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POWER EXTENSION PACKAGE (PEP)
SYSTEM DEFINITION EXTENSION

Orbital Service Module Systems Analysis Study

VOLUME 11
PEP Cost, Schedules, and Work Breakdown Structure Dictionary

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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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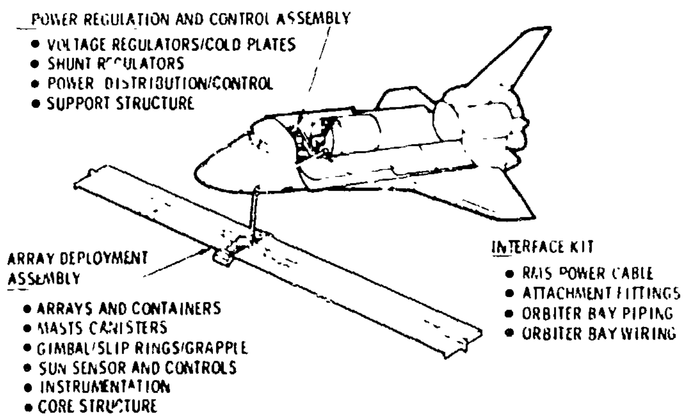
FOREWORD

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.

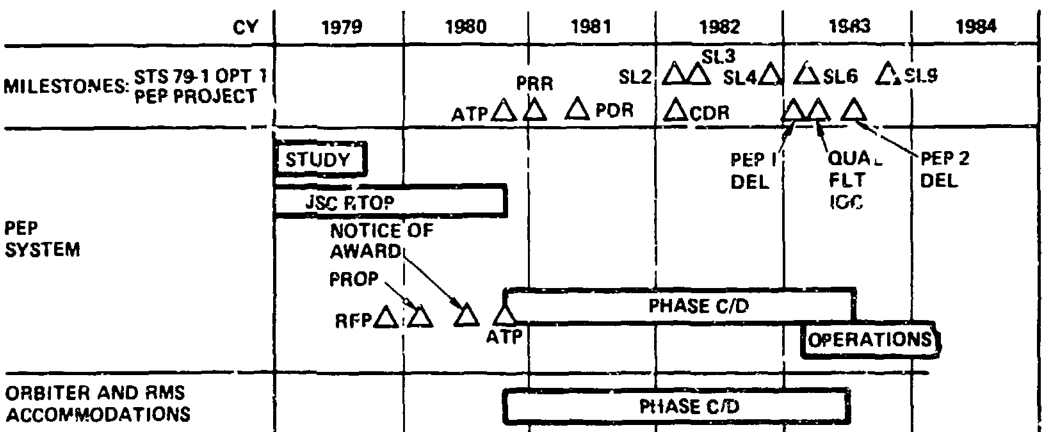


CONTENTS

Section 1
INTRODUCTION

This volume contains the WBS, cost, schedule and funding information for the PEP project. The data presented are for the Reference Design described in the technical volumes of this report. The costs and especially the funding distribution provide for minimum expenditure during the first year of the project.

Figure 1 presents a top-level summary of the cost, schedule and funding data presented in the rest of the volume. The figure correlates the major PEP schedule milestones with current Spacelab flight dates. The annual fiscal year funding shown across the bottom of the figure is in real year dollars. These values were calculated by applying the NASA directed 7% annual escalation rate to the constant 1978 year dollars used to document the detail costs presented in the rest of this volume.



FUNDING RL YR $M	FY79	FY80	FY81	FY82	FY83	FY84	TOTAL
SYS/SUBSYS AND INTEG			5.6	23.3	14.0	--	42.9
SOLAR ARRAY			5.5	21.1	12.2	--	38.8
PEP SYSTEM			11.1	44.4	26.2	–	81.7
ORBITER AND RMS ACCOMMODATIONS			1.0	4.7	1.2	–	6.9
TOTAL PHASE C/D			12.1	49.1	27.4	–	83.6

Figure 1. PEP Project Schedule and Funding (Reference Configuration Planning Baseline)

Section 2
WORK BREAKDOWN STRUCTURE

This section provides the WBS for the PEP project. It shows the relationship of the PEP project to the STS program along with providing detail through Level 7 elements.

2.1 WORK BREAKDOWN STRUCTURE DIAGRAM

Figure 2 depicts the program WBS by the major elements. As indicated, the PEP project is shown as a Level 3 project of the overall STS program. Level 3 PEP project implementation would be through the designated Project Office. The project WBS Level 4 elements are organized similar to other STS program-related projects and represent the major elements of this project, including prime, associate, and NASA civil service and support contractor elements.

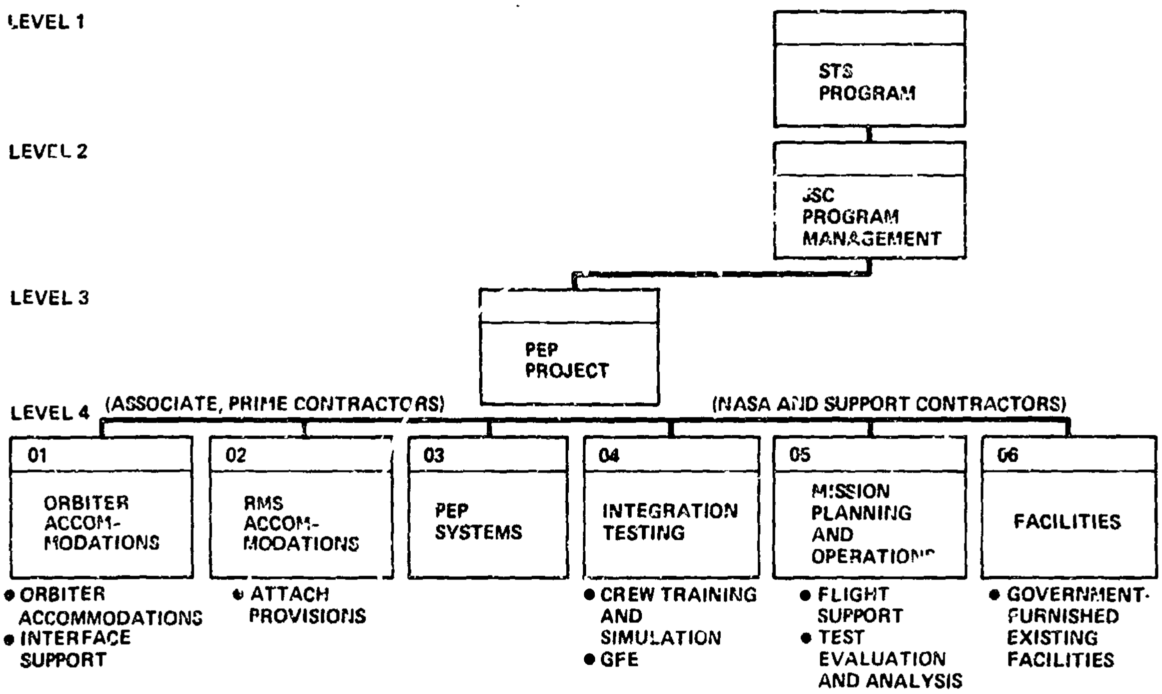


Figure 2. PEP Project Elements

Figure 3 depicts Levels 5, 6 and 7 for WBS Element 03, PEP System. Level 5 represents the system-level elements. Level 5, Flight Hardware element, is further broken down into Level 6, end-item elements. Lower-level WBS elements will be defined by the contractor as part of the Phase C/D proposal and approved by JSC during the initial project implementation period. For purposes of this study Level 7 is provided by a subsystem breakout to give adequate cost visibility for planning purposes.

2.2 WORK BREAKDOWN STRUCTURE DICTIONARY

This section provides the WBS Dictionary for the PEP Project.

WBS Element 01, Orbiter Accommodations, provides for Orbiter integration support and Orbiter accommodations assumed to be done by the Orbiter contractor.

WBS Element 02, RMS Accommodations, provides for the modifications to be made to the basic RMS, consisting of the attach provisions necessary for installation of the PEP RMS cable assembly.

