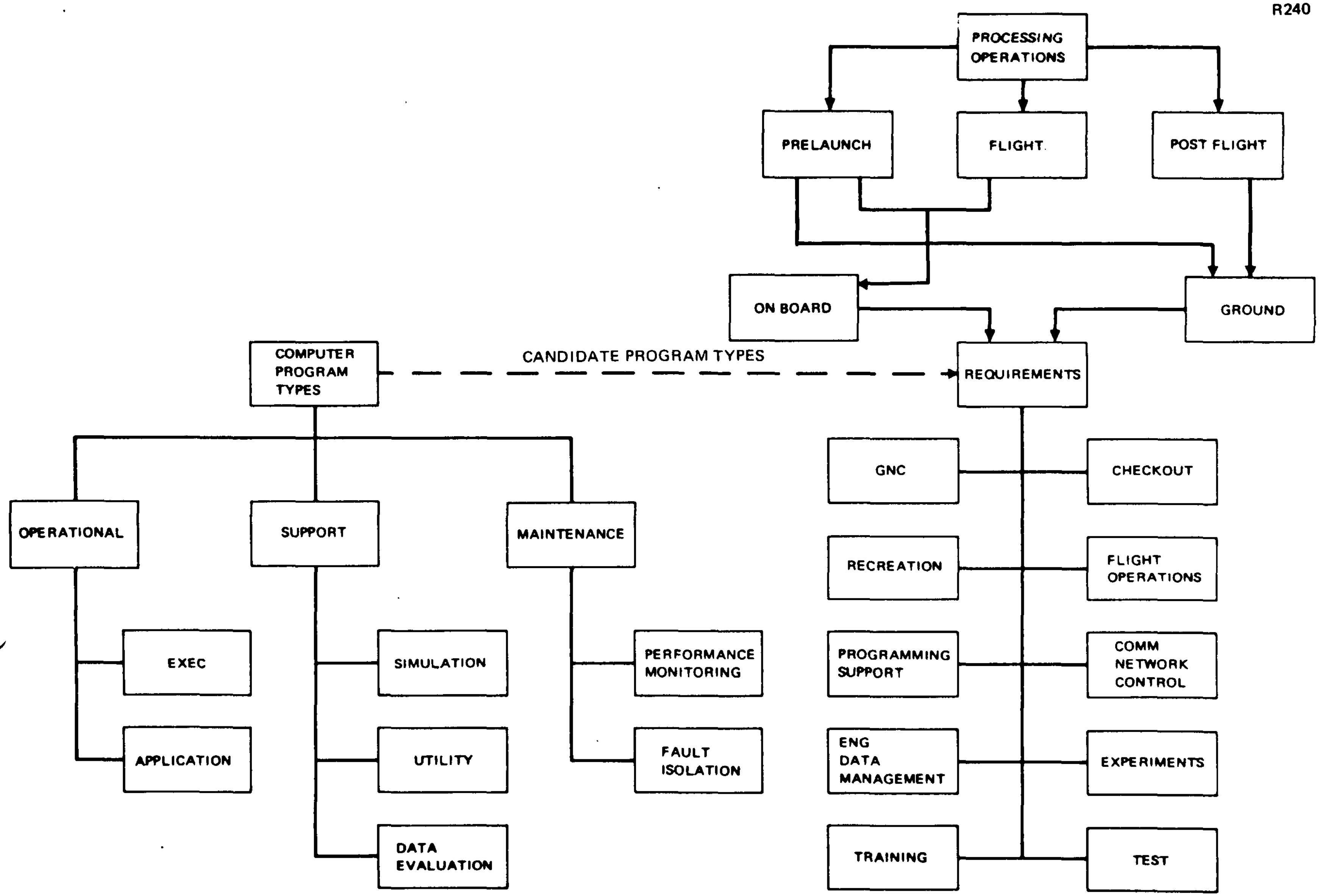

Figure 2-1. Computer Program Processing Allocation

2.2.1 Performance Requirements

The programs shall provide the necessary logic, data base, and data handling characteristics to provide:

