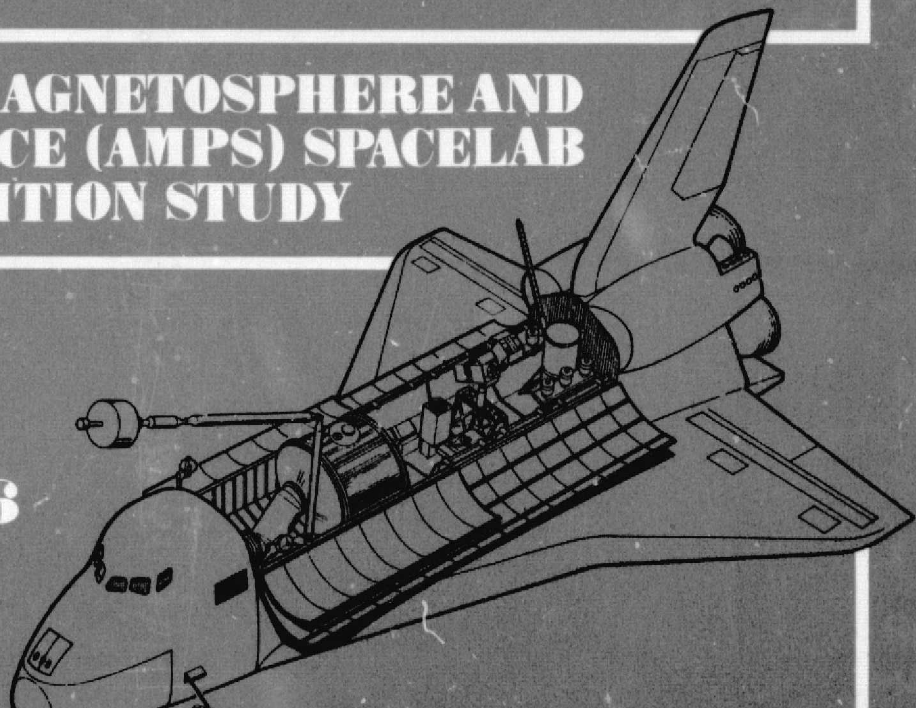
VOLUME 7

CONTRACT NO. NAS8-31690
27615-6007-RU-08
DR-MA-04A

BOOK 2

AMPS PHASE C/D ANALYSIS AND PLANNING DOCUMENT

ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS) SPACELAB PAYLOAD DEFINITION STUDY



Final Report
November 1976

Prepared for
National Aeronautics
and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

TRW
DEFENSE AND SPACE SYSTEMS GROUP

ATMOSPHERE, MAGNETOSPHERE AND PLASMAS IN SPACE (AMPS)
SPACELAB PAYLOAD DEFINITION STUDY
FINAL REPORT

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Approved by: W.F. Rector III

W.F. Rector, III
Project Manager, AMPS

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1. INTRODUCTION

The purpose of this documentation is to present the results of the AMPS Phase C/D (Design, Development and Operations) program analysis and planning effort completed during the AMPS Phase B study. It also serves as the basis of substantiation for cost and schedule estimates contained in this and Volume VIII of this Final Report.

The document is organized according to the Work Breakdown Structure (WBS) (Volume VII, Book 1) and summarizes the tasks to be performed and the recommended approach for each WBS element. The information presented is summary in nature since detailed plans will be submitted as part of the Phase C/D proposal.

Although the AMPS program has been specifically addressed, these task descriptions are basically adaptable to a broader-based program incorporating additional or different Spacelab/Orbiter payloads.

2. PROJECT MANAGEMENT

The organizational structure for the AMPS project is shown in Figure 2-1. It consists of a dedicated project management organization and departments directed by this organization. The project management organization includes the Project Manager (PM), seven Assistant Project Managers (APM), and staff. The organization is projectized, with resources and engineering and support personnel directly under the project manager's control. The Project manager also has two Flight Managers reporting to him. Their function will be to cut across departmental lines to assure that their respective payloads satisfy all technical, operational and schedule requirements.

This organization allows the best communications and visibility and the shortest lines of direction and control. Resource pools and special skills are still available to the project on an as-needed basis by calling upon the technical laboratories within the company which are primarily concerned with advanced research and development. Special activities such as quality assurance and manufacturing are carried on by the organizations best suited to perform them. This organization is structured to:

- Group the project tasks logically under appropriate levels
- Provide for a reasonable span of management control
- Assign important elements of project work to levels of adequate authority and access to higher management.

2.1 PROJECT ADMINISTRATION

The project management organization is responsible for the overall technical, cost, and schedule performance of the project. It is specifically responsible for:

- Project systems engineering and integration and technical program management through all applicable phases of the program
- Official communications and liaison with GSFC, other NASA and Government agencies, principal investigators, and major subcontractors.
- Establishment and control of overall project budgets, schedules, and work breakdown structure

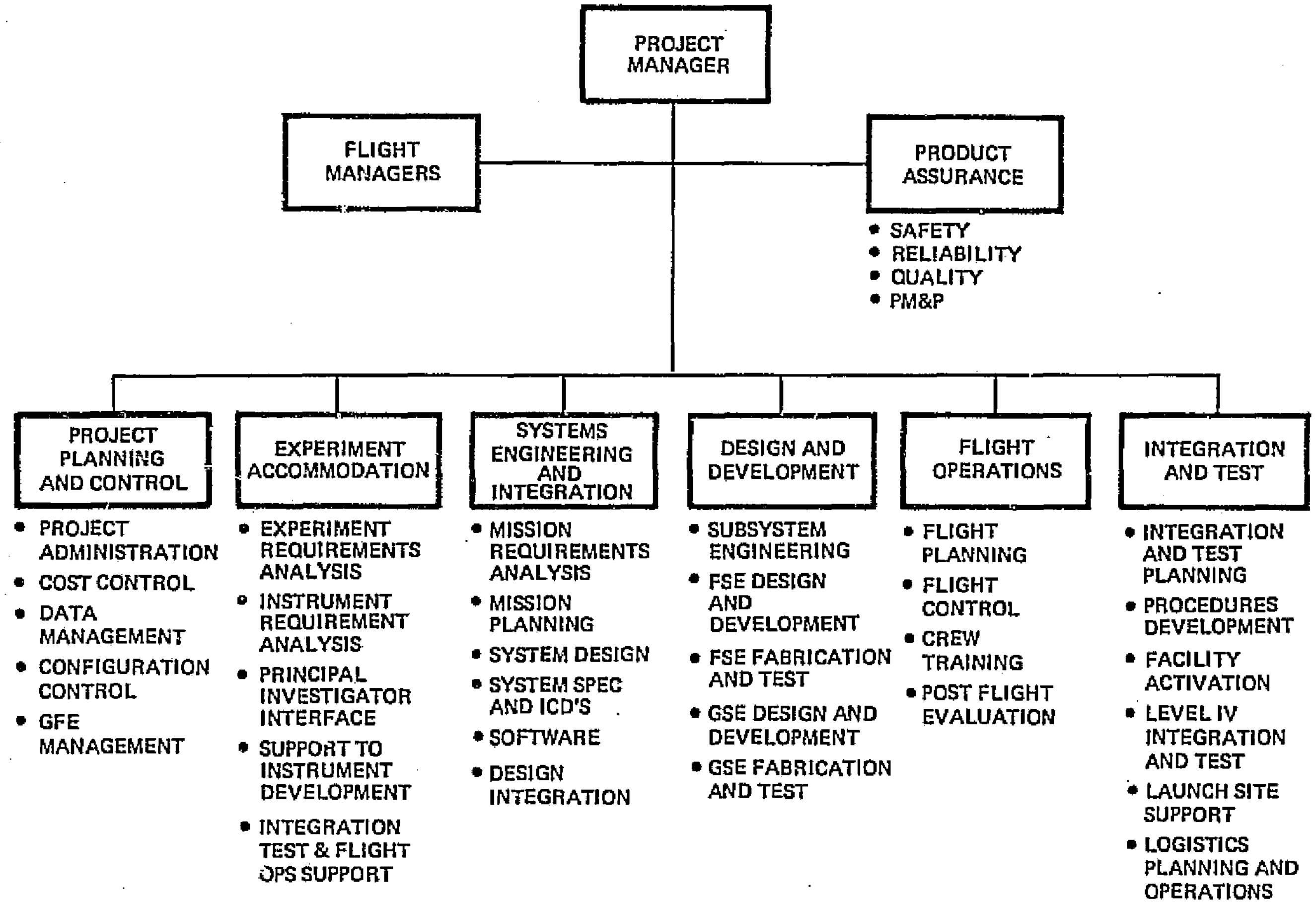


Figure 2-1. AMPS Phase C/D Organization

- Management of the activities of all personnel assigned directly to the project.

The project manager allocates the tasks of the statement of work to appropriate assistant project managers. Each of the assistant project managers in turn has single-point responsibility for technical, cost, and schedule performance of the work assigned to him. Below the assistant project managers, tasks will be assigned to departments and support sections in concert with their technical disciplines and resources capabilities, and will have the responsibility for accomplishment of the work under their control. Thus a logical treeing of the statement of work tasks occurs, with activities assigned to appropriate levels of the organization commensurate with authority and resources.

While this arrangement is sufficient to manage the work on most projects, it has been decided that the complexity of the AMPS project warrants the assignment of flight managers to each AMPS flight to ensure that the payload is delivered on time and that all technical and operational requirements have been fulfilled. The managers activities will include:

- Reviewing the progress of all activities related to their payloads, including subcontract and GFE delivery status, facilities availability, etc.
- Acting as a focal point for interfacing with the GSFC mission managers
- Chairing payload design reviews
- Resolving any problems, interdepartmental or otherwise, which jeopardize the successful completion and delivery of the payload.

Visibility on the project for both GSFC and TRW will be obtained in several ways. Formal reports such as cost and schedule reports and monthly progress reports provide a data base for GSFC visibility on the project. In addition, design reviews and other technical audits, along with test results and verification information supplied to Goddard provide visibility into the progress of the systems engineering, design, and development activities. Formal and informal meetings within TRW, including weekly progress reviews and monthly program reviews, provide TRW project and corporate management with visibility on the status of the program. Similarly, formal and informal progress review meetings with GSFC provide Goddard that visibility. Finally, the project control center serves as an open status center providing formal visibility into the major activities of the project.

The basis of control will be a continuous review of progress against plans with rapid replanning and redirection where deviations are observed. Early detection of problems is essential. It is also essential to operate continuously to updated plans. Basic direction of the projects is given by the approved plans and procedures and by Company Standard Practices. Technical control of the program is basically accomplished by having a strong experienced systems engineering management team using design reviews and the verification system. Schedule and cost control of the program are again accomplished by experienced managers using TRW standard cost and accounting systems and an effective project schedule control system. These tasks are described later in this book under the appropriate WBS elements.

2.2 PROJECT PLANNING AND CONTROL

The planning and control techniques and procedures to be used in Phase C/D will be based on existing TRW procedures with appropriate modifications to suit any unique contractual requirements. The company's cost/schedule system has been validated to the requirements of DODI-7000.2 and, with appropriate exceptions, is compatible with all NASA requirements. The following foldout illustrates the basic concept of the project cost/schedule system.

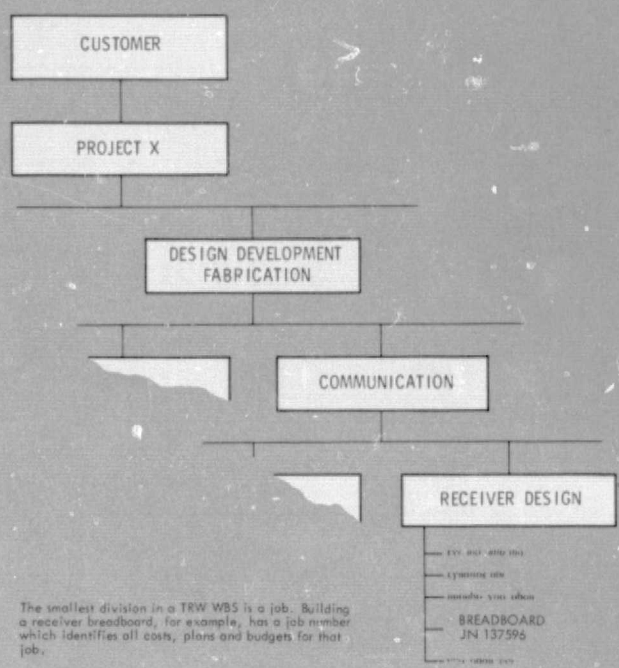
2.2.1 Work Breakdown Structure

Organization of work for project activities is defined by the project work breakdown structure (WBS), which is the framework for management control of the project. The WBS matches tasks to the project and technology oriented organizations who are performing the tasks, collects the costs at the level where the tasks are performed, and is compatible with NASA/GSFC cost reporting requirements. It also acquires historical data on dollar expenditures and tasks completed. The AMPS Phase C/D WBS is contained in Volume VII, Book 1, of this report.

TRW
SYSTEMS GROUP OF TRW INC

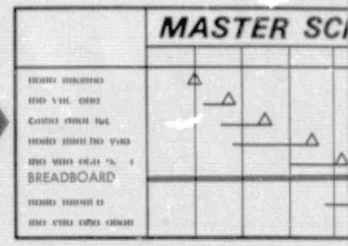
WORK BREAKDOWN STRUCTURE

FOR EVERY PROJECT, TRW SYSTEMS DEVELOPS A WORK BREAKDOWN STRUCTURE. THE WORK BREAKDOWN STRUCTURE IS THE FRAMEWORK FOR ALL PROJECT PLANNING AND CONTROL. CUSTOMER REQUIREMENTS AND END ITEMS DEFINE THE STRUCTURE.



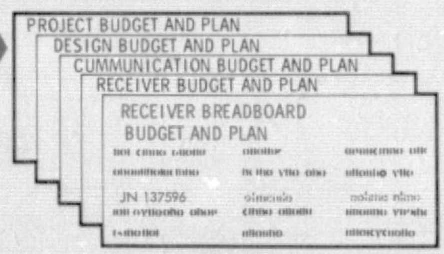
The smallest division in a TRW WBS is a job. Building a receiver breadboard, for example, has a job number which identifies all costs, plans and budgets for that job.

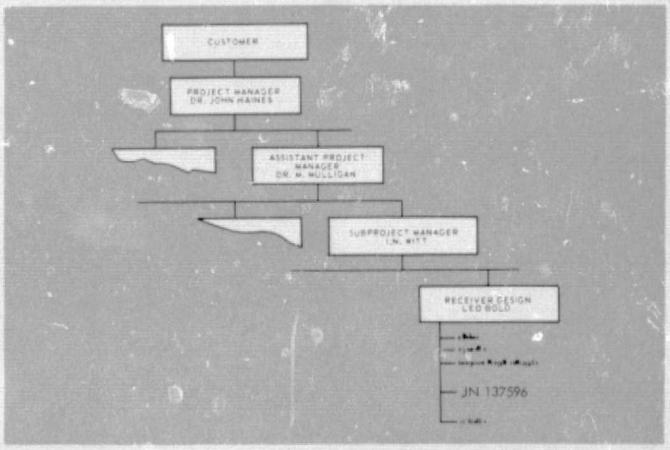
The project office prepares master schedules based on the framework of the work breakdown structure. Schedules include subcontracted work.



We establish a project organization compatible with the work breakdown structure. For every job there is a responsible engineer.

The project office prepares budgets and plans from the work breakdown structure. Internal budgets add up to contract target cost.



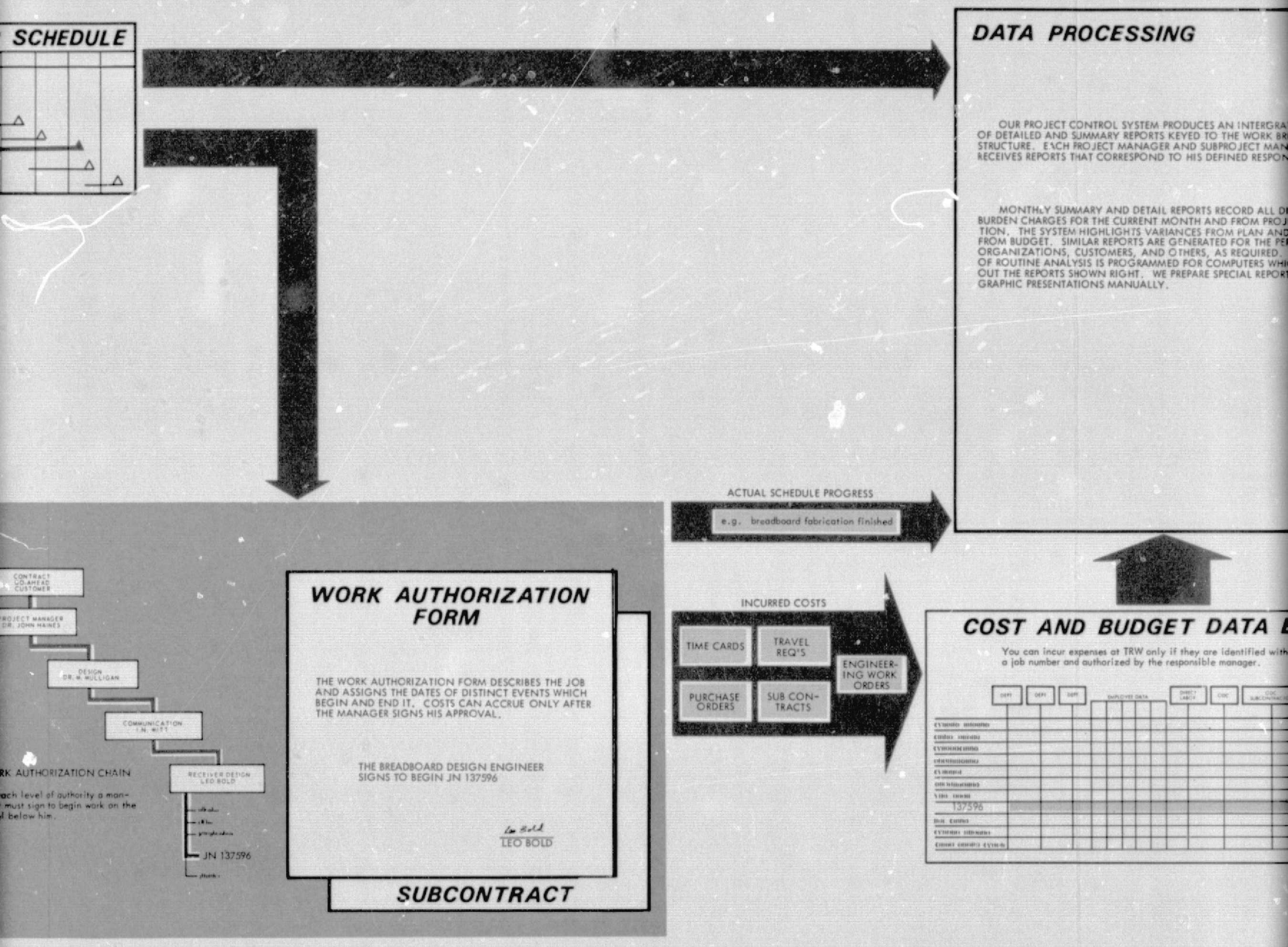


WORK AUTHO

At each level ... ager must sign ... level below hi

FOLDOUT FRAME 1

PROJECT COST/SCHEDULE SYSTEM



FOLDOUT FRAME 2

M

DATA PROCESSING

OUR PROJECT CONTROL SYSTEM PRODUCES AN INTERGRATED SERIES OF DETAILED AND SUMMARY REPORTS KEYED TO THE WORK BREAKDOWN STRUCTURE. EACH PROJECT MANAGER AND SUBPROJECT MANAGER RECEIVES REPORTS THAT CORRESPOND TO HIS DEFINED RESPONSIBILITY.

MONTHLY SUMMARY AND DETAIL REPORTS RECORD ALL DIRECT AND BURDEN CHARGES FOR THE CURRENT MONTH AND FROM PROJECT INCEPTION. THE SYSTEM HIGHLIGHTS VARIANCES FROM PLAN AND VARIANCES FROM BUDGET. SIMILAR REPORTS ARE GENERATED FOR THE PERFORMING ORGANIZATIONS, CUSTOMERS, AND OTHERS, AS REQUIRED. THE BULK OF ROUTINE ANALYSIS IS PROGRAMMED FOR COMPUTERS WHICH PRINT OUT THE REPORTS SHOWN RIGHT. WE PREPARE SPECIAL REPORTS AND GRAPHIC PRESENTATIONS MANUALLY.

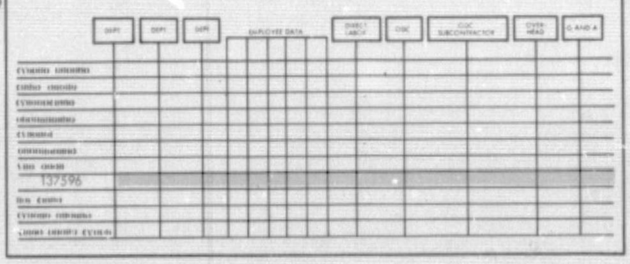
GRESS

on finished

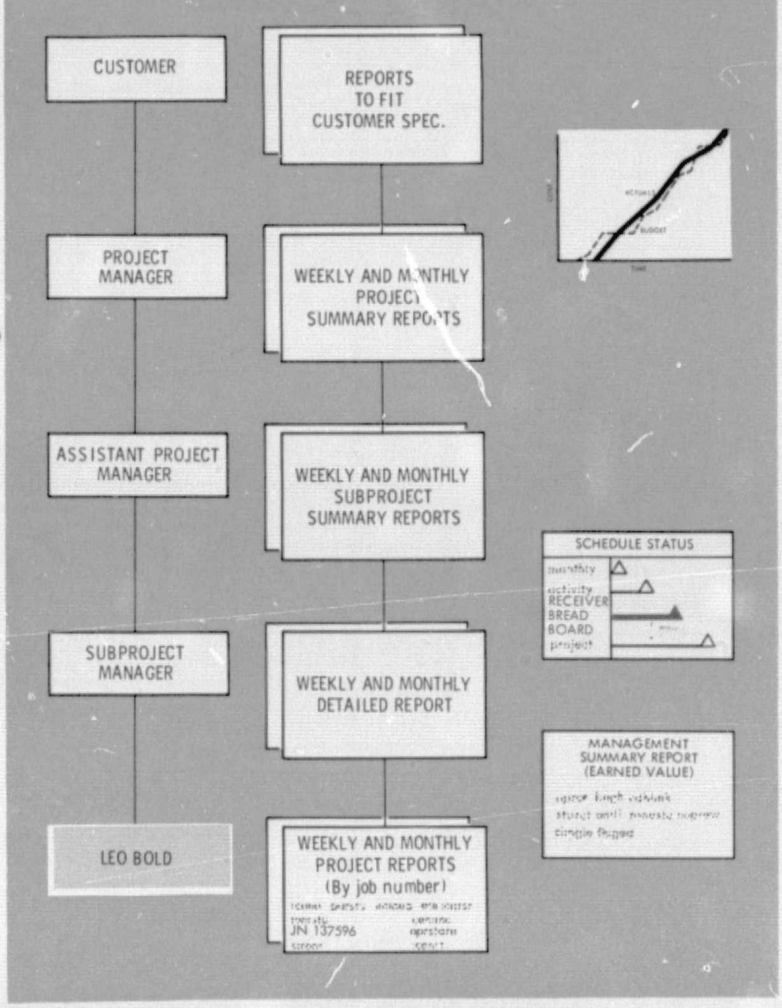
ENGINEERING WORK ORDERS

COST AND BUDGET DATA BASE

You can incur expenses at TRW only if they are identified with a job number and authorized by the responsible manager.



PROJECT COST/SCHEDULE REPORTS



EVERY TRW CUSTOMER AND MANAGER HAS DIRECT AND FREQUENT ACCESS TO THE COST AND SCHEDULE STATUS OF HIS PROGRAM. THE FLOW CHART SHOWS HOW TRW DIVIDES EACH PROJECT INTO A LOGICALLY ORGANIZED SET OF JOBS. RESPONSIBILITY FOR EACH JOB IS ASSIGNED TO A SPECIFIC ELEMENT OF THE PROJECT ORGANIZATION. PROJECT COSTS CAN BE INCURRED ONLY IF THEY ARE ASSOCIATED WITH A PARTICULAR JOB, AND ONLY AFTER WORK HAS BEEN AUTHORIZED BY THE RESPONSIBLE MANAGER. THE COMPANY-WIDE REPORTING SYSTEM NOW PRODUCES DETAILED CURRENT REPORTS FOR THE CUSTOMER AND FOR EVERY MANAGERIAL LEVEL WITHIN TRW. THE SYSTEM APPLIES BOTH TO SUBCONTRACTED WORK AND WORK INTERNALLY PERFORMED. COST AND SCHEDULE PROGRESS OF A TYPICAL JOB BUILDING A RECEIVER BREADBOARD, IS TRACED IN BLUE.

FOLDOUT FRAME 3

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2.2.2 Project Work Authorization

Each task defined by the WBS is initiated by the issuance of a project work authorization (PWA) by the project manager or his delegate. No work can begin without a PWA. The PWA identifies the following, as a minimum:

a) The WBS element

b) The work to be done (narrative description)

c) The responsible organizational unit

d) The schedule for accomplishing the work

e) The authorized budget

f) Special constraints or necessary administrative information.

In effect, the PWA is a contract between the project office and the performer. PWA revisions are issued for changes in scope of work when authorized by the project manager. The sum of all PWA's, revisions issued, and the project office budget equals the contract target cost. The APM for Project Planning and control maintains a log of all PWA's and revisions issued. PWA's must be issued by all managers who transfer responsiblity and authority for accomplishing contract tasks to the subordinate managers accepting that responsibility (for example, project manager to assistant project managers, assistant project manager to department manager). This authorization process is continued downward until PWA's have been issued to the level at which the contract tasks will be done. PWA logs will be maintained by all managers who either receive, or receive and issue, budgetary funds. The basic signature authorization system for initiating and completing direct cost work within TRW Systems is established in the TRW Controller's Manual.

2.2.3 Financial Management and Control

Financial management for AMPS is structured and dedicated to support the project in the areas of financial planning, cost collection, control, and reporting, with heavy emphasis on analysis of data, accurate trend prediction, and forceful recommendations to the APM's and department managers for corrective action.

Financial planning includes establishing policies and procedures for formatting expenditure plans that will provide NASA/GSFC and TRW management total and immediate financial visibility. Financial planning for the project places maximum emphasis on ensuring that the costs are credible and the customer fiscal requirements are met.

To accomplish the above, the project will use TRW's approved cost/schedule performance system and weekly head count control.

Project financial status and performance will be reviewed weekly, together with technical and schedule performance by the project manager and the responsible APM's and department managers. The APM for Project Planning and Control will prepare and issue financial status reports in accordance with contractual requirements.

2.2.4 Schedule Management and Control

The AMPS project will use four different types of schedule control techniques, which are keyed to various levels of work breakdown structure (WBS). The use of each depends on the particular type of WBS element (hardware versus software, measurable versus level of effort), and the phase the program is in (design and test versus manufacturing). The four types of schedules are:

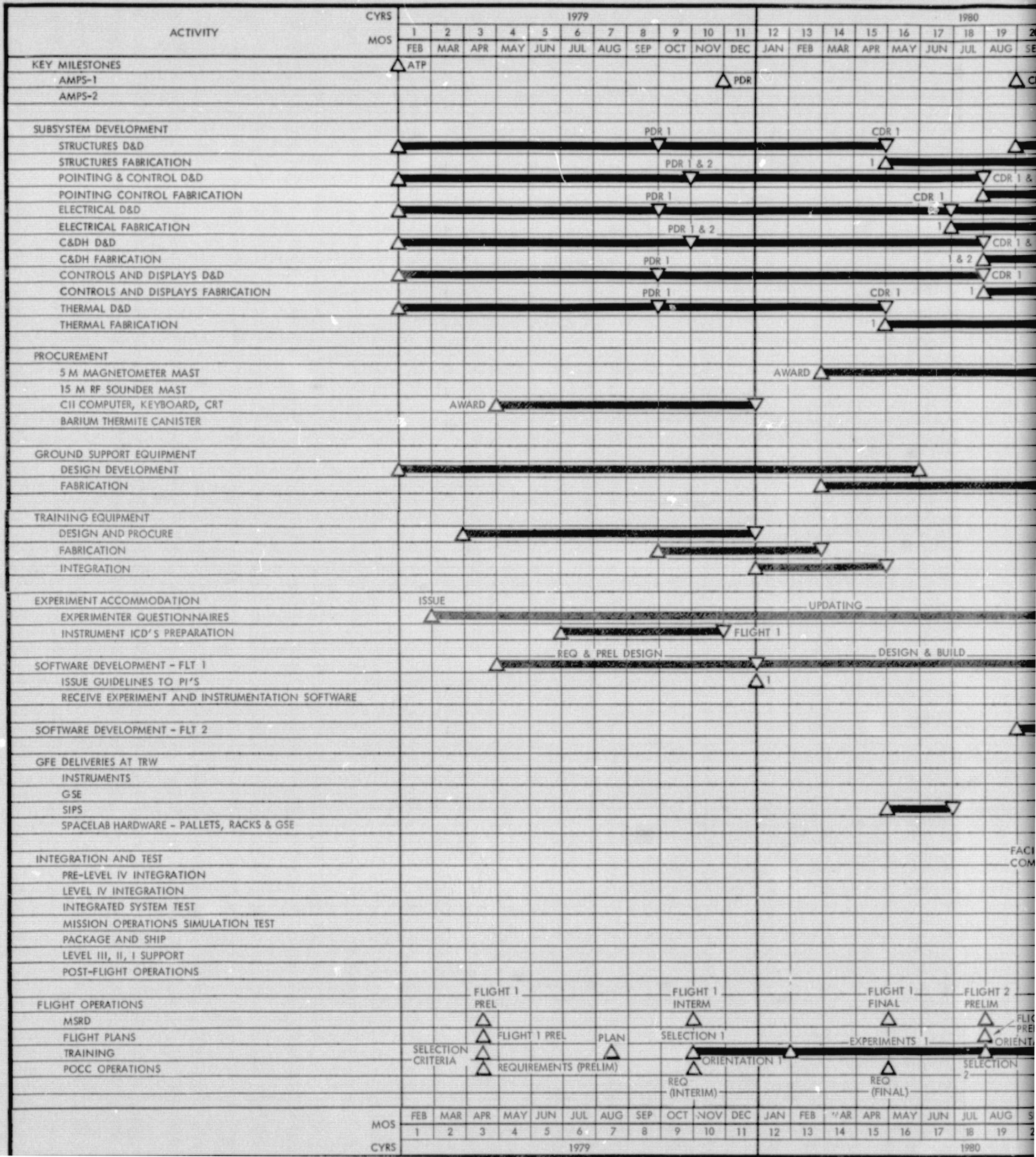
a) Milestone Schedules

Project Master Milestone Schedules (MMS) — The MMS is developed first to reflect the contractually required dates and the summary supporting milestone that must be met to achieve these dates from program go-ahead through program completion-- this is a Level 1 WBS schedule, and is considered the project baseline schedule. The AMPS preliminary MMS is shown in Figure 2-2.

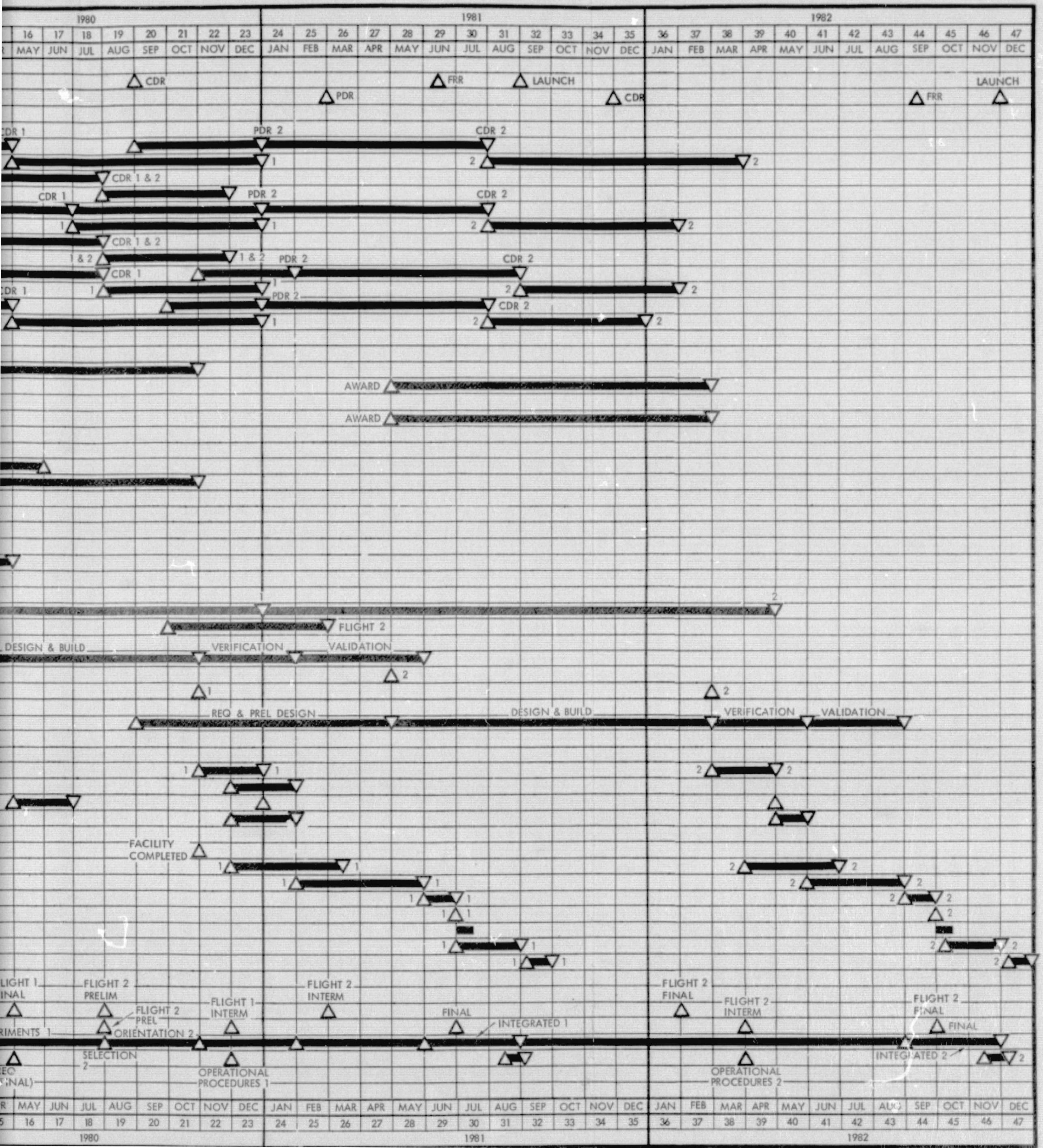
Level 2 and 3 Milestone Schedules - AMPS will have milestone schedules at either Level 2 or the Level 3, based on the amount of activity during a particular phase of the program (design versus mission operations) and the type of activity (hardware versus program management). TRW and GSFC will continually review the Level 2 and 3 milestone schedules to determine when a more detailed approach (delete 2 and create Level 3's) or summary approach (opposite) is in order.

TRW
DEFENSE AND SPACE SYSTEMS GROUP

AMPS PHASE C/D MASTER MI



/D MASTER MILESTONE SCHEDULE



b) Summary Task Planning Sheets (STPS's) — STPS's are developed for each measurable job number (cost account) on a rolling wave planning basis. This is a very important task since this is the place in the C/SPS where cost is integrated with the schedule to provide a basis for measuring earned value. The schedules for the subtasks on the STPS's will be consistent with all other schedules used on the program where a direct relationship exists between the various scheduling tools. A subtask is defined as an increment of measurable effort (within a job number), which has definable start and end points and whose average duration is no greater than 4 months.

c) Logic Networks — Logic networks will be developed at the subsystem and unit level for all areas of the program where hardware design, development, and fabrication are planned. Networks will not be required for level of effort or support areas.

The networks will be in sufficient level of detail to allow project office personnel to review status and task interrelationships with the department managers and serve as the basic replanning tool when necessary. The level of detail will be determined for each network by the following criteria:

- Complexity of design and development effort
- Number of critical interfaces with other WBS elements
- Criticality of item to overall schedule.

The networks will be hand drawn and updated as required.

d) Manufacturing and Integration Schedules — There are several types of scheduling techniques used during these phases of the program, e.g., first unit schedule, line of balance charts, master control sheet schedules, skill center schedules, etc. These are useful for tracking operations at a very low level of detail and providing an input for scheduling work flow through the various work stations. The data from the schedules is inputted on a regular basis to STPS's and other more summary schedules on the program.

The responsibility for the project master milestone schedule development and maintenance rests primarily with the project manager and his staff, specifically the APM for Project Planning and Control. They will assure that the master milestone schedule is properly updated monthly and that changes are reflected in a timely manner.

The responsiblity for development and maintenance of the Level 2 and 3 milestones lies jointly with the Level 3 managers and the APM's with assistance from the schedule control group. Monthly updating of these schedules from status monitoring tools such as STPS will be reviewed by the Level 3 managers and the cognizant APM's to assure that valid information is being reflected and that the milestones remain within the parameters and guidelines set forth in the project master milestone schedule.

It will be the responsibility of the Level 3 managers to achieve timely inputs and updates to the STPS by the lower level managers under their cognizance, again with the support of the schedule control group.

2.3 DATA MANAGEMENT

TRW has a large centralized Configuration and Data Management (CADM) organization which handles all released engineering data and provides a wide range of specialists and services to the project offices. The AMPS data management function will be the responsibility of a CADM Data Manager who will be under the direction of the APM for Planning and Control. The data management effort consists of three major tasks which are described in the following sections.

2.3.1 Contractual Data Requirements

The Data Manager will assist in defining the initial contractual data requirements and control any changes to these requirements throughout the life of the contract. He will ensure that data conform to the applicable Data Requirements (DR) and that they are delivered in accordance with the schedules in the Data Procurement Document (DPD). He will also periodically review the DPD to identify any possible cost reductions or changes which should be brought to the attention of GSFC.

A recommended list of major Phase C/D deliverable documents is contained in Table 2-1.

2.3.2 Data Center

The Data Manager will establish a data center to act as the focal point for daily operations and to contain the official project files. Data center activities include:

- Controlling all documentation flowing in and out of the project and providing automated standard distribution of data
- Indexing and cataloging all documents for rapid retrieval using the existing on-line, remote access information management system provided by CADM

- Providing any required microfilm services and equipment
- Storing all official project documentation
- Providing support to remote sites during Level III, II, I integration and during the AMPS flights.

Table 2-1. Recommended Phase C/D Deliverable Data

MANAGEMENT

Project Management Plan
Work Breakdown Structure and Dictionary
Progress Reports
Monthly Financial Management Reports
C/SPCS Plan
Master Schedule
Cost/Schedule/Technical Progress Report
Controlled Milestone List

CONFIGURATION MANAGEMENT

Configuration Management Plan
Configuration Status Accounting Report
Contract End Item Specifications
Specification Change Notices
Document Change Notices
Engineering Change Proposal
Deviations and Waivers

ENGINEERING AND PRODUCTION

Design and Development Plan
Engineering Drawings and Associated Lists
Design Review Data Packages
Interface Control Documents
Payload Interface Verification Plan
GSE Receiving, Acceptance and Maintenance Plan
Manufacturing Plan
Make or Buy Plan

INTEGRATION AND TEST

Integration and Test Plan
Test Procedures
Test Results Report

LOGISTICS/SUPPORT

Logistics Plan
Approved Spare Parts List
Maintainability Assurance Plan
Transportation Plan
Maintenance and Refurbishment Plan

PRODUCT ASSURANCE

Reliability Plan
Quality Plan
Safety Plan
Contamination Control Plan
Critical Items List
Failure Modes Effects Analyses (FMEA)
Failure Analysis and Corrective Action Report
Accident/Incident Report
Hazards Analysis Report
Flight Readiness Summary
Certificate of Flight Worthiness (COFW)
End Item Log Book
Acceptance Data Package
Certificate of Component Qualification

OPERATIONS

Mission Support Requirements Document
Flight Plan
Training Plan
Flight Operations Requirements Document
Flight Performance Report

SOFTWARE (S/W)

Experiment S/W Development and Integration Management Plan
Experiment S/W System Requirements Specification
Experiment S/W Interface Specification
Experiment S/W Interface Modules Design Spec.
Experiment S/W System Verification Test Plan
Experiment S/W System Verification Test Report
Experiment S/W System Validation Test Plan
Experiment S/W System Validation Test Report
Post-Flight Experiment S/W Evaluation Report
Software Program Library Catalog
Software Maintenance Plans and Procedures
Experiment S/W Standards and Guidelines
Experiment S/W Status/Problem Report
Experiment S/W User Manual
Experiment Flight Tapes (Level IV)
Experiment Flight Program Listings (Level IV)
Level III, II, I S/W Support Plan

EXPERIMENT ACCOMMODATION

Experiment Integration Plan
Instrument Systems General Specification
Instrument Interface Operations Questionnaire
Instrument Interface Control Documents

2.3.3 Project Control Room

As part of the data management task, the APM for Planning and Control will establish and operate the project control room. Planning of graphic displays, maintenance of display charts, scheduling of meetings, maintenance and security of display data, and maintenance of room furnishings and equipment will be performed by the planning and control staff.