WBS Element 03, PEP System, encompasses all effort, materials, tooling, support equipment, hardware and services to design, develop, test, produce and support the initial operation of the Orbiter Power Extension Package (PEP).

Work is not performed nor is cost estimated or collected, at this level of the WBS. Rather, this element summarizes the following WBS elements:

WBS element	Title
301	Project Management
302	System Engineering and Integration
303	Flight Hardware
304	Ground Support Equipment
305	Systems Test and Evaluation
307	Logistics
308	Ground Operations Support
309	Flight Operations Support

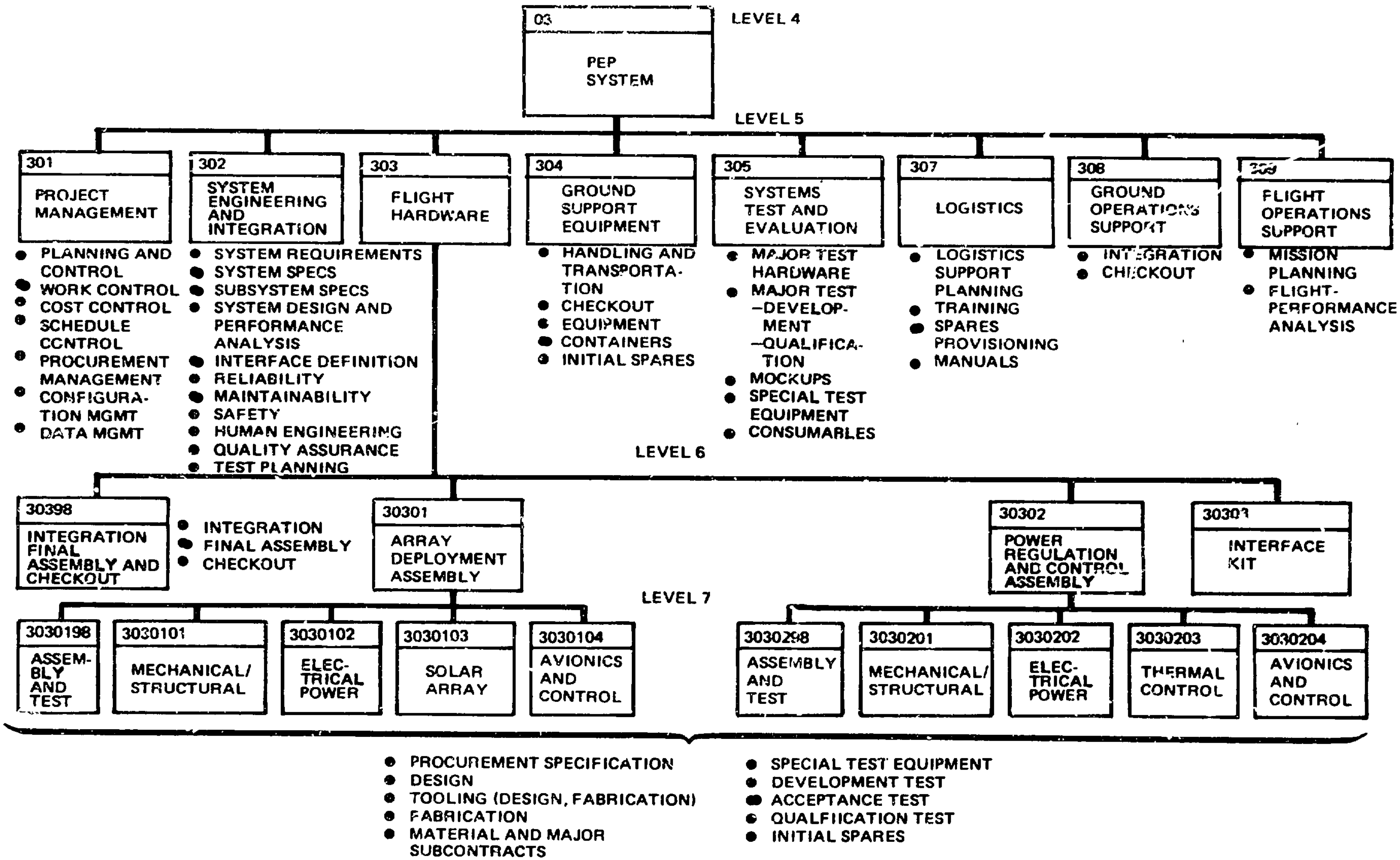


Figure 3. PEP System Elements

WBS Element 301, Project Management, encompasses the overall administrative effort of planning, organizing, directing, coordinating, controlling and approving project activities.

Included are such activities as: project direction and control, work authorization, status reviews and progress evaluation, configuration management, data preparation and management, budgeting, scheduling, conduct of project reviews, customer liaison and subcontract administration.

WBS Element 302, System Engineering and Integration, encompasses the technical and managerial effort of defining the PEP system and providing integrated planning and control of the technical activities.

Included are such activities as: performing system-level analyses and trade studies, developing system specifications, defining and controlling interfaces, conducting reliability studies and analyses, human engineering, quality engineering, safety analyses, maintainability analyses, preparation of a general test plan, life-cycle cost analysis, conduct design reviews, technical liaison with the customer and associate contractors and operation of an engineering check and release system.

WBS Element 303, Flight Hardware, encompasses the effort required to design, develop, manufacture and acceptance test the PEP flight hardware.

Work is not performed, nor is cost estimated or collected, at this level of the WBS. Rather, this element summarizes the following WBS element:

WBS element	Title
30398	Integration, Final Assembly and Checkout
30301	Array Deployment Assembly
30302	Power Regulation and Control Assembly
30303	Interface Kit

WBS Element 30398, Integration, Final Assembly and Checkout, encompasses the effort which cannot be readily assigned to any other subelement of WBS 303 (non-separable effort) or that effort which integrates hardware/services provided by two or more subelements of WBS 303 (common effort).

Included are such activities as: the preparation of engineering layouts and installation drawings; the preparation of acceptance procedures, the final factory assembly of hardware into deliverable entities, the conduct of factory acceptance tests, the design and manufacture of mating/attachment hardware, the design maintenance effort, the packaging and shipping to the system test/launch preparation locations, the design and manufacture of special test equipment which is employed during final factory acceptance tests, the maintenance of all production tooling and the conduct and evaluation of integrated development tests (including the design and manufacture of test fixtures, instrumentation and test consumables).

WBS Element 30301, Array Deployment Assembly, encompasses the effort to design, develop, manufacture and assemble the Array Deployment Assembly (ADA).

Work is not performed, nor is cost estimated or collected, at this level of the WBS. Rather, this element summarizes the following WBS element:

WBS element	Title
3030101	Mechanical/Structural
3030102	Electrical Power
3030103	Solar Array
3030104	Avionics and Control
3030198	Assembly and Test

WBS Element 3030101, Mechanical/Structural, encompasses the design, development, manufacture and assembly effort required to provide the mechanical or structural subsystem components of the ADA.

Included in the mechanical/structural subsystem are the mast canister suspension and lockout mechanism, solar array support structural assembly and 2-axis solar array drive gimbal assembly.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares and procure material/hardware from suppliers and subcontractors.

WBS Element 3030102, Electrical Power, encompasses the design, development, manufacture and assembly effort required to provide the electrical power subsystem components of the ADA.

Included in the electrical power subsystem are the power cable assembly and array diode assembly.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030103, Solar Array, encompasses the design, development, manufacture and assembly effort required to provide the solar array components.

Included in the solar array are the wing box assembly and mast assembly.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030104, Avionics and Control, encompasses the design, development, manufacture and assembly effort required to provide the avionics and control subsystem components of the ADA.

Included in the avionics and control subsystem are the pointing and control electronics assembly, 2-axis array pointing sun sensor assembly, sun sensor assembly, command and control harness and instrumentation harness.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030198, Assembly and Test, encompasses the end item assembly and acceptance testing effort required to integrate the subsystems of the ADA.

