NASA Contractor Report 3319

Satellite Power Systems (SPS) Concept Definition Study

Volume II, Part 2 - System Engineering

G. M. Hanley

CONTRACT NAS8-32475
SEPTEMBER 1980

NASA

NASA Contractor Report 3319

Satellite Power Systems (SPS) Concept Definition Study

Volume II, Part 2 - System Engineering

G. M. Hanley
Rockwell International
Downey, California

Prepared for
Marshall Space Flight Center
under Contract NAS8-32475

NASA
National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

1980

FOREWORD

Volume II, System Engineering, is presented in two parts. Part 1 encompasses SPS system engineering aspects. Part 2 consists of a volume on SPS cost and programmatics; an appendix is included in Part 2 to cover the SPS WBS and cost estimates. Volume II of the SPS Concept Definition Study final report is submitted by Rockwell International through the Satellite Systems Division. All work was completed in response to NASA/MSFC Contract NAS8-32475, Exhibit C, dated March 28, 1978.

The SPS final report will provide the NASA with additional information on the selection of a viable SPS concept, and will furnish a basis for subsequent technology advancement and verification activities. Other volumes of the final report are listed as follows:

Volume	Title
I	Executive Summary
III	Experimentation/Verification Element Definition
IV	Transportation Analyses
V	Special-Emphasis Studies
VI	In-Depth Element Investigations
VII	Systems/Subsystems Requirements Data Book

The SPS Program Manager, G. M. Hanley, may be contacted on any of the technical or management aspects of this report. He can be reached at 213/594-3911, Seal Beach, California.

ACKNOWLEDGEMENTS

Since the publication of earlier Rockwell SPS cost, economic, and programmatic documentation—dating back to 1976—a continuing effort has been maintained to incorporate the latest program developments, expand the Rockwell SPS cost model; conduct comparative cost/economic analyses; prepare integrated schedules or networks; and define SPS program plans and resource requirements. The results of this work represent a professional contribution on the part of many individuals, where most of them have been with the SPS contract activity and supplementing company-sponsored efforts since the start of our effort. It is this contribution that requires acknowledgement.

The overall study activity was also supported by other business/industrial organizations and technical members of the SPS program team and their management, making it possible to reach the desired conclusions with the minimum of effort.

The Rockwell SPS program development team that contributed to the search, analyses, and results of this study are:

• Dr. L. R. Blue	Cost/Risk Programming
• W. Cooper	Cost Analysis
• D. E. Lundin	SPS Schedules/Networks
• A. D. Kazanowski	Resource Analysis

The overall SPS program development activity on SPS costs, schedules, program planning, resource analysis, and computer programming was completed under the direction of F. W. Von Flue.

The help and support of personnel from NASA/MSFC and the SPS Program Planning Office is also acknowledged.

- Engineering Cost Group
  - W. S. Rutledge
  - J. W. Hamaker
  - D. T. Taylor

- Program Plans and Requirements Group
  - W. A. Ferguson
  - H. K. Turner

CONTENTS

ILLUSTRATIONS

TABLES

1.0 SPS COST AND PROGRAMMATICS

1.1 INTRODUCTION

U.S. energy demands continue to increase dramatically and the availability of traditional energy resources have become the focal point of national/international concern and economic balance. It is therefore important that alternate sources of energy be identified and evaluated as potential solutions to the law of supply and demand. In this regard, the possibility of generating large quantities of electrical power in space and transmitting it to earth offers a conceivable solution. However, economic and technological requirements of such a program needs to be established with confidence. This volume considers the cost and programmatic requirements for a recommended satellite power system reference concept evolving from a series of contracts[1] and company-sponsored work completed by the Rockwell International Satellite Systems Division of the Space Systems Group.

The Rockwell SPS reference satellite and rectenna concept are illustrated in Figure 1.1-1. These configurations were used in the definition of costs and programmatics described in this volume. Typically, a single SPS provides 5 GW of electric power to the utility interface on the ground. The satellite is located in geosynchronous orbit and converts solar energy to dc electrical energy using large GaAlAs solar arrays at a concentration ratio of two suns. The dc electrical energy is conducted from the solar arrays to the microwave antenna where the energy is transformed to microwave RF energy. A large, 1-km-diameter, antenna beams the energy to a receiving antenna (rectenna) on the ground. The rectenna converts the RF energy, at very high efficiency, to dc electrical energy where it is collected and routed to conversion centers for subsequent input to the utility grid.

The overall scenario for SPS space transportation involvement is shown in Figure 1.1-2. Eight major elements comprise the transportation system:

- Shuttle
- SPS heavy-lift launch vehicle (HLLV)
- Electrical orbit transver vehicle (EOTV)
- Intraorbit transfer vehicle (IOTV)
- Personnel orbit transfer vehicle (POTV)
- Crew module (CM)
- Leo propellant depot
- GEO propellant depot

The SPS HLLV is used to bring construction payload, crew expendables, and propellants for the EOTV and POTV. The IOTV is used to carry payloads over short

[1] *Satellite Power Systems (SPS) Concept Definition Study* (NAS8-32475)—*Exhibit C*, March 1978; *Exhibit A/B*, March 1977; and the *SPS Feasibility Study* (NAS8-32161), August 1976.

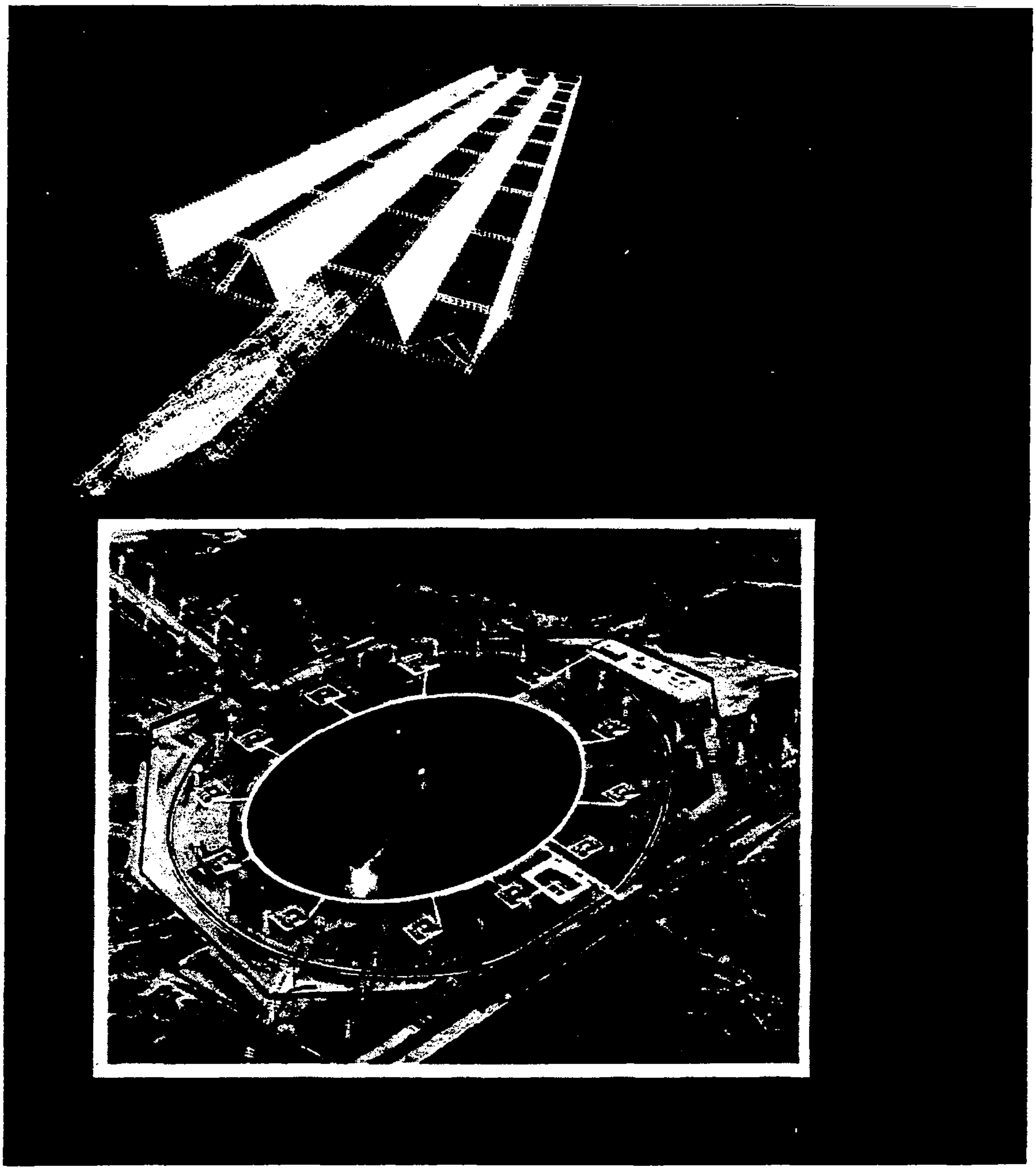


Figure 1.1-1. SPS Reference Satellite and Rectenna Concept

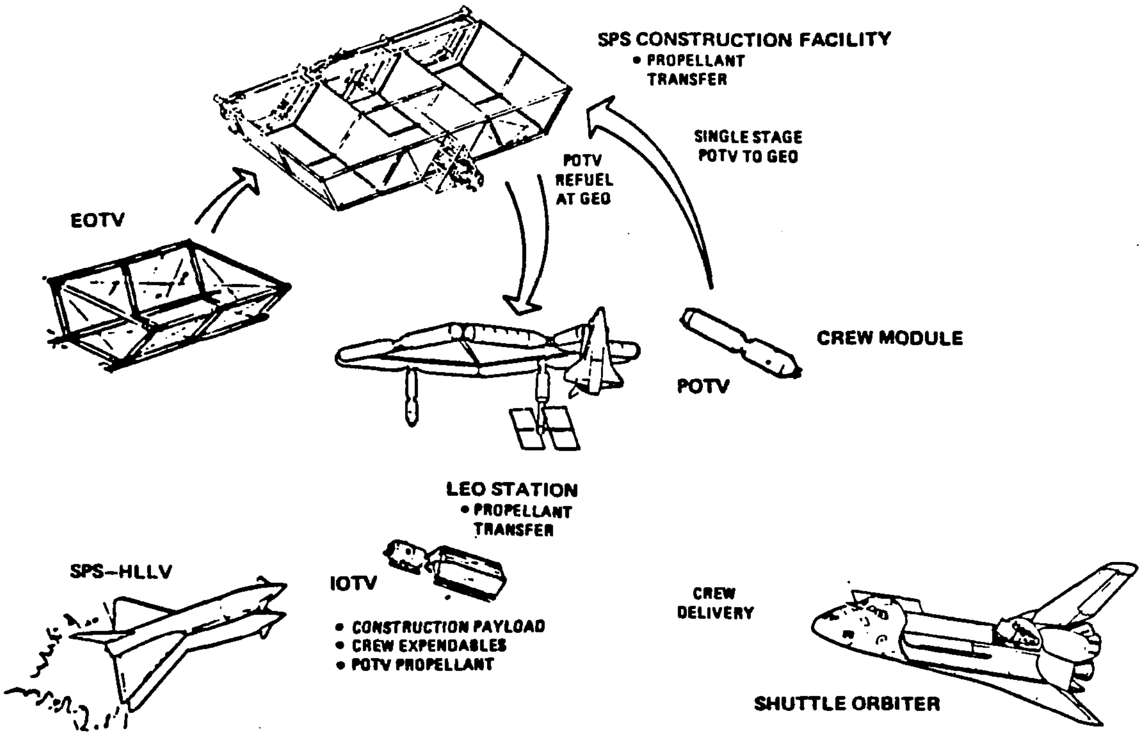


Figure 1.1-2. Transportation Operations Scenario

distances, e.g., between the SPS HLLV and the LEO station or EOTV, between the EOTV and space construction base (SCB), and between the Shuttle orbiter and the POTV. The EOTV carries payloads brought up in the HLLV between LEO and GEO. Because of the long flight duration of the EOTV, another vehicle (the POTV) is used to rapidly carry crew members between LEO and GEO. A crew module, capable of carrying 60 crew members, is needed to provide life support during crew transfer. The Space Shuttle provides transportation of crew, in its crew module, between earth and LEO.

The initial step in satellite precursor operations is to establish the LEO base as shown in the lower left of Figure 1.1-3. Crew and power modules are transported to LEO by Shuttle derivatives and assembled. When the base is fully operational, Shuttle external tanks are delivered and mated to form construction fixtures for SCB construction. Since the more economical HLLV will not be available, and since overall plans specify an EOTV test vehicle, it is probable that only the center trough of the SCB would be constructed initially. This trough would be used to fabricate the pilot plant EOTV with antenna. After proof of concept and SPS go-ahead, the remainder of the SCB would be completed, an initial fleet of EOTV's constructed, and the SCB transferred to GEO, using one or more EOTV's for propulsion and attitude control. Upon reaching GEO, satellite construction would commence, with the logistics support as shown at the right of the figure.

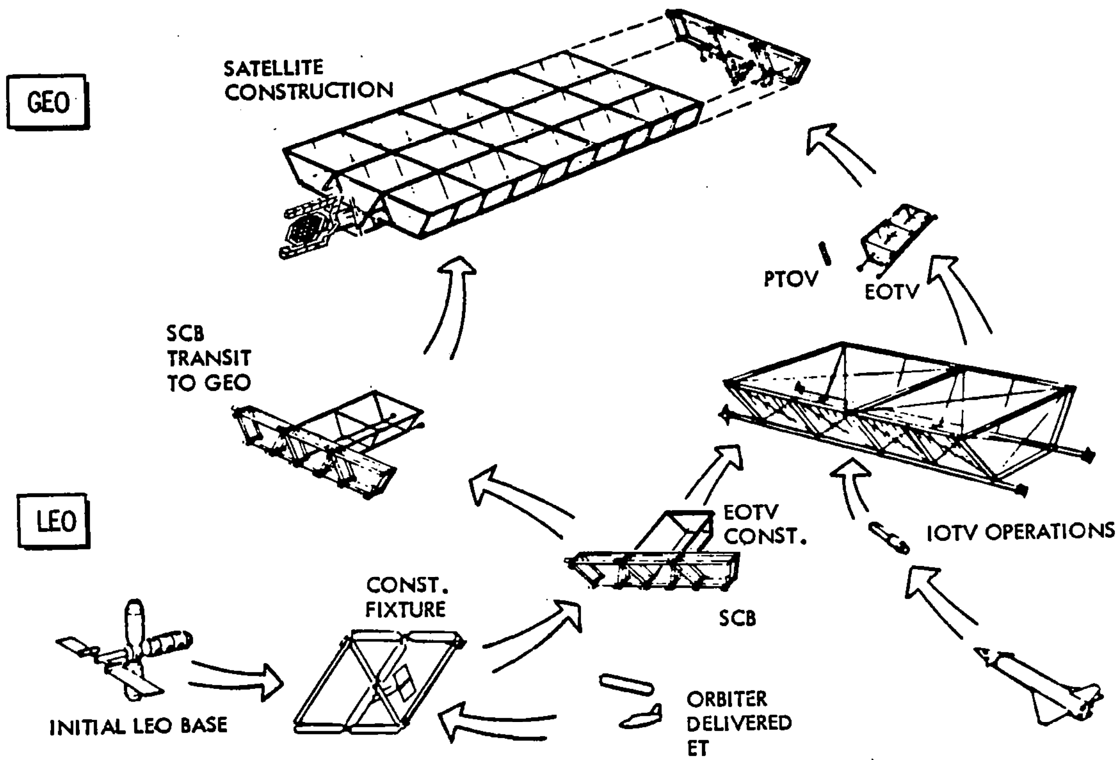


Figure 1.1-3. Overall Satellite Construction Scenario

This volume is divided into three sections that describe the program, study approach, and ground rules/guidelines (Section 1.0). Section 2.0 covers cost analysis definitions and summarizes SPS costs for each of the main elements—satellite, space construction and support, transportation/facilities, ground receiving station, and management/integration. Comparative assessments are presented along with a description of cost trades. SPS programmatic elements are presented in Section 3.0 to provide detail schedule/network information on the flow and sequence of design, development, construction, and operational activity. Included are some 13 program plans identifying operational requirements and considerations of the SPS program.