The primary purpose of the control room will be to provide convenient quick-look visibility to GSFC and TRW Systems project management people. A secondary purpose is to provide a convenient room for meetings such as:

- Preliminary and critical design reviews
- Monthly progress reviews
- Technical progress review meetings
- Contractor's configuration control board meetings
- Interface control working group meetings
- Briefings by subcontractors
- Project management reviews.

Data to be graphically displayed in the control room will be selected by the planning and control staff subject to approval of the Project Manager and will change progressively as the project proceeds through successive phases.

The generic types of data which will be maintained include:

- Master milestone chart
- Data procurement document delivery status charts
- Drawing release and revision status
- Specification release and revision status
- Test plans and procedures status
- Cost status charts
- Subcontractor and GFE status charts.

2.4 PROCUREMENT MANAGEMENT

The TRW central materiel organization will be responsible for procurement activities on the AMPS project. They will assign an AMPS Procurement Manager who will report to the APM for Planning and Control and be responsive to all project needs.

It will be the responsibility of the Procurement Manager to integrate the efforts of project, materiel, and other company organizations to assure that procurements are technically satisfactory, timely, and cost effective. In connection with individual procurements, his office will work with the assistant project managers to establish project policies, procedures, guidance, and controls for identifying requirements, selecting sources, placing procurements, and managing the procurements.

The Procurement Manager will monitor total performance in accomplishing the procurement mission. He will provide status as to plans, progress, and problems to the appropriate management level within and external to the project office to prevent or minimize impact on performance, schedule, and cost. He will also ensure that activities responsible for the procurement are progressing effectively in their implementation. This includes all phases of procurement and levels of management throughout the life cycle of the procurement.

2.4.1 Procurement Categories

The TRW procurement organization recognizes three categories of procurement: a) Subcontracts; b) Critical Procurements, and c) Standard Procurements. The AMPS program involves all three categories of procurement.

a) A procurement is a subcontract when it has all or most of the following characteristics:

- is identified in the contract as a buy item
- is fabricated and/or assembled from supplier drawing(s) and procedures; TRW detail drawings will not exist.
- includes design, development, analysis, and testing effort by the supplier
- will involve formal qualification testing by the supplier

- is a cost type and not a fixed price procurement, because of the considerable development effort
- has a contract value over $100,000.

The only subcontract which has been tentatively identified for the AMPS program is for the barium thermite release cannisters.

b) Procurement is categorized as critical procurement when it does not require appreciable supplier design or development testing effort, but

- exceeds $100,000 in value from a single supplier
- involves complex hardware
- presents unusual technical problems
- is on the critical program path
- requires a high level of TRW attention.

At this time, the following critical procurements for the AMPS program have been identified:

— 5 meter magnetometer mast and deployment and retrieval device

— 15 meter RF sounder mast and deployment and retrieval device

— CII computer with CRT and keyboard.

c) Procurement is categorized as standard procurement when it consists of:

- items made or services performed to TRW detail drawing and process specifications
- raw materials
- off-the-shelf hardware and small standard parts
- supplier catalog items.

The bulk of standard procurement consists of the procurement of piece parts and detailed items listed on the AMPS bill of material.

2.5 CONFIGURATION MANAGEMENT

The configuration management effort will be the responsibility of the APM for Planning and Control. The Configuration Manager (CM) and his staff will be supplied to the project by the TRW Configuration and Data Management (CADM) organization.

The CM will be responsible for:

- Preparing configuration management plans and procedures in accordance with contractual requirements and acting as the interface with GSFC on matters relating thereto.
- Establishing a project release system and controlling specifications, ICD's, drawings and all other released documentation. CADM has the responsibility within TRW for the release of all engineering data and, through the routine use of complex on-line computer systems, can provide rapid, complete status information and summary reports on all released data.
- Establishing a Configuration Control Board (CCB) and, in the capacity of CCB Secretary, publishing meeting agendas and official minutes.
- Preparing, coordinating and submitting ECP's.
- Maintaining a system for identifying the latest correct configuration of each item and verifying the incorporation of all approved changes.
- Provide support as required to offsite locations during Level III, II, I integration, launch and flight operations.

2.6 GFE Management

The detailed list of GFE required for the AMPS project will be contained in the Phase C/D contract and will include:

- Spacelab pallets, racks and associated flight hardware and GSE
- Instruments and associated GSE
- Small Instrument Pointing Systems (SIPS) with associated cannisters, controls, displays and GSE.

In addition to the above, TRW and its subcontractors will closely examine their support equipment requirements as they relate to system and subsystem design, to determine if any other GFE could be utilized on a cost-effective basis. In identifying this additional GFE, attention will be given to the scheduled usage of this equipment on other Government projects which currently have accountability. This availability information will then be correlated with project need dates, and those items which appeared to be available will be proposed for transfer to AMPS. Included in this second category are GFE data handling and transport equipment, computer equipment, and propellants, pressurants, and gases.

The TRW Materiel organization has the responsibility for managing this GFE in compliance with project needs and according to the Materiel organization's Property Manual Standard Practices. The Property Manual is subject to annual industrial property management surveys, and the Standard Practices are implemented as approved by resident Government Property Administrators. Because of the large number and high cost of AMPS GFE, a dedicated GFE Property Manager will be appointed to implement Standard Practices for the acquisition and control of GFE.

2.6.1 Acquisition

The GFE identified in the contract as being deliverable to TRW or its subcontractors will be furnished to the specified location points (destinations) in accordance with the scheduled need date. GFE will be shipped on a Government Bill of Lading and will be accompanied by a DD Form 1149 (or equivalent) shipping document. The shipment of those items which are being transferred from another contract and/or Government agencies will have been coordinated between the respective contracting officers involved in the transaction prior to shipping. In the event TRW identifies additional items of GFE the use of which would be to the Government's advantage, but which were not included in the GFE list at the time of contract negotiations, the contractor shall forward a formal request to the Contracting Officer at least three months prior to the need date and present his justification.

2.6.2 Control

Upon receipt of any GFE which is supplied pursuant to the contract, TRW shall immediately conduct a visual inspection of the GFE and bring it under the cognizance and control of its property management and control system. In accordance with this system, the TRW property management people are provided with a copy of the DD Form 1149. Property management will then physically locate the item and tag it with an accountability tag for identification purposes. The tag will include a tag number designating it as GFE, and will also indicate the contract number to which it is assigned. This tagging process will automatically place the new item in the reporting system for GFE. This reporting system will provide a monthly status computer run (sorted numerically by contract number) to AFPRO as well as the GSFC resident manager. This GFE will be maintained in good order and, if calibration is required, TRW will provide metrology services. A periodic inventroy of GFE will be conducted, and GFE will not be removed from the designated location without Contracting Officer direction to do so.

3. SYSTEMS ENGINEERING AND INTEGRATION

3.1 INTRODUCTION

The systems engineering function assures that the AMPS project design and operational objectives are met in a cost effective manner throughout the life of the AMPS project. During the initial phases of the project the major emphasis will be given the development and/or acquisition of hardware, software, facilities and the methodologies for ground operations and conduct of the AMPS mission. As the project progresses, increased emphasis will be placed on the mission planning, mission operations and equipment and software improvements to allow performance of increasingly complex scientific experimentation. A major activity will be the planning, analysis and coordination to assure that mission objectives can be achieved within the capabilities and constraints offered by the AMPS and Space Transportation System Projects.

3.1.1 Development Concepts

The systems engineering function during the development phase of the AMPS project will have two principal aspects:

a) The conduct of analyses and trade studies related to interfaces system compatibility, system performance, system operation, and other system-level considerations.

b) The development of tools for use in the implementation of the project. For example, computer programs will be used to assess the physical and operational compatibility of equipment elements into candidate payloads.

3.1.2 AMPS Mission Concept

The overall AMPS mission is comprised of a series of scientific experimentation flights designed to accomplish a broad and varying range of science objectives. An important Systems Engineering function will be to provide the tools for accomplishing the mission planning function in a manner that will allow long range project objectives to be accomplished efficiently within an environment of changing equipment, changing payload flight opportunities, altered scientific objectives, revised schedules, etc.

3.1.3 Mission Operations Concepts

Optimizing the AMPS flight and ground operations functions requires an iterative engineering and analytic activity that establishes compatibility of specific payloads that are proposed to meet time-phased scientific objectives. This compatibility assessment requires consideration of the availability of flight opportunities, the availability and performance capability of AMPS and STS equipment, flight planning and crew timeline analysis, design of the candidate payload, and the availability of ground operations resources. Computer programs and automated procedures will be used where they are cost effective.

3.2 SYSTEMS ENGINEERING AND INTEGRATION (SE&I) TASKS

Systems Engineering and Integration (SE&I) during Phase C/D of the AMPS program will involve the design, overview, coordination and synthesis of the many elements of the program into an operational flight capability. The SE&I encompasses the requirements definitions, systems analyses, mission analysis, specification, design review and analysis and integration of all elements of the program. It is a design function which has as its purpose the development of an itegrated functioning capability within the cost, schedule, safety, exisiting hardware and facility, etc. constraints of the program.

These activities will interact with each of the other Phase C/D program elements and with the organizations also contributing to the AMPS program. These relationships, described on Figure 3-1, continue throughout the AMPS development and operational phases.

In the following sections the task elements of SE&I will be described in further detail.

3.2.1 Mission Analysis and Requirements

The objective of the mission analysis and requirements tasks is to perform analysis to confirm mission related performance, design and interface requirements and to develop the mission operations program plans.

3.2.1.1 Performance, Design and Interface Requirements

AMPS performance, design and interface requirements will be developed. The requirements will define the envelope of flight duration, inclination, sun angle, altitude for the AMPS mission. The analysis will also consider the definition of coordinated ground and in-flight operations, allocating functions and activities to the ground support or Payload Specialist teams. From these basic studies the following requirements will be established.

1) Flight crew training
2) Communication
3) Data processing/flow
4) POCC functional requirements
5) AMPS control and display requirements.

3.2.1.2 AMPS Mission Operations Program Plans

Mission operations plans will be developed to establish the philosophy and requirements of the AMPS program. The plans will be used by other WBS elements to define the flight specific operations and design concepts. The following plans will be developed:

1) Communication and data transmission plan
2) Payload operations plan
3) Data preprocessing, verification, calibration and distribution plan
4) Crew training plan
5) Post-flight operations plan.

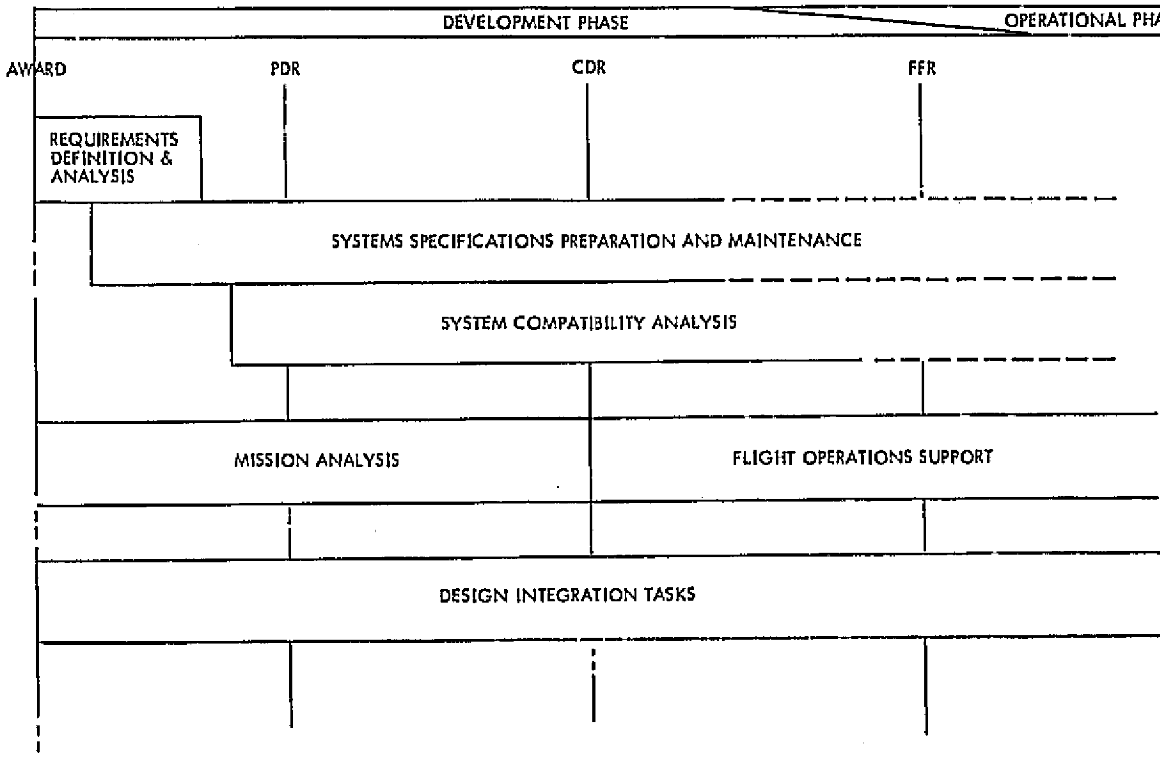


Figure 3-1. Systems Engineering and Integration Task Flows

3.2.2 Systems Analysis

This task includes the definition of all requirements on all hardware, software, facilities and operations required for the conduct of the AMPS program. The definition of requirements will be based on the scientific requirements imposed on the AMPS mission as constrained by the Spacelab/ Orbiter interfaces and capabilities, operational considerations, the need to meet safety, reliability, quality assurance, and maintainability specifications and the need to meet low-cost and schedule guidelines. These requirements will be translated into specific system design requirements as the result of system trade studies which, at a minimum, will cover: design trades, EMI, modularity, contamination, safety, electric power, thermal analysis, materials and processes, magnetic interference, spacecraft charging, logistics, dynamic interactions, ground operations, mass properties, integration and test, human factors, and crew habitability.

These analyses and trade studies will also consider overall payload layouts, ground operations concepts, facilities requirements, training requirements and evolution of hardware to achieve minimum annual and program costs. The results of these trades will be incorporated into the AMPS System Specification and into the other AMPS documents.

An AMPS system specification will be prepared to cover the hardware, software, and facilities that will be developed during the AMPS program. It will be the top specification covering all CEI's and ICD's produced by the integrating contractor and his subcontractors. This document will be responsive to the AMPS general specification issued by the NASA Contracting Officer.

During the Phase C/D, continuing analyses will be conducted to assure compliance with the general specification and other applicable control documents.

Areas of non-compliance with the approved specification will be identified and corrective actions taken as necessary to achieve program system level objectives.

3.2.3 Design Integration

The purpose of this task is to assure that the mechanical, electrical and thermal interfaces among all Spacelab, Orbiter, GSE, instruments, facilities and flight support equipment are compatible.

3.2.3.1 Mechanical Design Integration

This task assures mechanical compatibility and, at a minimum, will cover the following:

a) Payload Layouts. Prepare and maintain system level configuration layouts. Coordinate these layouts to assure that interface requirements have been incorporated.

b) Mass Properties. Prepare, maintain and analyze mass properties budgets and estimates for AMPS payloads. Assure that system-level mass, center of gravity and loading requirements are met. Prepare trend analyses and identify future problem areas.

c) Prepare, negotiate and maintain all mechanical ICD's. Conduct continuing analyses to assure interface compatibility.

d) Develop interface dimensional fixtures as required to assure interface compatibility.

e) Establish standardized interface criteria and implement hardware interface commonality to minimize program costs.

f) Prepare, maintain and implement AMPS alignment documentation and procedures to assure performance compliance.

g) Provide for interface compatibility in support of all hardware assemblies, MGSE, EGSE, ground handling equipment.

3.2.3.2 Electrical Design Integration

This task covers the electrical and electromagnetic compatibility of all electrical interfaces on the AMPS program, including the following:

a) Development and maintenance of overall power budgets, estimates, timelines and trend analyses for each AMPS payload and mission.

b) Allocation of requirements for command telemetry and power interface functions.

c) Preparation, negotiation, and maintenance of the electrical portions of ICD's.

d) Preparation and maintenance of signal and control lists.

e) Development of specifications and requirements for standardized cabling and electrical integration hardware.

f) Conduct of system level EMC analyses to verify that electrical equipment is in compliance with EMC requirements.

g) Preparation and publication of the systems interface definition documents defining the allocations of systems functions to subsystems.

3.2.3.3 Thermal Design Integration

The thermal design integration of all hardware required for AMPS payloads will include:

a) Preparation and maintenance of system level thermal models for all AMPS payloads.

b) Recommendation of thermal coatings and materials for instruments and flight support equipment.

c) Analysis and recommendation of overall thermal protection materials and processes for AMPS payloads.

3.2.4 System Design Reviews

System design reviews will be conducted within the authority of the APM for Systems Engineering and Integration. His task will be to organize the data packages for each review by the customer, to act as the point of liaison and coordination during the reviews, and to assure the completion of actions that are accepted during the reviews.

There will be three formal reviews for each flight payload. The Preliminary Design Review (PDR) for the AMPS flight 1 payload will be held 10 months after award of the phase C/D contract. The PDR for AMPS flight 2 will be held 15 months later. PDR-2 will be an addendum to PDR-1 and will only cover payload changes from flight 1. This approach will be employed for all three reviews. The purpose of the preliminary design will be to evaluate the progress, consistency and technical adequacy of the selected design and test approach before detail design begins.

The Critical Design Review (CDR) for flight 1 will be held immediately before fabrication and assembly of hardware. The flight 2 CDR will be conducted approximately 34 months after ATP. This review will be conducted to determine the acceptability of the detail design performance and test to achieve the required program objectives.

The Flight Readiness Review for flight 1 Level IV will be conducted immediately prior to shipment of the payload from the Level IV integration site. During the review the design, integration, and test results for the payload are reviewed before acceptance of the payload for flight.

4. FLIGHT SUPPORT EQUIPMENT DESIGN AND DEVELOPMENT

4.1 INTRODUCTION

This subsystem plan delineates the tasks required to design, analyze, and verify the AMPS subsystems. Manufacturing of these subsystems is covered in Section 5.

4.1.1 Purpose

The purpose of this plan is to provide planning data that ensures the successful translation of AMPS requirements into verified hardware for the project. This plan will serve as a baseline document for GSFC and TRW in implementing the AMPS project. The plan also serves as a communication media which ensures adequate liaison between TRW and the GSFC design personnel.

4.1.2 Scope

This plan covers all activities relating to the design, analysis, and testing of the AMPS subsystems. The plan outlines the organization and management approach and summarizes the technical features of the subsystems. The design and development plans present a summary description of the tasks required to successfully design and develop the AMPS subsystems. Tasks associated with testing and manufacturing are discussed to show interrelationships with design and analysis. The verification plans describe how compliance with the CEI specification will be demonstrated.

4.2 ORGANIZATION AND MANAGEMENT

AMPS subproject offices have been established to perform all subsystem design, analysis, and fabrication tasks for the AMPS project. The subproject managers are responsible for the technical, cost, and schedule performance of all tasks, and for interfacing with other project elements and GSFC.

The subproject managers are responsible to the APM for design and development.

The managers of the functional engineering laboratories will monitor the technical performance of the subprojects to ensure to the project the benefit of TRW's senior technical management experience. An organization chart of the subprojects for AMPS is shown in Figure 4-1.

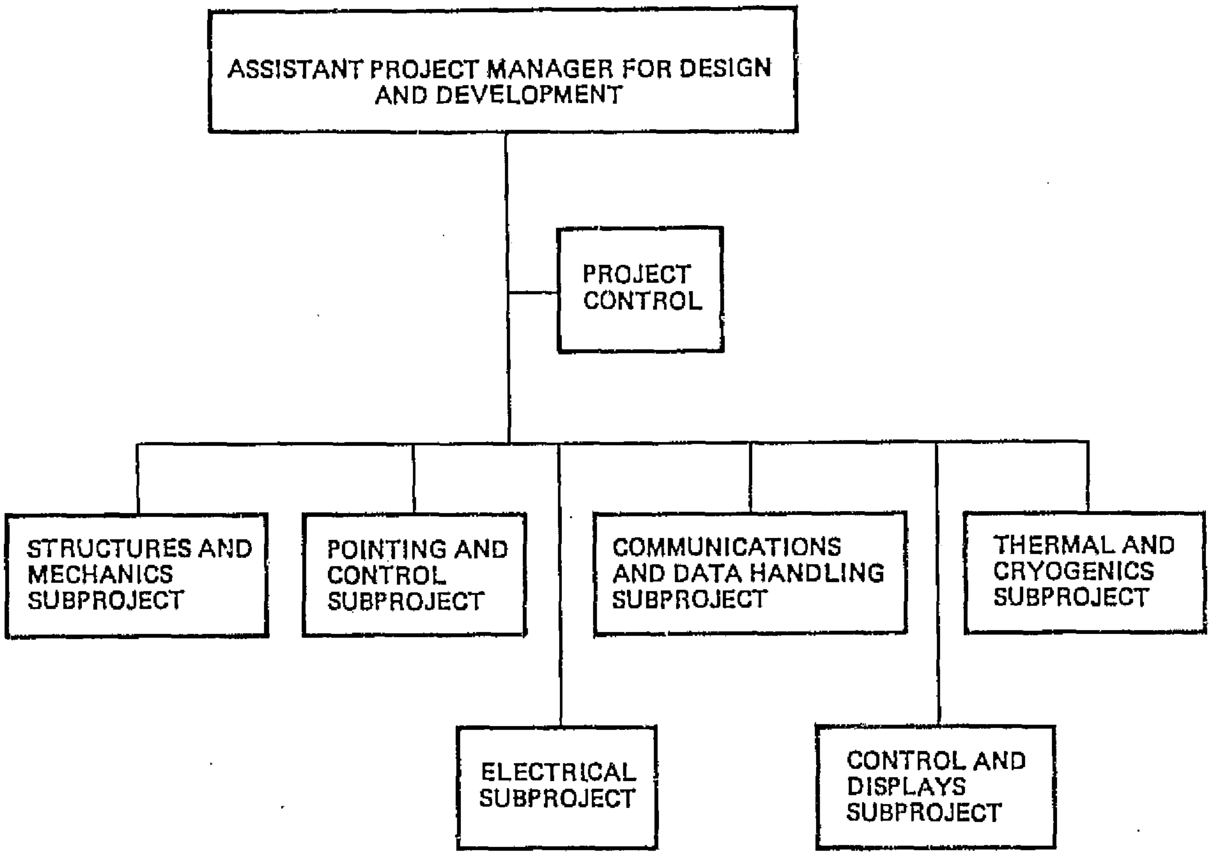


Figure 4-1. Subproject Organization for AMPS

4.3 STRUCTURES AND MECHANICS SUBPROJECT

4.3.1 Technical Requirements Description

The structures subsystem is concerned with the support of all instruments and subsystem components with the requisite strength and rigidity to withstand all environmentally induced loads and effects during all phases of the mission.

The structure subsystem design is governed by the following requirements:

- The structure must be based on conservative criteria to minimize testing and test hardware
- Maximum use must be made of common structural elements
- The structure must withstand the loads and environments induced by the Space Shuttle launch

- The design factors of safety for AMPS are shown below:

	With Test	Without Test
Limit load factor	1.1	2.0
Test load factor	1.25	-
Ultimate load factor	1.4	3.0

  Other requirements are set forth in Reference 1.

- Access must be provided to instruments and AMPS components

4.3.1.1 Technical Description

The AMPS support structure has been designed to make maximum use of the principle of commonality between the various missions and for multiple applications on the same mission. Figures 4-2 and 4-3 present the major support structure utilized on AMPS Flights 1 and 2. As can be seen, common aerospace materials and techniques are utilized.

4.3.1.2 Development Status

Although none of the structural flight support equipment presently exists, it is constructed from standard aerospace materials and utilizes standard aerospace fasteners and components such as ordinance devices, etc.

4.3.2 Implementation Plan

This section presents the plan for the design, analysis, and development testing of the structure subsystem. The plan is arranged in three major subsections:

- Structural and dynamics analyses
- Design
- Test

Engineering and development activities are summarized in the structures subsystem task flow shown in Figure 4-4.

Reference 1, "Safety Policy and Requirements for Payloads Using the Space Transportation System," NASA Headquarters, Office of Space Flight, June 1976.

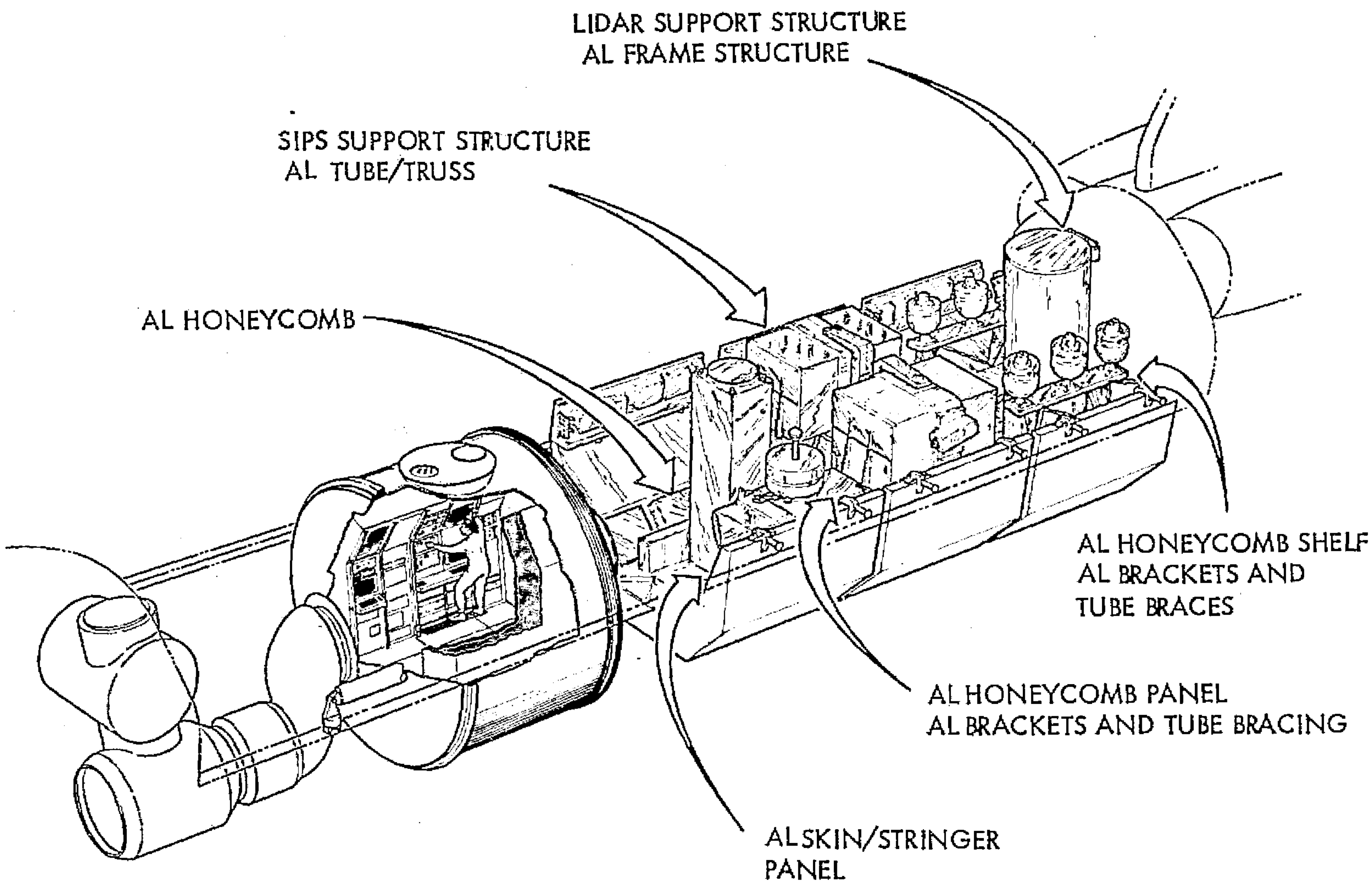


Figure 4-2. AMPS Flight 1 Structural Elements

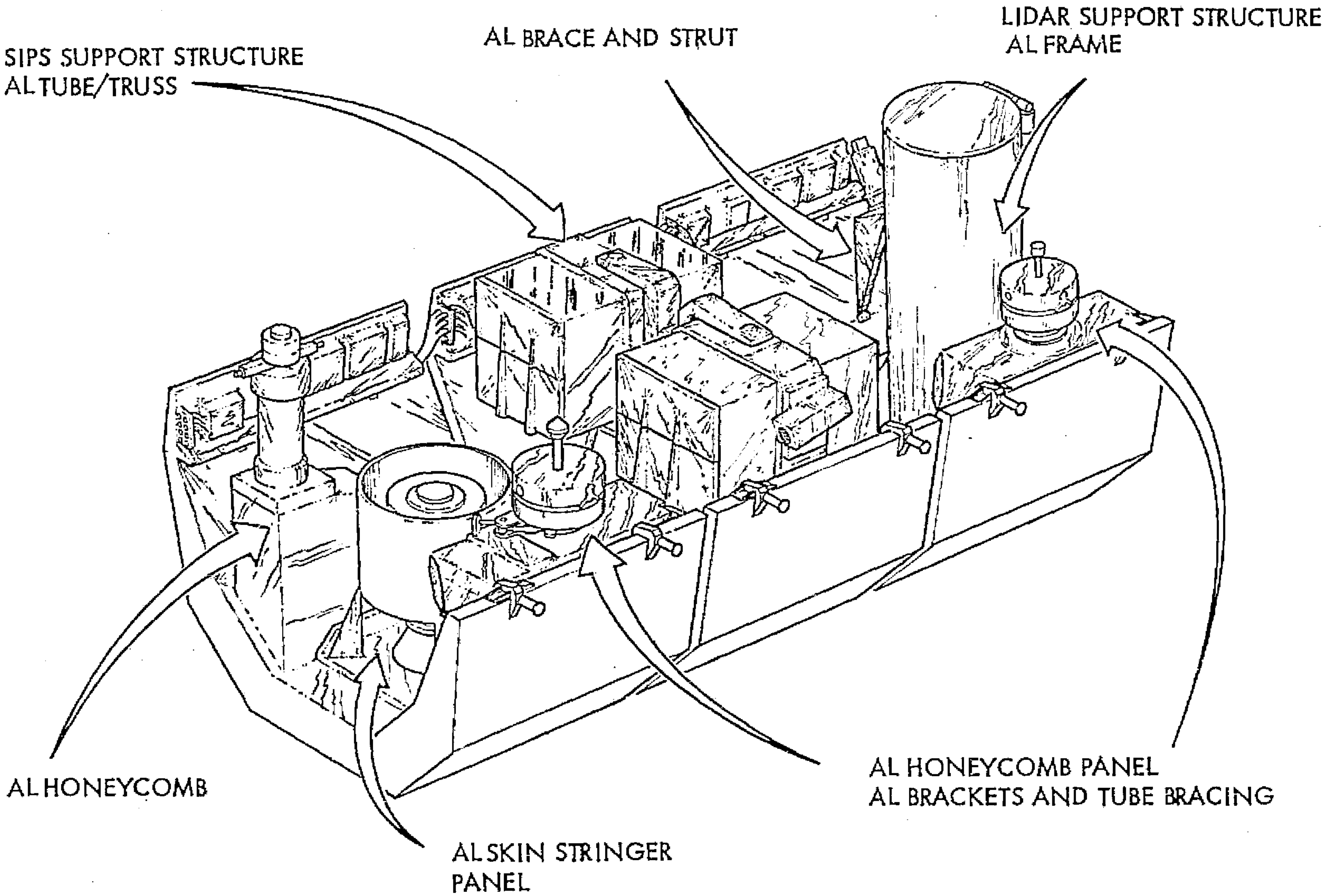


Figure 4-3. AMPS Flight 2 Structural Elements

Over the duration of the structures engineering and development phase, the structures subproject will maintain, in addition to monthly progress reports and scheduled design reviews, effective liaison with cognizant GSFC technical representatives to assure broad mutual agreement on design approach, and conclusions from current studies or tests. All technical correspondence and analytical data generated will be made available to GSFC personnel. Technical working group meetings will be held at intervals deemed necessary by either TRW or GSFC representatives.

4.3.2.1 Structural and Dynamic Analyses

TRW will perform structural and dynamic analyses on AMPS using the individual structures defined during the AMPS phase B study. The order of analyses is as follows once an initial sizing of the structure has been made:

a) Construct an analytical model for use in performing an Orbiter launch vehicle response analysis

b) Determine AMPS interface transients

c) With the AMPS model, establish loads at discrete locations in the structure (i.e., pallet hardpoints, etc.)

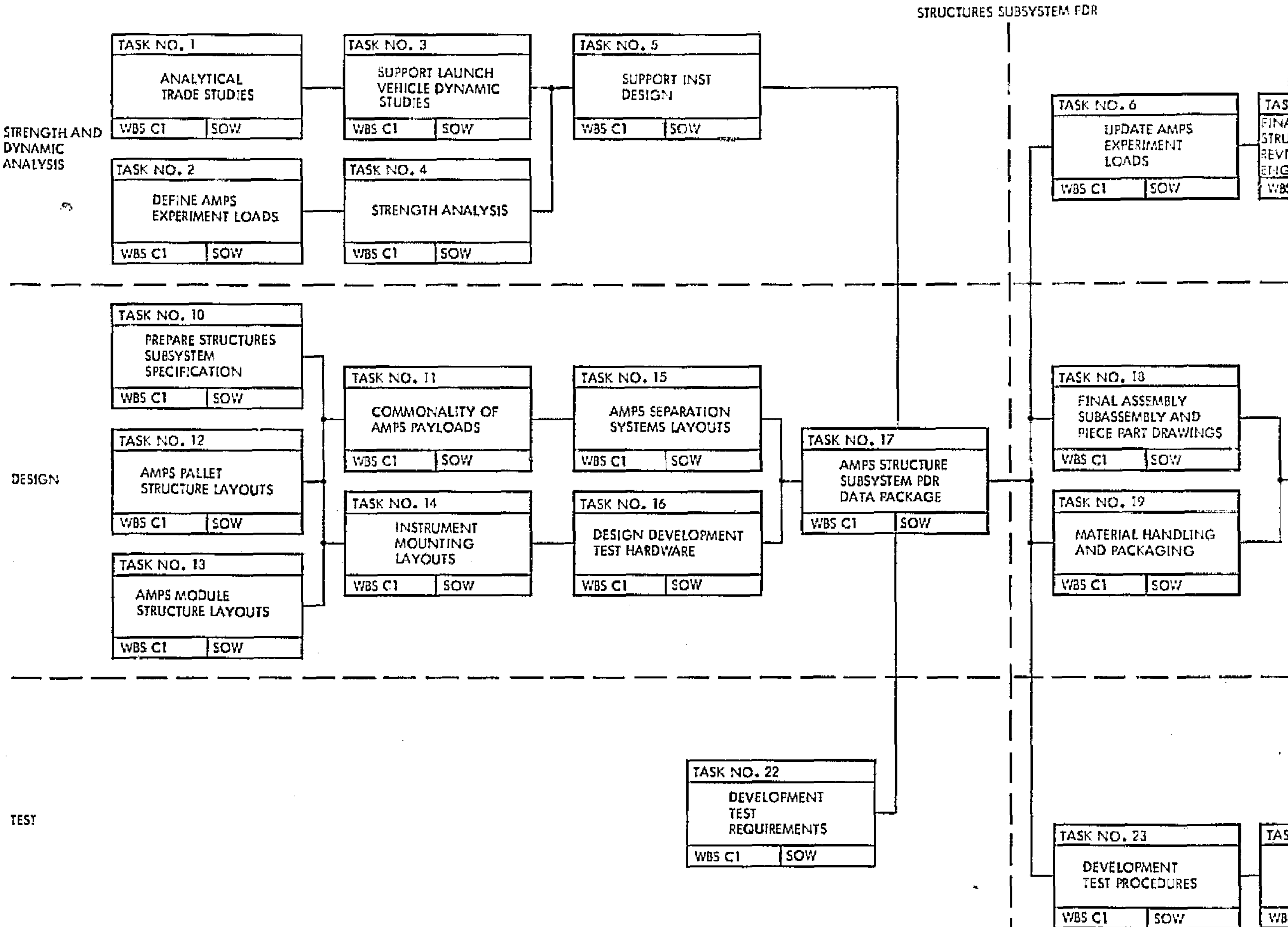
d) Use these loads to perform a strength analysis of the total AMPS payload.

These analytical steps are iterative with the design process for each payload and are repeated for each mission as indicated in the following tasks.

4.3.2.2 Design

The major design engineering activity is the preparation of layouts and of detail and assembly drawings. Other activities include:

- Preparation of the structures subsystem specification
- Coordination planning with manufacturing and test
- Monitoring structural and functional tests
- Action on disposition of discrepant piece parts
- Support the AMPS integration efforts



FOLDOUT FRAME

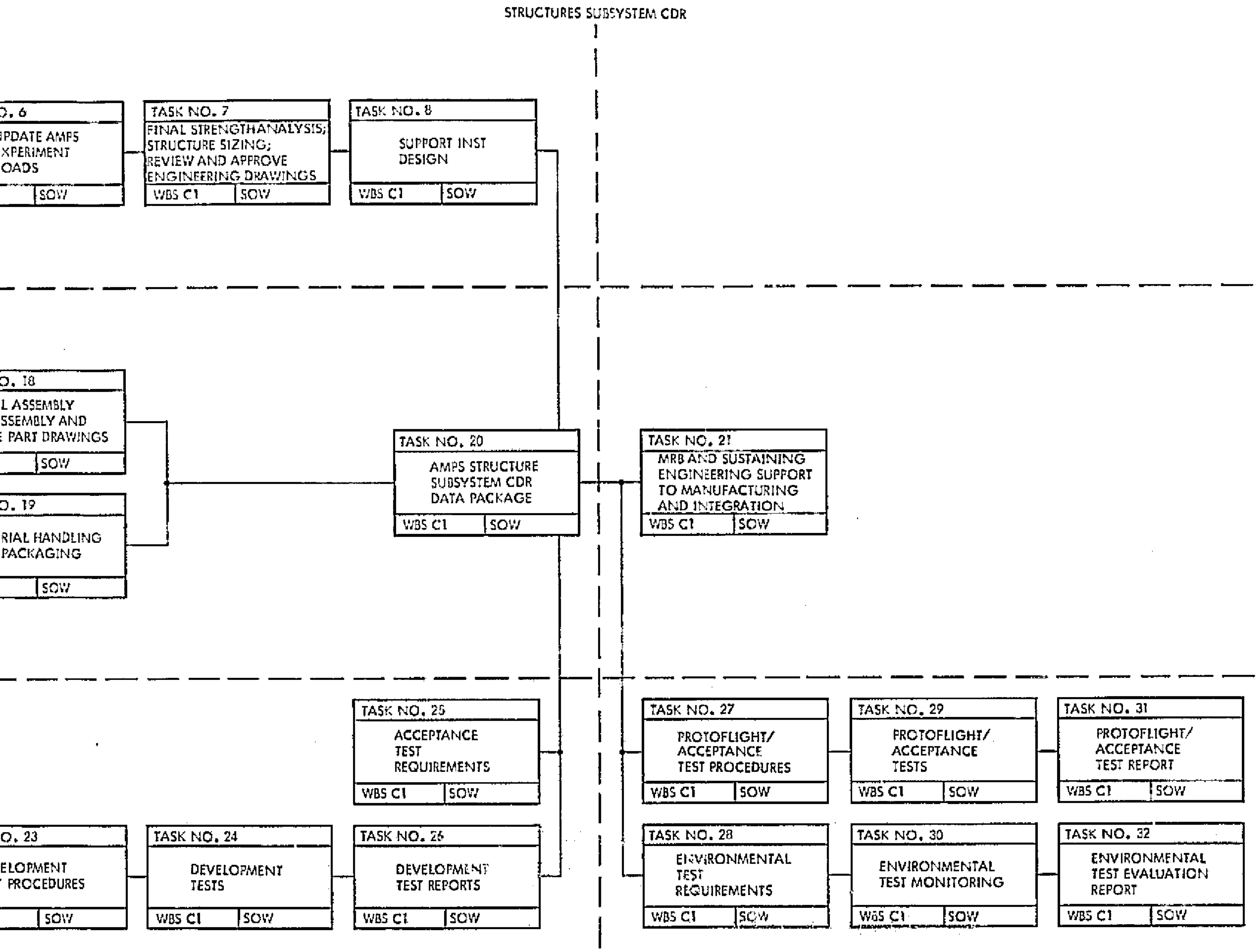


Figure 4-4. Task Flow

FOLDOUT FRAME 2

- Continuous coordination with the mechanical design integration activity, materials and processes (PM&P) engineers, and stress and dynamics engineers.