WBS Element 30302, Power Regulation and Control Assembly, encompasses the effort to design, develop, manufacture and assemble the Power Regulation and Control Assembly (PRCA).

Work is not performed, nor is cost estimated or collected, at this level of the WBS. Rather, this element summarizes the following WBS elements:

WBS element	Title
3030201	Mechanical/Structural
3030202	Electrical Power
3030203	Thermal Control
3030204	Avionics and Control
3030298	Assembly and Test

WBS Element 3030201, Mechanical/Structural, encompasses the design, development, manufacture and assembly effort required to provide the mechanical/structural subsystem components of the PRCA.

Included in the mechanical/structural subsystem is the structural assembly.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030202, Electrical Power, encompasses the design, development, manufacture and assembly effort required to provide the electrical power subsystem components of the PRCA.

Included in the electrical power subsystem are the power distribution box, voltage regulators, power cable assembly, and shunt voltage limiter.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030203, Thermal Control, encompasses the design, development, manufacture and assembly effort required to provide the thermal control subsystem components of the PRCA.

Included in the thermal control subsystem and the voltage regulator cold plates and cold plate plumbing assembly.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030204, Avionics and Control, encompasses the design, development, manufacture and assembly effort required to provide the avionics and control subsystem components of the PRCA.

Included in the avionics and control subsystem are the data bus coupler assembly, multiplexer/demultiplexer assembly, command and control harness and instrumentation harness.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 3030298, Assembly and Test, encompasses the end item assembly and acceptance testing effort required to integrate the subsystems of the PRCA.

WBS Element 30304, Interface Kit, encompasses the effort to design, develop, manufacture and assemble the Interface Kit.

The Interface Kit consists of a payload retention latch, custom Y_o load fitting, RMS power cable assembly, bus coupler/bus termination harness, instrumentation harness, power cable assembly and custom bridge fitting.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, design and manufacture production tooling, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors.

WBS Element 304, Ground Support Equipment, encompasses the effort to design, develop, manufacture and assemble PEP Ground Support Equipment (GSE).

GSE is used to support and maintain the PEP system or portions of the system while it is not directly engaged in the performance of its mission. Electrical GSE includes the Solar Array Simulator, Power Bus Load Simulator, Canister Electrical Simulator, Interface Test Unit and the Orbiter Cable Simulator. Mechanical GSE includes the Thermal Conditioning Unit, Freon Leak Detector, PEP Strongback, PEP Test Fixture, PEP Transporter, PGHM Adapter and the Transportation Kit.

Included are such activities as: perform design analyses and trade studies, prepare detail design drawings, prepare procurement specifications, manufacture hardware, plan and conduct development and qualification tests (including test fixtures, instrumentation and test consumables), perform acceptance tests, manufacture deliverable spares, procure material/hardware from suppliers and subcontractors, package and ship completed end items to the using locations.

WBS Element 305, System Test and Evaluation, encompasses the effort required to plan, conduct and evaluate PEP system-level tests.

Included are such activities as: design and manufacture of test specimens and test fixtures, preparation of test procedures, conduct of tests, reduction and evaluation of test data, design and manufacture of mockups and simulators. Special test equipment, instrumentation and test consumables are also included.

Testing which can be specifically associated with a hardware element is excluded. Test specimens which are identical to production units are also excluded.

WBS Element 307, Logistics, encompasses the effort required to plan and implement a logistics support system for the PEP.

Included are such activities as: develop a Logistics Support Plan, prepare manuals for operating and maintaining PEP equipment, implement a spares/repair parts provisioning program, develop a training program and conduct training classes.

WBS Element 308, Ground Operations Support, encompasses the effort required to prepare the PEP hardware for launch for the qualification flight.

Included are such activities as: hardware unpacking and receiving inspection, transportation to storage or assembly area, preparation for launch operations (final assembly, adjustments/alignments, loading of consumables, etc.), preparation and coordination of timelines for ground operations. monitoring Orbiter installation/integration operations, support the pre-Launch and launch countdown operations (including Preflight Readiness Reviews).

WBS Element 309, Flight Operations Support, encompasses the effort required to support and evaluate the initial PEP flight operations.

Included are such activities as: participate in mission planning activities, develop operational software pertaining to inflight deployment/operation, evaluate performance data, prepare data evaluation report.

WBS Element 04, Integration Testing, and 105, Mission Planning and Operations, provide for the PEP-peculiar NASA civil service and support contractor activities of integration testing and mission planning and operations at JSC and KSC. These elements will be expanded by JSC.

WBS Element 06, Facilities, provides for the facilities required for PEP other than contractor facilities. It is assumed that existing Government facilities at JSC and KSC will be made available and are believed to be essentially adequate. Any minor modifications, if required and identified as PEP-peculiar, would be included herein.

Section 3

GROUNDRULES AND ASSUMPTIONS

The following groundrules were used in constructing the schedules and estimating the costs:

1. All costs are in constant Fiscal 1978 dollars.

2. Costs exclude prime contractor and solar array subcontractor fee.

3. ATP is to be 1 October 1981. IOC of first PEP is 1 April 1983. The second PEP is delivered 15 July 1983.

4. No dedicated systems test flight article is required. System qualification is accomplished by first flight.

5. The solar array is to be provided by a subcontractor and delivered to the prime contractor's facility for assembly into the PEP prior to delivery to NASA.

6. NASA support contractor costs of $0.5 million are included in the costs which were provided to MDAC by JSC during 1978, and require updating.

7. Costs for Orbiter accommodation were furnished by NASA and are assumed to be performed in a separate contract.

8. Costs for the RMS accommodation (SCARS) were furnished by vendor estimate and will be performed under a separate contract. The RMS cable assembly costs are included in the Interface Kit estimate.

9. Solar array costs are based on data provided by vendor estimate and are adjusted to reflect the reference design.

10. The costs include development and delivery of 2 sets of PEP hardware and modification of 2 Orbiters.

11. Cost include activities through one flight of PEP 1 and delivery of the second PEP to KSC.

Section 4
PROJECT COSTS

The cost estimate for the Orbiter accommodations was supplied by NASA. The breakdown between development and production was assumed by MDAC cost personnel. The costs for the RMS accommodations were supplied by SPAR with the assumption that the cost includes only that due to the modifications to the baseline SRMS which are in excess of the recurring costs of a standard SRMS system.

4.1 COST APPROACH/METHODOLOGY

The costs for the PEP system were estimated using CERs, vendor data, direct estimates and factors.

The parametric estimates used CERs that are based on historical information in the MDAC data bank and data published by SAMSO. The CERs based on the MDAC data bank reflect data principally from the Saturn S-IVB, Spacelab Tunnel and Delta programs. The older data were adjusted by using technology factors from SAMSO. (Reference: "Technology Carryover Factors," Table V-3, page V-11 of Unmanned Spacecraft Cost Model, SAMSO TR-78-61, 4th Edition, February 1978.) These factors recognize that the manhours required to design and fabricate an item using current technology are different than the manhours required to produce the same item with early technology.

Analysis of recent data from the Delta program provided information suitable for deriving a CER for machined fittings. To assure the new CER was compatible with the existing catalog of CERs, the ratio of the cost of fittings to normal structure in the Delta program was applied to the catalogued CER used for normal structure. This technique preserved the correct ratio between the cost of normal structure and machined parts.

The basic non-recurring costs for the items were adjusted to reflect whether the item was a new development, off-the-shelf item, or an existing item that required modification to meet the requirements of this program. If an item was considered off-the-shelf, a minimum of 10% of the new engineering development cost was estimated as necessary to cover such effort as locating the item, verifying it met the requirements and including the item on the appropriate drawings and parts lists. If an item existed, but required minor modifications, a larger factor was used.

Vendor quotes were obtained on many of the off-the-shelf components for the various subsystems.

Most nonstructural production costs were generated by direct estimate via MDAC's Pricing department.