1.2 SPS GROUND RULES AND GUIDELINES

A series of ground rules and guidelines were used during the study to provide a common reference point for the uniform development of cost and programmatic elements of the SPS program. These considerations are itemized as follows.

1. The SPS WBS of Appendix A was used as the structure of program hardware, activities, and accounts.

2. Key dates of program planning:
   - 1980-1985 Ground-Based Exploratory Research Activities
   - 1981-1987 Key Technology Program Activities
   - 1990 Decision Point for SPS Commercialization (Phase C/D)
   - 2000 IOC of First SPS

3. Costs are reported at WBS level in terms of:
   (a) Development cost and TFU (theoretical first unit)
   (b) Initial capital investment average cost per satellite (Satellites TFU and No. 2 through No. 60)
   (c) Replacement capital investment (RCI) cost and operations and maintenance (O&M) cost per satellite per year

4. Cost estimates are projected in 1977 dollars and maximum use was made of past SPS studies and other associated data as appropriate.

5. SPS build rate will be two nominal 5-GW SPS systems per year for 30 years to provide a total capacity of 300 GW by 2030.

6. Overall SPS lifetime will be 30 years with minimum maintenance and no salvage value or disposition costs.

7. Complete construction and assembly will occur at geosynchronous orbit.

8. Calculations are based on 0% launch losses.

9. Program management and SE&I (management and integration) are costed at 5% of all other Level 2 costs.

10. 25% mass contingency is costed as a 15% cost contingency on SPS WBS items of the satellite (1.1), space construction and support (1.2), and transportation (1.3).

In order to promote a complete and understandable comparison of SPS concepts, and to maintain compatible economic and programmatic references, the SPS Work Breakdown Structure (WBS) Dictionary[1] was used as the baseline document for the definition and organization of program elements. This structure subdivided the program into lower-level elements within each major system grouping and associated the dictionary definition with special accounts and phases unique to the program. Accounts and phases were designated for the DDT&E; initial capital investment (covering initial procurement and placement of each SPS); replacement capital investment (capital asset replacement over the SPS operating life); and operations/maintenance (expendables and minor maintenance). This structural interface (Figure 1.2-1) provides the capability to view and analyze the SPS program from a number of programmatic, economic/cost, and management aspects. The WBS dictionary (Appendix A) was carefully maintained and updated throughout the study as the programmatic baseline.

---

[1]*SPS Work Breakdown Structure Dictionary*, National Aeronautics and Space Administration, November 1978.

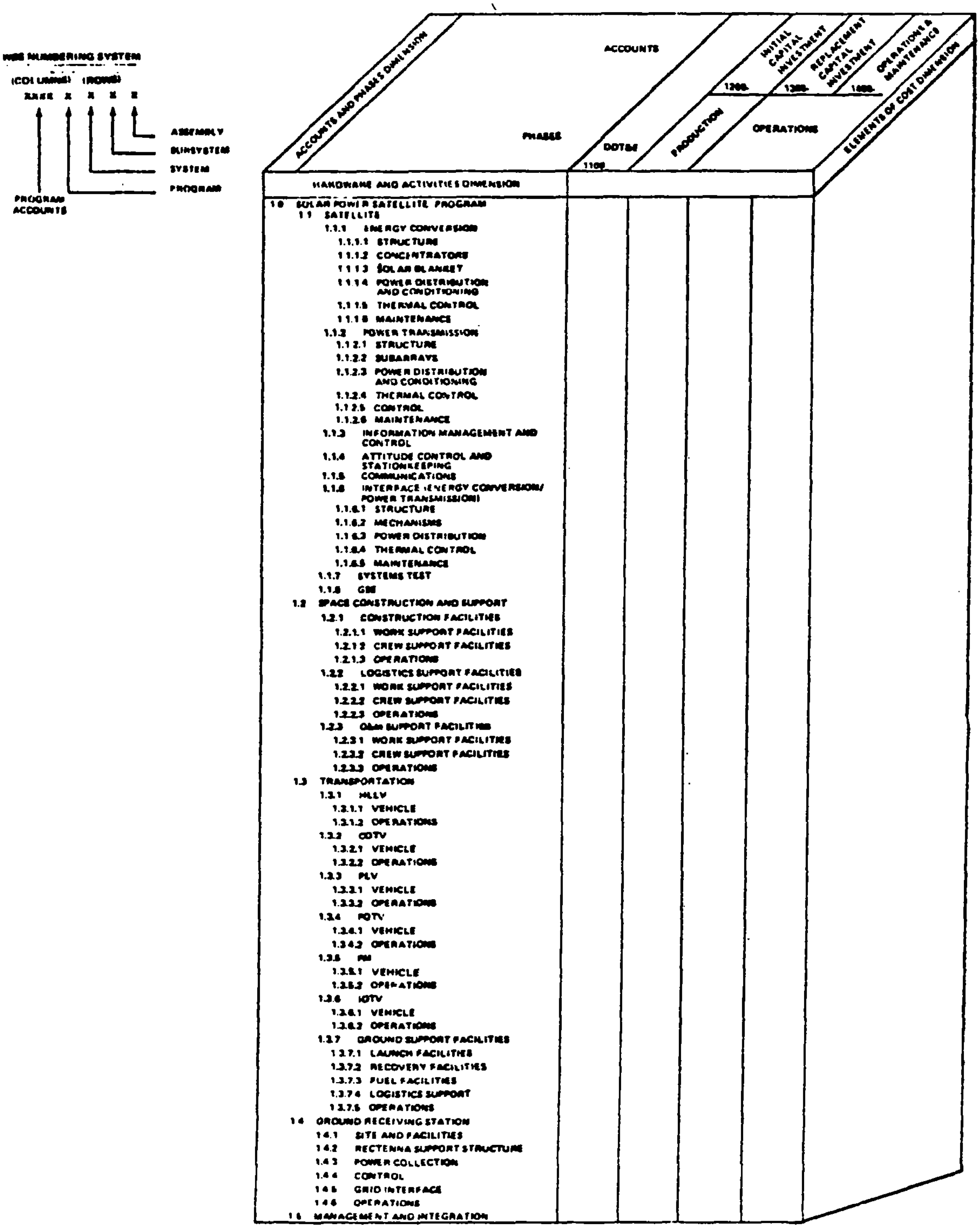


Figure 1.2-1. Satellite Power System Work Breakdown Structure

1.3 STUDY TEAM AND INTERFACES

The SPS program development group functioned as an integral part of the overall SPS studv team and participated in the progress and results of each task as it evolved. In addition to the daily interface with members of the Rockwell staff, discussions were held with representatives of the NASA/DOE. Supporting business/industrial representatives, such as those listed in Table 1.3-1, were contacted during the analysis and grass roots development of cost and programmatic estimates.

Table 1.3-1. Industry Contacts

ORGANIZATION	PURPOSE
• SME (SOCIETY OF MANUFACTURING) ENGINEERS)	OBTAIN TECHNICAL DATA ON ROBOTICALS AND TECHNOLOGY STATUS
• RIVERSIDE CEMENT CO.	RECTENNA CEMENT/CONCRETE REQUIREMENTS AND PROCESSES
• MODERN ALLOYS, INC.	METHODS & EQUIPMENT FOR CONTINUOUS PLACEMENT OF RECTENNA PANEL CONCRETE FOOTINGS
• SANDIA-SOLAR THERMAL	COMPARISON OF STTF CONSTRUCTION/HANDL-ING APPROACH WITH SPS RECTENNA REQ'TS
• TOWNSEND & BOTTUM, CONST. MGRS, 10 MW SOLAR PLANT IN BARSTOW, CA	SITE PREPARATION AND CONSTRUCTION OPERATIONS
• AMERICAN BRIDGE - A DIVISION OF UNITED STATES STEEL	STEEL REQ'TS & CONSTRUCTION APPROACH FOR INSTALLATION OF RECTENNA PANELS
• ALPHA-BETA DISTRIBUTION CENTER	ANALYSIS OF MATERIALS HANDLING SYSTEMS
• CATAPILLAR	EARTH MOVING & GRADING EQUIPMENT
• INTERNATIONAL HARVESTER	EARTH MOVING & GRADING EQUIPMENT
• SOUTHERN CALIFORNIA EDISON	DC/AC POWER DISTRIBUTION LINES/TOWERS

1.4 STUDY APPROACH

The objective of the study was to provide NASA with additional, accurate, and sufficient data and information to enable the selection of preferred viable SPS concepts by CY 1980 as a basis for subsequent technology advancement and verification activities in the CY 1980-1987 time frame. In this regard, the cost and programmatics contribution is documented in this final report. The results of each task evolved from two major activities: (1) a review and update of contract Exhibits A and B costs as reported in April 1978; and (2) the extensive analysis, selection, and determination of cost estimates, along with program plans/schedules applicable to the newly selected Rockwell SPS reference configuration of Exhibit C—especially the expansion of transportation and ground-receiving station data bases. All results of this work were consistent with SPS ground rules/guidelines and contract requirements covering four areas as detailed in the study plan:

- Cost Analysis
- Schedules/Networks
- Planning Packages
- Program Plans

Figure 1.4-1 identifies the close interrelationship of these tasks, the source of data, and the flow of cost and programmatic information into applicable final report volume such as this Part 2 of Volume II—Systems Engineering that summarizes the activity in all areas.

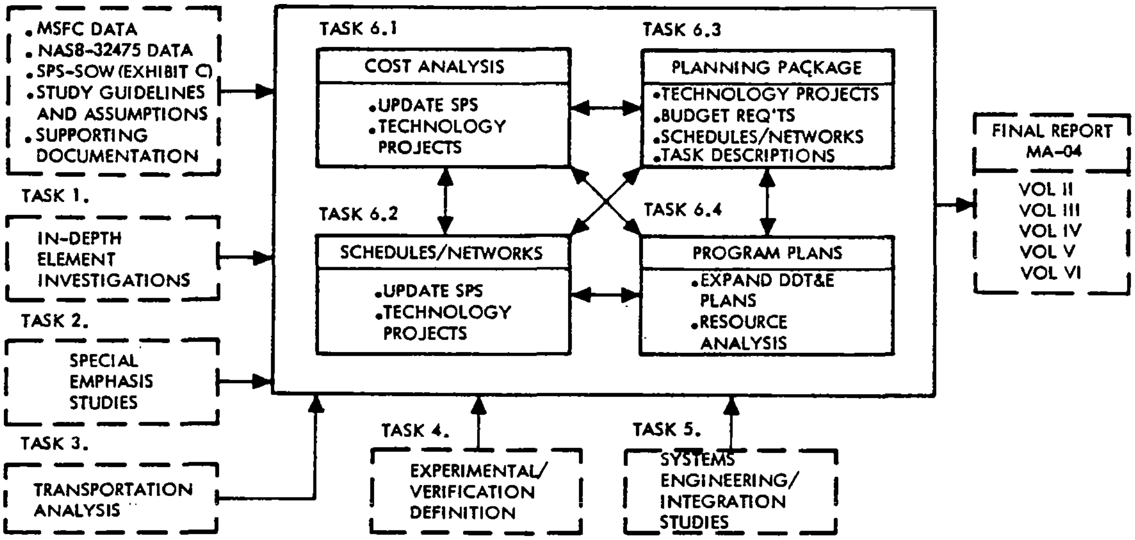


Figure 1.4-1. Cost and Programmatic Approach

2.0 COST ANALYSIS

2.1 INTRODUCTION

Results of SPS cost analyses, trades, and sensitivities are described in this section. Cost estimates of the Rockwell SPS baseline concept were updated in June of 1978, and shortly thereafter the reference NASA SPS concept replaced the earlier configuration. It is the reference configuration, with some design improvement, that was used in the development of cost and programmatics. The following discussion covers the costing approach/methodoloy; cost-effectiveness results; and SPS cost estimates, including time-phased costs of DDT&E and TFU.

2.2 SPS COSTING APPROACH

The SPS cost analysis has been performed on the Rockwell reference configuration discussed in this report. The Exhibit C study considered an SPS option of 60 units with an IOC in the year 2000 and the full 300-GW capability to become operational at the rate of two SPS's or 10 GW per year. The Rockwell cost model was structured to the NASA SPS Work Breakdown Structure and Dictionary of November 1978, utilized the MSFC CER data base, and incorporated grass roots analyses and information from the Rockwell CER data base. This continuous interaction to seek and establish better cost estimates has resulted in a higher degree of confidence in the resultant cost estimates, as compared with those of the Exhibit A/B final report. While the cost estimating relationships were developed to be as accurate as possible, it is too early in the definition process of the SPS to precisely predict either the final system point design or point estimate. However, it is believed that another step has been taken to predict the direction and relative magnitude of cost impacts and to aid in design determination/decisions of preferred concepts.

There are basically four types of cost equations in the model, corresponding to the four WBS accounts—DDT&E, initial capital investment, replacement capital investment, and operations and maintenance. The cost methodology is shown in detail in Appendix B as it covers CD (DDT&E), CTFU and CIPS (initial capital investment); CRCI (replacement capital investment); and CO&M (operations and maintenance). Appendix B also provides a brief narrative description of each CER, its application, input data, and the calculated value for each type of costs.

The DDT&E equation (CD) estimates the cost of design, development test/evaluation and non-recurring costs. Separate factors were utilized to calculate the proportional assessment for management and integration and as a cost contingency for mass growth. In view of the gross nature of the level of information currently available on WBS 1.1.7—System Test (hardware/operations) and Ground Support Equipment—the cost of systems test was assumed at 100% of the satellite system ICI cost; whereas GSE was factored at 10% of the satellite DDT&E cost through 1.1.7.

The applicable total system mass, area, or power was used as the inputs for DDT&E CER's. A development factor (DF) is included in the equation to adjust the cost to reflect only that portion of the total system mass, area, or power considered to be necessary for development of the complete system where it is not required to develop the total mass, area, or power. The CD cost equation also allows for the application of a complexity factor (CF) to adjust the cost results when it is determined that the item being estimated is either more or less complex than the CER base data.

The initial capital investment (ICI) cost equations estimate the initial capital investment cost of hardware items as a function of their mass, area, or power. The ICI cost equation is expressed in several different forms—CLRM, CTFU, CTB, and CIPS. The CLRM (cost of lowest repeating module) equation requires that the point estimate correspond to the mass, area, or power of the lowest repeating module (M). This is necessary because of the physical scale of the SPS and the production quantities required for many of the hardware elements. It is not reasonable to estimate the SPS initial capital investment cost as a historical function of the entire SPS mass, area, or power. Rather, it is desirable to cost the number of repeating modules required per satellite to establish the satellite theoretical first-unit cost (TFU), and then input the satellite TFU cost into a progress (learning) function for the quantity of satellites required to calculate the average unit cost (IPS). This calculation involves two steps in the cost equations. The first step (CLRM) is simply the portion of the equation which estimates the theoretical first repeating module cost as discussed above. The second step (CTFU) has the progress function incorporated into the equation for the quantity of repeat modules required per satellite. This is automatically taken into account with the progress over production quantities as required when calculating the cost to build (CTB). CTB calculations are then factored on the basis of a requirement to construct an SPS divided by the option quantity.

At the current level of SPS definition, it was difficult to define a repeating module. It is often impossible to know with any certainty just what portion of the total mass is appropriate to run through the equation as a module. It is just as difficult to identify how many distinct types or designs of modules will be required for any subsystem or assembly. In such cases, the study simply assumed a module mass (or area or power) based on an engineering best judgment.

Replacement capital investment (CRCI) CER's provide for the multiplication of the annual spares fraction (R) of each system by that system's cost to arrive at an RCI cost per satellite per year.

Operations and maintenance costs (CO&M) are estimated in terms of O&M cost per satellite per year. O&M costs include those expenditures incurred in day-to-day operations, beginning with SPS initial operating capability (IOC) and continuing over the life of each satellite. They consist of wages of O&M personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for delivery and transfer of on-orbit personnel, and cargo resupply of expendables and consumables, etc. O&M costs are calculated by the use of a direct cost input or by an annual factor per SPS times the cost to build the particular system.

The cost methodology seeks to account for five separate effects which influence SPS cost: scaling, specification requirements, complexity, the degree of automation, and production progress. Scaling refers to the relationship in cost between items varying in size, but similar in type. Economies of scale usually ensure that such a relationship will not be strictly linear, but rather as size increases the cost per unit of size will decrease. The scope of this relationship is reflected by the equation exponent which results from the regression analysis of the data used to develop the cost estimating relationship.