Final design drawings are released through TRW's Configuration Administration and Data Management (CADM) organization which maintains control of drawings at TRW. This process is described in the Configuration Management Plan.

4.3.2.3 Test

This section identifies the development and acceptance tests that will be performed on components of the structure subsystem and the associated tasks. Structures subproject tasks associated with Level IV environmental tests are also indicated. Activities include:

- Development tests
- Development test requirements definition
- Development test procedures
- Development test reports
- Protoflight/acceptance tests
- Protoflight/acceptance test requirements definition
- Protoflight/acceptance test procedures
- Protoflight/acceptance test reports
- Support to AMPS environmental tests
- Support to AMPS environmental test requirements
- Support to AMPS environmental test reports

4.3.3 Design Verification Plan

The design verification plan for AMPS describes the necessary analyses and test requirements for verification of structure subsystem components and assemblies. The plan covers activities beginning with launch loads analyses and continuing through final strength analysis, assessment of structure capability, and verifies that the structure subsystem meets the design, strength, and functional requirements of the CEI specification.

4.3.3.1 Analyses

Design verification of the AMPS structure will be accomplished by analyses to the greatest extent possible. These analyses encompass dynamic response analyses of AMPS and subsequent static strength analyses to establish internal structure loads and to assess structural capability. High factors of safety on yield and on ultimate are utilized to verify structural capability of all structure components and assemblies and ensure high confidence of adequacy.

4.3.3.2 Development Testing

A separation system development test program will be conducted to verify the structural adequacy, shock environment, functional performance of the separation V-band assembly utilized on the masts and the compatibility of the ordnance cartridges with the separation mechanism.

4.3.3.3 Protoflight/Acceptance Tests

All new structural elements will be subjected to a protoflight series of functional and environmental tests. The environmental levels will be established at values which will provide proof of concept but still allow flight of the assemblies.

4.3.3.4 AMPS Environmental Tests

The environmental test program planned for AMPS is TBD environmental tests. These tests will provide verification of the capability to withstand the specified design environments. The structures subproject will support the planning, procedures and Labcraft environmental test accomplishment.

4.3.4 Subcontracts and Critical Procurements

The tentative make-or-buy decisions for the structures subproject are listed in Section 5. However, there are no critical subcontracts in the structures subproject.

4.3.5 Hardware/Software/Documentation Deliverables

The hardware/software deliverables are (TBD). Documentation deliverables are described in Section 2.3.

4.3.6 Structure Subsystem Milestone Schedule

The structure subsystem milestone schedule is shown in Figure 4-5.

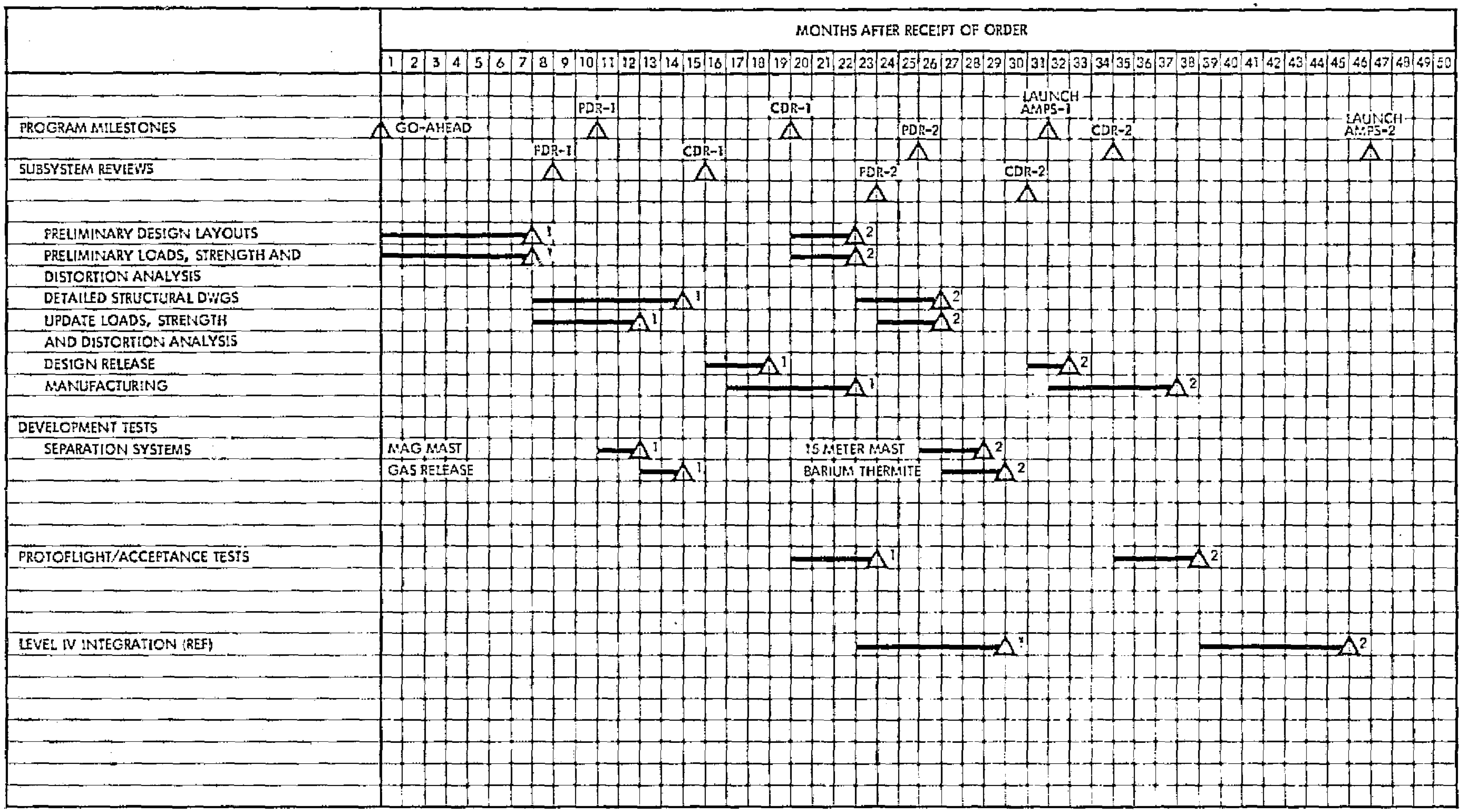


Figure 4-5. AMPS Structures and Mechanics Subproject

4.4 POINTING AND CONTROL

4.4.1 Technical Requirements

The pointing and control subsystem encompasses those elements which perform the pointing and stabilization of the AMPS scientific payload. The main function of the subsystem is to control the gimballed experiment pointing mount and to provide attitude transfer between pallet-mounted instruments. It consists of attitude sensors, on-orbit alignment devices, control processing software and electronics, and gimbal drive mechanisms. The pointing and control subsystem is of particular importance to AMPS since it must demonstrate the capability to correctly point and stabilize the scientific instruments so that useful experiment data can be obtained.

The design of the pointing and control subsystem must:

- Establish instrument pointing and stabilization requirements
- Recommend the gimballed experiment pointing mount to be used for AMPS
- Provide a stable and accurate attitude reference system
- Control the experiment pointing mount in the presence of Orbiter limit cycle motion, crew motion, and hinge friction disturbances.

4.4.1.1 Technical Description

The TRW pointing and control subsystem configuration baselines the Small Instrument Pointing System (SIPS) as the only instrument pointing mount that is required. Precision attitude reference is obtained from a stellar inertial attitude reference system employing gyros and a strapdown star tracker, all mounted to the SIPS canister. Attitude transfer to and between pallet-mounted instruments makes use of the SIPS resolvers and an optical alignment system. The majority of the software and electronic data processing functions is performed by programmable digital electronics (PDE). The configured pointing and control system meets and exceeds the performance requirements of the cryogenic instrument which is the design driver, and it is demonstrated that the SIPS can be pointed with 95 percent confidence to within 18.8 arc-sec (2σ) comprising a short-term (10 to 20 seconds) pointing stability error of less than 0.5 arc-sec (2σ).

These experiment pointing mount requirements are not unique to AMPS and have been recognized by NASA for general payload support. As a result, preliminary work has been done on the SIPS and development funding must take place in FY '78 in order to support an October 1981 AMPS launch date.

Throughout the remainder of this section, it is assumed that the SIPS will be fully developed as a piece of multimission support equipment and provided GFE to the AMPS project. This greatly simplifies the AMPS pointing and control subproject job.

The design driver for the pallet-mounted instruments is the attitude determination accuracy of 2 degrees of the vector magnetometer relative to the electron accelerator. It imposes the most stringent demands on the attitude transfer system because the accelerometer and the vector magnetometer are located on different pallets.

Attitude transfer/alignment between pallet-mounted instruments is accomplished by optical means. The alignment system contains three light sources, a solid-state detector, and a convex mirror. The position of the reflected images seen at the detector indicates the angular deviation of the magnetometer package. An error analysis demonstrates that an alignment knowledge within 2 degrees can be easily provided by this system.

4.4.1.2 Development Status

The SIPS is scheduled to be developed in the United States under NASA's direction. It is designed as a shuttleborne, balanced instrument pointing mount (payload CM and gimbal hinge point nominally coincide), is hard mounted, and will accommodate smaller instruments weighing up to about 600 kg. It will be capable of rastering and tracking and serve stellar-inertial pointing missions as well as earth pointing missions. Assuming adequate funding, there can be no question that the SIPS will meet the AMPS requirements.

The optical alignment transfer device is in the conceptual stage. Preliminary breadboard testing has been successfully accomplished. This is a low-risk development due to the simple nature of the detector, the standard light sources (LED's) and optics, and the considerable performance margin that exists in the preliminary design.

4.4.2 Implementation Plan

This section describes the activities required to design and develop the PCS hardware and software. It includes all development efforts from detailed hardware start through final release of hardware designs to manufacturing, engineering development and performance demonstration testing of the integrated subsystem, and design and verification of the PCS software programs. The design and development process comprises the following three categories:

- Subsystem engineering and test
- Design analysis
- Hardware design and development.

Figure 4-6 presents the task flows for the PCS development.

4.4.2.1 Subsystem Engineering and Test

Identifies the tasks which relate to subsystem interface design and subsystem level testing. Because the subsystem engineering role is one of integrating and demonstrating, the PCS development, subsystem reviews are grouped here also. The tasks of this category are indexed below:

- Subsystem development and interface engineering
- GSFC/TRW requirements development and review
- Subsystem testing and software verification plan
- Plan and implement engineering tests of development hardware
- Develop PCS ground operations requirements
- Subsystem test documentation: specifications and procedures
- Develop ground operations software requirements for PCS-POCC
- Document PCS operations requirements for PCS-POCC
- Support hardware compatibility tests
- Support integrated flight program and test
- Evaluate subsystem test results
- PCS critical design review.

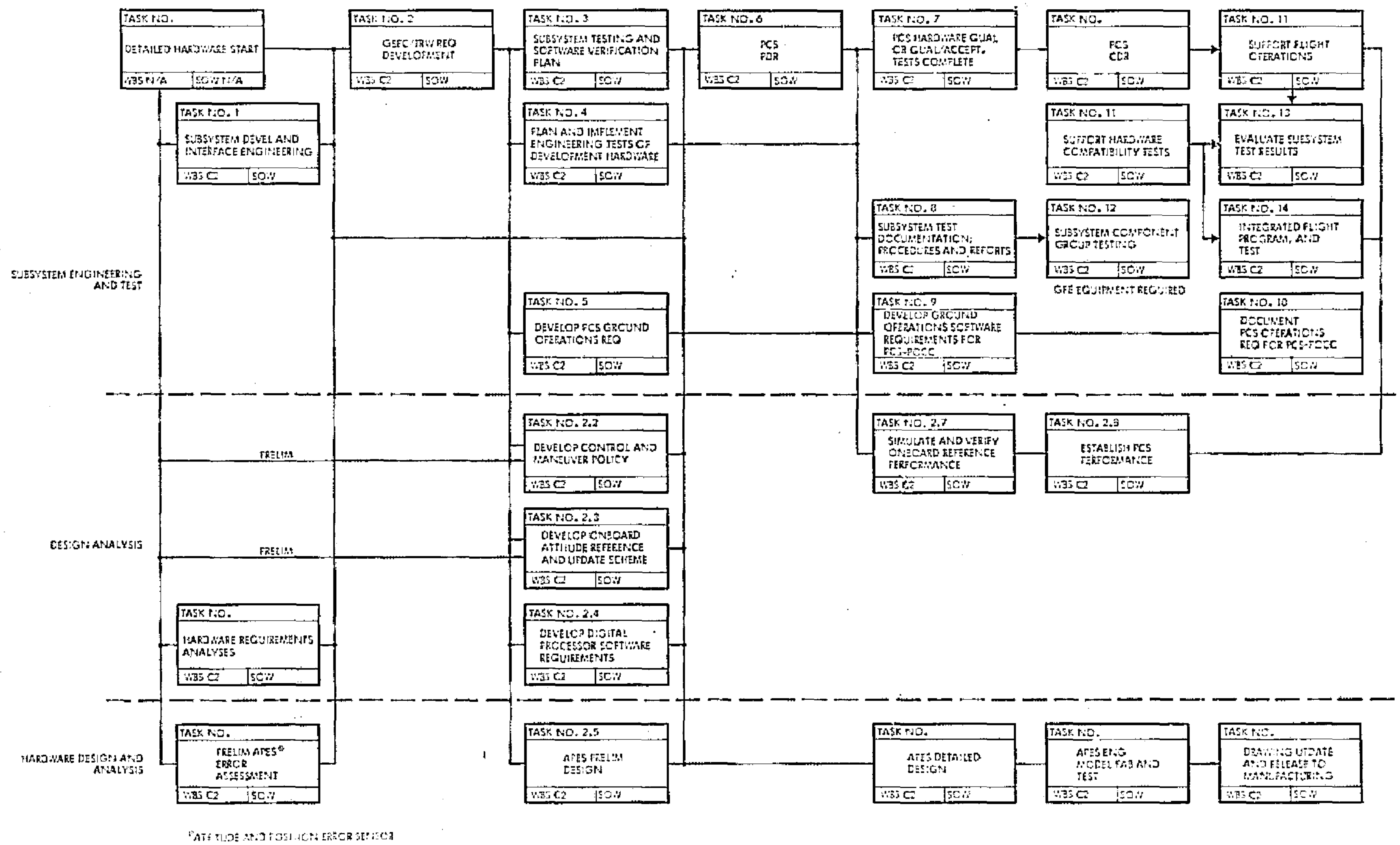


Figure 4-6. PCS Task Flow for Subsystem Engineering and Design Analysis

4.4.2.2 Design Analysis

This subsection contains the tasks which relate to subsystem conceptual design, analyses, performance predictions, and verification simulations by computer. The hardware and software functional design requirements proceed from these efforts, as do the analytical bases for subsystem engineering activities. The tasks of this category are identified below:

- Perform hardware requirements analyses
- Develop control and maneuver policy
- Develop on-board attitude reference and update scheme
- Develop digital processor software requirements
- Simulate and verify on-board reference performance
- Establish detailed combined mode simulation.

4.4.2.3 Hardware Design and Development

Identifies the effort required to design and develop the PCS attitude and position error sensor (APES) hardware components. The design and development tasks for PCS APES components are identified as the following: requirements, preliminary design, detailed design, breadboard fabrication and testing, test equipment design, product design, engineering model fabrication and test, design release, and verification testing. The equipment specifications for all of the PCS hardware shall be prepared in accordance with TRW standard procedure, with subsequent release and control through CADM as defined in the Configuration Management Plan. The verification (test) specification shall be prepared as Part 4 of the equipment specification. The verification (test) procedures and test reports will be prepared and submitted. Design audits are identified in the appropriate task areas. The interrelationships between tasks are provided in the form of task flows. Detailed scheduling of the tasks and associated milestones are provided in Section 4.4.6.

4.4.3 Design Verification Plan

The conceptual design and predicted functional performance of PCS are obtained originally by means of analyses and simulations. They form the functional requirements for implementation of the desired control approach. The objective of subsequent development effort is to produce equipment and software which achieves the performance predicted by the analyses and simulations. The purpose of the subsystem verification program is to measure the degree to which the combined components and software (i.e., subsystem) do approximate the predicted performance, and to establish correspondence between the two. The test program, along with correlation of test results with analytical predictions, provides the only means of establishing confidence that the real subsystem will behave as desired.

The purposes of the PCS verification program can, therefore, be summarized as the following.

- Validation of the hardware approximations and assumptions underlying the PCS design analysis
- Assurance of the soundness of individual equipment designs, both functionally and physically
- Assurance that the flight program software is functionally sound
- Assurance that subsystem components, integrated together, are electrically and functionally compatible
- Demonstration that the entire subsystem, including flight software, meets its performance requirements (justifying commitment to flight).

The baseline verification program realizes the stated goals by the following:

- Verification of the functional integrity of PCS APES components. Performance tests are developed which completely characterize the performance of each component for correlation with the analytical assumptions which led to its original specification.
- Verification of PCS performance with flight software. The integrated PCS components and the flight program will be exercised in conjunction with the Level IV integration. This test will represent orbital conditions and mission operations as realistically as possible. Key performance parameters will be measured, and the dynamic results will be used to corroborate earlier development simulations and design assumptions. Successful completion will validate the flight program, provide a data base for later system level testing, and afford insight into the operational use of the PCS

4.4.4 Subcontracts

No major subcontracts or major procurements are anticipated.

4.4.5 Hardware/Software/Documentation Deliverables

The hardware/software deliverables are (TBD). Documentation deliverables are listed in Section 2.3.

4.4.6 PCS Subsystem Milestone Schedule

The PCS subsystem milestone schedule is shown in Figure 4-7.

4.5 ELECTRICAL SUBSYSTEM

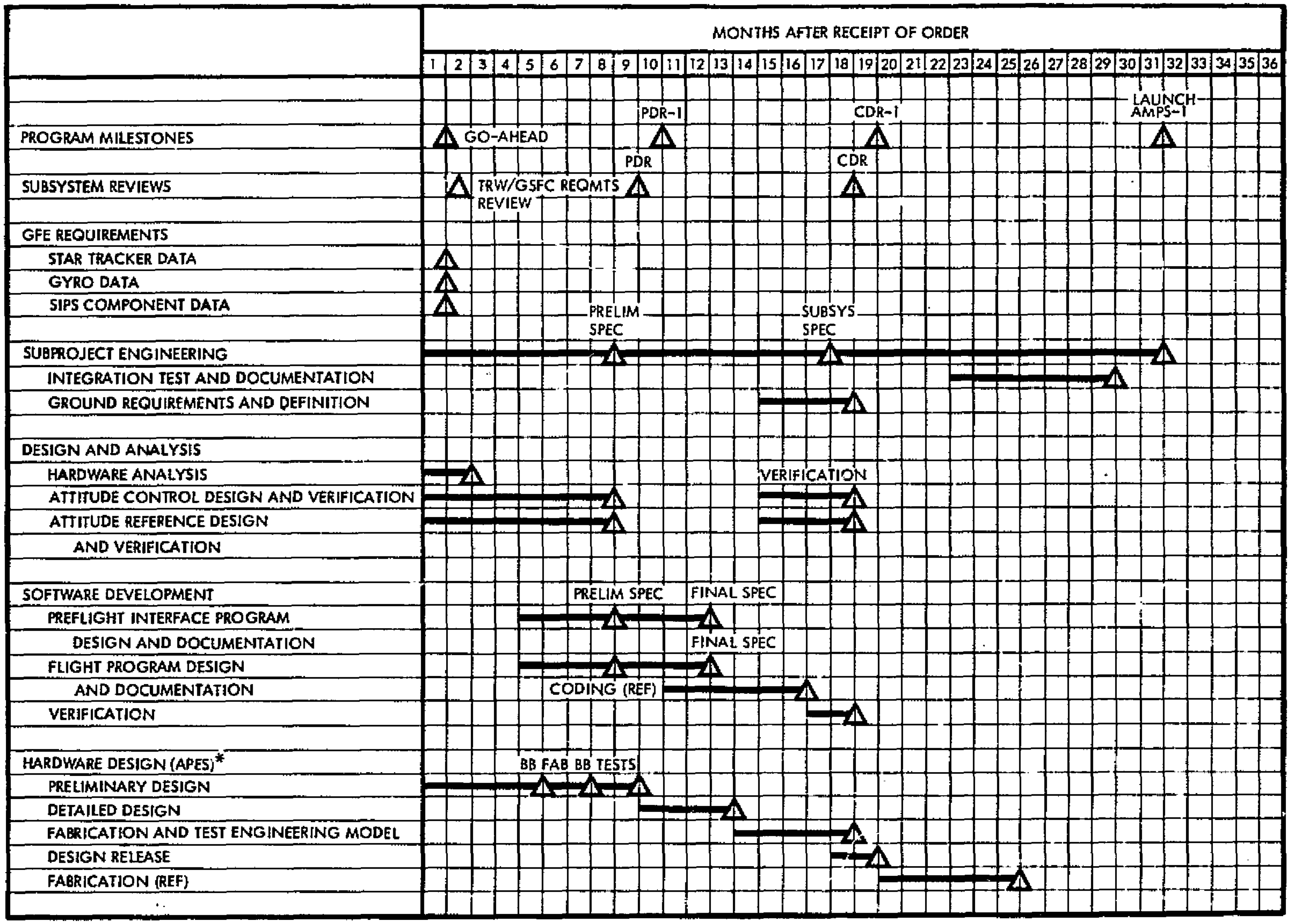
This section describes the TRW approach for implementing the electrical subsystem (ES) design and development for the AMPS project. The activity involves design, development, and verification of the ES hardware.

4.5.1 Technical Requirements

The electrical subsystem for AMPS does not require the design of an electrical power source because power is provided from a dedicated power source in the Orbiter through the Spacelab power distribution system. This fact does not, however, remove the need to establish electrical power and energy requirements for instruments and support equipment. In addition, it is necessary to perform the distribution of power and signals on the pallets and to satisfy the interface requirements with the Spacelab and Orbiter. The functions that the electrical subsystem must provide include the following:

- Power and energy management
- Primary power distribution
- Secondary power distribution
- Command and signal distribution
- Caution and warning distribution
- Fault isolation
- Common energy storage.

No changes are required to the existing Spacelab/Orbiter system, but some augmentation is required. A review of the electrical power and energy requirements for Flights 1 and 2 resulted in power and energy values within the capabilities provided.



*ATTITUDE POSITION AND ERROR SENSOR

Figure 4-7. Pointing and Control Subsystem Milestone

4.5.1.1 Technical Description

A major hardware item to be added to the Spacelab electrical subsystem is a common energy storage system. This system is used to store and deliver high energy and high voltage pulses to the electron accelerator. An investigation of devices to satisfy the high energy and voltage requirement was conducted and included flywheels, pumped pressure systems, batteries, capacitors, and inductors. Only capacitors and inductors could meet the high-power and high-voltage output requirements. Capacitors were selected because of low cost and available hardware. The common energy storage system is modular and can be increased in size to provide the increased energy requirements for later flights. The common energy storage system consists of a capacitor bank and a low-power processor. The low-power processor accepts a 28-volt input and delivers an output to the capacitors of 450 volts maximum.

The Spacelab-provided items include the remote acquisition units (RAU's), the electrical power distribution box (EPDB) and the power bus, interconnect station (IS), and essential power bus cabling. To these items, the AMPS payload will provide a caution and warning J-box, a Labcraft emergency safing unit, and the caution and warning, power, signal and essential/emergency cabling. The Labcraft emergency safing unit will be made up of slices as required, to provide safing functions in the event of power failure.

The use of standardized cabling has been studied and found to be desirable for AMPS and all Labcraft payloads. The use of a Labcraft interface bracket is required in lieu of a design change by ESA. Once the interface bracket is made and installed, it can be reinstalled and used on all Labcraft flights.

4.5.1.2 Development Status

Although none of the assemblies required for the electrical system presently exist, they are a low-risk development since the components and design techniques are standard for the industry and very familiar to TRW.

4.5.2 Design and Development Plan

This section of the plan describes the activities required to accomplish the subsystem engineering activities and to design and develop the ES hardware. It includes all development efforts from detailed hardware start through final release of hardware designs to manufacturing, including engineering development and performance demonstration testing of the integrated subsystem. The plan includes the following major phases:

- Requirements definition update
- Preliminary design and analysis
- Detail design and verification.

Figure 4-8 is a flow chart indicating all major tasks to be performed. The tasks are divided into the major phases as shown above. Where unique tasks are required for specific components, they are called out individually. The tasks fall into the general categories of:

- Subproject management and subsystem engineering
- Component design and development
- Harness development.

The design and development approach described for the ES has evolved from past space programs and has proven extremely effective in producing cost-effective hardware of high reliability and performance. Key features of the approach include the integrated design of the component and associated test equipment by the same personnel with a high degree of coordination between the electronic and product designs and manufacturing. A standard packaging technique will be employed for the electronic components.

4.5.3 Design Verification Plan

The design verification plan describes the necessary tests and test equipment requirements for the design verification of ES components. The plan covers test activity from the breadboard phase through the protoflight/acceptance programs which will be conducted to verify that the ES meets the performance, design, and test requirements of the CEI specification. The test equipment requirements for ES components and methods for fabrication of purchased components are discussed in the test equipment section of the manufacturing plan.

4.5.3.1 Development Testing

All new, unusual, or unproven circuitry and components will be subjected to developmental testing to verify operation under expected operating conditions. The development test program includes voltage, thermal, and mechanical stress variations as delineated in the development test plans. These development tests are outlined in Table 4-1 for selected components from the electrical subsystem.

4.5.3.2 Protoflight/Acceptance Testing

The acceptance test program is used to certify that the flight hardware complies with the electrical and structural design requirements (Table 4-2). Protoflight/acceptance testing is proof testing conducted in an environment exceeding that expected during the mission life, but less than the qualification level. All acceptance level environmental testing is conducted in accordance with (TBD).

4.5.4 Subcontracts

No major subcontracts or critical procurements are contemplated.

4.5.5 Hardware/Software/Documentation Deliverables

The hardware/software deliverables are (TBD). The documentation deliverables are listed in Section 2.3.

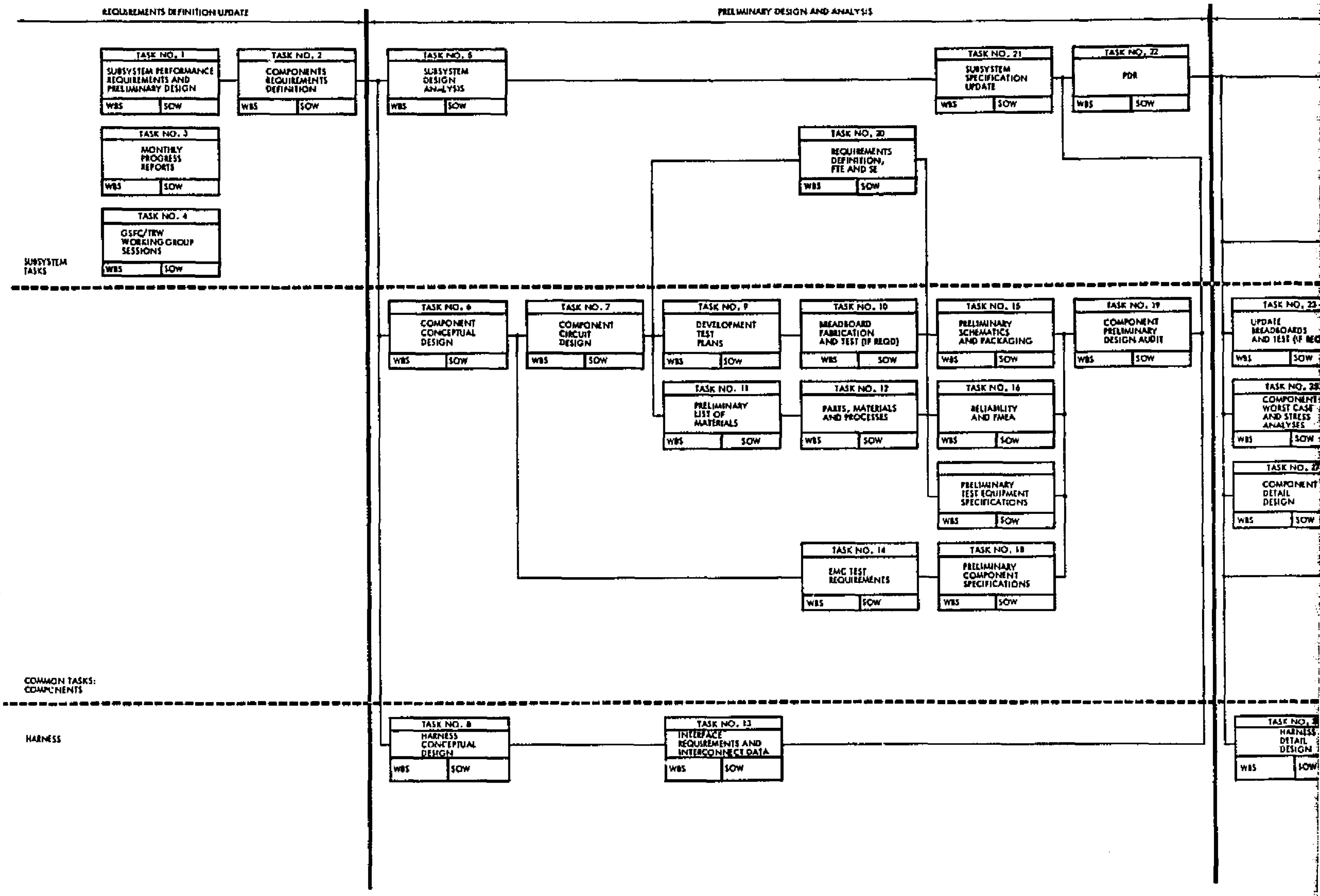
4.5.6 Subsystem Milestone Schedule

The development milestones schedule for the electrical subproject is shown in Figure 4-9.

4.6 COMMUNICATION AND DATA HANDLING SUBSYSTEM

4.6.1 Technical Requirements

The basic functions of the Communication and Data Handling Subsystem (CDHS) are to provide the payload all the services necessary for instrument command and control, data acquisition, data processing, data displaying, data storing, data transmission to the ground and to receive commands from the ground. The CDHS configuration utilizes the Shuttle Orbiter communication equipment and the Spacelab data management equipment to meet the AMPS payload communication and data management requirements.



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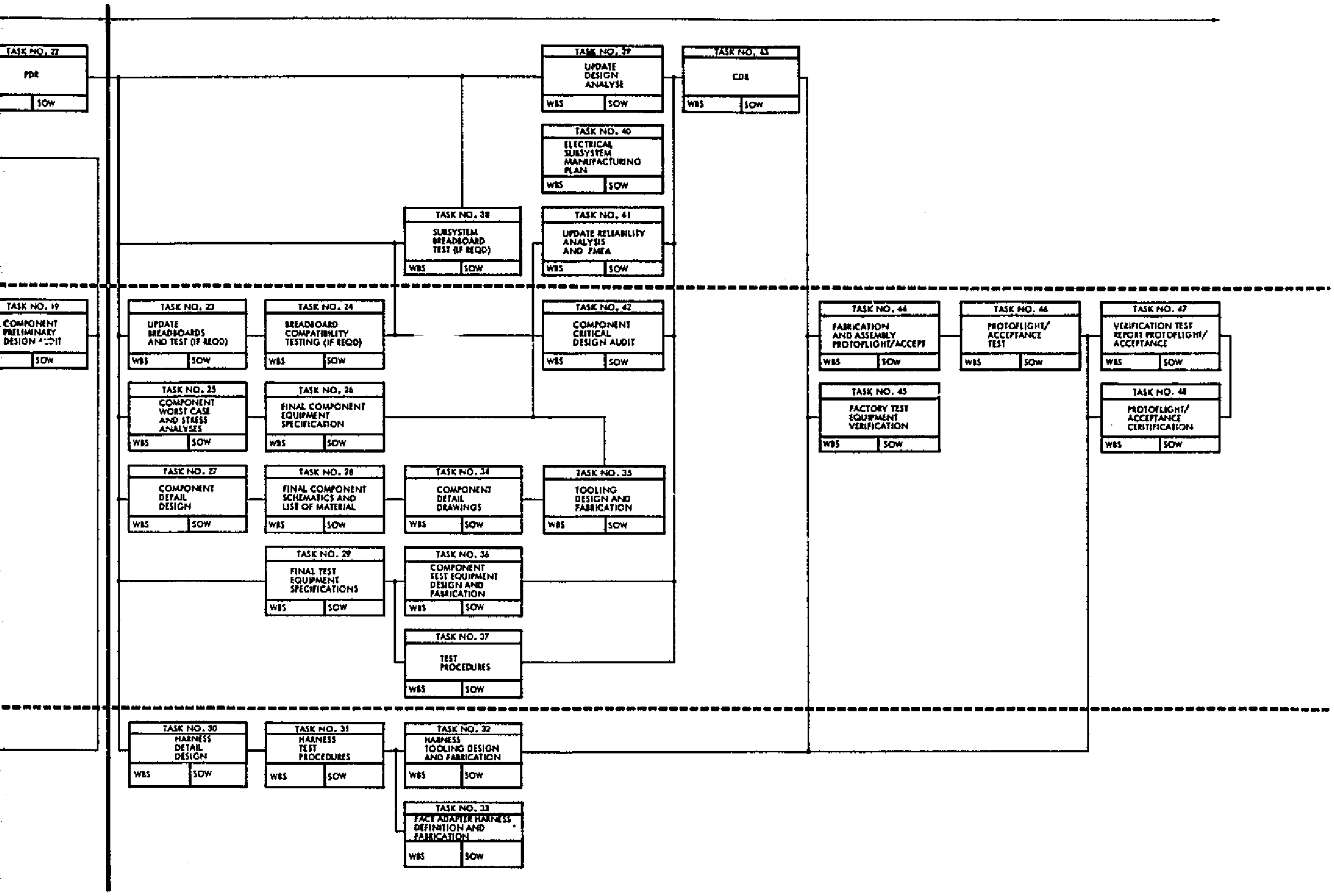

Figure 4-8. Electrical Subsystem Task Flow

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Table 4-1. Design Verification Plan

Unit	Purpose	Test Method	Test Article	Equipment and Facilities
Common energy storage	Determine operating characteristics of new, unproven circuits	Measure circuit response	Breadboard circuits	Laboratory test equipment, temperature chamber

Table 4-2. Protoflight/Acceptance Test Plan

Unit	Purpose	Test Method	Test Article	Equipment and Facilities
Common energy storage	Proof test for flight units to certify compliance with requirements	TBD	All flight units	Unit test set, laboratory equipment, and environmental facilities
Caution and warning units	Proof test for flight units to certify compliance with design requirements	TBD	All flight units	Unit test set, laboratory equipment, and environmental facilities
Emergency safing units	Proof test for flight units to certify compliance with design requirements	TBD	All flight units	Unit test set, laboratory equipment, and environmental facilities
Harness	Verify compliance with manufacturing drawings and specifications	Measure continuity and leakage resistance	All harness assemblies	Flexible automatic circuit test (fact)
Harness bakeout	Contaminant removal	$150 - 170^{\circ}F$ temperature exposure at 1×10^{-4} for 24 hours	All harness assemblies	Thermal vacuum chamber
Harness thermal vacuum, vibration, shock, and EMC tests	These tests are performed at the system level following installation of the harness assembly and all subsystem hardware.			

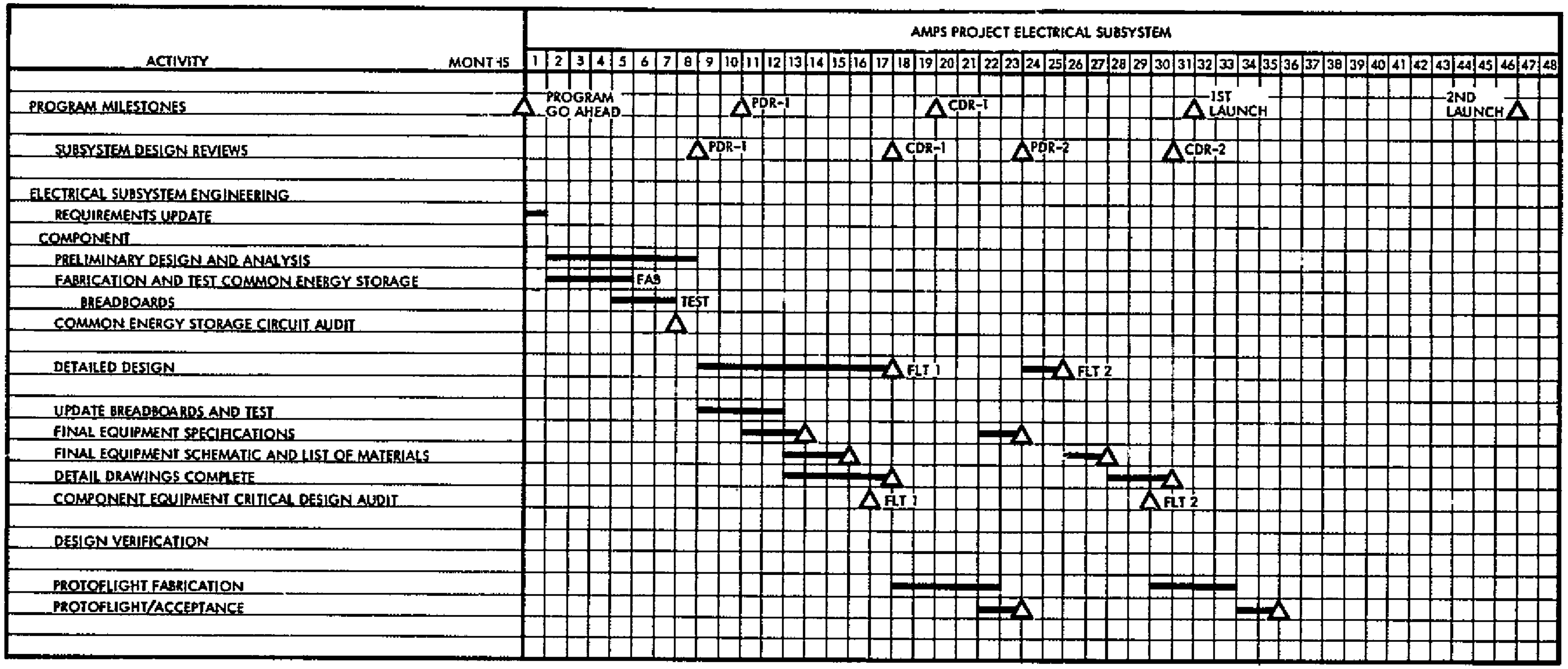


Figure 4-9. Electrical Subproject Development Milestone Schedule

The principal communication subsystem requirements are the following:

- Receive, demodulate, and retransmit ranging signals from STDN or TDRSS
- Receive, demodulate, and route to the AMPS payload command and voice data from the payload operations control center
- Transmit real time science, voice, and playback data from the AMPS payload to the payload operations control center on the ground
- Transmit and receive command and telemetry data from the environmental sensor package (ESP) via the Orbiter payload interrogator.