The system level costs were factored from the flight hardware end items. The factors used, in general, are as follows:

	NR	REC
Project Management	0.05	0.05
SE&I	0.25	0.10
Assembly and Test		0.08 - 0.32
GSE	0.10	

The cost estimate for integration testing was supplied by NASA.

4.2 DEVELOPMENT/PRODUCTION COST ESTIMATE

4.2.1 Cost Estimate by WBS Items (Data Form A)

Table 1 displays cost estimates for specified WBS items, the time-phasing recommended to spread the costs for funding purposes, and a method to derive unit costs for recurring items.

Each item of cost presented on Data Form A will be identified by its occurrence in the WBS. Separate costs estimates are presented for the non-recurring (development) activities and recurring (production) activities.

Table 1. Cost Estimate for PEP (Millions of 1978 Dollars), Data Form A

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	EXPECTED COST	REF LAUNCH DATE APR 83 LEAD TIME	COST DURATION	SPREAD FUNCT	LEARN INDEX
0	PEP PROJECT	3		66.856	-30	36	CUM	CUM
	NON-RECURRING(DEVELOPMENT)	3		30.530	-30	33	CUM	100
1	ORBITER ACCOMMODATIONS	4		3.617	-26	21	60	100
2	RMS ACCOMMODATIONS	4		.111	-21	12	60	100
3	PEP SYSTEMS - REF CONFIG	4		26.602	-30	33	CUM	100
301	PROJECT MANAGEMENT	5		1.340	-30	22	60	100
302	SYS ENG AND INTEG	5		3.133	-30	22	0	100
303	FLIGHT HARDWARE	5		19.214	-30	33	CUM	100
30301	ARRAY DEPLOY ASSY	6		14.638	-30	26	CUM	100
3030101	MECHANICAL/STRUCTURAL	7		2.636	-27	23	50	100
3030102	ELECTRICAL POWER	7		.2[illegible]5	-27	22	50	100
3030103	SOLAR ARRAY	7		8.214	-30	17	0	100
3030104	AVIONICS AND CONTROL	7		3.573	-27	23	50	100
30302	PWR REG AND CTL ASSY	6		1.783	-26	29	CUM	100
3030201	MECHANICAL/STRUCTURAL	7		.651	-26	17	50	100
3030202	ELECTRICAL POWER	7		.528	-26	20	50	100
3030204	AVIONICS AND CONTROL	7		.252	-18	12	50	100
30304	INTERFACE KIT	6		1.826	-18	19	50	100
30398	INTEGRATION/FACO	6		.967	-15	9	60	100
304	GROUND SUPPORT EQUIPMENT	5		1.058	-15	9	60	100
305	SYS TEST AND EVAL	5		1.516	-25	23	0	100
307	LOGISTICS	5		.140	-30	27	0	100
308	GROUND OPERATIONS SUPPORT	5		.200	-13	10	0	100
4	INTEGRATION TESTING	4		.200	-18	3	0	100
	RECURRING(PRODUCTION)	3	2	36.327	-30	36	CUM	100
1	ORBITER ACCOMMODATIONS	4	2	1.019	-14	16	50	100
2	RMS ACCOMMODATIONS	4	2	.486	-14	17	50	100
3	PEP SYSTEMS - REF CONFIG	4	2	34.521	-30	36	CUM	100
301	PROJECT MANAGEMENT	5		1.847	-16	22	50	100
302	SYS ENG AND INTEG	5		2.146	-16	22	50	100
303	FLIGHT HARDWARE	5	2	30.207	-30	36	CUM	100
30301	ARRAY DEPLOY ASSY	6	2	24.122	-30	36	CUM	100
3030101	MECHANICAL/STRUCTURAL	7	2	1.120	-14	17	50	100
3030102	ELECTRICAL POWER	7	2	.266	-14	17	50	100
3030103	SOLAR ARRAY	7	2	21.121	-30	31	50	100
3030104	AVIONICS AND CONTROL	7	2	1.332	-14	20	50	100
3030198	ASSEMBLY AND TEST	7	2	.283	-6	12	50	100
30302	PWR REG AND CTL ASSY	6	2	2.791	-17	21	CUM	100
3030201	MECHANICAL/STRUCTURAL	7	2	.150	-17	21	50	100
3030202	ELECTRICAL POWER	7	2	1.093	-17	21	50	100
3030203	THERMAL CONTROL	7	2	.416	-17	21	50	100
3030204	AVIONICS AND CONTROL	7	2	.783	-17	21	50	100
3030298	ASSEMBLY AND TEST	7	2	.349	-17	21	50	100
30304	INTERFACE KIT	6	2	1.427	-15	19	50	100
30398	INTEGRATION/FACO	6	2	1.868	-6	12	50	100
308	GROUND OPERATIONS SUPPORT	5		.239	-3	3	0	100
309	FLIGHT OPERATIONS SUPPORT	5		.082	-3	3	0	100
4	INTEGRATION TESTING	4		.300	-3	3	0	100

Development activities include design, development and test labor, ground test hardware and system test labor and hardware. Production activities include fabrication, manufacture, assembly and materials for the flight units as well as initial spares.

A description of the contents of each column of the form follows:

1. Identification Number - the appropriate WBS code corresponding to the item of cost.

2. WBS Identification - the name or title of the WBS element; i.e., electrical power, avionics and control, etc.

3. WBS Level - the appropriate level of the occurrence of the item in the WBS or FIL (Level 3, 4, 5, etc.).

4. Number of Units - the quantity of units for each WBS item used in the production and operations phases of the program. A value will not appear in this column for the non-recurring category.

5. Expected Cost - the estimate of the most probable cost of the item for the category under consideration (non-recurring or recurring). For production items, regardless of quantity, the expected cost will be the reference unit cost with successive item costs being determined either by averaging techniques or learning rates. The assumption that the Government will furnish the item will be indicated by displaying "GFE" in the column. The term "reference unit" is the production sequence number of the first unit that is used in the recurring phase of the program.

6. Lead Time - the number of months between beginning of cost accrual and launch milestone date. For the production and operations activities, lead time will be given for the reference unit.

7. Cost Duration - the time elapsed from beginning to end of cost accrual for the individual line item.

8. Spread Function - an index number representing a cost distribution curve which the estimator recommends for the time phasing of Column F costs over the cost duration as shown in Column (J).

9. Learning Index - a numerical index of a learning rate related to the recurring cost in Column F, which, in conjunction with the data in columns D and E, will provide a method of obtaining unit costs.

The total program cost for the PEP project is estimated to be $66.856 million with $5.323 million or 8% of the costs in Orbiter/RMS accommodations and $61.533 million or 92% of the costs in the PEP systems. The $5.323 million breaks down into $3.728 million or 70% for non-recurring (development) and $1.595 million or 30% for recurring (production). The $61.533 million breaks down into $26.902 million or 44% for non-recurring (development) and $34.631 million or 56% for recurring (production).

The PEP system cost of $61.533 million is classified into three major areas: flight hardware (without solar array), solar array and system level. The flight hardware (without solar array) contains $20.076 million or 33% of the PEP system cost.

The $20.076 million breaks down into $9.086 million or 45% for non-recurring (development) and $10.990 million or 55% for recurring (production).

The solar array contains $29.345 million or 48% of the PEP system cost. The $29.345 million breaks down into $8.224 million or 28% for non-recurring (development) and $21.121 million or 72% for recurring (production).

The system level contains $12.112 million or 20% of the PEP system cost. The $12.112 million breaks down into $9.59 million or 79% for non-recurring (development) and $2.520 million or 21% for recurring (production).

The flight hardware (without solar array) cost of $20.076 million is split into four major categories: ADA, PRCA, Interface Kit, and Integration/Final Assembly and Checkout. The ADA contains $9.415 million or 47% of the flight hardware (without solar array) cost.

The $9.415 million breaks down into $6.414 million or 68% for non-recurring (development) and $3.001 million or 32% for recurring (production).

The PRCA contains $4.574 million or 23% of the flight hardware (without solar array) cost. The $4.574 million breaks down into $1.783 million or 39% for non-recurring (development) and $2.791 million or 61% for recurring (production).