A. Processing capabilities to allow degraded-mode operation and fail-safe conditions.

B. A program structure that allows acquisition and processing of data from built-in test equipment, and interaction with operational programs and peripheral displays so that system downtime is minimized, allowing maximum available time for scientific and research activities. To accomplish this, the programs shall provide:

   1. Data to support the restoration of relevant in-flight system failures within the maximum allowable restoration time in order to maintain system capability for a given mission.
   2. Data to accomplish restoration of other in-flight failures to reduce turnaround time and reduce maintenance man-hours per flight hour.
   3. Data that will allow self-sufficient onboard organizational maintenance during flight.
   4. A capability to monitor continuously and display system operational status.

2.2.2 Operational Requirements

The programs shall provide those features which contribute to effective operation of the system as a whole. This will be accomplished by:

A. A processing configuration that allows for error recovery, automatic reconfiguration, and startup or startover.

   1. Reconfiguration to a safe status in the event of equipment failure or malfunction shall be accomplished within 30 sec from the time of detected malfunctions.
   2. Reconfiguration to an operating status in the event of equipment failure or malfunction shall be accomplished within TBD sec from the time of detected malfunctions.

B. A processing capability and program structure that will operate on a noninterference basis with operational programs. Fault and failure data shall be presented to the cognizant operator to allow him to take manual action to isolate further, via the maintenance programs, the cause of the failure to the lowest replaceable unit (LRU) level.

C. A readily adaptable and easily changeable program structure to accommodate day-to-day limit changes and test stimuli.

D. Periodically exercising all major elements of the system.

2.3 OPERATIONAL PROGRAMS

The Modular Space Station operational programs shall include those executive and supervisory control programs and application programs required to satisfy scientific and research functions, command and control functions, and mission operation and logistic functions.

2.3.1 Performance Requirements

The control programs shall provide for storage allocation of all application programs and data, task scheduling, data bus information transfer, and man-machine interface functions, as follows:

A. Schedule on a priority basis all application programs according to mission characteristics, including mission phase and amount of processing time available to meet real-time accuracy requirements.

B. Provide the resources to reconfigure the data management system in the event of a sensed malfunction so that operating status is restored within TBD sec. Provide the capability to change processing priorities dynamically, due to hardware failures, external load conditions, or emergency conditions.

C. Provide for movement of data and programs between main memory and auxiliary memory, and for reallocation of data in main memory, with protection logic to prevent destruction or inadvertent alteration of critical data.

D. Provide the resources for interfacing portions of the utility and maintenance programs in a time-shared or multiprocessing configuration, depending upon the given mode of operation.

The application programs shall include all programs or sets of programs for processing of data, solution of equations, and logical operations for a given system function as follows.

A. Provide for guidance and navigation information to establish Space Station position and velocity in inertial space, ephemeris parameters, attitude control, and rendezvous and docking maneuvers.

B. Provide display and formatting of information for onboard use.

C. Provide mission support, including short-range mission planning, inventory control, expendable management information, and recreation. All consumables will be included within inventory management. These consumables fall into general categories of life support, power system RCS, spares, photographic film, and data recording packets.

D. Provide crew support, including simulation for training purposes.

E. Provide experiment control and processing, including display and control, data storage and retrieval, and data correlation programs as follows:

1. Programs to correct for nonuniform sensitivity characteristics of sensors.
2. Programs to correct for degradations caused by sensors viewing objects.
3. Programs to identify changes by comparing images.
4. A control program for eliminating an image segment of no interest to the user (blanking).
5. Programs to map a black-and-white scene into a color image so that greater detail can be viewed by the human eye.
6. Programs to remove the random and nonrandom noise generated by film emulsion, video transmission, electronic sensors of equipment, etc.
7. Programs to correct for the geometry errors or environmental restrictions of the sensor.
8. Programs to correct for the blurred effect caused by atmospheric turbulence.
9. Programs to magnify and display various sections of an image and to use several images of the same scene to generate one best image.
10. Programs to provide experiment support, including short-range scheduling, inventory control, and maintenance procedures.

