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POWER EXTENSION PACKAGE (PEP)
SYSTEM DEFINITION EXTENSION

Orbital Service Module Systems Analysis Study

VOLUME 9
PEP Design, Development, and Test Plans

(NASA-CR-160328) POWER EXTENSION PACKAGE (PEP) SYSTEM DEFINITION EXTENSION, ORBITAL SERVICE MODULE SYSTEMS ANALYSIS STUDY. VOLUME 9: PEP DESIGN, DEVELOPMENT AND TEST PLANS (McDonnell-Douglas Astronautics Co.) N79-33244

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PEP Design, Development, and Test Plans

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PREFACE

The extension phase of the Orbital Service Module (OSM) Systems Analysis Study was conducted to further identify Power Extension Package (PEP) system concepts which would increase the electrical power and mission duration capabilities of the Shuttle Orbiter. Use of solar array power to supplement the Orbiter's fuel cell/cryogenic system will double the power available to payloads and more than triple the allowable mission duration, thus greatly improving the Orbiter's capability to support the payload needs of sortie missions (those in which the payload remains in the Orbiter).

To establish the technical and programmatic basis for initiating hardware development, the PEP concept definition has been refined, and the performance capability and the mission utility of a reference design baseline have been examined in depth. Design requirements and support criteria specifications have been documented, and essential implementation plans have been prepared. Supporting trade studies and analyses have been completed.

The study report consists of 12 documents:

Volume	1	Executive Summary
Volume	2	PEP Preliminary Design Definition
Volume	3	PEP Analysis and Tradeoffs
Volume	4	PEP Functional Specification
Volume	5	PEP Environmental Specification
Volume	6	PEP Product Assurance
Volume	7	PEP Logistics and Training Plan Requirements
Volume	8	PEP Operations Support
Volume	9	PEP Design, Development, and Test Plans
Volume	10	PEP Project Plan
Volume	11	PEP Cost, Schedules, and Work Breakdown Structure Dictionary
Volume	12	PEP Data Item Descriptions

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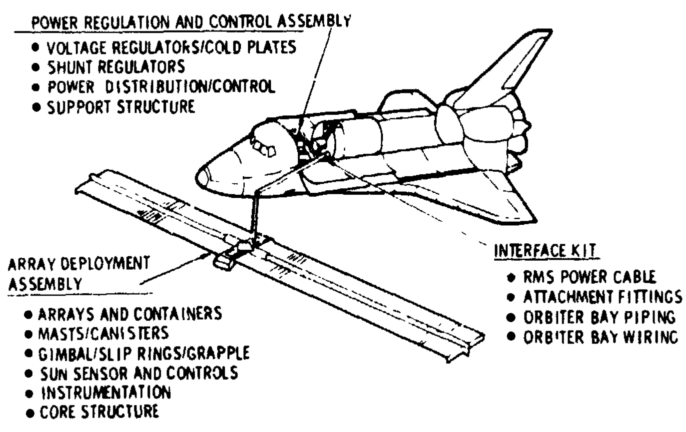
FOREWORD

The Power Extension Package (PEP) is a solar electrical power generating system to be used on the Shuttle Orbiter to augment its power capability and to conserve fuel cell cryogenic supplies, thereby increasing power available for payloads and allowing increased mission duration. The Orbiter, supplemented by PEP, can provide up to 15 kW continuous power to the payloads for missions of up to 48 days duration.

When required for a sortie mission, PEP is easily installed within the Orbiter cargo bay as a mission-dependent kit. When the operating orbit is reached, the PEP solar array package is deployed from the Orbiter by the remote manipulator system (RMS). The solar array is then extended and oriented toward the sun, which it tracks using an integral sun sensor/gimbal system. The power generated by the array is carried by cables on the RMS back into the cargo bay, where it is processed and distributed by PEP to the Orbiter load buses. After the mission is completed, the array is retracted and restowed within the Orbiter for earth return.

The figure below shows the PEP system, which consists of two major assemblies -- the Array Deployment Assembly (ADA) and the Power Regulation and Control Assembly (PRCA) -- plus the necessary interface kit. It is nominally installed at the forward end of the Orbiter bay above the Spacelab tunnel, but can be located anywhere within the cargo bay if necessary. The ADA, which is deployed, consists of two lightweight, foldable solar array wings with their containment boxes and deployment masts, two diode assembly interconnect boxes, a sun tracker/control/instrumentation assembly, a two-axis gimbal/slip ring assembly, and the RMS grapple fixture. All these items are mounted to a support structure that interfaces with the Orbiter. The PRCA, which remains in the Orbiter cargo bay, consists of six pulse-width-modulated voltage regulators mounted to three cold plates, three shunt regulators to protect the Orbiter buses from overvoltage, and a power distribution and control box, all mounted to a support beam that interfaces with the Orbiter.

PEP is compatible with all currently defined missions and payloads and imposes minimal weight and volume penalties on these missions. It can be installed and removed as needed at the launch site within the normal Orbiter turnaround cycle.



CONTENTS

Section 1
SCOPE

This document describes the effort required to implement the design, development and test tasks associated with the reference PEP configuration arrived at in the course of the Phase B study. The tasks and approaches described in this document served as the planning baseline for developing the schedule and cost estimates for achieving the requirements of the PEP project. The plan addresses all the areas of activity involved in proceeding from ATP through the acceptance test of the first set of PEP flight hardware. The activities have been defined to the depth necessary to establish the viability of the approach and identify those critical areas which will require concentrated attention during the Phase C/D contract. The ground-support activities have been defined for the prelaunch phase at KSC and described in Volume 8 of this report.

Appendix A to this document presents the topical outline and requirements for an in-depth design, development and test plan to be prepared as a part of the Phase C/D PEP program.

Section 2
SUMMARY

This plan defines a project based on the production of two PEP Flight Systems. It describes the tasks and establishes milestones to accomplish this development. Further, the plan provides for the development and assembly of new ground support equipment required for both testing and launch operations.

Figure 1 presents the baseline Master Schedule for the PEP reference configuration. It identifies major subassemblies, development tasks, performance periods, and major milestones. ATP has been assumed for October 1, 1980, based upon FY 1981 potential funding availability. The basic milestones have been established for the Preliminary Requirements Review (PRR) three months after ATP and the Preliminary Design Review (PDR) five months later. Critical Design Review (CDR) occurs in the seventeenth month with the first delivery of PEP flight hardware (i.e., set No. 1) in the twenty-eighth month following ATP. The qualification flight for PEP, establishing the Initial Operational Capability (IOC) occurs thirty months after ATP. The early PRR is predicated upon full application of the design, operational and interface requirements developed in this study. Figure 2 presents the PEP design, development, and test schedule which shows the relationship of the major technical efforts involved in producing qualified PEP hardware.

The PEP system is comprised of three major elements. These are the Array Deployment Assembly (ADA), Power Regulation and Control Assembly (PRCA) and Interface Kit. This plan addresses the three categories of hardware development activities involved in providing the PEP system. The PEP prime contractor will have responsibility for the development and production of the three major elements and the integration and system acceptance test of the deliverable configuration.