The Interface Kit contains $3.253 million or 16% of the flight hardware (without solar array) cost. The $3.253 million breaks down into $1.826 million or 56% for non-recurring (development) and $1.427 million or 44% for recurring (production).

Integration/Final Assembly and Checkout contains $2.835 million or 14% of the flight hardware (without solar array) cost. The 2.835 million breaks down into $0.967 million or 34% for non-recurring (development) and $1.868 million or 66% for recurring (production).

4.2.2 <u>Cost Estimating Methodology and Technical Characteristics</u> (Data Form C) Table 2 provides the data needed to allow NASA to evaluate contractor cost estimates. It presents the technical, physical and mission characteristics which may have significant effect on the cost of an item.

A description of each column of the form follows:

A. (1) WBS Identification Number - the appropriate WBS code corresponding to the item.

(2) WBS Name - the alphanumeric nomenclature of the item from the WBS (not limited in length).

B. Cost Estimate - estimated cost of the WBS item under consideration.

C. Type of Estimate - indicate whether the estimate is a direct estimate of manpower and materials (d), based on a vendor quote (V), a parametric estimate (P), provided by NASA (N), or factored from the flight hardware (F).

D. Historical Data Used - indicate the historical program considered most analogous to the one being estimated.

E. Complexity Factor Applied - indicate whether the subsystem being costed is more or less complex than the historical one to which it is being compared. A complexity factor of 0.5 would indicate that the subsystem being costed is one-half as complex as the analogous program cited in column D; 1.0 complexity would indicate equal complexity, and 2.0 would reflect a new subsystem twice as complex as the one to which it is being compared.

F. Quantity or Value - the numerical quantity or value of the characteristic under consideration.

Table 2. Cost-Estimating Methodology and Technical Characteristics, Data Form C

WBS identification number		Cost	Type	Historical	Complexity	Quantity	Key technical	
Number	Nomenclature	est.	est.	data used	factor	or value	characteristic	Remarks
1	Orbiter accommodations	4.64	N					JSC
2	RMS accommodations	0.60	V					Vendor quote
301	Project mgt.	3.19	F					Factored
302	SEI	5.28	F					Factored
3030101	Mech./struct.	3.76	P	Saturn	0.5	2	Wt.	CER's
3030102	Elect. power	0.47	D			2		Pricing est.
3030103	Solar array	29.34	V			4		Vendor quote
3030104	Avion. and control	4.91	D	PAM	1.0	2		Pricing est.
3030198	Assembly and test	0.28	F					Factored
3030201	Mech./struct.	0.80	P	Saturn	0.5	2	Wt.	CER's
3030202	Elect. power	1.62	D	P^3	1.5	2		Pricing est.
3030203	Thermal control	0.77	V	Orbiter	1.68	2	Area	Vendor quote
3030204	Avion. and control	1.04	D			2		Pricing est.
3030298	Assembly and test	0.35	F					Factored
30304	Interface kit	3.25	D	Delta	0.5	2	Wt.	CER's
30398	Integ. FACO	2.83	F					Factored
304	GSE	1.06	F			2		Factored
305	STE	1.52	F					Factored
307	Logistics	0.14	D					Direct est.
308	Ground ops.	0.44	D					Direct est.
309	Flight ops.	0.08	D					Direct est.
4	Integ. testing	0.50	N					JSC

G. Key Technical Characteristic - the identification of the technical property under consideration. Examples include: (1) sizing parameters (weight, KWH, volume, etc.), (2) performance parameters (minimum attitude, charge rate, etc.), (3) reliability parameters (mission duration, maximum operating distance from earth, etc.).

H. Remarks - any brief comments or explanations which will increase the clarity of the information presented.

4.2.3 Equivalent Hardware Quantities (Cost Data Form H)

Table 3 shows the equivalent units (fraction of first production unit cost) required for each of the different hardware categories from development test through spares.

Table 3. Summary of Hardware Quantities, Data Form H

Subsystem	No. of development units	No. of qual units	No. of major test units	Refurbishment units	No. of production units	Initial spares	Operational spares	Total units
ADA								
Mech./struct.	0.59	1.00	0.48		2.00	0.02		4.09
Elect. power	0.00	0.59	0.59		2.00	0.64		3.82
Avionics and controls	0.23	1.00	0.22		2.00	0.85		4.30
PRCA								
Mech./struct.	0.00	1.00	0.00		2.00	0.00		3.00
Elect. power	1.43	1.00	0.54		2.00	1.55		6.52
Thermal controls	0.00	1.00	0.73		2.00	0.00		3.73
Avionics and controls	0.00	0.19	0.12		2.00	0.93		3.24
Interface kit	0.00	0.21	0.83		2.00	0.09		3.13

Section 5
MAJOR MILESTONES AND MASTER SCHEDULE

This section contains a description and summary analysis of the FEP hardware development schedule. It is designed to provide a general understanding of the schedule logic, identify principal critical paths and discuss the relationship of the development plan to the FEP major milestones.

The FEP Project Master Schedule, Figure 4, has been structured in concert with the segregation of work displayed on the Work Breakdown Structure (WBS), Figures 2 and 3. This correlation with the WBS provides a direct relationship between cost and schedule.

As shown on the schedule, a thirty month period is planned from project ATP to IOC. This time period has been reviewed and is considered the shortest practical period in which to accomplish desired project objectives. The schedule is keyed to having FEP available for launch by the end of March 1983. To meet this schedule objective, sixteen months has been allotted for accomplishing activities associated with PRR, PDR and CDR. Accomplishment of these events within this time period will require timely and clear agreement on the design concept that is adopted.

Engineering Development, analysis and evaluation must be completed early in the project related to the long lead items. Solar array design and procurement activity is planned to be initiated concurrently with the FEP contractor system design. The PRR results must be mutually definitive and acceptable and allow for early and parallel commitments for long lead procurement of items such as solar cells by the solar array contractor and voltage regulators, electrical components and gimbal components by the FEP contractor. It is assumed that planned pre-ATP activities will provide the necessary system definition to facilitate placement of purchase orders on these long lead items in parallel with PRR.