2.3.2 Operational Requirements

The control programs shall provide the capability of meeting timing, mission criticality, and data accessibility requirements as follows:

A. Provide selection of application programs to be operated in a reduced processor equipment complement and present this information to an operator.

B. Provide for scheduling and processing of tasks for a 3-CPU processor configuration and for switchover of processing tasks to a redundant processor system without significant degradation in computations.

C. Provide for accessibility of data. Parameters unique to a program shall form a part of that program. Other parameters shall reside in a common data base, with provision for rapid accessibility of data.

The application programs shall provide for accurate, fast, and reliable processing of data as follows:

A. Utilize efficient mathematical techniques for solving identified processing tasks.

B. Provide for a centralized timing and distribution function for use by recording and display peripherals, subsystems, and other time-dependent application programs.

C. Provide a central source of mathematical routines (e.g., arc tan, sin, cos, etc.).

D. Provide for a common orthogonal, Earth-referenced coordinate system for purposes of aligning or pointing Space Station Module sensors, and for tracking.

2.4 SUPPORT PROGRAMS

Support programs shall be those sets of computer programs that accomplish off-line, non real-time processing in support of training, testing data management, and mission operations. The programs shall also include those required to produce and maintain Module Space Station computer programs.

The simulation program shall provide the capability to emulate system operating and performance characteristics under normal and worst-case conditions such that (1) data can be generated to support system integration testing and (2) ground and onboard crews can be trained in maintenance, mission operations, and experiment processing.

The utility programs shall provide the capability to assemble and compile processor machine codes derived from higher-order English language procedures and problem-oriented statements.

2.5 DESIGN REQUIREMENTS

Computer program design requirements have been identified by consideration of the long-range goals for the Modular Space Station. The design requirements are interdependent in most cases and to a large extent are oriented toward good programming practices to meet multiprogramming requirements. Figure 2-2 shows this interdependence.

2.5.1 Modularity

Computer programs shall be designed in a modular structure which breaks down the program requirement into a series of assignable tasks. This modularity shall be used to provide a base for system modification, maintenance, and testing.

2.5.2 Ease of Change

Computer programs shall be designed to facilitate changes through the use of modularity, good organization, well-commented program listings, standards, etc.

2.5.3 State of the Art

Computer programs shall be designed to parallel programming state of the art to ensure long-term compatibility with evolutionary system requirements.

	MODULARITY	EASE OF CHANGE	FLEXIBILITY	STANDARDIZATION	ORGANIZATION	AUTOMATION	EVOLUTION	RECONFIGURABILITY	GROWTH	TASK ALLOCATION	LANGUAGES	PROJECT BENEFITS
MODULARITY	–	X			X							RAPID DEVELOPMENT
EASE OF CHANGE	X	–	X	X	X			X	X		X	INEXPENSIVE MODIFICATION
FLEXIBILITY		X	–		X		X			X		FIELD ADAPTATION
STANDARDIZATION		X		–								MANAGEMENT CONTROL
ORGANIZATION	X	X	X		–	X		X				USER OPERATIONS
AUTOMATION					X	–				X	X	PERFORMANCE
EVOLUTION			X				–		X			AUTONOMY
RECONFIGURABILITY		X	X		X			–	X			RAPID CHANGEOVER
GROWTH		X					X	X	–	X		COSTS
TASK ALLOCATION			X			X			X	–		SCHEDULES
LANGUAGES		X				X					–	COSTS

Figure 2-2. Design Requirement Interrelationships

2.5.4 Standardization of Modular Interfaces and Linkage

Computer programs shall use standard module interfaces and linkages to promote modularity, facilitate change, and provide for an orderly evolution of software components.