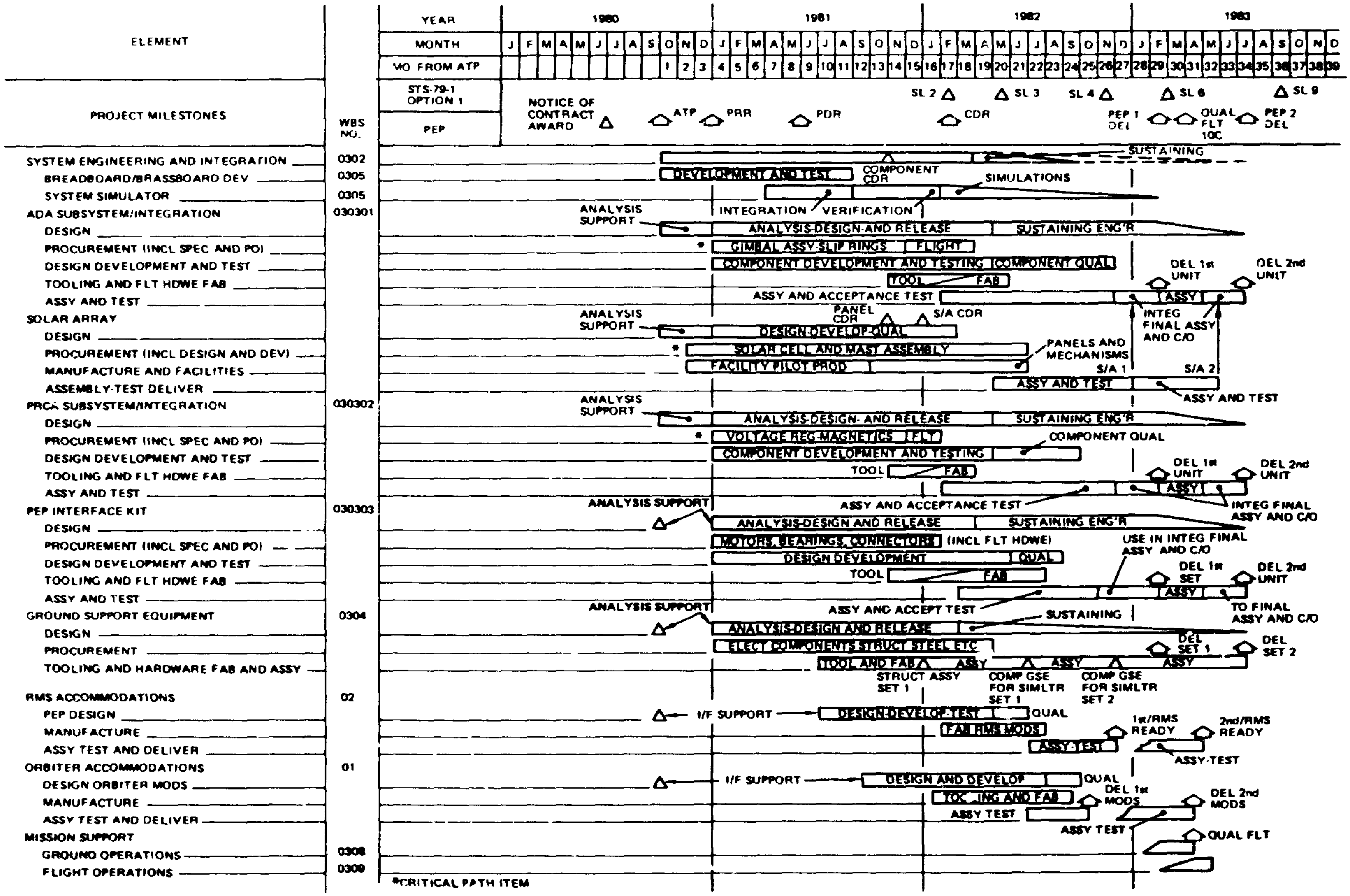


Figure 1. PEP Project Master Schedule

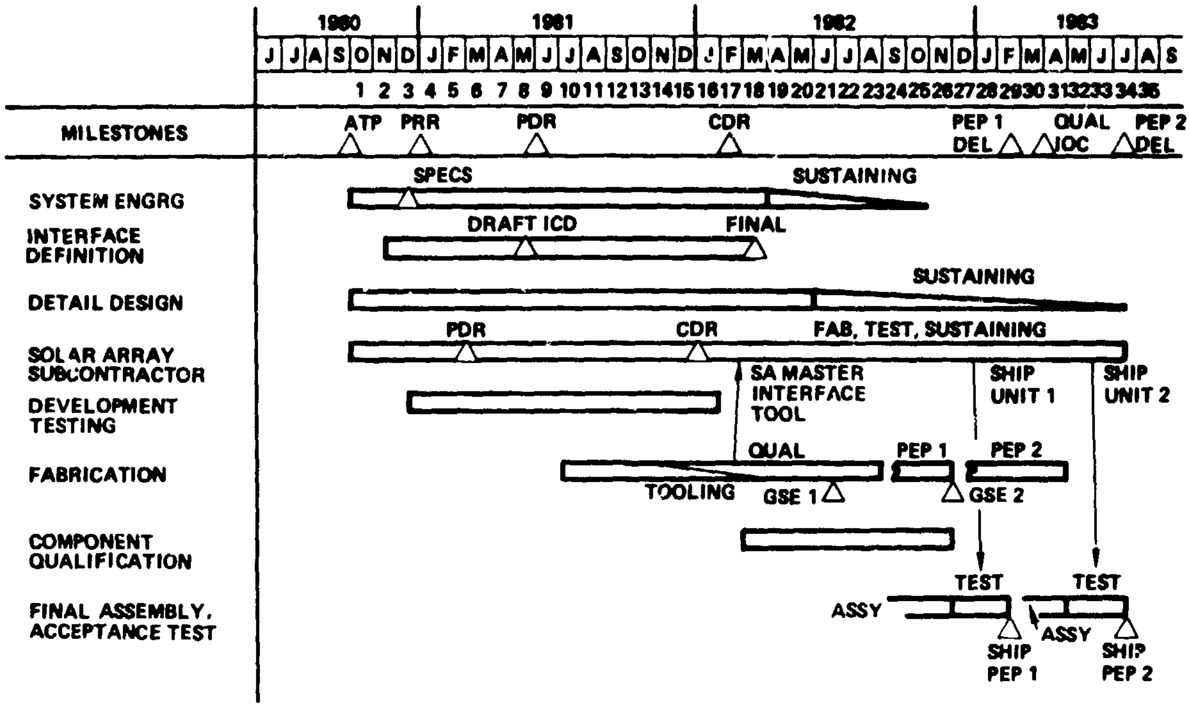


Figure 2. PEP Design, Development, and Test Schedule

The ADA will be assembled from both prime contractor manufactured parts and subcontractor supplied parts. The study reference configuration assumes that the prime contractor will provide the main support structure, selected mechanisms, and avionics equipment, while the solar array wings, coilable masts and two axis gimbal will be procured from major subcontractors.

On the ADA, only the support structure interfaces directly with the Orbiter. There are no electrical or thermal interfaces. The avionics and control interfaces occur through the grapple fitting Special-Purpose End Effector (SPEE) with the RMS. The solar array and two axis gimbal subcontractors will qualify their deliverable end items to a level consistent with a minimum risk, low cost development. The final qualification required of the ADA for first flight will be completed by the prime contractor. Of the ADA hardware elements, the solar array presents the principal critical path in the development/production schedule. For this reason, it is vital to establish the most efficient plan for designing, developing, testing and integrating the solar array into the overall PEP system.

The PRCA will be produced by the prime contractor from fabricated parts and vendor supplied components. The PRCA interfaces with the Orbiter in the cargo bay via (1) structural installation, (2) electrical power and data connections, and (3) fluid interface connections with the Orbiter thermal control subsystems. It interfaces with the RMS via electrical connectors near the shoulder. The functional connection between the ADA and PRCA is provided by a wire harness installed on the RMS between the shoulder and end effector.

The PEP impact on the RMS consists only of the installation of the aforementioned power cable. The prime contractor will supply the RMS subcontractor with qualified wire for the development of the power cable and with the electrical connector half interfacing with the PRCA connector half at the RMS shoulder. Modification to the Remote Manipulator System (RMS) must be closely coordinated with the RMS project. These modifications must be accomplished on a compatible development schedule to assure timely availability for installation in the Orbiter during the prelaunch ground operations phase.

The Orbiter accommodations required by PEP for the Design Reference Mission, utilizing the Spacelab and short tunnel, have been defined in detail by Rockwell International (RI) on the basis of a PEP/Orbiter interface study conducted jointly by MDAC and Rockwell. New Orbiter hardware includes (1) coolant interface panels and jumpers (port and starboard), (2) electrical interface panels (port and starboard), (3) payload bay attach provisions for electrical harnesses, plumbing, and PRCA bridge fittings (bearing pads) and (4) a SPEE switch for sharing RMS SPEE wiring with payloads. In addition, the Orbiter Power Distribution System and coolant loops are modified to accept PEP physical and functional interfaces. Software modifications are also required to support PEP flight operations.

The Interface Kit items required by the PEP project include:

- A. RMS power cable.
- B. Bridge fittings, custom (2).
- C. Payload retention latches, Orbiter (3).
- D. Reaction fitting, Y_o, custom.
- E. Cable assembly, Orbiter bay power.
- F. Disconnect, in-flight remote, receptacle.
- G. Cable assembly, Orbiter bay data bus.

The purpose of these items is to provide both physical and functional connections from the PEP system to the Orbiter subsystems.

The Phase B study has identified the requirements for 12 items of GSE to support the PEP operations. These items of GSE will be produced by the prime contractor. The noted items will be used at the prime contractor's facility during PEP system verification testing prior to being delivered with the flight hardware. The items of GSE are:

A. Array power simulator.*
B. Power bus load simulator.*
C. Mast/canister simulator.
D. Interface test unit.*
E. Orbiter cable simulator.*
F. Thermal conditioning unit (provided GFE).*
G. Freon leak detector.*
H. Strongback.*
I. Shipping container.
J. Test fixture.*
K. PGHM adapter.
L. Transportation kit.

*Used at contractor's facility prior to delivery with flight hardware.

Section 3
DESIGN

This section provides a summary of the reference design derived in the study phase and identifies the design tasks which will be accomplished in Phase C/D to transform this configuration into the final design.

3.1 SYSTEM DEFINITION

The Power Extension Package (PEP) is a solar array power system used to augment the Orbiter's fuel cell/cryogenic power system and extend the Orbiter's mission duration capability. When illuminated by the sun, PEP provides most of the electrical power for use by the Orbiter and its payloads. During the dark side of the orbit, the solar array is dormant and the Orbiter fuel cells supply the full power.

The PEP consists of: (1) solar array and supporting equipment, identified as the Array Deployment Assembly (ADA), which is deployed by the Remote Manipulator System and (2) power conditioning and control equipment which remains in the Orbiter cargo bay during the mission, identified as the Power Regulation and Control Assembly (PRCA). The PEP solar array power system has two arrays comprised of photovoltaic solar cells mounted on blankets of a lightweight, flexible substrate which are deployed by two coilable masts. When not operational, the arrays are retracted and folded into compact array storage boxes. The entire assembly is stowed in the Orbiter cargo bay during launch and descent, as shown in Figure 3. Figure 4 displays a typical sequence for on-orbit deployment of the array assembly using the Orbiter's Remote Manipulator System (RMS). As noted in step 4, the masts are used to deploy the two arrays. The assembly remains attached to the RMS during orbital operation. Electrical power is generated by orienting the array normal to the solar vector using an independent PEP control system. It is transmitted by power cables to the PRCA which remains in the cargo bay during the mission and conditions, controls,