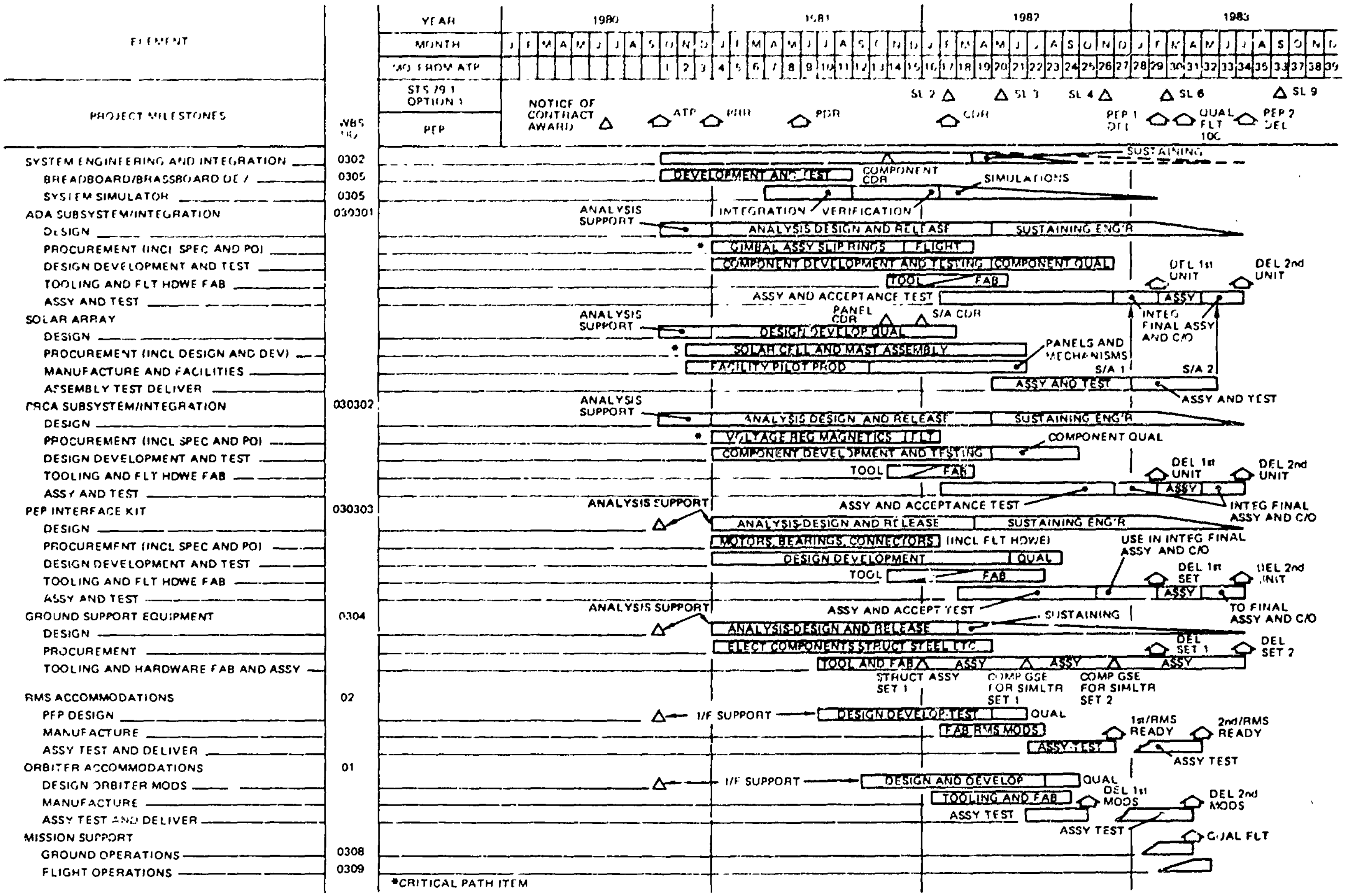


Figure 4. PEP Project Master Schedule

Design reviews at the component level, as appropriate, will allow the release of Engineering drawings required to design and fabricate tooling and begin the fabrication of detail parts in parallel with preparation for system level design reviews; e.g., CDR. This approach will also allow early manufacture of parts for prototype hardware buildup and test to verify flight hardware design. Breadboard/brassboard development will begin at ATP which will result in being able to start early integration/verification simulator operations for electrical development of the PEP system six months after ATP.

Qualification and flight hardware assembly will in most instances commence immediately following CDR. Thorough qualification testing and subsequent use of flight configuration components and GSE in the integration/verification simulator will reduce and/or eliminate possible incompatibilities during Orbiter interface tests at KSC and enhance Orbiter/crew safety during launch and landing as well as during in-flight deployment of the PEP system. The PEP/Solar Array, PEP/RMS and PEP/Orbiter interfaces will be verified prior to hardware delivery to KSC. This testing will begin two and one-half months prior to delivery of the PEP system to the launch facility.

Final delivery of the PEP system will consist of two major end items plus the Interface Kit and Ground Support Equipment. The Array Deployment Assembly, which includes the Solar Array, and the Power Control and Regulation Assembly, are these two end items. The RMS and Orbiter accommodations will be completed and available for delivery of the launch facility in parallel with the arrival of the PEP system.

The KSC ground operations for preparing PEP for its first flight are scheduled for six weeks which includes receiving, integration, checkout, Orbiter installation and launch preparations.

Three critical path items are identified on the schedule, consisting of the solar cell assembly, the voltage regulator, and the gimbal assembly components. In each instance, the principal critical issue relates to procurement lead-times. The procurement of long lead items, the manufacture and assembly of selected components for qualification to insure qualified flight hardware and the subsequent integration, final assembly and checkout of the PEP system are the critical paths that will bear constant and effective management if the project objectives are to be attained.

Project elements will be further analyzed and definitized during the Phase C/D proposal activity. Schedule logic and hardware leadtimes will be validated and revised as appropriate consistent with expanded definition. Schedules will be developed at lower levels during the C/D phase in keeping with expansion of the WBS as necessary to implement and validate the Master Schedule.

Figure 5 illustrates the Array Deployment Assembly schedule. This schedule demonstrates the activities of engineering, procurement, development testing, including the qualification of flight hardware, and the manufacture and assembly of flight hardware in order to proceed into the integration final assembly and checkout of the Array Deployment Assembly (ADA).

At the beginning of the assembly of the ADA the Solar Array (SA) will have been delivered to the PEP contractor by the SA subcontractor and will be installed on the ADA and the system will then be checked out. Electrical harnesses for the instrumentation and command and control will have been manufactured and will be available for use in the system checkout.

The critical path for the ADA will be the procurement of solar array and the gimbal assembly components and the subsequent qualification of the assembly.

Figure 6 illustrates the Power Regulation and Control Assembly schedule. The Power Regulation and Control Assembly (PRCA) will be engineered, assembled and qualified in parallel with the ADA. The support structure, voltage and shunt regulators, the power distribution box and the cold plate will be developed first as prototypes through the use of breadboard and brassboard techniques. They will subsequently be placed in the Integration/Verification Simulator (VIS) and refined by design improvements. During this VIS activity, qualification and flight hardware will be produced, assembled and integrated with the ADA and prepared for the start of the final assembly, integration and checkout of the PEP system. The critical path for the PRCA is the development of the voltage regulator.