Specification requirements have been accounted for by normalizing the CER data base to manned spacecraft specification levels, using factors from the RCA price model.[1] From that model, an average cost factor to adjust MIL-SPEC to manned spacecraft is around 1.75 for DDT&E and 1.6 for production cost. Under the assumption that some relaxation of Apollo-type specifications can be made for the SPS, a factor of 1.5 was assumed for both DDT&E and production cost. Furthermore, it was assumed that a factor of 3.0 would adjust commercial specifications to SPS requirements; therefore, military or commercial cost data used in the CER's were adjusted upward by factors of 1.5 and 3.0, respectively.

The cost equations allow a complexity factor input to adjust the cost result when it is determined that the item being estimated is either more or less complex than the listed CER data base.

The degree of automation is accounted for in certain cost equations through an adjustment to the CER coefficient by the tooling factors given in Appendix B. The effect of tooling is dependent upon the annual production rate. Higher production rates allow harder tooling and, thus, effect cost reductions. The tooling factors are used only on those CER's which are based on historical aerospace programs with limited annual production rates. Tooling factors are not used (and thus are not exercised as part of the equations in Appendix B tables) on those CER's which are based on data already reflecting automated production techniques (e.g., the commercial electronics data for the microwave antenna CER).

Finally, the decreasing cost effects of progress, due to production process improvements or direct labor learning, are accounted for through standard progress functions. Many SPS components will be mass-produced in a capital intensive manner and will experience little labor learning. Other SPS hardware items, however, will be produced at very low annual rates much in the labor intensive manner of historical spacecraft programs and would therefore experience learning. (Technically distinguishable from learning—but still predictable with the same form of exponential function—are the effects of production process improvements. In this model, when progress functions are used, they are meant to account for both of these effects.) A constant relationship has been assumed between the progress fraction and the annual production rate.

---

[1] *Equipment Specification Cost Effect Study, Phase II, Final Report,* November 30, 1976, by RCA Government Systems Division.

As required by the costing ground rules and assumptions, all CER's are in terms of 1977 dollars. The study did assume 1990 technology and 1990 supply/demand conditions which, in some cases, resulted in differential (non-general) price inflation or deflation between 1977 and 1990 being included in the CER's. Specifically, it was assumed that composite raw material prices and some electronic component prices will decrease relative to general prices, while aluminum coil stock prices will increase relative to general prices. Such effects are allowed for by the CER's but only to the extent that the expected price changes differ from expected general price changes. The CER's affected are those for the antenna structure, power source structure, and microwave antenna.

2.3 SPS COST ESTIMATES

Total program costs were developed for WBS sub-level elements of DDT&E, production, launch, orbital assembly/construction, ground operations, replacement capital, and operations/maintenance. This section will present summarized cost data and describe the elements contained in each program phase.

Tables 2.3-1 and 2.3-2 summarize cost information for each main segment and phase of the SPS program. Table 2.3-1 shows development cost data through the first full 5-GW operational satellite (TFU) including space transportation, construction, operations, and the ground receiving station plus grid interface and facilities needed to establish the SPS operational capability of the ground and space segments. As such, all cost estimates for the TFU include systems, equipment, facilities, and machinery that have a service life capable of building more than one SPS. Table 2.3-2 summarizes (1) the investment per satellite (including ground station) of the option of 60 SPS's at a build rate of two 5-GW systems per year, and (2) the annual cost per satellite for replacement capital and operations/maintenance. Figure 2.3-1 illustrates a distribution of the costs as the program moves through its phases of DDT&E, TFU, and production/operations. The investment per satellite (average cost) includes the cost to build a 5-GW satellite, ground receiving station, and apportioned transportation/space construction requirements.

Table 2.3-1. SPS Program Development Cost

		DEVELOPMENT		
WBS #	DESCRIPTION	DDT&E	TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33401.762	51103.242	84505.000
1.1	SATELLITE SYSTEM	7933.570	7950.922	15884.492
1.2	SPACE CONSTRUCTION & SUPPORT	7331.160	8602.523	15933.703
1.3	TRANSPORTATION	12468.316	22866.199	35335.016
1.4	GROUND RECEIVING STATION	115.699	3618.727	3734.427
1.5	MANAGEMENT AND INTEGRATION	1392.463	2151.918	3544.382
1.6	MASS CONTINGENCY	4160.031	5912.945	10072.977

Table 2.3-2. SPS Program Average Cost

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	13877.668	451.531	193.713	645.244	14522.910
1.1	SATELLITE SYSTEM	5325.422	205.265	0.705	205.970	5531.391
1.2	SPACE CONSTRUCTION & SUPPORT	1148.332	51.428	11.274	62.701	1211.033
1.3	TRANSPORTATION	1949.004	119.343	80.869	200.212	2149.216
1.4	GROUND RECEIVING STATION	3590.822	0.275	78.377	78.652	3669.474
1.5	MANAGEMENT AND INTEGRATION	600.679	18.815	8.561	27.377	628.055
1.6	MASS CONTINGENCY	1263.413	56.405	13.927	70.332	1333.745

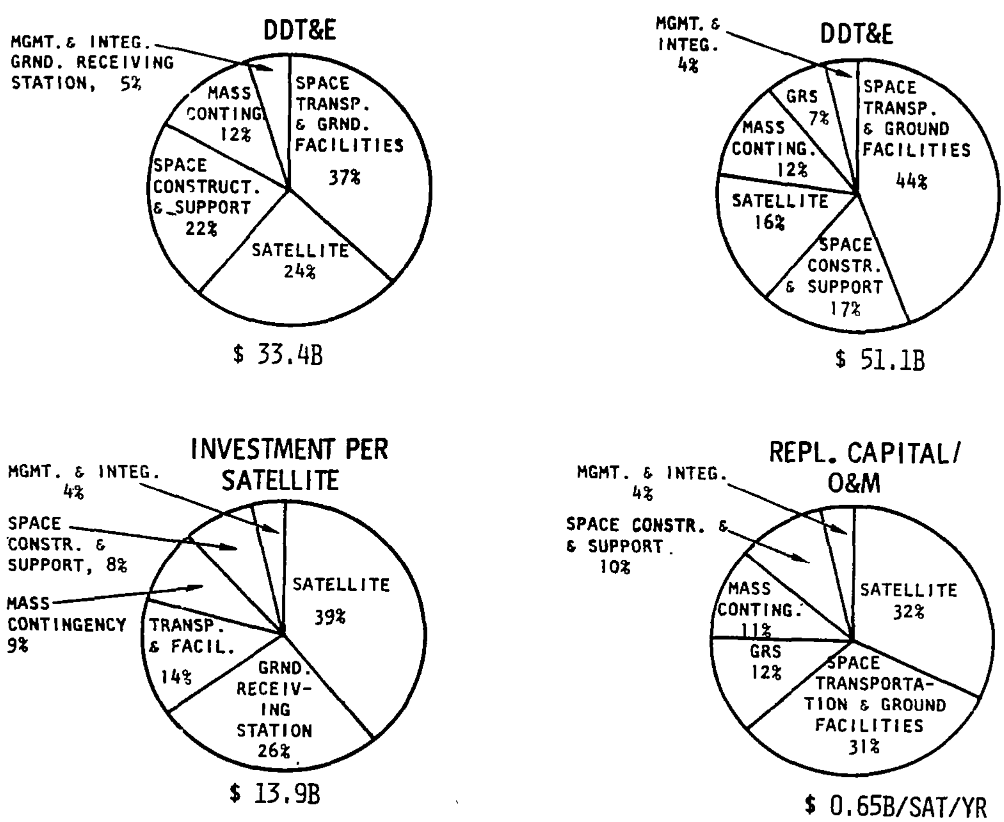


Figure 2.3-1. SPS Cost Relationships

DEVELOPMENT COST

The DDT&E phase consists of the one-time effort associated with designing, developing, and evaluating the components, subsystems, and systems required for the SPS project. It includes the development engineering, testing, and support necessary to translate a performance specification into a design. It encompasses the preparation of detailed drawings for system hardware fabrication, system integration and—depending on the system, subsystem, or component—structural, environmental, and other required tests. It includes the early supporting research and technology analyses, advanced study efforts and requirements definition related to the SPS microwave power transmission system, power conversion, structure and assembly and power distribution; component development; integrated ground test programs; the Geosat space tests and LEO Shuttle sortie demonstrations, both shared and dedicated. It also includes related Shuttle-derived HLLV transportation systems and development of an SPS prototype demonstration test article which, following demonstrations, will be upgraded to an operational EOTV. Also included are the analyses of data and the necessary redesign and retest activities to meet specifications; and ground support equipment, special test equipment, and other program-peculiar costs not associated with repetitive production. All DDT&E effort associated with SPS-related support systems such as transportation, space construction base, and assembly/support equipment necessary to accomplish the satellite DDT&E phase is also included.

DDT&E and TFU costs are combined in Figure 2.3-2, identifying major percentiles that make up the $84.5 billion total. The SPS VTO/HL HLLV is a main contributor to the space transportation requirement along with the rectenna

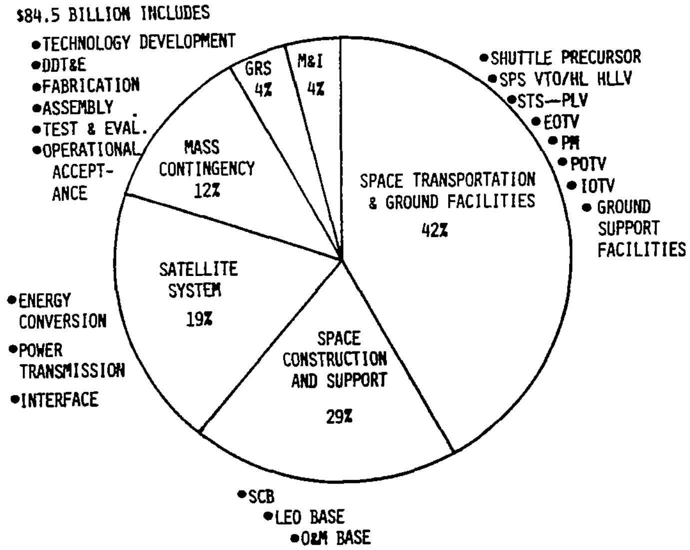


Figure 2.3-2. Cost Relationship Through the First SPS

support structure/power collection elements of the ground receiving station. TFU space transportation at $19.67 billion is divided among vehicle fleet and operations breakdowns as shown in Figure 2.3-3, where the SPS VTO/HL HLLV identifies a five-vehicle requirement and 234 round-trip flights. Space Shuttle

VEHICLE	TFU COST	GOZINTOS
SPS VTO/HL HLLV (1.3.1) • FLEET • OPERATIONS	$9530.5	• 5 VEHICLES • 234 R.T. FLIGHTS
STS - PLV & CARGO/EM (1.3.3) • FLEET • OPERATIONS	$6251.2	• 4 VEHICLES • 3 ORBITERS • 261 E.T.'S • 10 LRB'S • 3 CARGO/EM • 261 RT FLIGHTS
EOTV (1.3.2) • FLEET • OPERATIONS	$3625.7	• 6 VEHICLES • 7 FT FLIGHTS
POTV (1.3.4) PM (1.3.5) IOTV (1.3.6) • FLEET • OPERATIONS	$ 263.8	TFU FLEET WILL BUILD: • EOTV TEST ARTICLE • LEO BASE • SCB • FIRST SATELLITE
	$19671.2 x 10^6	

Figure 2.3-3. TFU Space Transportation

requirements represent vehicles and operations of the traffic model necessary to build the TFU and complete precursor activities covering the early program microwave test article, LEO base, satellite construction base (SCB), initial EOTV's; and to provide personnel during TFU fabrication/assembly and checkout activities. The SCB comprises over 76% of the $8.6 billion estimated for space construction and support, with about $4 billion required in work support facilities, and $2.6 billion in crew support facilities. Energy conversion (25%) and power transmission (48%) comprise the majority of satellite system costs projected at $7.95 billion. The TFU GRS breakdown identifies 88% of the cost in the rectenna support structure and power collector, with major costs in the steel panel/installation and antenna array elements as shown in Figure 2.3-4.

Costing of DDT&E for the space base elements, STS-HLLV, and the assembly and support equipment followed the more conventional method of determining DDT&E cost—that is, based upon total subsystem mass, area, or power. This technique was used mainly from the standpoint that the cost data utilized to develop the applicable CER's for these elements were comparable and were developed on the basis of total subsystem mass, area, or power. In the case of the satellite, comparable historical DDT&E cost data were just not available for the magnitude of the satellite subsystems.

In view of the physical size of the satellite subsystems and the large quantities required for certain parts and components, it was not considered reasonable to estimate the satellite subsystem DDT&E costs as a function of the total mass, area, or power per satellite as is generally the method. Rather, it was considered desirable to determine the satellite subsystem DDT&E costs by the application of a development factor.

WBS ELEMENT	GOZINTOS	TFU COST ($ x 10^6)
RECTENNA SUPPORT STRUCTURE (1.4.2)	• STEEL PANEL FAB & INSTALL (92%) • TRENCHING & CONCRETE	1849.6
POWER COLLECTION (1.4.3)	• ANTENNA ARRAY ELEMENTS (83%) • POWER DISTRIBUTION • INSTALLATION & CHECKOUT	1353.2
SITE & FACILITIES (1.4.1)	• LAND & PREPARATION • ROADS & BUILDINGS • UTILITIES & MAINTENANCE EQUIP.	195.2
GRID INTERFACE (1.4.5)	• ELECTRICAL EQUIPMENT • TOWERS	145.7
CONTROL (1.4.4)	• CONTROL CENTER EQUIPMENT • CONTROL ELECTRONICS	75.0
		$3618.7 x 10^6

Figure 2.3-4. TFU Ground Receiving Station

The development factor was determined by engineering and, in general, was estimated at a factor considered appropriate to the development of total system or subsystem based on parameters of mass, area, or power. In some cases it was determined that the factor should be slightly higher or directly related to the development scenario of the particular system. For example, crew and work support modules of the LEO, SCB, or satellite operations and maintenance base are of common design but required at different times of the program. Appropriately then, development factors were assessed at 100% for modules required at the first point of usage, whereas a factor of lesser value was used on subsequent modules as a means of compensating for subsequent development or design integration costs.

INVESTMENT AND OPERATIONS

Investment and operations costs developed during the study were presented in Table 2.3-2 and Figure 2.3-1. Investment costs were developed at two levels —initial capital investment (ICI) which is the cost of production, assembly, installation, transportation, and testing of each individual satellite produced, ground station system, and associated effort necessary to bring the power satellite on line to a full 5-GW operational capability; and replacement capital investment (RCI) which are those expenditures relating to capital asset replacement and major maintenance overhauls that are expected to last for more than one year and result in an improvement to the operating system. Replacement capital requirements for the systems used to construct the satellite through IOC are included in the initial capital investment costs. Costs for the fleet, for example, needed to support O&M, are estimated and included as replacement capital investment. Operations costs consist of the effort required to operate and maintain the SPS project over its operational lifetime.

Investment per satellite is equivalent to the average unit cost of the total SPS requirement (TFU plus Satellites 2 through 60). This total average cost of $13.88 billion includes a 15% cost contingency for growth in the mass of WBS elements 1.1, 1.2, and 1.3. Satellite system costs of $5.33 billion are made up of power transmission (59%) and energy conversion (35%). The GRS estimate of $3.59 billion is primarily in the rectenna support structure and power collection system. SPS replacement capital and operations/maintenance phases are estimated at a total annual cost of $0.65 billion per year per SPS. The total average (investment) cost per nominal 5-GW satellite yields an investment cost of $3010/kW.

An analysis of potential major cost drivers (Table 2.3-3) was prepared for the Rockwell SPS CR-2 reference configuration of March 1979. Over 90% of the costs are represented within each program phase DDT&E, TFU, average satellite, and RCI/O&M. Close review will show that certain elements are consistently cost drivers requiring programmatic studies and analyses of SPS design and technical approaches.