Similarly, the principle data management subsystem requirements are the following:

- Provide remote acquisition units (RAU) to distribute commands from the experiment and subsystem computers to the user subsystems and science instruments
- Provide for the acquisition of data from the user subsystems and science instruments via RAU's
- Provide for the processing of real time uplink commands, stored pre-programmed commands, and adaptive commands generated on board
- Provide timing data to user subsystems and instruments
- Provide data storage capability during TDRSS noncoverage periods.

4.6.2 Technical Description

The AMPS payload communication requirements are satisfied completely by the Orbiter S-band and Ku-band Communication Subsystems. Figure 4-10 shows an overview of the Orbiter communication links and capabilities to the ground. Two types of downlink facilities are available to the AMPS payload. They are the Space Tracking and Data Network (STDN), linking the Orbiter directly to these ground stations by S-band, and the Tracking and Data Relay Satellite System (TDRSS), which consist of two relay satellites and one ground station. The communication link between TDRS and its ground station is at Ku-band frequencies. The TDRS/Orbiter link is normally at Ku-band; and S-band; and S-band is used only until the Ku-band link is acquired and established.

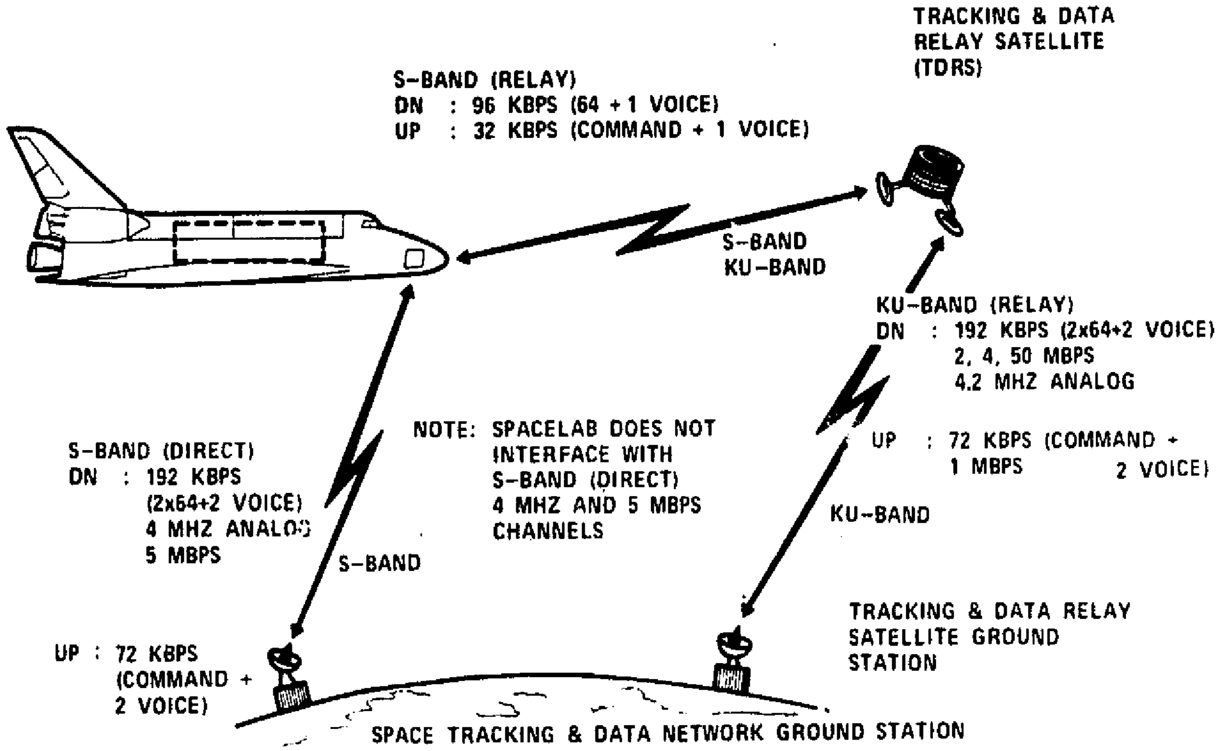


Figure 4-10. Orbiter Communication Links

The transmission of the data generated by the AMPS payload is performed by the Orbiter avionics equipment with the exception of the S-band command and telemetry equipment on the ESP. This equipment provides a data link between the ESP and the Orbiter. The S-band command and telemetry system is compatible with the Orbiter payload interrogator system.

A block diagram of the ESP command and telemetry subsystem is shown as Figure 4-11.

The Spacelab Command and Data Management Subsystem (CDMS) is used to accommodate the AMPS payload data acquisition and handling requirements. These CDMS services include data acquisition, data processing, data formatting, data transmission to the Orbiter, recording, monitoring, display, command and control capability for experiments and subsystems, audio communications, caution and warning, and provisions for closed circuit television.

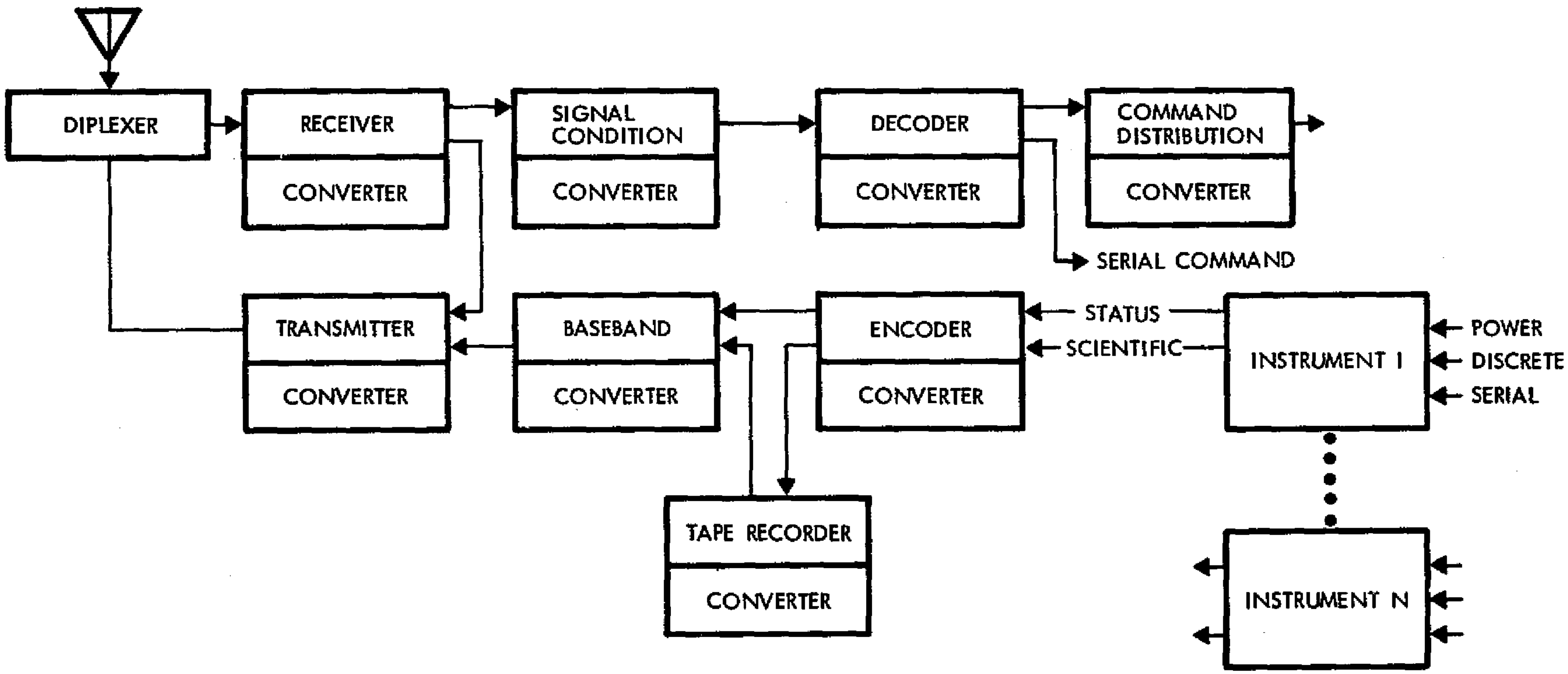


Figure 4-11. Command and Telemetry Subsystem Block Diagram

The CDMS design is based on the concept of remote multiplexing of telemetry data and remote distribution of commands. The Spacelab design utilizes two serial digital data buses (one for experiment instruments and one for Spacelab support subsystems) to route command and telemetry data to and from Spacelab and instrument subsystems. The data bus minimizes interconnect problems and allows sizing of the CDMS to the actual flight requirements on a flight-by-flight basis for modular growth capability.

Medium and high rate scientific digital data is accommodated by the high rate multiplexer (HRM). The HRM is capable of multiplexing up to 16 data sources and provides the interfaces with the high rate digital recorder (HRDR).

The HRDR is a variable speed recorder used to provide a data storage capability during TDRSS noncoverage periods in the Orbiter Ku-band system.

4.6.3 Implementation Plan

Based on the results of the Phase B Study, the CDHS requirements can be accommodated with the Orbiter communications equipment and the Spacelab data management equipment. To effectively accomplish the design and development of the C&DH subsystem for the AMPS Flights 1 and 2 payloads, the following tasks are to be performed during the design, development, and verification of the subsystem:

a) Design requirements definition

   1) Perform science instrument/flight and ground support equipment functional requirements analysis

   2) Allocate CDHS functional requirements for Flights 1 and 2

   3) Specify CDHS design requirements

   4) Define science instrument/flight support equipment interface requirements

   5) Perform make/buy trade-off analyses.

b) Hardware design and development

   1) Update hardware specifications

   2) Hardware design and verification

3) Perform hardware design reviews

4) Perform hardware design verification tests.

4.6.3.1 Design Requirement Definition

These tasks are directed toward the definition of the communication and data handling requirements at the science instrument level, at the experiment level, and finally at an integrated payload operations level.

Functional analyses will be performed on each payload complement to define the CDHS requirements of the science instruments, flight support equipment, and ground support equipment.

The results of these analyses will be used to allocate functional requirements to the Orbiter, Spacelab, and other flight support equipment. The functions assigned will provide the basis for the communication and data handling configuration design.

All interfaces with the CDHS that interest or affect the operation and design of the subsystem will be defined and controlled to ensure compatibility with all other subsystems. These interfaces include the following:

- Subsystem equipment interface
- Science instruments
- Electrical system and EMI
- Thermal environment
- Ground support equipment
- Shuttle launch vehicle environment.

A preliminary design and cost analysis will be prepared for CDHS flight support equipment that will be required in addition to the Orbiter and Spacelab communication and data handling equipment. The subsystem technical requirements identified in Section 4.6.1 will be implemented using essentially existing off-the-shelf hardware for the ESP communication equipment. A number of bid packages will be prepared and presented to hardware suppliers. The response to the bid package will be evaluated on the basis of cost, technical experience, and supplier history. This procedure will ensure an objective survey of the hardware suppliers with applicable experience. The final make/buy decisions will be based on these results.

4.6.3.2 Design and Development

With the finalization of the make/buy decisions, TRW will proceed with the detail design of the specific CDHS flight support equipment required above that of the Orbiter and Spacelab GFE equipment with the approval by the NASA Payload Office.

These designs will be documented through CEI design specifications. The detailed designs shall follow standard preliminary and critical design review cycles.

The verification of the CDHS flight support equipment design shall be accomplished through two related efforts. First the additional flight support equipment required by the CDHS shall be verified through normal qualification testing as defined in the CEI specification. Final verification will be accomplished with all CDHS hardware installed in the Level IV integration facility.

4.6.4 Subcontracts

(TBD)

4.6.5 Hardware/Software/Documentation Deliverables

The documentation deliverables are delineated in Section 2.3 Hardware/ Software deliverables are (TBD).

4.6.6 Subsystem Milestone Schedule

The subsystem milestone schedule is shown as Figure 4-12.

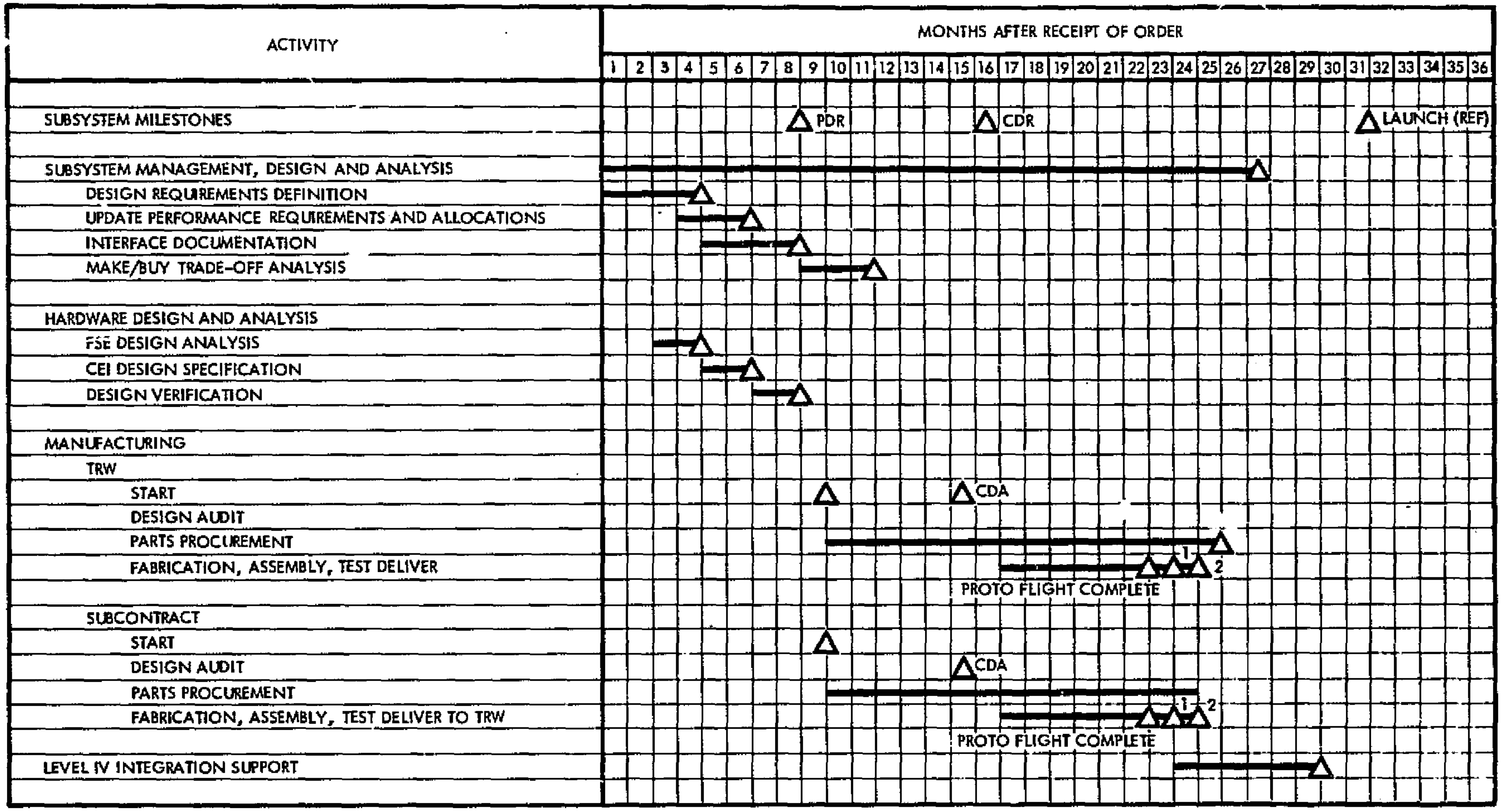


Figure 4-12. Communication and Data Handling Subsystem Milestone Schedule

4.7 CONTROLS AND DISPLAYS

4.7.1 Technical Requirements

The design and development effort for the AMPS Controls and Display (C&D) subsystem is devised to assure that the form, fit, function and layout of the C&D flight hardware is compatible with requirements of mission operations, experiment operations, Spacelab resources, flight crew capabilities, and safety and meets training and operations schedule.

4.7.1.1 C&D Functions

The AMPS controls and displays provide the sole means for the onboard operator to interface with the payload in order to activate, control, monitor and deactivate the various instruments, Spacelab Mission Dependent Equipment (MDE) and Multimission Support Equipment (MMSE) in accordance with the mission operations plan and timeline.

4.7.1.2 Baseline Design Requirements

Based upon the results of the Phase B study, the C&D subsystem shall be designed to:

1) Accommodate safety requirements
2) Be compatible with Spacelab resources
3) Meet science requirements
4) Meet payload specialist requirements and capabilities
5) Make effective use of Spacelab provided C&D capability
6) Accommodate future/multiple payload requirements
7) Minimize development costs
8) Comply with human engineering criteria.

The C&D subsystem design and development activity is to define the controls and displays required to conduct AMPS Flights 1 and 2 experiments from the pressurized module and/or aft flight deck (AFD) of the Orbiter and define, design and develop specific flight hardware classified as FSE or instrument dedicated as directed by the NASA Project Office. The activity also encompasses that equipment required for C&D development, layout evaluation and personnel training. The categories of equipment are summarized below:

1) FSE
   - Functional mockup and trainer
   - Safing and enable panels (flight hardware)
2) MMSE C&D
3) Spacelab mission dependent equipment (MDE) - C&D
4) Instrument dedicated C&D panels.

The functional mockup and trainer will be used for C&D design, development and layout, interface and cabling design, and personnel operations training. The equipment includes:

1) CII computer, CRT and keyboard
2) Simulated racks and panels
3) Commercial equipment equivalent to AMPS C&D panels and equipment.

Safing and enable panels in the AFD will provide central control and status display of payload elements critical to safety of operations. The C&D elements may be provided as GFE or developed as FSE similar to their equivalent in the pressurized module.

MMSE C&D equipment is anticipated to be furnished as GFE. Technical requirements primarily relate to location. These equipments include, but are not limited to:

1) SIPS control
2) Data retrieval unit.

Spacelab MDE - C&D required for payload operation control and data display are treated similarly to the MMSE.

Instrument dedicated C&D panels may be developed by the instrument manufacturer or the integrating contractor in accordance with design requirements established through the design activity.

4.7.2 Development Tasks

To effectively accomplish the design and development of the C&D subsystem for the AMPS Flights 1 and 2 payloads requires that the following tasks be performed (see Figure 4-13):

a) Design requirements definition

1) Instrument/FSE/MMSE functional analysis

2) Payload control and display function allocation analysis

3) C&D subsystem design requirements definition/specification

4) Make/buy/GFE decisions.

b) Design and development

1) FSE and directed instrument control and display design

2) C&D subsystem design and layout analysis and compatibility assessment

3) C&D subsystem inputs to MSRD

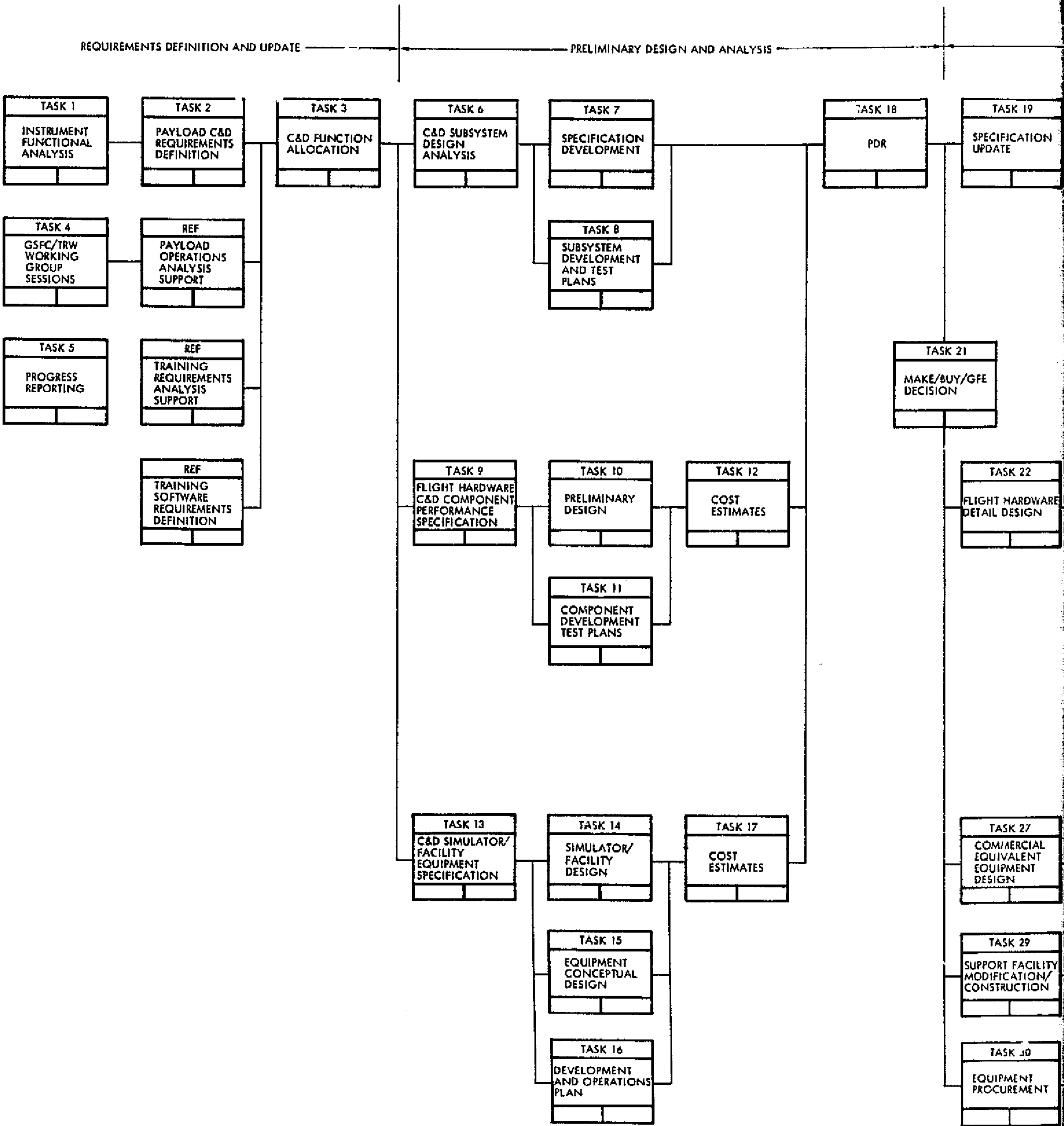
4) Design verification.

4.7.2.1 Design Requirements Definition

This phase of the activity is directed toward the definition of the individual instrument C&D requirements, experiment C&D requirements and integrated payload operations C&D requirements.

Instrument/FSE/MMSE functional analyses will be performed of each payload complement to define the C&D requirements of the respective equipment items. Equipment (instrument, MMSE, Spacelab) descriptions will provide the basis for these analyses.

From the results of these analyses, the controls and display functions will be allocated to man, equipment, or some man-equipment combination and the parameters of functional performance defined. The allocations of functions to equipment will then be grouped according to equipment type (e.g., instrument dedicated, SL-MD, SL-mission independent (MI, MMSE, or FSE-flight hardware). The functions assigned to man or man/equipment interaction will provide the basis for the payload activities analysis effort. Soft mockup evaluations of the C&D subsystem will be performed to verify the functions allocation assignments.



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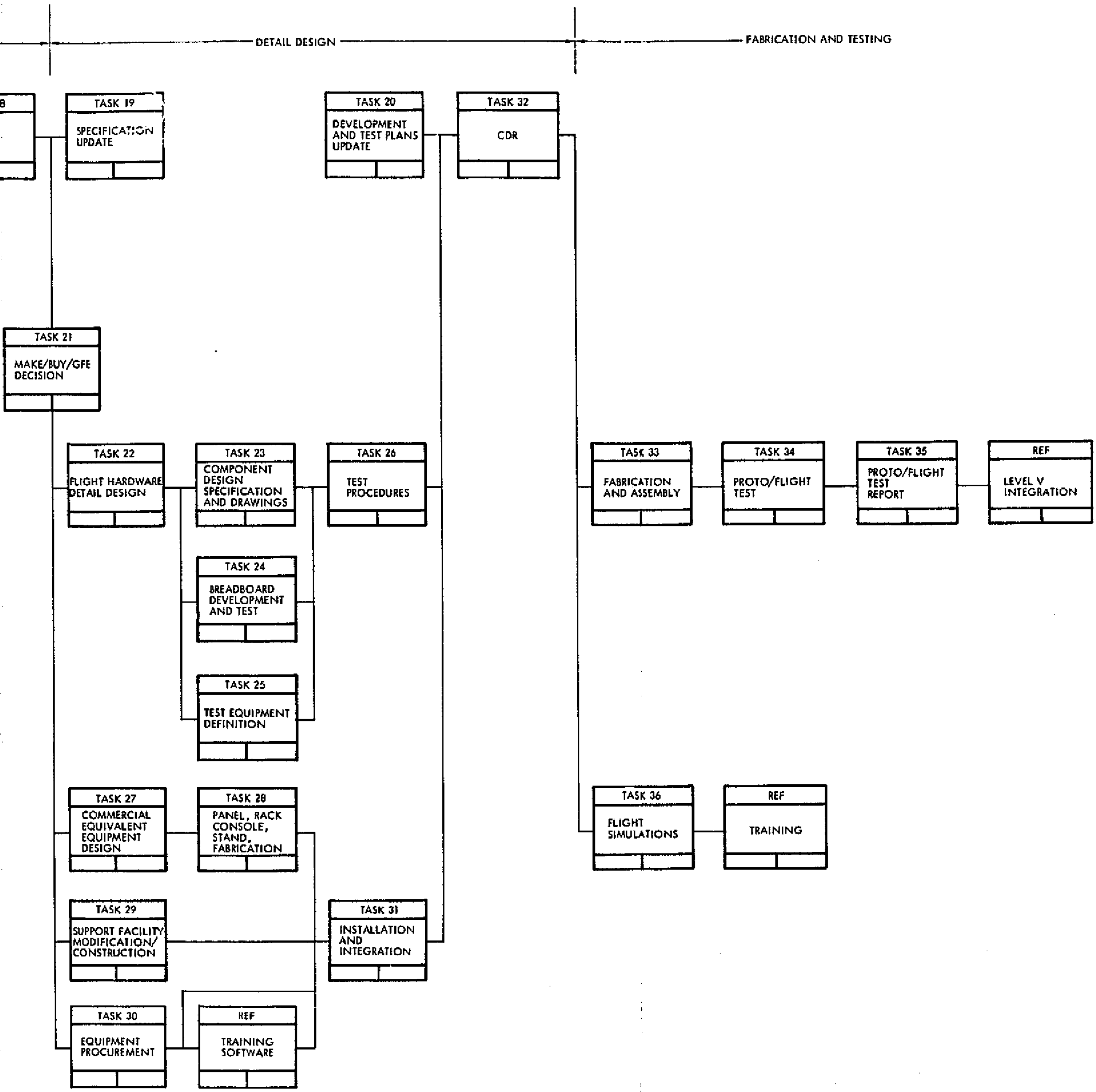

Figure 4-13. Controls and Displays Task Flow

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The functional and physical requirements for the C&D of each equipment item can be documented in either a CEI specification or modified level B sheet type format.

A preliminary design and cost analysis will be prepared for the flight hardware FSE and identified dedicated instrument control panels to aid in make, buy, GFE decision making. Based upon the results of the Phase B Study, the elements of the C&D subsystem identified are shown in Table 4-3.

Table 4-3. C&D End Items

Item	Make	Buy	GFE/ Instrument
Payload safing and enable panel (AFD) - FSE	X		
Payload safing and enable panel(s) (module) - FSE	X		
OBIPS panel - AFD	TBD		
OBIPS panel - module	TBD		
Lidar panel(s) - module	TBD		
RF sounder control panel	TBD		
RF sounder - pulse generator	TBD		
Electron accelerator panel(s)	TBD		
Functional mockup and trainer	X		

4.7.2.2 Design and Development

With the finalization of make/buy/GFE decisions, TRW will proceed with the detail design of the specific C&D panels approved by NASA Payload Office and with the hard mockup/trainer FSE equipment.

These designs will be documented in typical CEI design specification format. The detailed designs shall follow standard PDR and CDR review cycles.

Through participation in C&D related PDR's and CDR's and with receipt of the design packages analyses of the integrated C&D subsystem will be conducted using the functional mockup. Commercial equipment equivalents to the C&D panels will be fabricated for use in the hard mockup/trainer of the module and AFD portions of the Spacelab. Form, fit, and functional verification of the hardware, software, cabling, and interfaces will be conducted using this facility. Training of the payload specialists will also be performed using special training software scenarios.

The results of these studies will be documented in the appropriate sections of the Payload Support Requirements document.

4.7.3 Design Verification Plan

Verification of the C&D subsystem design shall be accomplished through two related efforts. First, design of the individual C&D subsystem elements will be verified through normal qualification testing as defined in the CEI specifications, conducted in accordance with approved test plans and procedures. Integrated verification testing will be accomplished using the functional mockup with the commercial equivalent equipment. Final verification will be accomplished with the flight hardware installed in the level IV integration facility.

4.7.4 Subcontracts

Subcontracting of FSE or instrument C&D elements are (TBD) and dependent upon make/buy decisions as identified in Section 4.7.2.1. It is relatively certain that a major subcontract will be the purchase of a ground version CII Mitra 125 computer.

4.7.5 Hardware/Software/Documentation Deliverables

The hardware/software/deliverables are (TBD). Deliverable documentation is listed in Section 2.3.

4.7.6 C&D Subsystem Milestone Schedule

The C&D subsystem milestone schedule is presented in Figure 4-14.

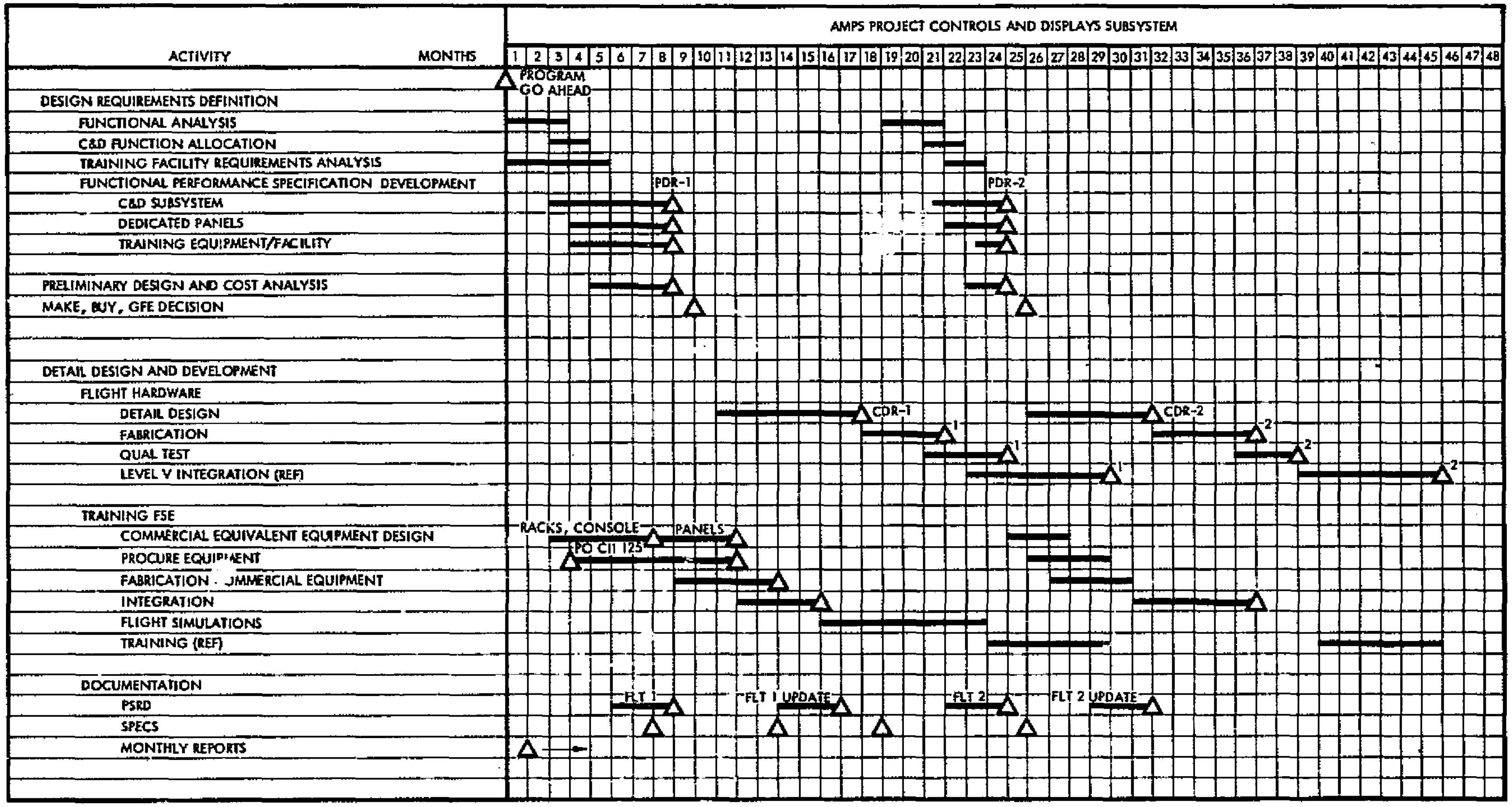


Figure 4-14. Controls and Displays Milestone Schedule

4.8 THERMAL SUBSYSTEM

4.8.1 Description and Requirements

The thermal control subsystem includes the insulation, heaters and stored cryogen necessary to control and maintain the temperature of all elements of the AMPS scientific payload and support equipment. The Spacelab thermal system, including the module avionics air cooling system, the pallet freon cooling loop and the pallet insulations, are used to the fullest extent possible to minimize supplemental provisions. Other GFE items such as the SIPS standard heat pipe cannister are employed.

There are no supplementary thermal hardware items associated with the module. The design of the panels and racks will incorporate thermal features to utilize the Spacelab forced air system.

The pallet mounted equipment interfaces with standard fluid cooled heat sinks provided. Insulation is provided on all AMPS packages within the cargo bay including subsidary structure. The boom mounted packages and canisters are also insulated. The multiple layered insulation (MLI) blankets generally consist of several layers of crinkled aluminized Mylar with an exterior layer of silvered Teflon.

Electrical heaters are employed in the electron accelerator, SIPS, vector magnetometer, lidar, gas release cannister, ESP, and common energy storage units for standby temperature control and reduction of instrument gradients. The electrical power required is within the AMPS payload power allocation.

The thermal design of all instruments utilize standard techniques and materials with the exception of the SIPS. The SIPS heat pipe cannister will require a high degree of interface coordination to assure overall compatibility. The cryogen cooled SIPS also presents challenging design problems to assure instrument performances and to meet the Space Transportation System safety requirements. The baseline cryogen cooling system utilizes solid hydrogen for detector cooling and solid nitrogen for optics cooling. These cryogens are maintained ready during launch preparations by a service cart for top-off and, during final preparations, by a dewar of liquid helium mounted on the pallet. The liquid hellium will be remotely disconnected after launch to enable SIPS gimballing. Provisions will be made to inactive or dissipate any unused hydrogen prior to landing.

4.8.2 Design and Development Plan

This section identifies the thermal subsystem desing, analysis, fabrication and test plan. The thermal subprogram functions and tasks are summarized in Table 4-4. As indicated by Table 4-4, there is no mechanical design and drafting nor mechanical fabrication support to the thermal subprogram. These functions are included in the structures subprogram and the thermal subsystem hardware is essentially limited to the insulations. The insulations will be made "form-to-fit" per standard TRW practice by insulation techniques. The insulation piece parts will be documented by means of Mylar masters of the annotated final templates. Similarly, the electrical integration subprogram has the responsibility for procurement and wiring of the required thermal heaters and the integration and test subprogram has the responsibility for protoflight module air coniditioning and instrument package thermal vacuum tests. The thermal subprogram provides thermal engineering support to these functions.

Figure 4-15 summarizes the engineering and development activities flow for the thermal subsystem. The thermal subsystem task matrix is presented in Table 4-5.

During the engineering and development phase, thermal system engineering will maintain, in addition to monthly progress resports and scheduled design reviews, effective liaison with cognizant GSFC technical representatives to assure mutual agreement on design approcah, and conclusions from current studies or tests. All technical correspondence and analytical data generated will be made available to GSFC personnel, via the AMPS project office, upon request or when deemed of significant value or interest to GSFC.

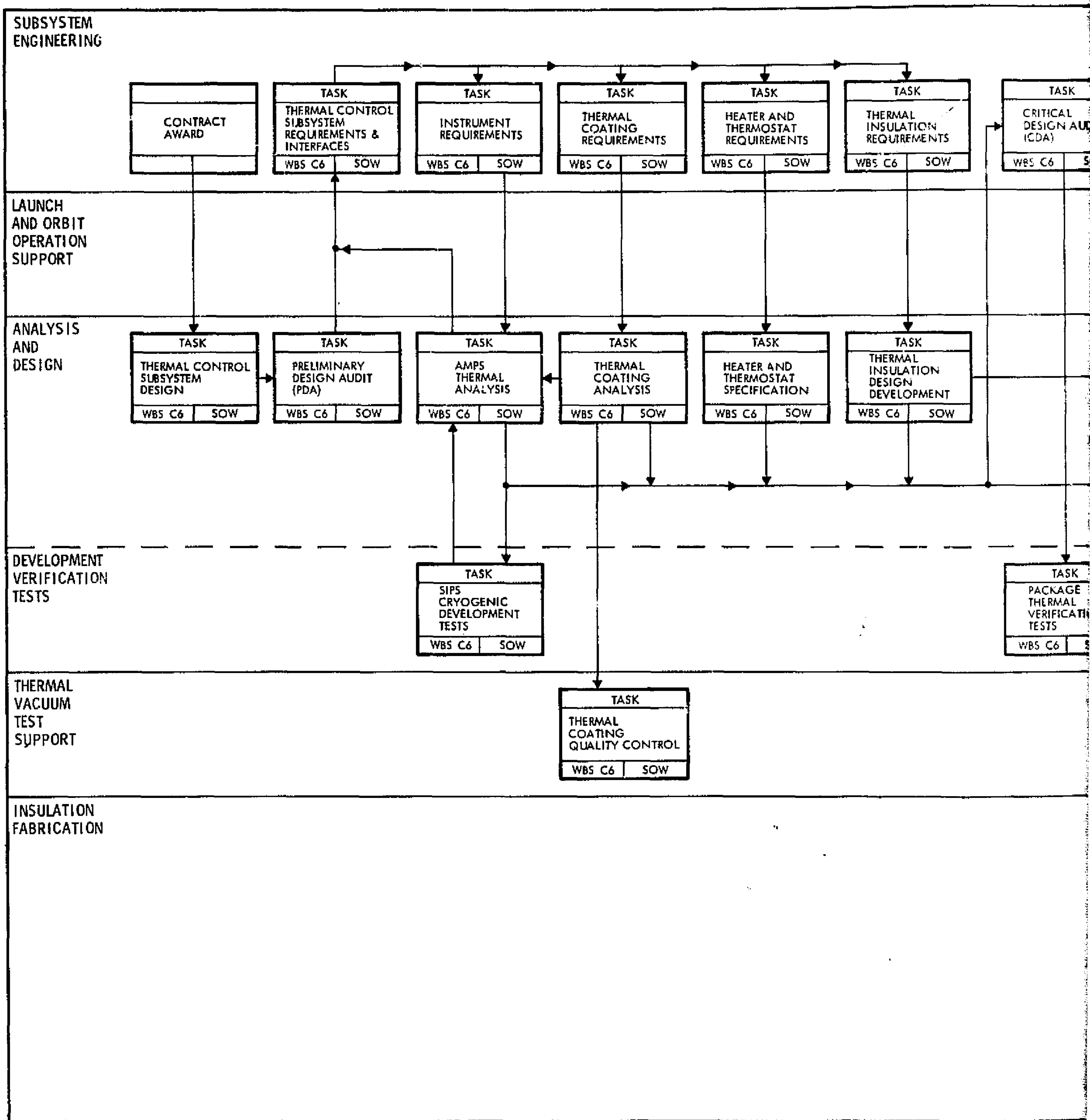
Table 4-4. Thermal Subprogram Functions and Tasks

1) System engineering and subsystem management • Subproject control and administration • Requirements definition • Performance allocations • Subcontract engineering support • Design reviews • Protoflight test engineering support • Launch and orbital operations engineering support 2) Analysis and design • Thermal computer models preparation • Predicted temperatures • Hardware requirements • Development test requirements • Development test engineering support • Thermophysical properties measurements 3) Insulation development and fabrication • Mockups, mandresl and template fabrication • Insulation fabrication 4) Thermal development test support • Detailed test procedures, facilities and fixtures • Test facility operation • Data measurements and collection

4.8.3 Design Verification Plan

The AMPS thermal subsystem will be verified by a combination of analysis, development test and protoflight verification test. Analytical methods will be used to the greatest extent possible since:

- Primary thermal control is by active techniques
- The instruments are, by design, insensitive to the external space environment.