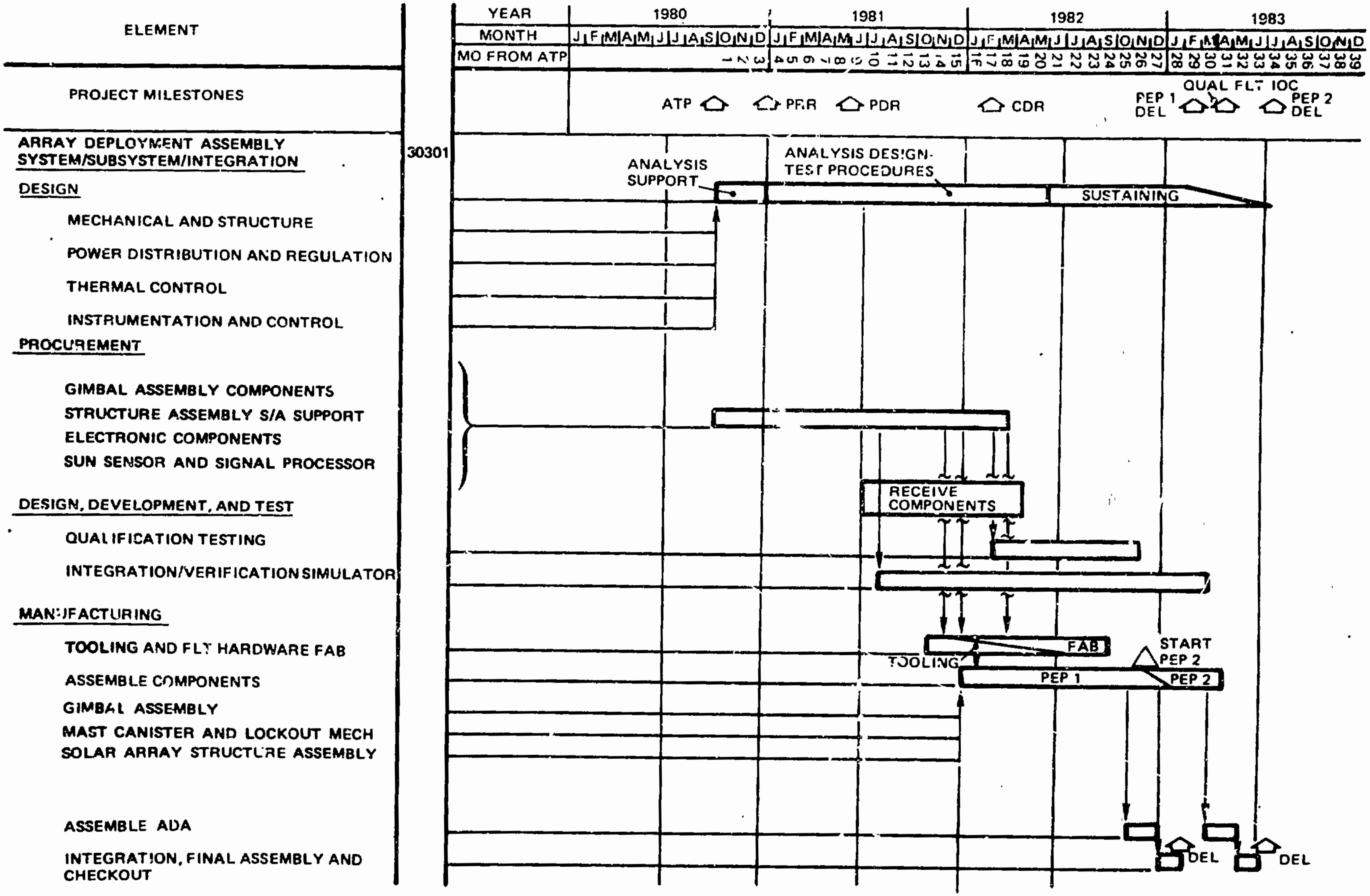


Figure 5. Array Deployment Assembly (Page 1 of 2).

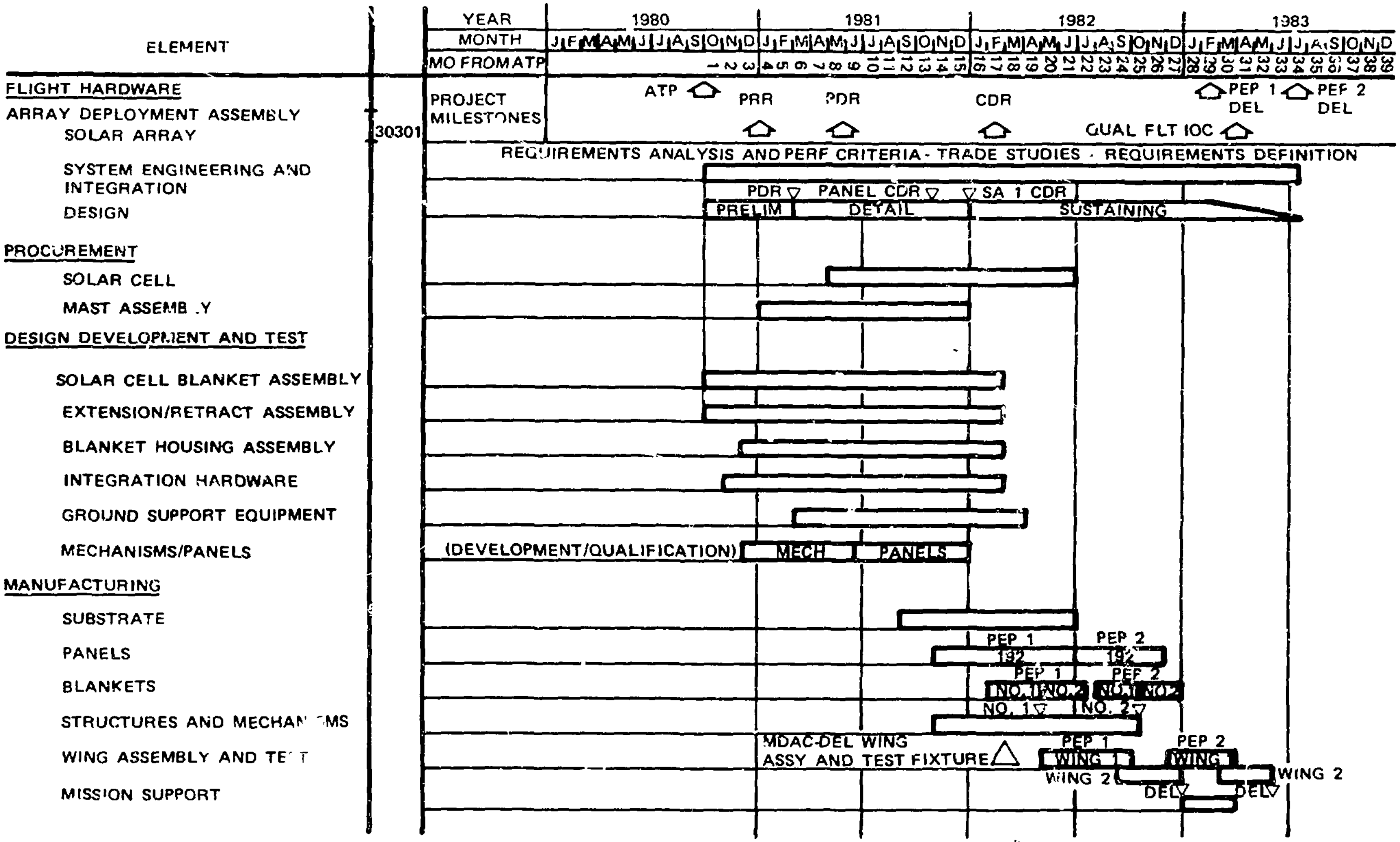


Figure 5. Array Deployment Assy — Solar Array (Page 2 Of 2)