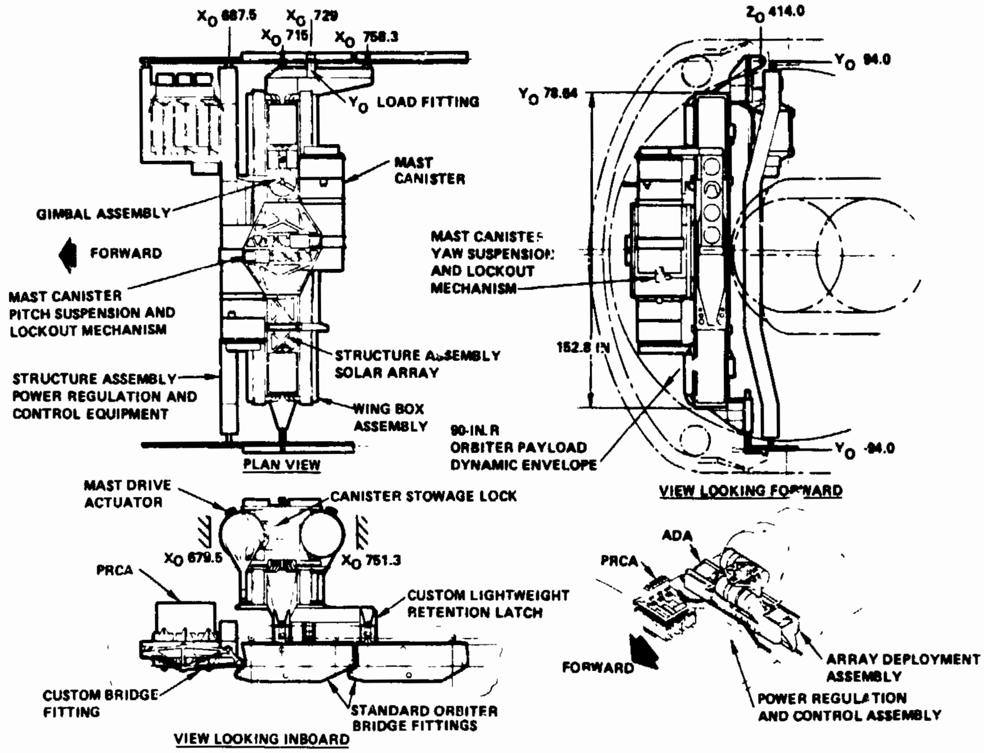


Figure 3. PEP Reference Configuration Installation

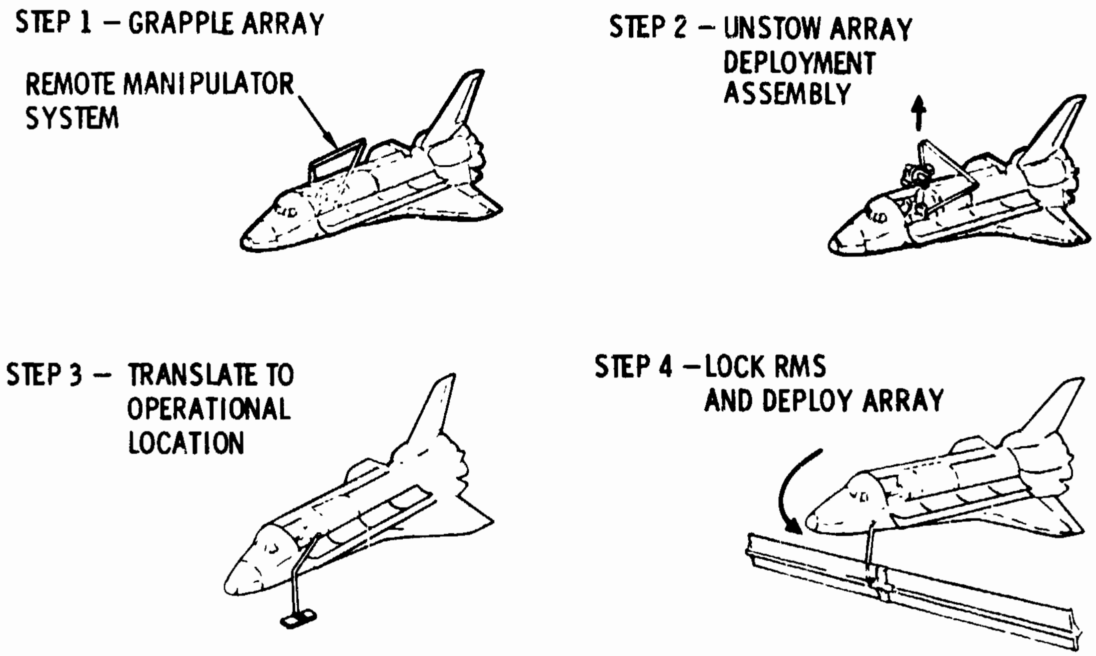


Figure 4. Deployment Sequence

and interconnects the PEP with the Orbiter's main buses. The resulting power is usable by both the Orbiter and its payloads. To stow the ADA for return to earth, the solar array is retracted and the RMS is activated. The RMS flight crew operator then guides the ADA into the stowage position in the Orbiter bay.

The PEP system is comprised of four functional areas:

A. Electrical Power Subsystem. Generates electrical power and conditions, controls and distributes that power to the Orbiter buses for use by the Orbiter and its payloads (reference Table 1). Major elements include:

- Solar array wings (2).
- Diode assemblies (2).
- Voltage regulators (6).
- Power distribution box (1).
- Shunt regulators (3).
- Cable assemblies.

B. Structural/Mechanical Subsystem. Provides support for other PEP subsystems and transfers ground and flight loads to the Orbiter structural interface. In addition, it performs the functions of array deployment, retraction, latching, suspension, tensioning and gimbaling. Major elements include:

- Structural assembly, solar array support (1).
- Structural assembly, PRCA support (1).
- Mast/canister assemblies (2).
- Mast/canister suspension and lockout assemblies (2).
- Gimbal assembly (1).
- Payload retension latches (3).
- Custom bridge fittings (2).
- Wing boxes and covers (2).
- Compliance mechanisms (2).

C. Avionics and Control Subsystem. Performs electronic equipment activation, initialization, position and rate control of deployed elements, and monitoring of equipment status as well as providing crew interfaces for PEP command and status display. Major elements include:

- Array pointing and control assembly.
- Sun sensor.
- MDM/data bus coupler.

D. Thermal Control Subsystem. Maintains PEP equipment within temperature limits using active and passive means. Major elements include:

- Cold plates.
- Freon lines, quick disconnects, and jumpers.

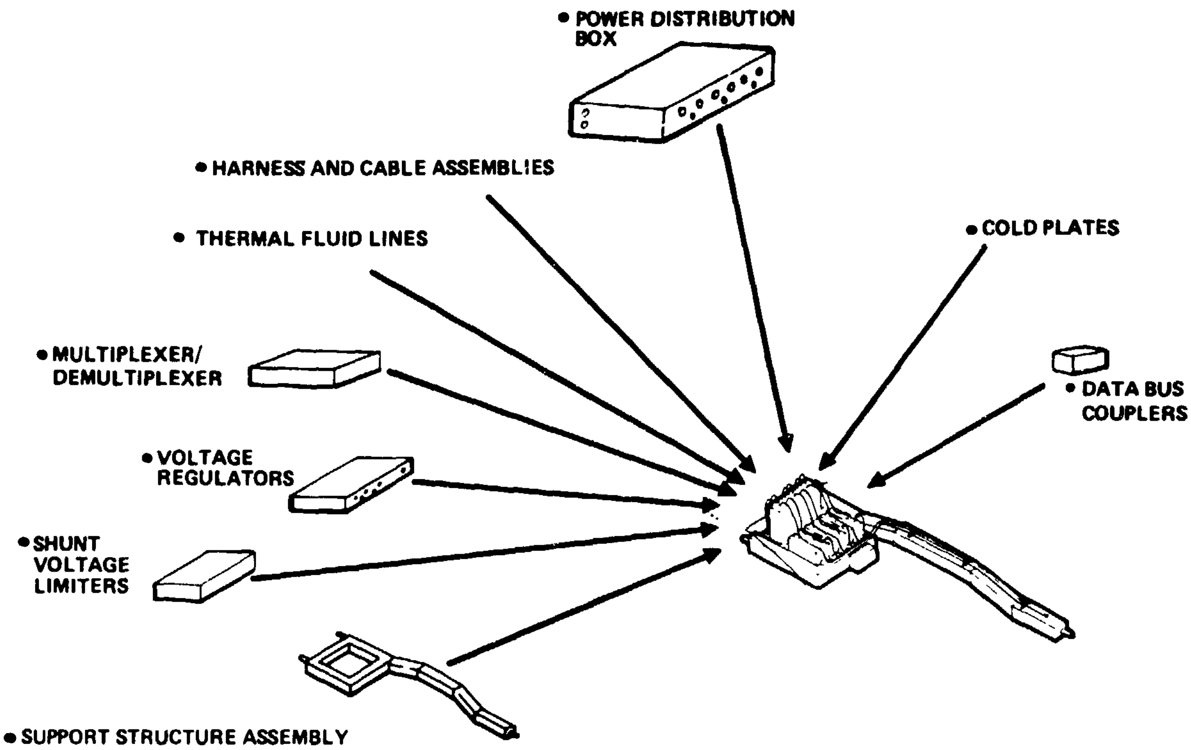
3.2 INITIAL ACTIVITIES

The reference design arrived at during the Phase B study will serve as the point of departure for the Phase C/D design effort. This design is fully described in Volume 2, PEP Preliminary Design Definition, and is represented herein in Table 1 and Figures 5, 6, and 7.

The design function, as described in this plan, consists of establishing detail requirements, performing the necessary designs and analyses to implement those requirements and analyze the resulting design to ensure that the functional

Table 1. PEP Baseline Characteristics

Power and duration	21 kW, 20 days at 55-deg inclination 29 kW, 17 days at 55-deg inclination 29 kW, 48 days at 97-deg inclination
Array size	2 sep-type wings, 3.84m X 3[illegible] 8m each
Stowage location	Over spacelab short or long tunnel Aft location optional
Stowage configuration	Integral wingbox; rotating canister; Trunnion/latch attachment
Deployment	Remote manipulator system (RMS)
Array rotation	Separate gimbal/torquer drive using sun sensor control RMS inactive
Weight	PEP, 2,266 lb; Orbiter attach fittings, 85 lb
Heat rejection	Uses Orbiter radiators Flash evaporator supplement - some orientations
Output voltage	32.6V ± 0.1 vdc during PEP operation 27 - 32 vdc during fuel cell-only operation