Table 2.3-3. Potential Cost Drivers
Rockwell SPS Reference Configuration (March 1979)

MAJOR PROG. ELEMENT	DDT&E	TFU	AVG. SATELLITE	RCI/O&M
	$33.40B	$51.10B	$13.88B	$0.65B/SAT/YR
PERCENTAGE OF TOTAL	95%	96%	91%	90%
Satellite Syst. (1.1)	21% • Ground test hardware & operations • Power transmission • Precursor EOTV	15% • Power transmission • Energy conversion • EOTV test article	36% • Power transmission • Energy conversion	30% • Power transmission
Space Construction & Support (1.2)	22% • Space construct. base • LEO base	15% • Space construct. base • Satellite O&M base	7% • Satellite O&M base	5% • Space construct. base
Transportation/Ground Facilities (1.3)	35% • SPS VTO-HL HLLV • Ground facilities • Pers. launch vehicle	44% • SPS VTO-HL HLLV • PLV • EOTV • Ground facilities	12% • SPS VTO-HL HLLV • PLV	28% • SPS VTO-HL HLLV • PLV
Ground Receiving Station (1.4)		6% • Rectenna support structure • Power collection	23% • Rectenna support structure • Power collection	12% • Operation
Management/Integration (5%) and Mass Contingency (15%)—(1.5, 1.6)	17% • Management & integra. • Mass contingency	16% Management & integra. Mass contingency	13% • Management & integra. • Mass contingency	15% • Management & integra. • Mass contingency

SPS COST BY YEAR

A spreading function curve (ojive) was used in the time-phasing of costs against each main line item of the SPS WBS at a subsystem level. The cost spreading was projected for DDT&E and TFU costs by using various functions between the 20/80 and 80/20 curve spread. This approach provided distributions supporting a low front-end buildup with the flexibility to shift costs in a manner suitable to the phasing of subsystem development and start-up requirements.

Table 2.3-4 summarizes full-scale DDT&E and the incremental cost buildup leading to the TFU IOC by the year 2000. A relatively low profile prevails through the 1980's, reflecting activity of the ground-based experimental research and technology development programs on power transmission, PD&C, energy conversion, large space structures, and space transportation. The costs expand rapidly through the mid/late 1990's as the DDT&E activities accelerate and the Phase C/D programs begin on the satellite, space operations, transportation, and ground receiving station including facilities and equipment for hardware buildup in support of early launches, ground operations, and space construction tasks.

Table 2.3-4. DDT&E Plus TFU Cost By Year ($ Millions).

YEAR	1.1	1.2	1.3	1.4	1.5/1.6	TOTAL
1980	0.16	0.0	7.07	0.0	2.10	9.32
81	1.55	0.0	47.26	0.00	14.15	62.96
82	5.41	0.0	121.37	0.02	36.81	163.61
83	12.54	0.0	222.25	0.05	68.44	303.26
84	23.96	0.0	342.31	0.09	107.34	473.71
85	44.17	0.0	473.73	0.14	151.74	669.78
86	77.57	0.0	608.27	0.20	199.80	885.83
87	126.38	127.61	777.32	0.25	249.03	1281.19
88	194.19	700.97	1060.75	0.29	299.25	2255.49
89	304.04	1385.59	1379.05	0.33	525.73	3594.75
90	407.19	1812.37	1742.91	1.35	911.76	4935.58
91	670.72	1760.71	2281.03	2.03	1240.52	5955.59
92	940.40	1158.46	2857.09	93.87	1491.14	6530.96
93	1445.59	501.35	3082.37	364.65	1613.62	7007.59
94	2047.66	659.73	3426.80	663.12	1628.74	8426.14
95	2534.40	1386.53	4017.93	798.15	1528.12	10265.13
96	2601.31	1900.73	4358.34	759.63	1324.23	10944.24
97	2202.48	1963.53	3957.70	601.30	1040.33	9770.32
98	1423.47	1557.52	2848.46	341.65	710.51	6881.62
99	603.99	836.79	1452.49	96.89	379.71	3369.76
2000	157.39	176.82	269.81	10.40	103.67	718.08
	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0
TOT	15884.46	15933.69	35334.97	3734.42	13617.33	84504.87

Figure 2.3-5 graphically displays the funding requirements and peak year distributions for DDT&E and TFU, where DDT&E costs peak at $4.27 billion in 1991. This time period corresponds to the activation of Phase C/D operations on the TFU. The TFU costs peak at $9.18 billion in 1996, which is the period of system/hardware production.

2.4 COST EFFECTIVENESS

During the study, a number of analyses were completed on the satellite, transportation, space construction, and ground station elements of the SPS program to develop specific system requirements for use in costing. These included traffic models, mass statements, system definitions, vehicle usages, and trade studies for cost assessments. The majority of these parameters are included in the discussions with appropriate CER's submitted in Appendix B.

Study activities completed under the Exhibit C contract include:

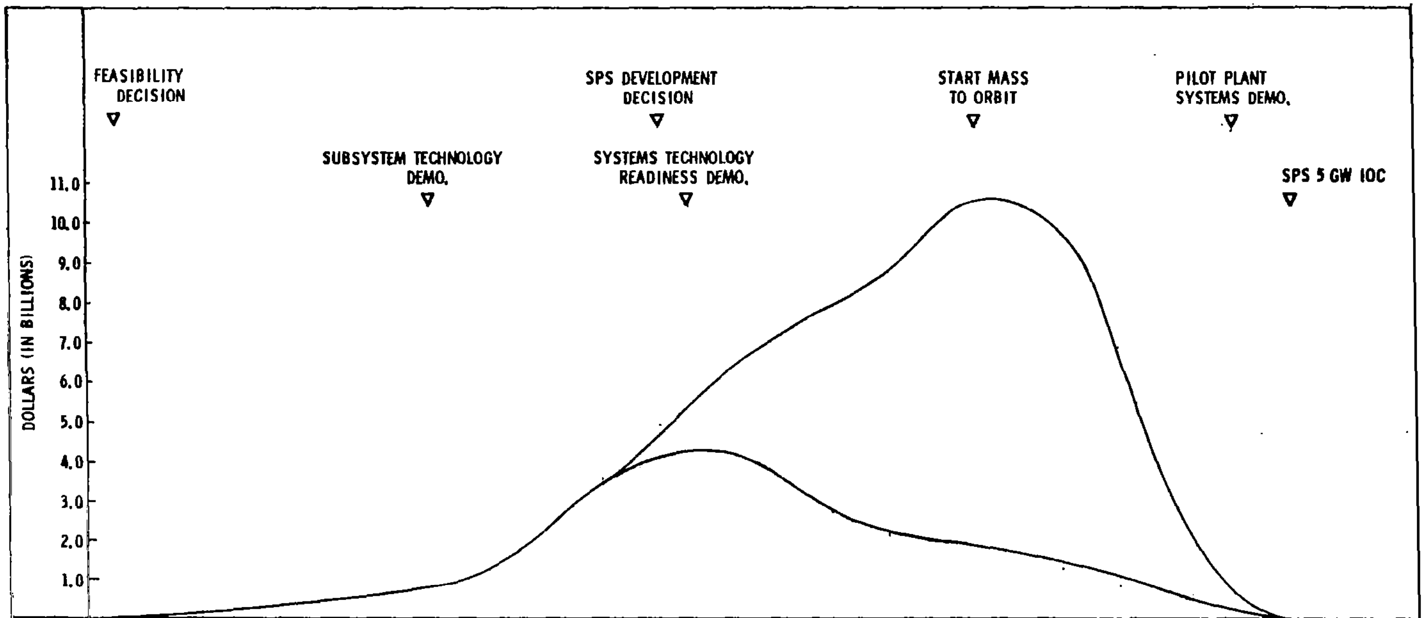
- A detail review and update of SPS economic/cost data as completed and submitted on the Rockwell SPS Point Design Concept of June 1978, focusing on operational requirements of the satellite, ground receiving station (rectenna), and transportation systems for that configuration. The analysis of space transportation elements identified construction and operations/maintenance flights, vehicle usages, and fleet attrition/spares.

- CER's were implemented and programmed on the computer as supplemented with the results of grass roots analysis and engineering assessments based on cost information in the NASA data base, Rockwell contracts, and company-sponsored studies.

- A transportation system study normalized cost data from NASA/Boeing contracts and the Rockwell Shuttle Growth contract study to project costs on the VTO-HL HLLV, Space Shuttle, orbiter, and PLV.

- A grass roots analysis was completed on the GRS to establish rectenna panel, concrete, power distribution, and supporting system costs. The results were compiled into line item estimates and total costs for GRS DDT&E, TFU and investment.

A rectenna panel payback analysis was completed to determine the cost effectiveness of a panel located in the perimeter of the rectenna farm. Revenue calculations were based on the incident microwave power per panel in the outer edge (Zone V) of the rectenna, as shown in Figure 2.4-1. The annual revenue from electric power was based on 40 mils per kWh, or $350 per year. An average cost of $5000 per panel was projected for the fixed costs, including some mark-up. Variable costs per panel considered replacements and O&M projections. Figure 2.4-2 identifies a payback period for panels in Zone V as varying from 3.5 to 14 years. However, the analysis shows that a panel intercepting 6 W/m^2 can break even in a 30-year period.



YEAR	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	TOTAL ($B)
DDT&E	0.009	0.063	0.164	0.303	0.474	0.670	0.886	1.281	2.256	3.363	4.125	4.266	3.699	2.753	2.203	2.070	1.769	1.316	0.893	0.606	0.233	0	33.402
TFU	0	0	0	0	0	0	0	0	0	0.232	0.810	1.690	2.832	4.254	6.223	8.195	9.175	8.454	5.988	2.764	0.486	0	51.103
TOTAL	0.009	0.063	0.164	0.303	0.474	0.670	0.886	1.281	2.256	3.595	4.935	5.956	6.531	7.007	8.426	10.265	10.944	9.770	6.881	3.370	0.719	0	84.505

Figure 2.3-5. Time-Phased DDT&E and TFU Costs

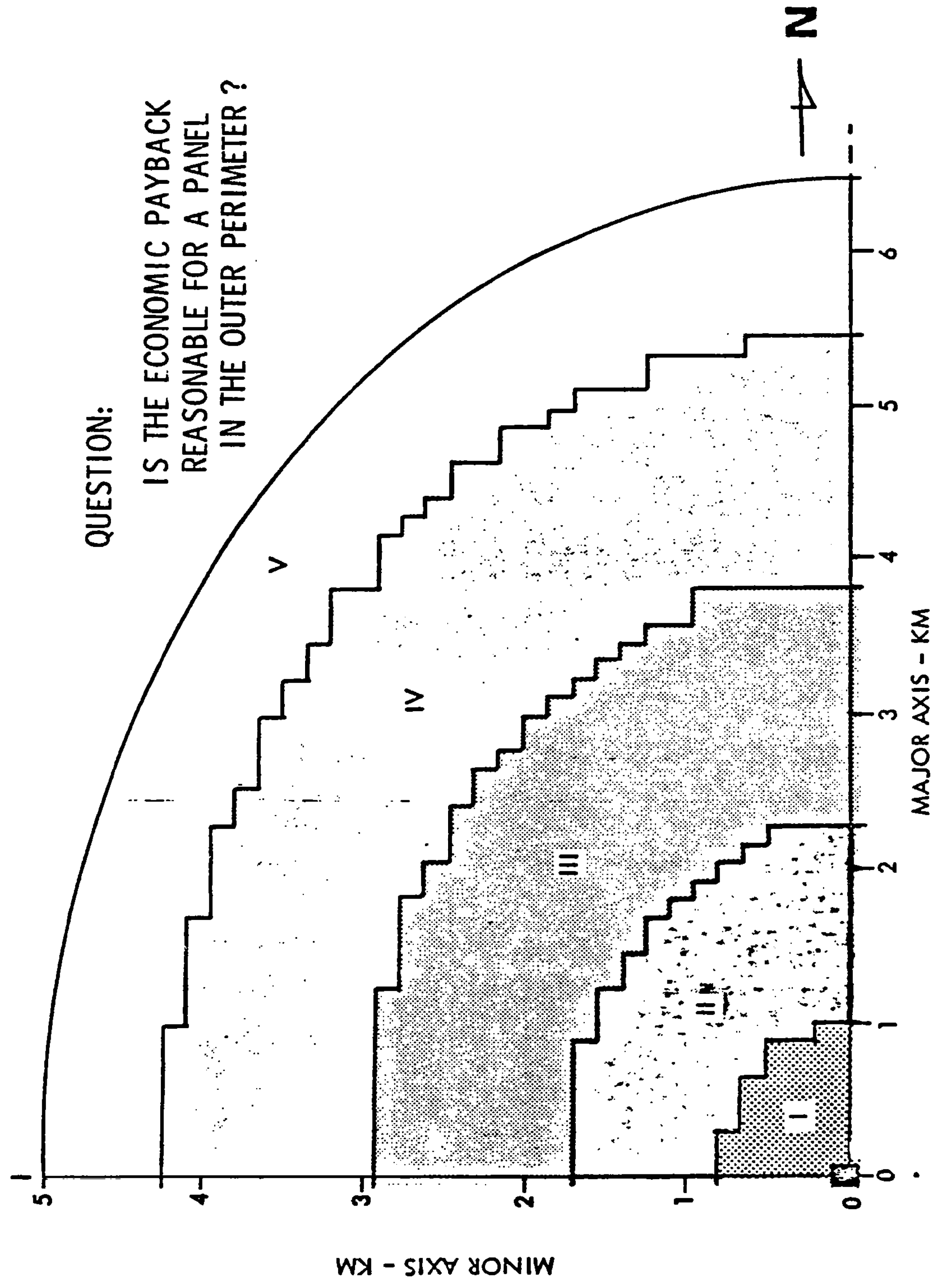


Figure 2.4-1. Rectenna Panel Payback

3.0 SPS PROGRAMMATICS

3.1 INTRODUCTION

This section presents SPS program plans for the implementation of Phase C/D activities leading to the initial operational capability of the first SPS by the year 2000. These plans describe SPS program schedules and networks, critical items of system evolution/technology development, and the natural resource analysis.

Most key technological issues (as described in Volume III) will have been resolved prior to the main Phase C/D effort and, therefore, technology in that sense is not the real concern of this section of the report on plans. Rather, the size of the SPS undertaking, its producibility, testing, logistics, facilitization, and support requirements dictate the main program plan areas covered in this section (Table 3.1-1). As a secondary objective, planning areas requiring substantial effort in the immediate future were identified. This work concentrated on the definition of specific problems, the solution of which might require the longest lead times for accomplishment or implementation.

Table 3.1-1. SPS Program Plans

• Program Management	• Product Assurance
• Systems Engineering and Integration	• Facilities
• Design and Development	• Ground Operations
• Systems Testing	• Space Operations
• Ground Support Equipment—D&D	• Launch Operations
• Manufacturing	• Specification Tree
	• Natural Resource Analysis

The SPS is a vast undertaking, requiring commitments of significant magnitude and long duration. Therefore, a well planned and funded SPS program is essential and the orderly, in-phase development of program plans is necessary to the accomplishment of long-range objectives and in permitting budgetary requirements to be established with sufficient lead time to assure commitment.

Success of the SPS program is critically dependent on bringing together a number of related system projects. In addition to the satellite and ground station, as major items of operational hardware, associated programs such as the Space Transportation System and supporting SPS facilities should be conducted in parallel and time-phased to interface as an integral part of a coordinated SPS program. Failure to complete any of these program efforts, in keeping with the SPS master schedule, would result in a corresponding delay in the availability of an operational system to serve as a significant national power resource.

3.2 PROGRAM PLANS APPROACH

The basic approach in plans development is to establish interrelationships between specific SPS program plan areas and elements of the WBS. Thirteen program plans (one divided into three sub-plans) were, therefore, identified and analyzed against elements of the SPS WBS. When combined with over 70 WBS elements, the resultant working-level matrix indicated 900 potential intercepts. At this time, however, we are concerned only with those intercepts for which long-range planning would be required or where the requirements analysis indicated major resource considerations, development or producibility concerns, areas of technology advancement, or support system sensitivity. Accordingly, Table 3.2-1 presents a summary of principal intercepts resulting from an evaluation of each plan at a working level, as compared with SPS reference solar photovoltaic design data. A total of 115 intercepts was established in three categories—A, B, and C. There are 27 Category A intercepts indicating the potential need of major resources, technology advancement, or support system requirements. Twenty-five Category B intercepts were secondary in magnitude, but important because of the long-term effort. A full description of these categories (including coverage of Category C) is presented in the following paragraphs.