NOTE: SEE TABLE 4-5 FOR TASK MATRIX

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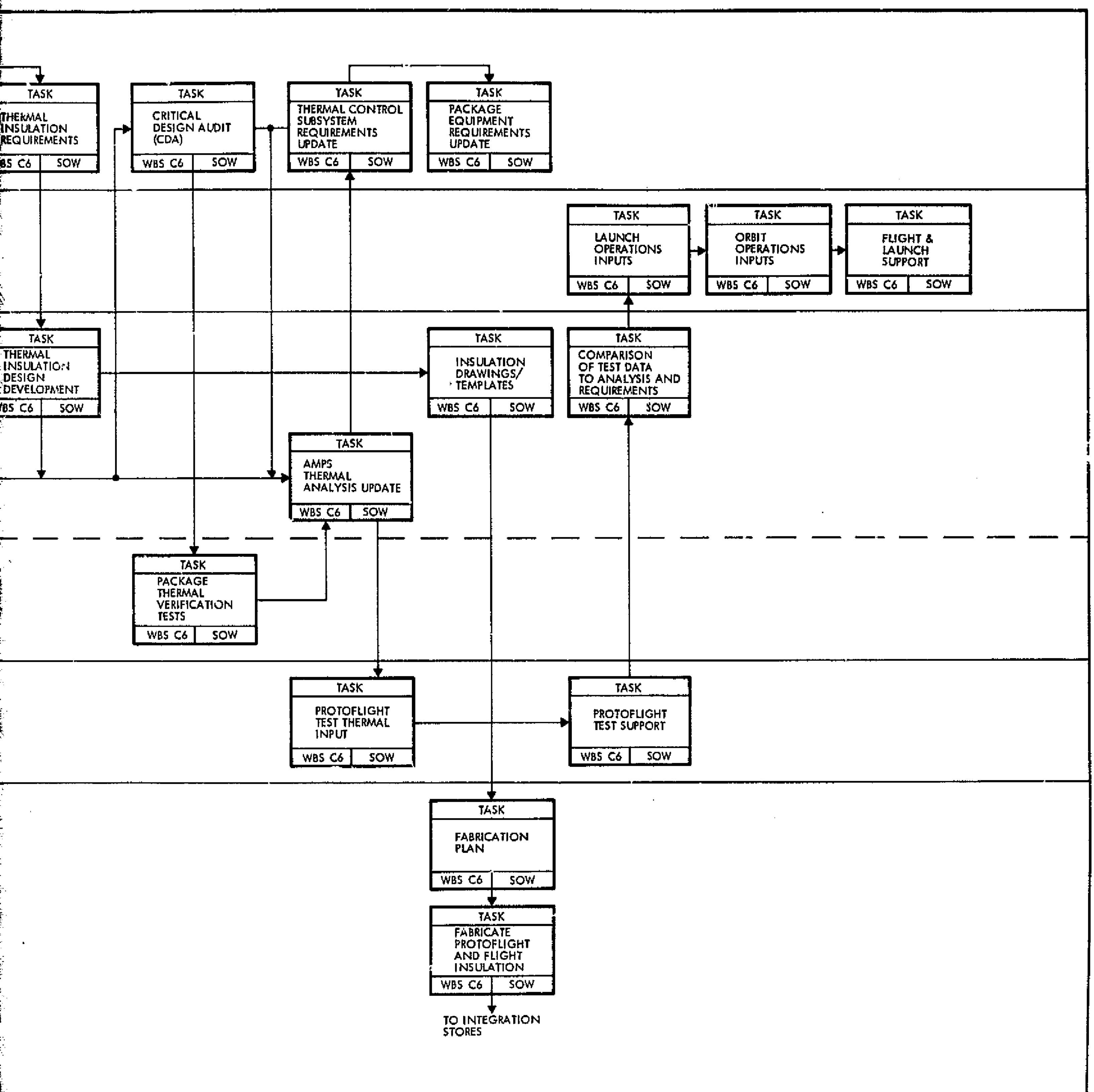

Figure 4-15. AMPS Thermal Design and Development Task Flow

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Table 4-5. Thermal Subsystem Task Matrix

Item	Formulate Thermal Model	Predict Temperatures	Insulation Fabrication	Testing
1) Module area	X	X	NA	Support protoflight A/C test
2) Pallet area	X	X	GFE	
Electron accelerator	X	X	X	Support protoflight T/V verification test
Lidar	X	X	X	
Others	X	X	X	
3) Heat pipe SIPS	X	X	X	Support protoflight T/V verification
4) Cryogen SIPS	X	X	X	Cryogen system development test. Support protoflight T/V verification
5) ESP				
Held model - Type 1	X	X	X	Support protoflight T/V verification with and without arm
Release model - Type 2	X	X	X	
6) Extended magnetometer	X	X	X	Support protoflight T/V verification
7) 15-meter mast package (F2)	X	X	X	Support protoflight T/V verification
8) Barium thermite canister (F2)	X	X	X	Support protoflight T/V

Hence reliance upon analytical methods is a relatively low risk approach for most elements of the payload. Thermal testing will be performed as a part of instrument package performance testing in most cases. Note that all of the pallet equipment for test purposes is thermally isolatable just as the pallets are isolatable from the module.

Since the control module is manned, it is necessary, as a minimum, to perform an ambient environment air-conditioning test to assure that the air conditioning capability of the all-up system is adequate. During this type of a test the temperature of critical equipment racks and panels will be verified.

Development T/V tests are required for the cryogen SIPS cooling system. These tests will be conducted with simulated flight instruments and package. The cryogen SIPS (and possibly the heat pipe SIPS) will be T/V tested as a part of the protoflight verification program.

It is planned to support a thermal vacuum verification test on the protoflight lidar and electron accelerator. Other protoflight thermal vacuum tests, identified in Table 4-5, will also be supported by Thermal Engineering. Analysis methods will be used to understand differences and variations encountered during verification testing.

4.8.4 Subcontracts

The SIPS cryogen cooling system, storage vessels and service cart will be subcontract items.

4.8.5 Hardware/Software/Documentation Deliverables

The documentation deliverables are identified in Section 2.3. Hardware and software deliverables are (TBD).

4.8.6 Subsystem Milestone Schedules

The subsystem milestone schedule is shown in Figure 4-16.

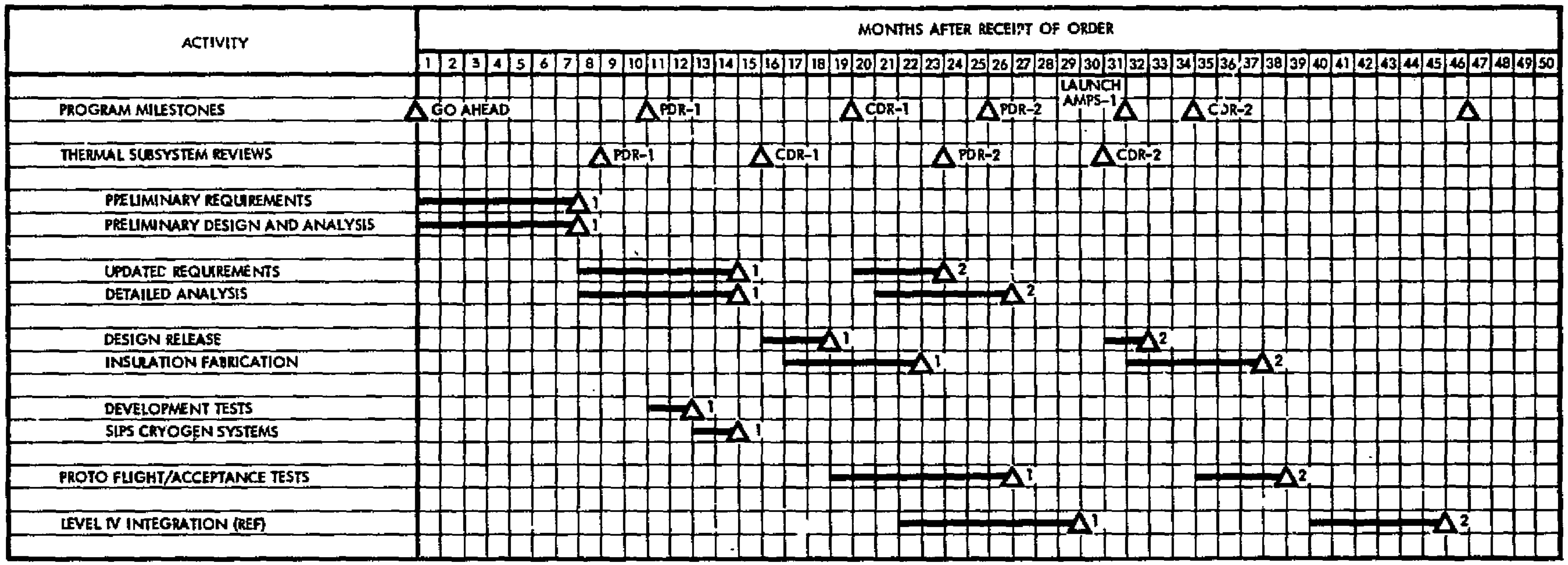


Figure 4-16. AMPS Thermal Subproject Milestone Schedule

5. FLIGHT SUPPORT EQUIPMENT MANUFACTURING

TRW's manufacturing facilities, equipment, experienced management, and personnel are project-integrated into one manufacturing team. Within manufacturing, special technical disciplines have been established; i.e., mechanical fabrication, printed circuit board fabrication, solar cell assembly, electronic assembly, spacecraft integration, and speciality shops. These technical resources are aligned with their engineering counterparts to provide the close liaison necessary to ensure a successful, cost-effective project.

This selected team of manufacturing specialists will be working with the Shuttle payload designers to ensure producibility and to define the critical tooling concepts for the structure. The assembly sequences have been reviewed and will continue to be refined to ensure a minimum-risk, cost-effective approach. This manufacturing processes review has determined that TRW's established process and existing experience satisfy AMPS requirements.

The purpose of this plan is to establish the basic flow in the manufacturing process and to delineate the management and control methods employed to implement this flow. The plan identifies the concepts, facilities, and procedures that will be used by TRW in the manufacture of AMPS flight support equipment.

The manufacturing plan encompasses all manufacturing activities and related tasks to be performed by TRW from the detailed hardware start to successful launch of AMPS-1 and -2. The plan presents a project-integrated team approach for producing all spacecraft systems, subsystems, and associated support equipment. Table 5-1 contains the AMPS project equipment list with a description of the TRW "make" and major subcontract hardware.

5.1 MANAGEMENT

TRW manufacturing for AMPS is integrated with the engineering design and development effort from detailed hardware start to launch. This combination of the engineering and manufacturing disciplines provides single-point responsibility for the end product and ensures that manufacturing considerations are incorporated into the design from the start. This

Table 5-1. AMPS Project Equipment List

	Make	Buy
Structures and Mechanical		
SIPS Side B		
Spar Structure	X	
SIPS Side A Cryo Canister		
Cryo canister structure	X	
Internal support structure	X	
5-Meter Magnetometer Mast		
Base structure	X	
Release mechanism	X	
5-meter mast and mast deployment/retrieval device		X
Instrument housing	X	
15-Meter RF Sounder Mast		
Base structure	X	
Rotator mechanism	X	
Release mechanism	X	
15-meter mast and mast deployment/retrieval device		X
Instrument housing	X	
50-meter RF sounder antenna booms (2) with deployment mechanism		X
ESP Structures		
ESP Type 1 support structure with support release and return clamp	X	
ESP Type 2 support structure with deployment and spin-up device	X	
ESP central structures	X	
Gas Release Module		
Deployment and spin-up device	X	
Support structure Type A	X	
Support structure Type B	X	
Gas release canisters (5)	X	

Table 5-1. AMPS Project Equipment List (Continued)

	Make	Buy
<u>Structures and Mechanical</u> (Continued)		
Chemical Release Module		
Spin-up and ejection device	X	
Support structures	X	
Barium thermite release canister		X
<u>Pointing and Control</u>		
Mast attitude transfer device	X	
<u>Electrical</u>		
Caution and warning boxes	X	
Labcraft emergency safing units	X	
AFD cables	X	
Module cables	X	
Pallet cables	X	
SIPS cables	X	
Common energy storage device	X	
ESP battery		X
ESP electrical integration assembly	X	
<u>Communications and Data Handling</u>		
ESP command receiver and Diplexer		X
ESP telemetry transmitter and antenna		X
ESP command decoder		X
ESP PCM endcoder		X
<u>Controls and Displays</u>		
Functional Mockup and Trainer		
C11 computer, CRT and keyboard		X
Simulated racks and panels		X
Commercial equivalent to AMPS controls and displays panels and equipment		X
Flight hardware		X
<u>Thermal</u>		
FSE thermal blankets	X	
FSE standby heaters	X	
Instrument to S/L fluid interconnect system		X
SIPS Side A thermal control devices	X	

arrangement has proven successful on TRW projects that, like AMPS, required relatively small quantities of precise hardware.

The AMPS Assistant Project Manager (APM) for Design and Development has the overall responsibility for engineering and manufacturing of all AMPS flight hardware. He has six AMPS subprojects: structure, PCS, communications and data handling, electrical, controls and displays, and thermal. Each subproject manager assumes the single-point responsibility for the design and manufacture of his subsystem; a responsibility is documented on a TRW standard project work authorization (PWA) form. The PWA assigns a block of work with budget and schedule. With the PWA, the APM transfers responsibility to the subproject manager and commits to him all of the required facilities, equipment, and manpower.

These subproject managers are primarily engineering and development specialists. To fulfill their manufacturing responsibilities, each has an Assistant Manufacturing Manager (AMM). The AMM is a senior manufacturing manager on the staff of TRW's manufacturing laboratory manager. Together they accept full responsibility for all of the AMPS manufacturing activities. The AMM receives the manufacturing work package by PWA from the subproject manager and is responsible for the preparation of detailed manufacturing plans, budgets, and schedules. These are then reviewed and approved by the manufacturing laboratory manager and subproject managers. The AMM issues specific lower level PWA's to the manufacturing areas, and directs and monitors all activities on behalf of the AMPS subproject manager. By accepting the PWA's, manufacturing management is committed to perform the required work.

5.2 MANUFACTURING PLANNING AND CONTROL SYSTEM

5.2.1 General

TRW has developed a manufacturing planning and control system that is currently being used on several TRW projects. This system is based on DOD Directive 7000.2 on cost/schedule control system criteria; it has been validated by the Air Force Systems Command to detail requirements of AFSCP 173-3, and is proposed for use on AMPS.

5.2.2 Manufacturing Management Interface and Control

Successful operation of the planning and control system is assured by active participation and project interface on the part of manufacturing line and operation level management. Existing policies and procedures describing functions, responsibilities, methods, processes, and documents required to conduct manufacturing will be utilized.

All manufacturing plans will be reviewed and approved by both the AMPS manufacturing manager and manufacturing management prior to implementation. As project tasks are implemented, progress review and corrective action will continue to involve all levels of manufacturing management.

5.2.3 Project Cost/Schedule System

The extent of the AMPS project cost/schedule control system is depicted in Section 2.2. The system relates the work breakdown structures to the organization performing the task. The foldout shows the technical, schedule, and cost spectrum from preliminary phases through detailed work performance, analysis, and reporting.

The project cost/schedule control system ensures that performance measurement and reporting requirements are defined and that techniques are implemented to provide optimum visibility and control. It also ensures that progress and/or problems are visible while cross effects (i.e., technical, cost, or schedule) are measurable and can be dealt with accordingly.

5.2.4 Manufacturing Planning and Control System

The manufacturing planning and control system is diagrammed in Figure 5-1. This chart explains the roles and responsibilities of key personnel and functions (i.e., production control), shows the primary documents used to plan and control project activity, and shows time as it relates to the phases of project progress. Manufacturing management and the AMM's are together responsible for ensuring that all steps of the planning and control system are accomplished effectively.

5.3 MANUFACTURING FACILITIES

TRW's Redondo Beach, California facilities were built specifically for space technology work; and continuing improvements have made them particularly suitable for developing, producing, and checking out large spacecraft. Backing the resources that are specifically dedicated to the AMPS project is a full spectrum of additional space technology capabilities that are available to provide further support to the project and its subcontractors and to GSFC, as needed.

As the project moves into the production phase, the AMPS manufacturing team begins fabrication, assembly, and unit-test operations in the manufacturing buildings. These are grouped as skill centers with each center equipped with the facilities and equipment needed for its area of technical responsibility.

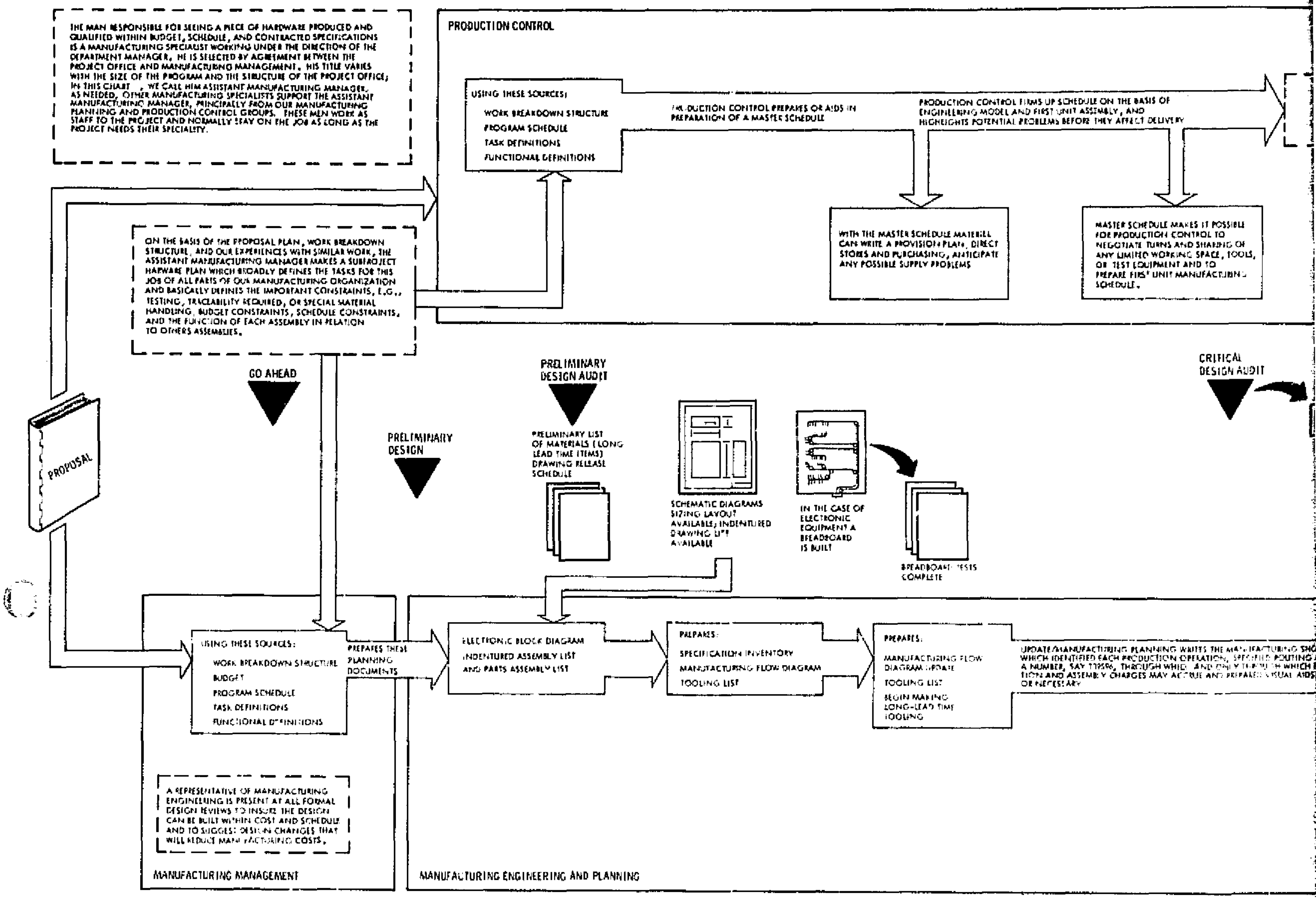
Electronic components, antennas, and cables are fabricated in Buildings R6, M2, and M5 in a clean, air-conditioned production area. Environmental test facilities for acceptance and protoflight testing of completed electronic components and electro-optical assemblies are also housed in Building M5.

Structural and thermal components will be fabricated and mechanically assembled in Building M3. This building is used for the fabrication of mechanical hardware, using proven spacecraft methods.

Figure 5-2 shows the relative location of these buildings and the principal hardware flow among them.

5.4 MECHANICAL MANUFACTURING

During the preliminary design phase, the manufacturing project team will refine preliminary implementation plans and establish methods of preventing problems in the areas of schedule, cost, and concept. Key technical direction for manufacturing will be provided by the AMM who works directly with the design engineers to ensure compatibility of design with sound manufacturing principles. Simultaneously, long-lead-time material requirements will be documented by the material planner in the form of PLM's. These will be reviewed by the manufacturing manager to ascertain lead time impact on manufacturing schedules and by the project quality engineer to



FOLDOUT FRAME

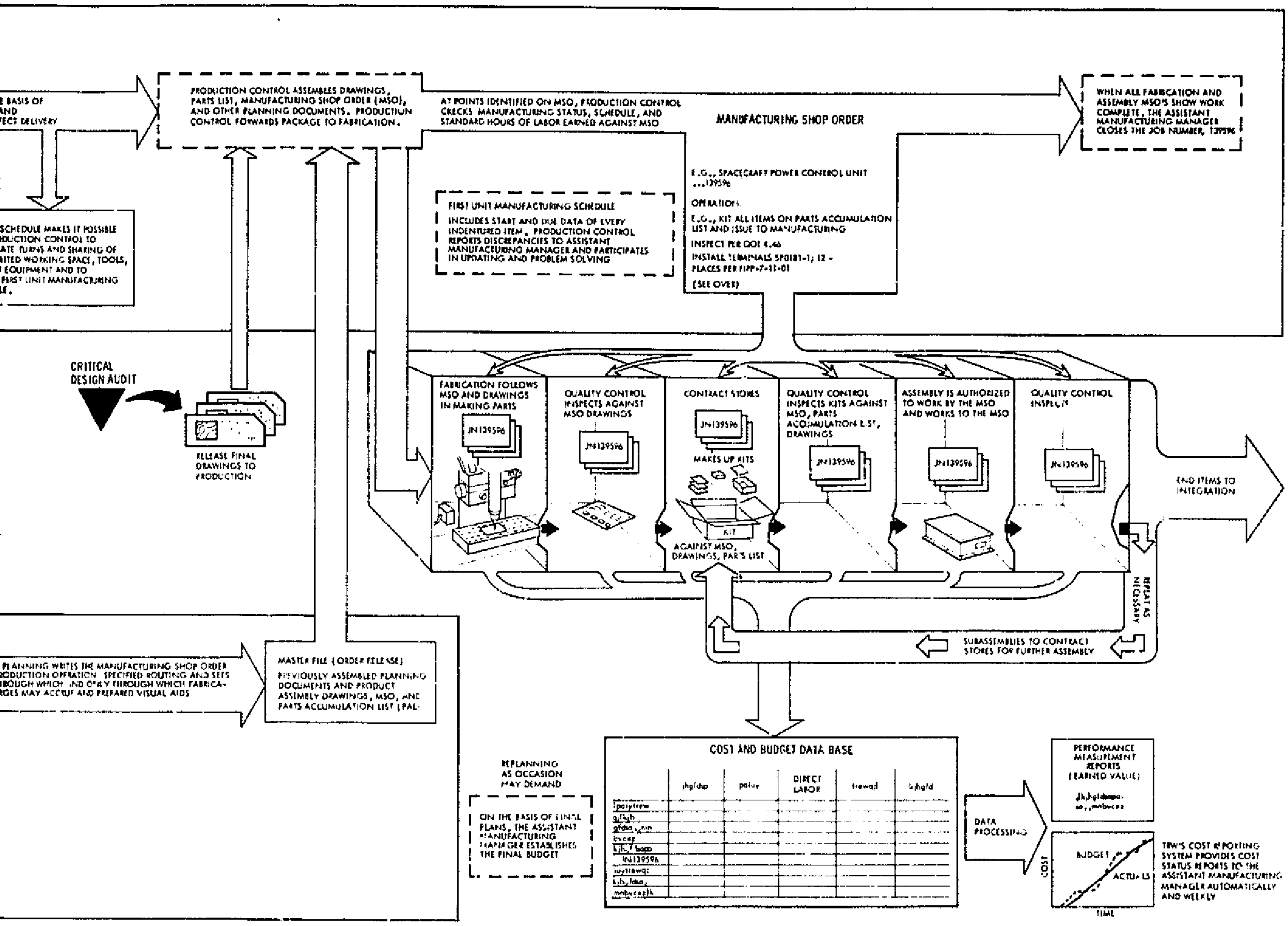
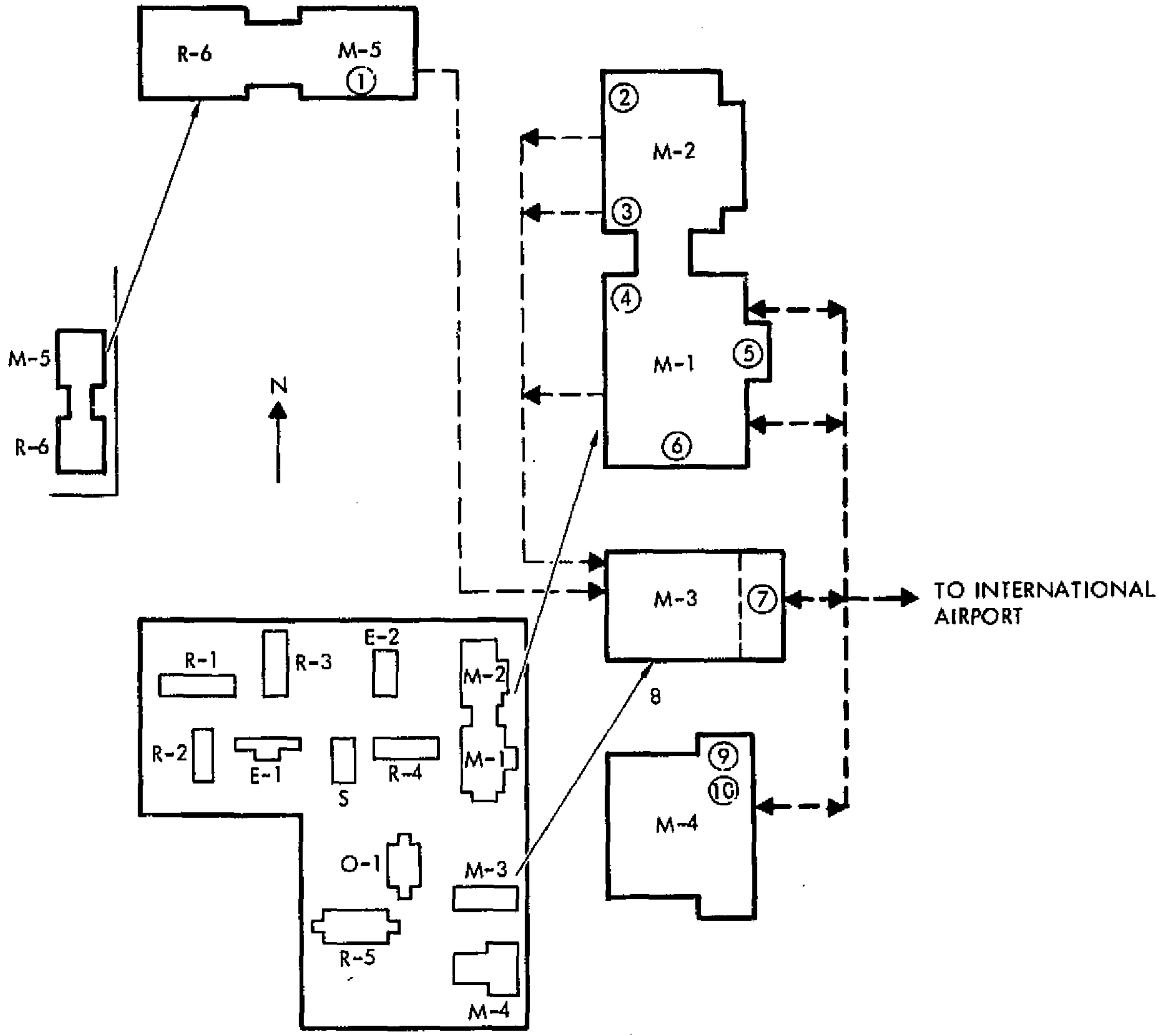


Figure 5-1. Manufacturing, Planning, and Control for AMPS

FOLDOUT FRAME 2



LEGEND

1 ELECTRONIC COMPONENT MANUFACTURING AND TEST

2 BATTERY ASSEMBLY AND TEST

3 PNEUMATICS ASSEMBLY AND TEST

4 SOLAR ARRAY AND ELECTRONIC SYSTEMS MANUFACTURING AND TEST

5 ACOUSTIC CHAMBER

6 STATIC TEST

7 PAYLOAD INTEGRATION AND TEST

8 MECHANICAL HARDWARE MANUFACTURING

9 THERMAL VACUUM CHAMBER 22 X 46 FT

10 VIBRATION (QUAD SHAKER)

▬ ▬ ▬ ➜ PAYLOAD FLOW

— — — ➜ HARDWARE FLOW

Figure 5-2. Flow Through Major Facilities initiate receiving inspection planning. When engineering models are required, manufacturing will support engineering, fabrication, and assembly to establish and verify systems and techniques.

During the system design phase, the manufacturing project engineer will conduct alternate mode tradeoff studies and assist in materials analysis and selection. Manufacturing will prepare preliminary design review data inputs as required.

Based on results of the PDR, the Manufacturing Plan will be updated and revised as required, taking into consideration statement of work changes, current project schedules, and the latest system design information.

During the detail design phase, the AMM will review design drawings prior to release to ensure that manufacturing producibility suggestions, techniques, and/or process developments have been incorporated.

Specific drawing release requirements will be coordinated with engineering and production control. Final refinements in d tail and subassembly tooling will be incorporated before tool design and fabrication starts and PLM's will be updated to reflect final engineering test experience.

The AMM will continue his detailed review of engineering drawings as they are assembled for critical design review, approval, and release to manufacturing. He will evaluate drawing requirement schedules and review detail master control schedules to ascertain manpower loading and facilities/equipment requirements in the various manufacturing areas.

Material status is continually reviewed to assess its conformance to schedule requirements and to implement timely corrective action as necessary.

The AMM is responsible for assuring that all manufacturing producibility requirements have been incorporated in the drawings. He will approve and sign the drawings signifying manufacturing acceptance of the design. The status of tooling, procedures, material, and detail schedule conditions will be part of the CDR.

5.4.1 Mechanical Manufacturing Techniques

A definition and a description of the mechanical manufacturing operations and processes associated with the AMPS hardware are given in the following paragraphs.

5.4.1.1 Honeycomb Assemblies

The majority of the functional subassemblies will be a honeycomb-bonded assembly. The platform construction will employ mechanical manufacturing's proven methodology of bonding the honeycomb core between two aluminum facesheets. The basic honeycomb lay-up will be oven-cured at temperature while under vacuum. After curing, a rough trim operation will provide test coupons which will be tested in the Materials Engineering Laboratory to verify criteria. The test results will be returned to manufacturing where the part will continue to the next operation. Insert holes will be drilled using templates prepared from engineering drawings. Inserts will be bonded in the drilled holes per TRW specifications. After insert bonding has cured, the inserts will be shaved off to the tolerances specified by TRW specifications and drawings. The outer periphery of the platform and cutouts will be routed to final size using a router template. All routed edges will be filled with core fill per TRW specification. Platform surfaces will be painted using a paint template that provides a bare surface for component mounting and structure EMI requirements.

5.4.1.2 Sheet Metal Fabrication

The sheet metal shop provides all formed, rolled, joggled, and drilled parts made from sheet stock. In addition, they will provide the expertise to build the separation systems.

5.4.1.3 Numerically Controlled Machined Parts

Machined parts, which are considered candidates for numerically controlled (NC) machining, will be reviewed for their cost-effective NC machining as compared to conventional machining.

5.4.1.4 Conventional Machining

The conventional machine shop provides a supporting capability to the NC machining center for selected operations. In addition, it provides the machining capability needed for functional assemblies such as spin tables release fittings, ESP clamping devices and numerous other brackets, and bathtub fittings.

C-2

5.4.1.5 Thermal Insulation

Thermal hardware consists of multilayer insulation blankets and mirror radiation panels. External surface thermal insulation will consist of 22 layers of crinkled aluminized Mylar, 1/4-mil thick, with an inner and outer aluminized facesheet.

The thermal blankets are fabricated using templates to control dimensions and to simplify the fabrication task of cutting the thin sheets of aluminized Mylar. The specified number of layers are sandwiched between the inner and outer layers, and the periphery of the blanket is ultrasonically spotwelded on approximately 1-inch centers. Formed sections are made in a similar manner using a simple mockup to simulate the desired shape. All thermal insulation work will be performed in the precision assembly thermal room by precision assemblers who have many years of thermal insulation fabrication experience.

The thermal radiation panels for the SIPS cryogenic canister will be constructed of simple sheet metal plates with quartz second-surface mirrors bonded in place. These radiation panels will be attached to the canister structure or the quartz second-surface mirrors will be bonded directly to a structure panel.

5.4.2 Cleanliness and Contamination Control

Mechanical Manufacturing will exercise careful control in manufacturing AMPS flight support equipment; e.g., all manufacturing will be performed in areas that are air-conditioned, well-lighted, and conducive to maintenance of cleanliness.

Figure 5-3 presents a flow diagram of the mechanical hardware and associated area cleanliness controls which will be exercised. Hardware containing critical components (such as sensitive optical surfaces or surfaces that can degrade due to films, particulate matter, etc.) will be assembled in clean rooms or stations that meet appropriate levels selected by GSFC. Applicable equipment specifications will define the level of cleanliness required for critical items.

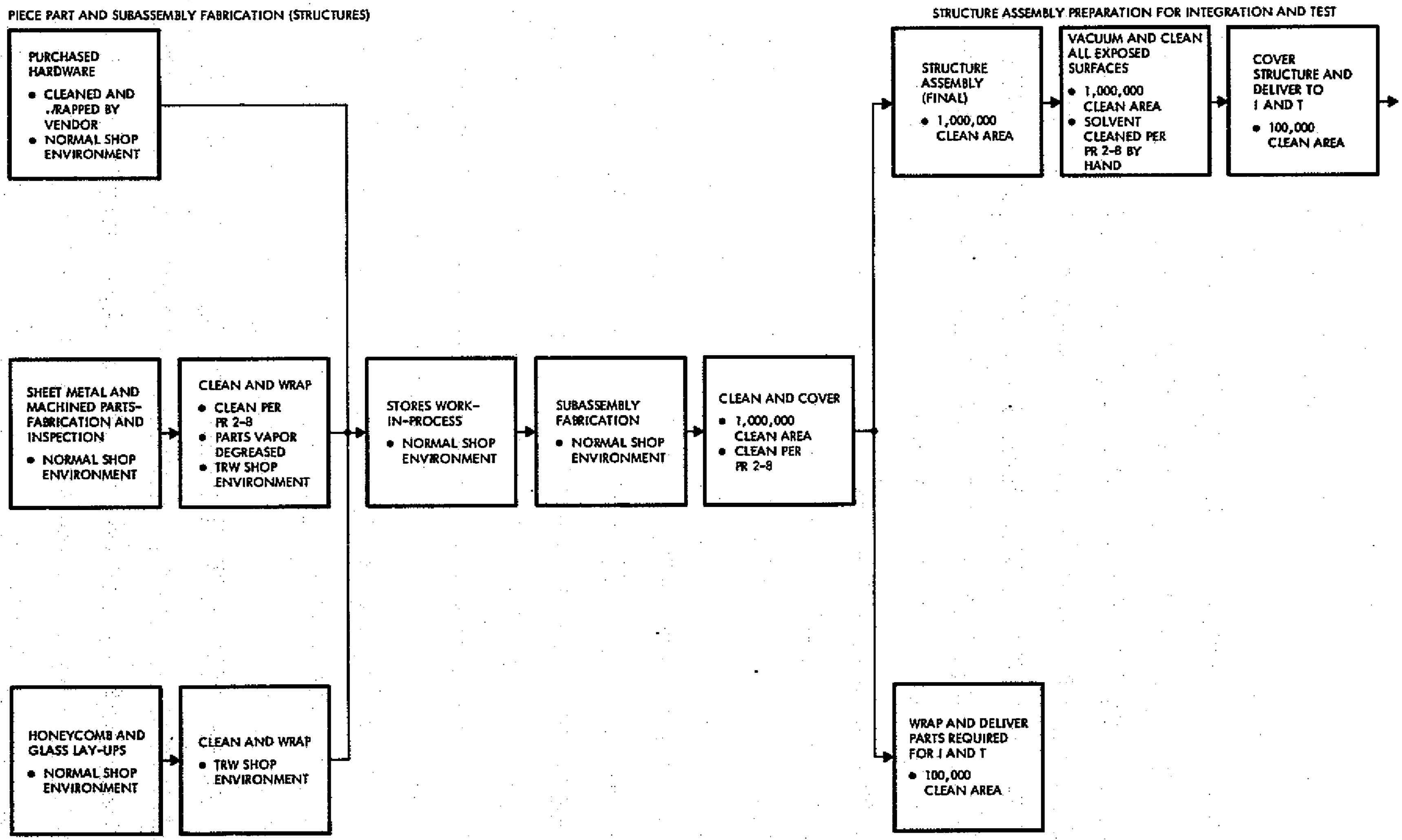


Figure 5-3. AMPS Mechanical Hardware Flow Diagram

5.4.3 Tooling

A high-complexity, low-quantity Shuttle payload with multiple configurations, such as AMPS, requires a balanced tooling approach to be cost effective. The TRW approach to tooling follows proven spacecraft assembly practices. The formal special-purpose designed tools will consist principally of subassembly and assembly fixtures and the construction features will accommodate change factors. Fabrication will be performed with general-purpose machine tools and equipment. Fabrication tooling, such as holding fixtures, templates, etc., will consist mainly of shop aids. Formal tooling will be provided only where absolutely necessary to control configuration. Shop aids are defined as not requiring special design, are low cost, and are usually expendable.

The purpose of the special-purpose assembly and subassembly tooling is to accurately control the spacecraft configuration, assembly interface, experiment mounting, and spacecraft hardpoints. The use of such tooling provides repetitive accuracy, interchangeability, and ease and economy of manufacture under controlled conditions. Although tooling will be as simplified and inexpensive as possible, payload integrity, performance, and reliability will not be compromised.

5.4.4 Production Scheduling

The production schedule is (TBD).

5.5 ELECTRICAL MANUFACTURING

This section describes the manufacturing process for chassis and detail fabrication, detail assembly, and production bench testing. The supporting discussions describe the specific tasks and/or contributions of each skill center as they apply to manufacturing of AMPS.