Fiqure 5. Power Regulation and Control Assembly

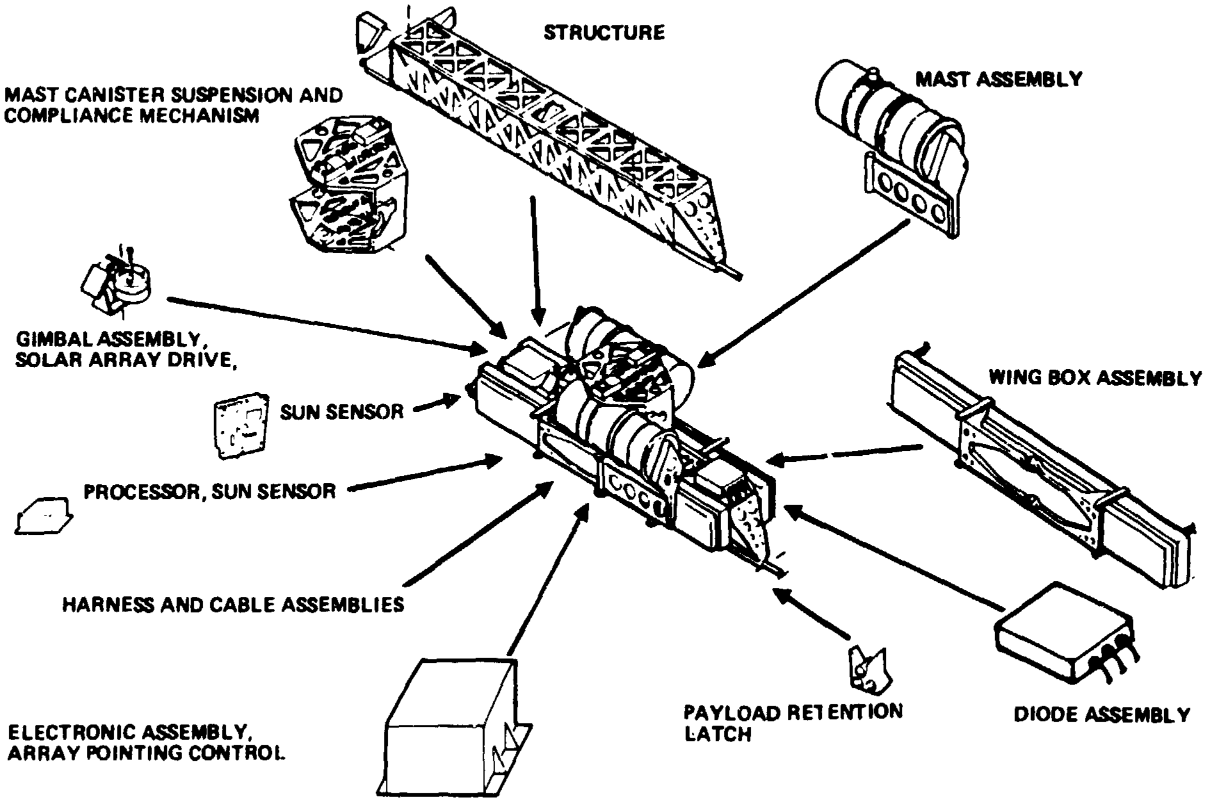


Figure 6. Array Deployment Assembly

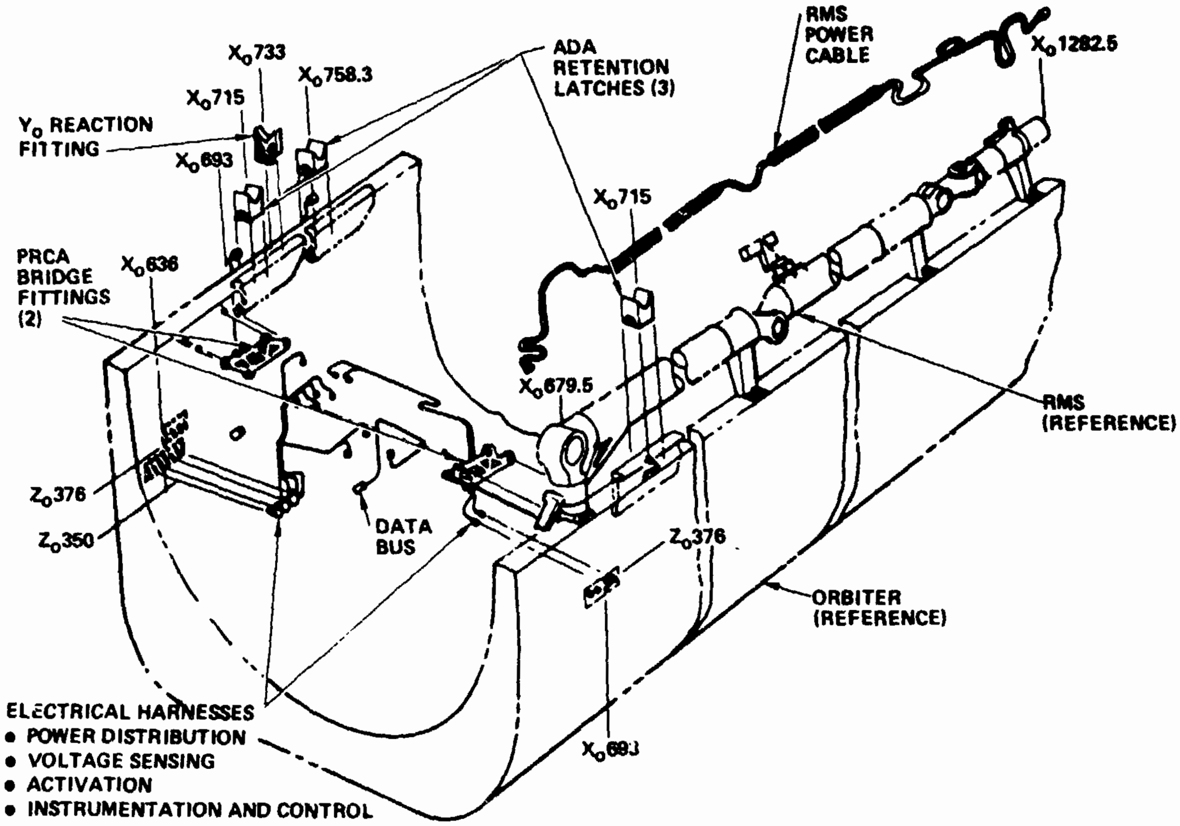


Figure 7. PEP Interface Kit

requirements have been met. This design function will be the responsibility of the prime contractor.

Due to the specialized nature of certain technology involved in the PEP system, the prime contractor will subcontract portions of the design effort as well as the production and test of those elements of the PEP system. It is presently foreseen that those elements to be procured through subcontract include (1) the solar array wings/masts and (2) the ADA gimbal assembly.

The design activity of the subcontractors will be subject to the approval of the prime contractor and will be subject to a series of formal reviews which must be completed prior to proceeding to the next phase of the activity.

Initial design efforts will involve the refinement and coordination of specifications and plans. The principal activities to be addressed in the period between ATP and PRR include:

A. Specifications

- System Specification.
- Solar Array Wing Specification.
- Ground Support Equipment Specifications.
- Voltage Regulator Specification.

B. Plans

- Update Management Plan.
- Update Design, Development and Test Plan.
- Update Product Assurance Plan.
- Prepare Manufacturing Plan.

C. Other Activities

- Incorporate SRT results.
- Initiate procurement of long-lead items.
- System Engineering to refine design definition.
- Continued mission/system analysis in support of specifications development.
- Prepare for early design and procurement activities in long-lead time areas (e.g., solar array).

Emphasis will be placed on early resolution of critical design areas identified in the study phase. This will involve refinement of design support analyses and trade studies, and the definition of design support testing and breadboard activities. Additionally, the results of the JSC RTOP activities will be incorporated into the design baseline.

Three months after ATP there will be a Preliminary Requirements Review (PRR) with NASA/JSC to review and approve the PEP requirements to be used in flight hardware design. The initial design effort following PRR will result in a baseline selection of components and materials, a preliminary detail design and final design and procurement specifications. The preliminary design documentation will include detail plans for manufacturing and testing of the hardware. This initial design activity will culminate in a PEP Systems Preliminary Design Review with NASA/JSC at eight months after ATP, where the final requirements and final design configuration will be established. Prior to the system PDR with NASA, the prime contractor will hold a preliminary design review with the solar array and gimbal assembly subcontractors to finalize those design approaches. The results of these PDR's will serve as inputs to the system PDR with NASA.

3.3 DETAIL DESIGN

Following the Preliminary Design Review and approval of the results, detail design of the PEP hardware will be completed. This design effort will consist of generating fabrication drawings and the analysis necessary to validate the design approach. Figure 8 presents a top level PEP drawing tree; this tree will be expanded early in initial design to assist in scheduling the engineering activity. This detail design activity will be accomplished by the prime contractor and by the solar array and gimbal assembly subcontractors. Prior to release of the fabrication drawings, a Critical Design Review will be held with NASA/JSC. This review will be a prerequisite to release of fabrication drawings and will consist of a comparison of design requirements to design and a review of the analysis and data supporting the adequacy of this design.

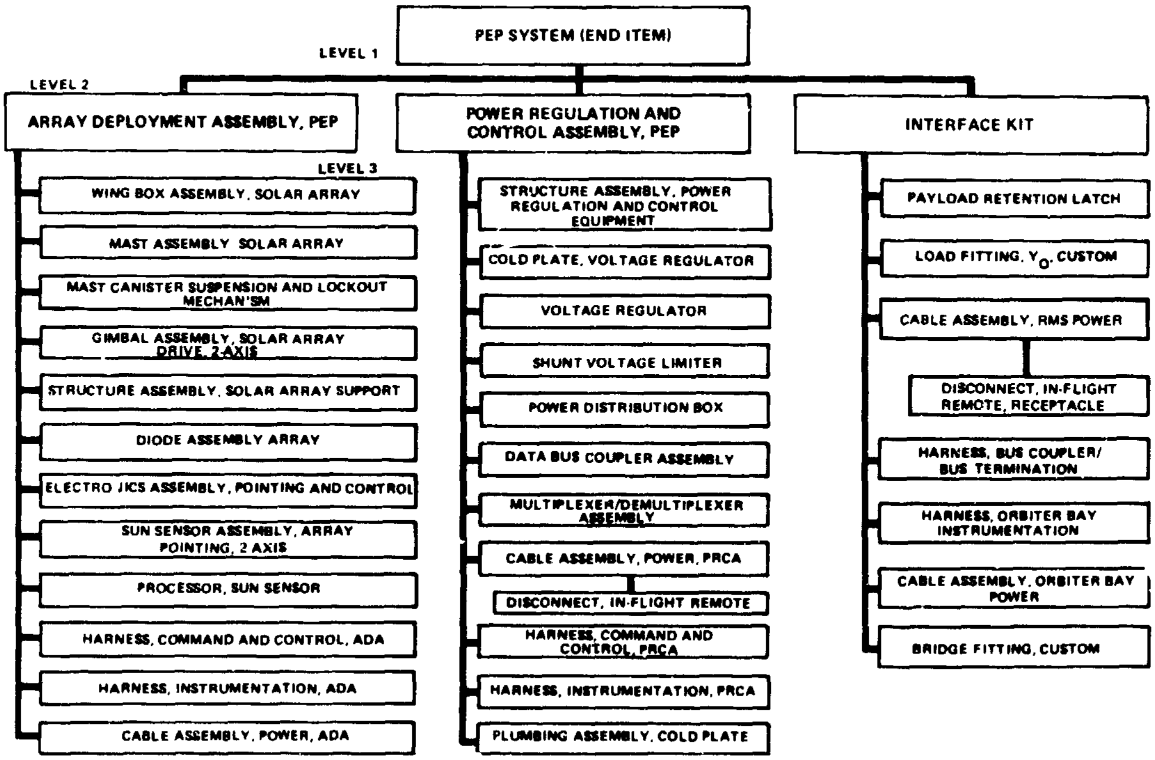


Figure 8. PEP Drawing Tree

Major supporting analyses to be accomplished include:

A. Power Subsystem

- Solar array performance mapping and degradation prediction.
- Voltage regulator/fuel cell performance mapping - including effects of fuel cell purge and heater operation.
- PEP/Orbiter safety analysis for anomalous conditions.
- PEP electrical system operating procedures development.

B. Avionics and Control

- Determination of PEP data bus characteristics and the analysis of crosstalk and impedance matching problems using slip rings.
- Microprocessor program design and sizing analysis.
- Instrumentation and signal conditioning requirements accommodation.
- Power distribution and sequencing of ADA equipment operation.
- Flight crew operation and interface with the PEP system via MCDS.
- Impact of Orbiter and ground EMI environment on PEP equipment design and operation.
- PEP electronics equipment failure analysis and examination.
- DAP/RMS/PEP dynamic interactions during PEP deployment (loads, deflections).
- DAP/RMS/PEP dynamic interactions while deployed (loads, deflections).
- PEP solar array pointing system design and analysis.
- PEP solar array pointing system processor software generation, verification and validation.
- Design and analysis of operating procedures for PEP deployment and operation.
- Failure and failure effects analysis.