2.5.5 Well-Oriented Separation of Data Base and Logic

Computer programs shall be designed to separate computer program logic from computer program data. This concept shall include, where applicable, the use of table-operated programs.

2.5.6 Automation

Computer programs which will be called upon to provide visual information about an automatic decision shall contain components to enable inquiries and gather and reassemble data. They shall also contain default options to reduce excessive information.

2.5.7 Evolution

Space Station Module computer programs shall be designed, where applicable, to include attributes which will allow them to be used as autonomous test beds for newly evolved programs.

2.5.8 Reconfiguration

Computer programs which support the experiment program shall be designed to allow rapid reconfiguration and rapid test and verification of the reconfiguration.

2.5.9 Provision for Growth

Space Station Module computer program organization shall provide for requirement growth at the outset of design to prevent foreseeable overcapacity problems from arising.

2.6 INFORMATION TRANSFER REQUIREMENTS

Data transferred over the onboard data bus, between subsystems, over the uplink-downlink telemetry loop, and between ground stations, the format and rate of which are under control of computer programs, is expressed in terms of information transfer requirements.

Three types of data will be exchanged between various Modular Space Station program elements and will be transmitted in different forms. Figure 2-3 shows this relationship. The three types are defined as:

A. Mission data which shall include all information necessary to meet program objectives, e.g., tracking, command and control, and engineering evaluation.

B. Checkout data which includes the status of the various vehicle and experiment subsystems, plus data necessary to support maintenance operations.

C. Experiment data, which comprises the scientific information resulting from the operation of the integrated, attached, and free-flying modules.

The computer program shall be capable of inputting, processing, and outputting mission, checkout, and experiments data by:

A. Assignment of message routing, priority, data status, and message identification tags to each block of information to be transferred.

B. Interpretation of received message control words to establish priority stacks and message validity.

C. Providing input-output validity checks by using a combination of the transmitting equipment features (echo checking) and software data formatting (one's complement, parity).

D. Providing a flexible format generator for allocation of data to specific data frames for subsequent transmission to the ground.

E. Decoding and routing received uplink information to the proper source for additional processing.

F. Having the capability to dedicate a selected input-output channel to a designated block of processor core memory.

Section 3
SOFTWARE STRUCTURE

The three programs defined in Section 2 shall be further identified as illustrated in Figure 3-1. This software tree provided the basis for allocating

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	SPACE STATION MODULE	EXPERIMENT MODULE (FREE-FLYING)	ATTACHED AND INTEGRATED EXPERIMENT	LOGISTICS MODULE	DATA RELAY SATELLITE	GROUND DATA HANDLING FACILITY	LAUNCH FACILITIES	PRINCIPAL USERS	PUBLIC DISSEMI-NATION	ARCHIVES
SPACE STATION MODULE		B E H C F J	B E J C F C G	A D H C F K G J	A D H B E C F	A D H E B F C G				
ATTACHED AND INTEGRATED EXPERIMENTS				A E J F			A E J B F			
LOGISTICS MODULE					A D N E F	A D H E K F	A D H E F			
DATA RELAY SATELLITE					A D N B F C F	A D N B F C F	A D H B E F			
GROUND DATA HANDLING FACILITY								C D H E J F G	A D J C E	C F K G
LAUNCH FACILITIES										
PRINCIPAL USERS									C D J E	C F K G
PUBLIC DISSEMINATION										
ARCHIVES										

