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Volume II

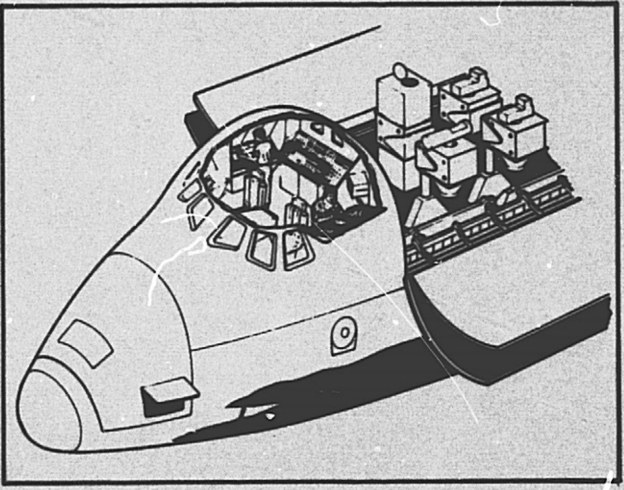
Final Study Report

November 1976

Technical Report

Payload Specialist Station Study

Part III
Program Analysis and Planning for Phase C/D



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TECHNICAL REPORT

PAYLOAD SPECIALIST STATION STUDY

PART III
PROGRAM ANALYSIS AND PLANNING FOR PHASE C/D

Approved

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FOREWORD

PSS PROGRAM ANALYSIS AND PLANNING DOCUMENT

DR-MA-04

This document provides management level visibility of the overall PSS Program as defined during the Martin Marietta Corporation study in conjunction with NASA-MSFC. The document describes the AFD C&D concept resulting from detailed analyses, preliminary design, and trade studies of the Payload Specialist Station C&D design, development, test and engineering, production and integration.

The Program Definition described herein is the basis for our Cost Estimate, DR-MF-003, and meets the requirements of the PSS CEI Specifications and pertinent Interface Requirements Documents. This definition is also in consonance with the Project Ground Rules and Assumptions coordinated with NASA MSFC and provided in DR-MF-003.

Where more detailed rationale for the selection of a particular approach is desired, the PSS Final Report, DR-MA-05, gives a summary of the analyses, trade studies, and design data that are pertinent to selection of that approach. The WBS Dictionary, DR-MA-06, gives a breakout of the tasks to be performed in the DDT&E and production of the PSS Core System, and serves as a baseline statement of work for the program definition presented in this document.

This document is submitted in response to Data Requirement No. MA-04 of Exhibit "A" to Contract NAS8-31789.

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CONTENTS

1.0 PROGRAM ELEMENT SUMMARY

1.1 PSS C&D Concept Definition - The controls and displays (C&D) required at the Orbiter aft-flight deck (AFD) and the "core" C&D required at the Payload Specialist Station (PSS) are identified in this document. The "core" C&D definition resulted from an analysis of a ten-year STS mission profile and represents the C&D required to satisfy the majority of payload functional C&D requirements.

The AFD C&D Concept consists of a multifunction display system (MFDS) and elements of multiuse mission support equipment (MMSE). The MFDS consists of two CRTs, a display electronics unit (DEU), and a keyboard. The MMSE consists of a manual pointing controller (MPC), five-digit numeric displays, 10-character alphanumeric legends, event timers, analog meters, rotary and toggle switches. The MMSE may be hardwired to the experiment, or interface with a data bus at the PSS for signal processing.

The MFDS has video capability, with alphanumeric and graphic overlay features, on one CRT and alphanumeric and graphic (tricolor) capability on a second CRT. The DEU will have the capability to communicate, via redundant data buses, with both the Spacelab experiment and subsystem computers. A capability for simultaneous independent operation, at the PSS and the Mission Specialist Station (MSS), is available for the more complex pallet-only missions; a CRT and keyboard are located at the MSS for experiment setup, data display, and instrument pointing system (IPS) display and commands.

1.2 PSS Equipment Definition - The PSS contractor will be responsible for the "core" C&D hardware, flight software requirements, the "core" software for the multifunction function display system (MFDS) processor, and the ground support equipment (GSE). The flight software requirements will encompass both the MFDS processor and the payload main computer. All functions required to make the "core" C&D hardware a functioning system will be included in this requirements document.

Three articles of equipment will be required in support of the first mission: one development unit, to be refurbished for the software development laboratory (SDL) and payload specialist (PS) training; one qualification unit, to be refurbished to support payload integration; and one flight unit. Two articles of GSE will be required in support of the delivered hardware.

The "core" C&D equipment located at the PSS is as follows: panel L-10, a CRT and full alphanumberic keyboard, including an array of payload dedicated keys; panel L-11, two event timers, a CRT with video capability, a manual pointing control system for fine pointing of experiments, and mission-unique C&D; panel L-12, elements of MMSE. Additional "core" C&D exists at the on-orbit station (OOS) at panel A-7, a series of switches, and at the MSS, panel R-12, a CRT and keyboard similar to L-10. Additional payload dedicated C&D is available at R-7, for Spacelab activation, and at A-6 for payload unique C&D.

1.3 PSS Systems Engineering and Integration - The PSS Contractor will perform systems engineering and integration in support of the AFD C&D concept in the following areas: functional C&D requirements peculiar to a mission; compatibility with Orbiter constraints (volume, weight, wiring interface, power, and thermal); design reviews; the preparation of specifications, ICDs, and a user's handbook.

The PSS Contractor will provide support to the mission contractor to ensure the PSS equipment and mission-unique C&D satisfies the mission functional C&D requirements. The PSS Contractor will provide the PSS C&D portions of the integrated procedures in support of the first mission.

2.0 MANAGEMENT APPROACH

This section of the Payload Specialist Station (PSS) Program Analysis and Planning Document, MA-04, presents Martin Marietta Corporation's Management Plan for MSFC's Phase C/D Design and Development. The plan describes the functions, organization, and systems required to manage and control those activities related to the design, development, and production of a "core" PSS Control and Display (C&D) Concept.

2.1 Purpose - This management plan presents an overall program description, discusses program and project schedules, defines management techniques and establishes requirements for a performance measurement system. This plan, when implemented, will provide for efficient design/development/production and economical PSS C&D operations.

2.1.1 Objective - This plan is specifically designed to provide visibility into management processes and thereby assure that the technical and cost targets are being attained as the program matures.

2.1.2 Guidelines - The guidelines used to develop this plan are the approved program ground rules and assumptions; the coordinated work breakdown structures; and system, subsystem, and programmatic analyses performed during the PSS study.

2.1.3 Scope - The MSFC and MMC management organization and performance measurement system provide timely visibility into contract performance. This approach assures NASA and our internal program management that the cost/schedule and technical performance management processes are sufficient and effective for planning and controlling the contract tasks.

2.1.4 Program Relationships - The MSFC and PSS Contractor design and development activities are influenced by and, in turn, impact activities of other elements of the Payload Integration Process. The PSS acquisition plans and management approach described herein are based on a program structure that includes a PSS Contractor, Mission Contractors and SL Contractor. The PSS Contractor is responsible for design, development, and production of a "core" concept of C&D equipments which satisfies a large percentage of payload requirements in the 1980's. The PSS Contractor will also provide flight software requirements, core C&D software for the MFDS electronics unit processor, GSE and associated ground test software. The PSS Contractor will interface with both the Spacelab and the mission contractors in the development and verification of flight software and payload integration. The PSS Contractor interfaces with the user community for payload unique C&D equipment, C&D requirements, and the interrelation of program elements shown in Figure 2.1-1.

A second program acquisition concept that underlies this plan is a two-phased development of the core PSS equipment. The PSS Phase I encompasses the total system design and development and the production of PSS C&D equipments required for the SL-2 STS mission. Phase II of the PSS acquisition provides the production of the remaining C&D MMSE equipment to complete the core system concept. This acquisition process is illustrated in Figure 2.1-2. Software development relative to C&D equipment is shown in Figure 2.1-3.

2.2 Program Definition and Schedules

2.2.1 Program Definition - The PSS Contractor effort encompasses hardware/software elements that must be integrated with various NASA and related contractor organizations to meet key milestones, tests, decision points, interfaces, and hardware deliveries. The functional elements of the PSS core development are shown in the Work Breakdown Structure (WBS), Table 2.2-1. The WBS is the basic planning structure, providing the framework for development of program schedule(s), cost, and the performance control system.

2.2.2 Schedules - The program, project, development, and major element schedules and applicable logic networks, subdivided and keyed to the Work Breakdown Structure (WBS), are portrayed in this section. The schedules provide the basic time phasing tools required by MSFC, Martin Marietta, and other program participants. These schedules provide the basis for implementation and/or further delineation for Phase C/D program planning and control functions.

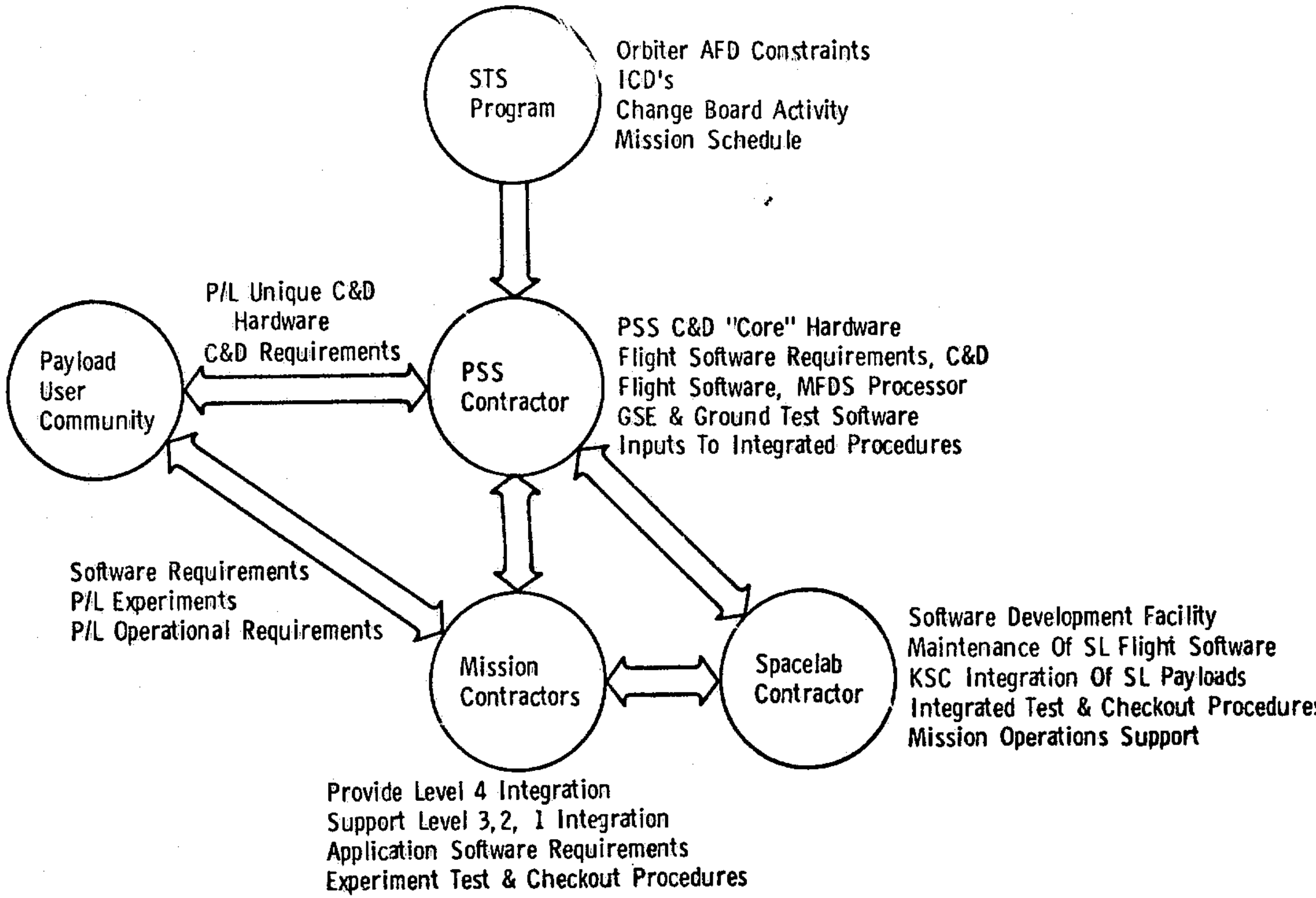
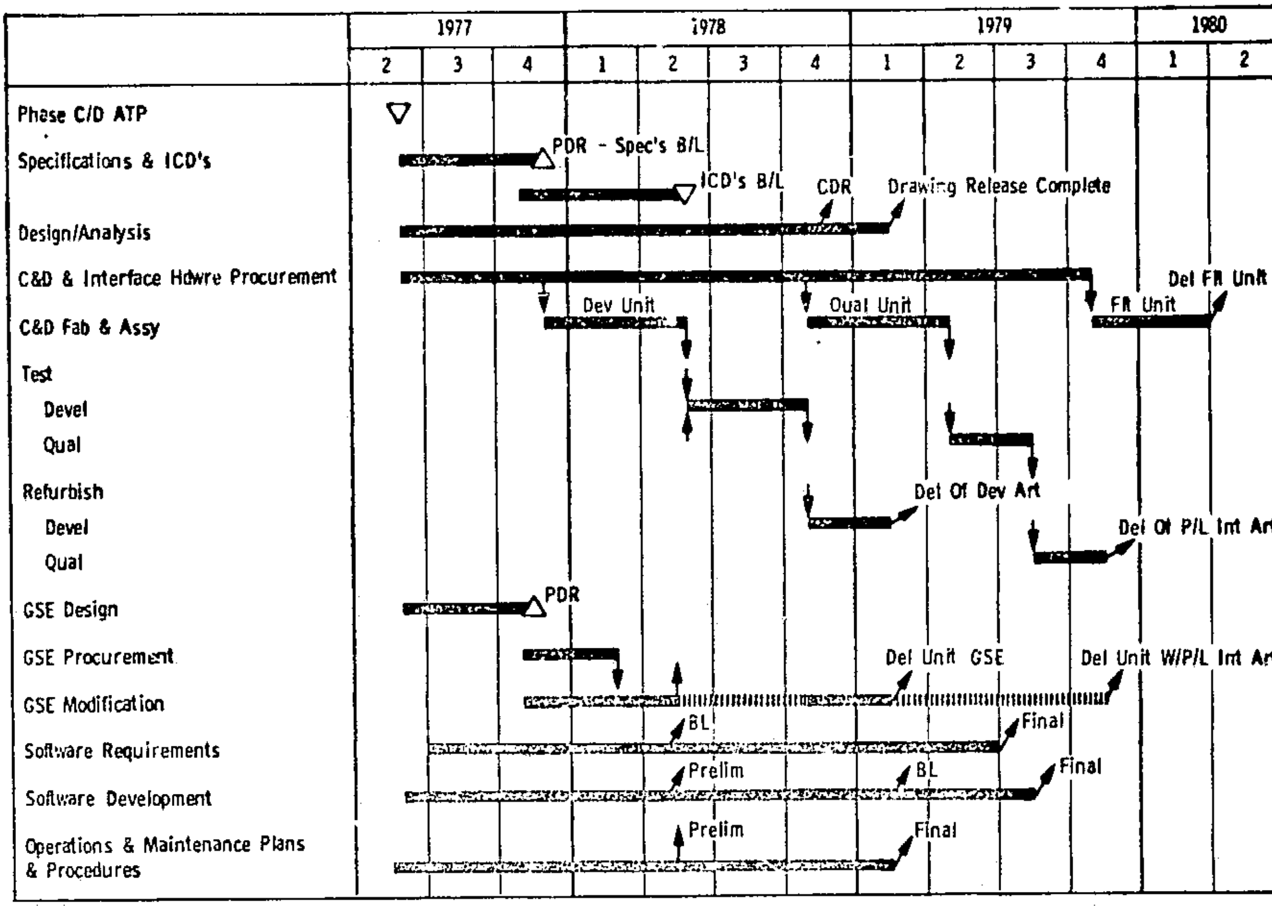
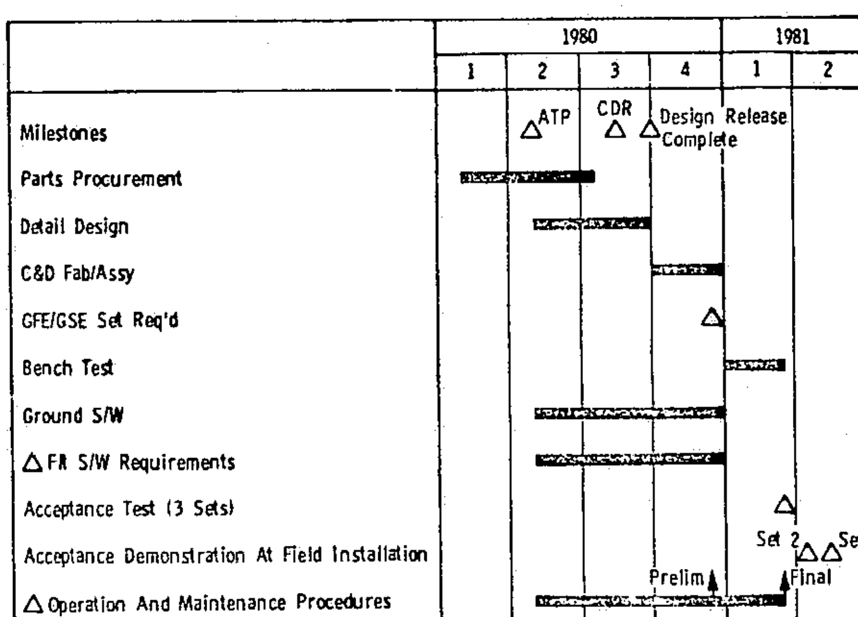


Figure 2.1-1 Contractor Structure for PSS Programs



A) Phase I



B) Phase II

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Figure 2.1-2 PSS Schedule

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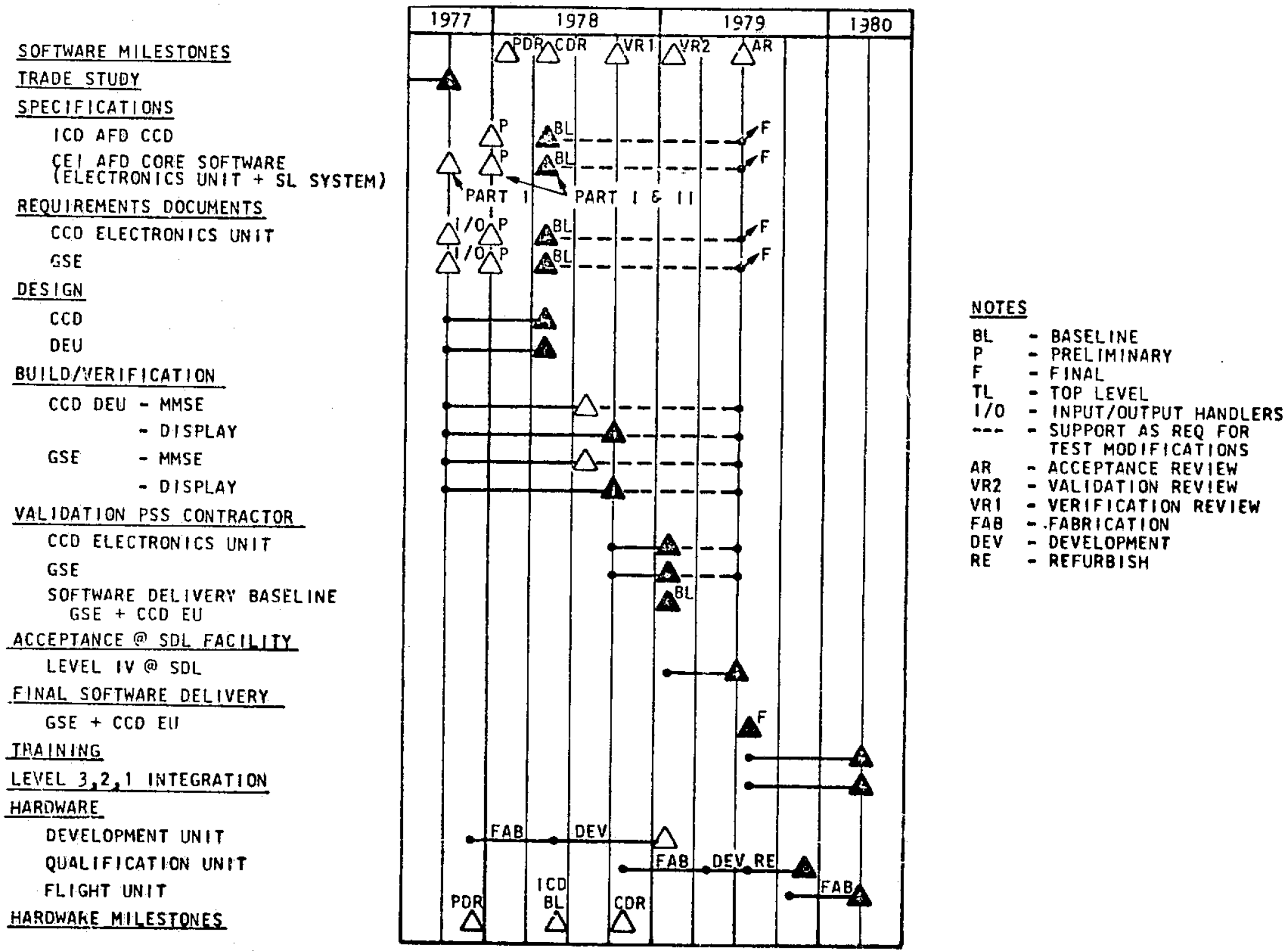

Figure 2.1-3 Detailed Software Development Schedule

TABLE 2.2-1 PSS CONTRACTOR WBS

MAJOR ELEMENTS		SUB ELEMENTS	
01	Project Management	01 01	Project Administration
		01 02	Project Planning and Control
		01 03	Data Management
		01 04	Procurement Management
		01 05	Configuration Management
		01 06	GFE Management
02	Systems Engineering and Integration	02 01	Mission Analysis and Requirements
		02 02	System Analysis, Design, and Integration
		02 03	Specification and ICDs
03	Control and Display Equipment Design and Development (including Test Hardware other than Flight Hardware)	03 01	Structures and Mechanical
		03 02	Controls and Displays
		03 03	Electronics
		03 04	Electrical Power, Control and Distribution
		03 05	Thermal Control
04	Control and Display Equipment Manufacturing (Flight Hardware)	04 01	Structures and Mechanical
		04 02	Controls and Displays
		04 03	Electronics
		04 04	System Assembly, Integration and Checkout
05	GSE and STE D&D	05 01	Electrical
		05 02	Mechanical
06	GSE and STE Hardware Manufacturing	06 01	Electrical
07	Software Development	07 01	Flight Software Requirements
		07 02	Flight Software for MDFS Processor
		07 03	Ground Test Software
08	Product Assurance	08 01	Quality and Reliability
		08 02	Safety
		08 03	Parts, Materials, and Processes
09	System Test	09 01	System Test Requirements
		09 02	System Test Operations (Development Only)
		09 03	System Test Verification
10	Ground Operations Support	10 01	PSS C/D Integration and Verification
		10 02	Logistics
		10 03	Maintenance & Refurbishment

2.2.3 Schedule Description and Discussion

2.2.3.1 Program Description Highlights - Highlights of the program schedules are summarized as follows:

1) Activities are time phased to control fiscal-year funding.
2) Maximum use is made of existing STS-qualified MMSE to minimize cost/schedule uncertainty and reduce overall program risk.
3) Task management is clearly defined to insure performance accountability.
4) Sufficient schedule margin is available to accommodate program uncertainties and/or achieve desired cost tradeoffs.

2.2.3.2 Time-Phased Activities - Activities have been subdivided into two time-phased periods. The highlights of those periods are described in the following paragraphs.

Phase I, Initial PSS Core Capability - During this phase the following activities occur:

1) The PSS "core" system (MFDS and elements of MMSE) is designed, developed and tested in a 34-month period. The effort includes development of all specifications, ICDs and drawings to define the "core" PSS design.
2) The systems engineering and integration will be performed to ensure that the PSS design is compatible with all pertinent STS design requirements.
3) Required qualification testing and analysis will be performed to ensure the PSS "core" design meets STS environmental requirements.
4) GSE and associated ground test software will be developed.
5) Flight software requirements for both the MFDS processor and the payload computer will be developed. This will allow the Spacelab contractor to develop the flight software to support the AFD C&D and the mission contractor to supply the payload application software requirements.

6) Flight software for the MFDS processor will be developed.

7) Procurement will be made of a portion of the MFDS hardware needed for the PSS in support of early missions.

8) PSS "core" hardware will be fabricated for the first PSS mission. This includes: panels L-10, L-11, L12-A1, and A-7. This configuration includes the MFDS and that portion of the MMSE C&D equipment required for the first mission. Phase I equipment does not require a Spacelab RAU interface at the PSS. In this phase the delivered PSS equipment includes: one PSS C&D software development unit, one PSS payload integration article, one flight article, critical component spares, and two sets of GSE.

Phase II, Complete PSS Core Capability - During this phase the following activities occur:

1) The detailed design drawings for the remaining portions of panels L-11, L-12 will be developed and released in a 12-month period.

2) The additional quantities of MMSE and interfacing hardware will be procured; the additional capability provided requires a Spacelab experiment RAU at the PSS.

3) The additional L-12 subpanels will be built and tested.

4) Delta "core" software requirements will be defined for the additional MMSE equipment on panel L-12. New software programs will be developed and delivered for the MFDS processor and GSE processor which include the additional MMSE requirements.

5) The new subpanels will be acceptance tested at the factory, delivered and installed, and tested as a part of the PSS C&D development unit, the PSS P/L integration article, and the flight article.