5.5.1 Hardware Description

5.5.1.1 Standard Slice Packaging

Figure 5-4 illustrates TRW's standard electronic packaging concept. The slice housings shown were developed for the Pioneer program and have been mechanically and thermally qualified for flight. The standard package uses machined aluminum housings assembled into a complete stack. Hollow dowel pins located in the four corners allow indexing and shear

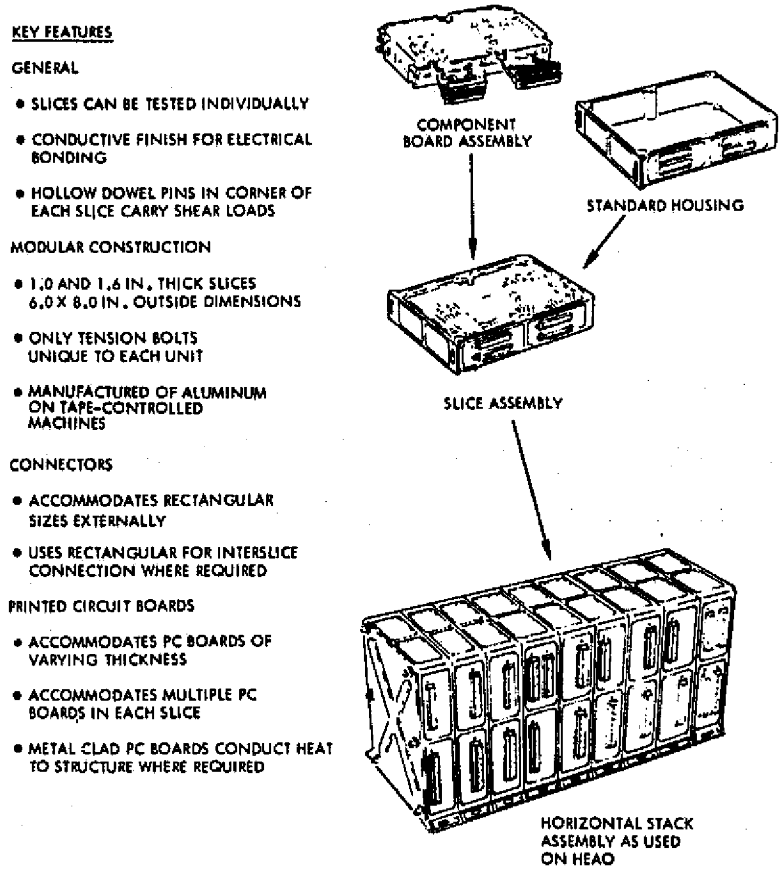


Figure 5-4. AMPS Standard Electronic Packaging

load transmittal. Four bolts pass through these hollow dowels, and two additional bolts pass through clearance holes to hold the slices together. While the slices can be assembled vertically or horizontally, the horizontal configuration will be used in most AMPS applications. In this configuration each slice has a surface in contact with the spacecraft, thus facilitating heat transfer. Each slice also has a good EMC interface through its own mounting feet to the spacecraft platform or panel. Two sheet metal end covers complete the stack. The maximum horizontal dimension of each stack is limited by the platform layout.

The slices are available in two standard sizes, 6 x 8 x 1.0 and 6 x 8 x 1.6 inches. The housings have integral bosses to mount the printed circuit boards and internal connectors, with locking inserts installed in the bosses to secure the printed circuit board and connector mounting hardware. Each housing will accommodate one or more printed circuit boards and can be assembled and tested independent of other slices. Interslice connections can be made with internal connectors or external cabling.

The basic housings are machined with a numerically controlled Cin-X-Matic tool changer and the NC tapes are tool proofed. When the basic housings have been machined, these NC tapes will be issued to the users who arranged for the machining process. These subsequent operations are minimum, and generally consist of the following:

- Printed circuit board mounting bosses are machined to the desired height
- Unused bosses are machined off
- Inserts and dowel pins are installed
- Specified housing finish is applied
- Housings are packaged in protective containers.

5.5.1.2 AMPS Harness Assembly

The harness cables run the length and width of the payload to accomplish the electrical interconnections. Silver-plated, Kapton insulated wire will be used. Rectangular crimp pin connectors will be used throughout the payload except where special connectors are dictated by Spacelab components, and at experiment interface where round connectors are used. Halo rings are used for shield terminations. Connectors are potted with an elastanetic preseal. The potting is conducive for ordnance connectors.

5.5.1.3 RF Cables

The AMPS RF cable assembly set consists of semirigid coaxial cables, 0.250 inch in diameter, with a silver-plated aluminum center conductor and an aluminum outer jacket with an air-articulated Teflon dielectric. This design was developed by TRW for the NASA Pioneer 10/11 Program.

5.5.2 Tooling and Test Equipment

5.5.2.1 Tooling Philosophy

Electronic hardware will be manufactured using primarily shop aids and fixtures defined as low cost, expendable, and not requiring special design. Designed and controlled tooling will be used only when specific dimensions require repeatability. For example:

- Harness boards
- Encapsulation molds
- Piece-part lead forming and trim tools
- Holding and final assembly fixtures.

The tooling concepts and requirements for AMPS will be continuously refined in the early states of design development and will result in a firm list of manufacturing tool requirements. The project control supervisor will make a master control schedule, with tool requirements identified to the detail part, subassembly, or assembly. The fabrication span for any part will include any time needed for the design (if required) and fabrication of special tools.

5.5.3 Production Schedule

The production schedule is (TBD).

6. EXPERIMENT AND INSTRUMENT ACCOMMODATION

Successful accommodation of experiments and instruments consists of four major functions. The first is the early development and continuous maintenance of close communication ties between the AMPS contractor on one hand and, on the other, the GSFC experiment manager and the scientific investigator teams. This communication link with the AMPS contractor will be through a single point of contact and is further discussed in Paragraph 6.1.

Another function is the issuance and maintenance of experiment and instrument documents throughout the course of the program. From the Instrument General Specification and experiment questionnaire issued early in the program, through the AMPS to Instrument Interface Control Documents, to the Instrument Integration and Test Procedures and the Experiment Operations Procedures and Time Lines, the close liaison and coordination with the GSFC experiment manager and the scientific investigator teams discussed above will be zealously maintained. The details of these and other experiment and instrument accommodation documents are discussed in Section 6.2 below.

A third function is to provide a single point of contact and responsibility for experiment and instrument information required in the AMPS development and operation areas. This provides the necessary engineering and operations data to the system, subsystem, and operations areas as they are needed, and makes sure that the requirements of the instruments and experiments are being met in the AMPS design and planning efforts. The tasks associated with performing this interface function are discussed in Section 6.3.

The fourth function is development of instrument integration and test plans; assisting in the scheduling and conducting of the actual integration and test sequences; preparation of on-orbit operations procedures; and provision of launch, on-orbit, and post-flight support. A summary of these tasks is included in Section 6.4.

6.1 LIAISON AND COORDINATION

All AMPS experiment liaison and coordination activities are consolidated under a single experiment-oriented manager to provide a single point of contact for all TRW, GSFC, and scientific investigator personnel. This has proven highly successful and cost effective when used on the OGO, VELA, Pioneer, and HEAO projects.

The experiment accommodation consists of scientists who are actively engaged in atmospheric and space research, thus providing the needed scientific background, and systems engineers who will be responsible for the detailed coordination and liaison activities with the experimenters and within TRW. In addition, assistance will be provided by the subsystem and system design groups as required to establish the detailed design interfaces.

6.1.1 Questionnaire Response

During the early phases of the experiment accommodation effort an Instrument Interface/Operations Questionnaire will be prepared and sent to each Principal Investigator for his response. During a series of meetings the experiment accommodation staff will assist the PI's in responding to this questionnaire and in developing the AMPS to Instrument Interface Control Documents that will be developed from these responses. The questionnaire will be an open document; that is, it will continue to be added to and updated during the life of the program up to the integration and test activities. It will form the basic written document representing the PI's experiment/instrument description and requirements, and will be the document around which most of the meetings and liaison activities will take place.

Meetings with the AMPS instrument subcontractors will determine the mechanical, electrical, thermal, and fluids interfaces for the instruments, all areas included within the questionnaire. Similar meetings, probably occurring later in the program, will develop the experiment test and related software requirements. The questionnaire will also include sections on operations, integration and test, and flight support requirements. These sections will all be developed through correspondence with the PI groups and the NASA GSFC experiment manager.

6.1.2 Principal Investigator Support

The experiment accommodation staff will provide several important support functions to the Principal Investigators throughout the course of the program. This group will provide the PI's with required system/subsystem/operations data as well as information concerning the Orbiter and Spacelab.

The experiment accommodation staff will actively participate in instrument design reviews, both to represent the details of the AMPS contractor design efforts and to become more familiar with the characteristics of the instruments and any problems that may have been encountered in their development. An important function is to recognize any interface problems and assist the instrument designers/builders in effecting a solution.

In a similar manner, guidance will be provided to the PI's in defining and developing crew operations, and data handling and formatting within the Orbiter/Spacelab/AMPS framework. Support will also be provided to the PI's in failure mode effects analyses and in safety analyses.

6.2 DOCUMENTATION

During the AMPS Phase C/D effort a number of documents describing the experiments and instruments and establishing their requirements and interfaces will be prepared. The experiment accommodation staff will have a key role in their preparation. As noted in 6.1.1, many of these documents will be based on the responses to the Instrument/Operations Questionnaire, itself forming a part of the documentation requirement. In all cases, the documents will be issued only with the formal approval of the NASA GSFC program office.

6.2.1 Initial Program Documentation

The intial AMPS documentation consists of a series of users guides which will accompany the NASA-issued Announcement of Opportunity, the AMPS Instrument General Specification, and the Instrument Interface/Operations Questionnaire.

The first of these documents, the users guides, will describe the Spacelab and each of the AMPS support systems that an experimenter might wish to use in performing his experiment or accommodating his instrument.

The total users guide package would thus consist of inputs from ESA, NASA, and the AMPS integration contractor. The AMPS integration contractor will issue users guides for contractor-provided support systems; e.g., booms, ESP's, gas and chemical release modules, etc. These guides will aid prospective Principal Investigators in responding to the Announcement of Opportunity.

Following NASA's selection of PI's the Instrument Interface/Operations Questionnaire and the AMPS Instrument General Specification will be sent to the selected PI's. (The questionnaire has been described in 6.1.1.) The specification contains all the detailed information regarding the AMPS interface that an instrument builder will need to satisfy the Orbiter/Spacelab/AMPS system in his design. This document is a specification of the interface only and thus does not contain performance requirements. As such, its issuance is the responsibility of the AMPS integration contractor and forms the top interface specification for any instrument. It is a single document which defines all the general interface requirements to which the instrument must be designed. Details of all electrical interfaces between the support systems and the instrument, including detailed schematics of the interface circuits within the support systems and suggested schematics of the interface circuits within the instruments will be included. Similar sections on the mechanical, thermal, and command and data handling interfaces will form parts of this specification. All general requirements, such as safety and software, will be included in this specification as well as sections on integration, test, and shipping requirements.

6.2.2 Interface Control Documents

Based on the responses to the questionnaire, AMPS to instrument interface control documents (ICD's) will be prepared for each instrument. Each of these ICD's provides a single controlled document which contains all the design interface information for one instrument. The mechanical and electrical interface control drawings will be included as part of these specifications. System allocations of weight, power, thermal, and telemetry requirements as specified by GSFC will also be included in these documents.

The initial drafts of the individual ICD's will serve to define the baseline configuration for the Phase D effort.

6.2.3 Other Experiment Accommodation Documentation

For each experiment, an Experiment Operations Procedure will be developed. Each of these procedures will describe in step-by-step fashion all the operations required to perform the given experiment. Each will include the orbit, time-of-day, orientation, etc., constraints, as well as the detailed allocation of thermal, power, energy, data, software, etc., resources. These procedures, again, will be developed through extensive meetings and liaison activities with the Principal Investigators and their staffs and the GSFC experiment manager.

All data for each experiment for each AMPS flight will be collected into a central Experiment Description Manual. Such a manual will provide a central point of reference for the instrument designs and experiment operations.

6.2.4 Documentation Protocol

The AMPS Instrument Interface/Operations Questionnaire and AMPS Instrument Systems General Specifications will be sent to each PI. The initial drafts of the instrument ICD's will be prepared from information received from GSFC, from the replies to the questionnaires, from information received from the experimenters, and from information received in meetings with experimenters. In cases of conflicting data, the information received from GSFC will take precedence. However, TRW will inform GSFC of all conflicting information received from experimenters so that the discrepancies can be efficiently resolved. Data received from experimenters will be controlled and distributed within TRW by TRW configuration and data management organization (CADM). GSFC will automatically receive copies of all information received from experimenters. However, such data will be used only to prepare the interface control drawings contained in the ICD's. After their approval by GSFC, the experimenters, and TRW, the specifications will become the official source of interface information.

The experiment accommodation staff will participate in TRW system and subsystem design reviews to ensure that the scientific requirements of the experiments are met. They will also assure interinstrument physical and functional compatibility, as well as support system-instrument, Spacelab-instrument, and Space Shuttle-instrument compatibility. Whenever necessary, analyses will be performed and test guidelines generated for the instrument contractor and AMPS system and subsystem design personnel to aid in meeting the experiment-environmental requirements.

6.3 INTEGRATION, TEST, AND FLIGHT OPERATIONS SUPPORT

Support will be provided during AMPS experiment/instrument integration, test, and flight operations activities.

6.3.1 Integration and Test Support Activities

Analysis of instrument integration requirements will be performed and instrument integration and test plans developed. Following the development of the plans, detailed integration and test procedures will be written for each instrument. These procedures form part of the Mission Support Requirements Document. An instrument EMC plan will also be developed at this time.

Support will be provided to the integration and test activities by coordination between the experimenters and the integration and test team, and by defining the instrument integration requirements, including ground support equipment, for the integration site.

An experimenter laboratory will be provided for the PI's and their teams, enabling them to make last minute checks or possibly repairs and modifications of their instruments at the integration site.

Finally, during and following completion of the integration and test sequences, assistance will be provided in the preparation of instrument system level test reports and evaluation of the interface test data for compatibility between instruments.

6.3.2 Flight Operations Support

An analysis will be made of the individual experiment operations to derive mission requirements. These requirements will form the baseline for developing the Experiment Operations Procedures and timelines discussed in 6.2.3. These procedures will be used to assist in developing the mission operational profile. The requirements will be developed for experimenter participation in the experiment operational tests during prelaunch operations, as well as in orbital and post-flight operations.

7. PRODUCT ASSURANCE

This section describes the Product Assurance requirements and related tasks that must be completed to meet the AMPS project objectives. The Product Assurance Plan will define and integrate into a single function the following disciplines:

- Quality Assurance
- Parts, Materials, and Processes (PM&P)
- System Safety
- Reliability.

Product Assurance requirements apply to the design, development, material procurement, fabrication, assembly, test, integration, and system checkout activity on AMPS payloads. The basic requirements for Product Assurance will be taken from the NASA NHB 5300.4, "Specifications for Quality Assurance, PM&P, System Safety, and Reliability."

7.1 QUALITY ASSURANCE

The Quality Assurance (QA) requirements for the AMPS equipment will be in compliance with NHB 5300.4 (1C), "Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components and Services." At the payload system integration level, the QA requirements will meet the intent of NHB 5300.4 (1D), "Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program," as outlined in this document.

The QA program will be structured with a strong interface in the System Safety, Reliability, PM&P, Test and Verification, and Manufacturing areas to ensure that any special controls needed to support these disciplines are implemented. Examples of this are flammable materials control, toxic materials control, contamination control, and control of safety hazards. Coordination with all of these areas will take place to prevent duplication of effort.

7.1.1 Quality Assurance Program Management and Planning

The AMPS payload quality program will be administered by a Project Quality Manager who will be responsible for the definition, interpretation, implementation, and application of AMPS quality requirements. The Project Quality Manager will report to the Assistant Project Manager (APM) for Product Assurance who has the responsibility for planning and implementing the Product Assurance program, and operates as an integral member of both the Project Office and the Product Assurance Organization. During the design, procurement, and fabrication phases, the project will be supported by a project quality engineer who will be responsible for support to design reviews, quality audits, Discrepancy Review Board (DRB), and Test Review Board (TRB) proceedings.

The tasks outlined in the Quality Program Plan will be planned in conjunction with other project functions necessary to satisfy all of the requirements of the AMPS contract. The program will ensure that quality requirements are satisfied throughout all phases of contract performance including design, manufacture, inspection, test, checkout, packaging, shipping, storage, and flight preparation of AMPS equipment. Objective evidence of quality conformance, including records of inspection and test, will be maintained on file for NASA/GSFC review. The Project Quality Manager will be the primary interface with the NASA/GSFC representative on all quality activities.

7.1.2 Procurement Controls

Quality Assurance procurement controls for suppliers of parts, materials, processes, and components for the AMPS payload equipment will be in accordance with the requirements specified in this Quality Program Plan.

Procurement will be made from suppliers that have been evaluated and approved as having the capability to perform to the requirements of the AMPS subcontract. As a part of the evaluation and approval, supplier quality surveys shall be conducted, if necessary, to verify the capability of new sources or existing sources with no current performance history.

The review of procurement documents will be according to the quality requirements for the equipment involved. The review will assure that the special outgassing and flammability requirements for the Spacelab environment are included.

Source surveillance of supplier activities will be performed in accordance with the quality system requirements for the payload equipment. The level of source surveillance will be dependent upon the supplier's control systems and demonstrated past performance. For safety or mission-critical units, this includes surveillance of discrete electronic devices to be identified in the AMPS parts screening documents referred to in the AMPS PM&P Program Plan

Receiving inspection of AMPS parts, materials, and components is performed to ensure conformance to program procurement document requirements. The degree of inspection and testing is determined by the type of product, its end-use, verification inspection performed at the supplier, and supplier performance history. Nonconforming items detected during receiving inspection shall be segregated from normal flow and submitted for material review disposition.

7.1.3 Fabrication Controls

The AMPS equipment to be fabricated, assembled, and tested shall be in accordance with engineering drawing and specifications. For safety or mission-critical hardware, the manufacturing documents will include inspection planning, operator instructions, and detailed inspection callouts to ensure that the hardware meets required design characteristics. Parts and materials to be used in the fabrication of these items will be maintained in controlled stores after acceptance by receiving inspection. Traceability to source shall be maintained except for common stock items such as nuts, bolts, washers, etc. purchased to MIL-Spec or Industry Standards. Quality Assurance will audit stores operations to ensure that equipment identification is maintained, packaging and preservation are adequate to prevent item deterioration while in storage, and damaged or unidentified material is removed from stores.

Work areas requiring temperature, humidity, and particulate contamination controls as specified by engineering documentation will also be monitored by inspection to ensure compliance.

7.1.4 Inspection and Tests

Payload assembly, integration, and test of AMPS equipment shall be performed in accordance with written planning documents. Quality Assurance planners will review these documents for incorporation of government inspection points, identification of the articles to be assembled, identification of necessary jigs and fixtures, reference to technical documents such as process specifications, environmental and packaging and handling requirements, and other requirements essential to build the assembly to drawing or specification.

Payload test operations will be performed to approved test procedures to verify functional integrity of the AMPS equipment. These procedures shall incorporate detailed steps for the performance of each step and shall include precautionary notes to inspection and test personnel to prevent the occurrence of hazardous conditions that can cause damage or contamination to equipment and injury to personnel. Controls for the hazards identified in the AMPS System Safety Analysis will be included as these procedures.

Quality Assurance will provide inspection surveillance of tests conducted on flight equipment, ground support equipment (GSE) simulators, and government-furnished equipment (GFE). Surveillance is performed to assure that the test equipment is currently calibrated, the test setup is in accordance with prescribed requirements (i.e., verification of power connectors, workability of apparatus), and the test is executed in accordance with the governing test procedure. This includes surveillance during tests for hazards in support of the AMPS Safety Plan. In the event a malfunction occurs, the failure will be reported and disposition made to resolve the condition. Payload integration, environmental testing, and prelaunch interface verification checkout will also be monitored by inspection to appropriate test and launch preparation procedures. Inspection of AMPS equipment refurbishment, modification, and retest shall be performed prior to equipment assembly as payload for reflight.

7.1.5 Nonconforming Article and Material Control

During payload integration, nonconforming material that is detected will be identified and, if possible, will be segregated in controlled areas. When segregation is not feasible or physically possible, the item will be bonded in place with a withhold tag and held for material review.

Discrepant items will be reported by inspection on a discrepancy report form. Discrepancies that can be reworked to drawing or specification requirements, scrapped, or return-to-vendor are dispositioned by preliminary review and forwarded for rework. Other dispositions, repair or use-as-is, require disposition by Material Review Board (MRB) action. The MRB will consist of a contractor QA representative, a contractor engineering representative, and a government QA representative.

Formal corrective action will be initiated for correction of: 1) design deficiencies or other technical requirements, 2) administrative procedures or practices, 3) processes or processing techniques, 4) inspection techniques, 5) failure to comply with established procedures and instructions, and 6) any other nonconformances which may affect the quality of the product. Corrective actions will be administered and controlled by internal corrective action control procedures, and will be subject to NASA/GSFC review.

7.1.6 Metrology Controls

For payload integration activities, policies and practices for calibration evaluation, maintenance, and control of test and measuring equipment will be in accordance with MIL-C-45662, Calibration System Requirements. Measurement standards traceable to the National Bureau of Standards for equipment calibration will be maintained. Also, test equipment calibration work orders will be sent to the thest equipment custodial organization for equipment recall for calibration. Inspectors monitoring test operations will verify that all test and measuring equipment are in current calibration prior to the start of hardware testing. AMPS ground test equipment will be calibrated prior to functional testing both at the unit and system levels.

7.1.7 Handling, Storage, Preseration, Marking, Labeling, Packaging, Packing, and Shipping

Through all levels of AMPS integration and testing processes, QA will ensure that items are handled in accordance with engineering drawings, procedures, and instructions. Items will be inspected at predetermined points to ensure that they are adequately protected and that the characteristics of quality are not impaired or degraded by handling. These requirements are incorporated into work instructions, manufacturing planning, and shipping requests and are reviewed by QA prior to use.

After checkout and clean up of the payload, the equipment will be inspected, sealed, and stored in containers until shipment to the launch site. Inspection of equipment container marking and labeling will be in accordance with engineering drawing and specification requirements or contractor process specification to provide the necessary information and protection for the equipment in the container. Special attention will be given to critical, sensitive, dangerous, and high-value articles. QA will monitor packaging for adequacy of protective containers and packing materials for prevention of damage, deterioration or corrosion, compliance of marking requirements, and inspection of packaging before shipping or storage. The method of packaging is defined by engineering or MIL-Specs and shall include, as necessary, critical item environment. Concurrent with the inspection of the packaging operation, QA will determine the adequacy of packing provided to prevent equipment damage due to shock or vibration during handling and transit. Packing requirements will meet the appropriate military or contractor process specification requirements.

7.1.8 Government Property Controls

Government property will be inspected upon receipt for proper identification, as-received condition, completeness, correct size, type, operational characteristics, and support documentation. This includes AMPS flight and ground support equipment. Provisions for periodic reinspection of GFP after the custodian has been established are implemented to ensure that equipment is not damaged or deteriorated by handling, use, or storage and that records reflect proper maintenance, use, and application. Equipment is identified by customer identification tags and associated serial numbers.

Equipment detected by inspection to be damaged, malfunctioning, or not suitable for use will be reported to the cognizant government representative by the property department and will be controlled in accordance with the contractor's standard practices.

7.2 PARTS, MATERIALS, AND PROCESS CONTROL

A Parts, Materials, and Processes (PM&P) Plan will be prepared which will set forth the organization, requirements, methods, and controls for managing the selection, procurement, and use of PM&P for AMPS design, test, and manufacturing efforts. The project requirements and controls will be established for contamination control (outgassing and dusting characteristics), cleanliness control (cleaning methods and area control), toxicity control (offgassing), and flammability control. The plan will cover electronic, electromechanical, mechanical, and structural flight equipment.

The philosophy is to maximize the use of established TRW standards and approach for PM&P control. Additional program specific controls will be applied as agreed between TRW and GSFC. All PM&P selections are to be subject to review and approval by GSFC and no unproven PM&P will be incorporated without first undergoing documented tests.

The PM&P Plan will be implemented by the Product Assurance Assistant Program Manager through the PM&P Manager and materials and processes specialists and components engineers. It is TRW's philosophy to separate the parts from the materials and processes functions, and both are separate from design and manufacturing.

AMPS PM&P program controls will include the use of:

- PM&P program schedule and master milestone charts
- The generation and maintenance of project approved parts, materials, and processes lists
- A project Parts Control Board (PCB)
- Participation in project design audits and reviews
- Initiation of specifications, specification revisions, and engineering orders
- Review and approval of engineering drawings.

TRW will control PM&P used in subcontracted hardware through the use of document (TBD), "AMPS Product Assurance Subcontractor Requirements."

7.2.1 Parts Program

TRW will use a design to cost approach to parts control similar to that employed on other NASA programs. This approach is to:

- Minimize qualification testing. Parts will be qualified by proven design, existing data, similarity, higher level of assembly, or (if necessary) test.
- Lot qualification will be by exception only; that is, if a problem is indicated.
- Screening tests will be minimized.
- Select high reliability parts as a first precedence

  MIL-S-19500 (JANTX, JANTXV)

  MIL-M-35810 (Level B or better)

  ERMIL Specs (Level P or better)
- Select commercial or military-equivalent parts only with extra controls/tests.
- Avoid new technology and unnecessary parameter restraints.
- Maximize parts standardization and minimize the number of different parts.
- Use the PCB to review and approve requests for new parts and changes in the PAPL, and all changes and deviations to the AMPS parts derating requirements documents.
- Use new parts only when absolutely necessary. New parts must be approved by Product Assurance, Components Engineering, the PCB, and GSFC.

The specific tasks to be implemented by the TRW parts engineering activity include:

- Implement AMPS parts selection, control, and derating requirements
- Develop, promulgate, and provide periodic updates of the AMPS Project Approved Parts List
- Define and implement part derating requirements and maintain the AMPS Parts Derating and Design Requirements document for designer use
- Define and implement part screening procedures, and maintain the AMPS Parts Screening Test Requirements document for Quality Assurance and Procurement purposes

- Process part approval requests from designers and subcontractors and present for AMPS PCB action

- Provide direct part engineering support to system and subsystem designers pursuant to selection and application of parts

- Authorize and direct part testing, characterization, qualification, and critical item testing to support program and Product Assurance objectives

- Provide direct engineering support to Procurement relative to part acquisitions, specification preparation, and specification negotiations with suppliers

- Perform failure analysis on failed parts

- Assure performance of Destructive Physical Analysis (DPA) on received part lots as required by project requirements

- Attend and direct participation of part specialists at AMPS PCB meetings and internal design audits/reviews to support part selections, applications, derating, and standardization

- Provide direct part engineering support to subtier subcontractors relative to selection, control, and utilization of parts for AMPS flight hardware

- Provide part engineering support to Manufacturing relative to part or test problems, failures, replacement, acquisitions, receiving, nonconforming material, Material Review Board (MRB) dispositions, and equipment test problems

- Serve as primary technical interface relative to customer notifications of AMPS part status, problems, alerts, technical tradeoff assessments, deviation requests, and PCB actions.

7.2.2 Materials and Processes Program

Materials and Process (M&P) selection and control will be based upon TRW-proven methods. Selection of M&P will be based on the following criteria:

- Appearance on the project-approved M&P list

- Existence of use-experience data and control documentation

- Suitability for use in the intended design application

- Cost effectiveness of the selection

- Proven TRW usage in equivalent spacecraft applications
- Adequacy of testing/data/criteria to verify suitability
- Proven ability for use by manufacturing personnel when using available facilities, equipment, and resources.

The following specific material properties will be controlled:

- Offgassing of possibly toxic or odorous trace contaminants from materials used inside the habitable area of the Spacelab or Orbiter
- Flammability of materials which can result in fire hazards inside the Orbiter or Spacelab or on the pallets
- Outgassing products from materials exposed to vacuum which may interfere with the correct function of experiments or equipment
- Corrosion or material compatibility which may effect the correct operation of the experiments or equipment; stress-environment interactions which could result in premature failure of components or structure will also be controlled
- Specific properties of "Forbidden Materials" or "Restricted Materials" which can be dangerous to personnel or mission safety or are known to cause extreme contamination.

No specific requirements are imposed on materials used inside sealed containers providing such containers do not rupture and emit gasses or flames under expected worst-case conditions including an internal ignition.

The specific tasks to be implemented by the TRW M&P engineering activity includes:

- Implement AMPS M&P selection and control
- Develop, promulgate, and provide periodic updates of the AMPS project-approved M&P list
- Provide direct M&P engineering support to system and sub-system designers pursuant to selection and application of M&P
- Perform failure analysis on failed materials
- Attend and direct participation of M&P specialists at AMPS internal audits/reviews

- Provide direct M&P engineering support to subtier subcontractors relative to selection, control, and utilization of M&P for AMPS flight hardware

- Provide engineering support to manufacturing relative to M&P test problems, failures, replacement, acquisitions, receiving, nonconforming material, Material Review Board (MRB) dispositions, and equipment test problems.

- Prepare and implement AMPS Contamination Control and Cleanliness Control Plans

- Serve as primary technical interface relative to customer notifications of AMPS part status, problems, alerts, and technical tradeoff assessments

7.3 SAFETY

The safety program for AMPS Phase C/D will be based on requirements found in NHB5300.4(1D-1) "Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program," and the June 1976 version of "Safety Policy and Requirements for Payloads using the Space Transportation System."

The safety program is based on the concept of designing payloads and operations to meet acceptable levels of accident risk. The safety program will be implemented by the Product Assurance Assistant Program Manager through the Safety Manager and the supporting system safety engineers.

7.3.1 AMPS Safety Program Controls

AMPS safety program controls will consist of:

a) Developing and maintaining safety program schedules and master milestone charts

b) Performance of safety audits

c) Participating in all design reviews and audits of safety critical equipment

d) Performing operational readiness inspections and attending operational readiness meetings. Operations will not be allowed to proceed without approval of the AMPS safety manager

e) Reviewing and approving engineering drawings, procedures, and plans

f) Maintaining a single point of contact for all safety-related matters on the project

g) Performing accident risk evaluations and coordinating with project management, NASA centers, and instrument suppliers

h) Approving certificates of safety compliance of all GFE and subcontractor-supplied equipment

i) Imposing safety requirements, that are consistent with the AMPS payload level safety requirements, on all instrument suppliers and subcontractors that will supply safety critical equipment for the payload. Also imposing safety requirements on all training activities that effect flight or personnel safety

j) Establishing an accident/incident reporting system

k) Establishing a hazard closure/tracking system

l) Developing project level procedures/instructions which will assure that safety considerations are properly included in all engineering analyses and activities

m) Requiring the AMPS Project Manager to formally approve the safety related risks accepted for the AMPS program

n) Development of special safety plans where needed for high risk operations on ground or during flight

o) Development of an AMPS safety requirements document.

In addition to the safety management controls to be implemented, the following areas of system safety engineering activities will be performed:

a) Accident risk management

b) Analyses

c) Participating organization interface

d) Safety verification

e) Safety training and certification

f) Hazard description information

g) Industrial safety interface

h) Accident/incident reporting.

7.3.2 Accident Risk Management

The accident risk management activity will consist of informing all responsible persons (TRW AMPS Project Manager, NASA/Goddard, JSC, KSC, and GSFC responsible personnel) of the accident risks being taken in various operations and designs and obtaining TRW and NASA positions on the acceptability of these risks.

7.3.3 Safety Analyses

Analysis activity will consist of performing safety related analyses necessary to determine specific design and operations requirements and to assess the risk of an accident during all phases of the program. Examples are: preliminary hazard analyses, design hazard analyses, and operating hazard analyses.

Safety analyses will be required of all suppliers (instrument suppliers and GFE) of safety critical equipment that will be integrated into the AMPS payload.

7.3.4 Participating Organization Interfaces

A safety interface will be established with all organizations that participate in the AMPS program. For all subcontractors to TRW, the safety interface will be defined in the subcontracts. For instrument suppliers, an informal interface will be established directly with the suppliers with formal interface being through the TRW AMPS payload accommodations manager then through NASA Goddard to the suppliers. AMPS system safety will establish safety requirements for instruments, attend instrument suppliers desirn reviews, provide safety information support, and review and approve the final designs and operations to be integrated into the AMPS program. An interface will also be established with NASA/JSC, KSC, and MSFC for Accident Risk Management purposes as indicated above.

7.3.5 Safety Verification

System safety will assure that all requirements are verified and that the data required in the safety compliance data package is available. System safety personnel will support integration and test personnel in determining which tests and analyses are required to verify that the safety requirements have been met.

7.3.6 Safety Training and Certification

System safety will support the training program defined in the AMPS Mission Operations Plan.

7.3.7 Hazard Description Information

Information on the hazardous nature of various operations will be made available for review by all personnel (TRW employees, NASA personnel, subcontractor personnel, instrument supplier personnel, etc.) that will be exposed to potentially hazardous operations.

7.3.8 Accident/Incident Reports

All accidents/incidents will be reported to AMPS project management and NASA personnel per the requirements of the June 1976 version of the Shuttle Payload Safety Requirements.

7.4 RELIABILITY

7.4.1 Reliability Management

The plan contained herein serves as a baseline to the development of a comprehensive reliability plan at the beginning of Phase C/D.

7.4.1.1 Reliability Organization

Reliability is a discipline which should be separated from the design, manufacturing, and testing to assure independent evaluation of the AMPS hardware. A reliability manager appointed for the AMPS project will report to the AMPS Project Manager through the Product Assurance Project Manager. He is responsible for assuring satisfactory completion of the required reliability design and development tasks.

Reliability manpower for these tasks will be obtained from the contractor's functional reliability organization. When final design functions are completed, a dedicated failure reporting specialist will be assigned to perform the failure reporting task.

7.4.1.2 Reliability Audits

Audits will be conducted of internal reliability activity and those of suppliers, where applicable, in order to assess the progress and effectiveness of the reliability effort and to determine the need for any changes which become apparent.

7.4.1.3 Subcontractor Control

The overall system reliability requirements for AMPS payloads will be allocated down to the equipment level based on the inherent reliability characteristics of the AMPS hardware involved. For example, off-the-shelf hardware allocations are constrained by the fact that the design already exists and reliability improvement, if required, is only practical through the use of higher quality parts and further testing. Greater flexibility exists for new design, and reliability may be substantially increased through redundancy. Consistent with the above, subcontractor and vendor specifications will contain appropriate quantitative and qualitative reliability requirements. This process entails providing subcontractor and vendor guidance and control to ensure adequacy of implementation.

7.4.1.4 Reliability of Government-Furnished Equipment (GFE)/Off-the-Shelf

For GFE/off-the-shelf equipment, the reliability data needed to assess the suitability of proposed hardware will be determined. Subsequently, this data will be analyzed, or testing performed if required, to assess the hardware reliability for consistency with overall system requirements. This assessment includes examination of historical data relating field experience, number of like items in service, reliability and maintainability trends, failure mode and effects analysis, problems and corrective actions, and NASA-sponsored studies on commercial equipment for Spacelab and Shuttle missions. GSFC shall be immediately notified of any inconsistencies which arise.

7.4.2 Reliability Engineering Tasks

Reliability engineering tasks are performed for all AMPS payload flight equipment, launch ground support equipment, spares, and GFE. In the performance of these tasks, major emphasis will be placed on the critical hardware. Critical hardware items will be identified early in the Phase C/D effort.

7.4.2.1 Reliability Model

A mathematical model will be developed and maintained for each AMPS mission for the purpose of assessing:

- Probability of mission success
- Potential weak or marginal equipment in various facilities
- Required and/or possible cost-effective redundancies.

Inherent in the development of this model is the generation of mission success and launch criteria, degraded mode analysis, and potential improvements from limited on-board maintenance.

7.4.2.2 Failure Mode and Effects Analyses (FMEA's)

FMEA's shall be performed at the system interface level. For single-point failures (SPF's) identified which result in loss of life or vehicle, a mission abort, or launch scrub, the FMEA shall be performed down to the piece-part level. (FMEA's are performed in coordination with the hazards analysis activities.)

7.4.2.3 Critical Items List (CIL)

A CIL will be developed and maintained which provides a summary of single-failure points (SFP's).

7.4.2.4 Failure Reporting

A system for documenting, reporting, and implementing corrective action for all hardware problems will be provided. This will be initiated during the Phase C/D hardware manufacturing and test cycle (i.e., acceptance testing) and continue through all test integration, and launch site activities. Failure reports will be initiated at the black-box level of failure. Failure analyses to the lowest level of equipment necessary to identify the mode and cause of failure will be conducted. Status and history files shall be maintained on all problems.

7.4.2.5 Maintainability Parameters

The capability of the hardware to meet measurable maintainability requirements such as mean time to repair, fault detection/isolation capability, and maintenance manhours per turnaround will be assessed. Analyses will be performed when an unacceptable parameter appears and corrective action implemented.

8. GSE DESIGN AND DEVELOPMENT

8.1 INTRODUCTION

This plan delineates the tasks required to design and develop the ground support equipment.

8.1.1 Purpose

The purpose of this plan is to provide data so that the GSE requirements can be translated into hardware. It will also cover the activities which are related to the design, development, and testing of electrical and mechanical GSE.

8.1.2 Organization and Management

Subprojects have been established to perform the EGSE and MGSE design, development, and testing tasks. The subproject managers will be responsible for technical, cost, and schedule performance, and will report to an assistant project manager responsible for GSE design and development.

8.1.3 Equipment Description

8.1.3.1 Electrical Ground Support Equipment

The electrical ground support equipment (EGSE) which will be developed will include a Labcraft payload checkout unit (LPCU) and an ordnance tester. The key elements of these units are shown in Table 8-1. Conceptual designs have been prepared during the Phase B AMPS Study for each of these hardware items in order to demonstrate that all requirements can be met and to provide a firm basis for defining the costs.

8.1.3.2 Mechanical Ground Support Equipment

The mechanical GSE is segregated into four major categories:

- Assembly
- Handling
- Servicing
- Development.

Table 8-1. Key EGSE Requirements

Hardware	Use
Labcraft Payload Checkout Unit (LPCU)	Control, monitor, and distribute electrical power. Provide hardwire safing commands for experiments. Control, display, and monitor sequenced events. Monitor red line conditions. Provide for automatic and manual shutdown commands. Provide communication links with the experiment and subsystem RAU's. Process and display caution and warning signals. Detect out-of-tolerance conditions. Perform fault isolation. Record wideband analog and digital experiment data. Process recorded data. Record data. Control and monitor experiment coolant and heating. Provide timing signals (GMT and MET) and sync signals. Provide interface for experiment-unique GSE. Provide interface for the Payload Operations Control Center.
Ordnance Tester	Verify ordnance firing commands and circuitry. Verify "no voltage" status of ordnance circuits.

The assembly hardware consists of the major assembly stands which are used during the payload integration phase during Level IV. It specifically consists of a five-pallet stand and rack stand which uses the ESA rail roll-in-and-out system.

The handling equipment is the family of MGSE required to lift, turn, position the various items of flight support equipment and Spacelab hardware. It generally consists of slings, handling dollies, and supports.

The servicing equipment is the MGSE which is required to provide the ground environmental services to the pallets and racks. They consist of a freon servicer and a ground air conditioner with associated plumbing and ducting.

The development hardware that has been identified consists of a pallet and rack(s) hard mockup. These articles will be used to assist in the development of the electrical cable layouts, development of crew habitability-functional requirements, instrument, and FSE layout verifications. The elements of the MGSE are shown in Table 8-2.

Table 8-2. Key MGSE Requirements

Hardware	Use
Pallet/Rack Hard Mockup	Support the fabrication, test, and operational checkout of the flight support equipment.
Handling Dolly*	Provide in-plant mobility for a single pallet segment and a rack and flow structure.
Pallet/Rack Checkout Stands	Provide a dedicated working area for pallet and rack integration.
Optical Alignment Kit	Perform assembly stand, instrument, pallet mating operation alignment.
Thermal Blanket Handling Kit	Support and protect thermal blankets during handling and hoisting.
Rack and Floor* Braces Kit	Provide structural support to the racks during assembly and integration.
Labcraft Payload Checkout Cooling Unit	Provide cooled dehumidified air to the rack-mounted experiments. Drain, purge, and circulate freon through the pallet cold plates.
Vertical Sling* Kit	Hoist and rotate the pallets and racks.
Pallet Segment* Floor Covers	Provide protection to the pallet floor during integration operations.
Rack and Floor* Installation and Removal Kit	Provide support for racks and floor assembly combinations.
Pallet Segment* Support	Support the pallets during integration and transportation activities.
Pallet Mate/* Demate Kit	Facilitate the alignment of the pallet attach fittings.
X-Ray Unit	Detect internal malfunction, stress, or corrosion.
Continuity Tester	Perform continuity tests on Labcraft electrical cables.
Grounding/Bonding Tester	Verify the bounding compatibility of the equipment after installation.
EMC Test Equipment	Verify electromagnetic compatibility between instruments.
Payload Integration Assembly Stands	Provide a dedicated working area for the assembly of pallets and racks.
Instrument Positioning Aids	Assist in the removal and installation of hardware components weighing over 20 kg.
Weight and Balance Kit	Perform weight and center of gravity determination.