C. Structural/Mechanical

- ADA and PRCA support structure dynamic analysis and modal survey test correlation.
- ADA and PRCA support structure strength analysis.
- PEP system weight and mass properties analysis.
- Gimbal system servo analysis.

- Array wing suspension analysis and mast strength determination.
- Mechanical subsystem failure modes and effects analysis.

D. Thermal Control

- Refine Orbiter/PEP thermal performance.
- Detailed Orbiter interface analyses - thermal expansion, pressure, and pressure drop.
- Detailed transient analyses of regulator/cold plate.
- Detailed cold plate/regulator thermal analysis; need for thermal grease and temperatures of regulators.

These detail hardware design activities will be supported by the following system level analyses which will provide substantial inputs to the design:

- Crew interface.
- System safety.
- Reliability.
- Ground and flight operations.
- Parts, materials, and processes.

3.3.1 Crew Interfaces

The crew operational interface requirements will be evaluated for both shirt-sleeve and EVA tasks during the initial period preceding the PRR. These requirements will be coordinated with the JSC Flight Operations Directorate and, upon final approval, applied to the final hardware design. Review and approval of the hardware applications will be coordinated during the design phase and reviewed for approval at the PDR and CDR.

3.3.2 System Safety

The prime contractor will perform the necessary analysis to define the tasks to be accomplished and design features to be employed in the development, production, and launch of PEP in the Orbiter environment. The safety efforts will be directed toward identifying potential hazards early in the development process and resolving them through incorporation of safety design features which will prevent hazards to personnel and equipment. System Safety would (1) provide a system safety checklist, and (2) perform safety analysis.

3.3.3 Design Reliability

During development, Reliability will (1) perform failure mode and effects analysis, (2) assess subsystem reliability, and (3) verify that designs meet reliability requirements.

3.3.4 Ground and Flight Operations

In conjunction with the development of the Ground Operations Plan and the Flight Operations Plan, the related design requirements will be defined. These will be coordinated with NASA/KSC to assure compatibility of the flight hardware with all KSC prelaunch activities and with JSC for Orbital operations. Appropriate reviews and approvals will occur during the design phase at PRR, PDR, and CDR.

3.3.5 Parts, Materials, and Processes

A parts, materials and process control and standardization program (PMPCSP) will be established for PEP. Experienced engineering specialists from each discipline will team with Reliability, Quality Assurance, and Procurement to provide a cost-effective PMPCSP for PEP during development. The PMPCSP will encompass approved parts, materials, and process selection lists; control of parts, materials and processes at subcontractors and suppliers; minimize use of nonstandard parts, materials, and processes; use of electronics parts with established reliability specifications; and part screens, failure analysis, and testing. During PEP development specialists will (1) prepare the parts, materials, and processes selection list; (2) establish a Parts, Materials and Processes Control Board; (3) provide specifications and standards for parts, materials, processes and components; (4) prepare a finish document for corrosion protection controls; and (5) perform destructive physical analysis on parts.

3.4 CONFIGURATION CONTROL

Configuration control of the PEP system requirements and system design definition documents will be per the PEP Configuration Management Plan.

The system specifications for PEP flight hardware and ground support equipment, as approved during PDR, will form the requirements baseline for the PEP program. Any changes subsequent to PDR will be per provisions of the NASA approved configuration management plan.

Similarly, the design as approved at CDR will form the design baseline for the PEP program and any changes will be controlled per the requirements of the Configuration Management Plan.

Section 4
DEVELOPMENT

The design of the physical and functional characteristics of the PEP system will be supported by development activities at the prime contractor, subcontractors, RMS contractor and the Orbiter contractor.

4.1 PRIME CONTRACTOR

The prime contractor will provide early verification of system operation and compatibility through utilization of an integration/verification simulator. This simulator will consist of representations of PEP flight hardware, together with simulators of Orbiter systems and the solar array wing assemblies. The development of this simulator will follow an evolutionary process.

Initial electrical/electronic component circuit design will be supported through utilization of breadboard models of the components in the circuit study laboratory. These breadboards will utilize the normal technique of assembling the various circuit elements into a functional representation of the component being designed. The breadboard components will be varied to establish design sensitivities and to optimize the component design.

When the individual component designs have been finalized, a brassboard model of the component will be fabricated. The brassboard model will consist of the breadboard model repackaged so that it is a portable unit capable of being interconnected with other elements of the PEP system. Where possible, the brassboard model will utilize flight standard detail components.

The integration/verification simulator will be initially made up of these "brassboard" representations of the flight hardware. As actual flight configuration components become available through qualification test unit refurbishment or flight spares, the simulator will be upgraded to flight hardware quality at the component level. No effort will be made to simulate physical arrangement or mounting provisions.

The simulator will initially utilize STE or laboratory equipment in place of the GSE. As the GSE becomes available, it will be phased into the simulator replacing the STE.

This simulator will be utilized to verify system design, establish a data base for predicting the overall span of system performance, verifying the validity of mission models, and finally to provide support to flight operations during the first flight which will combine IOC operations and flight qualification. The simulator would be available for subsequent support of the operational flight program under a support contract.

In addition to utilizing the verification/integration simulator, the prime contractor will, in conjunction with NASA/JSC, utilize the EPDC simulator at JSC to simulate PEP power subsystem operation in conjunction with Orbiter systems.

The prime contractor will also support PEP-ADA deployment array pointing and control simulations utilizing the Shuttle Avionics Integration Laboratory (SAIL). Examples are as follows:

- Simulation of PEP/crew interface assuring PEP operability with single and dual crewman participation.
- Detailed solar array pointing system simulation (including structural dynamics and disturbances).
- Detailed deployment dynamic simulation for PEP.
- Detailed dynamic simulation for deployed PEP including Orbiter DAP, RMS dynamics, PEP dynamics and solar array pointing system.
- PEP processor software verification and validation tool (simulation with PEP processor in the loop or emulation of the PEP processor in the loop).

In addition to the integration/verification simulator, physical development fixtures will be required. These fixtures will be physical representations of the ADA and the PRCA. The development fixtures will be utilized in support of configuration design activities to develop precise component location selection and investigate possible areas of interference. They will also be used to develop proper routing and support provisions for cable harnesses and coolant plumbing installations.

4.2 SUBCONTRACTOR

The PEP development efforts of the solar array and gimbal assembly subcontractor will be extensions of development activities already initiated under separate NASA contracts. The development activity to be accomplished after ATP will be negotiated based on the subcontractor's proposals.

4.3 RMS CONTRACTOR

The RMS contractor will develop the physical installation of the PEP power cable installation on the RMS.

The physical and functional interface between the PEP power cable and the ADA and PRCA will be defined in an ICD to be coordinated between the prime contractor and the RMS contractor. The RMS contractor will develop the routing and attaching provisions for the power cable between these interfaces.

4.4 ORBITER CONTRACTOR

The Orbiter contractor will develop the harness and plumbing modifications required to accommodate the PEP system in the Orbiter. Physical and functional interfaces will be coordinated between the prime contractor and the Orbiter contractor and documented in an ICD.

Section 5
TEST PROGRAM

The purpose of the PEP test program will be to prove that the PEP components and systems, as designed and built, satisfy the program requirements. Since final system activation in an operational environment can only be accomplished in orbit, the first flight will serve to finally qualify the system and demonstrate IOC. The ground test program must be structured to provide maximum confidence that all elements affecting system performance have been identified and considered.

The PEP system will consist of elements procured from subcontractors, purchased parts, and components fabricated by the prime contractor. All development, qualification and acceptance tests of subcontracted components will be the responsibility of the subcontractor. The test plans, procedures, and test reports will require the approval of the prime contractor. The prime contractor will perform the development, qualification and acceptance tests of those items purchased or designed and fabricated by him, and additionally will perform all system tests of the completely assembled PEP.

Each functional component will be acceptance tested prior to installation into the PEP system. Acceptance testing of the solar array wing assembly and the gimbal assembly will be conducted by the subcontractors prior to delivery to the prime contractor.

5.1 DEVELOPMENT AND QUALIFICATION PHASE

The test program being planned for PEP will be similar to the Design Evaluation and Qualification test program used effectively on manned spaceflight programs.

The D/Q approach to testing will qualify a component/equipment during a development test if the test specimen is sufficiently representative of the flight article and is subjected to test levels meeting qualification test requirements without failure. D/Q testing, together with evaluation and qualification of components/equipment by analyses and similarity comparisons to previously qualified hardware, provides the opportunity to develop PEP at the least possible cost while taking minimum technical risks.

Table 2 shows the preliminary test requirements generated for the Development/ Qualification program. This figure shows the requirements to be satisfied at each level of system assembly.

5.2 SYSTEM ACCEPTANCE TEST

The system acceptance test will be conducted by the prime contractor after integration of the PEP components into the PEP system. A block diagram of the system acceptance test configuration is shown in Figure 9. The tests to be accomplished in this configuration are as follows:

- Continuity and insulation resistance.
- Operational sequence.
- On-line power performance.
  - Verify operational start-up sequence.
  - Verify shutdown sequence.
  - On-line power performance.
  - Verify voltage regulator peak power tracking and current limiting.
  - Day/night transition.
  - Voltage regulator set point adjustments.
  - Cold plate performance.
  - Shunt regulator operation.
  - Dark IV test.
- Verify ADA sequence and operation.
- Partial array deployment.

The schedule for accomplishing this integration and test activity is shown in Figure 10.