2.2.3.3 Derivation and Description - The various element schedules and related logic networks were derived and developed using programmatic analyses, logic, and functional flows. These schedules are presented as Figures 2.2-1, 2.2.-2, and 2.2-3. They are structured to use the WBS as the common denominator, and are generally divided into subdivisions of work; i.e., engineering, procurement, manufacturing, and test. This approach provides management-level visibility for correlation with the subdivisions

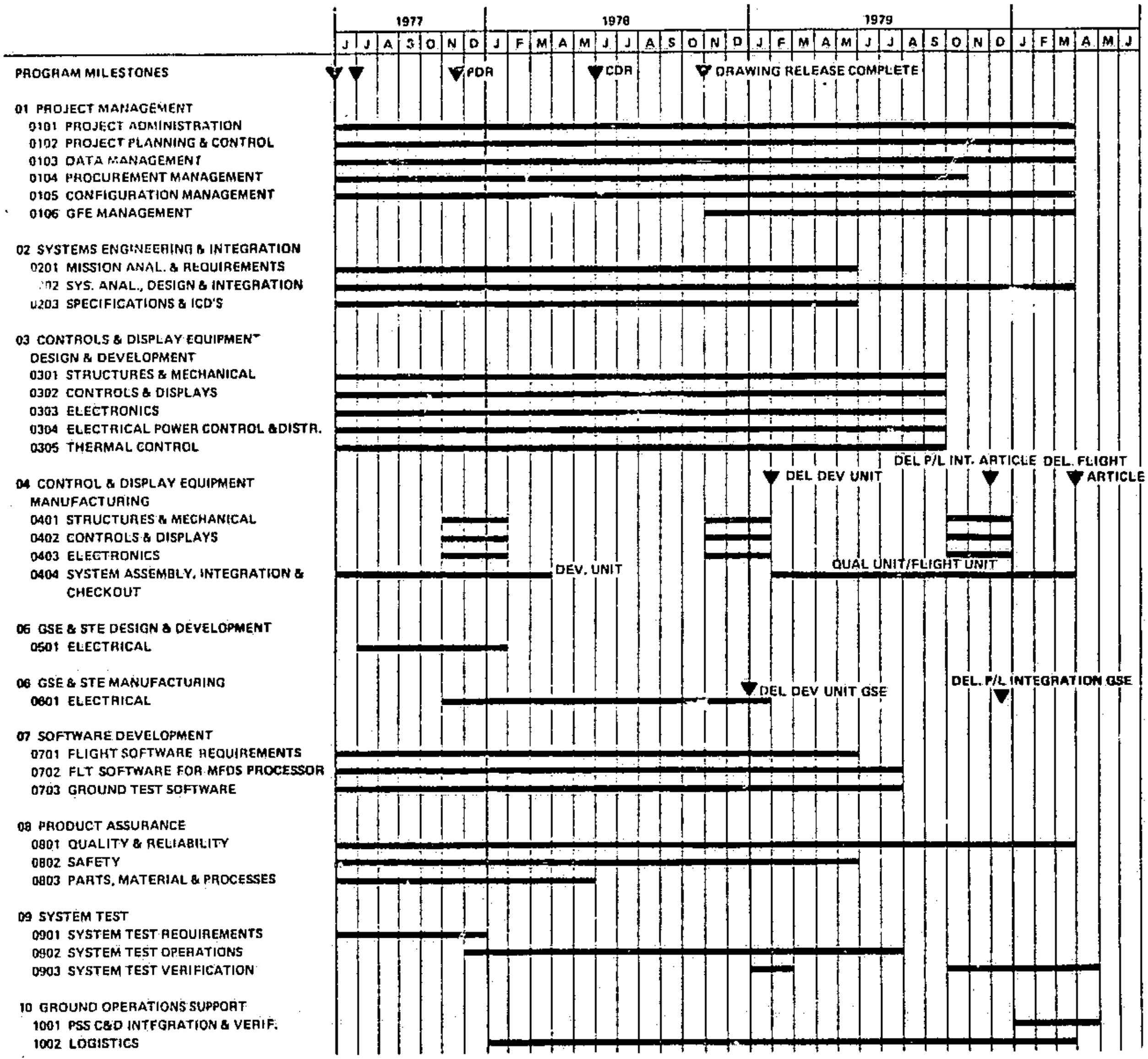

Figure 2.2-1 Phase 1 Master Schedule

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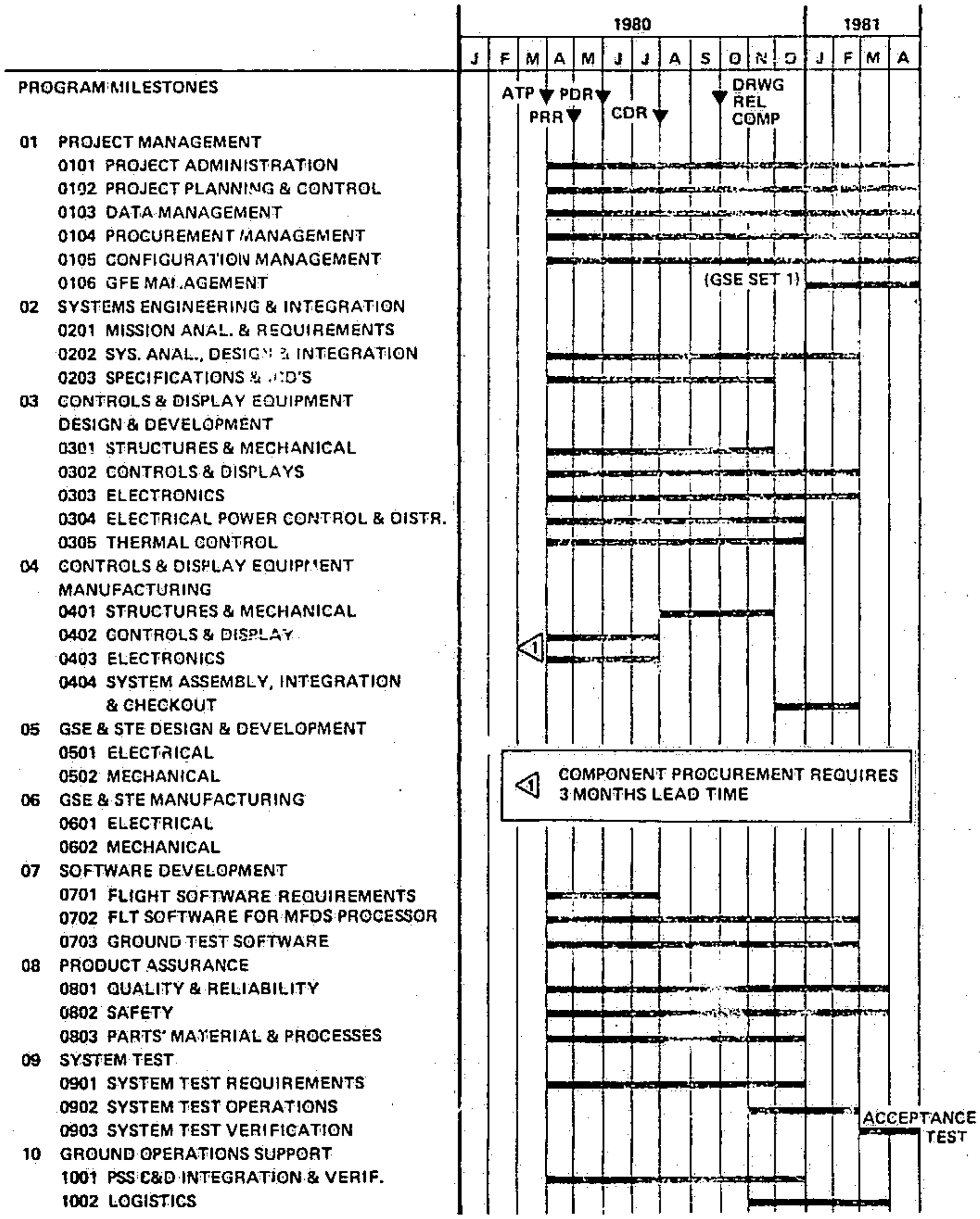

Figure 2.2-2 Phase II Master Schedule

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of work and the elements of costs contained in our Cost Estimate Document, DR MF-003S.

The time phasing of the Payload Specialist Station program depicted permits the orderly development of the required technologies within the program constraints of technical requirements and cost targets.

2.3 Program Management

2.3.1 Organization - The PSS management challenge is to provide a core C&D system that meets the needs of a large percentage of STS payloads at projected costs. To meet this challenge we have structured our PSS project organization to provide direct management participation. Our organizational approach features direct lines of communications of the highest levels of our corporate and division management. We have assigned the disciplines and committed the resources required for effective management and control. The program team selected by the Program Director has the required C&D, systems and NASA contract experience. This team is collocated in a dedicated area and operates under a task-oriented concept designed to augment a low-cost development approach.

The Martin Marietta Corporation recognizes the role of the PSS program as a major element in the NASA Shuttle Payloads plan. The PSS Manager will report to the Director of NASA Business who reports directly to the Vice President and General Manager of the Denver Division (Figure 2.3-1). The Vice President and General Manager is closely involved in the overview of the PSS program activities. He will continually evaluate the technical and cost/schedule performance as the program advances through its development. He will provide executive-level assistance to the Program Director in obtaining support from the Denver Division and other corporate resources.

2.3.1.1 Payload Specialist Station Program Organization - Our program organization has been structured to emphasize task management and preclude responsibility/accountability handoff. The program organization shown in Figure 2.3-2 has short lines of communication and clearly defined areas of responsibility.

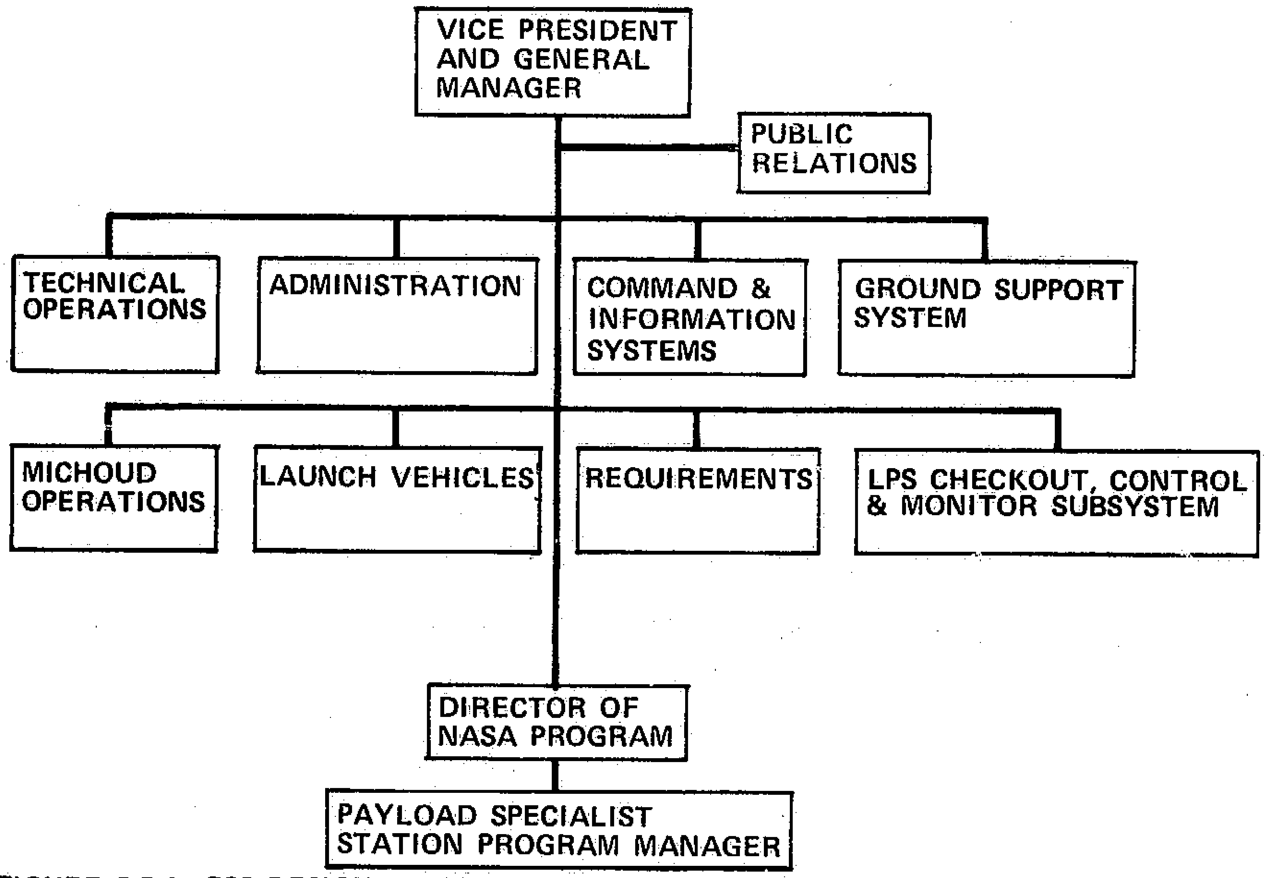

FIGURE 2.3-1 PSS DESIGN & DEVELOPMENT WILL RECEIVE HIGH LEVEL MANAGEMENT ATTENTION

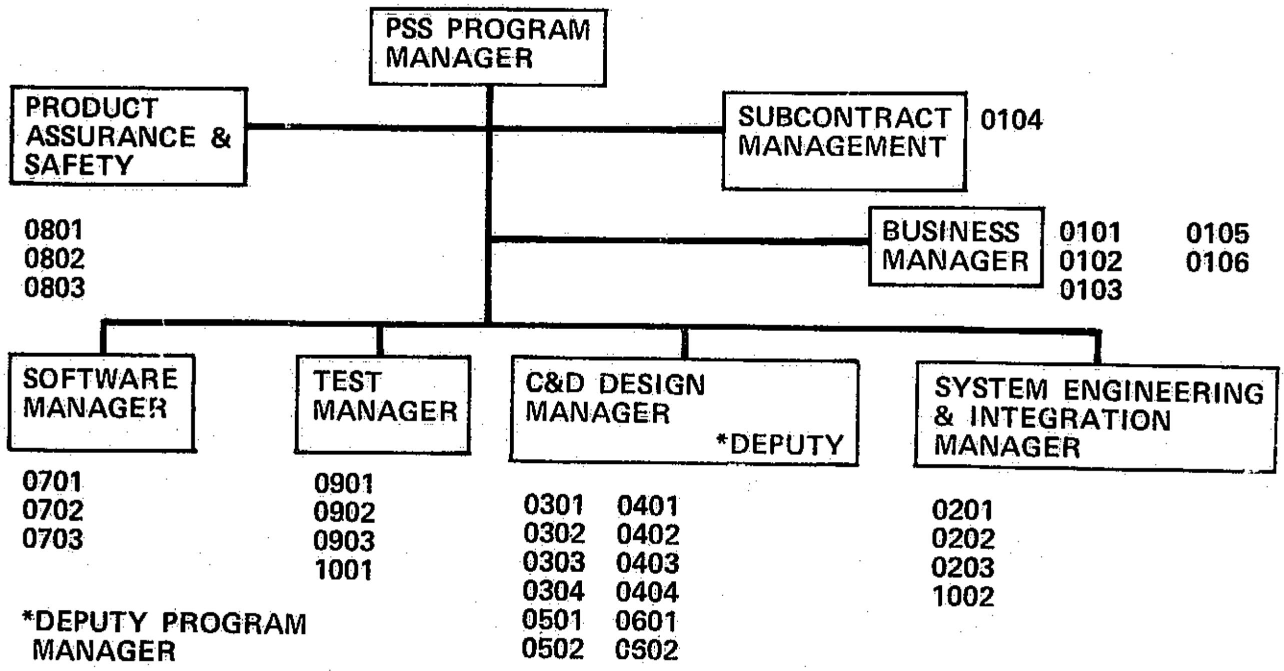

FIGURE 2.3-2 PAYLOAD SPECIALIST STATION ORGANIZATION

Program Manager - The PSS Program Manager is responsible to the Director of NASA Business for the management and direction of all Martin Marietta activities related to the Payload Specialist Station program. He is responsible for meeting the program technical, schedule, and cost goals and has full authority to represent and contractually commit the corporation in all matters dealing with fulfillment of contract obligations.

Subcontractor Manager - The Subcontract Manager will report directly to the PSS Program Manager. He will be responsible for major subcontracts for the CRT and keyboard elements.

Product Assurance Manager - The Product Assurance Manager is responsible for establishing and maintaining effective quality assurance, reliability, and safety programs across all elements of the Phase C/D activities. These tasks include reviews to assure the incorporation of quality and safety requirements in the design selection and fabrication of materials, components, subassemblies, final assemblies, acceptance test reviews, and final approval and acceptance of all delivered hardware for the Martin Marietta Corporation. He is also responsible for the program activities related to calibration and failure analysis, production support and the identification, tracking and status of engineering and hardware discrepancies, and the development of program product assurance procedures and controls.

Business Management - The Business Management staff consists of those activities related to contract management.

Contract Administration - Responsible for negotiation and administration of the PSS contract and all changes thereto; preparation and control of the work authorization operation directives, operation of the change management program, configuration accounting, control of documentation, and primary accountability of GFE.

Planning and Cost Management - Responsible for development and implementation of program-level schedules, approving all supporting-level schedules, and monitoring and evaluation of program schedule performance. Responsible for implementation of the performance measurement system; issuance, updating, and monitoring of program budgets; maintaining financial accounting systems; and providing financial status, analysis, and reports for Martin Marietta and NASA management.

Materiel Management - Responsible for the acquisition of required materials, components, and assemblies within the cost and schedule constraints of the program. Under the direction of the cognizant task manager, the Materiel Manager processes, controls, and provides status on all procured or acquired items including GFE and spares; the buying operations; and inventory management including the receiving of all procured and subcontract material items, GFE, spares, and warehousing of received components and commodities.

Task Managers - The Task Managers for software and C&D design are charged with the total responsibility of design, development, qualification, and fabrication of the PSS hardware and software. These task managers have total budget authority and are held responsible for the technical performance of their PSS components. Each Task Manager will be provided with a statement of work, within the framework of the contract, represented by the WBS element for which he is responsible. The Task Manager will also receive cost targets and technical performance goals against which he will be evaluated.

The C&D Design Manager - This Manager has overall responsibility for the detail design and development of the PSS core hardware and the GSE required for checkout and verification. He will direct and control all required engineering disciplines and in addition will act as the Deputy Program Director. He will be given a definitive statement of work, budget and milestone schedule to measure work accomplishment.

The Software Manager - The Software Manager will be responsible for the development of flight software requirements for the MFDS processor and the payload computer. This will allow the mission contractor to develop the mission-unique application software requirements for the payload computer, and the PS contractor to develop the flight C&D software for the MFDS processor. He will also be charged with developing ground test software for use in checkout and verification testing of the core C&D hardware in conjunction with the GSE. This manager will be provided a statement of work, budget allocation and schedule milestones for the control and evaluation of his performance.

The System Test Manager - The System Test Manager is responsible for developing integrated test requirements for the PSS system, planning and conducting development testing to support design and planning, and conducting systems test verification at Martin Marietta. Our delivery acceptance plan calls for integration and verification testing at MSFC and KSC with the payload and the System Test Manager will be responsible for planning and providing this support. The Test Manager will have a statement of work, cost targets, and schedule milestones against which his performance will be evaluated.

The Systems Engineering and Integration Manager - This manager has responsibility for engineering and integration activities to ensure the PSS core system design meets all performance and design requirements and that the design is compatible with all STS requirements and constraints. This manager will be responsible for definition and control of requirements, weight management, compatibility analyses, reviews, specifications and ICDs. He will be given a definitive statement of work, budget allocation and milestones for performance evaluation.

This task-oriented manager concept, with the functional and service organizations reporting directly to the Task Managers, provides management visibility, personal accountability, and motivation.

2.3.2 Performance Management - The performance management system will measure and control planned vs actual cost/schedule/technical performance. This system will integrate work authorization, scheduling, budgeting, cost accumulation, performance measurement, management reporting and analysis, and customer reporting through the work breakdown structure and the organization structure.

2.3.2.1 WBS Accountability - Responsibility for major WBS elements have been assigned to individual Task Managers as shown in Figure 2.3-2. This assignment includes work scope, schedule performance, budget and

and cost control, variance analysis, and corrective action. The basis for implementing this effort is task work packages and level-of-effort work packages for every WBS element.

2.3.2.2 Program Work Authorization - All work to be performed on the program will be initiated through Operations Directives (ODs). Each directive will be reviewed and approved by the Program Director. These ODs will define the authorized work, identify the manager or managers responsible for implementation, describe technical requirements, establish cost targets, authorize distributed budgets, and direct schedule requirements.

2.3.2.3 Planning and Scheduling - Proved planning techniques will be applied to integrate program elements to produce a master schedule and WBS element schedules. From the WBS element schedules, the Task Managers will direct that detailed working schedules be developed for each functional department; i.e., engineering, manufacturing, etc. Special emphasis will be placed on management of subcontracted effort. Our plan is to maximize use of previously qualified and residual hardware from other programs that meet our requirements.

There will be program control milestones for each WBS work package. Schedule statusing and milestone tracking will be correlated with WBS schedules to show progress by each WBS element. The cost aspects of the system will be integrated with schedule and technical requirements so that the impact of any changes will be visible on the total performance baseline.

2.3.2.4 Budgeting - The contract cost agreement established during contract negotiations will become the budget baseline. The Program Director will extract a management reserve that will be held as a separately identified class of funds. The status of this reserve, controlled at the appropriate contract level, will be visible to MSFC. Planning and Cost Management is responsible to administer the management reserve and to maintain records that provide traceability to the use of such funds. Formal allocations of funds from these accounts will be made only at the direction of the Program Director.

The balance of contract cost remaining after the establishment of the management reserve is the program's performance measurement baseline. This baseline is subdivided and allocated to designated control-level WBS elements as cost accounts, and to the functional organizations responsible for performing the work defined in the contract statement of work, under the direction and control of the WBS Task Manager. Planning and Cost Management establishes and applies controls to assure that the sum of the allocated budgets (including authorized changes plus management reserve) equals the original contract budget baseline plus authorized changes.

2.3.2.5 Cost Management - The WBS Task Managers have the responsibility for accomplishing task efforts, within the established cost target, for assigned WBS elements. The steps that will be used to manage cost performance to cost targets are shown in Figures 2.3-3 and 2.3-4.

Actual manpower will be tracked on a weekly basis. This manpower report showing plan, actual and variance will be provided to the Program Director and his managers on a weekly basis. An analysis of all WBS costs will be made against the budget values on a monthly basis. Included will be labor dollars, material commitments, other direct charges and overhead. Variances will be identified and brought to the attention of the Program Director and his Managers.

The cost accounting system will also provide the data required for NASA forms 533M and 533Q Financial Management reports.

2.3.2.6 Performance Measurement and Analysis - Performance measurement and analysis of schedule and cost data will be the responsibility of the Business Management group in direct support of the Program Director and his Managers.

Performance measurement will be made at designated levels of the WBS, where schedules, time-phased resource plans, and actual costs are integrated.

Schedule performance will be measured each week by comparing actual or promised completion dates to planned schedule dates. A determination will be made of the scheduled work accomplished.

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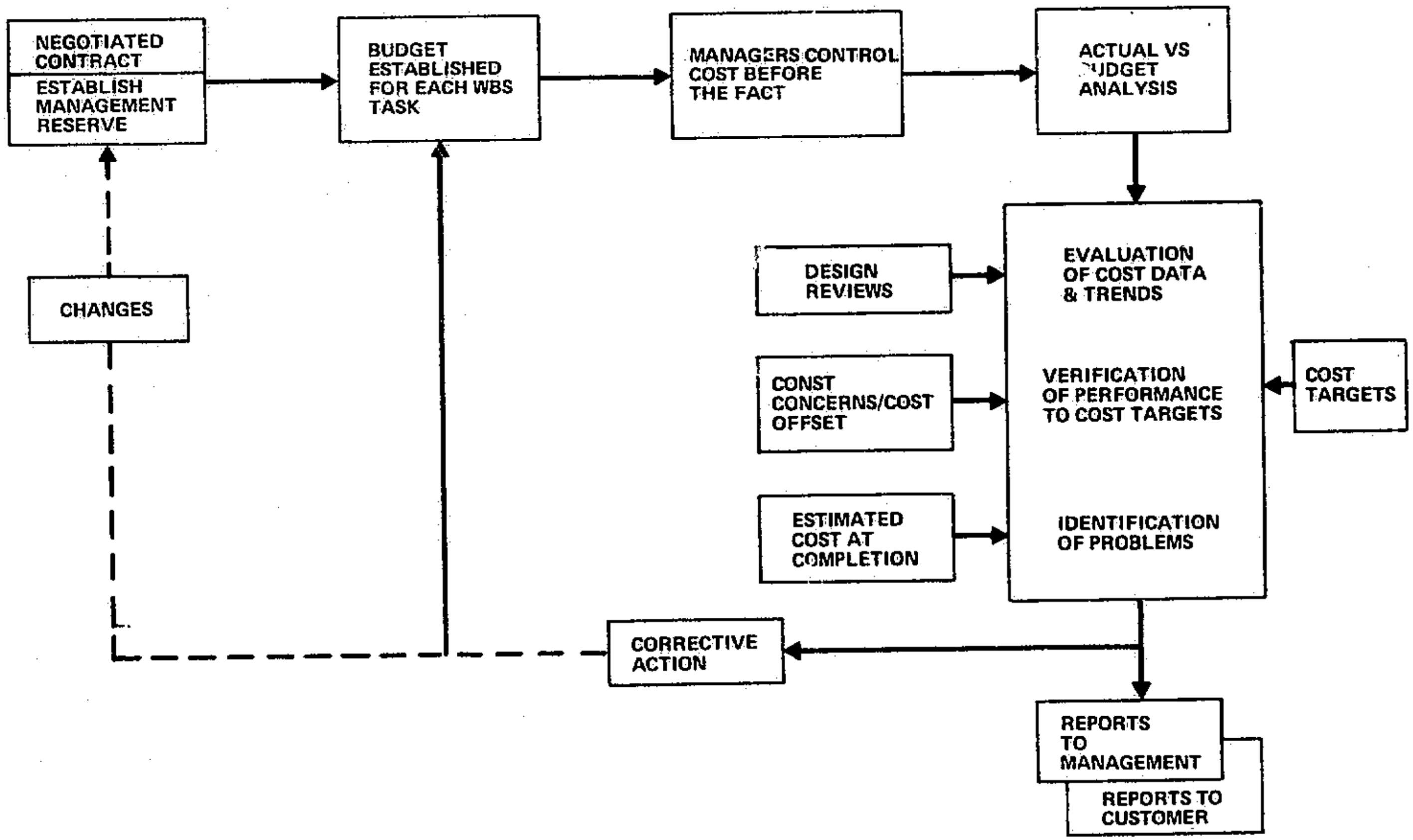

FIGURE 2.3-3 CONTROL TO COST TARGETS

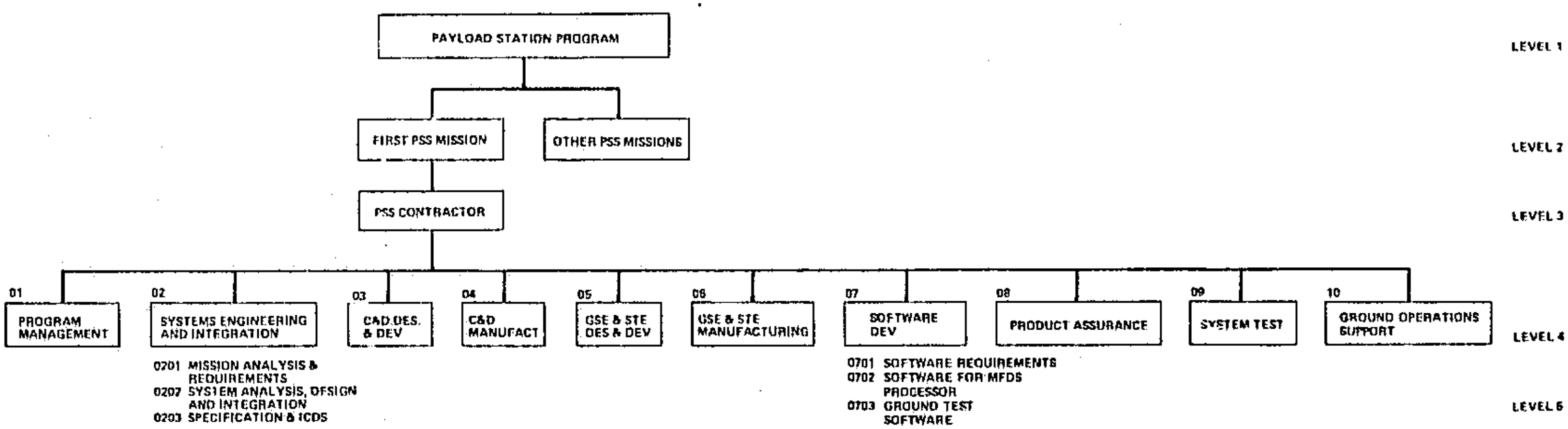

Figure 2.3-4 Cost Targets for WBS Elements at Levels 3, 4 and 5

Cost performance will be measured each week by comparing actual manpower costs to the planned value of work scheduled (budget plan). See Figure 2.3-7 for an example of a format to be used. This example is recommended because it represents a return to basics. For any cost/schedule performance criterion, the question that must be answered is, "If the money is X% spent, is the job X% complete?". For Earned-Value or Planned-Value-of-Work-Accomplished, many tabular/bar/curve techniques have come and gone, but none offer the straightforward simplicity of combined milestone/time/dollar charts.