- *Category A*—Implementation requires major resources in terms of manpower, dollars, raw materials or new facilities, etc. High-voltage test facilities for power distirbution equipment is an example. Major new system programs, critical to the overall SPS such as Shuttle-derived STS and EOTV, would also fall into this cateogry. HLLV, while not scheduled to support the prototype, needs to be time-phased to become operational by IOC to preserve program continuity. Therefore, HLLV would also be in Category A. New or greatly improved technology, requiring extensive and long-term development, would be placed in this category. One example would be high-rate production capability of thin-film GaAs solar blankets. Finally, items of special concern—but which may be of unknown magnitude—are placed in Category A. Examples would be verification of microwave beam control and utility interface considerations.

- *Category B*—Requires minor commitment of resources relative to Category A, but nonetheless, substantial long-term commitment may be required. An example would be verification tests of the rotary joint and slip rings.

- *Category C*—Certain programmatic aspects must be implemented and maintained over the long term to provide continuity and coordination. All planning areas should be maintained at some level of effort, and are so designated at the program management or SE&I levels.

Table 3.2-1. SPS Program Plans/DDT&E Relationship Matrix

SOLAR PHOTOVOLTAIC, CR–2 CONCEPT:

CAT. A – MAJOR RESOURCES, TECHNOLOGY ADV OR SUPPORT SYS PROGRAM REQD
CAT. B – SECONDARY IN MAGNITUDE BUT CRITICAL REQUIRING LONGTERM EFFORT
CAT. C – LONGTERM PROG PLANNING REQD
(–) EVALUATED AT NEXT HIGHER LEVEL

WBS NO.	WBS TITLE	SPS PROGRAM PLAN														
		1	2	3	4	5	6	7	8	9 GND OPS			10	11	12	13
		PROGRAM MANAGEMENT	SYSTEMS ENGRG & INTEGRATION	DESIGN AND DEVELOPMENT	SYS. TESTING	GSE DESIGN & DEVELOPMENT	MANUFACTURING	PRODUCT ASSURANCE	FACILITIES	GROUND INTEG	MAINTENANCE & REFURBISHMENT	LOGISTICS	SPACE OPS	LAUNCH OPS	SPECIFICATION TREE	RESOURCE AVAIL. ANALYSIS
1.1	SATELLITE	A	C	A	A		B	C					A			C
1.1.1	ENERGY CONVERSION			A	A	B	A	C	A	C		C				C
1.1.2	POWER TRANSMISSION			A	B		B	B	B							
1.1.3	INFORMATION MANAGEMENT AND CONTROL															
1.1.4	ATTITUDE CONTROL AND STATIONKEEPING							C								
1.1.5	COMMUNICATIONS															
1.1.6	INTERFACE			B	B											
1.1.7	SYSTEMS TEST	C		B	A		B			C		B				
1.1.8	GSE					C										
1.2	SPACE CONSTRUCTION & SUPPORT	C	C	A	C		C						C			
1.2.1	CONSTRUCTION FACILITIES (SCB)												C			
1.2.2	LOGISTICS SUPPORT FACILITIES (LEO)												C			
1.2.3	O&M SUPPORT FACILITIES												C			

Table 3.2-1. *SPS Program Plans/DDT&E Relationship Matrix (Cont.)*

SOLAR PHOTOVOLTAIC, CR–2 CONCEPT:

CAT. A – MAJOR RESOURCES, TECHNOLOGY ADV OR SUPPORT SYS PROGRAM REQD
CAT. B – SECONDARY IN MAGNITUDE BUT CRITICAL REQUIRING LONGTERM EFFORT
CAT. C – LONGTERM PROG PLANNING REQD
(–) EVALUATED AT NEXT HIGHER LEVEL

		SPS PROGRAM PLAN														
		1	2	3	4	5	6	7	8	9 GND OPS			10	11	12	13
WBS NO.	WBS TITLE	PROGRAM MANAGEMENT	SYSTEMS ENGRG & INTEGRATION	DESIGN AND DEVELOPMENT	SYS. TESTING	GSE DESIGN & DEVELOPMENT	MANUFACTURING	PRODUCT ASSURANCE	FACILITIES	GROUND INTEG	MAINTENANCE & REFURBISHMENT	LOGISTICS	SPACE OPS	LAUNCH OPS	SPECIFICATION TREE	RESOURCE AVAIL. ANALYSIS
1.3	TRANSPORTATION	B	C	B									C			C
1.3.1	VTO-HL HLLV	B	C	A	C	C	C		C					B		
1.3.2	EOTV	B	C	A	C	C	C						C			
1.3.3	PLV	A	C	B	C		C		C		C	C	C	C		
1.3.4	POTV	B	C	A	C	C	C						C			
1.3.5	PM															
1.3.6	IOTV															
1.3.7	GROUND SUPPORT FACILITIES	A	C	C	A		A		A					A		C
1.4	GROUND RECEIVING STATION	B	C	C	A				A							C
1.4.1	SITE AND FACILITIES								A							
1.4.2	RECTENNA SUPPORT STRUCTURE						C									
1.4.3	POWER COLLECTION			B			A									
1.4.4	CONTROL															
1.4.5	GRID INTERFACE			C	B											
1.4.6	OPERATIONS										C	B				
1.5	MANAGEMENT AND INTEGRATION	C	C	C	A	C	C	B	A	C	C	B	A	B	C	C

The next step, as shown in Figure 3.2-1, was to prepare a summary planning sheet for each of the designated program plans. These were structured to include (1) a description of the plan; (2) a synopsis of requirements on technical and programmatic definition, associated with elements of the SPS point design description; (3) major resource considerations; and (4) a discussion section that established parameters, guidelines, assumptions, or constraints with regard to the respective plan. Areas considered critical or important to the completion of a specific WBS element were researched, identified, and studied. SPS point design requirements were constantly iterated during this period to develop line item descriptions, within identified categories, of Phase C/D DDT&E program planning concerns. The results of this work are presented on *impact sheets* as attached to the various plans included in a subsequent part of this section.

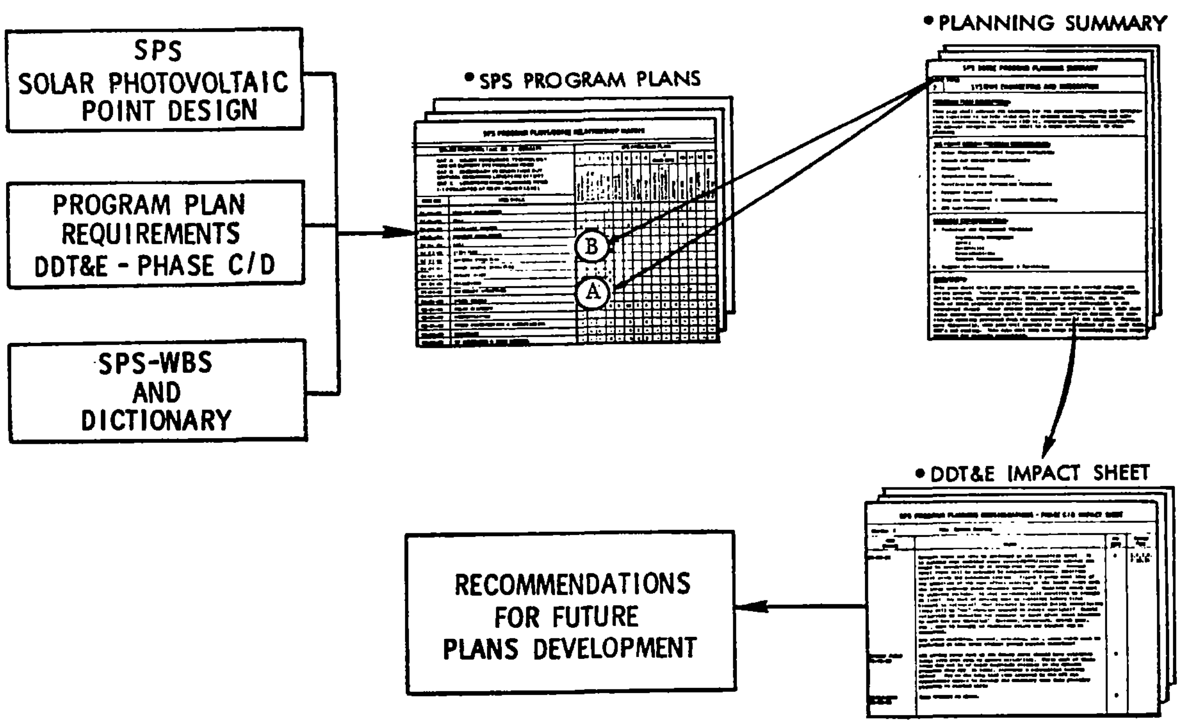


Figure 3.2-1. Program Plans Development Logic

3.3 PROGRAM PLANS

The implementation of each plan entails a scope of work such that the summation of all plans will cover every facit of organization, management, and hardware/software activity necessary to carry out the Phase C/D SPS efforts. Although the implementation of certain planning activities may be delayed, it is necessary to conduct some effort in each plan area throughout all phases of the program for purposes of coordination and continuity.

Overall program planning requirements, schedules, milestones, and master network are contained in this part of the report. Program elements are described as they apply within the program plan area. Special emphasis is placed on any major or critical area that is likely to have an impact or add some degree of risk in meeting SPS program objectives, schedules, and cost constraints. Where appropriate, the data are supported with analyses or discussions to provide the applicable level of assessment based on the SPS concept definition at this time, such as that presented in Plan 13 on natural resources.

The planning data presented in this section are contained within the following program plan areas:

1. Program Management—SPS schedules were developed over the program through year 2000, with emphasis on the 1980-1990 period. These schedules are developed to incorporate NASA, MSFC and DOE programmatic milestones applying to the DDT&E phases. On this basis, a series of SPS schedules showing design, development, technology advancement, production, operations, and initial phasing were developed and have been included in this plan.

2. Systems Engineering and Integration

3. Design and Development

4. Systems Testing

5. Ground Support Equipment (GSE) Design and Development

6. Manufacturing

7. Product Assurance

8. Facilities

9. Ground Operations

   - Ground Integration
   - Maintenance and Refurbishment
   - Logistics

10. Space Operations

11. Launch Operations

12. Specification Tree

13. Natural Resource Analysis

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
1	PROGRAM MANAGEMENT

PROGRAM PLAN DESCRIPTION

This plan shall include project schedules showing key milestones, test, decision points, interfaces with other program elements, hardware deliveries, facility requirements, major reviews, reporting requirements, etc.; and logic networks depicting major milestones and the interrelationship of events and activities throughout the design, development, operations, technology advancement, technology verification, and commercialization phases with the identification of critical paths. Any analyses necessary to support the defined program and schedules shall also be included. Particular emphasis shall be placed on the 1980-1990 time frame.

All major hardware and software—flight, as well as GSE—required for the development and operational phases, and identified in other sections, shall be scheduled including any hardware, equipment, and services required to be government-furnished and any long-lead hardware.

Major make-or-buy assumptions used in developing the recommended program shall be identified with supporting rationale.

SPS GaAlAs ROCKWELL REFERENCE CONFIGURATION PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- 30-Year Design Life with Maintenance
- Nominal 5-GW Busbar Output at End of Life
- Satellite-DDT&E Configuration
- SPS Phase C/D DDT&E Program Coverage
- 2000 IOC for SPS Operation
- State-of-the-Art Technology, 1987
- Technology Verification Period, 1981-1987
- Planning in Accordance with SPS Work Breakdown Structure (November 1978)
- SPS Schedule and Network Approach
- Specify Key Milestones, Decision Points, Interfaces
- Identify Make-or-Buy Approach

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
  - Program Planning and Control
  - Engineering Management
  - Manufacturing Management
  - Contract Administration
  - Support Management
  - Quality Assurance Management
  - Configuration Management
  - Data Management
- Support Materials, Equipment, and Facilities

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
1	PROGRAM MANAGEMENT (Cont.)

DISCUSSION

The program management plan addresses all schedules, logic, budget planning, and decision-making functions. Its implementation produces only software. However, it is the only level at which all SPS activities are coordinated. It is also the level at which major system interfaces occur, such as between satellite/rectenna and satellite/STS. Therefore, although it represents no major impact on its own, it is essential that the plan be started early and updated continuously to reflect both current activity and future planning at this summary level.

Major systems which are coordinated through this plan are:

- Satellite
- Transportation
- Space Construction and Support
- Ground Receiving Station

One function of the plan is to assure continuity and an orderly transition from Phase C/D through IOC and into the operational phase. Often, large programs encounter peaks and valleys in funding and manpower needs. When these occur, the overall economy is normally elastic enough to accommodate such changes; but this is not the case for SPS. Due to the huge size of the SPS undertaking and the order-of-magnitude increase in resource requirements after IOC, it is essential to plan an orderly buildup as a continuous process during Phase C/D and beyond. Only in this way can a healthy economy be maintained and the solar resource be exploited without a large gap occurring between IOC and significant operational buildup. The program management plan provides the vehicle for planning this buildup and making the necessary transition. As an example, the HLLV will not be operational during the main Phase C/D. However, its development will require a major program which must be time-phased to integrate with the overall SPS in the IOC time frame as an essential element in follow-on construction and operation of multiple systems.

A summary SPS schedule is presented in Figure 1-1. It identifies ground-based exploratory research activities and key technology programs preceding the 1990 Phase C/D commercialization decision. The 335-MW EOTV precursor pilot plant is shown as an extension of the systems test activity. The 1990 C/D kick-off will activate work on all major elements leading to the SCB fabrication, EOTV test article assembly, transfer to GEO, and precursor testing/beam mapping. The growth Shuttle and Shuttle-derived cargo carrier will have an earlier start to transfer the necessary mass to orbit. Subsequent SPS VTO-HL HLLV operations will combine with the Shuttle for full-scale build of the TFU. The GRS is proceeding as an earth-based receiver of MW energy.

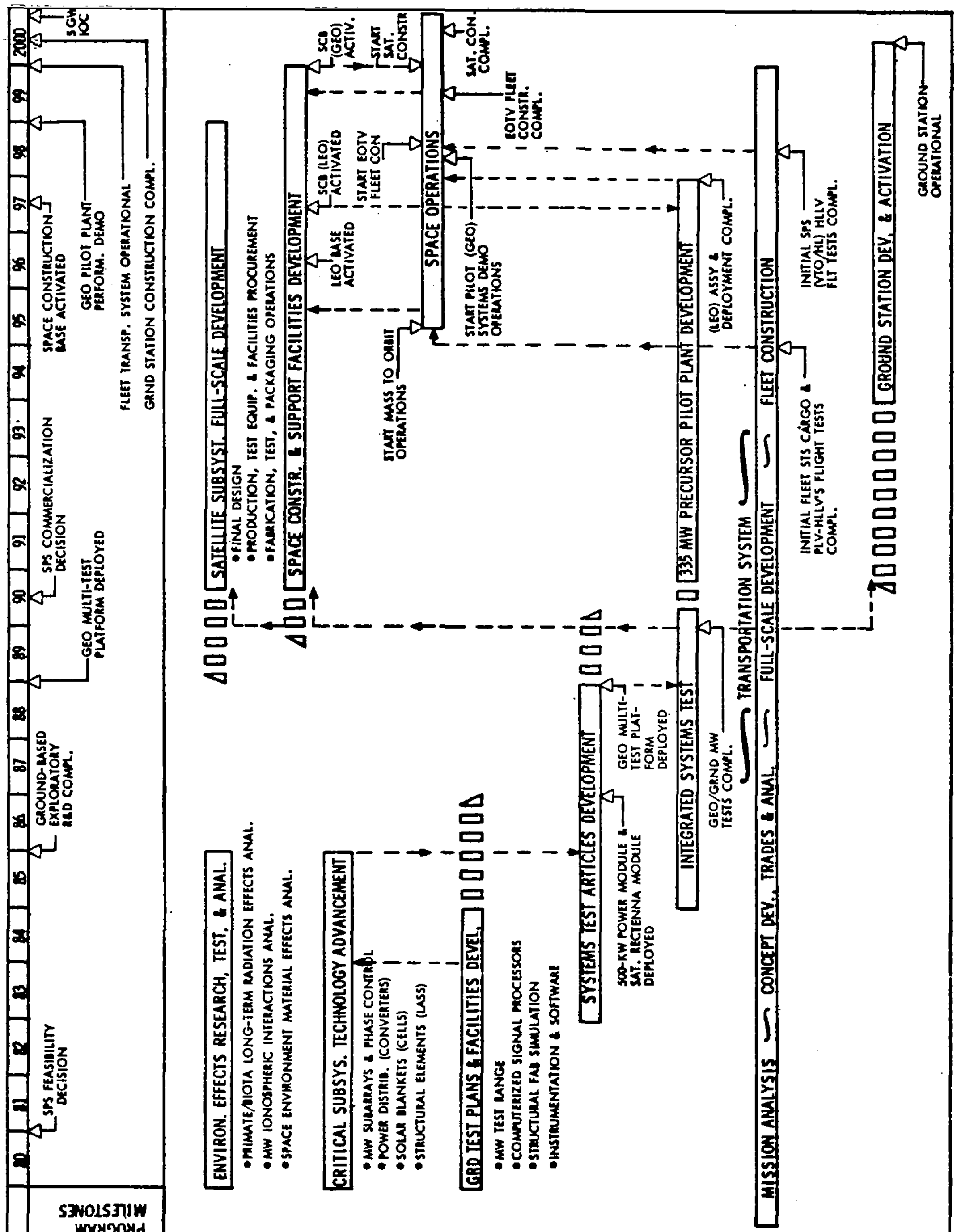


Figure 1-1. SPS Summary Schedule

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
1	PROGRAM MANAGEMENT (Cont.)