Table 2. PEP Test Project Plan (Page 1 of 2)

Level (1 2 3 4)	Nomenclature	Development										
		Test requiremen										
		Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load
1	PEP System											
2	Array deployment assembly, PEP											
3	Wing box assembly, solar array – qual test unit to be refurbished for flight use											
4	Instrumentation assembly, array monitor*											
4	Blanket assembly, solar array* development – partial blanket (with live cells)							X	X			
4	Harness, wing box instrumentation*											
4	Tension mechanism, blanket*									X		
4	Linkage assembly, mast interface*											
4	Latch assembly, cover*									X		
4	Wing box structure assembly*											
4	Box cover assembly*											
4	Cable assembly, wing box power*											
3	Diode assembly		X	X								
3	Sun sensor, array pointing, 2-axis											
3	Processor, sun sensor											
3	Electronics assembly, array pointing control		X	X								
3	Mast assembly, solar array		X	X	X	X				X		
4	Canister, mast											
4	Actuator, mast drive											
4	Linkage, array interface											
4	Mast, extendable											
3	Harness, instrumentation, ADA											
3	Harness, command and control, ADA											
3	Structure assembly, solar array support											
4	Beam, assembly, array support											
4	Trunnion, array support											
3	Cable assembly, power, ADA											
3	Gimbal assembly, solar array drive, 2-axis											
4	Slip ring – brush assembly, power and signal transfer		X	X	X		X	X	X			
4	Drive actuator assembly, Alpha axis											
4	Drive actuator assembly, Beta axis											
4	Angle encoder, Alpha axis											
4	Angle encoder, Beta axis											
4	Grapple fixture, standard RMS											
4	View mirror											

*Qualification of these items in next assembly (wing box assembly).

lopment										Qualification																
quirements										Test requirements																
Humidity	Static load	Trunnion friction	EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load	Trunnion friction	EMI	Performance	Life cycle	Ultimate	Acoustics
										X			X	X		X	X		X	X			X			X
								X	X																	
					X																					
					X																					
					X																					
			X	X							X	X	X			X	X		X			X	X			
											X	X	X			X			X			X	X			X
											X	X	X			X			X			X	X			X
			X	X							X	X	X			X			X			X	X			X
					X		X	X								X				X						X
											X	X	X	X	X	X	X							X		
																							X			
																							X			
										X								X		X	X				X	
		X																								
																							X			
											X	X	X	X	X	X	X		X			X	X	X		
			X	X							X	X		X		X	X		X				X	X		

2

FOLDOUT FRAME

Table 2. PEP Test Project Plan (Page 2 of 2)

Level 1 2 3 4 / Nomenclature	Development										
	Test requireme										
	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac enviro.	Vibration	Shock	Fatigue	Humidity	Static load
Pivot assembly, gimbal structure											
Umbilical assembly, power transfer											
Mast canister suspension and lockout mech., [illegible]lar array											
Pivot assembly, canister											
Latch assembly, canister											
Power regulation and control assembly, PEP											
Cold plate, voltage regulator											
Voltage regulator		X	X								
Support bracket, voltage regulator											
Power distribution box		X	X								
Data bus coupler assembly											
Multiplexer/demultiplexer assembly (1 module only)		X	X								
Cable assembly, power, PRCA											
Disconnect, inflight remote, plug											
Harness, instrumentation, PRCA											
Harness, command and control, PRCA											
Plumbing assembly, cold plate											
Support structure assembly, power regulation equip.											
Trunnion, PRCA support											
Beam assembly, power reg support											
Shunt regulator		X	X								
Cooling fluid, power regulation cold plate											
Interface kit											
Bridge fitting, custom											
Payload retention latch, custom lightweight											
Drive actuator assembly											
Load fitting, Y_O, custom											
Cable assembly, RMS power											
Disconnect, inflight remote, receptacle											
Cable assembly, Orbiter bay power											
Harness, Orbiter bay data bus											

FOLDOUT FRAME

opment										Qualification																
uirements										Test requirements																
Humidity	Static load	Trunnion friction	EMI	Performance	Life cycle	Ultimate	Other	Acoustics	Zero-G	Modal survey	Thermal high	Thermal low	Thermal vac	Thermal cycle	Vac environ	Vibration	Shock	Fatigue	Humidity	Static load	Trunnion friction	EMI	Performance	Life cycle	Ultimate	Acoustics
											X	X	X	X	X	X	X		X			X	X	X		
			X	X							X	X	X			X	X		X			X	X			
																				X					X	
			X	X							X	X	X			X	X		X			X	X			
			X	X							X	X	X	X	X	X	X		X							X
																							X			
											X	X		X		X	X		X				X			
																							X			
																							X			
										X								X		X	X				X	
		X																								
			X	X							X	X	X	X		X	X		X			X	X			
																				X					X	
											X	X	X	X	X	X	X		X			X	X	X		
																				X					X	
																							X			
											X	X		X		X	X		X				X			
																							X			
																							X			

2 FOLDOUT FRAME

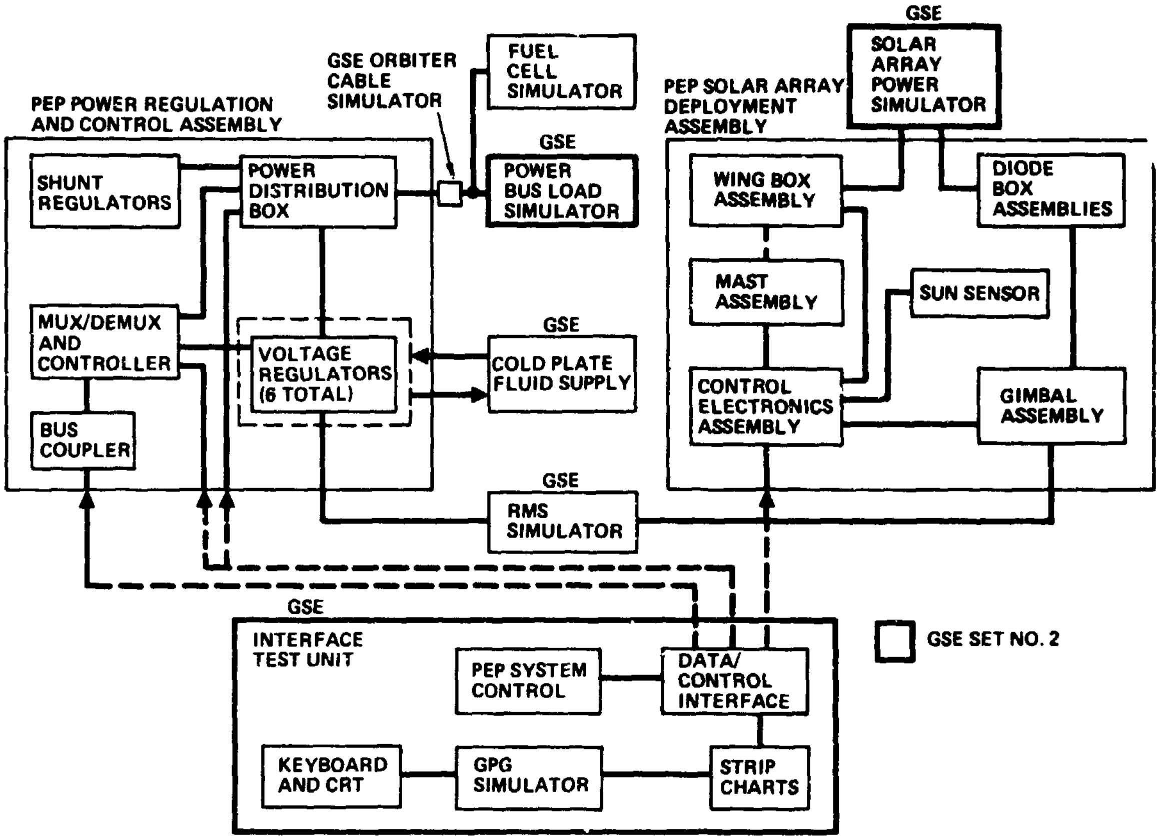


Figure 9. PEP System Acceptance Test

As can be seen from the schedule, a major portion of the system test is accomplished prior to solar array wing assembly installation. The testing necessary to be accomplished after solar array installation is that necessary to validate the installation operation; the verification of those actuation operations that could be affected by the wing assembly mounting provisions; and a test of dark I-V characteristics. This test approach will provide maximum assurance of hardware integrity with minimum facility cost and exposure of delicate hardware to 1 g operation.

5.3 GSE UTILIZATION

The MDAC approach to development and acceptance test utilizes selected models of GSE in support of flight hardware development and acceptance testing. This usage of GSE saves program cost through elimination of extra GSE units and also demonstrates compatibility of the GSE and flight hardware before it is exposed to operational usage. The planned utilization of the GSE in the verification/ integration simulator and in support of acceptance test and flight operations is shown in Figure 11.