*Possible GFE.

9. GSE MANUFACTURING

9.1 INTRODUCTION

This element covers the task of manufacturing the AMPS mechanical and electrical ground support equipment.

The manufacturing discipline together with special technical disciplines such as mechanical fabrication, printed circuit board fabrication, and electronic assembly will be aligned with the respective engineering counterparts to provide the close liaison required for an effective organization. In order to accomplish these tasks, a manufacturing plan will be developed.

The purpose of this plan is to establish the basic flow in the manufacturing process and to delineate the various control methods employed to implement this flow. The plan identifies the concepts, facilities, and procedures that will be used to manufacture the GSE.

The manufacturing plan encompasses all manufacturing activities and related tasks to be performed from the detailed hardware start through equipment activation. The plan is to have a project-integrated team for producing the ground support equipment. Section 9.2 describes the manufacturing organization and its responsibilities. Figure 9-1 describes the hardware development tasks.

9.2 ORGANIZATION AND MANAGEMENT

The AMPS GSE manufacturing is integrated with the engineering design and development effort. This combination of the engineering and manufacturing disciplines provides single-point responsibility for the end product and ensures that manufacturing considerations are incorporated into the design from the start.

The AMPS Assistant Project Manager (APM) for design and development has the overall responsibility for engineering and manufacturing of all ground support equipment. He will have two departments: the electrical ground support equipment (EGSE) and the mechanical ground support equipment (MGSE). Each department will assume the single point responsibility for the design and manufacture of his subsystem.

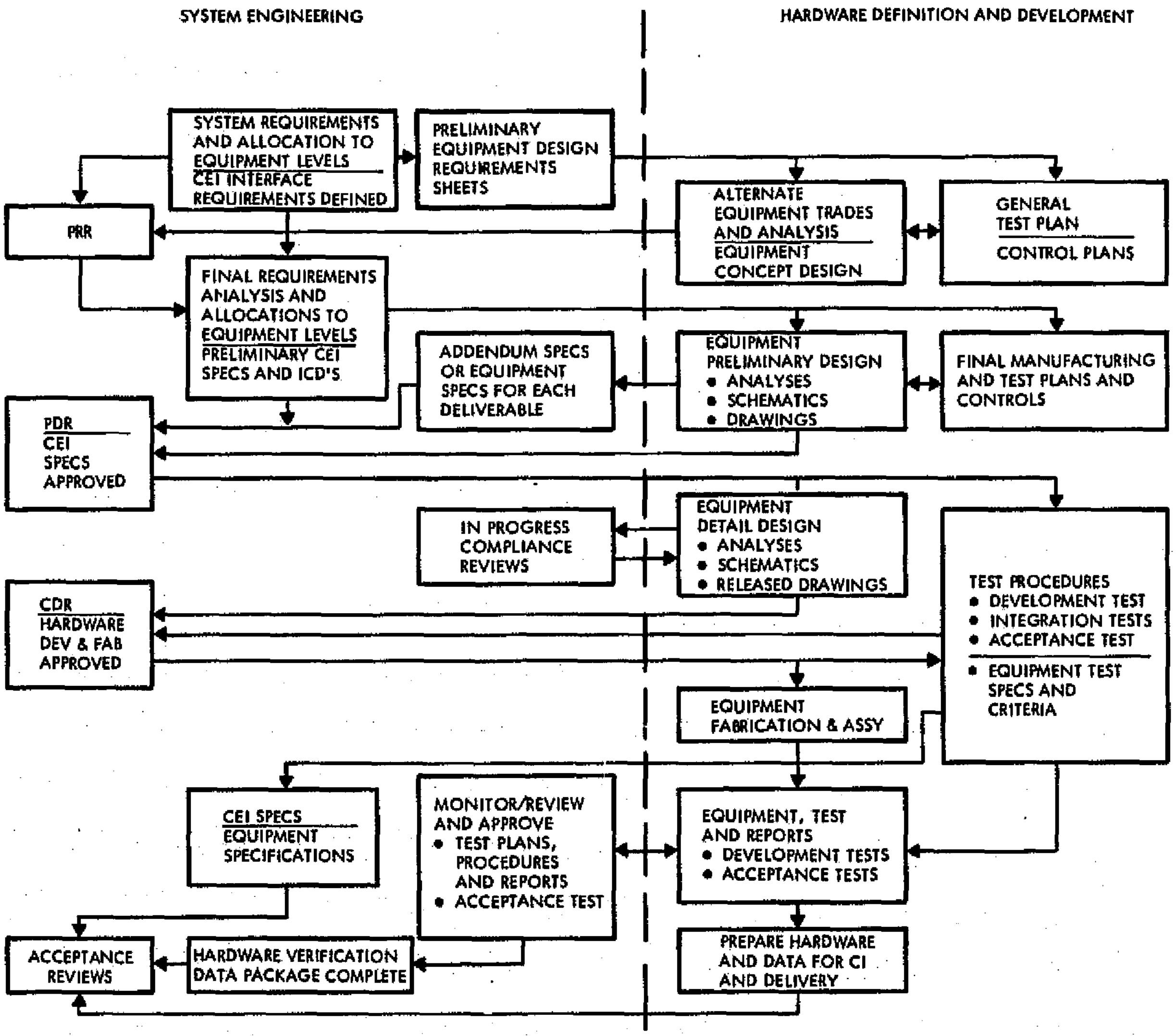


Figure 9-1. Hardware Development Tasks

In addition to this line organization, the APM for design and development has a senior manufacturing manager on his staff to act as a consultant, provide a central manufacturing focal point to assure hardware fabrication and test in a timely manner, and to act as an expert troubleshooter for manufacturing matters.

9.3 MAKE OR BUY DECISIONS

The general policy is to use commercial or other existing equipment for GSE whenever it will fulfill the requirements, or can do so with minor modification.

The LPCU and ordnance tester can be assembled predominantly from commercial units. In particular, the computational capability required in the LCPU will be most economically fulfilled by purchase of the Cll 125S computer. Any other solution would require a simulation of the flight computer with much higher costs for interface hardware and software.

Much of the MGSE must be specifically designed for fit with Spacelab hardware. Some of this equipment is expected to be available as GFE or as purchased from ERNO. These items are identified in Table 8-2. When the actual Spacelab GSE is not available the designs or hardware elements will be used wherever possible.

9.4 MANUFACTURING FACILITIES

The existing manufacturing facilities are specifically constructed for space technology work and are highly suitable for developing, producing, and testing ground support equipment. As the project moves into the production phase, the AMPS manufacturing team begins fabrication, assembly, and unit-test operations in the manufacturing buildings. These are grouped as skill centers with each center equipped with the facilities and equipment needed for its area of technical responsibility.

9.5 MECHANICAL GROUND SUPPORT EQUIPMENT (MGSE) MANUFACTURING

9.5.1 Hardware Description

The mechanical ground support equipment (MGSE) which will be fabricated and assembled will include hardware for flight support equipment (FSE) development, and payload testing, handling, transportation, servicing, and storage.

9.5.2 Manufacturing Activities

During the preliminary design phase the preliminary implementation plans will be established. Make or buy decisions will be made. Long-lead-time material requirements will be developed.

During the detail design phase there will be an active monitoring of the on-going design to ensure that manufacturing producibility suggestions and techniques and/or process developments have been incorporated.

Material status will be continually reviewed to assess conformance to schedule requirements. After the completion of the critical design, formal manufacturing drawings will be released.

9.6 ELECTRICAL GROUND SUPPORT EQUIPMENT (GSE) MANUFACTURING

9.6.1 Hardware Description

The main EGSE items are the Payload Checkout Unit and Ordnance Tester. These items are used during the Level IV checkout activities.

9.6.2 Manufacturing Activities

Printed circuit boards are fabricated at the circuit board skill center, continuity checked and shipped for subsequent kitting into the next assembly. The assemblies are functionally tested. Environmental and functional electrical tests are then performed and the units delivered to integration.

10. GROUND OPERATIONS

10.1 REQUIREMENTS AND PLANNING

This task covers the requirements analysis and planning for payload integration, verification testing and ground operations of the AMPS program.

10.1.1 Payload Integration and Ground Operations

Payload integration as defined within the context of this report encompasses the period from the end of instrument certification through Pre-Level IV and Level IV activities and ending with shipment to the Level III integration site. The instrument certification is primarily a government responsibility and it entails certifying that the instruments are ready for flight. The Pre-Level IV activity is the preparation of the instruments and racks and pallets for integration. The Level IV activity is the integration of the instruments into the racks and onto the pallets. Ground operations in the context of this report addresses all of the functions which are performed upon the receipt of the payload at KSC. This includes the Level III, Level II, and Level I, and post-mission activities and maintenance and refurbishment of the Spacelab elements for subsequent flights (reference Figure 10.1).

The development of the integration and ground operations requirements for AMPS will be based on functional level, activity level, and procedural level integration flow analyses. This is the key to an effective integration capability. The generation of the integration and ground operations flows will be based upon the established verification test program. The analyses will also derive requirements for ground support equipment that will be required to support the operations and will stipulate what documentation will be required to integrate the system (development of system level checkout procedures, subsystem level checkout procedures, equipment level checkout procedures, and interface checkout procedures).

The flows will also be used to derive the software requirements for the ground checkout software packages, experiment unique software packages, and the integrated system test software packages. General requirements to support the integration and ground operations will also be derived. These include accessibility, safety, facility, logistics, product assurance, and manpower requirements (reference Figure 10-2).

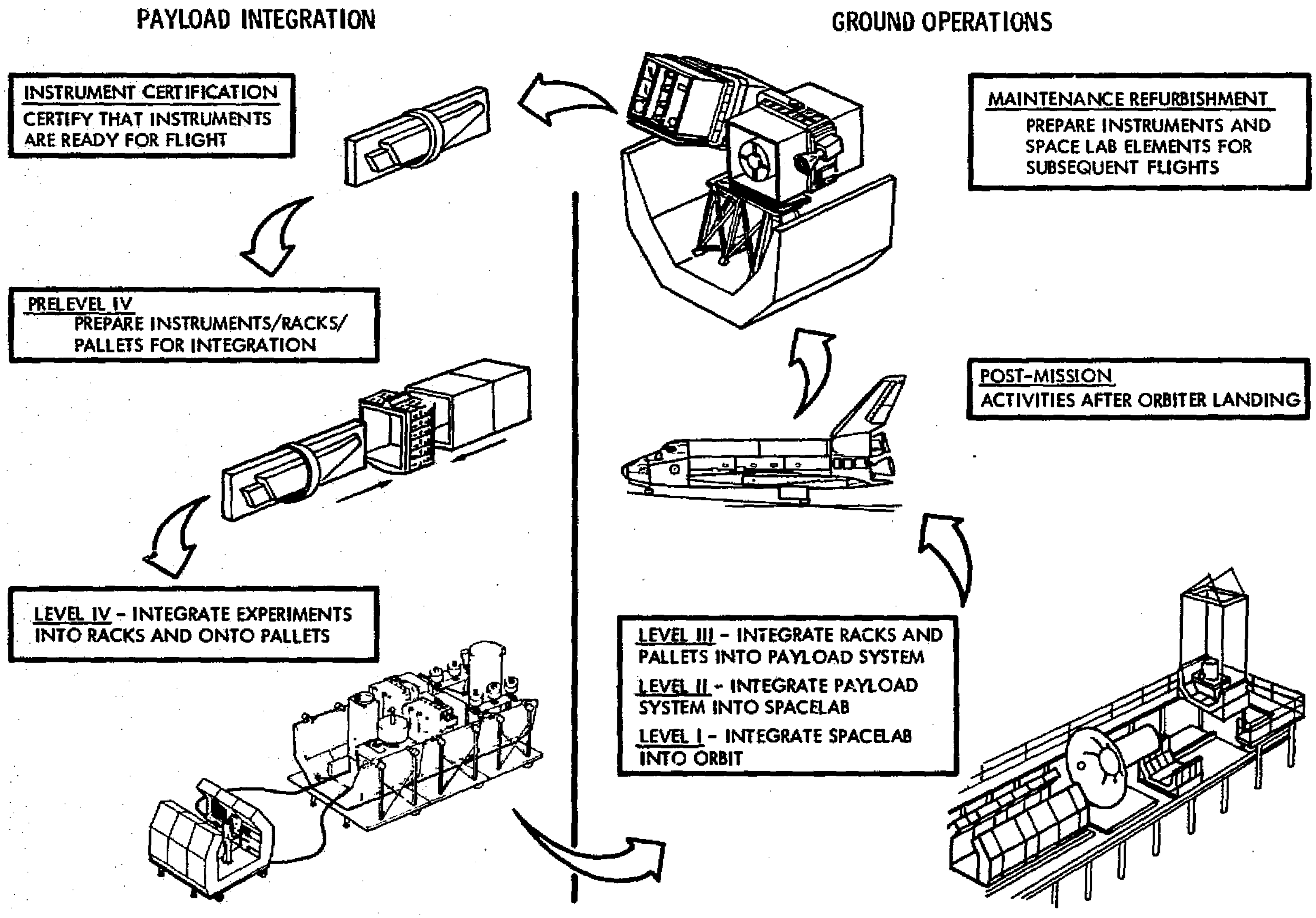


Figure 10-1. Payload Integration/Ground Operations Definitions

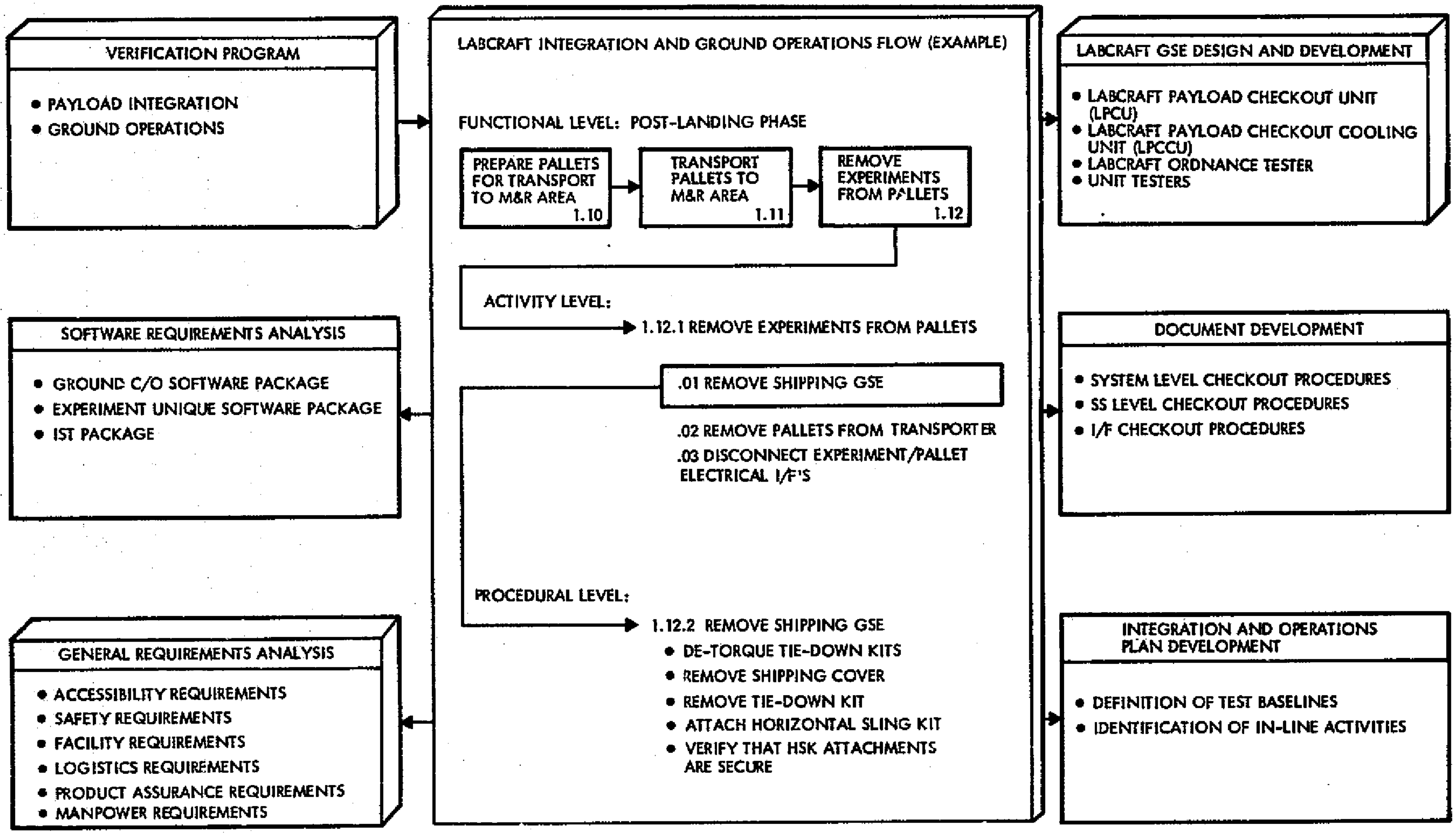


Figure 10-2. Paylcad Integration/Ground Operations Flow Analysis Approach

10.1.2 System Verification Testing

The system verification test program covers the development, qualification, acceptance, payload integration and ground operations test phases. The program assumes receipt of certified instruments and is primarily concerned with contractor-built flight support equipment.

A verification plan will be developed structured around the three hardware levels: flight support equipment (FSE), functional assemblies, and systems.

The FSE verification will be detailed and comprehensive to assure successful verification at higher and more critical functional assembly or system levels. The FSE tests will be to standards established according to the expected equipment duty cycles and the reusable nature of the hardware and will include a series of environmental and functional tests. Early development tests on breadboard and engineering models may be conducted where such tests are determined to be critical in providing confidence in design and in determining design margins. Qualification or qualification-acceptance tests will be conducted to demonstrate that the flight support equipment is capable of surviving and/or operating in all the expected environments of handling, shipping, storage, launch, and orbital operations. Acceptance tests on the flight hardware will demonstrate that the design is the same as the qualified design and that workmanship was performed to the required standards. A matrix will be designed to show how the design environments will be verified (test or analysis) during each verification phase, as well as to indicate the requirements derivations and verification status.

Functional assembly testing will be minimal and performed on a case-by-case determination. Specific functional assembly tests will be performed to verify that the assemblies will meet all of the expected environments. These tests will be supported by analysis and by data which was obtained during lower levels testing.

System verification will involve the activities beginning after the FSE and functional assemblies are integrated into the Spacelab hardware elements. It will include end-to-end systems verification tests, the duplication of operational sequences expected during the orbital mission, the development of a baseline technique for evaluating functional performance, and the scheduling and sequence of tasks to permit fault isolation correction, and repair with minimum schedule impact. The integration of the AMPS hardware will be accompanied by sufficient testing to verify satisfactory performance at each critical step.

In summary, the verification program which will be developed will be designed to achieve maximum flight readiness. The program will include active verification planning and control which will involve continuous review and evaluation. There will be close coordination with GSFC and the PI's to assure their participation and support.

10.2 PAYLOAD INTEGRATION

The AMPS payload integration task (see Figure 10-3) will consist of:

- Performing certification of contractor-developed FSE
- Receipt, inspection and checkout of all other hardware
- Integration of instruments and FSE into functional assemblies and performance of test as required on these assemblies
- Integration of functional assemblies and other hardware items with Spacelab pallets and racks and performance of tests on these elements prior to performing an end-to-end integrated system test
- Performing an integrated system test.

The integrated task also includes implementation of the verification test program described earlier.

At the system level the verification test program will subject the pallet assembly to acoustic tests in order to verify workmanship. Detailed checks of functional performance before and after each environmental test will provide the baseline from which functional transactions and trends will be detected. Operational monitoring during environmental exposure will be designed to reveal problems which might not be evident until exposure to the actual environment. The verification program reduces testing cost with a minimum risk to accomplishing the experiment. The program economies are realized by reducing environmental facility expenditures, shortening the schedule time, and reducing test crew costs.

At the conclusion of the integration activities at the Payload Integration Center, the hardware will be packaged and transferred to the launch site.

10.3 GROUND OPERATIONS SUPPORT

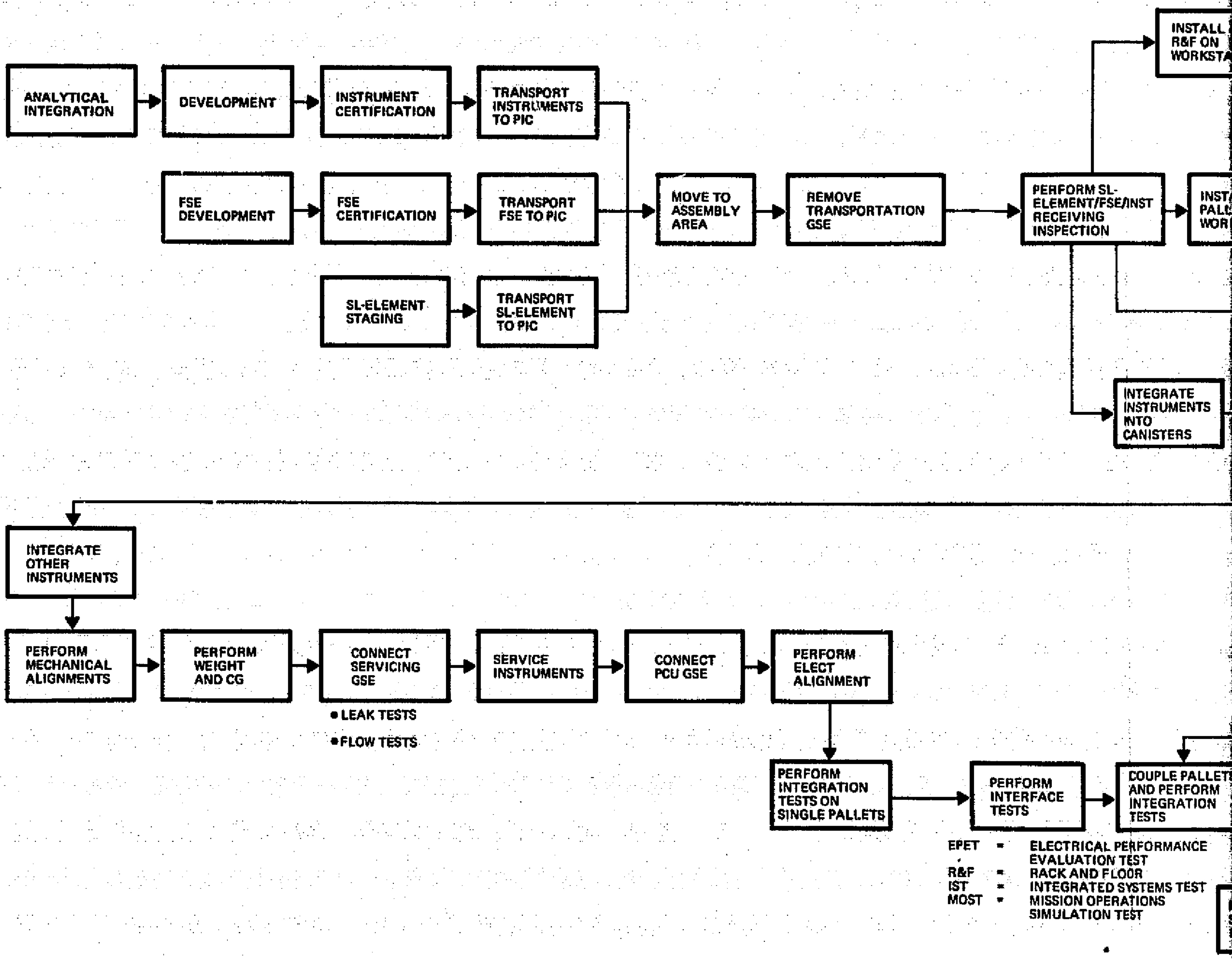
Ground operations support during the activities conducted at the Operations and Checkout Building will consist of performing post-shipment tests and then supporting the instrument checkout and calibration compatibility tests. Detailed tasks include:

1) Preparing test summary sheets
2) Supporting KSC in test readiness and status meetings and providing overall payload checkout coordination
3) Performing data analysis
4) Performing data reduction
5) Participate in payload scheduling and coordinating test day activities
6) Providing inputs to the payload checkout procedures and STS integrated procedures
7) Assisting laboratory personnel in checkout operations
8) Participating in payload systems and integrated tests
9) Directing and performing troubleshooting, including disposition of failed items and recommended design fixes
10) Coordination/liaison with KSC counterparts
11) Arranging for test support
12) Conducting pre-test and post-test briefings for each test activity.

The support will continue through the activities performed at the Orbiter processing facility, the Vertical Assembly Building, and the launch pad. Post-landing and maintenance and refurbishment tasks will also be supported by the payload integration contractor (reference Figure 10-4).

10.4 LOGISTICS

This task will include all effort needed to plan and apply integrated logistics considerations to the AMPS program.



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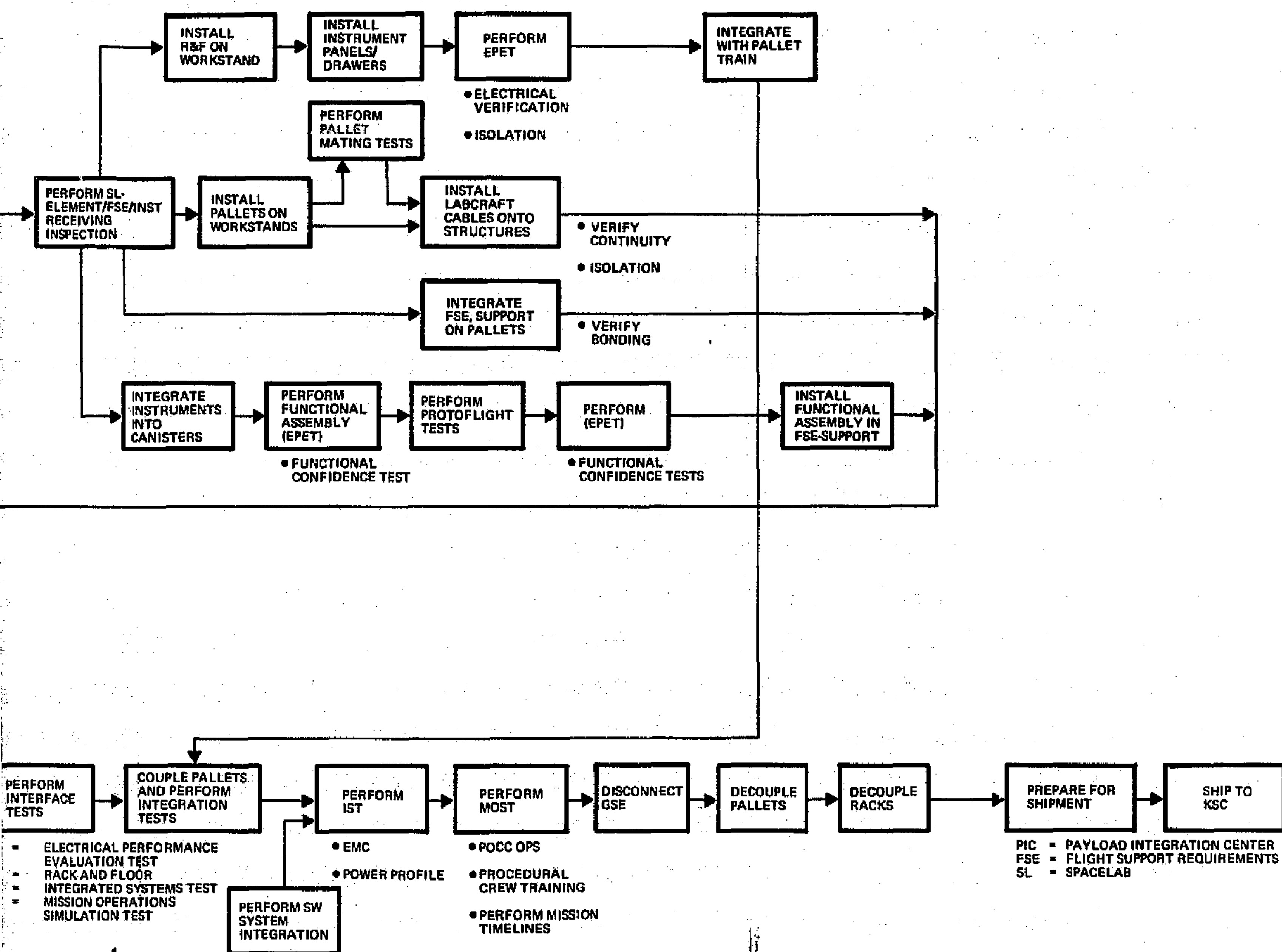

Figure 10-3. AMPS Payload Integration Task

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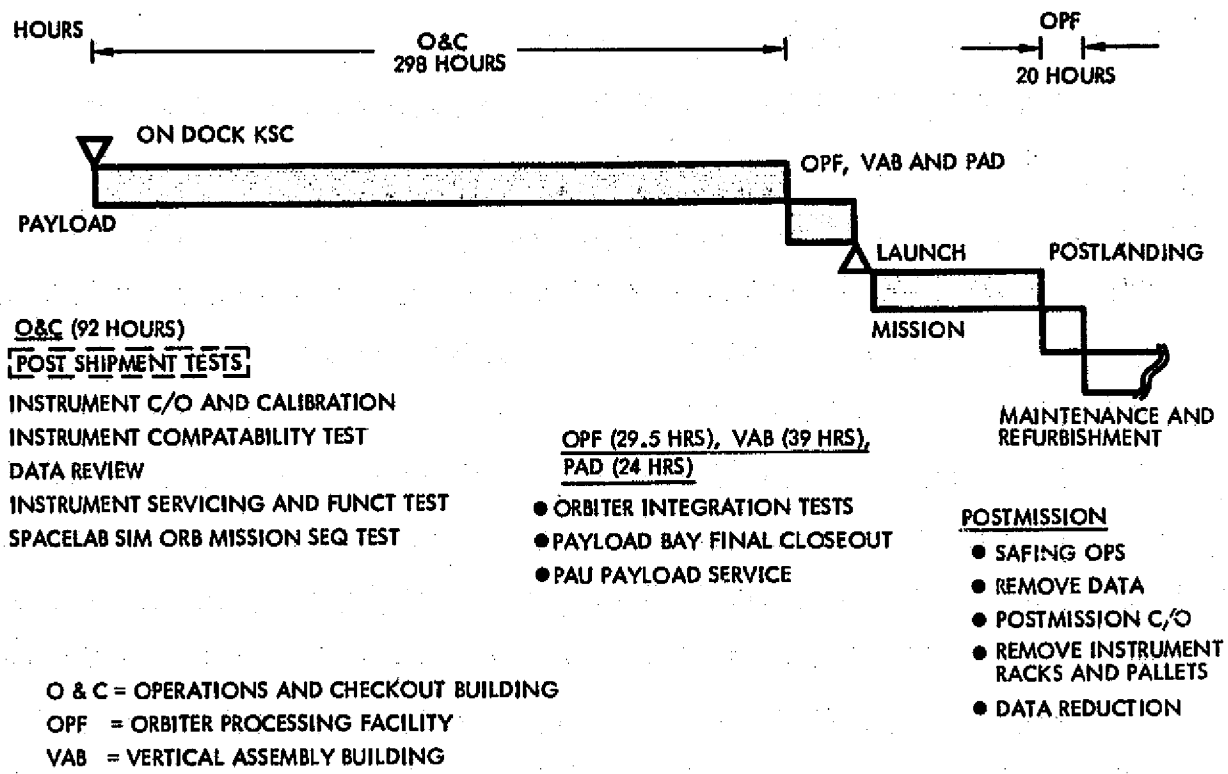


Figure 10-4. Ground Operations Support

10.4.1 Logistics Engineering Analysis

Logistics Support Requirements Analysis (SRA) will be performed on the flight and ground support equipment. This analysis will identify documentation, maintenance actions, personnel resources, support and test equipment, spare/repair parts, training and facilities necessary to satisfy AMPS logistics requirements.

An optimum repair level analysis (ORLA) will be performed on all flight hardware to determine whether or not each should be repairable and, if so, where the repairs should be done.

10.4.2 Maintainability

A maintainability program plan will be established to ensure that maintainability requirements are designed into all AMPS hardware. Explicit maintainability design criteria, maintainability performance evaluation, maintainability task/time line analyses, maintainability predictions, maintainability demonstration/verifications and analyses of engineering changes will all be tasks performed under this work element.

10.4.3 Maintenance Planning

Maintenance planning for AMPS will be developed to define the maintenance support and test equipment necessary to maintain the system in an operable condition. The maintenance concepts will be developed in consonance with the maintainability goals, data derived in the logistics support requirements analysis and data derived from the ORLA.

Three maintenance levels will be addressed:

1) Organizational level
2) Intermediate level maintenance
3) Depot level maintenance.

Based upon the performance of trade studies, the optimum repair location for each LRU will be selected.

Maintenance concepts will be evaluated in terms of equipment life cycle cost.

10.4.4 Supply Support

The concept of a centralized spares provisioning system will be established and implemented for the purpose of selecting, quantifying, cataloging, documenting, and furnishing spare/repair parts for the AMPS project.

The spares and supply effort will be consistent with the maintenance concept, the maintenance plan and the logistics baseline established by the SRA. The proposed centralized spares provisioning system will encompass all AMPS hardware, including spares for mockups and ground support equipment.

Spare/repair parts will be required to support both the flight and refurbishment cycles.

10.4.5 Technical Documentation

The necessary organizational and intermediate level technical instructional materials for each hardware item will be prepared. The validation of technically adequate procedures will be performed by the integrating contractor. In-process reviews of the documentation will be held as the hardware moves through its development process. Technical documentation will be based upon results of logistics support requirements analysis and maintenance concepts developed through ORLA studies.

10.4.6 Transportation Handling and Storage

The transportation and handling analysis will be initiated to ensure safe movement and handling of hardware by the most economical mode of transportation. An economic analysis of reusable containers will be included.

Storage requirements will be identified for short and long term storage items. Short term criteria will cover periods up to three months; long term criteria will cover periods over three months.

The criteria will be based on requirements analysis and contractor end item specifications. The criteria will also identify parameters to be protected against such as corrosion, deterioration and damage during the periods of storage. The criteria will be based on the concept that all items will be stored in their delivered shipping containers to the maximum extent possible.

Storage criteria will also identify environmental limits and preflgiht/postflight storage requirements.

10.5 MAINTENANCE

This task includes the actual work of maintaining equipment in accordance with the plans described in Para. 10.4.3, "Maintenance Planning." It covers all AMPS equipment in storage or at any of the integration sites.

11. FLIGHT OPERATIONS

Flight operations encompass those activities on-board the Spacelab or Shuttle that take place between launch and landing of the Orbiter. The planning for these activities must be adequate to assure efficient utilization of the time on orbit. However, in order to conduct planning and activities connected with orbital operations at minimum cost, the following guidelines shall be used:

a) Flight plans, crew procedures, crew training procedures, and flight data file material shall be developed in modular form to assure flexibility and so that only minor changes need be made from flight to flight.

b) Initial flight planning will be only to a depth of detail necessary to establish feasibility of meeting flight objectives.

c) Detailed flight planning and procedures development will be performed only after the flight equipment has been developed and exercised sufficiently to establish a firm understanding of its actual characteristics, such as: mass, power consumption, operating time, crew activities timing, etc.

d) Only limited flight planning for contingency operation of AMPS equipment will be performed. Rather, adequate documentation and engineering expertise will be retained so that malfunction analysis and contingency replanning of the flight can be performed during the flight in the event of equipment difficulties.

11.1 FLIGHT PLANNING

The general flow of planning for AMPS payloads will be as shown in Figure 11-1. Activities below the dotted line in Figure 11-1 will be covered by this plan, i.e., those functions that are the responsibility of the payload operator. The AMPS contractor will support the payload operator, GSFC, in the preparation and maintenance of the flight plan.

a) The general content of all flight plans will be

1) Identification of operational requirements (electric power, heat rejection, data processing, crew time, etc.)

2) Selection of the flight orbits, trajectories and schedules for AMPS operations

3) Development of experiment procedures

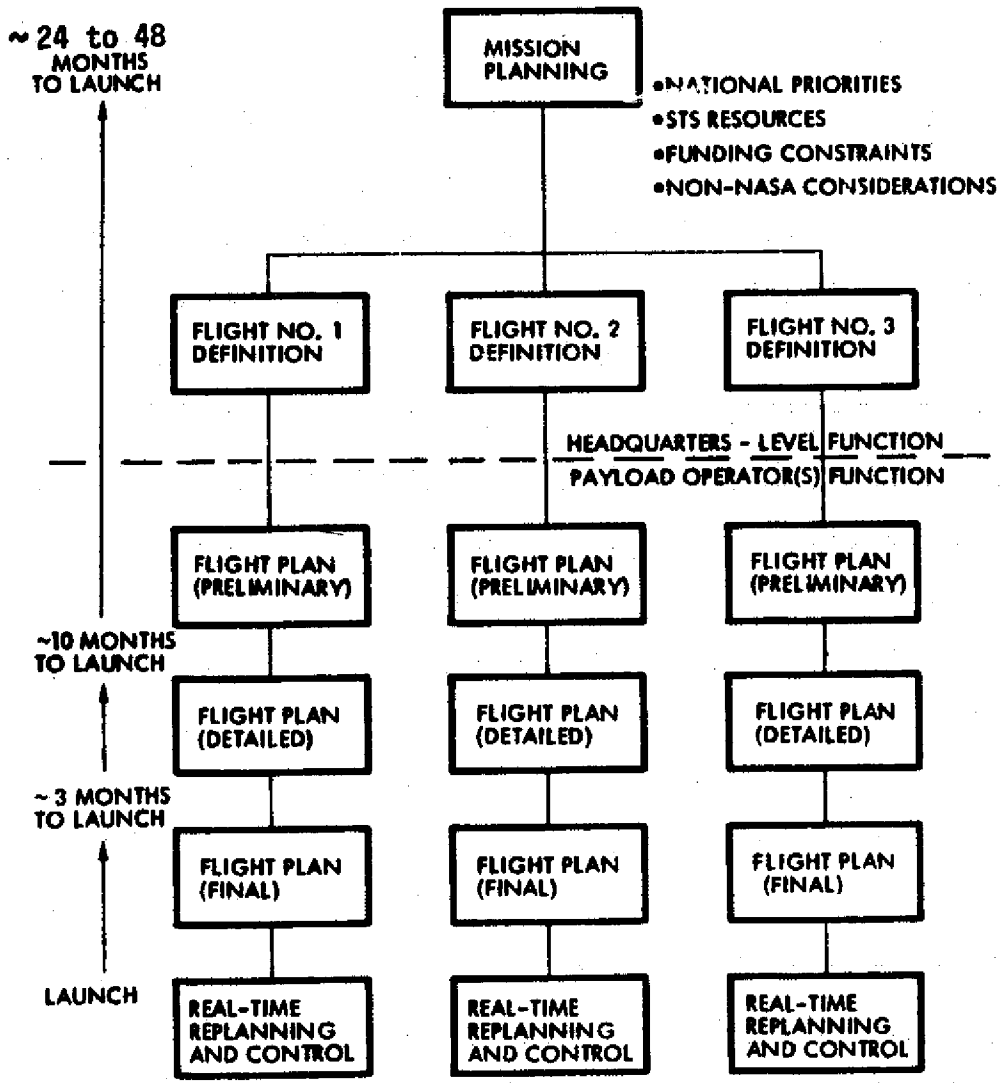


Figure 11-1. Definition of Mission and Flight Planning

4) Crew timeline development

5) Flight data file.

<u>The Flight Plan (Preliminary)</u> - will be brief. Its purposes are as follows:

a) To provide preliminary information for those agencies that will manage the flight (i.e., the STS operator) and who must arrange for integration schedules, STS equipment assignment, support from other agencies (e.g., for STDN and TDRSS), and STS facilities.

b) To provide information for use in development and design of AMPS equipment and FSE.

This flight plan will be produced at a time frame on the order of 3 years before launch of a first-flight experiment. For repeat flights during the operational era, this time frame may move closer to the launch date.

<u>The Flight Plan (Detailed)</u> - will expand the preliminary plan on the basis of hard data that become available after manufacture and test of experiment equipment. This plan is as close to the final version as possible. It will be produced about 10 months prior to launch.