SPS Program Schedules

The objectives, magnitude, complexity, and duration of the SPS program demand an orderly and logical approach that will provide full implementation of program projects to achieve an operational SPS consistent with the plan. Accordingly, a major requirement existed for the development of fully integrated schedules/networks at all levels of the multi-faceted WBS. To provide an overall control of the scheduling activity, control milestones were established and maintained in a logic network of integrated program activities (Figure 1-2).

The network divides the program milestones into four major sub-categories which include:

- Technology verification and full-scale prototype development
- Support facilities and equipment development, including transportation
- Major programmatic milestones
- Continuation decision points

These milestones logically support succeeding events in their own sub-categories and, in certain cases, will support or impact succeeding milestone events in other sub-categories.

The central catalyst for development of the satellite power system and its primary supporting equipment and facilities is the SPS decision category of milestones. Examination of the network will demonstrate that supporting equipment and facility developments encompass a scope of effort nearly equal to development of the satellite system itself; therefore, with due consideration taken for the technical lead times required for development of each major subsystem, an overall plan was established that incorporates parallel development of the several major subsystems in order that their timely completion supports major satellite system development objectives.

The decision milestone sequence was developed to program the flow of separate developmental subprograms. Timely promulgation of these decisions will undoubtedly exercise overriding impact on the program and its progress. Further, justification for each of these decision areas—for the most part—will be predicated on the achievement of specified goals within a subprogram and may be only casually related to the results of major efforts in other subprograms at that point in time. As an example, the long-lead technology required for development of an HLLV transportation system whose availability is critical to the construction and deployment of the initial satellite in the year 2000, necessitates initiation of a full-scale development program in the year 1988. This precedes a satellite systems technology readiness demonstration conducted with the "multi-test platform: test article by two full years.