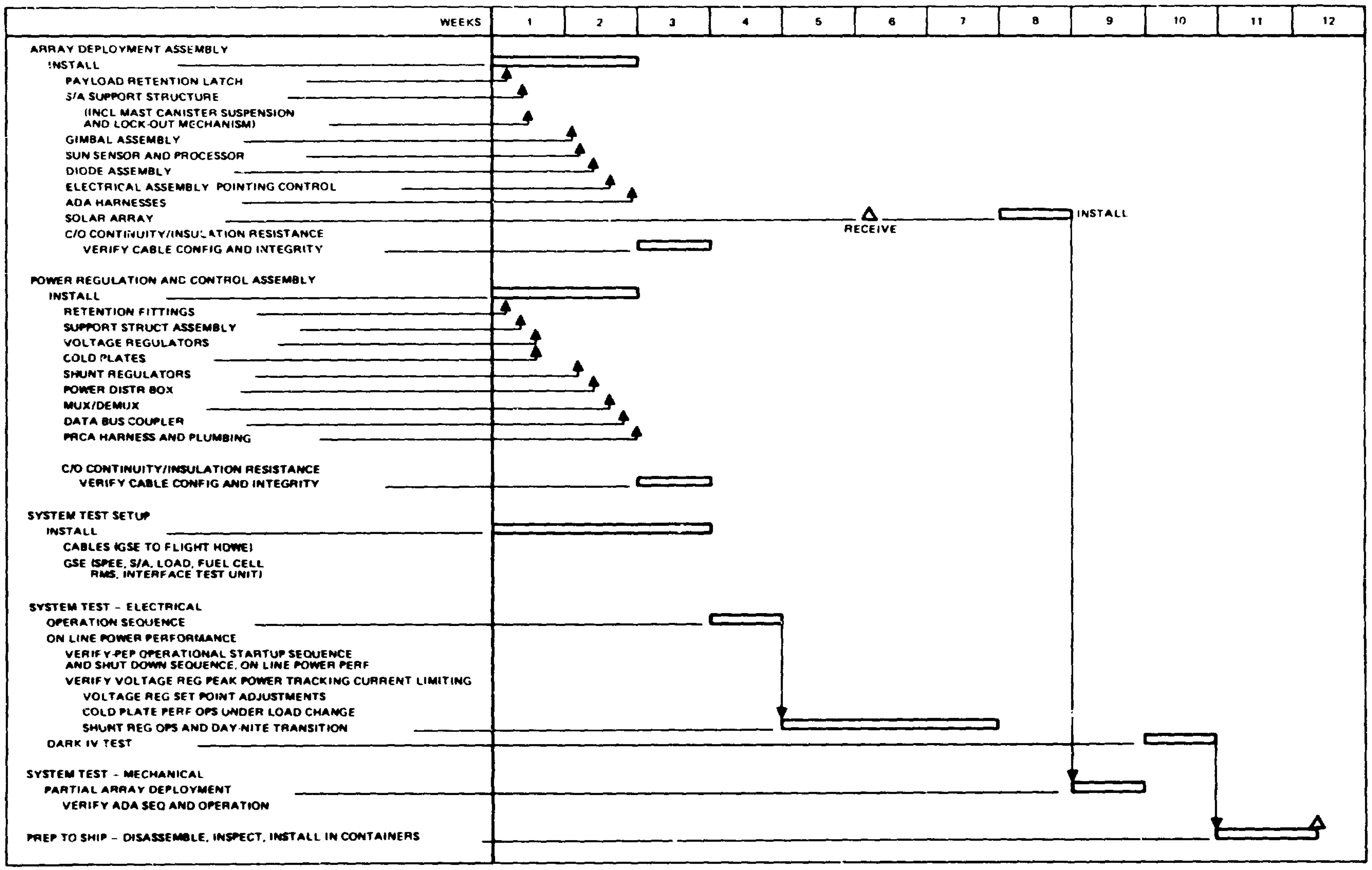


Figure 10. PEP System Integration and Test

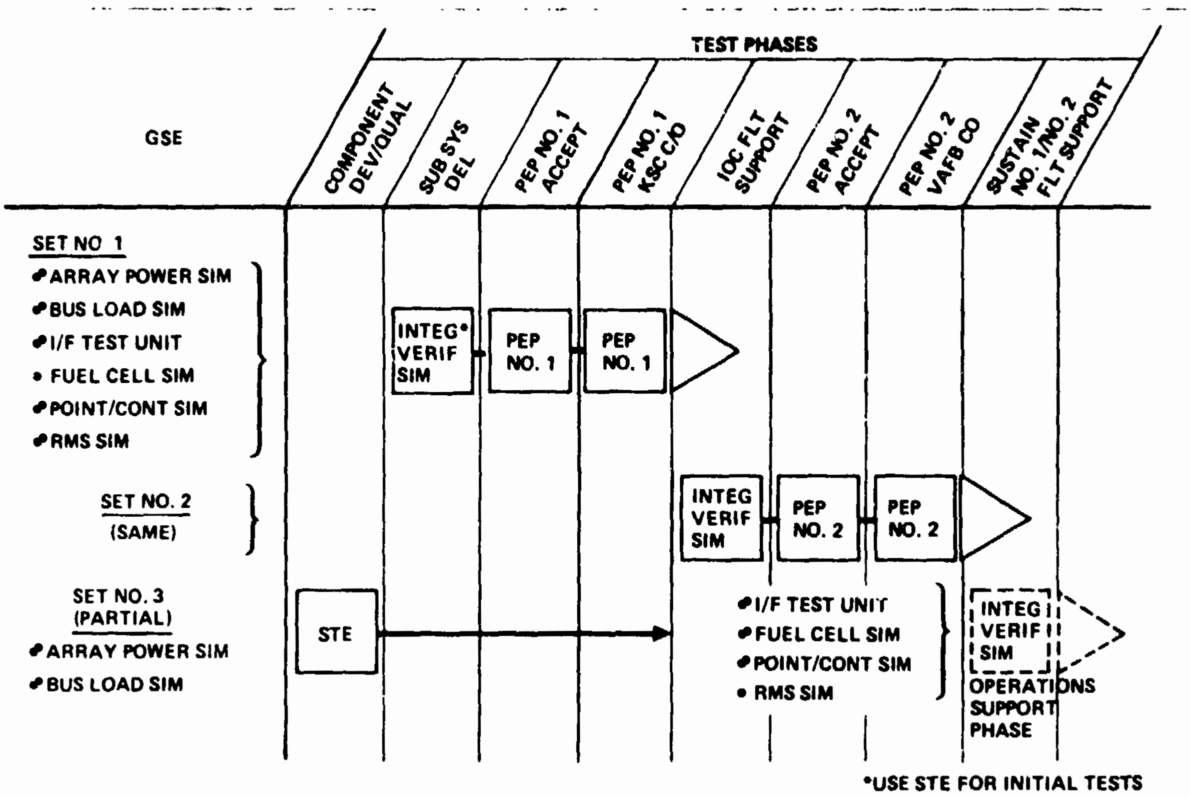


Figure 11. PEP Electrical GSE Flow, Multiple Utilization

Section 6
VERIFICATION

The Verification program to be accomplished within the PEP project will be structured so as to provide visibility as to the extent program technical requirements have been met.

The prime contractor will extract from all specifications those technical requirements for which objective evidence of satisfaction is required. For each requirement a determination will be made as to the method by which satisfaction of that requirement will be achieved; i.e., analysis, test, review of design, etc.

This document will be presented as part of the data package for PDR. During PDR, agreement will be reached between the prime contractor/NASA-JSC as to (1) proper requirement selection for verification and (2) proper of verification. This agreed-upon document will serve as the basis for the prime contractor verification program.

Closeout of the document will require review of the listed evidence/activity as it is available or occurs, and formal validation that the evidence or activity does prove that the requirement has been met. Satisfactory closure of a line item will require agreement between the prime contractor and NASA-JSC. Closeout activities will be an on-going activity in parallel with other program activities.

The status of the verification document will be reviewed during CDR. Closeout of all items will be a requirement for delivery of the hardware to NASA.

Section 7
MANUFACTURING PLAN

The study has resulted in a planned approach to procuring, manufacturing and assemblying the hardware elements that will make up the PEP. The study has identified those elements which, due to their specialized technology, should be procured from other agencies, and those that due to their criticality to system operation, must be fabricated and assembled by the prime contractor.

The following paragraphs summarize the approach to procuring, fabricating and assemblying the four major elements of the PEP system.

A. Array deployment assembly.

B. Power regulation and control assembly.

C. Interface kit.

D. RMS installations.

7.1 ARRAY DEPLOYMENT ASSEMBLY

Table 3 below lists the assemblies that make up the Array Deployment Assembly and indicates a tentative decision as to whether these elements will be fabricated by the prime contractor or procured from a subcontractor.

The final assembly of the Array Deployment Assembly will be accomplished at the prime contractor's facility. Figure 12 depicts the sequence of fabrication activity for the ADA.

In addition to the flight and test hardware required by the prime contractor, the prime contractor will fabricate and supply to the wing box and mast/ canister subcontractor, high fidelity replicas of various items of flight hardware to be used in solar array subsystem development. Examples of these items to be furnished are the solar array support structure and the mast canister suspension and lockout mechanism.

Table 3. Array Deployment Assembly

Item	Make	Buy
Wing box assembly, solar array		X
Mast assembly, solar array		X
Diode assembly	X	
Sun sensor, array pointing		X
Processor, sun sensor		X
Electronic assembly, array routing control	X	
Harness, instrumentation ADA	X	
Harness, command and control ADA	X	
Structure assembly, solar array support	X	
Cable assembly, power ADA	X	
Gimbal assembly, solar array, drive, two axis		X
Mast/canister and lockout mechanism, solar array	X	

7.2 POWER REGULATION AND CONTROL ASSEMBLY

Table 4 below lists the assemblies that make up the Power Regulation and Control Assembly (PRCA) and indicates preliminary decisions as to whether the component will be fabricated and assembled by the prime contractor or procured from a subcontractor.

The final assembly of the Power Regulation and Control Assembly will be accomplished at the prime contractor's facility. Figure 13 shows the sequence of fabrication and assembly activity for the PRCA.

7.3 RMS INSTALLATIONS

A cable will be provided to transfer power between the Array Deployment Assembly and the Power Regulation and Control Assembly. This cable will be mounted on the RMS.

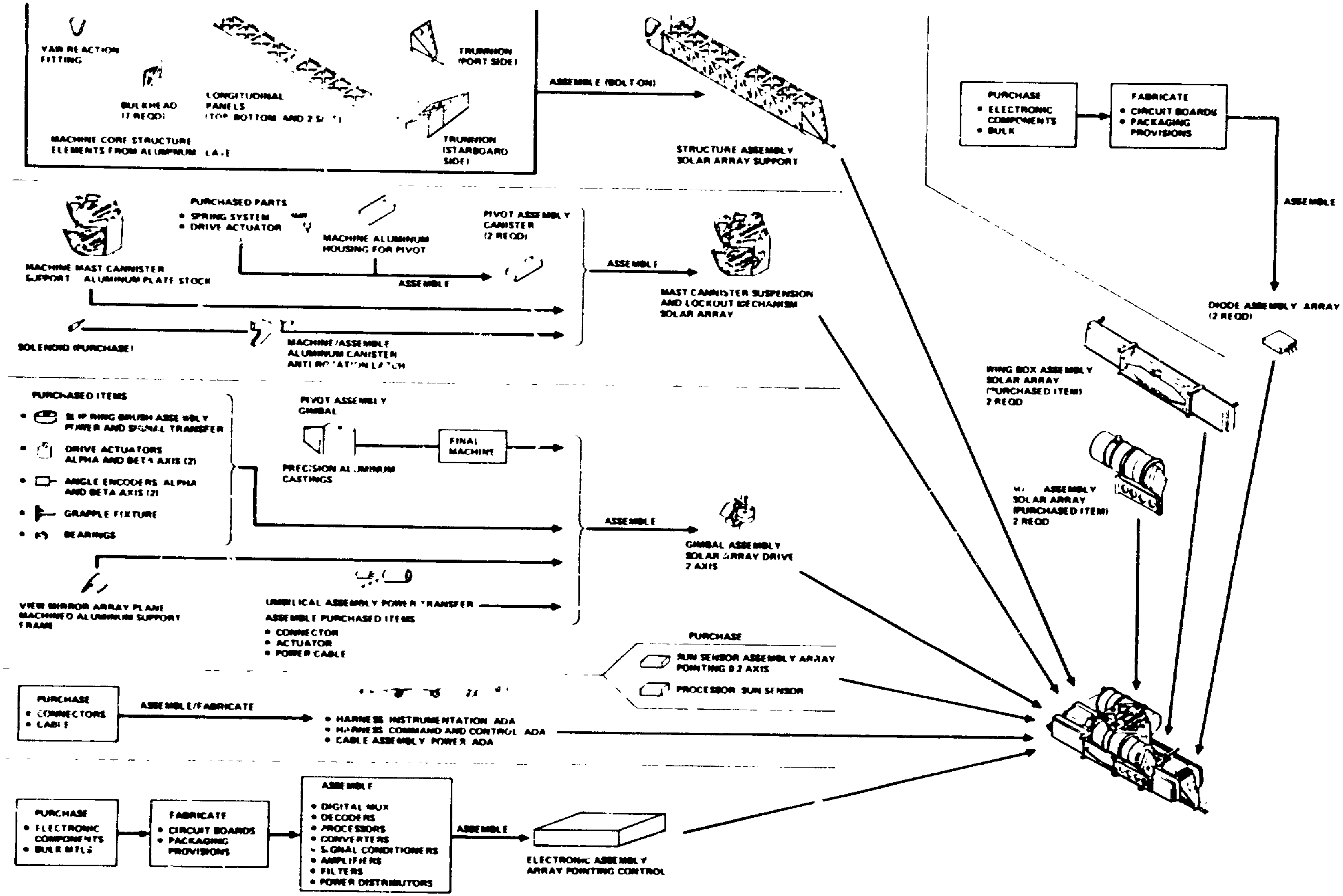


Figure 12. Manufacturing Sequence Array Deployment Assembly

Table 4. Power Regulation and Control Assembly

Item	Make	Buy
Voltage regulator	X	
Cold plate voltage, regulator		X
Power distribution box	X	
Data bus coupler		X
Multiplexer/demultiplexer assembly	X	
Load fitting Y_o custom	X	
Cable assembly, Orbiter bay, power	X	
Harness Orbiter bay, bus coupler/bus termination	X	
Harness Orbiter bay, command and control	X	

This cable will be manufactured by the RMS contractor from wire and shoulder connector half supplied by the prime contractor. The RMS contractor will:

- Design and install cable-mounting provisions on the RMS.
- Develop, manufacture, and test the cable assembly.
- Initially install the cable assembly on the RMS (cable assembly is removable for non-PEP flights).