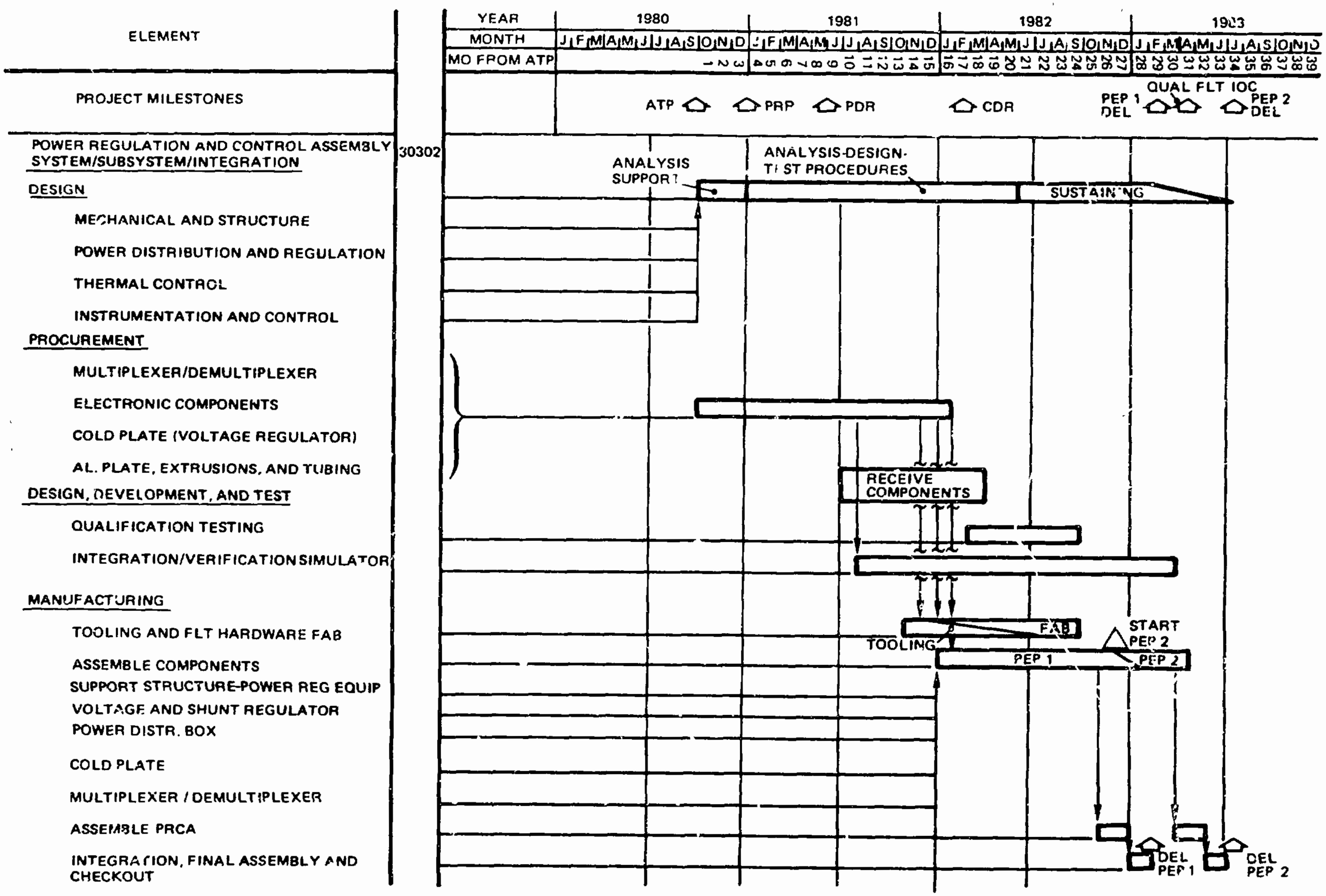


Figure 6. Power Regulation and Control Assembly

Section 6
PROJECT FUNDING AND MANPOWER

6.1 PROJECT FUNDING DISTRIBUTION (Data Form D)

Table 4 presents an estimate of the resources required to accomplish subsequent phases of the project. Funding schedules are presented separately for the non-recurring (development) and recurring (production). A description of the contents of each column of the form follows:

A. WBS Number - the appropriate WBS code corresponding to the item of cost.

B. WBS Title - the name or title of the WBS element; i.e., electrical power, avionics and control, etc.

C. Cumulative Total - the estimate of the most probable cost of the item for the category under consideration (non-recurring or recurring).

D. Fiscal Years - the estimate is time-phased by fiscal year by using the appropriate spreading function.

The total program cost of $66.86 million is spread between the fiscal years as follows: $9.89 million or 25% in FY 81, $37.48 million or 56% in FY 82, and $19.49 million or 29% in FY 83. The non-recurring (development) cost of $70.53 million is spread with $9.89 million or 32% in FY 81, $19.55 million or 64% in FY 82 and $1.09 million or 4% in FY 83. The recurring (production) cost of $36.33 million is spread with $0.0 million or 0% in FY 81, $17.93 million or 49% in FY 82, and $18.40 million or 51% in FY 83.

6.2 MANPOWER ESTIMATE

Table 5 presents the manpower estimate in man years for each of the fiscal years shown on the project schedules.

Table 4. PEP Funding Distribution (Millions of 1978 Dollars), Data Form D

WBS NUMBER	WBS TITLE	CUM TOTAL	FISCAL YEARS 1981	1982	1983	1984
0	PEP PROJECT	66.86	9.89	37.48	19.49	0.00
	NON-RECURRING(DEVELOPMENT)	30.53	9.89	19.55	1.09	0.00
1	ORBITER ACCOMMODATIONS	3.62	.83	2.78	.01	0.00
2	RMS ACCOMMODATIONS	.11	.02	.09	0.00	0.00
3	PEP SYSTEMS - REF CONFIG	26.60	9.03	16.48	1.09	0.00
301	PROJECT MANAGEMENT	1.34	.91	.42	.01	0.00
302	SYSTEM ENG AND INTEG	3.13	1.71	1.42	0.00	0.00
303	FLIGHT HARDWARE	19.21	6.32	12.33	.57	0.00
30301	ARRAY DEPLOY ASSY	14.64	5.83	8.48	.33	0.00
3030101	MECHANICAL/STRUCTURAL	2.64	.49	2.08	.07	0.00
3030102	ELECTRICAL POWER	.20	.05	.15	.00	0.00
3030103	SOLAR ARRAY	8.22	4.50	3.54	.19	0.00
3030104	AVIONICS AND CONTROL	3.57	.79	2.72	.06	0.00
30302	PWR REG AND CTL ASSY	1.78	.49	1.22	.08	0.00
3030201	MECHANICAL/STRUCTURAL	.65	.34	.31	0.00	0.00
3030202	ELECTRICAL POWER	.53	.14	.38	0.00	0.00
3030203	THERMAL CONTROL	.35	0.00	.28	.08	0.00
3030204	AVIONICS AND CONTROL	.25	0.00	.25	0.00	0.00
30304	INTERFACE KIT	1.83	0.00	1.66	.16	0.00
30398	INTEGRATION/FACO	.97	0.00	.97	0.00	0.00
304	GROUND SUPPORT EQUIPMENT	1.06	0.00	1.06	0.00	0.00
305	SYS TEST AND EVAL	1.52	.03	1.05	.44	0.00
307	LOGISTICS	.14	.06	.06	.02	0.00
308	GROUND OPERATIONS SUPPORT	.20	0.00	.14	.06	0.00
4	INTEGRATION TESTING	.20	0.00	.20	0.00	0.00
	RECURRING(PRODUCTION)	36.33	0.00	17.93	18.40	0.00
1	ORBITER ACCOMMODATIONS	1.02	0.00	.51	.51	0.00
2	RMS ACCOMMODATIONS	.49	0.00	.22	.27	0.00
3	PEP SYSTEMS - REF CONFIG	34.52	0.00	17.21	17.32	0.00
301	PROJECT MANAGEMENT	1.85	0.00	.75	1.10	0.00
302	SYSTEM ENG AND INTEG	2.15	0.00	.89	1.26	0.00
303	FLIGHT HARDWARE	30.21	0.00	15.56	14.64	0.00
30301	ARRAY DEPLOY ASSY	24.12	0.00	13.60	10.52	0.00
3030101	MECHANICAL/STRUCTURAL	1.12	0.00	.49	.63	0.00
3030102	ELECTRICAL POWER	.27	0.00	.10	.17	0.00
3030103	SOLAR ARRAY	21.12	0.00	12.61	8.51	0.00
3030104	AVIONICS AND CONTROL	1.33	0.00	.40	.93	0.00
3030198	ASSEMBLY AND TEST	.28	0.00	0.00	.28	0.00
30302	PWR REG AND CTL ASSY	2.79	0.00	1.34	1.45	0.00
3030201	MECHANICAL/STRUCTURAL	.15	0.00	.08	.07	0.00
3030202	ELECTRICAL POWER	1.09	0.00	.50	.59	0.00
3030203	THERMAL CONTROL	.42	0.00	.23	.19	0.00
3030204	AVIONICS AND CONTROL	.78	0.00	.34	.44	0.00
3030298	ASSEMBLY AND TEST	.35	0.00	.19	.16	0.00
30304	INTERFACE KIT	1.43	0.00	.62	.81	0.00
30398	INTEGRATION/FACO	1.87	0.00	0.00	1.87	0.00
308	GROUND OPERATIONS SUPPORT	.24	0.00	0.00	.24	0.00
309	FLIGHT OPERATIONS SUPPORT	.08	0.00	0.00	.08	0.00
4	INTEGRATION TESTING	.30	0.00	0.00	.30	0.00

Table 5. PEP Project Manpower Distribution
(Man-Years of Effort)

Elements	Phase	WBS number	FY 80	FY 81	FY 82	FY 83	Total
PEP system (excluding solar array)	Devel.			61	136	29	226
	Prod.				44	120	164
	Total			61	180	149	390
Solar array	Devel.			50	40	2	92
	Prod.				125	59	184
	Total			50	165	61	276
Total PEP system	Devel.	03		111	176	31	318
	Prod.				169	179	348
	Total			111	345	210	666
Orbiter accommodations	Devel.	01		12	40		52
	Prod.				7	7	14
	Total			12	47	7	66
RMS accommodations	Devel.	02		1	1		2
	Prod.				3	4	7
	Total			1	4	4	9
Total prime/ associates/subcontractors	Devel.			124	217	31	372
	Prod.				179	190	369
	Total			124	396	221	741