SUPPORT FACILITIES +
EQUIPMENT DEVELOPMENT

SPS DECISION
GATES

TECHNOLOGY VERIFICATION
+FULL SCALE DEVELOPMENT

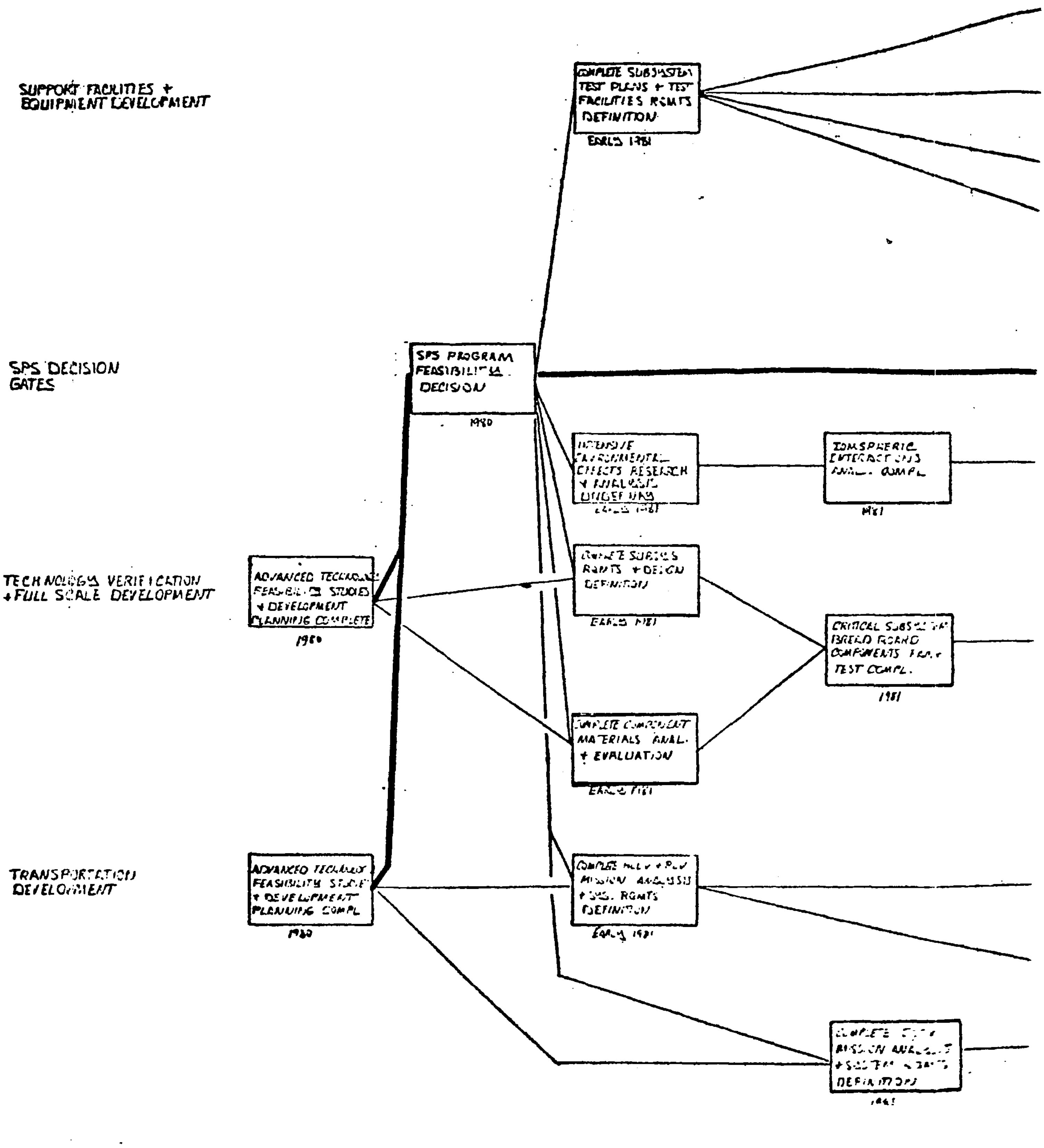
ADVANCED
FEASIBIL
+ DEVELOP
PLANNING (

19

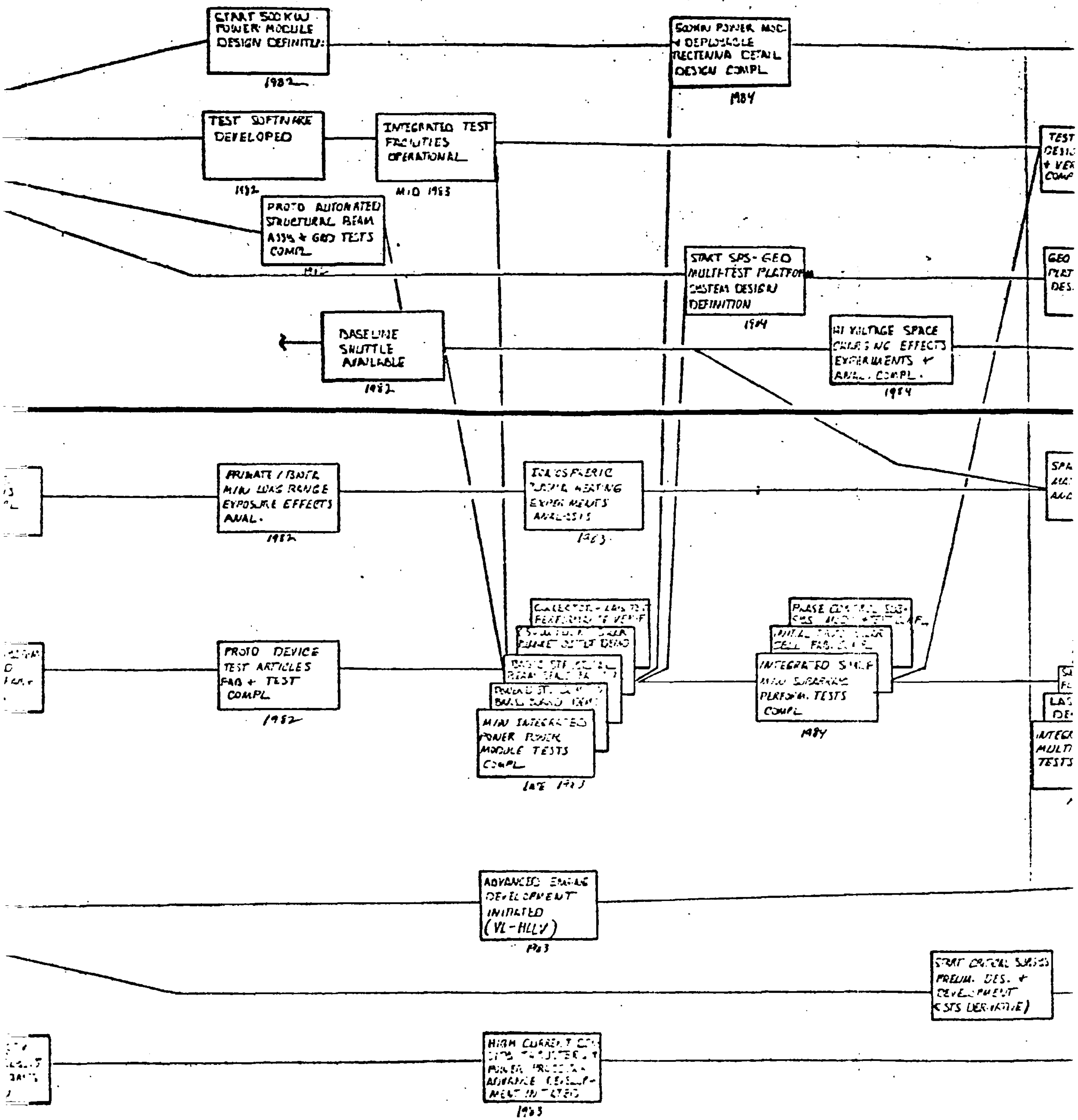
TRANSPORTATION
DEVELOPMENT

ADVANCED T
FEASIBILITY
+ DEVELOP
PLANNING (

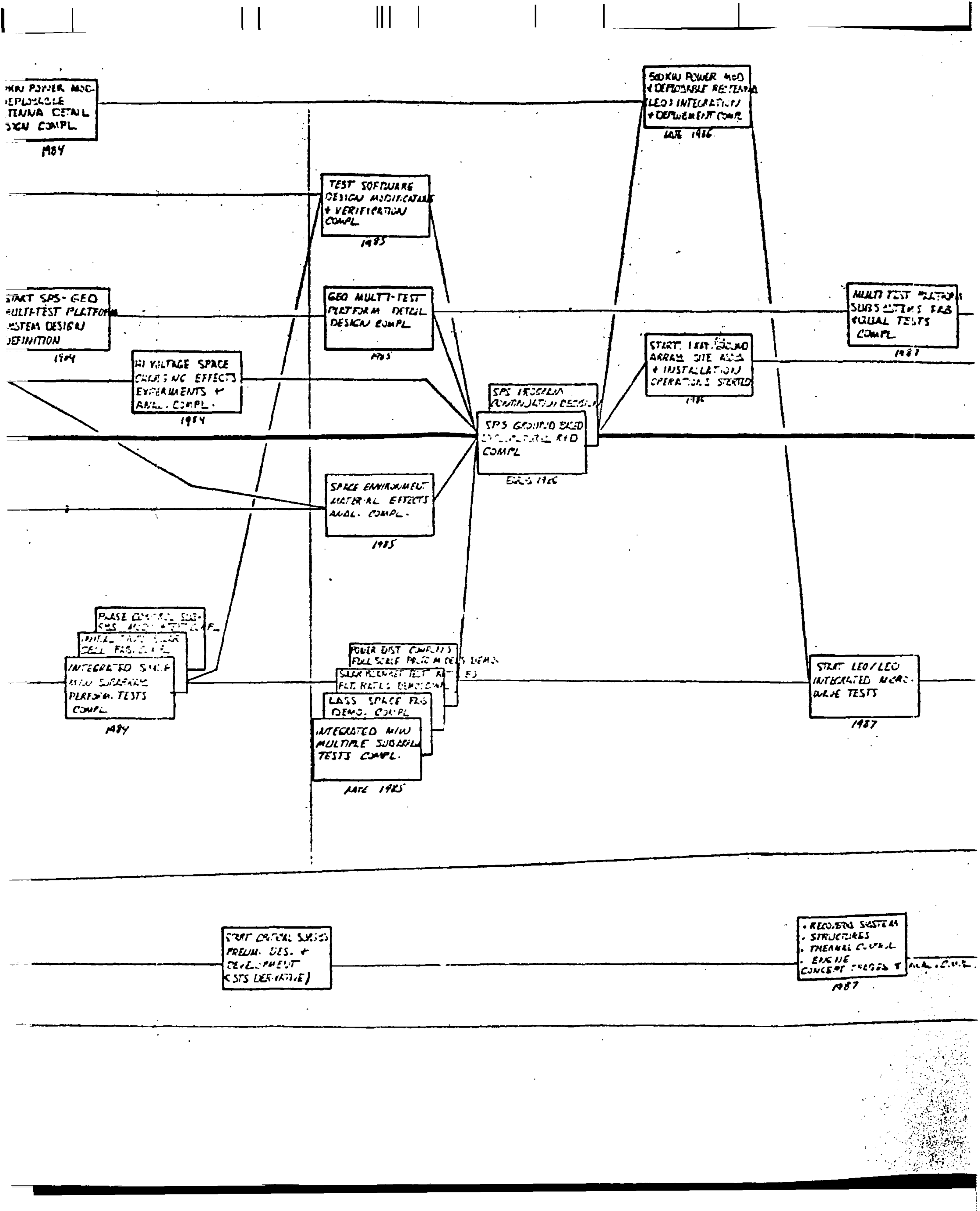
198



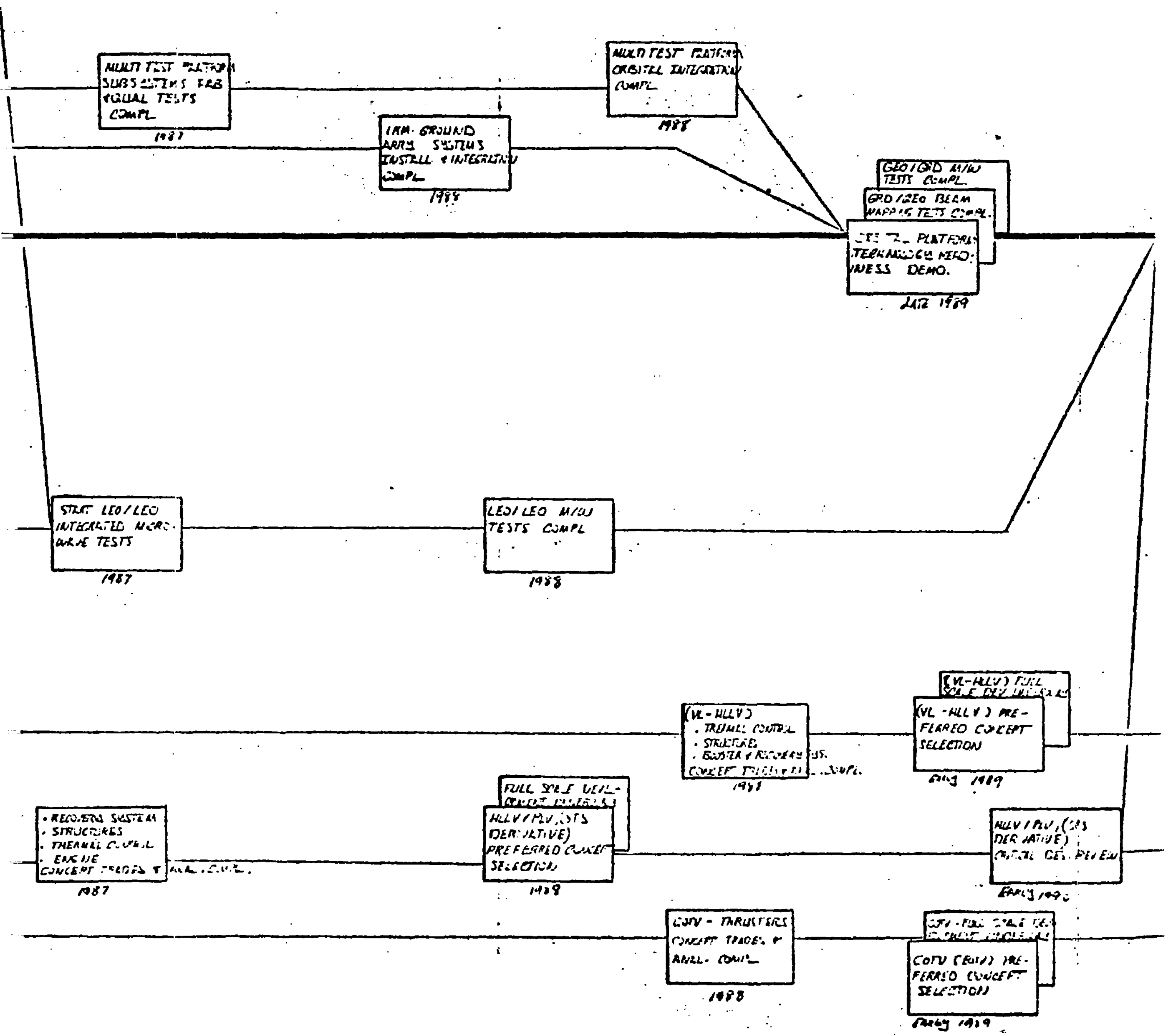
SUPPORT FACILITIES + EQUIPMENT DEVELOPMENT
SPS DECISION GATES
TECHNOLOGY VERIFICATION + FULL SCALE DEVELOPMENT
TRANSPORTATION DEVELOPMENT
COMPLETE SUBSYSTEM TEST PLANS + TEST FACILITIES RQMTS DEFINITION
EARLY 1981
SPS PROGRAM FEASIBILITY DECISION
1980
ADVANCED TECHNOLOGY FEASIBILITY STUDIES + DEVELOPMENT PLANNING COMPLETE
1980
ADVANCED TECHNOLOGY FEASIBILITY STUDIES + DEVELOPMENT PLANNING COMPL
1980
CRITICAL SUBSYSTEM BREAD BOARD COMPONENTS FAB. + TEST COMPL.
1981
COMPLETE COMPONENT MATERIALS ANAL. + EVALUATION
EARLY 1981
EARLY 1981



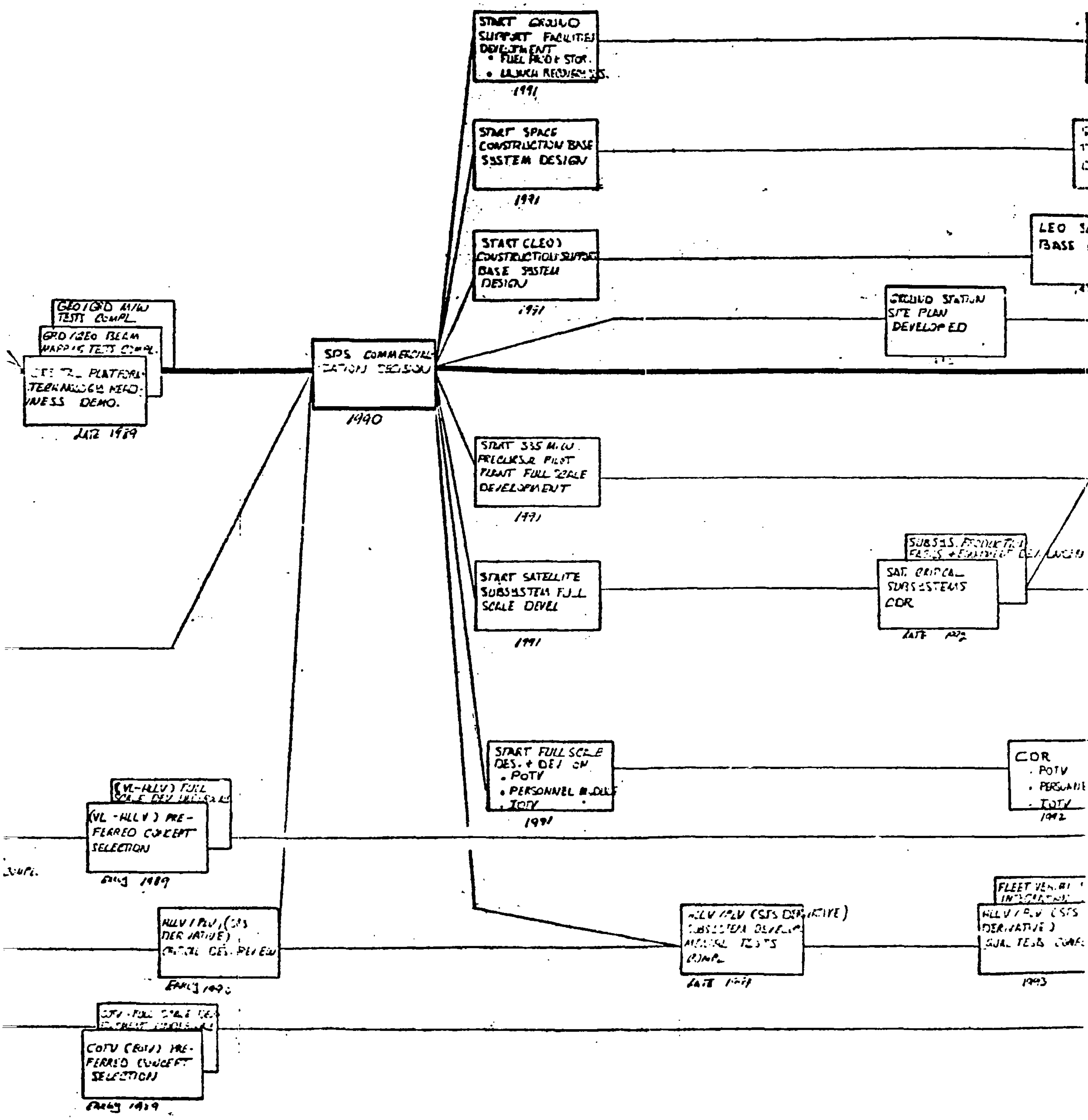
START 500 KW POWER MODULE DESIGN DEFINITION
1982
500 KW POWER MOD. + DEPLOYABLE RECTENNA DETAIL DESIGN COMPL.
1984
TEST SOFTWARE DEVELOPED
1982
INTEGRATED TEST FACILITIES OPERATIONAL
MID 1983
PROTO AUTOMATED STRUCTURAL BEAM ASSY + GRD TESTS COMPL.
START SPS-GEO MULTITEST PLATFORM SYSTEM DESIGN DEFINITION
1984
BASELINE SHUTTLE AVAILABLE
1982
HI VOLTAGE SPACE CHARGING EFFECTS EXPERIMENTS + ANAL. COMPL.
1984
PRIMATE / BNEL MIN LONG RANGE EXPOSURE EFFECTS ANAL.
1982
1983
PROTO DEVICE TEST ARTICLES FAB + TEST COMPL.
1982
MIN INTEGRATED POWER MODULE TESTS COMPL.
LATE 1983
INTEGRATED SUBSCALE PERFORM. TESTS COMPL.
1984
ADVANCED ENGINE DEVELOPMENT INITIATED (VL-HLLV)
1983
START CRITICAL SUBSYS PRELIM. DES. + DEVELOPMENT (STS DERIVATIVE)
1983



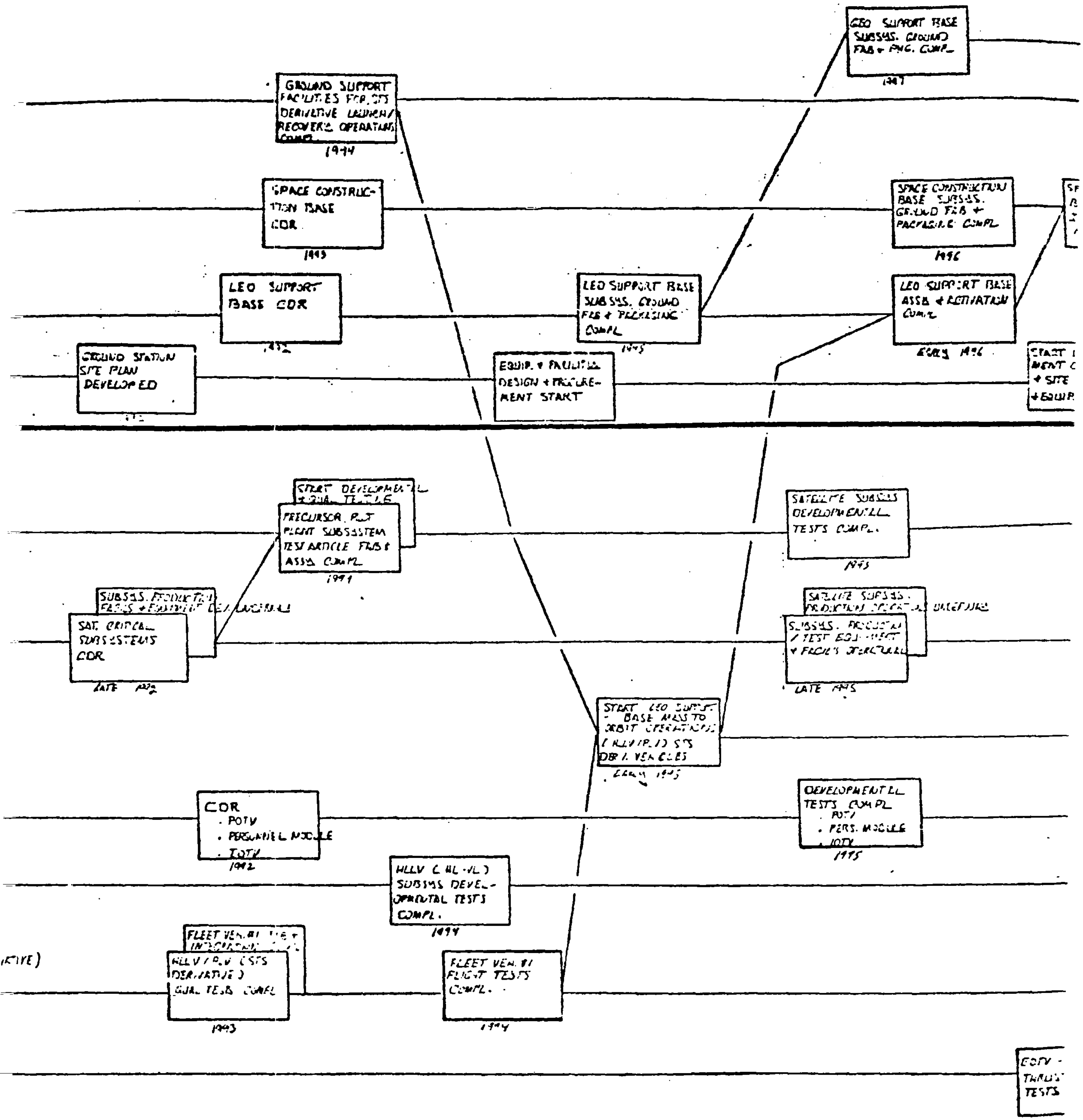
TENNA DETAIL
COMPL
1984
500KW POWER MOD
LEO INTEGRATION
+ DEPLOYMENT COMPL
LATE 1986
TEST SOFTWARE
DESIGN
+ VERIFICATION
COMPL
1985
START SPS-GEO
MULTI-TEST PLATFORM
SYSTEM DESIGN
DEFINITION
1984
GEO MULTI-TEST
PLATFORM DETAIL
DESIGN COMPL
1985
MULTI TEST
SUBSYSTEMS FAB
+QUAL TESTS
COMPL
1987
HI VOLTAGE SPACE
EFFECTS
EXPERIMENTS +
ANAL. COMPL.
1984
START
ARRAY SITE
+ INSTALLATION
OPERATIONS STARTED
1986
SPS PROGRAM
SPS GROUND BASED
COMPL
SPACE ENVIRONMENT
MATERIAL EFFECTS
ANAL. COMPL.
1985
INTEGRATED
PLATFORM TESTS
COMPL
1984
POWER DIST
LASS SPACE FAB
DEMO. COMPL
INTEGRATED MW
MULTIPLE
TESTS COMPL.
LATE 1985
START LEO/LEO
INTEGRATED
TESTS
1987
START
PRELIM. DES. +
DEVELOPMENT
(STS DERIVATIVE)
STRUCTURES
THERMAL
ENGINE
CONCEPT
1987

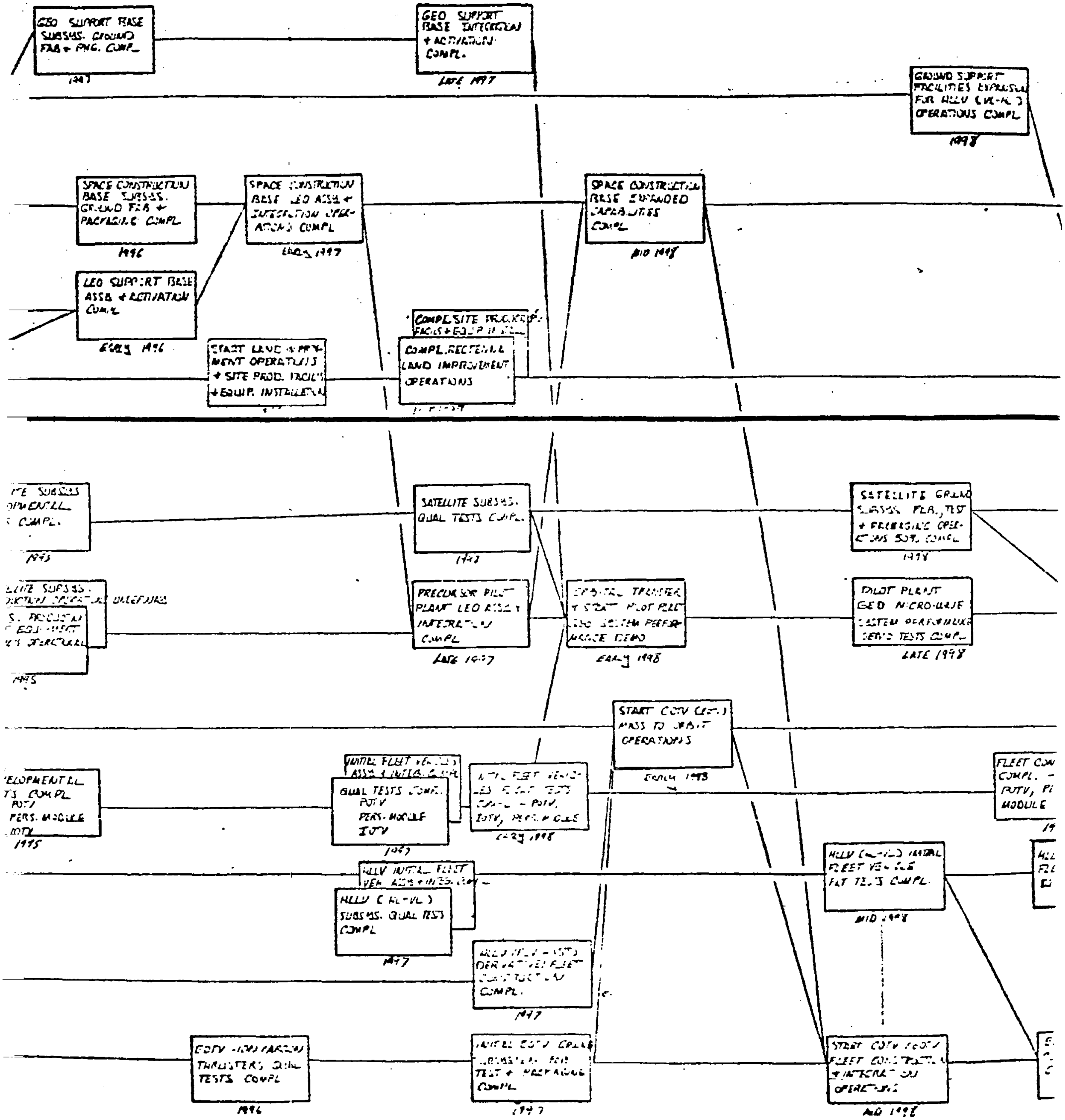


1987
IRM GROUND
COMPL
1988
GEO/GRD M/W
TESTS COMPL
DEMO.
1989
INTEGRATED
TESTS
1987
LEO/LEO M/W
TESTS COMPL
1988
(VL-HLLV)
STRUCTURES
(VL-HLLV) PRE-
FERRED CONCEPT
SELECTION
1989
STRUCTURES
1987
SELECTION
PREFERRED CONCEPT
COTV - THRUSTERS
CONCEPT TRADES &
ANAL. COMPL
1988
COTV (EOTV) PRE-
FERRED CONCEPT
SELECTION
EARLY 1989