The format in Figure 2.3-5 is for 0404 System Assembly, Integration and Checkout. A deviation to the planned spending curve becomes apparent as both a function of time and as a function of milestone completion. Any replan of the curve will be documented in the change block, as will any change in milestone dates. At all times this element of program cost will be under surveillance, the estimated final cost of the element will be known, schedule changes will be apparent, and any adjustments from beginning to completion will be presented in the change block.

It is recommended that these element curves be used for each fifth level WBS element. These would be in addition to the 533M and 533Q reports, and would be accompanied by an explanation of any deviations with recommended corrective action or cost-concern/cost-effect activity.

Our performance management is keyed to the WBS Task Managers. They are assigned the responsibility and necessary resources, and are held accountable for performance (Figure 2.3.6).

The Program Director will hold weekly and monthly status meetings with his Managers and staff to review cost/schedule/technical performance. The monthly review will be in greater depth and detail than the weekly status reviews. NASA is invited to attend these meetings.

The Program Manager will use a cost-concern/cost-offset system. This is a discipline to identify potential cost problems and cost savings, so that total program impact can be assessed and evaluated. A cost concern is initiated if a potential cost overrun is identified.

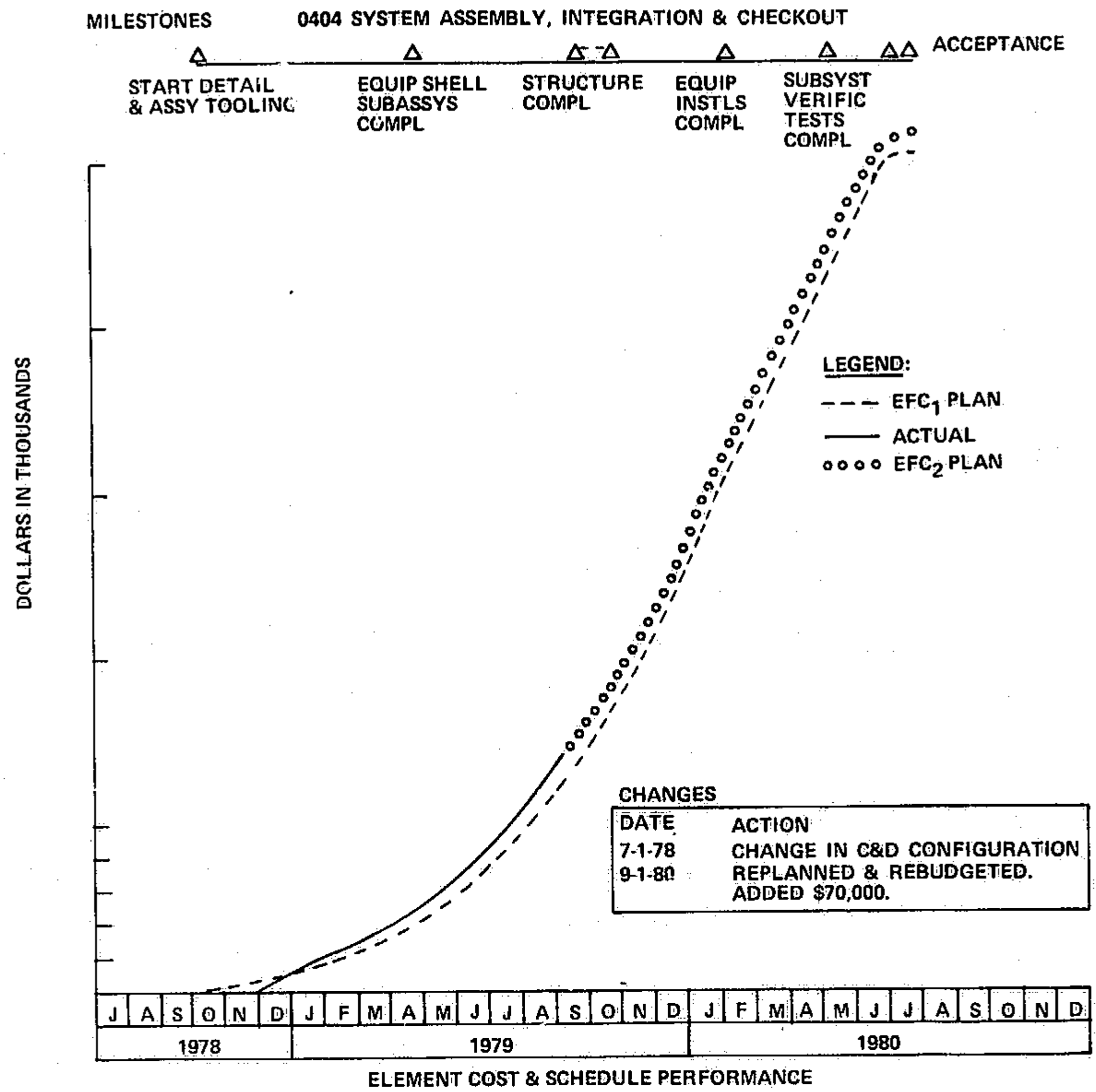

FIGURE 2.3-5 SAMPLE COST PERFORMANCE REPORT FORMAT

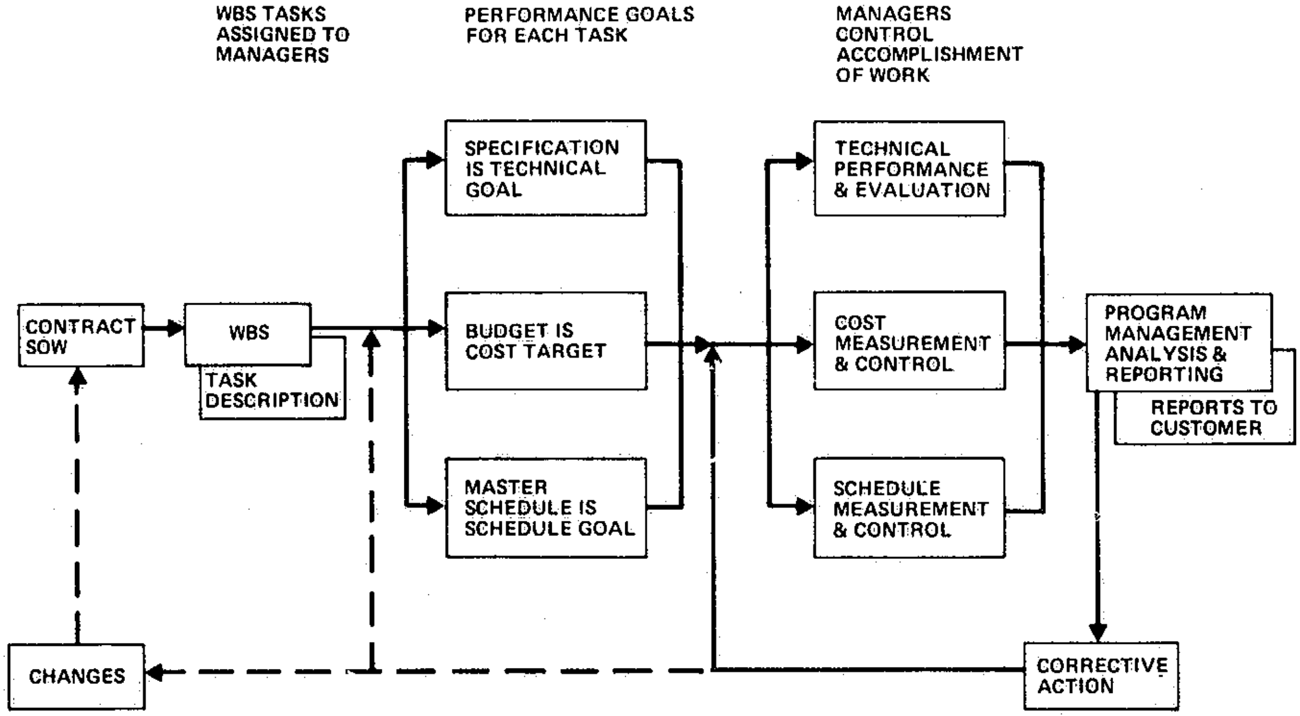

FIGURE 2.3-' PERFORMANCE MANAGEMENT IS KEYED TO INDIVIDUALS

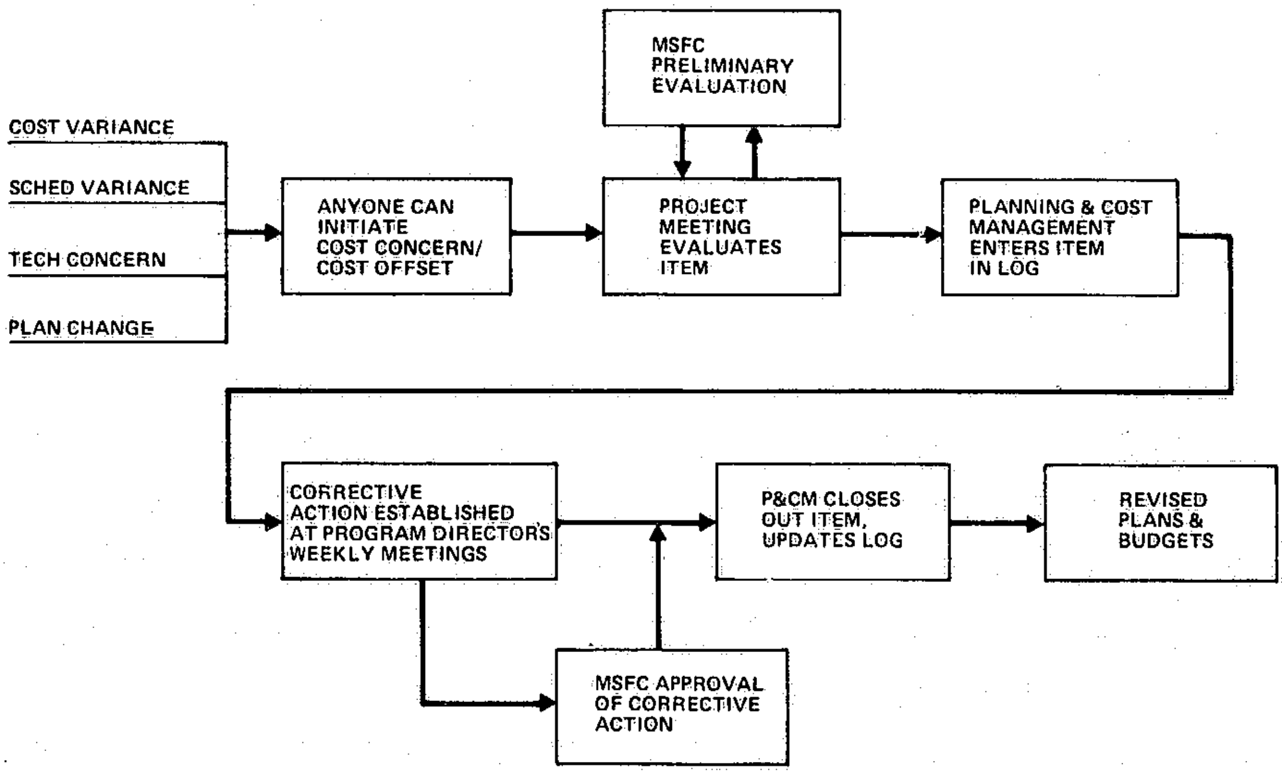

FIGURE 2.3-7 COST CONCERN/COST OFFSET

The system is outlined in Figure 2.3-7. The Program Director will hold a weekly meeting with his Managers and management staff to review new cost-concern/cost-offsets that have been submitted and to assess action items on those that are already in work.

The PSS system is relatively uncomplex and, therefore, no complex technical performance system is justified. The critical parameters for this C&D equipment are the wiring interface, weight, and power. These will be monitored by Systems Engineering and comparisons of current estimates and budget allocations will be provided to the Program Manager on a monthly basis.

2.4 Configuration and Data Management

2.4.1 Requirements and Functions - Configuration management will provide the control of technical requirements which define the products to be delivered.

The following functions will be performed as detailed in subsequent paragraphs:

a) Configuration Identification and Accounting

b) Baseline Management and Design Reviews

c) Configuration Control

d) Documentation Management

The Configuration Management relationship to the program and the CM functions are shown in Figure 2.4.1

2.4.2 Configuration Identification and Accounting - Configuration identification for the PSS will be established at the CEI level in the form of technical documentation. Initially, the CEI specification will define the performance and design requirements for the design and development of the PSS C&D equipment. Engineering drawings and software requirements will then be developed which establish the design and build requirements. The engineering drawings will incorporate interface requirements defined in Interface Control Documents (ICDs) which will reflect agreements between interfacing elements.

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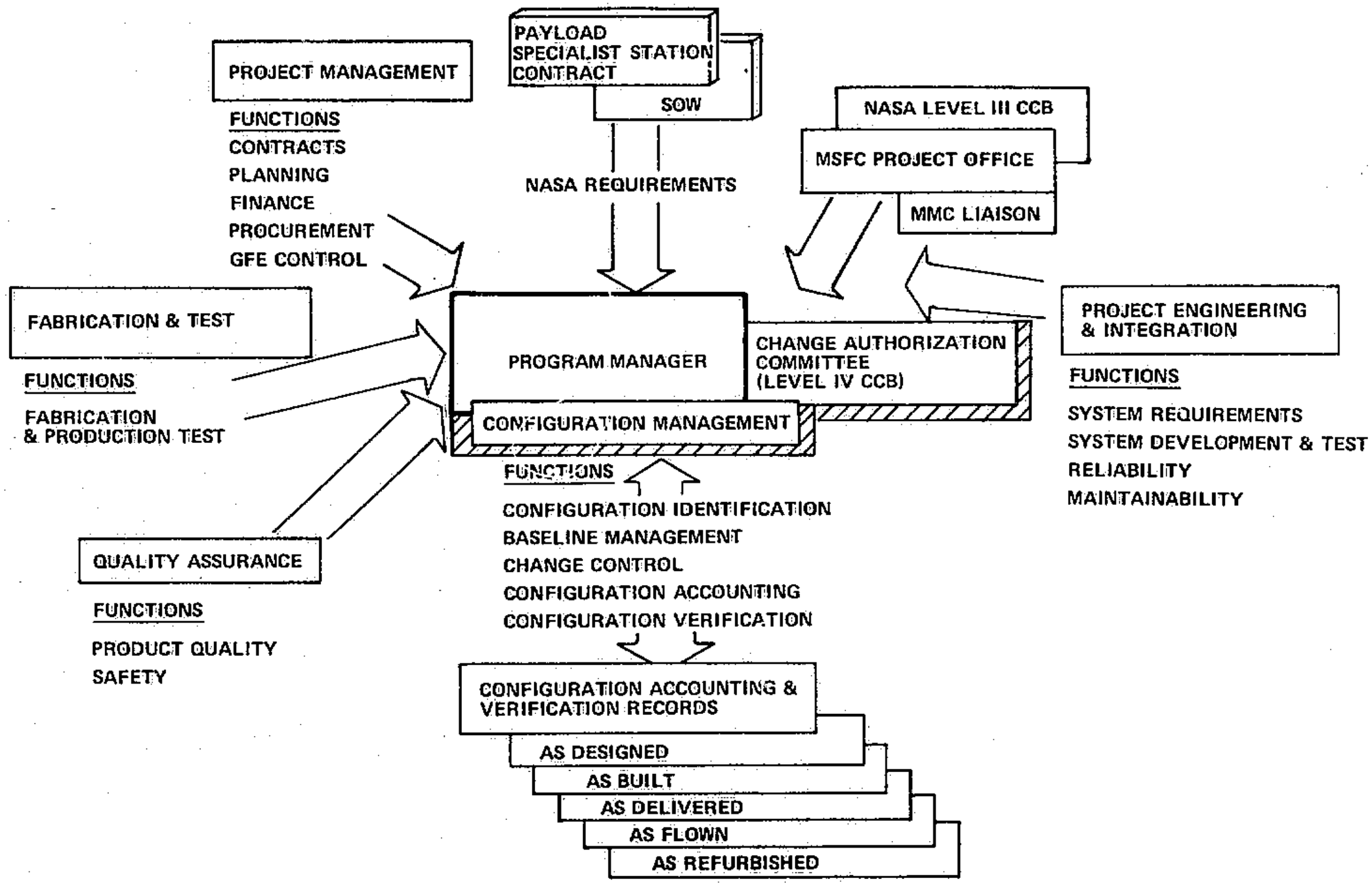

FIGURE 2.4-1 CONFIGURATION MANAGEMENT FUNCTIONS AND PROGRAM RELATIONSHIPS

An on-program engineering release system will be established that will develop and maintain a record and change status of all released engineering. The release system will provide a single point of release and a formal procedure for assigning and controlling document numbers, verifying release requirements, effectivity and approval signatures, and recording and transmitting documentation required to support fabrication and test.

PSS configuration accounting to maintain, store and correlate configuration documentation status will be developed to define the "as-designed", "as-built", "as-qualified", "as-flown", and "as-refurbished" configuration accounting data.

The accounting system will be compatible with the MSFC SCIT (standard change integration and tracking) and CMA (configuration management accounting) systems.

2.4.3 Baseline Management and Design Reviews - Approval of technical and program documentation resulting from scheduled reviews will serve to establish hardware and software baselines. The design reviews will be conducted to assure that the evolving design implements the technical requirements.

The PSS design reviews will be as follows:

1) Preliminary Design Review (PDR) establishing the design requirements baseline.
2) Critical Design Review (CDR) establishing the released design baseline.
3) Configuration Inspection (CI) establishing the product configuration baseline.

2.4.4 Configuration Control - Configuration control will be established to assure a systematic evaluation, coordination and disposition of proposed changes to established baselines and requirements. PSS configuration control will be accomplished through a contractor Configuration Control Board (CCB). The control board will assess the total impact of all changes and submit Class I changes to MSFC for approval. The change flow for contractor changes is shown in Figure 2.4-2.

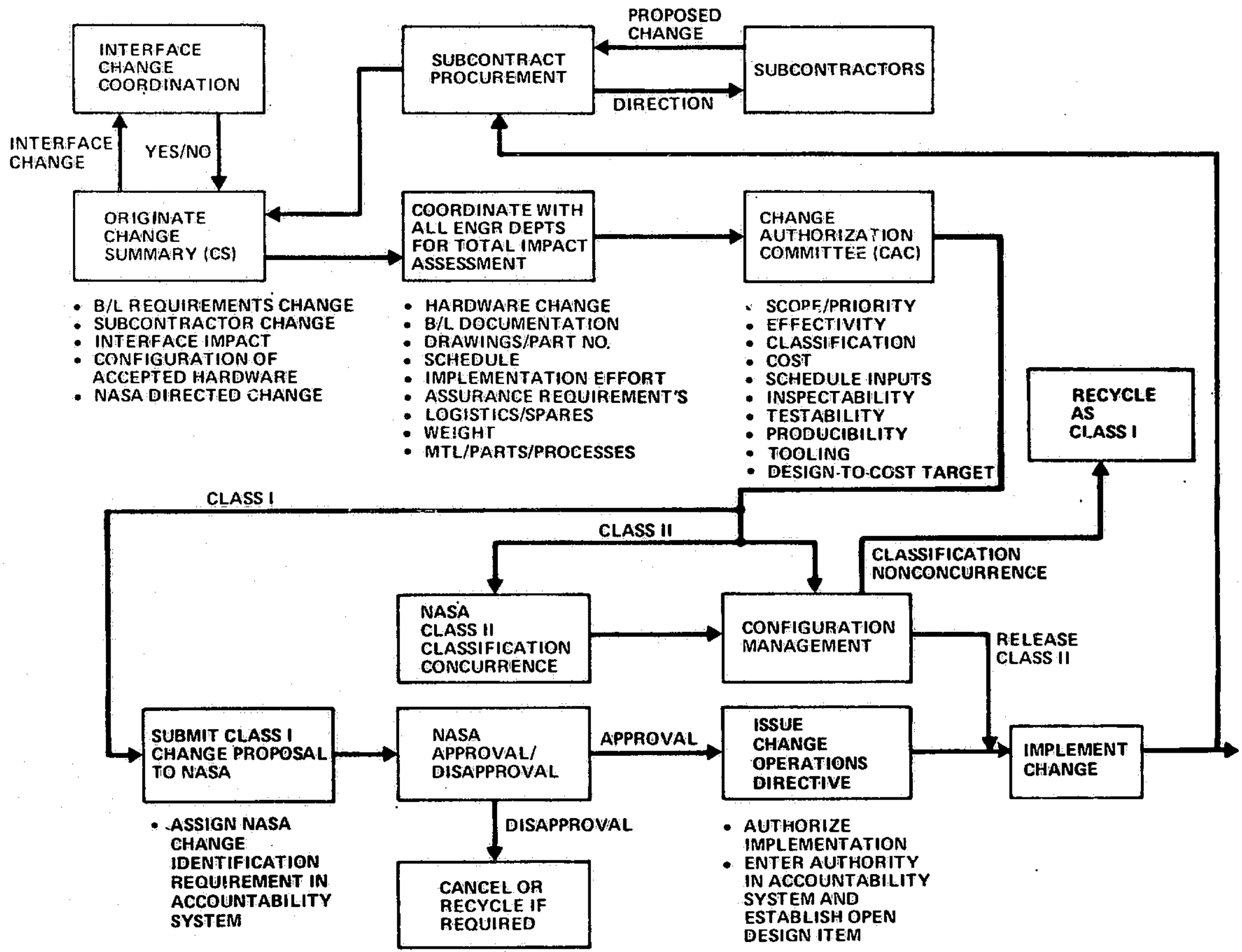

FIGURE 2.4-2 CONFIGURATION CONTROL CHANGE FLOW

2.4.5 Data Management - Data management will provide the identification and control of documentation required for the PSS program. The following functions will be performed:

1) Establish documentation preparation responsibilities.
2) Monitor and control the development of documentation to meet program schedules.
3) Inspect and transmit documentation to MSFC.

The categories of documentation required are identified in a Data Requirements List (DRL). The DRL defined from our Phase B study is given in the Table 2.4-1. This DRL defines the general categories of documents to be delivered.

2.5 Procurement and Subcontract Management - This section of our management plan describes Martin Marietta's approach to provide procurement and subcontract management functions for the Payload Specialist Station Program.

2.5.1 Procurement Management System - Our existing approved Procurement Management System includes the necessary controls to assure performance and provides flexibility to meet PSS program requirements. The effectiveness of our system has been demonstrated in the successful placement and management of over $500 million of subcontracts during the last 10 years. Major elements of our system are discussed in the following paragraphs as they apply to PSS program requirements.

2.5.1.1 Phase B Requirements Definition/Industry Capability Determination - During the PSS C&D study, the PSS "core" was defined and the procurement requirements were identified. The PSS core system consists of C&D equipments that mount in panels on the Aft Equipment Deck of the Orbiter. This equipment interfaces with the Orbiter systems through GFE racks, computer access units and power distribution box elements. The PSS C&D equipment consists of Orbiter-qualified MMSE C&D equipments and CRT/keyboard elements which may be either modified Orbiter equipment, qualified by IBM, or a new design Multifunction Display System which is in an advanced state of development at Bendix.

TABLE 2.4-1 DATA REQUIREMENTS LIST

MANAGEMENT
- MANAGEMENT PLAN
- PROJECT SCHEDULES
- MONTHLY PROGRESS REPORTS
- MONTHLY FINANCIAL MANAGEMENT REPORT
- GFP MAINTENANCE PLAN

CONFIGURATION MANAGEMENT
- CONFIGURATION MANAGEMENT PLAN
- CONFIGURATION VERIFICATION ACCOUNTING REPORTS
- SPECIFICATIONS
- DOCUMENTATION, SPECIFICATION AND DRAWING TREE
- SPECIFICATION CHANGE NOTICE AND REVISION
- PROJECT AND ENGINEERING CHANGE PROPOSALS
- CHANGE STATUS AND ACCOUNTING
- MODIFICATION INSTRUCTIONS
- INTERFACE CONTROL DOCUMENTS
- DEVIATIONS AND WAIVERS

DATA MANAGEMENT
- INFORMATION MANAGEMENT PLAN

TEST MANAGEMENT
- MASTER VERIFICATION PLAN
- TEST REPORTS
- MANUFACTURING TEST PLAN
- SUBSYSTEM DEVELOPMENT/QUALIFICATION PLANS
- TEST AND CHECKOUT PROCEDURES

ENGINEERING
- ENGINEERING DESIGN DRAWINGS & LISTS
- WEIGHT MANAGEMENT STATUS REPORT
- PS USERS HANDBOOK
- ENGINEERING DESIGN AND DEVELOPMENT PLAN
- REPORTS EVALUATION/STUDIES/ANALYSIS
- DESIGN REVIEW DATA PACKAGE
- SOFTWARE DOCUMENTATION, INCLUDING:
  - SOFTWARE DEVELOPMENT PLANS
  - SOFTWARE FUNCTIONAL RQMTS & PROGRAM DESCRIPTION DOCUMENT
- GSE REQUIREMENTS DOCUMENT
- EMC CONTROL PLAN

SAFETY, RELIABILITY, AND QUALITY
- QUALITY, RELIABILITY, AND SAFETY REQUIREMENTS
- FAILURE MODE EFFECTS ANALYSIS (FMEA) AND CRITICAL ITEM LIST (CIL)
- RELIABILITY & MAINTAINABILITY PLAN
- PARTS, MATERIALS AND PROCESSES PLAN
- END ITEM ACCEPTANCE DATA PACKAGE
- NONCONFORMANCE REPORTS
- QUALITY TEST PLAN
- HAZARD ANALYSIS REPORT
- RISK MANAGEMENT SUMMARY

The MMSE equipments consists of parts such as switches, indicator, timers, etc which have been qualified for the STS. All RI vendors were contacted and their capability to supply these parts for the PSS was verified. The only major subcontract identified was the CRT and keyboard. RFIs were submitted to IBM and Bendix and their response confirmed that either approach would satisfy the PSS requirements within acceptable risk.

2.5.1.2 Phase C/D Procurement Planning - Experience has shown that effective procurement action requires the formulation of a sound procurement plan. Pursuant to any decision to subcontract, we prepare, coordinate and issue a procurement plan which includes all key milestone events leading to subcontract definitization. The procurement plan is structured within the framework of the total program master plan and issued with the approval of the Program Director. After release, the plan will be maintained in a current status by periodic updating. Such updating will include narrative reports providing necessary detail to indicate current status, problem areas, actions proposed or being taken and a summary of any changes to the previous plan.

2.5.2 Subcontract Management - PSS program subcontract for the MFDS will be controlled through a management system that uses low-cost controls and monitoring techniques to do the job effectively. These controls are discussed in the following subparagraphs.

2.5.2.1 Subcontractors/Supplier Performance Surveillance - The level of activity for surveillance of subcontractor and supplier performance is determined by the criticality category established for the procurement. MFDS for the subcontract, task identification with cost, manpower and schedule correlations is required along with provisions for formal management and technical reviews at predetermined milestones; e.g., preliminary and critical design reviews.