DATA TYPES: A – MISSION CONTROL
B – CHECKOUT
C – EXPERIMENT

DATA FORM: D – VOICE
E – VIDEO
F – DIGITAL ANALOG
G – PHYSICAL

TRANSFER MEANS: H – R.F.
J – HARDWARE
K – PHYSICAL TRANSFER

Figure 2-3. Information Transfer Requirements Matrix

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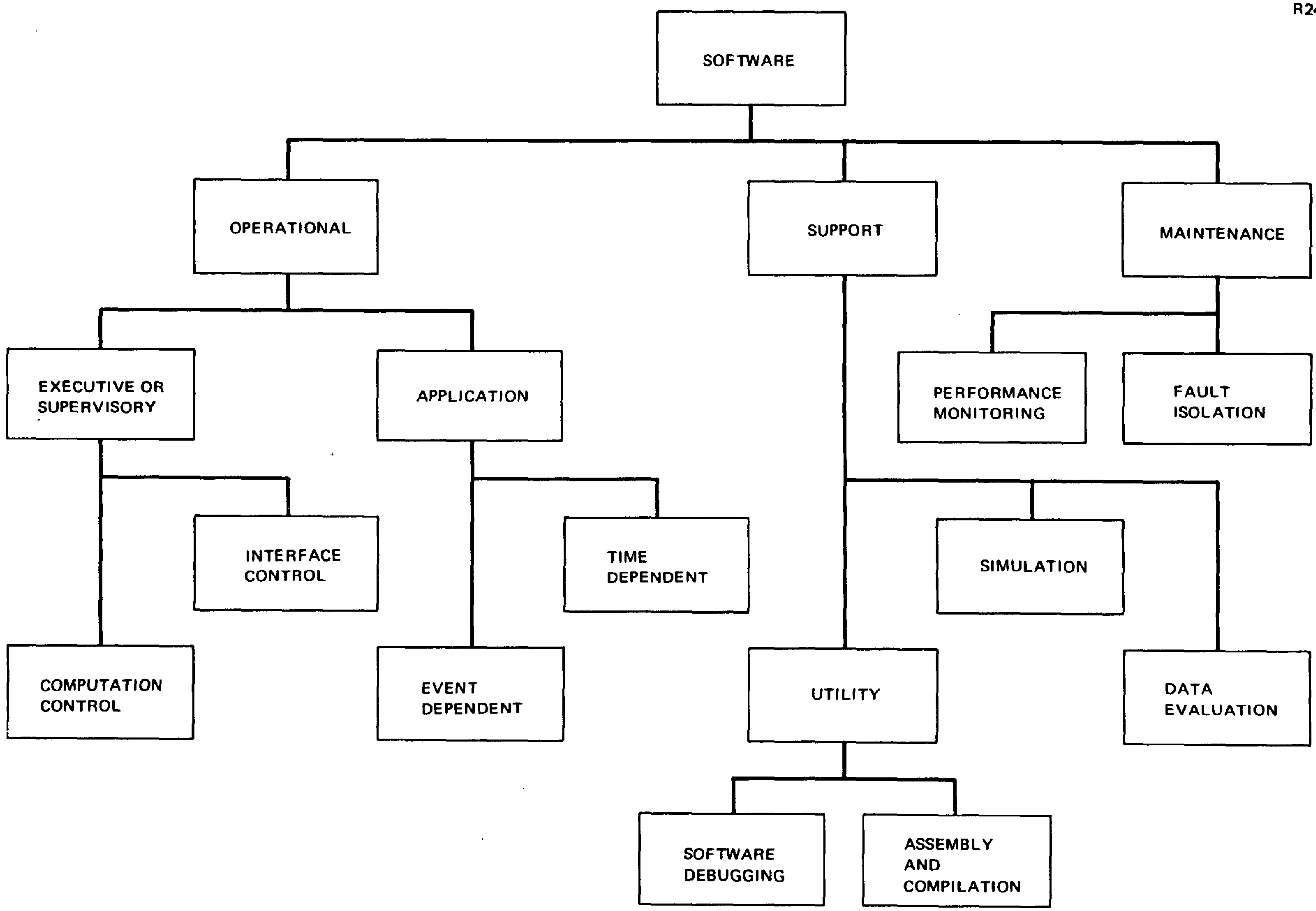

Figure 3-1. Software Structure

the requirements derived for operations, maintenance, and support to the design of the computer program contract end items (CPCEI's). Brief descriptions of the major subdivisions are as follows:

A. Executive or supervisory is software that resides in the computer on a full-time or nearly full-time basis. Different supervisory programs may be loaded when the basic function to be performed by the computer is changed. An example that would exist in the Modular Space Station is the transfer of operational control from the data management operational multiprocessor to the experiment multiprocessor. This could occur in the event of a major malfunction of the operational computer. In this event, the experiment supervisory program would be replaced by the operational supervisory program, and operational processing requirements would revert to the multiprocessor to which experiment processing had been formerly assigned.