7.4 PROCESSES AND FACILITIES

7.4.1 Prime Contractor

The PEP study has identified no requirements for the development of new processes or facilities at the prime contractor level. The PEP fabrication, assembly, and checkout/system test activities require facilities consistent with normal aerospace production facilities. Examples of facilities are those dictated by:

- Printed circuit board fabrication.
- Electrical harness fabrication.
- Black box build up and test.

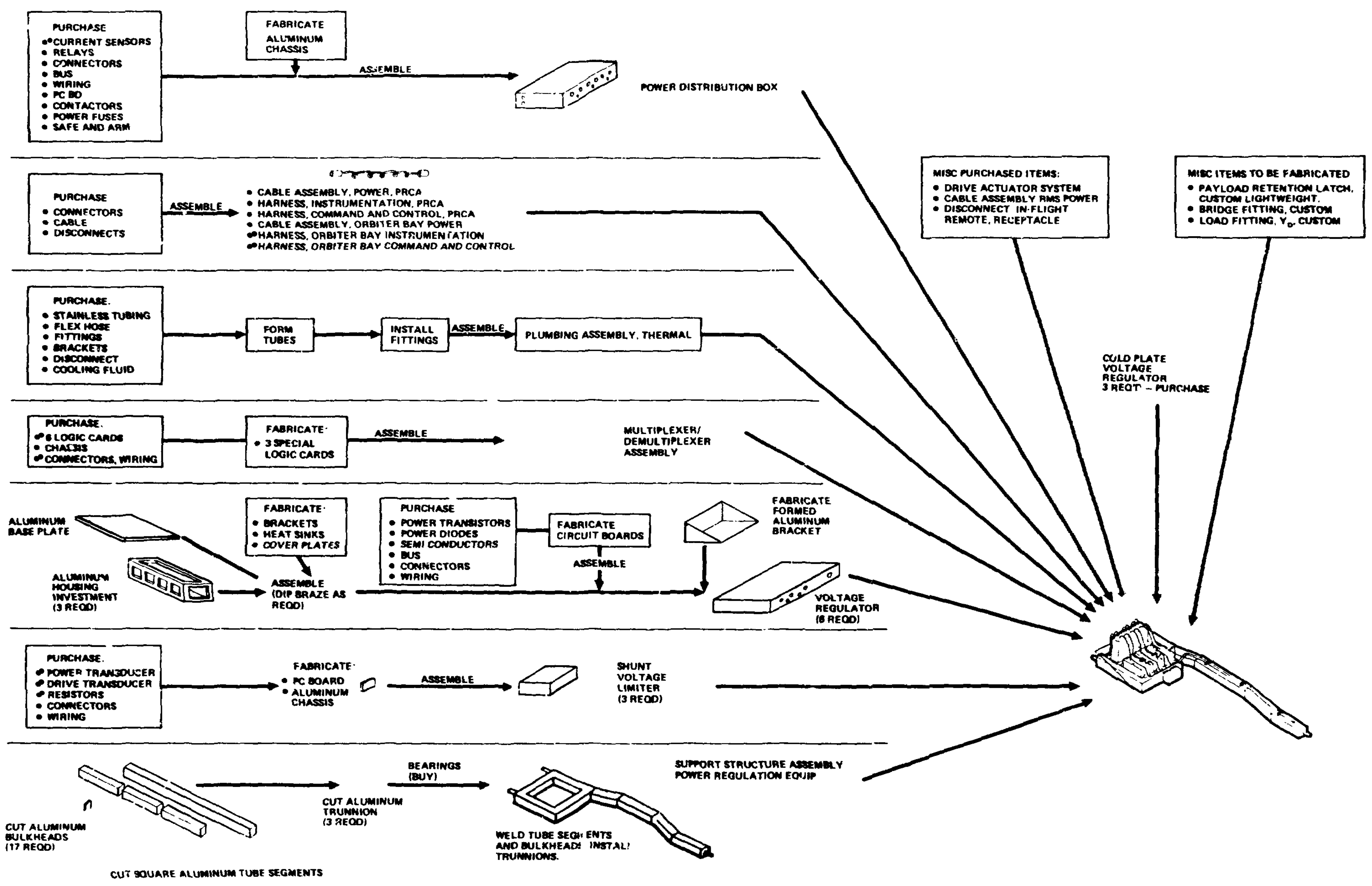


Figure 13. Manufacturing Sequence of Power Regulation and Control Assembly

- Machine shop.
- Welding.
- Cleaning.
- System assembly and test in class 100,000 clean room.

In the area of processes, the PEP production will require the well disciplined application of previously developed processes and techniques. Examples of these are as follows:

A. Mechanical

- Precision machining of complex structural elements.
- Welding of lightweight alloy structures.
- Assembly of precision machined components into an operating mechanism.
- Production of tooling and jigs to assure interchangeable assemblies.

B. Electrical

- Production of circuit boards.
- Fabrication of electrical harnesses.
- Assembly of electrical components; i.e., soldering, welding, potting.

C. Operational

- Component cleaning.
- Clean room assembly and operation.
- Safe handling of flight hardware.
- Documentation and traceability of assembly activities.
- Documentation of quality control activities.
- Packaging and shipping of spaceflight hardware.

7.4.2 Solar Array Subcontractor

Production of PEP solar arrays will require the further development of processes and facilities which exist now only in the conceptual or breadboard phase. The degree to which this is necessary will be one factor in the subcontractor selection criteria.

7.4.2.1 Facilities

If selected, the production of the wraparound type of solar cell in the quantities required for this program will require new facilities at the solar cell vendors.

Depending on the solar array subcontractor selected, varying amounts of facility construction and/or expansion will be required in order to produce blankets of the size required for this program.

7.4.2.2 Processes

Dependent upon solar array subcontractor selected, processes for assembling the cells into blankets will require various degrees of development and qualification.

Appendix A

REQUIREMENTS FOR PEP DESIGN, DEVELOPMENT, AND TEST PLAN

The Design and Development Plan shall present the Contractor's approach to accomplishing the effort necessary to design, develop, test, and deliver all hardware required to fill the needs of the PEP program. The Plan shall include, as a minimum, the following elements of data:

A. Introduction. The introduction shall provide the purpose and scope of the plan. It shall provide a narrative description of the program and the tasks to be accomplished, the purpose of the tasks and the specific goals.

B. Technical Program Planning and Control. The Contractor shall describe his systems for planning and controlling the technical effort involved in accomplishing the PEP program. As a minimum, he shall provide visibility as to:

- Technical organization.
  - Responsibilities/authorities.
- Approach to managing technical program.
  - Work authorization.
  - Scheduling.
  - Design reviews.
  - Customer participation.
  - Risk analysis.
  - Management of subcontracted design effort.
  - Performance measurement.
- Technical data management.
  - Drawing and specification generation.
  - Configuration control.

C. Design and Development Activities. The Contractor shall describe his approach to identifying and accomplishing the effort which will transform the PEP operational needs into delivered, qualified hardware which fulfills these needs. He shall, as a minimum, provide the following elements.

1. Design and Development Flow Diagram. This diagram shall identify and sequence those activities necessary to proceed from the Phase B

study results and the proposal design to the final approved PEP system design. This diagram will show the incremental progress from ATP through PDR and CDR.

2. Narrative Discussion of the Design Process to be Followed in Accomplishing the Final PEP Design:

- System Engineering:
  - — Trade studies.
  - — System analysis.
  - — Specification generation.
  - — Design analysis.
  - — System test planning.
  - — Test evaluation.
  - — Interfaces.
  - — Schedule for accomplishing System Engineering activities.
- Design Implementation.
  - — Analysis to be accomplished.
  - — Development test planning.
  - — Relationship of development test results to design progress.
  - — Inputs to make or buy decision.
  - — Schedule for design completion and release.

D. Testing. The Contractor shall provide a description of his PEP test program and show how this program supports the design activity to produce a qualified flight hardware and support equipment design to validate the manufacturing activities.

1. Development Testing.

- Detailed description of development tests to be conducted on components and systems in the evaluation of hardware performance under actual or simulated environmental conditions to evaluate hardware failure modes, safety factors, and off-limit operating points.
- Detailed description of test techniques necessary to ensure that all parameters are completely defined early in program.

2. Qualification Testing. A detailed description of the qualification tests to be accomplished. Included shall be a discussion of any limitations or compromises caused by environment and/or facilities and a description of how these tests will be supplemented and augmented by the first flight test.

3. System Testing. A description of the system test program that will validate system operation to the extent possible on the ground and give maximum assurance of proper system operation in flight.

E. The Contractor shall provide a program schedule portraying all major milestones and key interrelationships:

- Design reviews.
- Design freeze dates.
- Relationship of design, test and procurement activities.
- Facility utilization.
- Hardware required delivery dates.

F. Facilities. The Contractor shall provide a listing and utilization schedule of facilities and equipment required to perform the design and development and test effort for the PEP program.

G. Manufacturing Approach. The Contractor shall summarize his approach to manufacturing/procuring the PEP hardware. This summary is in addition to the detailed Manufacturing Plan required by the PEP contract, and its purpose is to identify in the context of the design and development plan those activities which are major factors in planning the overall approach to designing, developing and procuring the required hardware. This summary shall identify:

1. Major make or buy decisions.
2. New processes requiring development.
3. Prime contractor hardware provided to support subcontractor activities.
4. New facility/equipment requirements.

H. Hardware Requirements. The Contractor shall identify all hardware to be produced under the PEP contract and show the utilization of this hardware in support of development, test and delivery.