2.5.2.2 Organization - Figure 2.5-1 shows the reporting relationship of the Task and Materiel Managers and depicts the relationship of these key personnel to central materiel department functions. The C&D Design Task Manager directs the subcontractor under the subcontract Technical Direction Clause for in-scope activity, while Materiel issues

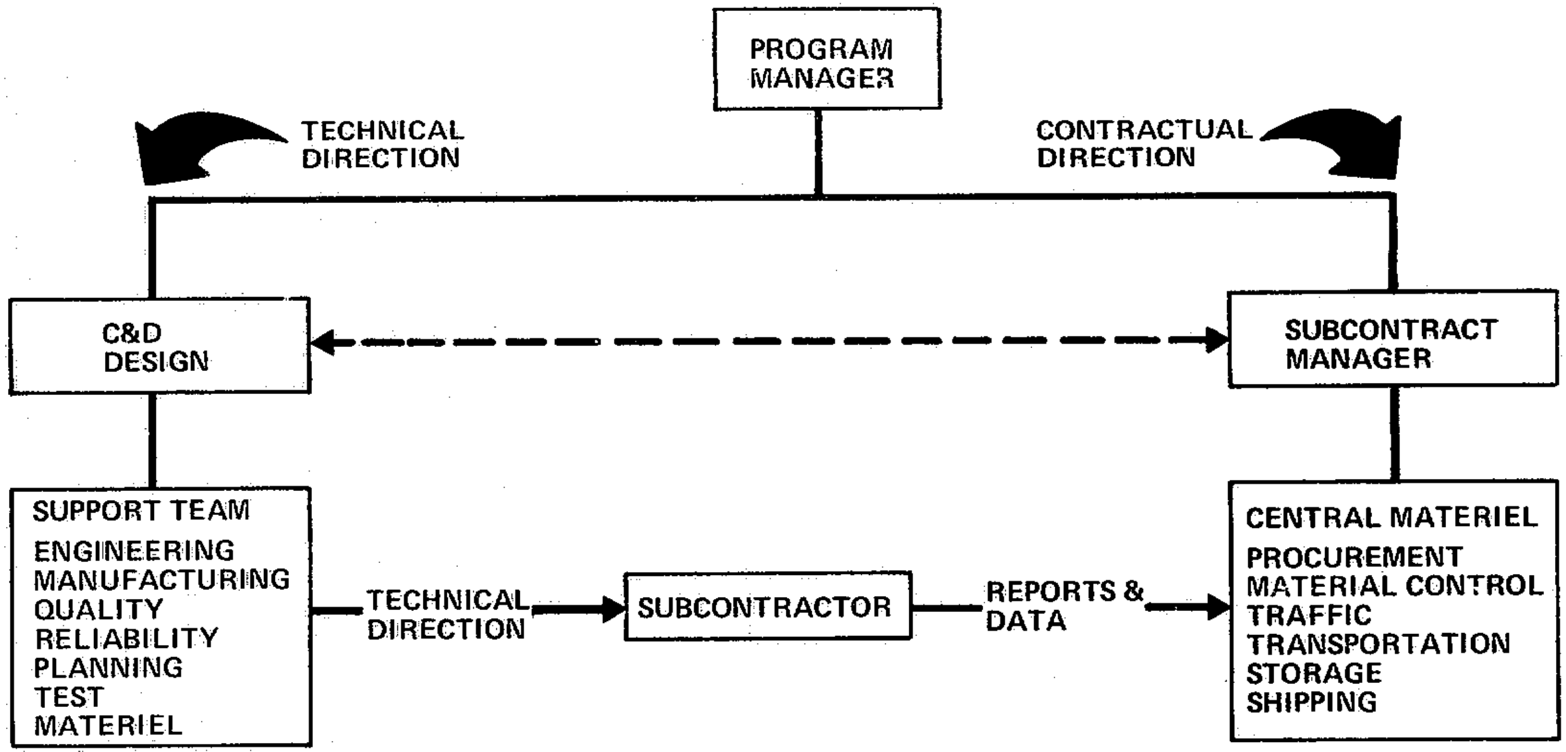

FIGURE 2.5-1 PSS MATERIEL SUBCONTRACT MANAGEMENT ORGANIZATION

change orders for out-of-scope direction. The Materiel Manager provides policy direction, guidance, and assistance in support of each Task Manager's team.

The PSS Program Materiel Manager's responsibilities include placement and administration of subcontracts and procurements. He delegates authority to central department buyers and subcontract administrators for placement, cost analysis, cost estimating and cost status. The subcontract administrator negotiates the original subcontract and subsequent changes, and establishes and maintains the official subcontract file. Contractual documentation and correspondence with the subcontractor are received by the subcontract administrator who makes program distribution through the Materiel Manager. The C&D Design Task Manager has the authority to deploy his manpower and budget to best meet subcontract needs. Engineering, quality, reliability, planning, and finance personnel provide support by monitoring their respective functions and communicating with their subcontractor counterparts. This free flow of information within the bounds of the ST program, is the basis for progress evaluation and early problem identification and correction.

2.5.2.3 Postaward Program Review (Critical Category 3 Subcontractors) - Within 30 days after the date of selection, an orientation conference between Martin Marietta and the subcontractor will be held. The overall objective of this review is to reaffirm that each subcontractor understands the technical, schedule and cost requirements, has established an acceptable plan and is proceeding with implementation.

2.5.2.4 Periodic Program Management Reviews - The subcontractor will conduct a monthly management review for PSS program personnel. Copies of data presented will be available for distribution to participants. The content of these reviews will be as follows:

a) Technical Portion - Description of accomplishments according to his plan and summary supporting data. Problem identification, its description, alternative solutions and the preferred solution.

b) Schedule Portion - The subcontractor will present data showing accomplishments toward meeting the contract schedule and will be required to report schedule progress on individual major milestones.

c) Cost Portion - Cost status reporting will be required of subcontractors who have cost-type subcontracts. The monthly cost reporting requirements include: an updated expenditure plan; status of management reserves; a comparison of actuals to plan; an estimate at completion (EAC); and summary overall analysis of the subcontractor's financial position.

d) Overall Assessment - Function and task cost reporting together with technical and schedule reports provide a basis for assessment of subcontractor performance and corrective action direction.

e) Action Items - The Task Manager will be responsible for directing actions and assigning responsibilities resulting from these reviews. Action items will be recorded.

Program reviews will be conducted at contractually specified events defined in the quality and reliability plans. Written progress reports and periodic informal evaluation will be accomplished and corrective measures will be initiated.

2.5.2.5 Other Progress Measurement Methods

Formal Measures - We will conduct formal, scheduled mission assurance audits to verify that each subcontractor is complying with the reliability and quality requirements of the program. Formal configuration management audits will be conducted to assure compliance with configuration and change control procedures. Task Managers will attend the formal design reviews. Corrective actions identified in these formal audits and meetings will be directed by the Task Manager. Follow-up audits will be held to assure compliance.

Informal Measures - Engineering, subcontract management, planning and finance functions will ascertain progress by visits, telephone, telefax and TWS as required in day-to-day interchanges with the subcontractor.

3.0 SYSTEMS ENGINEERING AND INTEGRATION

3.1 Systems Analysis, Design and Integration - Systems engineering and integration will include performance of the analyses and studies necessary to define requirements for the PSS system, interfaces, GSE and STE, and product assurance. Systems design and integration, operations requirements analyses, GSE and STE requirements, and systems test requirements are all a part of the Payload Specialist Station (PSS) systems engineering and integration (SE&I) task. Also included are interface analyses and definition, PSS specification development and weight management. The objective of the SE&I analysis is to assure an integrated PSS design that provides a core capability for operating and controlling the many anticipated payloads for the Shuttle Orbiter, at the lowest life cycle cost to the Shuttle Program, compatible with the required level of capability and limitation information to prospective payload developers.

3.1.1 Requirements - The essential functional requirements of the core of the PSS will be verified by reviewing the specifications of each of the selected experiments that will fly on the Shuttle missions as they are defined. The user community will be interviewed and the control and display needs of each experiment will be identified. As the C&D design requirement parameters have been established, an effort will be made to verify the PSS design and achieve the greatest possible commonality. The final design will be the result of tradeoffs between weight, space, power requirements, and life cycle costs resolved jointly with the PSS program office. Figure 3.1-1 depicts the interrelationships between systems engineering and integration functions and the PSS acquisition process.

3.1.2 Compatibility Analysis - Interface analyses will be performed between the PSS, the Space Shuttle, the Spacelab, the IUS, and their ground systems to identify and resolve incompatibilities. During the establishment of the PSS functional requirements, the limitaitons of the Shuttle Orbiter aft flight deck (AFD), with respect to available

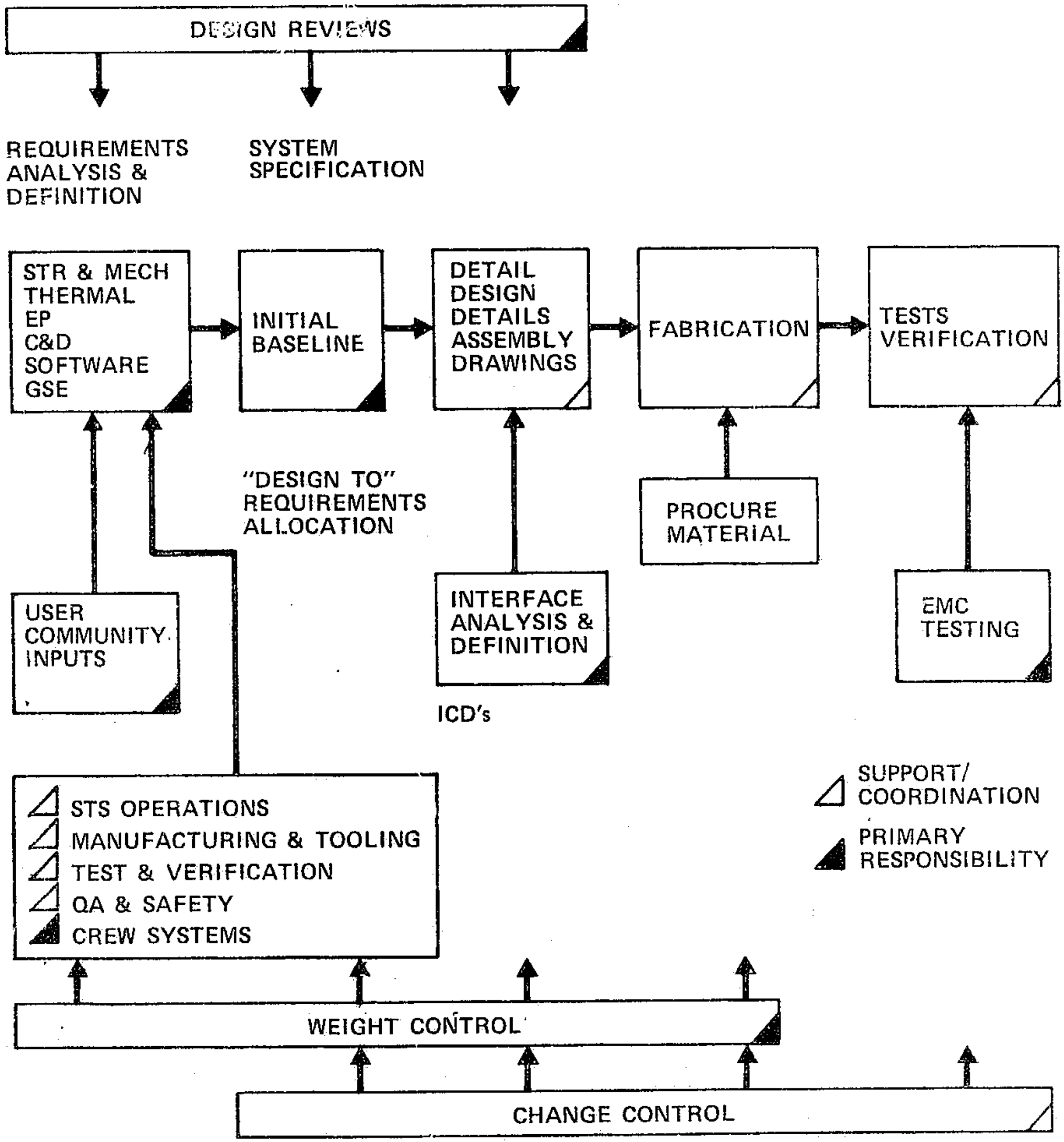

FIGURE 3.1-1 SE&I IN THE PSS DESIGN DEVELOPMENT PROCESS

deck, overhead and bulkhead area and volume, heat dissipation capability, wiring circuit capacity and electric power availability, will control. Tradeoffs will be made to utilize the available space, weight and other commodities to achieve a design with low life cycle cost.

3.1.3 Program Reviews - The progress of the design and development of the PSS core equipment will be reviewed periodically with NASA. Each major program review will be preceded by preparation, update and review of the required program and supporting documentation necessary for efficient conduct of the review.

The PSS core equipment project procedure will be to prepare material for each design review, hold in-house design reviews, correct or change material appropriately, and submit advance data packages for NASA review prior to the actual review date. These advance submittals will be:

- 10 days prior to PRR
- 15 days prior to PDR
- 30 days prior to PDR

This procedure will assure early input contributions by the technical advisory group and our senior engineering department reviewers, avoid surprises at the oral presentation, and permit NASA time to prepare oral responses or questions regarding the material being presented. Reviews will be held on the dates shown in the Master Schedules in Section 2.0.

- Preliminary Requirements Review (PRR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Delta Critical Design Review (DCDR)

Preliminary Requirement Review - The PRR will be held to verify the suitability of the conceptual configuration, and to establish the requirements and action necessary to achieve a design requirements baseline at the PDR. The following activities will be accomplished at PRR:

a) The compatibility of the PSS core equipment detail performance and design requirements, with the program (project) specification, will be established.

b) The rationale of the selected configuration approach for the system/CEI with mission objectives.

c) The system/CEI suitability of the selected configuration by reference to drawings, study reports, models, sketches, etc.

d) The expected suitability of the system/CEI configuration to meet the required schedule.

e) The development tests required to select and substantiate design approaches.

f) Operational requirements generated by the selected configuration and design concept.

Preliminary Design Review - The PDR will be held to provide formal identification of specific engineering documentation by which the physical and functional interface relationship of PSS core equipment to other systems shall be established. The PDR is planned to result in the decision to commence the development tests.

The following activities will be accomplished at PDR:

a) The ability of the selected design approach to meet the requirements of Part I of the detail specifications for the PSS core equipment estalbished and supported analytically.

b) The compatibility of the PSS core equipment with other system equipment/facilities will be established. This will be accomplished by review of predesign drawings, schematic diagrams, layout drawings, envelope drawings, review of performance characteristics for functional compatibility, etc. Since system engineering will be accomplished, system compatibility of the CEI will be established by review of the schematic block diagrams, fucntional block diagrams and other system engineering documentation.

c) The integrity of the selected design approach will be established, This will be accomplished by review of analyses, breadboard models, mockups, circuit logic diagrams, packaging techniques, etc. This will be accomplished by MMC as the basis for selection of the design approach presented.

d) The producibility and maintainability of the selected design will be established. This will be accomplished by review of requirements for special tools and facilities necessary to manufacture and maintain the PSS core equipment in the quantities required.

Critical Design Review - The CDR will be accomplished immediately prior to committing the design for manufacture of the development unit. The following will be accomplished at the CDR:

a) The compatibility of the PSS core equipment, as designed with Part I of the detail specification for CEI, will be established.
b) The system compatibility of the completed design shall be established. This will be accomplished by comparison of the interface control drawings with the engineering drawings for the CEI. Since system engineering or functional analysis will be accomplished, schematic block diagrams, functional block diagrams, and other system engineering documentation, will be used to support the interface control drawings in established system compatibility of the CEI.
c) The integrity of the design shall be established by review of analytical and test data.

The decision to proceed with final design release, and fabrication of the flight unit, is expected to result from the CDR.

The Δ CDR data package will revise the data in the CDR data package and will be prepared and submitted 30 days prior to Δ CDR.

3.1.4 Crew Systems Design Requirements - Crew systems engineers will input the PSS design to insure placement, lighting and identification of controls meets human engineering standards. Adequacy of crew system requirements will be assured by having Shuttle crews evaluate the human engineering design work, the development unit, and test evaluations. All PSS drawings, tests, procedures and plans will be reviewed for compliance with crew systems ICD and CEI specification requirements documents such as MSFC-STD-512, MIL-STD-1472A and JSC 07700.

3.1.5 Weight Management - The PSS core equipment mass properties summary presented in Table 3.1-1 has been derived from calculations and estimation s based on preliminary design layout drawings and coordination with systems design personnel. A 10 percent growth/contingency allowance is included in the mass properties statement. This allowance accounts for items not included in preliminary design activities, minor in-scope changes, and upward weight trends historically experienced during deisgn and fabrication. It must be noted that the total weight indicated in Table 3.1-1 is 250 pounds, which is the maximum specification weight. In order that the PSS weight does not exceed 250 pounds at delivery, a weight management plan will be established. A weight allocation for each design group will be determined for each of the following program phases: I-Start of Design; II-PDR; III-CDR; and IV-Delivery.

The weight will be continuously monitored during each of these phases and whenever it exceeds the allocation, a weight reduction program will be initiated to drive the weight below these goals.

Management of this weight control plan will include the following tasks:

1) Define the critical mass properties and establish weight allocations for in-house design and subcontractor parts.
2) Monitor and assess design progress, provide visibility of mass properties trends, support trade studies and make recommendations on design improvements or weight reductions.
3) Prepare and negotiate reporting requirements, disseminate status and issue DRL reports.
4) Identify PSS assembly and component mass measurement requirements, issue operating procedures and perform measurements to verify design weights and to satisfy the contractual requirements.

Table 3.1-1 PSS Core Equipment Weight Breakdown

PANEL L-12		
1 Spacelab Recorder		83.0
14 Toggle Switches		2.8
10 Status Indicators		2.0
Cabling and Structure		5.0
	TOTAL	92.8
PANEL L-11		
1 DU, DEU, Keyboard		66.0
2 Event Timers		2.0
1 Manual Pointing Controller		3.0
10 Toggle Switches		2.0
2 Potentiometers		0.5
1 Rotary Switch		0.2
Cabling and Structure		5.0
Mission-Peculiar Equipment (Estimate)		5.0
	TOTAL	83.7
PANEL L-10		
1 DU, DEU, Keyboard,		65.0
Cabling and Structure		5.0
	TOTAL	70.0
PANEL A-7		
12 Locked Switches		1.0
Cabling and Structure		2.5
	TOTAL	3.5
TOTAL ALL PANELS (L-12, L-11, L-10, A-7)		250.0 lbs

Approximate Mass Properties for Final CEI DD250
(Each panel separate)

Orbiter Coordinates

$X =$, $Y =$, $Z =$ } TBS

$I_X =$, $I_Y =$, $I_Z =$ } TBS

3.1.6 Specifications and Interface Documents - Five specifications will be written as part of the PSS core SE&I effort. They will be for the Multifunction Display System (MFDS), the Multiuse Mission Support Equipment (MMSE), the GSE, ground test software and MFDS processor flight software. Four interface documents will be written to cover mechanical relationships of the PSS core to the Shuttle Orbiter (including panel nomenclature and outlines), electrical relationships (including detail connector configurations), and the relationships of GSE, and the core C&D software relationships.

3.1.7 Change Control - In support of the total change management process, engineering will exercise a control function over all designers who will work on the PSS core equipment and software. When a designer recognizes the need for a design change, he will prepare a design change summary (DSC) that describes, as fully as he then recognizes the problem, a complete description of the change, the reasons why the change should be made, the consequences if the change is not made, the retest requirements the change will cause, a summary of the impact of the change on considerations such as interfaces, reliability and maintainability, performance and weight, safety, etc., and finally, a listing of the other engineering disciplines that the originator thinks will become involved in the change. Weekly meetings will be held by representatives of each engineering discipline/section where the originator will present his proposed change for discussion. The section representatives will be assigned a schedule for responding with a detailed definition of each of their efforts for that change, including the cost and the schedule for accomplishing the change. Iterations of that process will assure that all ramifications of the change have been considered. After this thorough scoping of the change, and before its release for pricing and scheduling, the change will be discussed with the PSS program office. With that concurrence obtained, the finalized design change summary (DCS) will be released to the change authorization committee (CAC) for the balance of the configuration management activities.

3.1.8 Electromagnetic Compatibility - An electromagnetic compatibility plan will be written to control the design and development of the PSS hardware, to assure that it will perform under the EM environment of the aft flight deck of the Shuttle Orbiter plus conducted influences of payload bay energy. The EM environments and susceptibility given in Volume 14 of the Shuttle Orbiter design requirements (when issued), and as further defined through a liaison to be set up with Rockwell International, will be the basis of the EMC plan, to the end that the plan will neither exaggerate nor underestimate the severity of the environment and the sensitivity of related equipment. Studies of the several payloads will be performed to establish the EMI limits applicable to signal and control lines interfacing the PSS core equipment, the Orbiter and the payloads. Radiated emissions from imaging devices such as CRTs are considered intentional signals and therefore exempt from radiated emission limits. In addition to the design guidance to be provided by the EMC plan, periodic EMC reviews will be made of the progress of the PSS design. Finally, the compliance tests described in the EMC plan will be performed on the qualification unit.

4.0 PSS CORE C&D DESIGN AND DEVELOPMENT

4.1 Engineering and Development - In this section, the engineering and design development requirments for the PSS core C&D hardware and GSE are described. The PSS C&D hardware consists of a MFDS and MMSE hardware mounted in panels L-10, L-11, L-12, R-12, and A-7 of the Aft Flight Deck of the Orbiter. It includes the structural panels, C&D components, interfacing components such as dc/dc converters, display electronics and interconnecting wiring. The PSS core C&D hardware interfaces structurally with the AFD equipment rack, electrically with Orbiter and a GFE power distribution box; and the signal interface is via a GFE Remote Access Unit (RAU) and MFDS bus to the I/Os of the Spacelab computers. The following paragraphs describe the engineering activities required to design and develop these equipments. Software requirements, "core" software for the MFDS processor, and ground test software are an integral part of the PSS core system. Software development activities are described in Section 5.0 of this document.

4.1.1 Structures and Mechanical - The structures elements consist of panels, subpanels to mount the C&D components, and brackets for mounting interfacing hardware and wiring. The panel layout options for the PSS core is shown in Figures 4.1-1 and 4.1-2. Once final configurations have been established, structural design assembly and detail drawings will be developed for the main panels and subpanels. The locations for bracketry, electronics, and connectors will be determined based on loads analysis. Drawings will be released to manufacturing for a lot build of all three articles. Because of the simplicity of the structural design, only minor modification can be expected from development and qualification testing, which can be incorporated as out-of-position changes.

Structrual design activity will also include the design of test tooling for thermal control tests.

4.1.2 Controls and Displays - The C&D design and analysis activity will define the PSS core equipment required to support the mission functional requirements. The C&D effort encompasses, the definition of

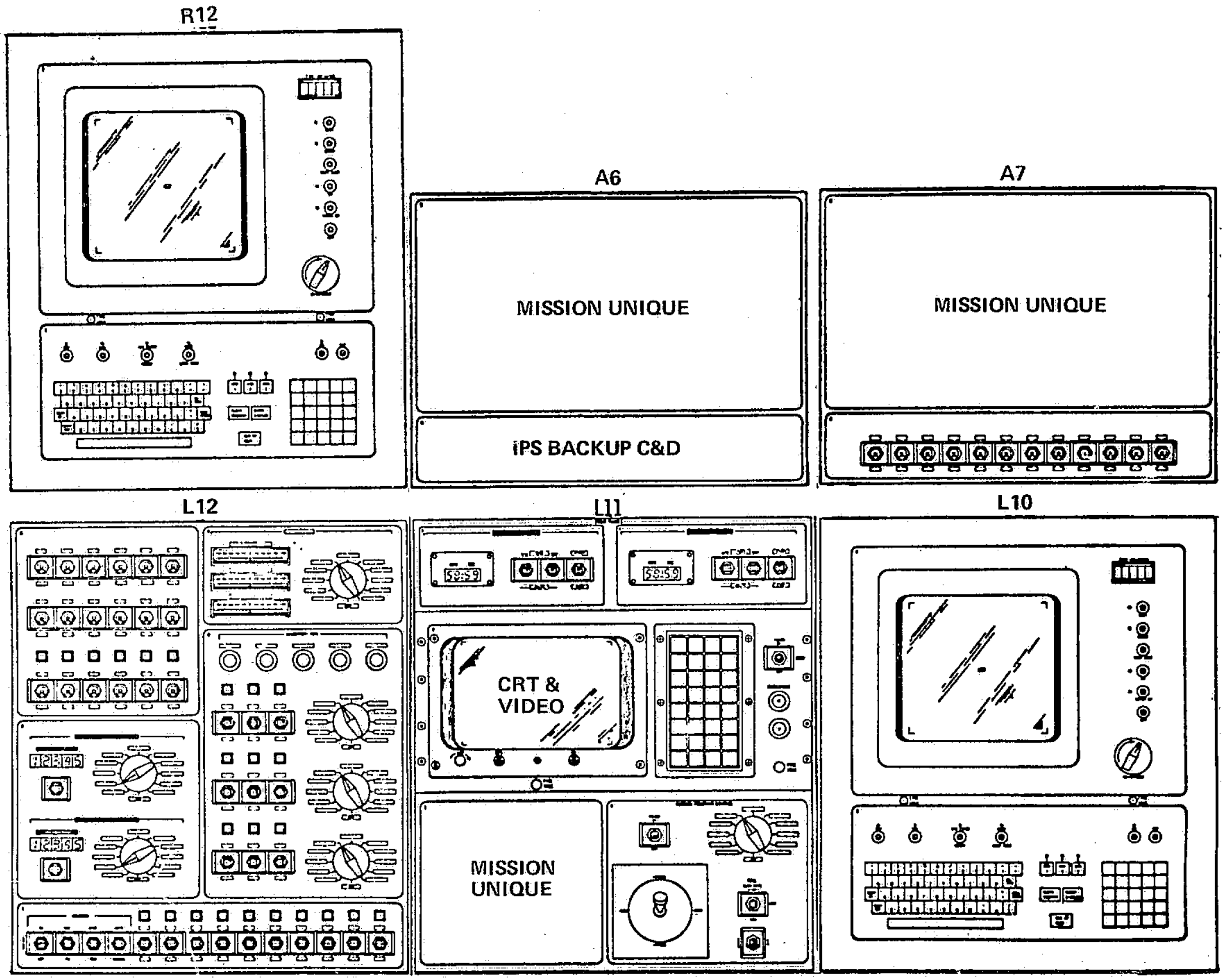

FIGURE 4.1-1 PSS C&D Concept for STS Equipment

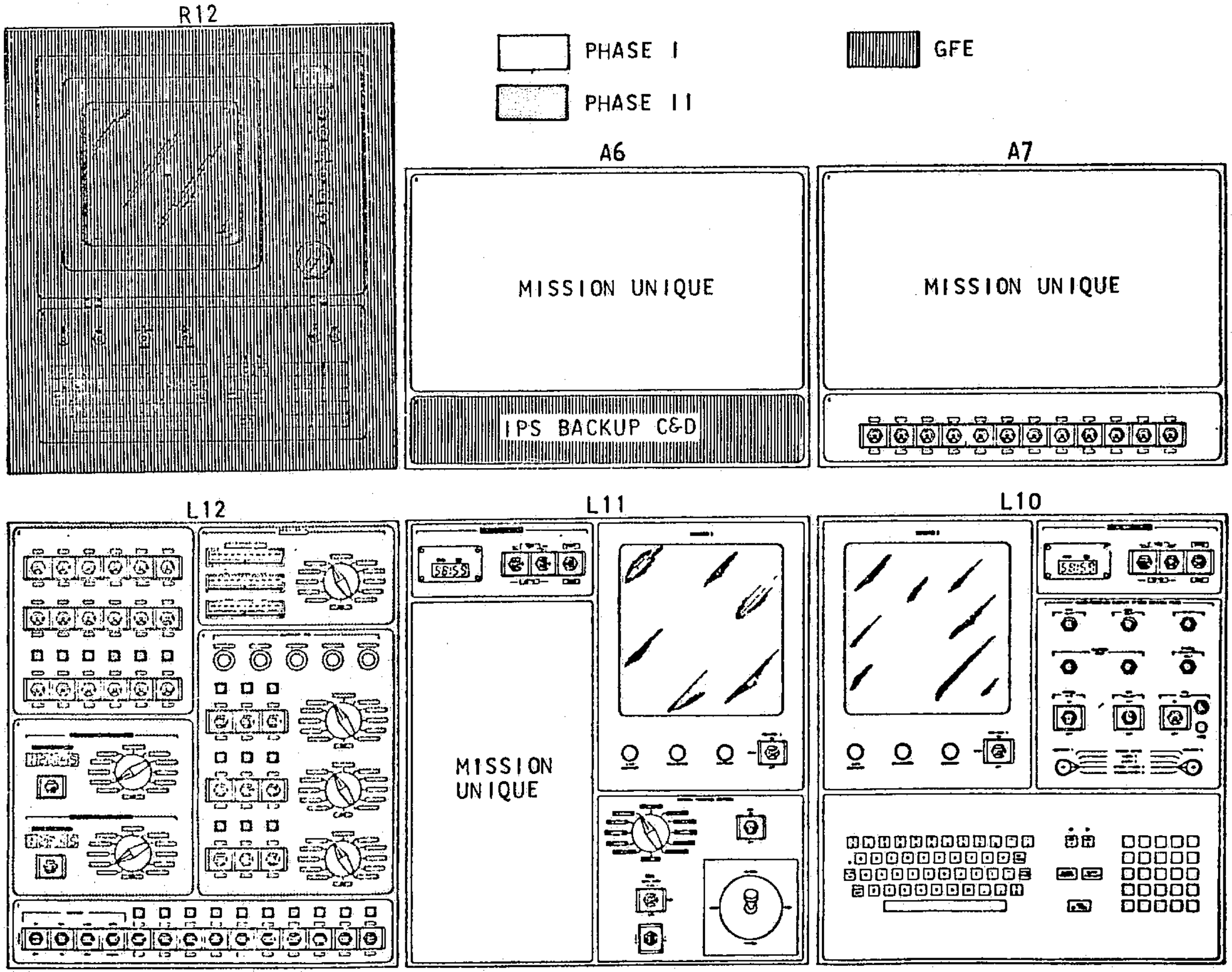

Figure 4.1-2 PSS C&D Concept for New Development

C&D hardware to implement the PSS design requirements. The design effort will integrate the requirements such as weight, power, space limitation, human factors, reliability and environment into a design described by schematics, block diagrams, layouts, component and system detail and assembly drawings.