<u>The Flight Plan (Final)</u> - will be the detailed plan modified on the basis of flight simulations. This is the plan that will be used by the flight crew and in the POCC to conduct experiments, i.e., it is the AMPS flight data file. It will be produced within the 2-3 months prior to launch. The Final Flight Plan must still be flexible enought to accommodate equipment failures during level III/II integration. Techniques and procedures for making late changes to the final plan will be described.

11.1.1 <u>Experiment Procedures</u>

Experiment procedures will be prepared in rudimentary fashion for the preliminary flight plan; these will be used only for determining the number of payload specialists needed for the flight, rough assignment of Spacelab resources and basic planning for space-ground communications.

The detailed and final flight plans will include step-by-step procedures for the experiments to be conducted. At least the following major topics will be covered:

a) Determination of readiness for the experiments on the part of the Orbiter, Spacelab and its subsystems and experiment participants

b) Preparation of the experiment equipment, including the associated flight support equipment (FSE)

c) Functional and calibration checks of the experiment equipment

d) Conduct of the experiment

e) Evaluation of the need to repeat the experiment, e.g., preliminary analysis of results, verification of experiment data-recording

f) Post-experiment calibration of experiment equipment and documentation of results

g) Shutdown of experiment equipment

h) Stowage of equipment

i) Documentation of experiment results

j) Coordination among on-board crew and POCC to be conducted during the flight.

11.1.2 Crew Timeline Development

Crew timelines will be prepared to cover the activities of all crew members as they relate to the AMPS experiments. The basic areas of responsibility for the crew will be:

a) Payload specialist(s) - primary responsiblity for experiment preparation, conduct and shutdown

b) Mission specialist - primary responsibility for Spacelab support; secondary responsibility for preparation, conduct and shutdown of the experiments

c) Pilots - primary responsibility for flight safety and for Orbiter support to the experiments. Secondary responsibility is for support to payload and mission specialists on an as-available basis.

For the preparation of crew timelines, the preliminary availability of payload and mission specialists' time for experiment operations will be based on Table 11-1.

11.1.3 Flight Data File

The flight data file will be prepared for use by the on-board crew for conduct of the flight. It will contain at least the following:

a) Flight plans - the data file will contain those portions of the final flight plan that are needed by the on-board crew to perform the experiments and to understand POCC and MCC activities related to the AMPS experiments.

b) Procedures - in addition to experiment procedures, the data file will contain procedures for other activities that may be required. These will include flight-management procedures between on-board and POCC people, communications protocols, and troubleshooting procedures for experiment equipment.

Table 11-1. Crew Activity Time Allocation

Activity	Hours: Minute/Day
Post-Sleep Activity	0:30
East Period (0:30 each)	1:30
Planning/Review of Next Day's Activities	0:45
Daily Status	0:15
Pre-Sleep Activities	1:00
Sleep	8:00
Experiment Operation	12:00
TOTAL	24:00

c) Reference material - within the data file, reference material will be compiled for on-board use in support of the experiments. Among the data to be provided will be equipment design data (schematics, drawings, instructions, test data) descriptions of the science objectives and anticipated experiment results (for use in on-board evaluation of experiment results), and such additional material as may enhance mission success.

d) Crew aids - the data file will describe a set of recommended crew aids for accomplishing the experiments.

Recommendations will be prepared for stowage of the flight data file considering availability to the crew, constraints of the Spacelab and the Orbiter, and cost to the AMPS program. Consideration should be given to loose-leaf file books, microfilm, and the mass memory of the on-board computers.

11.2 FLIGHT CONTROL

AMPS flight control plans and procedures will be developed. The roles of the following personnel will be described for the conduct of an AMPS flight:

a) The payload mission manager and his staff

b) Principal investigators (PI's) for the AMPS experiments

c) Government and contractor people who are familiar with the experiment and flight support equipment.

The plan will include recommendations for location of the above people during the flight, their data-processing and display facilities, communications links with the on-orbit crew and with the MCC, and anticipated work schedules. The functions to be performed by all participants will be defined.

Guidelines for use in preparing the flight control plan include the following:

a) Maximum autonomy will be assigned to the crew, consistent with capabilities and resources available for on-board data-processing and display

b) The POCC will provide assistance in case of malfunctions or in case of unusual experiment results

c) The STS/MCC will be responsible for overall conduct of the flight, including functions of the Orbiter and management of Spacelab resources

d) Low-cost approaches for mission control are of major importance. Maximum use will be made of resources and facilities that can be made available at no cost to the AMPS program.

11.3 CREW TRAINING

The crew training requirements and planning will define the specialized background and training for the Payload and Mission Specialists who will operate the AMPS experiment equipment.

The plan will identify the commonality of skills and training among the proposed AMPS experiment types. It will also include a proposed schedule for the AMPS-peculiar training for the payload and Mission Specialists. Recommendations will be made in the plan for the locations at which the training should be conducted.

As a guideline for this plan, training will be accomplished by the AMPS equipment manufacturers and by the Principal Investigators. The training will be accomplished on the actual experiment equipment to the maximum extent possible. The plan will minimize the need for specialized simulators, software, or other extra-expense items.

The plan will consider the impact of learning curves on the training requirements for later flights of the AMPS experiments. Also, the plan will not address the integrated crew training that will be conducted by the STS operators (safety, habitability, integrated operations, STS/Spacelab O&M).

11.4 POST-FLIGHT EVALUATION

Post flight evaluation of each AMPS flight will be prepared. The major elements of the evaluation include:

a) AMPS hardware performance

b) Flight Crew assessment of flight

c) STS/Spacelab performance

d) POCC performance.

The evaluation will include a log of equipment operating time, analysis of failures and an assessment of the operational support including the flight hardware, ground support and the flight data file. The report will assemble appropriate logs, flight data and records and contain recommendations for improving the efficiency and effectiveness of flight operations.

12. FACILITIES

12.1 PROJECT OFFICE

As explained in Section 2, the TRW AMPS organization will be projectized, with full time management and engineering personnel co-located in one project office area. This area will include the Project Control Room and be located in building R5 of the TRW Redondo Beach complex. The TRW Space Vehicles Division management staff is also located in building R5, together with project offices for other major NASA space vehicle procurements.

12.2 PAYLOAD INTEGRATION

Two facilities have been identified as required for performance of AMPS integration activities as follows:

a) The Payload Integration Center where the primary integration and test activities take place. This would include pre-Level IV assembly and test, proto-flight certification of functional assemblies, Level IV integration, and maintenance and refurbishment of selected instruments. A generalized layout of the PIC facility is shown in Figure 12-1.

b) An off-line maintenance facility at KSC for post-shipment testing, some pre-Level III assembly and interface testing, and integration of late arrival instruments. A sketch of this facility is shown in Figure 12-2.

Layouts and plans will be prepared for each facility to satisfy the following requirements:

a) Integration stand placement
b) Space for movement of equipment
c) Environment conditioning
d) Monitoring and test control areas
e) Storage and support areas
f) Laboratories
g) Offices
h) Environmental test equipment.

Existing facilities will be evaluated together with those modifications that would be required to make them ready. This evaluation will consider constraints due to schedule and to provable availability of flight hardware.

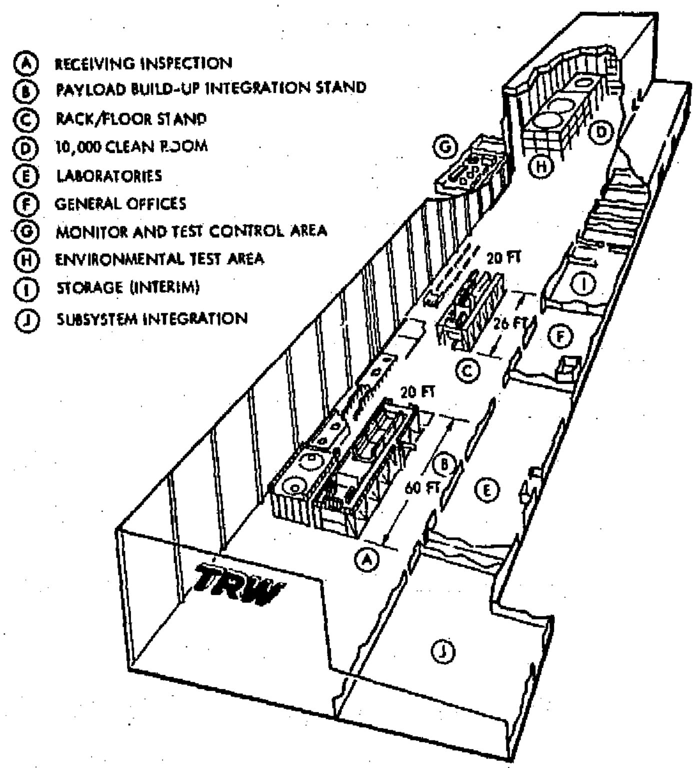


Figure 12-1. PIC Facility

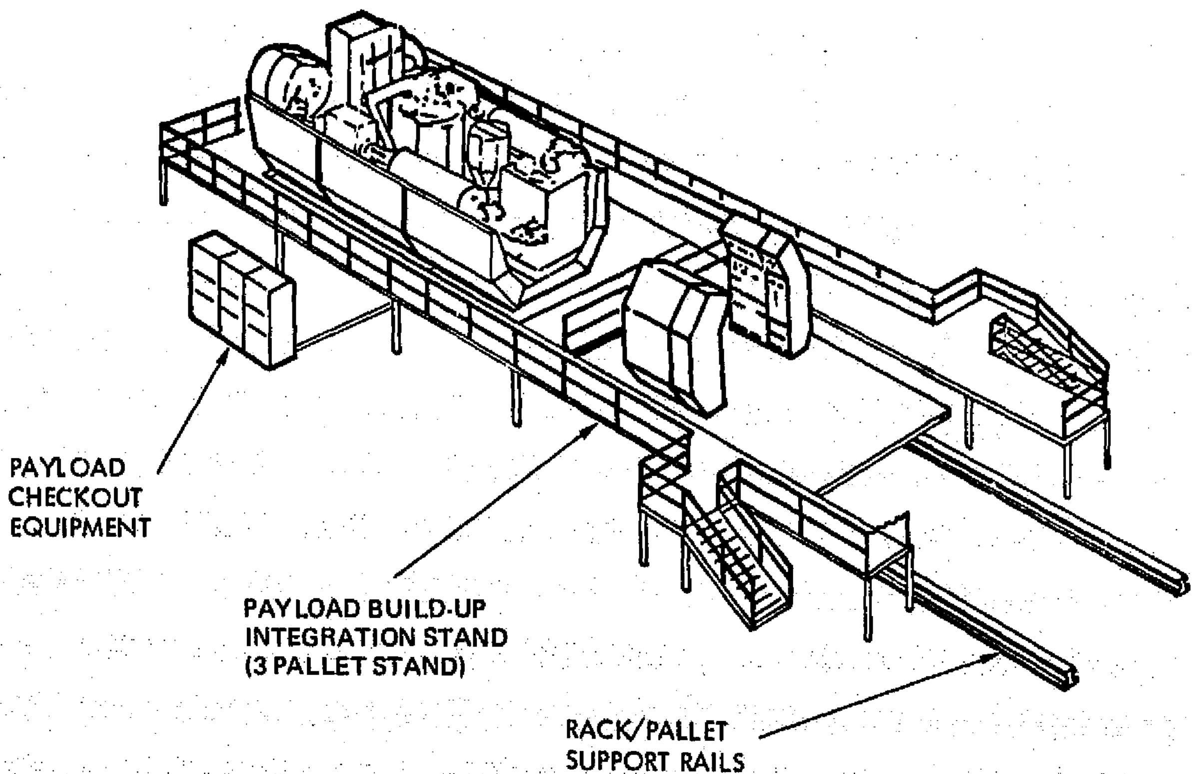


Figure 12-2. Off-Line KSC Facility (O&C)

13. SOFTWARE DEVELOPMENT

This section describes the Phase C/D development, integration, verification, validation and training tasks that the Phase C/D contractor will perform under the Software Development WBS element. The supporting software packages and facilities that NASA must provide in support of this work are identified. The tasks described are applicable to AMPS experiments, but would also be applicable to Spacelab projects involving other payloads. In what follows, it is assumed that the software development and integration facility (SDIF) is the central location where all software development and integration activities are tied together. (See Figure 13-1.) The concept illustrated in the figure shows how the developers and users of the flight application software are in immediate communication with the SDIF via remote terminals.

The present concept visualizes the SDIF to consist of a large scale computer such as an IBM 370/360 with peripherals. This computer would simulate the CDMS flight computer and its data bus, software RAU, keyboards, displays and other directly connected processing equipment on an exact bit-for-bit basis. Internal timing would likewise be simulated on an exact basis but the software might not operate in real time.

The large size of the host computer is also beneficial because it permits the insertion of test and diagnostic tool software in addition to the flight software. The test software, whether resident in the flight computer or in the EGSE/ATE will also be developed on this host computer. Upon delivery of the flight applications software and the flight and ground test software to the Level IV site, the software is validated with the actual payload hardware at this site. This validation facility uses bit-for-bit identical models of the CDMS and ground test computers with the payload instruments all operating in real time.

13.1 SOFTWARE GENERAL REQUIREMENTS DEFINITION AND ANALYSES

13.1.1 Interfacing and Impacting Systems Requirements Analysis

At the beginning of the Phase C/D program there will be a review of the software and facilities being planned to support the payload software development, integration, test, acceptance operation and maintenance.

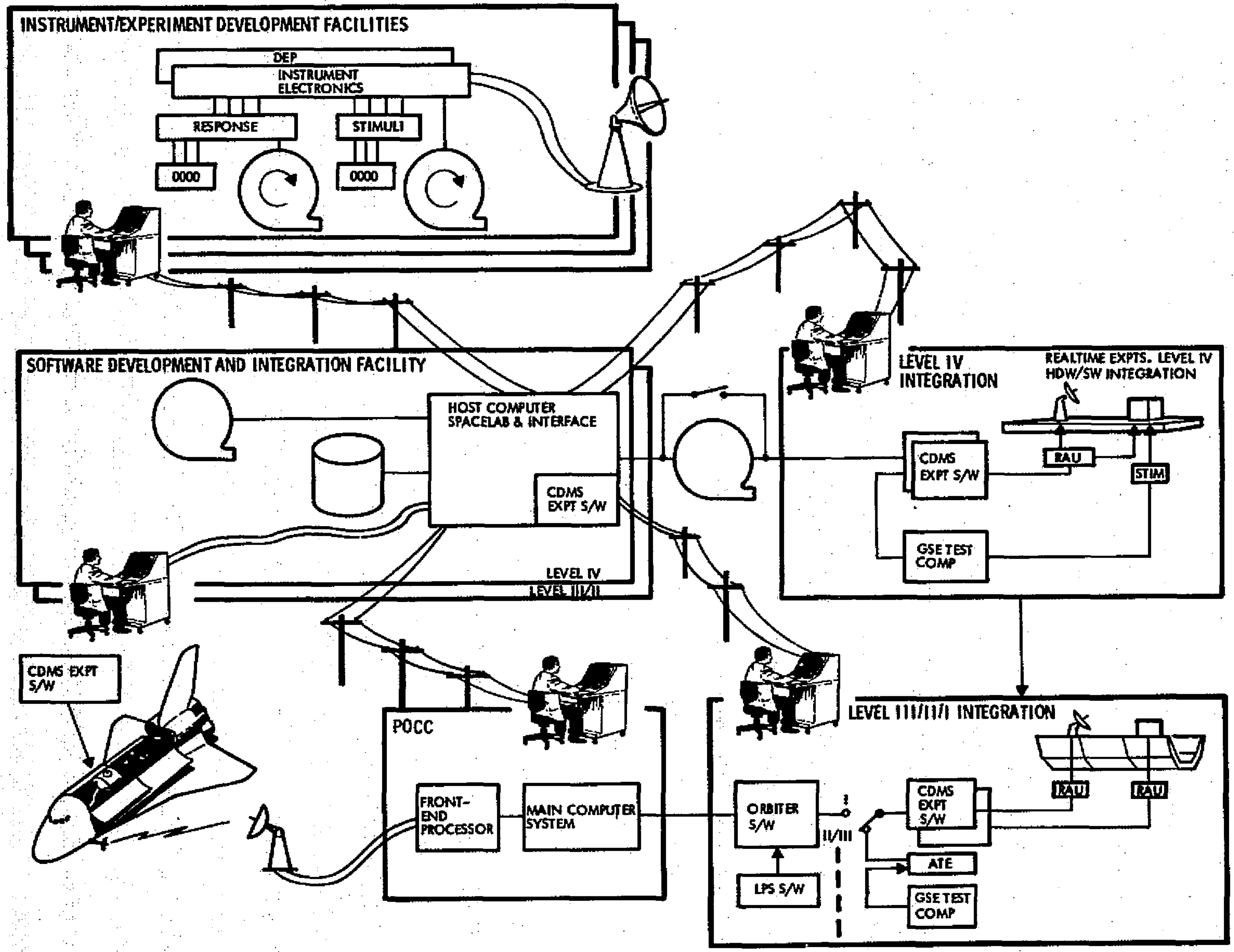


Figure 13-1. Centralized Software Development and Integration Facility Concept

This review will include determining the impact of the following systems that interface with, or impact the operation of the software, and includes:

a) POCC data processing downlinks and uplinks

b) MCC-H data processing downlinks and uplinks

c) Orbiter software

d) Training software

e) Post flight analysis of system performance

f) Refurbishment operations

g) Flight planning

h) Flight operations

i) Capabilities and limitations of ground support equipment already built

j) Capabilities and limitations of ESA software

k) Capabilities and limitations of already-built payload equipment

Recommendations will be made to NASA concerning the most promising or cost-effective resolution of any problem areas or costly requirements allocations discovered during this review.

13.1.2 Documentation Requirements

Table 13-1 lists a representative set of software documentation requirements that will be produced during the Phase C/D program if traditional requirements are followed. The application of a centralized facility for software development, using remote terminals and common simulation tools, promises to greatly reduce the number of documents that must be produced. In a few cases, the contents of the documents can also be simplified.

Table 13-1. Representative Documentation Requirements

a)	Experiment Software Development and Integration Management Plan
b)	Experiment System Software Part I Specification
c)	Experiment Software Interface Specification
d)	Preliminary Experiment Software Interface Module Design Specification
e)	Detailed Experiment Software Interface Module Design Part II Specification
f)	Experiment Software System Verification Test Plan
g)	Experiment Software System Verification Test Report
h)	Experiment Software Validation Test Plan
i)	Experiment Software Validation Test Report
j)	Postflight Experiment Software Evaluation Report
k)	Experiment Software Program Library Catalog
l)	Experiment Software Maintenance Plans and Procedures
m)	Software Problem Report
n)	Experiment Software User Manual
o)	Experiment Software Flight Tapes
p)	Experiment Software Program Listings
q)	Level III/II/I Software Support Plan
r)	Experiment Software Standards and Guidelines

13.2 FLIGHT SOFTWARE

The Software Activity flow for Phase C/D is shown in Figure 13-2 for flight software. Documentation will be produced as specified by the results of the activities of the previous section.

13.2.1 Update the Part I Specification

The Part I Software System Specification will be updated early in the Phase C/D program to take account of any changes or improved knowledge acquired between the end of Phase B and the beginning of Phase C/D.

13.2.2 Preliminary Design Review Package

The contractor will participate with NASA in a software preliminary design review (PDR). A PDR package will be prepared that will consist of the following documents:

a) Preliminary Interface Specifications specifying both program external and program internal interfaces in sufficient detail to permit design activities by all users to proceed.

b) A Software Standards and Facilities Document in sufficient detail to permit software design activities undertaken by instrument, FSE and experiment personnel tp proceed. The instrument, FSE, and experiment management modules will be incorporated as illustrated by Figure 13-3.

c) Preliminary designs of common interface programs and data modules of those modules that will be used by more than a single user.

13.2.3 Design and Build Common Modules

Those common modules that will be used by more than one experimenter will be designed and built. These modules include primarily that software that will cause data and commands to cross system and subsystem interfaces, but may include other common-use modules as well, such as a common-use data base structure as specified in the Part I specifications. These common-use modules will be a part of the Labcraft system management package, illustrated in Figure 13-3.

As a minimum, the following operations will be provided with common modules:

a) Transfer of set-up, calibration and operation control commands to payload equipment

b) Transfer of timing and state vector information to payload equipment

c) Transfer of data acquisition commands to payload equipment

d) Receipt of science data from payload

e) Receipt of commands from payload and console switches and dials

f) Transfer of computed quantities to high rate multiplexer/ high rate digital recorder or PCMMU (PCM master unit) for downlinking control of the recorder speed

g) Transfer of data, control feedback and other quantities to CRT and other console displays

h) Transfer of data to auxiliary test or ground support equipment via data bus to Orbiter or to payload during ground test or training

i) Acceptance of data from auxiliary test or ground support equipment via data bus to Orbiter or to payload during ground test or training

j) Data base structure accommodating commonly used elements

k) Assembly of composite commands based on single command inputs

l) Assembly of composite displays from single display commands.

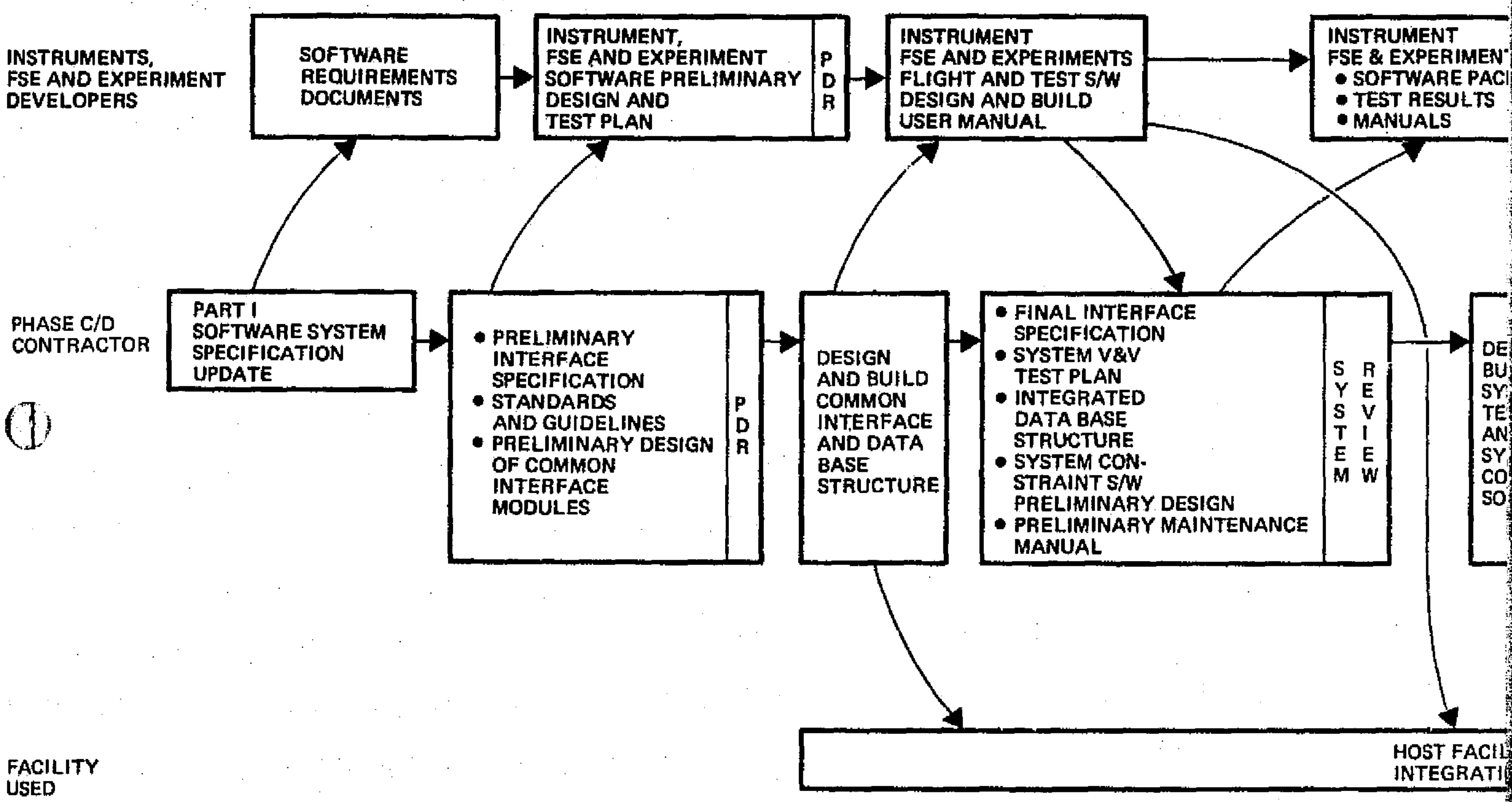
To a maximum practicable extent, the modules will be designed in such a way that the user need supply only data inputs to use them effectively.

13.2.4 System Review

A system review based on the results of the PDR and the initla detailed design and build activities will be supported. By this time, sufficient visibility will have been obtained to produce the following documents for review:

a) Final Interface Specifications to be baselined

b) A System Test Plans document based on detailed design work to date, covering both verification and validation testing



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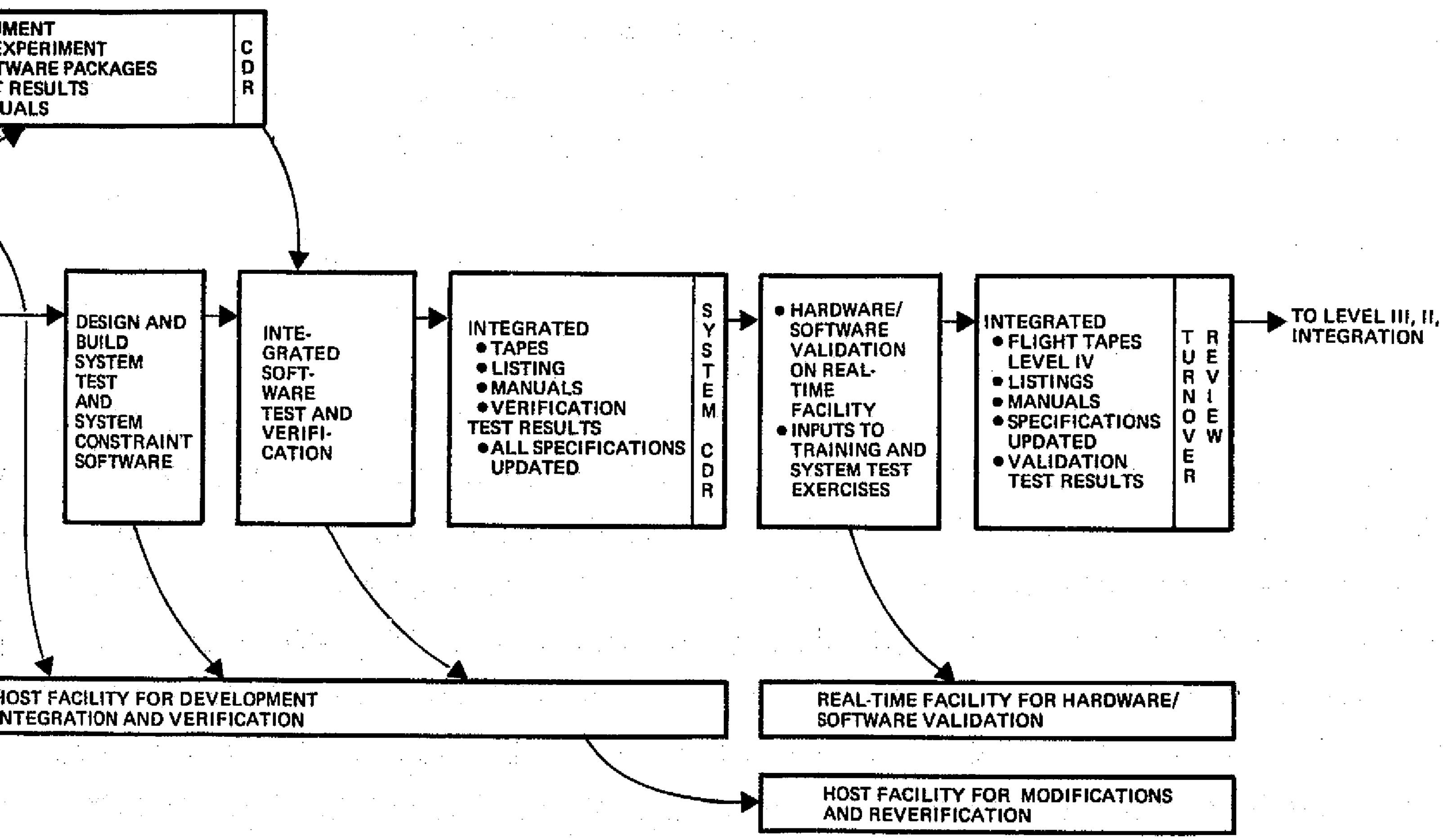

Figure 13-2. Software Activity Flow Phase C/D

c) Integrated data base structure supporting the interface specifications and detailing access and protection mechanisms

d) System Constraint Software modules preliminary design - to prevent mutual damage or delays between instruments, FSE, and experiments because of interference effects or safety-related considerations.

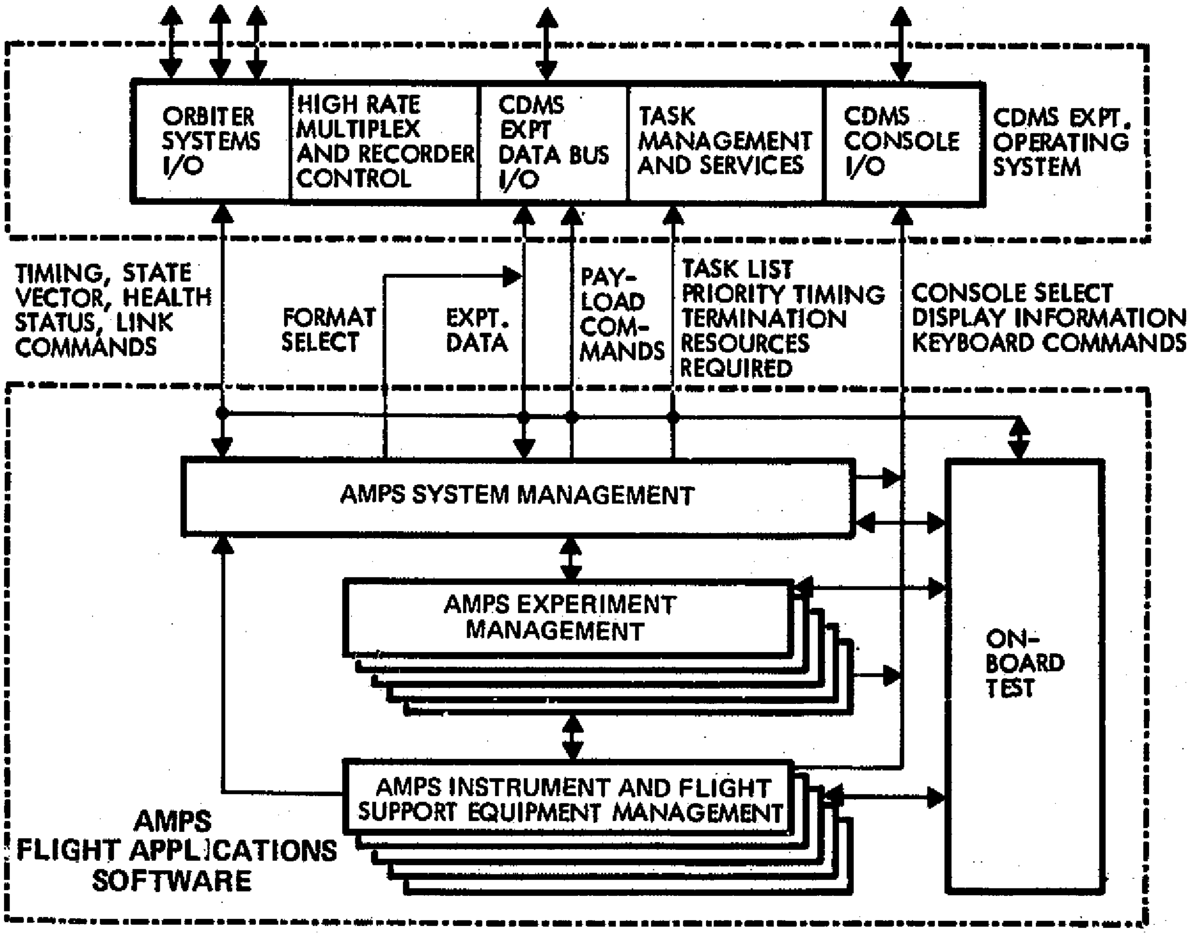

Figure 13-2. CDMS Flight Software

13.2.5 <u>System Test and Coordination Software Design and Build</u>

The experiment system test software modules that verify the integrity of the total experiment system as far as interface operations, mutual interference, and safety are concerned will be designed and built.

13.2.6 <u>Integrated Software Test and Verification</u>

The packages submitted for integration by instrument and FSE developers, experimenters, ESA or other sources will be integrated with the experiment system software, experiment test and coordination software for each mission.

Verification tests will verify the interface compatibility of all these packages. These tests will be accomplished in a host computer. They will use simulated interfaces and other ground test software described in the next section.

13.2.7 System CDR

A NASA review of the integrated verification test package will be held. It will consist of the following:

a) Experiment software verification (Level IV) flight tapes
b) Experiment software listings
c) All manuals
d) Verification test results documents
e) Updated design specifications from all contributors to Level IV.

This review may be incrementally held as desirable. If significant deficiencies are found, the software will be scheduled for rework by those responsible.

13.2.8 Hardware/Software Validation

Real-time integrated experiment hardware and software validation will be performed as follows: The software is loaded into the actual flight computer (or exact equivalent) communicating with actual flight payload instruments or exact equivalent. Simulations are only used to a minimum extent, where necessary to exercise the total hardware/software system interfaces. The integrated hardware and software tests, with emphasis on the testing of all hardware/software interfaces, will be performed including any problems that could be discovered by transitioning from the host computer software simulations to flight hardware.

Any training exercises that are planned using the real-time facility will be supported at the end of the validation.

13.2.9 Turnover Review

A NASA review of the validated (Level IV) software will be held. The software part of the review package will consist of:

a) Flight tapes
b) Listings

c) Manuals
d) Updated specifications
e) Validation test results.

If significant deficiencies are found in the software, they will be scheduled for rework by those responsible. Prior to final delivery to the higher levels (III, II, I) of integration, the turnover review will be completed.

13.3 GROUND SOFTWARE

13.3.1 Ground Software Activity Flow

Such ground test simulation and other ground support software as is necessary to accomplish the development and integration of Level IV experiment software will be developed and maintained. The additional or modified software development that needs to be procured will be identified and recommended to NASA. However, minor modifications or development of small packages needed will be made, subject to NASA approval. Documentation will be produced as specified by the result of the activities of the Software Requirements section.

The new ground applications software to be developed follows the same event sequence depicted on Figure 13-2 for those ground test, simulation or other ground support packages that become a permanent part of the software inventory. (A much reduced documentation requirement for "throw-away," one-time test software that is designed and used for temporary investigative purposes will be recommended.) The intent of Figure 13-2 is that individual instrument, FSE and experiment test software be developed during the same time period that the flight software is being developed. Likewise, the Level IV experiment system test software is developed during the same time period that the system coordination and constraint software is being developed, both the the host software verification and the hardware/software real-time facility tests.

13.3.2 Software Packages Required

The list below shows the packages required to be developed or maintained for experiment software. Where more than one source is given, this should be interpreted to mean that no single source is expected to be able to cost-effectively do the whole job on that package.

IBM 370 (Host) Software Packages	Source
OS/VS-1	IBM
Timeshare monitor	Commercially available
Host displays and printouts	Integration contractor
Host Keyboard interpreter	Integration constractor
Terminal software monitor	Commercially available
Software text editor	Commercially available
Macro Assembler for IBM 370	Commercially available
Linkage editor for IBM 370	Commercially available
Utilities	Commercially available
HAL/S 360 compiler	Intermetrics
HAL/S CII compiler	ESA
GOAL compiler for CII	NASA modified by ESA
Data base generator and maintenance	ESA modified by integration contractor
HAL/S cross compiler to CII	ESA
GOAL cross compiler to CII	ESA
Cross assembler to CII	ESA
Cross linkage editor to CII	ESA
Management package	ESA
ICS for CDMS computer	ESA
ICS for EGSE computer	ESA
Experiment computer operating system (ECOS)	ESA
EGSE computer operating system (GCOS)	ESA
Spacelab/Orbiter interface simulation	ESA

IBM 370 (Host) Software Packages	Source
Spacelab I/O box and peripherals simulation	ESA
Experiment payload simulators	Each instrument/FSE developer, Experimenter and integration contractor as required
Host flight software, test modules and data inputs	Each instrument/FSE developer, Experimenter and integration contractor as required
EGSE test software	Each instrument/FSE developer, Experimenter and Integration contractor as required
Test data reduction	ESA integration contractor, Instrument and FSE developer or experiment developer, as required
Test data storage and retrieval system	Commercially available
Code auditor	Language supplier and integration contractor
Branch usage check	Integrating contractor
Debug tools	Commercially available
Training software on host	TBD
(ECOS) experiment computer operating system	ESA
(GCOS) ground computer operating system	ESA
Payload stimulator interface with EGSE computer	Integration contractor
GOAL keyboard command interpreter	ESA
GOAL checkout language interpreter	ESA
Orbiter software simulation	ESA
EGSE experiment, instrument and FSE test software developed on HOST computer	Developers of instruments, FSE and integration contractor
EGSE experiment system test inputs developed at real-time integration site	Integration contractor

IBM 370 (Host) Software Packages	Source
CDMS on-board test software developed on Host computer	Developers of instruments, FSE and integration contractor
CDMS on-board test software inputs developed at real-time integration site	Integration contractor
CDMS ground checkout package	ESA modified by integration contractor
EPDS ground checkout package	ESA modified by integration contractor
ECS ground checkout package	ESA modified by integration contractor
Experiment ground checkout monitor	ESA modified by integration contractor
Ground checkout instrumentation test	Integration contractor
Test data recording package	ESA
Test data reduction at real-time facility	Integration contractor
EGSE self-test	ESA
CDMS self-test	ESA
Analog to PCM convertor	ESA
EGSE training inputs developed on HOST computer	(TBD)
CDMS training inputs developed on HOST computer	(TBD)

13.4 SOFTWARE SUPPORT FUNCTIONS

13.4.1 Problem Reporting

Any significant discrepancies, interface incompatibilities, now-functional conditions in software, documentation compliance or other problems encountered with software supplied by others will be reported to NASA. Problem resolution, where appropriate, will be recommended to NASA.

13.4.2 Test Records Maintenance

Adequate test records will be maintained so that the configuration identification of each software package tested and a record of the tests that have been completed will be available.

13.4.3 Software Change Evaluation

Evaluation of proposed software changes to experiment software to NASA and recommendedation of the most cost-effective solution will be supported.

13.4.4 Pre-flight Exercise Support

Such software exercise tapes as are required to simulate experiment operation for POC software checkout or personnel training purposes will be produced.

13.4.5 Software Development, Integration and Test Facility Support

Changes, additions or deletions as are required to maintain a cost-effective host computer development and integration facility will be recommended to NASA. The same will be done for the software aspects of the real-time Level IV test facility under this task.

13.4.6 Software Development Support

The instrument and FSE software developers and experimenters and other sources and users of software in their use of the software development facility will be supported. This support will include:

a) Clarification and updating of standards and guidelines issued to these sources and users

b) Real-time consultation via remote terminal support to advise and remove problems encountered in experiment software coding and testing

c) Support of instrument and FSE developer's PDR and CDR by NASA. Critique of software and documentation as required by NASA.

13.4.7 Level III, II, I Integration Support

If problems are discovered at higher levels of integration with the experiment software, their resolution as appropriate to the Level IV integration role as defined by the other tasks herein will be supported.

13.4.8 Flight Support

If problems or other necessary action is required during the flight operations, the diagnosis, analysis, software changes or other appropriate action to achieve best flight performance as appropriate to the Level IV integration role as defined by the other tasks herein will be supported.

13.4.9 Post Flight Support

After each mission, a postflight software performance evaluation report concentrating on the analysis of problems and discrepancies (if any) encountered will be produced.