   Executive or supervisory software is subdivided into computation control and interface control.

   1. Computation Control—The software maintains control of the computation tools. Internal timing sequence and sensing are maintained, interruptions from external sources and internally operating software are sensed and serviced, priorities are acknowledged, and resources are allocated accordingly. Dynamic reallocation of memory and other control functions not performed by processor hardware are accomplished by this software.

   2. Interface Control—This software provides information formatting and control to facilitate transfer between application software and peripheral hardware. The principal function is to provide common processing software that can be used for a variety of applications rather than to include this interface software with each application.

B. Application programs are programs that perform a particular task, such as rendezvous computations. Generally they are in residence on a transient basis.

C. Utility programs are those used in the preparation of software and include dump and tracer outlines; automated checks for nomenclature, reference, loop closure, and other common programming errors; and the programs necessary to convert data from one language to another.

D. Simulation programs are those that make a nonreal environment look like a real environment. Their applications are numerous, but for software development they can be constructed to substitute for external systems or to exhibit end-item processor characteristics when software is tested in a non-end-item processor.

E. Data evaluation programs include those used for determining the results of an on-line operation in an off-line mode.

F. Performance monitoring programs are those which operate on a continuous basis or on a predetermined (usually periodic) basis.

G. Fault isolation programs are those which perform predetermined fault isolation routines upon some abnormal initiating request. The request can be externally derived (manual or automatic) or internally derived by a performance monitoring program.

Associated with each of these programs will be a grouping of numerical and symbolic data that will be static or dynamic in nature. This grouping of data, which is pertinent to the operation of the computer program, will be called the data base.

Section 4
SOFTWARE DEVELOPMENT SCHEDULE

The Software Integration Plan shall define the schedule for software development in the three areas noted in Section 2 and shall identify the organizations and interfacing activities that will be utilized in the definition of the programs described in Section 2. This schedule shall be in accordance with the overall Space Station Project schedule.

Section 5
SOFTWARE INTEGRATION ACTIVITIES

Activities and supporting documentation required during the design phase are summarized in Table 5-1. It should be noted that each of the three programs identified in Section 2 will define requirements which, in turn, will be allocated to and incorporated in the computer program segment specifications. These segment specifications shall be prepared for definite portions of the total software system and shall contain sets of functionally related requirements. These specifications shall include requirements extracted from the Modular Space Station Program Specification and will be the governing documents for the performance requirements of the computer program contract end items (CPCEI's).

Section 6
DOCUMENTATION REQUIREMENTS

The contractor shall prepare a Software Integration Plan that schedules and defines the activities necessary to develop the documents described in Table 5-1. In the course of this definition, the contractor shall describe in detail the contents of these documents.

Table 5-1

PHASE C DATA REQUIREMENTS

Title	Purpose
Segment Performance Specifications	To specify the overall system-level design and performance requirements applicable to programs operating within a major processing system
Software Development Plan	To define management tasks during Phase D software development activities and to ensure effective management controls of the software effort
Detailed Technical Report—Computer Programs	To determine, justify, and document the technical approach, analyses, and choice of program performance requirements and configuration
	For technical evaluation in selection of contractor
Computer Program Contract End-Item Detail Specification, Part I	To record the design and performance requirements peculiar to the design, development, test, and qualification of a computer program
Software Technical Design Plan	To define technical tasks to be performed during Phase D software development
Detailed Technical Report—Data Processor	To document results of Phase C studies on processor characteristics and operating principles
Software Progress Report	To review status and progress of software studies