The C&D design effort will define development, and qualification test requirements, conduct testing and prepare inputs to test reports. The effort will also include liaison and evaluation of subcontractor and vendor test results to ensure that C&D components meet PSS and STS requirements.

Functional operation of the C&D equipment is closely tied to the flight MFDS processor software and checkout and verification determines the ground test software requirements. Close coordination will, therefore, be maintained with the activities of the software development effort described in Section 5.0 of this document and the electronics and electrical power activities described below. The C&D design development effort will be described in a detailed plan and schedule which will be integrated into the Program Master Schedule.

4.1.3 <u>Electronics</u> - The electronics activities provide the analysis and design of interconnection of C&D components and signal interfaces with Spacelab and Orbiter equipment. This activity input comes from the C&D design layouts. The effort encompasses definition of interfacing hardware such as dc/dc converters, D/A converters, panel electronics for interfacing between C&D components and the RAU and between C&D elements. The design effort will result in schematics, layouts, component drawings and detail and assembly drawings from which material can be procured and C&D subpanels and panels can be fabricated.

The effort will also include qualification of interfacing components which do not meet Orbiter requirements. Test plans and procedures will be developed and qualification and development tests will be supported. This design effort will be closely coordinated with both the software development task and the C&D design effort through the master schedule and detailed engineering work plans and schedules.

4.1.4 Electrical Power, Control and Distribution - This design and development effort will consist of providing the electrical power required to drive the C&D components from the Orbiter and SL power distribution box which is GFE and located at the PSS. This effort will result in schematic diagrams, layout drawings and component drawings. Wire routing will be called out as a "Development" requirement on back-of-panel drawings but separate harness drawings will be provided of harnessing interconnections to the PDB.

Electrical power management is a critical factor in the PSS design and a part of this effort will be to maintain current assessment of power requirements to assure that the PSS stays within its allocation, and where problems exist, to make design changes to rectify them. The electrical power effort will provide support to C&D and electronic design efforts through assisting in component selection and development and qualification test evaluations. This effort will be planned and scheduled as a part of the overall engineering effort and the Master Program Schedule.

4.1.5 Thermal Control - The objective of the thermal control effort is to ensure that the PSS core C&D hardware functions and is compatible with the active cooling system (forced air) provided by the Orbiter to the PSS console. The input to this effort is the C&D layouts and back-of-panel design. Thermal analysis will be performed to ensure all components operate within temperature limits and to maintain allowable touch temperature limits. The average power utilized by payload C&D must be 750 watts in any three-hour period; the maximum allowable power (in the same period) is 1000 watts for 15 minutes.

Verification that thermal protection is adequate will be achieved in a thermal qualification test in which the thermal cooling from the Orbiter and the mounting configuration in the Aft Flight Deck are simulated and the PSS hardware is instrumented to verify all components operate within their qualification limits. Where required, baffels, heat sinks and thermal coatings will be added to the back-of-panel design. The design and test effort will be scheduled as a part of the design and development effort and appear as a part of the detail engineering and master schedules.

Since the PSS core hardware design uses many procured components, liaison will be maintained with the subcontractor for the MFDS and with the vendors for MMSE to ensure that all components meet STS thermal qualification requirements.

4.1.6 GSE Design and Development - The GSE for the PSS core C&D hardware will be a computer system that simulates the data bus, RAU, and hardwired interfaces. It consists of a standard inexpensive commercial computer and a ground test software program which will be used for checkout, training and payload integration. The ground software development is discussed in Section 5.0. The GSE hardware effort consists of defining the detailed requirements, selecting a vendor that can meet the requirements at lowest cost, and making minimum modifications to the system to adapt it through an input/output device to the C&D hardware. Research has verified that the adaptation of computer currently available can be accomplished with a simple plug in integrated circuit board.

The design skills required to accomplish the GSE task are: digital logic design, power switching and electronic equipment packaging.

The task elements for the GSE design and development are: definition of system design requirements, solicitation of proposal, evaluation of proposal, selection of a vendor/computer system, design of the I/O adapter and test and verification of the GSE with the ground test software and the development test article.

GSE design review will be held to ensure an orderly baseline management approach is followed and that the design proceeds in coordination with the PSS core hardware and the ground test software. If possible the GSE CDR will be held in conjunction with or just prior to the PSS hardware CDR to provide maximum assurance that PSS-to-GSE interfaces are compatible.

4.2 Manufacturing and Tooling - This plan identifies the Manufacturing and Tooling tasks and activities associated with the PSS Phase C/D. It presents the approach for accomplishing each manufacturing and tooling task for development hardware, flight hardware, GSE, and spares.

4.2.1 Fabrication and Assembly - The flow for assembly and checkout of the PSS shown in Figure 4.2-1, is a sequential buildup of components and assemblies and includes mating and checkout of the C&D panels with the GSE. The schedule for accomplishment of the work is given in Figure 4.2-2. The design concept supports an efficient fabrication approach, making maximum use of subassembly techniques for each of the major C&D panels.

These assemblies will take place in designated project areas within existing facilities (see Figure 4.2-3). Structure sections will be fabricated and assembled in the factory under conventional shop temperature, humidity, and cleanliness conditions. Electrical/electronic component assembly will be performed in the class 100,000 clean room of the Electronic Manufacturing Facility (EMF). Wire harnesses will be fabricated in the class 100,000 second floor area of the Space Support Buidling (SSB). Installation of components into the C&D panel structure mating of the modules, and testing of the subsystems and systems will be performed in a class 10,000 clean Final Assembly Area of SSB.

The PSS detail parts will be fabricated primarily with standard equipment and standard tooling. The use of special tools will be minimized by continuous review for producibility during detail design of the hardware. Milling, drilling, and boring for the low quantities of frames, fittings, and brackets will not require special holding fixtures. Electrical wiring will be developed on the panel structure to eliminate the need for a development tool. Drilling of precision hole patterns will be accomplished with standard jig boring and vernier positioning drilling equipment.

4.2.2 Equipment Installation - Assembly of the PSS panels will be performed in the SSB class 10,000 clean room assembly area. Assemblies,

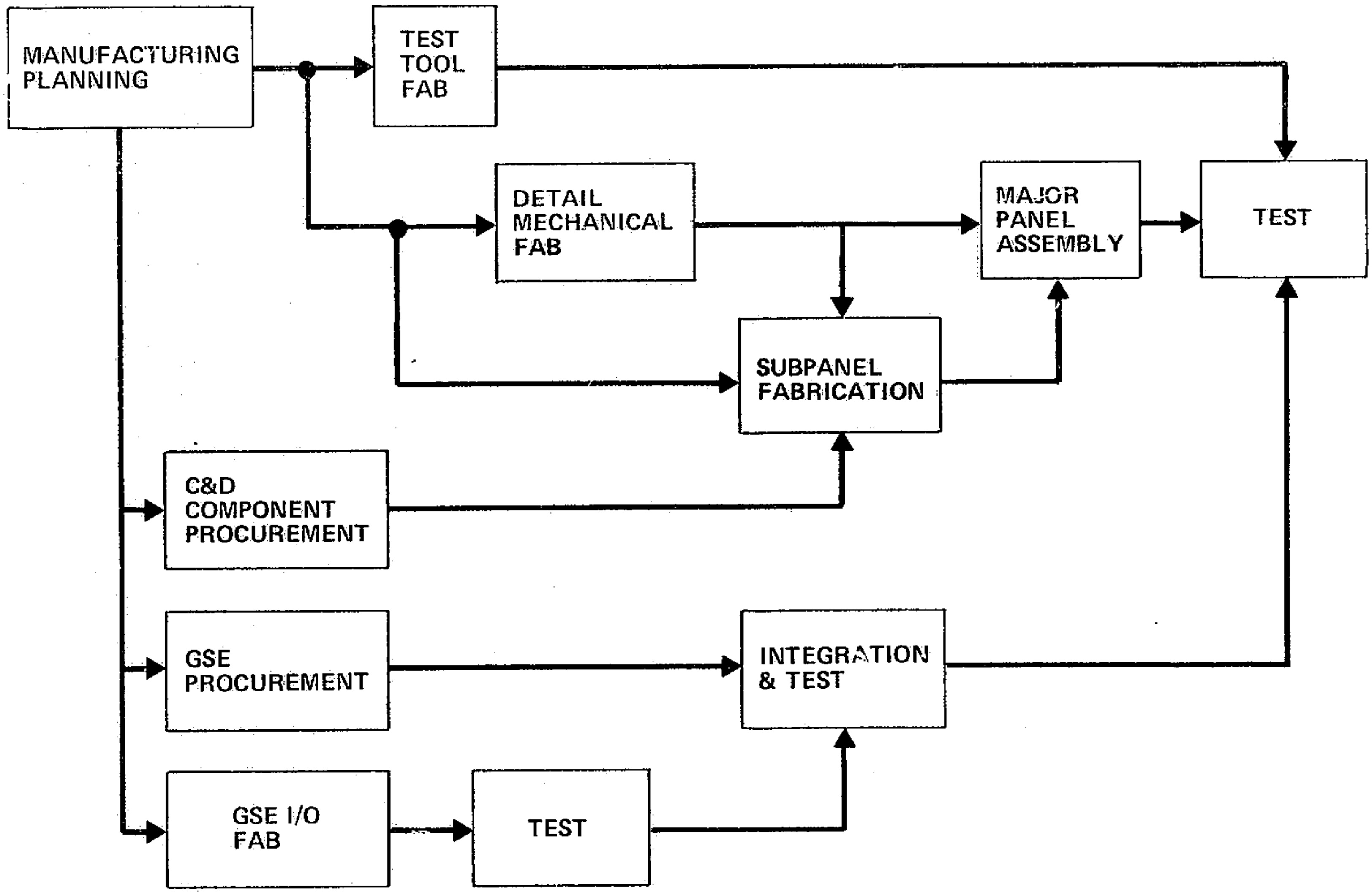

FIGURE 4.2-1 PSS CORE C&D FABRICATION & ASSEMBLY FLOW

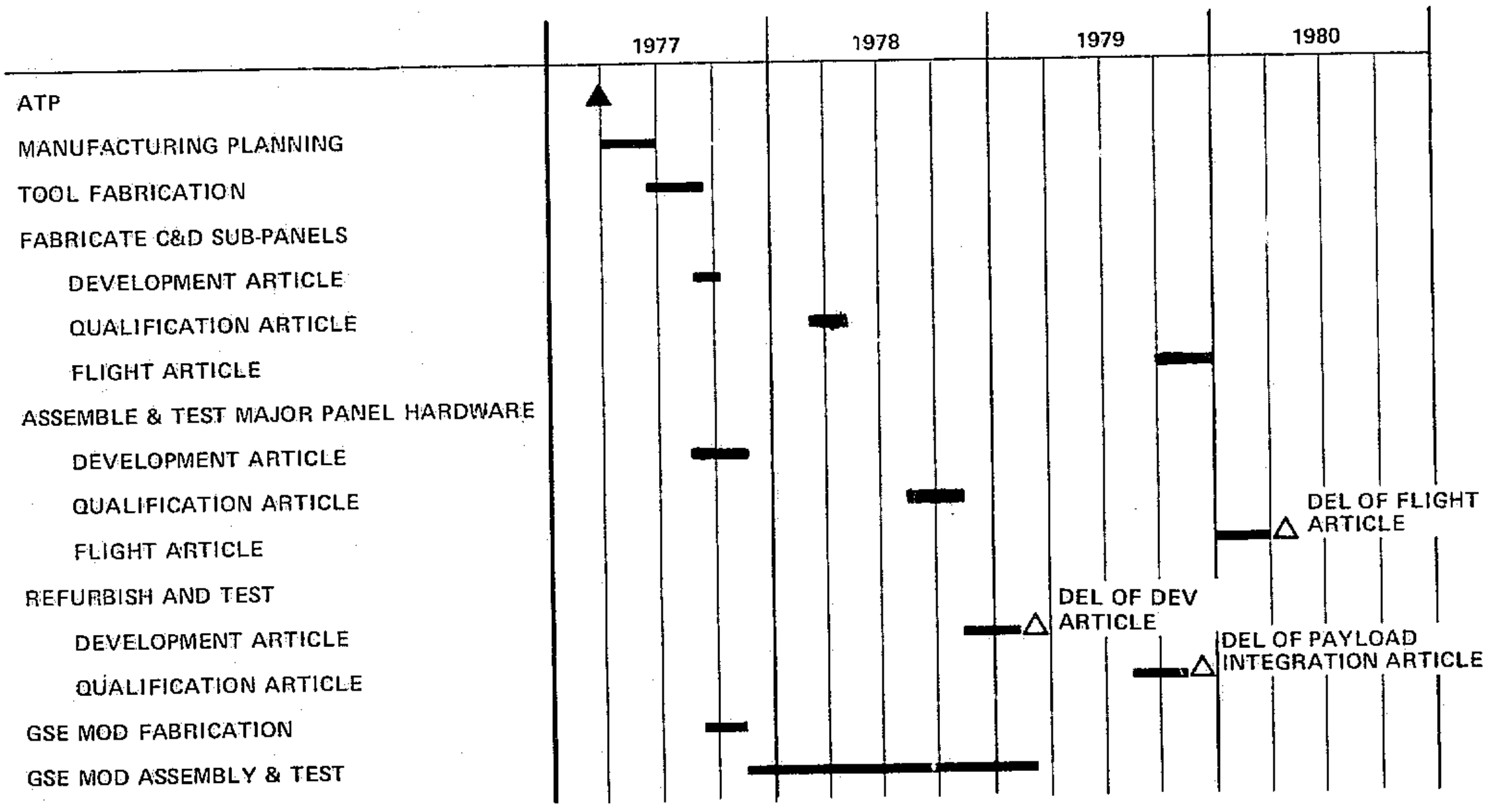

FIGURE 4.2-2 PSS FABRICATION & ASSEMBLY

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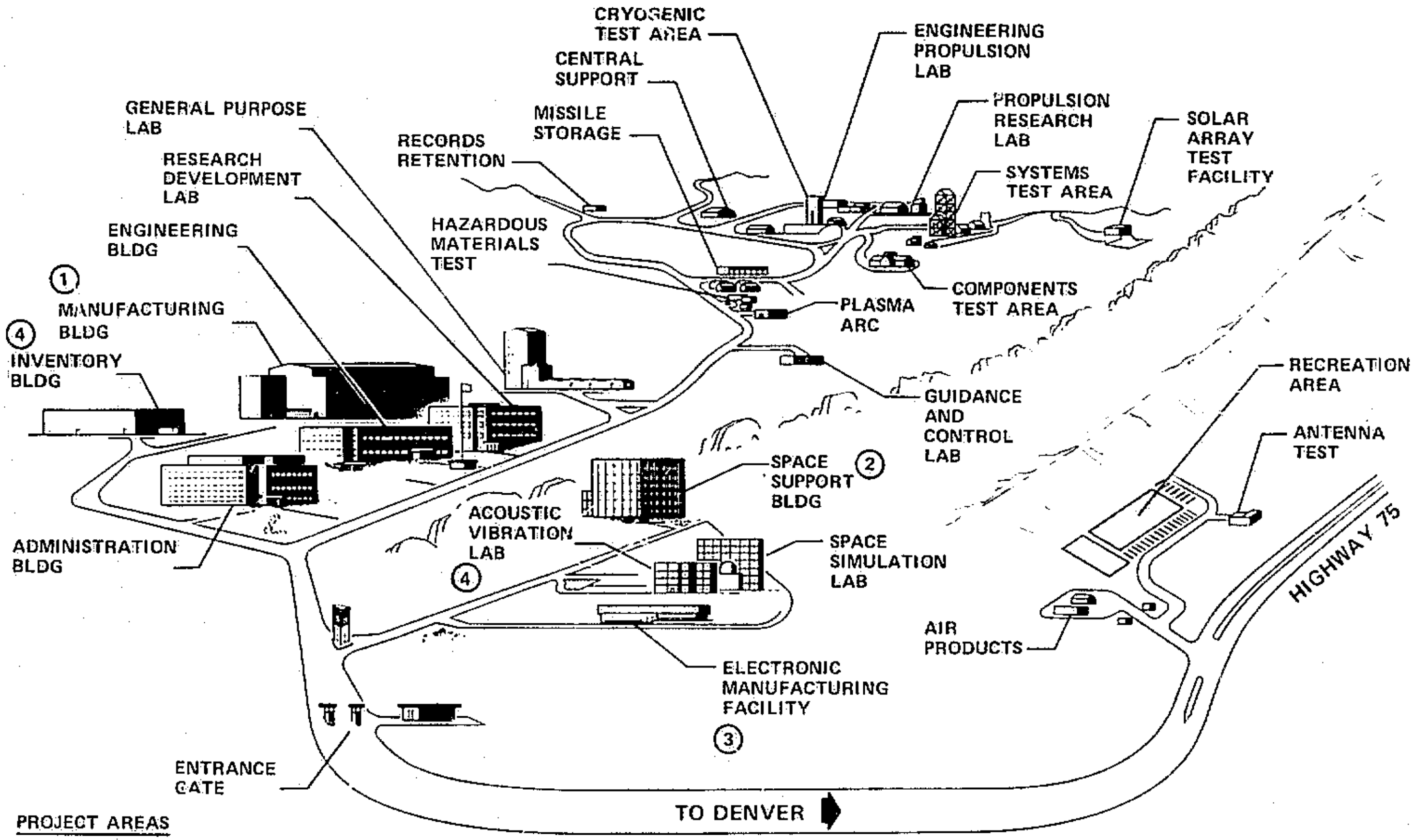

PROJECT AREAS

STRUCTURE FAB ①

ELECTRONIC ASSY ② ③

FINAL ASSY ②

INTEGRATION ②

SYSTEM TEST ② ④

FIGURE 4.2-3 MARTIN MARIETTA DENVER FACILITIES parts, and components will be staged for assembly in a controlled project area.

Detail parts fabricated in the detail shop, purchased piece parts and PC boards from subcontractors will be staged in the controlled project area of Electronic Manufacturing. All subassembly and assembly of electrical and electronic flight hardware will be performed in class 100,000 clean work areas. Certification logs will be used to control and record the buildup, test, and acceptance of all components.

Functional testing will be performed at each level of subassembly. The special equipment and skills for element brazing, welding, soldering, potting, encapsulating, functional test, vibration test, and thermal cycling will be available within the Electronic Manufacturing Facility.

4.2.3 GSE/STE Fabrication and Verification - The GSE concept proposed for PSS provides a simple low-cost solution to the training, payload integration and premission checkout of the Payload Specialist Station core system. An off-the-shelf rack mounted computer with only minor modification and a ground test software program is all that is needed to verify the C&D system configuration. The I/O unit will be fabricated in our Electronics Manufacturing Facility and the completed unit will be verified as a subassembly prior to system verification testing with the C&D hardware.

The STE electrical checkout and test support GSE will be modified, fabricated, and tested in the Engineering Electronics Laboratory concurrent with flight equipment development.

All GSE will be fabricated and assembled in conventional factory environments. The external surfaces of the equipment will be cleaned after assembly to upgrade it for the class 10,000 clean room compatibility. Certification logs will be used to control and record assembly and test of all GSE/STE components.

4.2.4 Transportation Preparations - After completion of PSS testing, the hardware will remain in the Final Assembly Area for transportation preparations.

4.2.5 Organization and Responsibilities - The projectized manufacturing operation will be tailored to support the three PSS articles build. Manufacturing management, planning and supervision will be onboard the project team at the beginning of Phase C/D. This nucleus will physically move with the design, fabrication, assembly, and integration activity. Simplified process and fabrication instructions will be prepared on project. Fabrication of test support equipment will be performed in existing engineering laboratories. All other major assemblies will be built in dedicated project areas within existing manufacturing facilities. Project areas will have on-site liaison coverage with Advance Design Change Notices (ADCN) issued as the authority to proceed with changes. Detail fabrication and component assembly is planned with standard tooling and multiple function tooling. Most detail tools will be built on project. All material and hardware movement will be controlled by manual statusing.

4.2.5.1 Dedicated Shop Operation - Selected shops within existing manufacturing facilities will be assigned as dedicated areas for fabrication, assembly, and test tasks. Fabrication in the dedicated project areas will be directed and controlled by the C&D Design Manager. The manager will provide direction to area supervisors for all fabrication activity. The fabrication supervisors will be responsible for area operation. The supervisors will have been resident Project Team Members from the outset of the design phase with responsibility for coordination of requirements, material, tooling and the fabrication plan. At the start of hardware build they will move to the fabrication area (detail fabrication, electronic fabrication, and final assembly and test). The dedicated shops will use experienced personnel in the use of summary or single step shop traveler plans, shop-aid/nondesign tooling and end item inspection. Those detail fabrication items which require specialized equipment or large capacity equipment will be processed through the production shops or subcontract shops to utilize their existing special abilities.

4.2.5.2 Production and Material Support - Production and Material Support team members will direct and regulate the orderly flow of hardware through the fabrication, test, checkout, and delivery cycles. During the engineering design, development and release they will establish material and parts requirements. They will prepare a plan to status and control materials, shelf items components, vendor components, in-process hardware, tools, and shop loads. They will be responsible for developing, issuing, and maintaining page and line schedules for all manufacturing tasks. The page and line schedules will provide the basis for identifying long-lead activities.

Production Support will be responsible for the movement and staging of materials, tools, and components. They will control pack and ship operations for in-process hardware and program end items.

4.2.6 Manufacturing Controls

4.2.6.1 Cost Control - A manual and mechanized data collection system will be used to compile labor costs and to provide job status, shop load data, and machine operations scheduling. The production activities performed in dedicated shops with simplified process and fabrication instructions and reduced supporting functions will require only that portion of the mechanized system capability that is necessary to assure the ability to maintain positive control of fabrication costs.

Cost data will be collected daily, accumulated, and reported to project management. The data will be provided by functional element and Manufacturing Control Points (tasks) which relate directly to the Work Breakdown Structures (WBS).

Project Directives will be issued to authorize and direct manpower and material expenditures for specific tasks. The project industrial engineer will initiate and control the collection of costs that must be analyzed with the budgeted elements. He will prepare timely reports for the appropriate subsystem managers. The reports will provide actual labor and material costs to the WBS unit for the current reporting period and program accumulation.

4.2.6.2 Production Control - Production Control support will consist of three basic elements--Project Production Control, Integrated

Planning and Scheduling, and Shop Control.

Project Production Control will be responsible to the Assembly and Checkout Manager for all manufacturing planning and status. Integrated Planning and Scheduling will develop the detailed manufacturing schedules for assuring effective use of manufacturing resources. PSS fabrication effort must be integrated with other on-going programs. Shop control, using the page and line schedule, and indentured parts lists will be responsible for the control, movement, and status of all raw material, procured items, vendor components, shop folders, certification logs tools and shop loads.

Project Directives will direct all manufacturing functional elements, define the tasks, and establish quantity requirements, schedules, and cost accounts for labor and material. Production Control will identify and initiate all parts requirements in accordance with engineering drawings. They will participate in configuration control, direct change activity within manufacturing and will control pack and ship operations.

Production control manual and computerized systems will be the tools for project management to maintain visibility of performance to build status, schedule, and cost. Progress reviews at the working level will provide timely recognition and resolution of problems.

4.2.6.3 Manufacturing Engineering - Preproduction engineers will be collocated with engineering during the complete design phase. The manufacturing engineer will review design concepts to assure the interchange of producibility and design requirements. He will develop the fabrication plan, analyze alternate approaches, and minimize technical and production risk. Manufacturing data establishing the fabrication plan, techniques, tooling, manufacturing processes and special considerations will be issued by the preproduction engineer and released with the engineering design. The preproduction engineer will select components, parts, and operations to be subcontracted in order to use available equipment, processes, techniques, and experience to achieve the lowest total cost. Manufacturing engineers will review all engineering releases. They will assure producibility and completeness of manufacturing information (material, processes and techniques) to achieve the lowest total cost. Manufacturing engineers will be responsible for the technical interface between designers and fabricators during the hardware build phase.

4.2.6.4 Fabrication Process Control - All processes and technology required for producing the PSS hardware are within the state-of-the-art. Manufacturing processes will be adapted to the PSS from existing NASA and industry technology. Adapted processes will be reviewed by experienced laboratory technicians and manufacturing specialists and approved by Quality, Safety, Manufacturing, and Materials Engineering before release for production. Potential problems or concerns with existing processes which may necessitate modification for use on the PSS will be identified and the planned approach for adaptation will be described.

4.2.6.5 Material Control - Material Control will be responsible for the preparation and issue of all purchase requisitions and will maintain the status of all procured material and parts. They will review engineering for material and procured parts requirements and establish availability data. They will consult with the design engineer on substitute materials and parts based on stock availability or off-the-shelf procurement. Material Control is the single-point for all project matters concerning material and procured parts.

4.2.6.6 Cleanliness Control - The C&D panel structures will be fabricated in a general factory environment. All faying surfaces and "blind" areas will be cleaned prior to the electronic assembly process. On completion of assembly, all surfaces of these assemblies will be cleaned to upgrade them for compatibility with the class 10,000 clean final assembly and test work area. All external surfaces will be cleaned to a cleanliness level 300, and a nonvolatile residue level "A" as specified in NASA specification SN-C-0005.

4.3 Test and Verification - The goal of the test and verification program is to demonstrate through component, subassembly, and system level tests and verification methods, that the PSS core hardware will satisfactorily accomplish their mission functions. The test program described herein encompasses qualification and acceptance testing from components through system level acceptance of the PSS C&D equipment. This section also contains an overview of the test program management plan and describes the (MMC) approach to test program control. A general flow diagram and schedule of the PSS C&D test program is shown in Figure 4.3-1.

4.3.1 C&D Test Program - This section describes the Test Program from qualification and acceptance of C&D components through PSS C&D system acceptance. The specific subjects addressed in this section are: Test Analysis and Requirements, PSS C&D Component Test Program, Panel Assembly and Test, and PSS C&D Systems Test.

Each C&D component will be subjected to the applicable tests identified in paragraph 4.3.1.2, with further detailed requirements to be contained in each component end item test specification supplied during Phase C/D. The C&D components will be installed on subpanels with certain "in-line" tests performed such as insulation resistance, and ground isolation. The subpanels will be assembled and integrated into the major panels, followed by functional tests to verify the operation of each panel using bench test equipment. Following the panel functional tests will be a systems test using GSE and ground test software . At the completion of this phase of testing with the C&D hardware together with its MFDS processor software and the GSE together with its ground test software will be shipped to MSFC for a final acceptance demonstration test at the SDL.

4.3.1.1 Test Analysis and Requirements - Engineering analyses and studies will be conducted to develop the verification program, and identify the optimum test approach. The need for incremental step-by-step verification of piece parts through systems level testing will be evaluated. Verification concepts and CEI specifications will be updated and coordinated with NASA. Detail component test requirements and specifications will be finalized, resulting test procedures will be reviewed and test data/results will be evaluated. Selected component testing will be monitored from the standpoint of providing real-time engineering support.

The PSS verification planning and the test requirements and specifications will be developed and will identify the test hardware and software

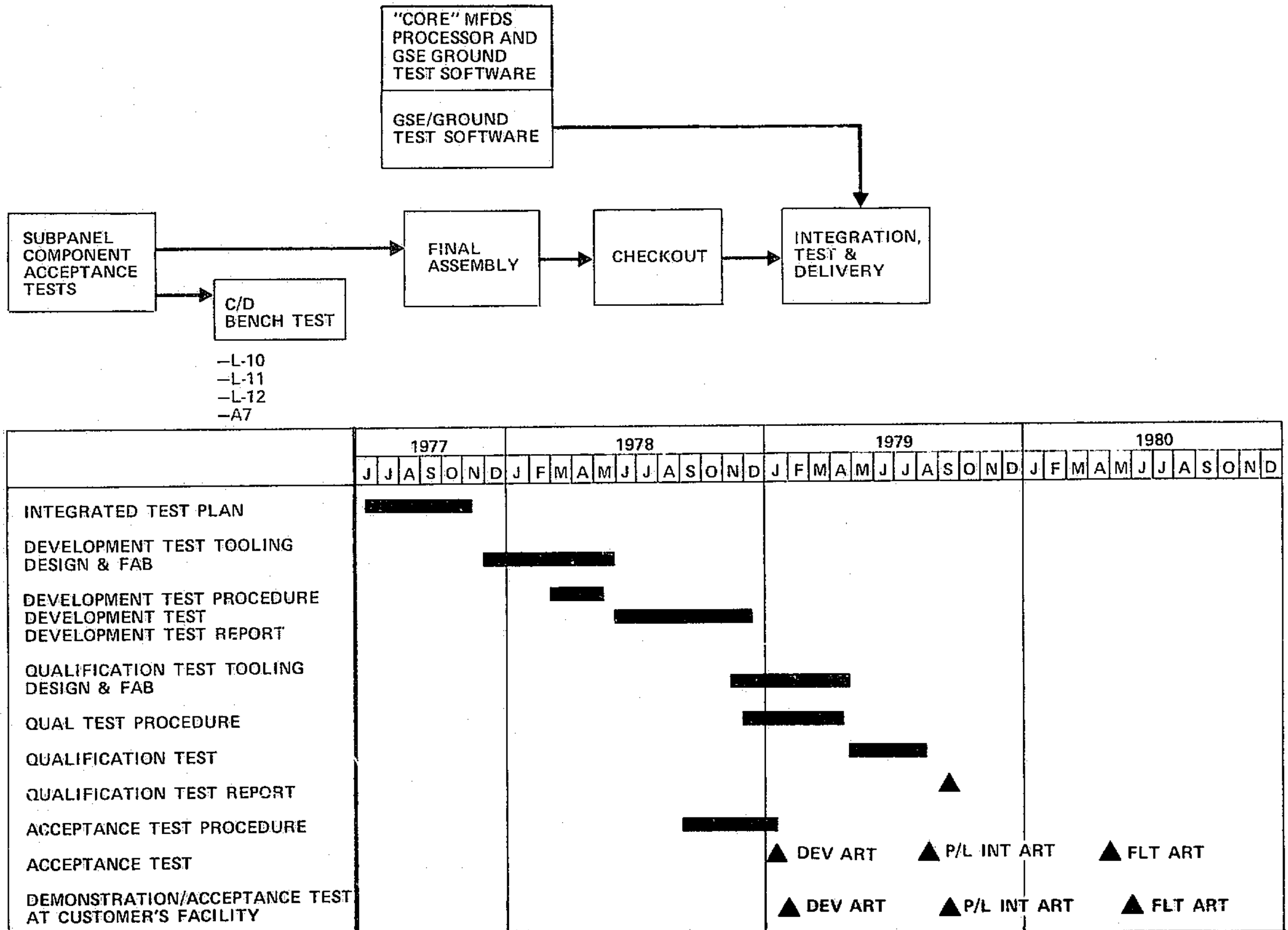

FIGURE 4.3-1 PSS FLOW DIAGRAM AND SCHEDULE

required for the planned test program. Test procedures will be developed to properly exercise the PSS C&D system elements. Test personnel and the test data/results reviewed and analyzed for compliance with design specifications. Engineering personnel will also support any test anomaly/problem resolution activity. Test results will be coordinated with the COR to obtain concurrence that the PSS core system meets its performance requirements. Test reports will be written to document testing results. Experienced engineering personnel in each discipline will provide technical support to the test activities during assembly, functional and environment testing.

4.3.1.2 PSS C&D Component Test Program - The MFDS will be a major subcontract procurement against the CEI specification developed during the PSS C&D study. The MMC program includes a resident engineer at the subcontractor facility to conduct liaison and insure technical and programmatic compliance. Initial acceptance testing will be conducted at the subcontractor's facility; a systems level test will be conducted at the MMC facility utilizing the GSE and ground test software; the final acceptance test will be conducted at a NASA facility.

The MMSE consists primarily of RI STS-qualified C&D components; however, behind the panel electronics will be designed, developed, manufactured, and tested in the MMC facility. Phase I procurement requires event timer electronics and a DC to DC converter; Phase II procurement requires I/O electronics necessary to interface with a Spacelab computer. Initial acceptance testing of this hardware will utilize the GSE simulating analog, digital, and discrete signals.

4.3.1.3 Panel Assembly and Test - Each PSS panel comprising the core C&D, panels L-10, L-11, L-12, A-7, R-12, will be qualified to the Orbiter AFD environmental specifications. Structural compliance with the GFE PSS rack structure, weight limitations for AFD panels, and compliance with the thermal cooling capability will be demonstrated during the test program. Thermal maping of the panel front faces (touch temperature considerations) will be verified by actual test readings.

Each PSS panel will be capable of acceptance testing with the GSE utilizing the ground test software program. The test philosophy will utilize an interactive computer checkout technique to verify each C&D command and display function.

4.3.1.4 PSS C&D Systems Test - The MFDS and elements of MMSE have three systems interfaces--the Spacelab computers via redundant data buses, a Spacelab RAU, and hardwired to the PSS bulkhead through the PSS distribution panel. The GSE and ground test software must be capable of duplicating the data bus interface and respond to commands from the PSS C&D equipment relative to test displays. The GSE developed during Phase I will be capable of supporting the total MMSE checkout, including the MMSE equipment delivered during Phase II.

The ground test software will be developed in two parts for the Phase I and Phase II procurement. It will verify the command and display capability of the PSS core equipment utilizing an interactive computer checkout technique. The GSE will include the Spacelab RAU functions to allow the PSS core equipment to be functionally verified without the RAU flight hardware. Figures 4.3-2 and -3 illustrate key factors in the PSS test effort.

4.3.1.5 Tools, Simulators, and Test Fixtures - Test hardware which interfaces with flight hardware will be controlled by tooling drawings and design reviews. Before use in flight hardware testing, such items will be physically and functionally inspected to verify configuration compatibility and assure that damage will not result through tool usage.

4.3.2 Test Program Management, Planning and Controls - Prime responsibility for articles undergoing test at Denver will be the responsibility of the Test Program Manager. Schedules will be generated for each phase of the test program, with continuous monitoring and update as required. Both long range and day-to-day activities will be scheduled to provide the visibility required to maintain a smooth flow of operations. All test team members will receive adequate training to enable them to perform their tasks in a safe, professional manner. Individual certification requirements will be monitored and maintained current. The testing organization will employ a disciplined operating

PSS COMPONENT NOMENCLATURE	PROCUREMENT & QUANTITIES				CONFIGURATION			TEST AS A PART OF C&D ASSEMBLIES			
	MAKE OR BUY	DEVEL	QUAL	FLIGHT	AS IS	MOD	NEW	FUNCTIONAL	VIBRATION	THERMAL	EMC
PHASE I											
MULTIFUNCTION DISPLAY SYSTEM	B	1	1	1			X	X	X	X	X
MMSE											
LOCKED SWITCHES, 2 POSITION	B	12	12	12	X			X	X	X	X
MOMENTARY SWITCHES	B	20	20	20	X			X	X	X	X
3 POSITION SWITCHES	B	4	4	4	X			X	X	X	X
2 POSITION SWITCHES	B	1	1	1	X			X	X	X	X
STATUS INDICATORS	B	10	10	10	X			X	X	X	X
EVENT TIMERS	B	2	2	2	X			X	X	X	X
ROTARY SWITCH	B	1	1	1	X			X	X	X	X
MANUAL POINTING CONTROLLER	B	1	1	1	X			X	X	X	X
GSE	B			2*		X		X			
PHASE II											
MMSE LOCKED SWITCHES, 2 POSITION	B	18	18	18	X			X	X	X	X
MOMENTARY SWITCHES	B	11	11	11	X			X	X	X	X
STATUS INDICATORS	B	15	15	15	X			X	X	X	X
5 DIGIT DISPLAYS	B	2	2	2	X			X	X	X	X
ROTARY SWITCHES	B	6	6	6	X			X	X	X	X
LED DISPLAYS, NOMENCLATURE	B	6	6	6	X			X	X	X	X
POTENTIOMETERS	B	5	5	5	X			X	X	X	X
ANALOG METERS	B	3	3	3	X			X	X	X	X

*2 SETS OF GSE
1 SUPPORT TRAINING AT MSFC
1 SUPPORT P/L INTEGRATION AT KSC

**SPARES NOT SHOWN -- ONLY CRITICAL ITEM SPARES WILL BE IDENTIFIED AS A PART OF LOGISTIC SUPPORT ANALYSIS IN PHASE C/D

FIGURE 4.3-2 PSS PROGRAM C&D & GSE REQUIREMENTS

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FUNCTIONAL PERFORMANCE TEST (1, 2 & 3)

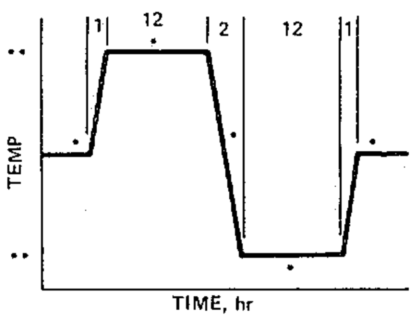
- VERIFY COMPONENT MEETS ELECTRICAL AND MECHANICAL REQUIREMENTS
- ELECTRICAL TEST TO INCLUDE VOLTAGE, CURRENT, FREQUENCIES, PULSES, ETC, AND VARIATION OF PARAMETERS ACROSS SPECIFIED RANGE.
- MECHANICAL TESTS TO INCLUDE OPERATION, DEPLOYMENTS, ETC.
- FUNCTIONAL TEST PERFORMED BEFORE, DURING, AND AFTER EXPOSURE TO ENVIRONMENTS, AS APPLICABLE.

VIBRATION TESTS (1, 2 & 3)

- RANDOM VIBRATION AT DEVELOPMENT AND QUALIFICATION LEVELS VERIFY COMPONENT CAN WITHSTAND RANDOM VIBRATION ENVIRONMENT.
- RANDOM VIBRATION AT ACCEPTANCE TO DETECT LATENT MANUFACTURING AND MATERIAL DEFECTS.
- RESONANCE SURVEY DURING DEVELOPMENT AND QUALIFICATION TO DETERMINE RESONANT CONDITIONS.
- SWEEP THROUGH FREQUENCY RANGE FROM 5 TO 2000 Hz AT A 1g PEAK.

THERMAL VACUUM (1, 2 & 3)

- VERIFY COMPONENT CAN WITHSTAND THERMAL VACUUM ENVIRONMENT.
- FUNCTIONAL TESTS AT MISSION EXTREMES AND DURING TRANSITIONS.
- CORONA CHECKS DURING CHAMBER PUMPDOWN.
- COMPONENTS EXPOSED TO A MINIMUM OF THREE CYCLES.

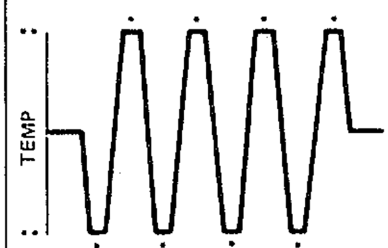


*FUNCTIONAL CHECK AT AMBIENT AND 1×10^{-5} TORR, CORONA CHECKS AT 1×10^{-4} TORR.

**WORST CASE TEMPERATURE WITH SAFETY MARGIN.

TEMPERATURE CYCLING (1, 2 & 3)

- DETECT LATENT MANUFACTURING AND MATERIAL DEFECTS.
- ELECTRICAL PERFORMANCE TESTS PERFORMED AT AMBIENT AND AT MISSION EXTREMES.
- FLIGHT UNIT EXPOSED TO EIGHT CYCLES. DEVELOPMENT AND QUALIFICATION UNITS WILL HAVE 24 CYCLES.



*FUNCTIONAL TESTS

**WORST CASE TEMPERATURE

EMI/EMC (1 & 2)

- CONDUCTED EMISSIONS ON POWER AND SIGNAL LINES.
- SUSCEPTIBILITY TO ELECTROMAGNETIC ENERGY INJECTED ON POWER LEADS.
- RADIATED ELECTROMAGNETIC EMISSIONS.
- SUSCEPTIBILITY TO EXTERNAL RADIATED ELECTROMAGNETIC EMISSIONS.
- TEST LEVELS AND PROCEDURES PER MIL-STD-461A.

TEST CODE

1. DEVELOPMENT
2. QUALIFICATION
3. ACCEPTANCE

FIGURE 4.3-3 COMPONENT TEST DESCRIPTION

procedure for controlling, defining and documenting all test work that was not previously defined in process plans or procedures.

4.3.2.1 Test Controls - Project Management will provide the following test program control functions:

a) Define and approve test work to be accomplished.
b) Define the form of approval for all proposed test work.
c) Review and approve detailed plans prepared by testing organizations for the enforcement of the test control disciplines.
d) Define the type of test work inspection following work accomplished.
e) Plan and conduct test readiness reviews as deemed necessary.
f) Define any special considerations.
g) Ensure that work specified in the test plan is performed.
h) Maintain documentation required to control the work sequence and the hardware configuration.

4.3.2.2 Procedures - The test procedures developed from the test requirements and specification documentation will be formatted for use during integration test.

4.3.2.3 Readiness Reviews/Procedure Control and Reporting - Procedures will be available for review 30 days prior to start of test and/or usage of the procedure. Contractor project approval by his responsible design, quality, and safety personnel shall precede procedure release.

Prior to starting a test sequence, the contractor will convene a test readiness review meeting. Members of the test review committee, including personnel from test engineering, safety, test operations team, and responsible subsystems engineers, will conduct the review. This group will review the test procedures to be performed, the readiness status of test facilities, the adequacy of test fixtures, the capability of assigned personnel, and the safety considerations imposed on the tests.

4.3.2.4 Test Reports - A report will be prepared by the testing agency which describes the results of the test activity conducted. The test report will include the test procedure(s) and contain the general additional information outlined below, as applicable:

a) Tabular Summary of Test Results
b) Brief Discussion of Test Results and Failures
c) Functional Data Sheets
d) Environmental Data
e) Vibration PSD Plots
f) Temperature Log Sheets
g) Photographs
h) Failure Documentation and Failure Analysis Reports

All test reports shall be reviewed and approved by the responsible engineer. Test reports shall be submitted with the Monthly Technical Progress Report.

4.3.2.5 Test Data - All test data, including facility data, procedure data, log books, commands transmitted, and telemetry received, shall be recorded to permit post-test analysis, accumulate trend data, and to provide a data base for subsequent test or anomaly investigation. Time and cycle records shall be maintained as required by the Quality Assurance Plan.

4.3.2.6 Calibration - The instruments and test equipment used shall be calibrated in accordance with the requirements of MIL-C-45662. Quality Assurance shall verify the current calibration of all equipment prior to test start.

4.3.2.7 Cleanliness Control - Spacecraft cleanliness control shall be maintained during test activities in accordance with the requirements defined in the opeational checkout procedures. Clean room discipline will be controlled by Quality Assurance personnel in accordance with the Quality Assurance Plan.

4.3.2.8 Safety - Analyses of operation functions will be performed to determine safety requirements for personnel, procedures and equipment which will be used in the installation, maintenance, support of test operations and equipment. Results of these analyses will provide a basis for design changes where feasible and inputs to test operating and maintenance procedures. During testing, safety regulations and precautions will be observed as stated in the Safety Plan.

4.3.2.9 Test Anomalies - Anomalies which occur during testing shall be resolved before proceeding with scheduled tests. All test anomalies will be documented.

4.4 Quality Assurance and Safety - This section consists of two parts. The first part starts with paragraph 4.4.1 and addresses the PSS program tasks that relate directly to the Work Breakdown Structure. The second part starts with paragraph 4.4.4 and provides a discussion of the Quality Assurance and Safety functions that will be included in the appropriate Phase C/D program plans. This second part outlines the ways we will satisfy the specific requirements of NHB 5300.4(1D-1).

Quality and safety activities will begin during the design and development phase and will be maintained throughout the program to provide a series of checks and balances during procurement, design, fabrication, test, launch and ground operations to ensure a safe quality product.

Figure 4.4.-1 provides a general program overview depicting the activities with Product Assurance involvement.

The following "Low Cost Concepts" will be implemented to the maximum extent possible within the guidelines of NHB 5300.4(1D-1):

Collocated Project Team - Quality Assurance and Safety personnel will form an integral part of the PSS team. This will allow for the early development of solution-oriented project teams. This team will physically be located in the hardware work areas.

Experienced Personnel - Personnel assigned to the PSS project team will possess the background and maturity to accomplish their assigned tasks with a "low-cost attitude", yet will maintain the disciplines necessary to complete these tasks in a safe manner with high quality standards.

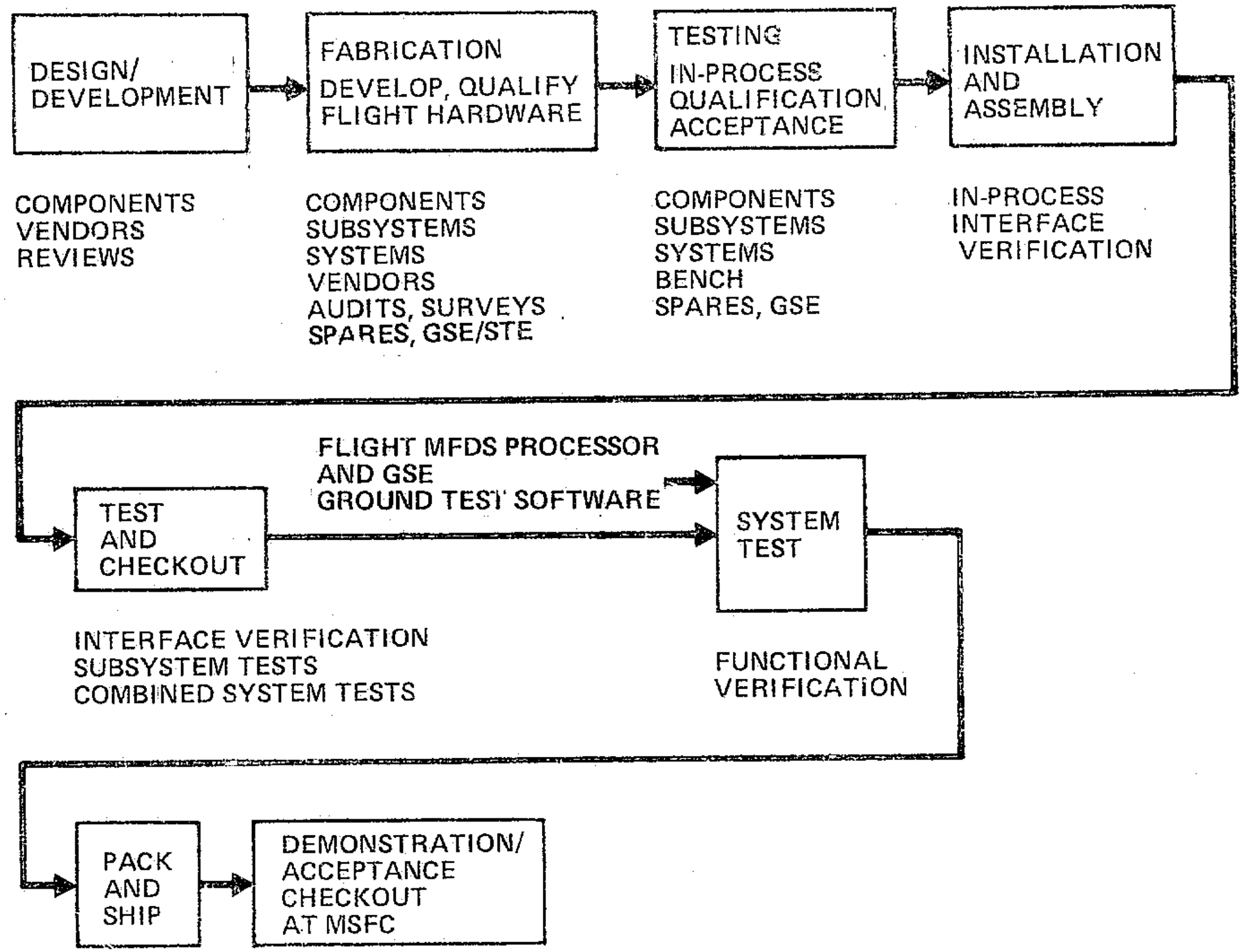


FIGURE 4.4-1 PROGRAM FLOW

Dedicated Project Shop - Special areas within the Denver Facility will be assigned to the PSS project for fabrication, assembly and test. Work effort can be accomplished very efficiently within these areas due to the reduction in written communications. The project teams will collocate in these areas until the completion of the specific task being conducted in that area.

Minimum Documentation - The collocation of experienced project team personnel in the various dedicated project areas allows many problems to be resolved with a significant reduction in documentation. Drawing changes can be accomplished within the working sphere of the project team with greatly minimized liaison. Extreme care will be taken, however, to retain any historical significance in the fabrication and test data that would have a long range impact important to any downstream activity.

Soft Tooling - Shop aids and fixtures will be designed consistent with the fabrication and assembly of three articles. That is, whenever practical, the material selected during the design of the fixture will be determined for its minimal durability and not for long term, high production rates.

Task Manager Philosophy - The lead designer in discipline will be designated as the Task Manager for that particular subsystem. In this capacity, he will be accountable for the budget, schedule, and performance of his portion of the PSS system. The standards and controls specified in the Quality Assurance and Safety Plan will be administered uniformly across all system areas.

Integrated Design/Test Teams - Engineering, Manufacturing, Test, Quality Assurance and Safety personnel will originate on the design and development team. These same personnel will carry their experience and technical knowledge into the assembly and checkout.

4.4.1 PSS C&D - The fabrication of subpanels and panels will be accomplished in accordance with approved manufacturing work instructions. Production inspection flow charts identifying required processes, tests, and inspection points will be developed and used to control these operations. Qualification and end-item tests will be witnessed by Quality Safety to assure tests are run in accordance with approved procedures, equipment logs are maintained, nonconformances are documented and inspection check points are completed. Quality will review and accept the overall acceptance data package prior to submitting it for acceptance. End item data packages will be prepared for each end item required by contract.

4.4.1.1 Assembly and Test - Quality engineers, safety engineers and test inspectors will be assigned to the PSS C&D assembly and test team to provide surveillance during the assembly and test operations. Assembly operations will be accomplished to approved processes and tests conducted to approved test procedures. Where applicable, the results of Failure Mode Effects Analysis (FMEA) will be used to establish inspection test points to verify design criteria are maintained. Quality will assure that test results and nonconformances are documented, reported and available for review at time of acceptance.

4.4.2 GSE/STE and Test Tools - The Quality program designed for the fabrication, test and use of the GSE/STE and test tools will be identified in a section of the Quality Plan. Maximum use of the "quality assurance designee" concept will be used where it is economically advantageous and can be implemented with little or no program risk. In-process inspections will be selectively applied on an audit basis with the primary quality controls concentrated during test to verify that the intended fucntional requirements and interfaces are maintained. Functional testing at the assembly level, rack or equivalent, will be witnessed and accepted by Quality. Hardware general checks will be performed before and after test. Integration and checkout of the GSE/STE with flight hardware will be witnessed by Quality.

4.4.3 Spares - Since spares for the PSS C&D will be components which have been qualified, they will be treated as flight hardware and will receive the identical quality controls from time of receipt or fabrication until they are installed for use.

4.4.4 Refurbishment, Test and Checkout - Quality Assurance and safety will assure that operations associated with the disassembly, refurbishment, test and checkout of designated articles are documented, inspection points established, required environments maintained, nonconformance documented and retested and acceptance criteria satisfied prior to acceptance.

4.4.5 Safety - The responsibility for identification and elimination or control of hazards associated with the design, development, and testing of PSS C&D hardware is inherent in the role of management and all technical organizations. The PSS safety program has been established in recognition of the need for systematic and effective methods to coordinate the efforts of all technical organizations in order to ensure timely identification and implementation of safety criteria and requirements, and to minimize oversights that could contribute to systems failure or loss, equipment damage, or injury to personnel. The safety program, as outlined herein, will be further defined in the PSS Program Safety Plan and implemented as an integral element within the total systems engineering and management process throughout all phases and activities of the project. The safety program will be implemented in accordance with requirements defined in NHB 5300.4(1D-1) and established safety policy as defined in Martin Marietta Operating Instruction PO-6-(1)-D1.

4.4.5.1 Management and Organizational Approach - The Denver Division's centralized safety organization consists of a single safety department whose functions and responsibilities encompass all aspects of safety including safety management, system safety engineering, test and operations safety, and occupational safety and health.

A PSS Project Safety Engineer will be assigned to perform comprehensive planning and analysis, and to ensure that all safety criteria and requirements applicable to flight and ground hardware and operations are identified and implemented throughout the contract period of performance. The Project Safety Engineer will be responsible for directing the PSS design, development, fabrication and test safety effort, and serve as the focal point for all safety matters pertaining to the project. Through the Project Safety Engineer, the combined experience of Denver Division safety personnel will be available to the PSS project. The primary benefit of this organizational approach, coupled with detailed planning and scheduling of safety tasks, is to provide the PSS project with the most appropriate safety personnel to perform phase-related or specialized tasks while maintaining continuity and visibility of overall safety program activities and status.

4.4.5.1.1 System Safety - Hazard identification and analysis activities will be performed for C&D equipment and GSE. These activities will be keyed to overall project design and development schedules in order to provide maximum effectiveness in the elimination or control of hazards in accordance with the established hazard reduction precedence sequence defined in NHB 5300.4(1D-1). This approach also provides effective utilization of manpower through establishment of safety task priorities through a building block concept. Inherent hazards associated with the various system elements and operations (energy sources, environments, etc) will be identified and documented. Based on the results, safety design criteria and requirements will be identified for immediate use by contractor project engineering organizations, and priorities will be established for more detailed analyses to be subsequently performed. This will provide the design organizations with safety criteria which can be used to minimize oversights and assure maximum safety consistent with program objectives and cost constraints designed into the system prior to design release to manufacturing. The hazard identification and analysis effort will use, to the maximum extent, the outputs of other activities such as systems design analyses and FMEAs. Specialized safety data used in support of this effort will include both Government and MMC Safety Standards, Manuals, Handbooks and System Safety Checklists. Applicable safety criteria will be included in design specifications, procurement drawings, process specifications and similar documentation as appropriate.

In order to ensure an integrated effort throughout the project, all potential hazards, identified as level A and B in accordance with NHB 5300.4(1D-1) definitions, will be documented on hazard analysis worksheets and issued for coordination or action by appropriate contractor subsystem management or discipline specialists. Upon completion of this coordination and validation process, a formal tracking number will be assigned. All responses to actions will be reviewed by system safety personnel for adequacy in the elimination or control of identified hazards. At such time as a hazard analysis is completed to the point of closure in accordance with criteria as defined in NHB 5300.4(1D-1), or Conditional Closure as defined herein, hazard analysis worksheets will be updated to include the disposition based on design changes, analyses, tests or other actions taken. The disposition of each hazard analysis will be formally approved by both systems engineering management and the project safety engineer. Hazard analyses will not be officially closed until the disposition has been approved by MSFC.

Conditionally Closed is a term used by MMC only for tracking purposes, as an aid in establishing priorities for effective use of manpower, and as a communications tool and management indicator of safety program performance. A hazard analysis is designated as Conditionally Closed when the primary analysis effort has been completed to the extent of identification and acceptance by systems engineering management and the project safety engineer of corrective actions which are considered necessary to eliminate or control an identified hazard, and for which final closure is dependent upon implementation of the corrective action or controls. An exception would exist in cases where system level verification or action would be required in order to resolve a hazard affecting interfacing hardware for which MMC is not responsible. At such time as a hazard analysis reaches a point of completion that it may be designated as Conditionally Closed, it will be approved by systems engineering management and the project safety engineer and submitted to MSFC with appropriate supporting data. This approach will provide MSFC with progressive visibility of hazard analysis activities and will provide a basis for precoordination and technical evaluation of anticipated closure action. Figure 4.5-1 is an

HAZARDS ANALYSIS

HAZARD CLASS	
STATUS	
PROGRAM PHASE	

NO.	
PAGE	
DATE	

SYSTEM:

OPERATION/PHASE:

HAZARD GROUP:

REFERENCES:

HAZARD DESCRIPTION:

POTENTIAL EFFECTS

ASSUMPTION/RATIONALE:

REQUIREMENTS:

DISPOSITION:

FIGURE 4.5-1 HAZARD ANALYSIS WORK SHEETS

example of the Hazards Analysis Weeksheets we will use in the PSS Preliminary Hazards Analysis.

Hazard analyses will be summarized in a project hazard catalog in order to provide visibility to management of all hazard analyses and their status in sufficient detail to eliminate the need to review detailed hazard analysis worksheets and supporting data. The Hazard Catalog will reflect risk decisions made by project management and will be structured to provide a quick reference to each hazard analysis by number, latest revision, date of issue, hazard description, original and current hazard level (will reflect progress achieved in elimination or reduction of risk), actions taken or in progress, and disposition. Also, the Hazard Catalog will reflect residual hazards and other pertinent data. The Hazard Catalog will be used as the primary document for tracking and statusing hazards and will be periodically submitted to MSFC as an input to major design and project milestone reviews.

4.4.5.1.1.1 Trade Studies - Directives are issued defining scope of effort, requirements and responsibilities for the performance of formal trade studies. System safety personnel will progressively review documentation developed by trade studies to ensure safety requirements and considerations are factored into such activities. Trade studies involving significant safety considerations will require direct participation by system safety personnel.

4.4.5.1.1.2 Review and Evaluation of Changes - Design changes will be reviewed by system safety personnel to ensure that safety requirements are adequately considered, and to ensure that potential hazards which may be introduced by the change are identified. Changes affecting the previous safety status of the hardware or invalidating or otherwise affecting the technical accuracy of closure rationale for hazard analyses which may have been previously submitted to MSFC will be either reopened or updated to reflect such changes and resubmitted to MSFC.

4.4.5.1.2 Industrial Safety - Continuous maintenance of safety standards, a safety procedures and requirements manual, and an accident-incident investigation handbook by the Denver Division central safety organization will provide up-to-date information for use by the project safety engineer and area safety engineers throughout the PSS program. Existing safety policies, standards, requirements and procedures are in compliance with NHB 5300.4(1D-1) and MSFC requirements governing such aspects as accident-incident investigation and reporting.

A Denver Division internal audit program is implemented to ensure compliance with the standards imposed by the Occupational Safety and Health Act (OSHA). The Denver Division complies with all applicable aspects of OSHA, including conformance to State plans and their attendant standards.

The Denver Division maintains its own fire protection organization, which includes facility equipment, vehicles, and personnel on duty 24 hours a day, seven days a week. All ordnance, chemical and other hazardous material storage areas, as well as manufacturing, test and office work areas are protected by either automatic fire detection and suppression equipment or by design, location, and 24-hour security surveillance, or both, as appropriate. Comprehensive procedures, training, auditing and maintenance are major elements of the Denver Division's fire protection and security program.

Some specific safety tasks to be performed during the PSS design and development phase, which will be further defined in the Project Safety Plan, are as follows:

a) Review and approve tooling designs.
b) Review training requirements, identify project peculiar safety requirements, and ensure implementation of training and certification requirements for personnel involved in such activities as fabrication, assembly, crane operations, handling transportation and storage of hazardous high cost or mission critical hardware.

c) Review and approve purchase requisitions and/or shipping requests for hazardous materials.

d) Review and approve manufacturing processes.

e) Perform monitoring and surveillance of manufacturing, test, product handling, storage, and office areas to ensure adherence with safety standards and requirements.

4.4.5.1.3 Test and Ground Operations Safety - Test plans, specifications and requirements documents will be reviewed and evaluated to ensure adequate tests are specified for materials, systems, subsystems, and critical devices or components under all anticipated environments. These reviews will ensure tests are adequate to determine such factors as degree of hazard or margin of safety in design. These reviews and evaluations will be an integral function of the progressive performance and refinement of FMEAs and hazard analyses. Requirements for special safety tests will be identified as required.

Ground support equipment will be evaluated for planned ground operations and tests in order to identify hazards to personnel, flight or flight-type hardware, ground support equipment and facilities. Special emphasis will be given to ensuring protection of flight and flight-type hardware, from damage which could be caused by human error or ground equipment malfunction.

Procedures to be used for testing PSS C&D hardware, and other procedures involving hazardous operations or tests as determined by review and evaluation of test data and performance of hazard analyses, will be reviewed and approved by safety personnel prior to their use. Tests and operations determined to be hazardous will include prerequisite requirements for safety surveillance or direct participation by safety personnel as a member of the test team, as appropriate. Testing will be performed only by approved procedures. Safety personnel will review and approve all changes to procedures.

4.4.6 Quality Assurance

4.4.6.1 Management, Planning and Training - For Design and Development Phase C/D of the PSS program, the quality plan which follows has been developed to define and describe the quality assurance functions which will be implemented to assure the quality and reliability of the PSS core C&D hardware. The scope of the plan encompasses all aspects of the program beginning with preliminary design and continuing through acceptance. The plan will also provide for the early detection, documentation and analysis of nonconformance and anomalies and for timely and effective remedial and preventive action.

4.4.6.1.1 <u>Organization</u> - All quality assurance operations will be managed and controlled by the Product Assurance Manager. Reporting directly to the Program Manager, he will have both the responsibility and the authority to evaluate quality problems and initiate solutions.

4.4.6.1.2 <u>Quality Plan</u> - The Quality Plan will be the primary governing and planning document controlling quality assurance activities. The plan defines the quality tasks to be performed throughout the contract, describing the controls to be implemented to assure that all hardware and software meet engineering and contract specifications. The detailed instructions are contained in MMC Standard Procedures and Quality Procedures which will be available for customer review. Revisions to these procedures, where needed to implement requirements unique to the PSS program, will be prepared and released as program-unique appendices or as Program Procedures. Procedures that define or require customer involvement will be available for customer evaluation. Quality assurance requirements unique to an off-site operation such as MSFC or KSC will be addressed in appendices to the Quality Plan, to be developed after contract go-ahead.

4.4.6.1.3 <u>Quality Controls</u> - Management control of quality assurance operations will be achieved through the implementation of MMC Procedures and Standards. Standard Procedures describe management techniques and systems to be used in conducting the company's business and generally affect all departments of the company. Quality Procedures define and describe the policies, systems, methods and responsibility assignments through which the Quality Department assures satisfaction of the quality requirements of the contract and the company. Quality Technical Instructions provide Quality personnel with uniform instructions where standardized methods are necessary. The Workmanship Standards Manual augments company acceptance criteria for workmanship where the basic measure of quality is largely subjective. Quality requirements imposed on in-house operations and on suppliers are tailored to the requirements of the specific item to be produced or procured by:

a) Insertion of specific inspection requirements in fabrication plans and test procedures;
b) Issuance of program-unique Program Procedures and Quality Procedure appendices;
c) Issuance of Quality Project Directives approved by the Product Assurance Manager;
d) Quality requirements coding of purchase requisitions.

4.4.6.1.4 <u>Nondestructive Evaluations (NDE)</u> - Specific nondestructive evaluation requirements and techniques will be identified during the preliminary design review. Design, Manufacturing and Quality engineers will participate. This group constitutes our NDE review board and formulates NDE development planning.

Standard Procedures and Quality Procedures identify people certification requirements, process validation and equipment controls and validations, including all processes as well as NDE.

For NDE we have specific Quality Technical Instructions (QTI) which specify general NDE. Special NDE requirements are specified in the engineering drawings. The requirements are met by specific Quality Laboratory procedures which include the fabrication of special standards, specific equipment, and controls, operational instructions and special people certification requirements. These procedures require the use of enough samples to demonstrate that we have inspection reliability and confidence to the level of program requirements.

4.4.6.1.5 Management Assessment Data - Quality management assessment data will be presented periodically to the NASA as requested. The data will include significant accomplishments, problem areas, corrective action status, quality costs, test/inspection status, significant material review actions, and a summary of supplier quality activities. Other quality data will be available for review upon request. Special emphasis will be placed on reviewing all appropriate data before starting production activities, if significant periods of time elapse between production operations.

4.4.6.1.6 Training - Personnel controlling critical processes or performing critical operations will be trained and certified. A Skills Training and Certification Committee will be established for the program, which will determine the requirements for certification of any employee skill and the tasks to be certified. The committee will include representatives from Quality, Systems Safety, Manufacturing and Test, Engineering Training and Certification, and Professional and Industrial Relations (Medical). Satisfactorily trained employees will be issued personal certification cards as evidence of certification. Recertification will be required on a scheduled basis, or whenever processes or techniques are changed, performance is unsatisfactory or the allowable time period for nonperformance has expired. Records of the training, the testing and the certification status of employees will be maintained by the training organization and audited by Quality.

4.4.6.1.7 Quality Program Audit - The existing audit program will be utilized for the PSS program. They include a division-wide, systematic appraisal of operational performance to assure that management objectives, contract commitments, product integrity, and mission objectives are successfully and effectively achieved. Also, a Quality Department self-audit program, which complements the Division audit program, is performed within Quality and of Quality's interfaces with other departments. This audit program reviews applicable company procedures for compatibility with contractual quality requirements, to verify that the Quality Department is, in fact, complying with these procedures and contract requirements. These audit programs are planned and scheduled. Results are documented, and reviewed by upper management. In addition, unscheduled audits are performed at the direction of upper management to provide instantaneous assessment of performance or to determine the magnitude of a real or potential problem.

Auditing of supplier activities is normally conducted concurrent with source inspection activities. This supplier audit program does not preclude unscheduled or special audits by program management personnel or others as the need may arise either to resolve a problem at the supplier's or to "audit the auditor".

4.4.6.2 Design and Development Controls - Quality engineers will review contract and engineering specifications, drawings, fabrication plans, test procedures and other technical documents. These reviews will assess the compliance level of program technical documents with established quality and design control criteria.

Quality personnel will participate in prerelease reviews of drawings and in the preliminary and critical design reviews with the NASA. In preparation for the preliminary and critical design reviews, Quality will review drawings and process plans, FMEAs, and the nonconformance history of similar systems, components and parts, using a checklist developed specifically for this purpose.

Prior to an acceptance review, the Product Assurance Manager will assure that the following items have been accomplished: evaluation of the end item acceptance test results; anomalies encountered; failure history, and remedial and preventive actions; status of all open work, including tests and identification of those which constrain further activities, such as integration or flight; identification of waivers and deviations to contract requirements and specifications, and verification of the basis for approval; status of limited life components and their remaining life; identification of shortages, open work items, and the schedule for completion; development of a form DD250 indicating shortages and deficiencies which must be resolved prior to further activities, such as flight readiness; verification that departures from specifications and drawing requirements have been processed; verification that all data packages and support manuals for the operational checkout, and maintenance of the end item are complete, compatible and accompanying the hardware, and that all shipping requirements have been met.

4.4.6.3 Identification and Data Retrieval - Identification and data retrieval systems have been developed which are compatible with engineering documentation and configuration management systems and provide for identification to which procurement, fabrication, processing, inspection, test, and operating records can be related. The systems also provide the means for locating articles and materials in end items. When required by engineering drawings or procurement specifications, items will have identification traceable to their origin such as: manufacturer's data; date purchased; lot number; inspection and test data; or other pertinent information, as applicable. EEE piece part identifications will be recorded in fabrication records to permit tracing backwards from fabricated hardware to the manufacturing records for the piece parts. As required, limited life items, serialized components and other critical hardware identifications will be recorded in the fabrication records to allow traceability from the end item back to the tests performed, the test results, and the specific processes employed in the manufacture of each lot of parts.

4.4.6.4 Procurement

4.4.6.4.1 Procurement Controls - Responsibility for the overall planning and management of procurement quality activities is vested in the Product Assurance Manager. He will provide program direction for the detailed planning and implementation of the procurement quality activities for the program.

4.4.6.4.2 Selection of Contractor Procurement Sources - Quality will participate in the selection of suppliers of articles and materials procured to MMC drawings and specifications. Historical data from supplier quality performance reports, preaward surveys, and technical reviews will be used in the supplier selection process. Information supplied by the NASA will also be evaluated. Procurement sources for standard hardware and raw materials will be selected on the basis of the Approved Vendor List (AVL), Qualified Products List (QPL) or supplier performance records. Procurement sources for Military Specification parts will be selected from suppliers listed as qualified to furnish that part.

4.4.6.4.3 Procurement Documents - All purchase requisitions applicable to the program will be reviewed by Program Quality assisted by specialists from central Quality. Program Quality, from a review of drawings and other technical documents, from participation in design reviews, and from contract requirements will determine the quality requirements to be imposed on the supplier of each item. These quality requirements will be added to the purchase requisition by Program Quality. Quality will verify that the supplier has been selected in accordance with paragraph 4.6.4.2 above.

4.4.6.4.4 Quality Assurance Personnel at Source - Procurement Quality will provide source inspection at the supplier's facility as required. Source inspection will include, as appropriate, review of special processes, review of manufacturing/inspection plans and procedures, review of test plans and procedures, inspection and acceptance of hardware and test results, and verification of hardware documentation prior to delivery. Through their Perpetual Evaluation Program (PEP), our Quality Source Representatives will perform planned, continuing evaluation of the supplier's activities, which will provide documented control of product and processes.

A list of assigned personnel, duties, responsibilities and authorities will be supplied to the NASA and to the Government quality representative at the supplier's facility upon issuance of the Purchase Agreement.

Where other contractors of Space Shuttle hardware are purchasing similar hardware from a supplier under MMC Quality Procurement Representative surveillance, the services of our representative will be made available to the other contractors as may be mutually agreed upon.

4.4.6.4.5 Government Source Inspection (GSI) - GSI requirements will be determined by the designated government representative. He will make the appropriate entry on the purchase requisition. MMC recognizes its responsibility for the adequacy and quality of purchased items, notwithstanding any Government source inspection.

4.4.6.4.6 Receiving Inspection - All hardware and material procured for the program, and all GFE and GFP provided for the program will be inspected upon receipt at MMC by Receiving Inspection, a Quality Department organization. Inspections are performed to Receiving Acceptance Plans (RAP) written by Quality and developed from reviews of drawings and specifications and from the quality assurance and documentation requirements imposed upon the supplier.

Conforming items are identified by acceptance stamping the item or its associated documentation, and repackaging the item prior to release to a controlled stockroom. Metallic materials are not acceptance stamped. They are coded and acceptance is shown on the receiving report and the inspection record card. Nonconforming items are so identified, segregated pending disposition, and documented in accordance with paragraph 2.5.5.7, Nonconforming Articles and Materials.

4.4.6.4.7 Receiving Records - The Receiver (a copy of the Purchase Agreement) and the RAP constitute the primary receiving inspection and test records. Results are recapped onto inspection record cards which, by part number and supplier provide summary records of quantities received, dates inspected, and inspection results. Data from the records are used to generate supplier evaluation reports for management assessment of supplier performance.

Data packages received with procured hardware are reviewed for completeness and accuracy and, if acceptable, are retained by Program

Quality or the Quality Data Center.

4.4.6.4.8 Procurement Source Data - The summary records described in paragraph 4.6.4.7 above together with rejection history from other sources (e.g., source inspection) are compiled into a tab run keyed to supplier. A folder is also maintained for each supplier containing other information relative to the supplier such as PEP findings, survey results and the like. All of these data and records are available for use in the selection and qualification of procurement sources.

4.4.6.4.9 Post-Award Survey of Procurement Source Operations - Post-award surveys of suppliers will be conducted by Procurement Quality based on hardware criticality, complexity and problem history; Quality history of the supplier; supplier capability; and remaining period of performance of the Purchase Agreement.

4.4.6.4.10 Coordination of Contractor Procurement Source Inspections and Tests - The program managers will have primary responsibility for coordinating supplier and MMC inspections and tests. These managers will provide the technical requirements to be executed at the supplier's and at MMC. They will approve supplier and MMC test procedures and will furnish technical assistance as required.

4.4.6.5 Fabrication Controls

4.4.6.5.1 Fabrication Operations - Fabrication plans (Manufacturing Process Plans, Shop Folders, step tags, procedures, Work Authorization (MARS) will be used to control and document fabrication. assembly, installation, and inspection operations.

Fabrication plans and changes are reviewed and approved by Quality for compliance with engineering requirements and for inclusion of inspection check points, before release.

Fabrication plans become the historical record of fabrication, assembly and installation operations and inspections performed, and are maintained on file.

4.4.6.5.2 Article and Material Control - Articles and materials will be stored in controlled areas. Conforming items, or their containers, are acceptance stamped. Quality will verify that articles and materials issued against a fabrication plan are correct and conforming and that age- or use-sensitive items have sufficient remaining life or cycles. Limited life items are identified by date-of-expiration labels. Items requiring contamination control are environmentally protected and identified by tags indicating cleaning level status. Articles or materials requiring a temperature-controlled, contamination-controlled or other special environment for fabrication or processing will be inspected, tested, repaired or modified in a similar environment to the extent necessary to prevent quality degradation or deterioration of cleanliness level.

Life/time/cycle limitations will be recorded in the equipment log and nonconforming articles and materials will be so identified and segregated to the extent possible pending disposition. Quality will maintain surveillance of stockrooms to assure proper storage, documentation and identification of limited life items.

4.4.6.5.3 Cleanliness/Contamination Control - Contamination control specifications applicable to the PSS program will be defined in the engineering drawings, which will specify the pertinent Engineering Process Specifications (EPS). Instructions to personnel performing and inspecting cleaning operations are found in Manufacturing Processes (MP). They bear the same basic numbers as the related EPS. Fabrication plans and test procedures will call out the MPs to be used. Quality will enforce all contamination control requirements. Suppliers of contamination controlled hardware will have their cleaning operations and processes surveyed and approved in writing by MMC before cleaning operations begin.

4.4.6.5.4 Process Controls - Manufacturing processes, where the quality of the operation cannot be determined by inspection alone, and inspection processes such as radiographic inspection, dye penetrant inspection, or magnetic particle inspection, are defined in EPS. MPs define in detail the step-by-step operations to be performed, the tools required, necessary materials, special requirements, certifications, environmental controls, sample requirements, inspection requirements, and workmanship standards. MPs and revisions thereto are reviewed, validated, and approved by Quality before release. Applicable MPs and mandatory product inspection points are specified in fabrication plans.

Hardware integrity is assured by process control, by process sampling, and by nondestructive evaluation techniques. Overall hardware integrity definition, assessment, validation and applications are integrated into EPSs, MPs, and test procedures to meet program requirements.

Equipment used in special processes is certified by Quality when the process results depend upon equipment performance; e.g., heat treat equipment and clean room facilities. Qualification and recertification requirements are established in the EPS and MP. Recertification is also required when test results or inspections indicate a need for changes to the normal process or when equipment changes may affect the process. Certification records are maintained by Quality.

4.4.6.5.5 Workmanship Standards - Standards of workmanship have been developed for selected processes such as solderless connections, soldered connections, printed circuit board packaging, conformal coating, microelectronics assembly. These standards augment acceptance criteria where the basic measure of quality is largely subjective. Applicable workmanship standards will be identified by reference in MPs or fabrication plans and compliance with these standards will be a prerequisite to acceptance. Workmanship standards are updated as required and will be available for review by the NASA.

4.4.6.5.6 Control of Temporary Installations - Temporary installations will only be allowed by engineering drawing, fabrication plan, test procedure or MARS/DR. All temporary installations will be recorded in the equipment log and the entry will remain open until the temporarily installed item is removed. Any temporarily installed item which will remain installed at the time of shipment of the end item from MMC will carry a distinctive identification with visual impact and be recapped as an open item in the end item equipment log.

4.4.6.6 Testing, Inspections and Evaluation

4.4.6.6.1 Inspection and Test Planning - In order to demonstrate and verify that contract, drawing and specification requirements have been met for all deliverable hardware and software, the previously described Purchase Agreements, RAPs, fabrication plans, EPSs, MPs will provide a documented trail of written instructions and evidence of compliance from initiation of the Purchase Agreement through fabrication and assembly. The manufacturing flow plan which has been developed for the fabrication, assembly, integration and test operations will include inspection points at all levels. MMC Engineering, supported by Quality, will develop an integrated test plan which will identify all testing requirements including production in-line testing, acceptance testing, component testing and systems testing for the program. From this test plan and the appropriate test specifications, individual test procedures will be developed which will provide all of the detailed information and direction necessary to the proper execution of the tests. Testing of components, subpanels, the PSS core C&D system will be witnessed by Quality. Quality will verify hardware configuration prior to testing, will ensure the documentation of test failures, will witness troubleshooting and will approve corrective action taken to prevent recurrence.

4.4.6.6.2 Test Specifications and Inspection and Test Procedures - MMC will prepare and maintain test specifications and test procedures for those tests defined in the test plan. Test specifications establish the criteria for performance and acceptance of the tests; test procedures provide the detailed operations for test implementation and verification of criteria. All test procedures will be reviewed by Quality to verify incorporation of test specifications and general quality requirements. Quality approval of test procedures and procedure changes will be required before start of test.

4.4.6.6.3 Inspection and Test Performance

4.4.6.6.3.1 Inspection and Tests - The inspections and tests performed on deliverable hardware will verify compliance with requirements. Approved fabrication plans and test procedures will be used to control all inspection and test operations. Quality inspections will verify the acceptability of the fabrication operations and acceptance stamp applicable steps in the fabrication plan. Critical manufacturing and test operations in fabrication plans and test procedures will be stamped or signed by technicians. Test procedure certification sheets will be signed by the responsible organizations upon satisfactory completion of the test and closure of open items.

Hardware integrity will be strictly maintained during test. Rework, repair, modification, adjustment or replacement will not be permitted except as specified in controlling documentation. Test control and discipline is basically the responsibility of the testing organization, but will be closely monitored by Quality.

Environmental controls will be exercised when required to protect product qulaity or control contamination. In the event of nonconformance or test anomaly, documentation and control will conform to the requirements of paragraph 4.6.7, Nonconforming Articles and Materials. Reinspection and retest requirements will be included in the controlling documentation.

4.4.6.6.3.2 Qualification/Certification Tests - Program Quality will verify that qualification test hardware is ready for qualification testing through a review of fabrication and test documentation. This review will assure that:

a) The hardware is configured to the flight hardware baseline, or configuration differences are identified;
b) All required pretest operations are complete and accepted;
c) Nonconformance, deviations and waivers have been resolved/ approved;

d) The test procedure is approved and available;

e) All requried documentation is available.

Quality will monitor qualification testing to assure that approved test procedures are followed, equipment historical records are maintained, test equipment is currently calibrated, and nonconformances and test anomalies are documented and dispositioned.

4.4.6.6.3.3 <u>End Item Inspections and Tests</u> - The test plan will include the requirement for inspection and testing of completed hardware before delivery to the NASA. These inspections and tests will be performed to Quality-approved acceptance test procedures.

Nonconformances discovered before, during or after testing, and test failures and anomalies will be documented, dispositioned prior to succeeding operations and closed out prior to shipping. Testing will be stopped when safety of personnel is in jeopardy or when damage to the end item or test equipment appears probable. Any adjustment, modification, repair, replacement or rework after completion of end item inspection and acceptance test will require NASA approval. Such rework, repair or modification will be performed to MARS, or to fabrication plans which have been processed and approved in the same manner as the basic fabrication plans.

Functional tests will be performed on components prior to installation when required because of questionable component integrity, inability to verify component acceptability by subsequent testing, or potential system damage in the event of component failure.

4.4.6.6.4 <u>Inspection and Test Records and Data</u> - MMC Quality Department will maintain secure files of fabrication, inspection, and test records of articles fabricated by MMC and its suppliers. These records will provide documented evidence that the required inspections and tests have been completed, verified, and accepted by Quality. These records and data are traceable to the hardware and to the accepting Quality inspector. Ancillary data such as material laboratory analyses, test reports, supplier data, receiving inspection records, calibration records are maintained by the Quality functional organizations using or generating the data.

An equipment log will be initiated for each component, subsystem, system and the ST at the point of completion of fabrication which will contain the history of the hardware from that time, including major operations, storage, testing, modifications, rework, nonconformances and test anomalies and refurbishment. Time and cycle history will be recorded as applicable. Subsidiary equipment logs will be folded into the ST log at the time of integration.

An end item data package will be prepared for each end item, to include the data elements required by the contract.

4.4.6.6.5 Quality Assurance Actions - Quality will participate in testing activities. Prior to test start, Quality will verify that the test procedure has been approved; test constraints have been resolved; test equipment is currently calibrated; required personnel certifications are valid; verify configuration of the test hardware and the test equipment; notify the Government quality representative, as required; and concur in test start.

Quality will monitor or witness testing to assure that testing is accomplished in accordance with the test procedure; that data and test results are recorded; that rework, repair or modifications are documented; and that nonconformances and test failures and anomalies are documented and dispositioned.

Following the testing operation, Quality will ensure proper disposition of test hardware; ensure that remedial and preventive action has been accomplished relative to nonconformances; and ensure that test results are accurate, complete and traceable to the tested hardware.

4.4.6.7 Nonconforming Articles and Materials

4.4.6.7.1 Nonconforming Article and Material Control - Nonconformances of articles and materials will be documented and the item so identified, segregated to the extent practicable, and controlled pending disposition. The nonconforming hardware, and/or the accompanying documentation, as appropriate, will initially be identified as nonconforming by "D" stamping. A subsequent interlocked triangle stamp indicates that the hardware has been dispositioned. An interlocking acceptance stamp indicates reacceptance.

Articles that have received government acceptance will be treated as described in paragraph 4.6.10, Government Property Control.

Nonconforming hardware will not be shipped with an open nonconformance without prior government approval.

4.4.6.7.2 Nonconformance Reporting and Correction - A system will be used which will provide closed loop documentation for recording, reporting, analyzing, correcting, verifying and feeding back data on nonconformances, by whomever discovered. At MMC, the Martin Automatic Reporting System (MARS) is the form used for documenting, reporting, dispositioning, controlling, and providing corrective action for significant problems, acceptance test failures and anomalies, Material Review Board actions, and where a detailed engineering disposition is needed.

For nonconformances that do not require MARS action, the Discrepancy Report (DR) may be used. DRs may be used to describe conditions which require work, calibration, maintenance, and/or authorization for use of facilities, tooling and test equipment. Finally, DRs may be used to describe problems associated with documentation when hardware nonconformance is not involved.

At the discretion of the Quality supervisor, the Graphic Defect Identification (GDI) inspection form may be used to document defects in printed wiring board (PWB) assemblies which can be reworked to drawing requirements. The form consists of the PWB layout and a set of defect codes. Upon satisfactory rework, the form is acceptance stamped by the inspector and filed in the fabrication plan.

The MARS will be used exclusively during the operations phase of the contract. Nonconformances will be accumulated by Program Quality in summary reports to program management. Trends will be charted to detect adverse quality developments. MARS are reviewed by Quality supervision or Program Quality to assure the adequacy of disposition and corrective action. The DR and the GDI will also be reviewed by Quality for correct application, trends, and requirements for corrective action. If corrective action is required or unacceptable trends develop, Quality will initiate remedial action.

Failures will be assessed by Program Engineering and Program Quality for formal failure analysis requirements. Failure analysis reports will be approved by Program Quality. Functional nonconformances for which MMC recommends a disposition to repair or use as is, and the resulting condition adversely affects the requirements of the contract, will be submitted through the MMC Contracts Department for a waiver approval.

4.4.6.7.3 Material Review Board - A Material Review Board will be established for the program. The MRB will disposition all nonconformances submitted to it for MRB action.

The MRB will consist of one authorized MMC Quality member, one authorized MMC Engineering member, and the delegated Government quality representative. Manufacturing and other technical organizations may participate in MRB deliberations as consultants, but may not vote.

All MARS that have received full MRB action are considered to be material review records and are retained as such. The MARS is considered to have had full MRB action when the designated MRB members have signed in the appropriate blocks of the MARS.

4.4.6.8 Metrology

4.4.6.8.1 Metrology Controls - All inspection standards, gages, measuring and testing equipment, and tools necessary to determine conformance specification, drawing and contract requirements will be selected, evaluated, maintained and controlled.

The MMC Quality Department Metrology Laboratory and Gage Laboratory provide the facilities and the prime, secondary and working standards used to calibrate inspection standards, gages, measuring and testing equipment, and tools used to verify the quality of materials, supplies, products and processes.

4.4.6.8.2 Acceptance - Measuring and testing equipment and tools are inspected and calibrated as applicable before Quality acceptance. 'll new equipment and tools are entered into the mechanized property accountability system and those calibrated are added to the mechanized recall system. An initial calibration interval is specified by the Metrology Laboratory.

4.4.6.8.3 Evaluation - Measurement standards and equipment identified for use on the ST program will be evaluated by Quality for intended operating use to verify that the equipment will measure the characteristic to the required accuracy; the hardware to be measured and the measuring equipment are compatible; and operating instructions are correct and complete.

4.4.6.8.4 Article or Material Measurement Processes - Measurement process random and systematic errors will not exceed 10% of the tolerance of the characteristic being measured. Quality will verify that this accuracy requirement has been maintained during its review of process plans and test procedures.

4.4.6.8.5 Calibration Measurement Process - Calibration measurement process random and systematic errors will not exceed 25% of the tolerance of the parameter being measured, within the limitation of the state-of-the-art. Where this ratio cannot be maintained, measurement limits will be established so that they fall within a band defined by reducing the allowable tolerance by the estimated uncertainties of the measurement process. Where this is not feasible, authority for exception will be requested of the NASA.

4.4.6.8.6 Calibration Controls - All standards and measuring and testing equipments receive inspections and calibrations at regular intervals determined by instrument reliability, accuracy requirements and usage. Calibrations are performed to written procedures/instructions which define the specifications and tolerances, the standards and test equipment to be used, and test methods. A certificate is applied to each item of calibrated equipment indicating the date calibrated, next calibration due date, and the stamp of the technician certifying the calibration. If a deviation from calibration specifications is approved, the deviation will be stated on the calibration certificate.

4.4.6.8.7 Environmental Requirements - The calibration laboratories are environmentally controlled to ensure compatibility with the accuracy and design characteristics of the standards and equipment in the laboratories.

4.4.6.8.8 Remedial and Preventive Action - If a commercial test equipment exceeds one and one-half times its allowable tolerance limits as received for recalibration, the cognizant Quality Manager is notified. He will effect a review of the uses made of the defective equipment to determine what measurements are suspect because of the nonconformance.

4.4.6.9 Stamp Control - Inspection stamps, planning stamps and sealing devices will be used to indicate the acceptance status of articles, materials and documentation. MMC Quality stamps are instantly identifiable and traceable to the responsible individual. Quality stamps are controlled by Quality and records are maintained to account for all stamps. Retruned stamps and lost stamps are not reissued for a suitable period of time.

4.4.6.10 Handling, Storage, Preservation, Marking, Labeling, Packaging, Packing and Shipping

4.4.6.10.1 Procedures and Instructions Control - Special handling and transportation, storage, preservation, marking, labeling, packaging, packing and shipping requirements will be specified in the engineering drawings. These requirements will be reflected in purchase orders, fabrication plans, test procedures or special procedures. Quality will monitor these operations to assure compliance.

4.4.6.10.2 Handling - Besides handling requirements, engineering drawings will specify the handling fixtures and test fixtures to be used on the program. Necessary fixtures will be designed and built.

Fabrication plans and test procedures will spell out instructions for handling the hardware during integration, test, packaging, packing and shipping. Quality will monitor handling operations.

4.4.6.10.3 Storage - Articles and materials will be stored in dedicated, controlled areas. Quality will verify that environment-sensitive items are stored in suitable environments. They will also verify that the containers of age-sensitive items are so marked and that date of manufacture and life expiration date are clearly indicated. Special storage/maintenance/periodic inspection/periodic test requirements will be specified on engineering drawings and appropriate procedures generated for performance.

4.4.6.10.4 Preservation, Marking, Labeling, Packaging and Packing - Engineering drawings will specify the preservation, marking, labeling, packaging and packing requirements. These requirements will be reflected in fabrication plans, test procedures or special procedures. Quality will verify that all requirements have been satisfied.

4.4.6.10.5 Shipping - For all hardware shipped from MMC, Quality will verify that the hardware meets all drawing, specification and contract requirements, that all required fabrication, assembly, integration and testing is complete and acceptable, and that the hardware is in all respects ready for shipment. The documentation accompanying the hardware will be reviewed by Quality to verify that it is complete and has been accepted by Quality and by the Government as required. The documentation included in the shipment will be that specified in the contract.

4.4.6.11 Sampling Plans, Statistical Planning and Analysis - The use of sampling techniques will be limited to receiving inspection. Sampling plans used at MMC are based on MIL-STD-105D. No statistical analyses are planned for inspection operations.

4.4.6.12 Government Property Control

4.4.6.12.1 Contractor's Responsibility - Government property received at MMC will be controlled as specified in Standard Procedures and Quality Procedures.

Government property received at MMC will be processed through Receiving Inspection to Receiving Acceptance Plans (RAP) prepared by Receiving Inspection in accordance with direction from Program Quality. If an equipment log is not furnished with the GFP, a history sheet will be originated at Receiving Inspection to document the history of the hardware while at MMC and to record maintenance, calibration, and inspection. The GFP will be identified, if not consumable, and will be incorporated into MMC's property accountability system. GFP will be stored in the segregated, controlled program stockroom. Stock records will be initiated and maintained for accurate accountability.

4.4.6.12.2 Unsuitable Government Property - Any damage, malfunction, test failure or other GFP anomaly will be documented on a MARS and the MARS presented to the Government representative. If MRB action is requested by the Government representative, the MRB will perform MRB action and determine a recommended disposition. If the Government representative concurs, disposition will be effected as described in paragraph 4.6.7, Nonconforming Articles and Materials. If not, the Government representative will direct disposition of the hardware.

GFP will not be repaired, modified, reworked, replaced, or otherwise dispositioned except as authorized by contract or directed by the Government.

4.4.6.13 Flight Test/Ground Operations

4.4.6.13.1 Planning, Procedures and Procedural Controls - The flight test development program and associated ground operations will be controlled by procedures developed specifically for these operations, as described in paragraph 4.6.6, Testing, Inspections, and Evaluation. These procedures will be subject to the same review and approval by Quality as acceptance procedures. Quality will witness all testing operations to assure compliance with procedural requirements. Nonconformances and test anomalies will be documented on MARS which will be subject to the same controls and requirements as described in paragraph 4.6.7, Nonconforming Articles and Materials.

4.5 Reliability and Maintainability - Reliability and maintainability program will be implemented to insure the PSS core C&D meets STS requirements. This program will provide the necessary controls to assure identification and resolution of all potential critical failures and will assure achievement of the highest PSS reliability and availability at the least cost. Based on the requirements established during PSS study, and utilizing a Reliability Program Plan, which satisfies NHB 5300.4, adequate PSS reliability will be achieved.

The reliability/maintainability design criteria and requirements will be developed to ensure compatibility with the established STS maintenance policy.

A failure mode and effects analysis (FMEA) will be performed and will be used to prepare the Critical Items List (CIL), which will be used to identify critical spares. This CIL includes the Single Failure Point Summary and Critical Redundant Items. The corrective action required and/or rationale for retention will be determined for each critical single failure point.

Reliability/maintainability will support the PSS design reviews, monitor all integration and test activities, and support the Acceptance/Demonstration Tests at MSFC and KSC. This will include failure reporting and corrective action and problem/failure history and status for the PSS C&D and GSE.

The maintenance requirements will be provided to the mission integration as an input to the Integrated Logistics, Maintenance/Refurbishment, and Mission Operations Programs.

5.0 SOFTWARE

The software required for the PSS Phase C/D contract includes flight and ground test software. The flight software will interface the software driven controls and displays with the application software in the Orbiter Spacelab, or Payload computers. This software is designated the Core Control and Display (CCD) software and is resident in the MFDS Processor. The ground test software will reside in the ground support equipment (GSE) and provide test sequences to check every function on the core C&D panels.

The software development and validation concept for both flight and ground will be finalized during the Phase C/D and documented in the Software Development Plan. Preliminary analysis of this concept has resulted in the approach summarized in Figure 5.0-1.

The software for both the ground and flight will be developed in a dual-organization concept to provide a series of checks and balances. In this concept the requirements, trade studies, verification and validation are the responsibility of the software systems group; while the software design, coding, coding test, and program documentation are assigned to the software development group. The interplay between these groups throughout the development cycle ensures that the programmers understand and implement the correct requirements and that the requirements remain consistent with efficient and cost-effective software coding practices.

5.1 Flight Software - The CCD software is defined to interface with both the C&D hardware panels and the applications software residing in the Oribter, Spacelab, or Payload computers. Since modern display electronic unit designs contain processors with significant computational and logical capabilities, the first task of the PSS Phase C/D contractor will be to perform trade studies to determine the best distribution of the CCD software. This resultant distribution by function will be documented in the CCD software CEI. This functional assignment of software program responsibilities will allow the software ICD and detailed requirements to be developed.

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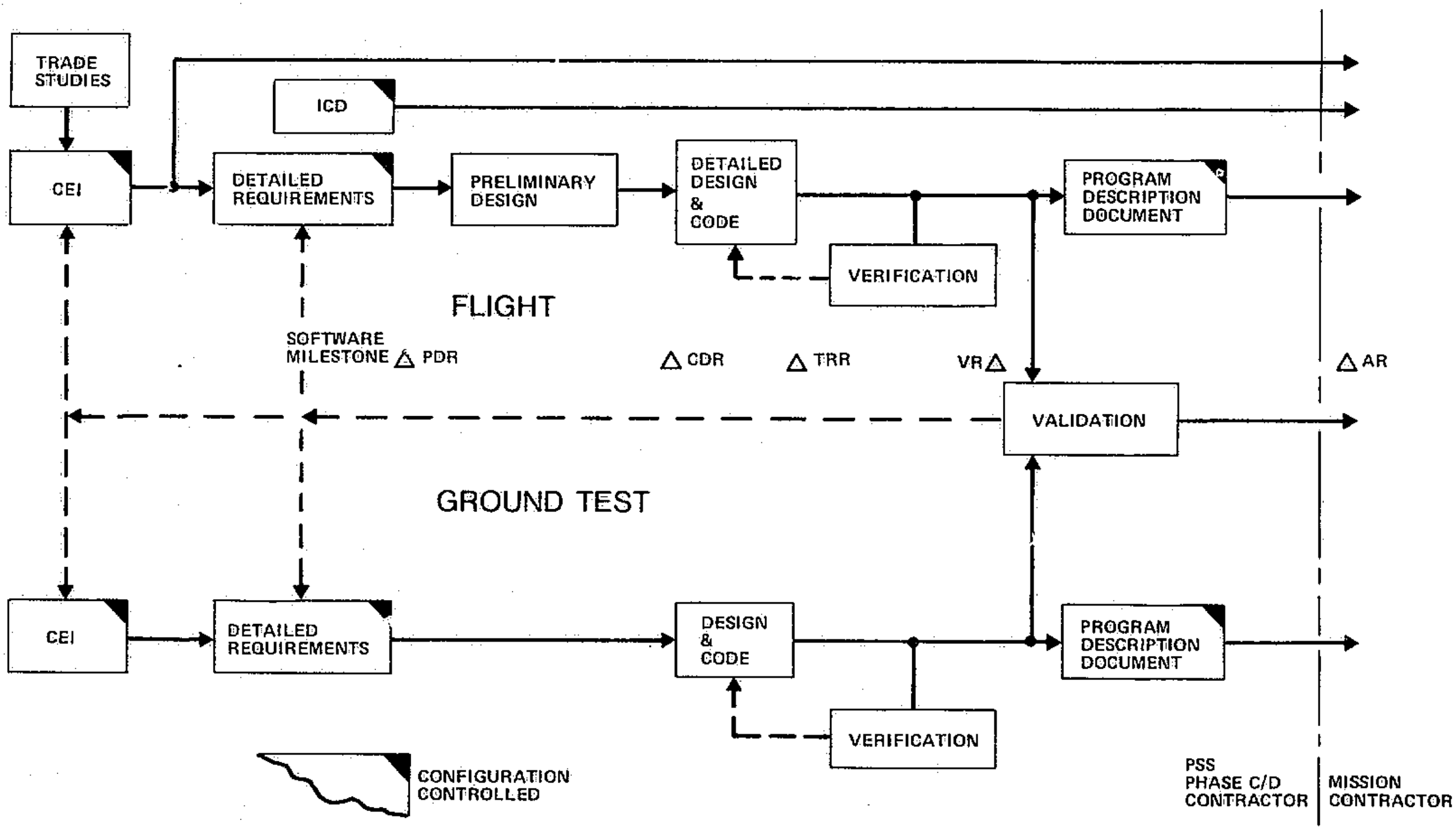

FIGURE 5.0-1 SOFTWARE DEVELOPMENT FLOW

5.1.1 Software ICD - The software ICD will define the software to hardware data interface including all command and data formats. This definition will be provided for both Orbiter and Spacelab data bases. Detailed requirements will be written for that portion of the CCD software which resides in the electronics unit. The requirements will be analyzed to determine whether they can be changed in such a manner to allow more cost-effective implementation. At the completion of these reviews the software development group can initiate the preliminary design, detailed design and coding of each specified function. Since the flight CCD software spans multiple projects, a preliminary design will be initiated after the PDR. The preliminary design will be reviewed at the CDR prior to proceeding into the detailed design and coding.

5.1.2 Verification - The verification will be carried out in accordance with the software development plan. The responsible agent for this action in the requirements generator of the software systems group, with the software developer in a support role. Once verification is complete, the software designer will formalize a Program Description Document (PDD). This document will be approved and placed under configuration control.

5.1.3 Validation - After software verification, the software will go through a series of system level tests called validation. The tests will be conducted on the development hardware, and utilize the GSE together with its ground test software. These validation tests will be under the control of the software systems group.

5.2 Ground Test Software - The ground test software will follow a development cycle similar to the flight software. Since this software, controlled by CEI, is totally contained in the GSE, trade studies will not be required. The development cycle will begin with submittal of the final requirements for both the CEI and Detailed Requirements Documents. Since the GSE test software only consists of a test sequence module, interpreter module, and an I/O module, the preliminary design cycle can be eliminated allowing final design and coding to proceed right after the CDR. Verification will also be a very simple cycle, requiring only that each I/O device respond properly to the straightforward test sequences.

The validation cycle will utilize the development unit together with its verified software combined with the commercial GSE and its verified software. This combination of hardware and software will go through a series of system level tests to validate all CEI and detailed requirements. The test sequences will be conducted by the systems software group under the control of the software development plan.

6.0 GROUND OPERATIONS

Plans and procedures will be developed to support a ground operations concept in which factory test and checkout are performed at the MMC Denver facility with final acceptance at a NASA facility; components are to be returned to the PSS Contractor for repair. Ground operations functions, documentation, equipment, facilities and prerequisites for a PSS C&D maintenance concept will be developed as a part of DDT&E.

The PSS C&D ground operations will consist of providing field support to MSFC and KSC for the test and checkout of the PSS C&D flight article, the training article, the payload integration article, and GSE. Logistics planning, transportation, and spares management will be provided for the C&D hardware and GSE. Logistics support will be provided for maintenance, repair and refurbishment of hardware and GSE.

Launch site functions are limited to providing inputs to integrated test procedures, unloading, visual inspection and demonstration/acceptance test support at KSC. Requirements are coordinated through the Launch Site Support Manager to obtain support for these activities.

Maintenance functions will be centered at Denver. In the case of failure, systems tests will be performed utilizing the GSE, then the affected subpanel will be removed. Control and display components will be bench tested, and after MRB disposition, returned to vendors for repair. The MFDS will be shipped to the subcontractors for refurbishment. Reintegration will be similar to the initial integration, but no environmental tests will be performed.

C&D hardware and GSE will be transported by truck.

6.1 <u>Ground Operations Plans and Procedures</u> - Plans and procedures for ground maintenance will be written in the DDT&E phase of the PSS program, concurrent with the initial assembly, integration, and test activities. Documentation for these activities will have been updated/revised during its usage. Since many of the ground maintenance functions and requirements are similar to those of the initial assembly, this documentation should be directly applicable in many ground maintenance activities.

It will be a major input for preparation of plans and procedures. Table 6.1-1 shows the documentation requirements.

TABLE 6.1-1 GROUND OPERATIONS DOCUMENTATION

PSS C&D Payload Integration and Verification Inputs to Integration Procedures

PSS C&D and GSE Maintenance Manual

Handling & Transportation Plans

Handling & Transportation Procedures

Spares Documentation

7.0 FACILITIES

Martin Marietta Aerospace Denver Division facilities are ideally suited for the test and production of the PSS C&D core hardware. The existing laboratories and manufacturing facilities capabilities require no new or unique facility addition. The technology and facilities utilized on similar endeavors such as ATM and EREP C&D will be used by the Denver Division to develop, build, assemble, and test the PSS equipment. The Denver Division facilities include all necessary capabilities to design, develop, fabricate and test man-rated aerospace equipment.

The facility is located on a 5057-acre site approximately 25 miles southwest of Denver, Colorado. Additional Government-owned test facilities are located on an adjacent 460-acre site. Engineering, Administration, Cafeterias, Factory, General Purpose Laboratories, Space Simulation Complex, and supporting services are located close to each other, providing a functionally oriented organization with excellent communication for management, supervision, and liaison tasks.

7.1 PSS Core Equipment Facilities Summary - The project management, Systems Engineering, and Design Engineering will be housed in the Space Support Building (SSB). During the development cycle, PSS ground test computer models will be developed using the Martin Marietta Aerospace computer capability in the Electronic Manufacturing Facility (EMF). Material, component and breadboard tests will be conducted in a dedicated laboratory in the Space Support Building. Design and testing will result in hardware designs described by drawings and specifications that will be used to procure material and subcontracted components and to fabricate the PSS C&D hardware in the EMF. Procured parts and material will be received, inspected and stored in the Inventory Building. Structural components such as panel plates, brackets and clips will be fabricated in the precision machine shop of the Manufacturing Assembly Building.

All mechanical environmental tests will be conducted in the Accoustics Vibration Laboratory and electromagnetic interference tests (EMI) will be performed in the dedicated laboratory in the SSB. The following paragraphs describe the capabilities of these facilities which will be used in the design, development, fabrication and testing of the PSS C&D core system.

7.1.1 Administration Building - This building houases the scientific and business computer facilities to be used in the management control of the PSS program. This computer center has remote computer terminals in the Engineering and Space Support Buildings and various other locations throughout the Denver complex. Additionally, a high speed telecommunication network is used to provide balanced computer loads with other Martin Marietta Aerospace computers at Baltimore and Orlando. The Denver Data Center computing systems are listed below.

1) EAI 8900 hybrid	Real Time System Simulation
2) One CDC 6500 digital	Analog and Hybrid Simulation Engineering and Research Studies
3) CDC 3150 digital	Manufacturing On-line System
4) IBM 370-158 5) IBM 370-145 6) IBM 360-20	Business Management Systems

7.1.2 Space Support Building (SSB) - The Electronic Systems Technology Laboratory in SSB has the capability necessary for the design, development, and testing of electronic equipment ranging from individual devices to systems such as the PSS C&D. It occupies 12,000 square feet, including test benches, equipment, parts storage, and offices plus printed-circuit development facility; mechanical shop for basic assembly and prototype fabrication; telemetry ground station; remote scientific computer terminal; test facility for computer hardware and software development. The laboratory is equipped with modern test equipment covering a wide range of test requirements, including a complete line of general-purpose electronic and electrical measurements; frequency generation and measurement from dc to 10 GHz; low-level, high-speed logic; logic circuit synthesis; solid-state circuit parameters; electomagnetic interference, dc to 10 GHz; evaluation of power-generation equipment, ac and dc; wave analysis; impedance measurements; transient analysis; communications; evaluation of RF systems and components; pulse and switching circuits; electronic systems compatibility and analysis; computerized launch, checkout, and control systems; computerized on-board checkout systems.

7.1.3 Electronic Manufacturing Facility (EMF) - This building is designed for fabricating, assembling and testing electrical and electronic components and subsystems used in aerospace applications. It encompasses more than 79,000 square feet of floor space with the following features:

1) A 7500-sq-ft clean room that can be operated in compliance with FED-STD-209A, Class 100,000 is provided. The room has a horizontal air velocity of 100-ft per minute, relative humidity is maintained at 45%, temperature is 70 ± 2°F and the illumination level is 150-ft-c. The room is continuously monitored for airborne particulate content by a Royco Model 200 light scattering automatic particle counter. Class 100 laminar flow benches are used as required within the area for critical operations.
2) A 1200-sq-ft potting/encapsulation room is equipped with Class 100 clean benches, flosoldering equipment, ultrasonic cleaning equipment, vacuum encapsulator, curing ovens, refrigeration unit, and an X-ray system. Bonding, conformal coating, encapsulation, impregnation, and potting operations of subassemblies as well as flosoldering of printed wiring boards is performed in this area.
3) A 400-sq-ft coil winding room is equipped with four torodial and bobbin-type winding machines and a reflow solder system. Winding of transformers, inductor coils, etc, and reflow soldering of printed wiring boards is accomplished in this area.
4) The mechanical shop, consisting of approximately 600-sq-ft, is used for minor machining and sheet metal fabrication.

5) A wire, plug, harness, and chassis assembly area for ground equipment is provided for electronic manufacturing. Quality is maintained by using computerized in-line test facilities. The Denver Division has developed a computer aided test system called the DIGIDAT for the automatic testing of all electronic components and subsystems. It is capable of performing logic and complete functional tests, concurrent with environment testing.

6) Environmental acceptance testing at component and subsystem levels are performed in a controlled environment. Capabilities include two shaker systems rated at 6000 force-lb sinusoidal and 5000 force-lb random with a frequency range from 5 to 3000 cycles. A third shaker system is rated at 17,5000 force-lb sinusoidal and 15,000 force-lb random with a frequency range of 5 to 3000 cycles. Temperature cycling is performed at temperatures between $-100^{o}F$ to $+400^{o}F$.

Other facilities available in the EMF include engineering and manufacturing development laboratories, thin-film laboratory, shipping and receiving area, and bonded storage area.

7.1.4 Factory - The Factory is a two-story building with a gross area of 384,000 square feet. The lower floor contains detail manufacturing, tool and die shop, chemical process facility, tube shop, clean rooms, quality control laboratory, and other support areas. The second floor has a 28-ft hook-height high-bay area with low-bay support areas on two sides. The capabilities are listed as follows:

1) Machining - Detail manufacturing (Figure 4.2.3) will take place in the factory which is fully equipped with both conventional and numerically-controlled machine tools, and provides the capability to perform all necessary operations to fabricate the panels, brackets and other structural parts for the PSS C&D hardware.

2) Sheet Metal and Tube Fabrication - Sheet metal forming and precision tube fabrication for the PSS C&D will be done in an area that contains a wide variety of brakes, rolls, and presses

Facilities are provided for tube fabrication from 1/8-in. diameter to 3-in. diameter.

3) Heat Treat - Aluminum and ferrous metals are heat treated in a variety of furnaces, ovens, and refrigerators. The principal facility for large aluminum parts is a 2500-lb capacity drop-bottom furnace with a temperature range of 300° to 1200°F and 30 sec quench capability. The oven size is 10.5 ft wide, 26 ft long and 12.5 ft high.

4) Welding - Conventional and automatic welding equipment on the Factory upper level can handle a broad range of sizes, shapes, thicknesses, and materials.

7.1.5 Inventory Building - Receiving inspection operations for PSS C&D material and parts acquired from outside suppliers are performed in the Inventory Building. The Parts Evaluation Laboratory in the Inventory Building performs component part evaluation and screening programs to identify and remove marginal devices as part of acceptance procedure. The capabilities are:

1) Predictive test techniques using step-stress-to-failure data applied to the spring rate reaction mathematical model;
2) Monolithic circuit worst-case and sensitivity analysis using microprobe data applied to computer-aided desi-n models and programs;
3) Understanding of failure mechanisms associated with solid state microelectronic design, materials, and processes;
4) Pilot line design and fabrication of complex hybrid micro-circuit arrays;
5) Automated testing techniques to perform complete electrical characterization and complete functional testing using known address or pseudo-random methods.

7.1.6 Acoustics/Vibration Laboratory (AVL) - The acoustic/vibration test facility, adjacent to SSL, provides a simulated environment compatible with spacecraft environments. This four-story building contains four principal areas: a high bay with a 33-ft hook height; a

20 x 20-ft acoustic test area; a 25 x 40-ft vibration test area; and a 40 x 40-ft multipurpose area.

Noise generation equipment consists of two 30,000-w acoustic generators that can be coupled to the specimen shroud to produce shaped random acoustic/spectra with overall sound pressure levels up to 156 dB.

The vibration test area has a 200,000-lb self-leveling seismic mass that supports a 30,000-lb electrodynamic shaker and steel base place. The shaker can be rotated for either vertical or lateral excitation. During vertical excitation testing, fixturing is provided about the shaker to bias out the specimen's static load and overturning moments. During lateral excitation testing, the surface of the seismic mass is covered with steel plate to allow the placement of fixturing and vibration exciters for torsional vibration tests.