START GROUND SUPPORT FACILITIES DEVELOPMENT
• FUEL PROD. & STOR.
1991
START SPACE CONSTRUCTION BASE SYSTEM DESIGN
1991
START (LEO) CONSTRUCTION SUPPORT BASE SYSTEM DESIGN
LEO
BASE
GROUND STATION SITE PLAN DEVELOPED
GEO/GRD M/W TESTS COMPL.
GRD/GEO BEAM
DEMO.
LATE 1989
SPS COMMERCIAL- IZATION DECISION
1990
START SPS M/W PRECURSOR PILOT PLANT FULL SCALE DEVELOPMENT
1991
START SATELLITE SUBSYSTEM FULL SCALE DEVEL
1991
SAT. CRITICAL SUBSYSTEMS CDR
START FULL SCALE DES. & DEV. ON
• POTV
• PERSONNEL MODULE
1991
CDR
• POTV
1992
(VL-HLLV) PRE- FERRED CONCEPT SELECTION
1989
HLLV/PLV (STS DERIVATIVE) CRITICAL DES. REVIEW
1993
COTV (EOTV) PRE- FERRED CONCEPT SELECTION


GEO SUPPORT BASE SUBSYS. GROUND FAB + PKG. COMPL.
GROUND SUPPORT FACILITIES FOR STS DERIVATIVE LAUNCH/ RECOVERY OPERATIONS COMPL.
1994
SPACE CONSTRUCTION BASE CDR
1993
SPACE CONSTRUCTION BASE SUBSYS. GROUND FAB + PACKAGING COMPL.
1996
LEO SUPPORT BASE CDR
LEO SUPPORT BASE SUBSYS. GROUND FAB + PACKAGING COMPL.
1995
LEO SUPPORT BASE ASSB. + ACTIVATION COMPL.
EARLY 1996
GROUND STATION SITE PLAN DEVELOPED
EQUIP. + FACILITIES DESIGN + PROCUREMENT START
START DEVELOPMENTAL + QUAL. TESTS
PRECURSOR PILOT PLANT SUBSYSTEM TEST ARTICLE FAB + ASSY. COMPL.
1991
SATELLITE SUBSYS. DEVELOPMENTAL TESTS COMPL.
1995
SUBSYS. PRODUCTION FACILS + EQUIPMENT DEVELOPMENT
SAT. CRITICAL SUBSYSTEMS CDR
LATE 1992
SATELLITE SUBSYS. PRODUCTION OPERATIONS UNDERWAY
SUBSYS. PRODUCTION / TEST EQUIPMENT + FACILS OPERATIONAL
LATE 1995
START LEO SUPPORT BASE MASS TO ORBIT OPERATIONS (HLLV/PLV) STS DERIV. VEHICLES
EARLY 1995
CDR
· POTV
· PERSONNEL MODULE
· IOTV
1992
DEVELOPMENTAL TESTS COMPL.
· POTV
· PERS. MODULE
· IOTV
1995
HLLV (HL-VL) SUBSYS. DEVELOPMENTAL TESTS COMPL.
1994
FLEET VEH. #1 INTEGRATION
HLLV / PLV (STS DERIVATIVE) QUAL. TESTS COMPL.
1993
FLEET VEH. #1 FLIGHT TESTS COMPL.
1994
EOTV THRUST TESTS


GEO SUPPORT BASE SUBSYS. GROUND FAB + PKG. COMPL.
1997
GEO SUPPORT BASE INTEGRATION + ACTIVATION COMPL.
LATE 1997
GROUND SUPPORT FACILITIES EXPANSION FOR HLLV OPERATIONS COMPL.
1998
SPACE CONSTRUCTION BASE SUBSYS. GROUND FAB + PACKAGING COMPL.
1996
SPACE CONSTRUCTION BASE LEO ASSY + INTEGRATION OPERATIONS COMPL.
EARLY 1997
SPACE CONSTRUCTION BASE EXPANDED CAPABILITIES COMPL.
MID 1998
LEO SUPPORT BASE ASSY + ACTIVATION COMPL.
EARLY 1996
START LAND IMPROVEMENT OPERATIONS + SITE PROD. FACIL'S + EQUIP. INSTALLATION
COMPL. SITE PRODUCTION FACIL'S + EQUIP.
COMPL. RECTENNA LAND IMPROVEMENT OPERATIONS
SATELLITE SUBSYS. QUAL TESTS COMPL.
1997
SATELLITE GROUND SUBSYS. FAB., TEST + PACKAGING OPERATIONS COMPL.
1998
PRECURSOR PILOT PLANT LEO ASSY + INTEGRATION COMPL.
LATE 1997
ORBITAL TRANSFER + START PILOT PLANT GEO SYSTEM PERFORMANCE DEMO
EARLY 1998
PILOT PLANT GEO MICRO-WAVE SYSTEM PERFORMANCE DEMO TESTS COMPL.
LATE 1998
1995
START COTV (CREW) MASS TO ORBIT OPERATIONS
EARLY 1998
INITIAL FLEET VEHICLES ASSY + INTEG. COMPL.
QUAL TESTS COMPL. POTV PERS. MODULE IOTV
1997
INITIAL FLEET VEHICLES FLIGHT TESTS COMPL. - POTV, IOTV, PERS. MODULE
EARLY 1998
FLEET CONST. COMPL. - POTV, PERS. MODULE
DEVELOPMENTAL TESTS COMPL. POTV PERS. MODULE IOTV
1995
HLLV INITIAL FLEET VEH. ASSY + INTEG. COMPL.
HLLV (FLEVL) SUBSYS. QUAL TESTS COMPL.
1997
HLLV INITIAL FLEET VEHICLE FLT TESTS COMPL.
MID 1998
DERIVATIVE FLEET CONSTRUCTION COMPL.
1997
EOTV ION/ARGON THRUSTERS QUAL TESTS COMPL.
1996
INITIAL EOTV SUBSYSTEMS FOR TEST + PACKAGING COMPL.
1997
START EOTV FLEET CONSTRUCTION + INTEGRATION OPERATIONS
MID 1998

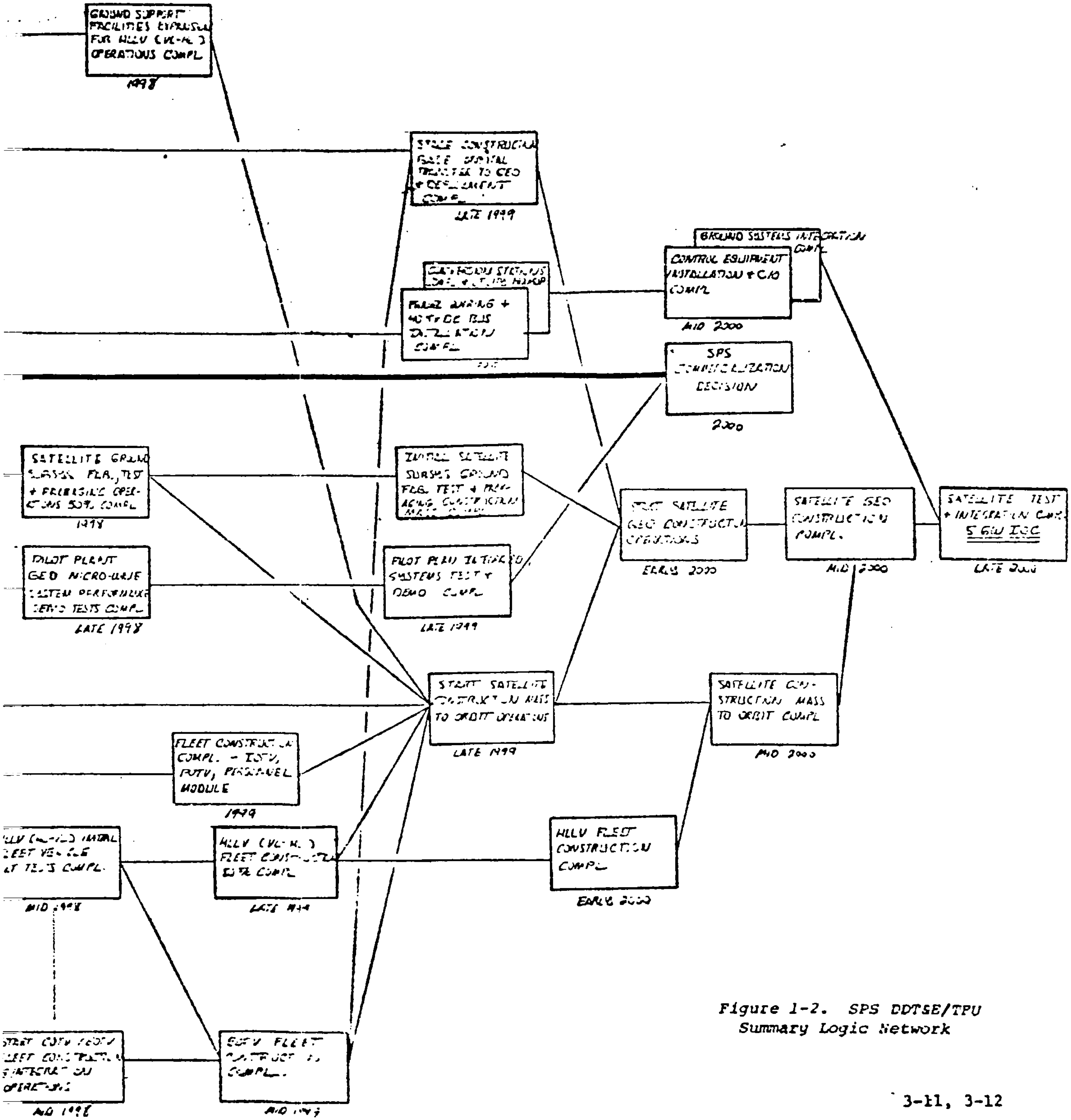


Figure 1-2. SPS DDTSE/TPU Summary Logic Network

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 1 | TITLE

PROGRAM MANAGEMENT (Cont.)

To delay a transportation development decision until a high-confidence level is achieved through the satellite systems demonstration would vitally impact the program capability to achieve IOC by the year 2000.

Other SPS program schedules have been prepared to identify (1) systems technology development tasks, as will be shown on the *DDT&E Technology Advancement Program Schedule*; (2) detail design, production engineering, equipment and production operations activities as will be shown on the *DDT&E/TFU Full-Scale Development Schedule*; (3) a "special emphasis" network on the technology development steps of a microwave transmission system; and (4) a phasing schedule on the site activation and construction sequence of the ground receiving station (GRS).

1. *SPS DDT&E Technology Advancement Program Schedule*

The objective of this phase is to develop a system/subsystem technology base upon which a full-scale development program may systematically evolve. The schedule of Figure 1-3 addresses those key technology elements whose development is requisite to an overall SPS subsystem performance design and definition and the development of test equipment and facilities needed to support this technology effort. SPS hardware development in this phase is confined to experimental and limited prototype articles needed to prove out design concepts such as the areas covered in MPTS, power conversion, power distribution, and structures. The transportation effort during this phase is primarily directed at providing preliminary design definition to those vehicles needed for specific transportation missions further identified in subsequent program phases.

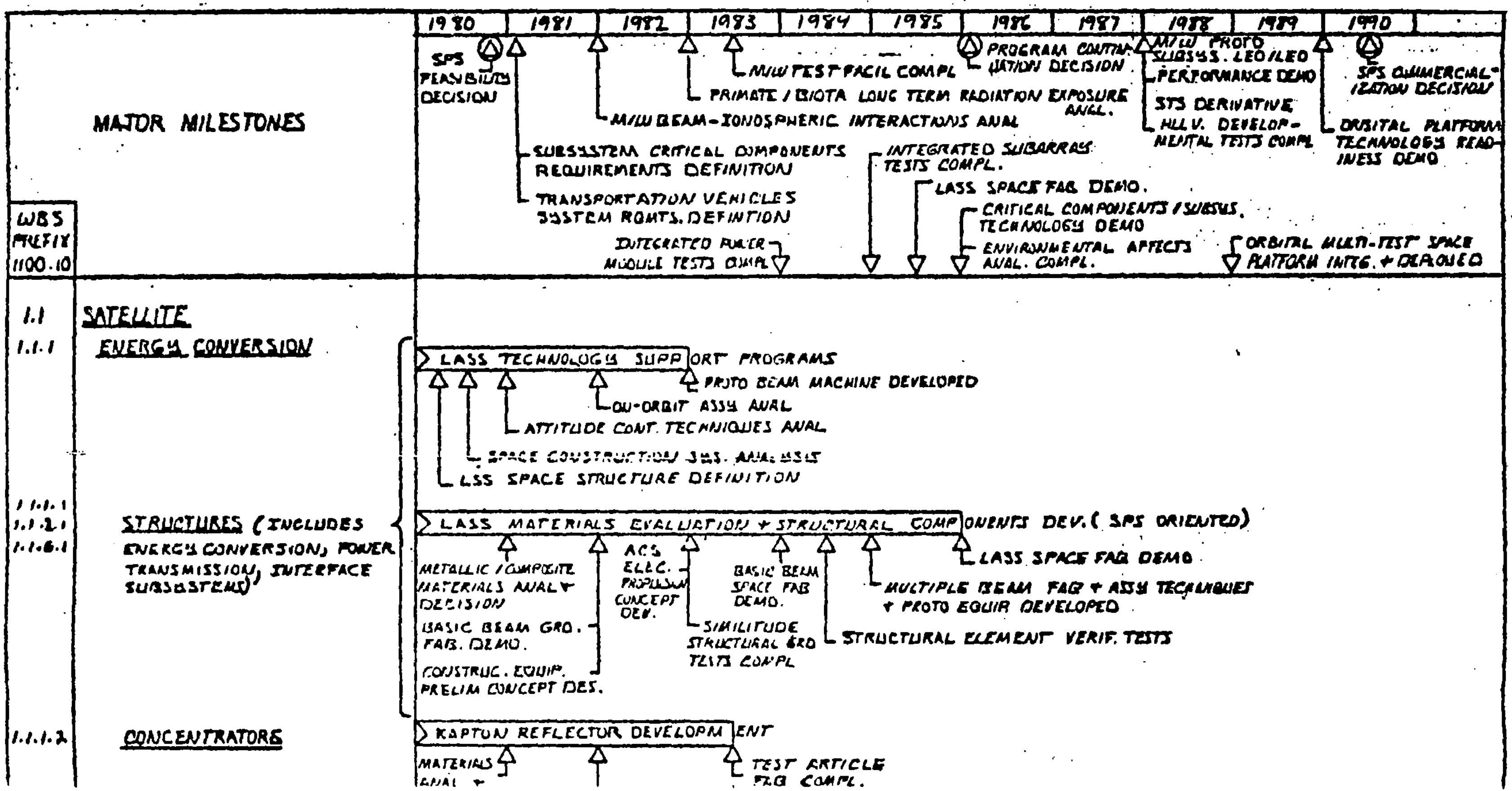
The culmination of this phase is through the integration of these subsystems into a GEO multi-test platform and application of this test article in performance of a total system technology readiness demonstration by late 1989.

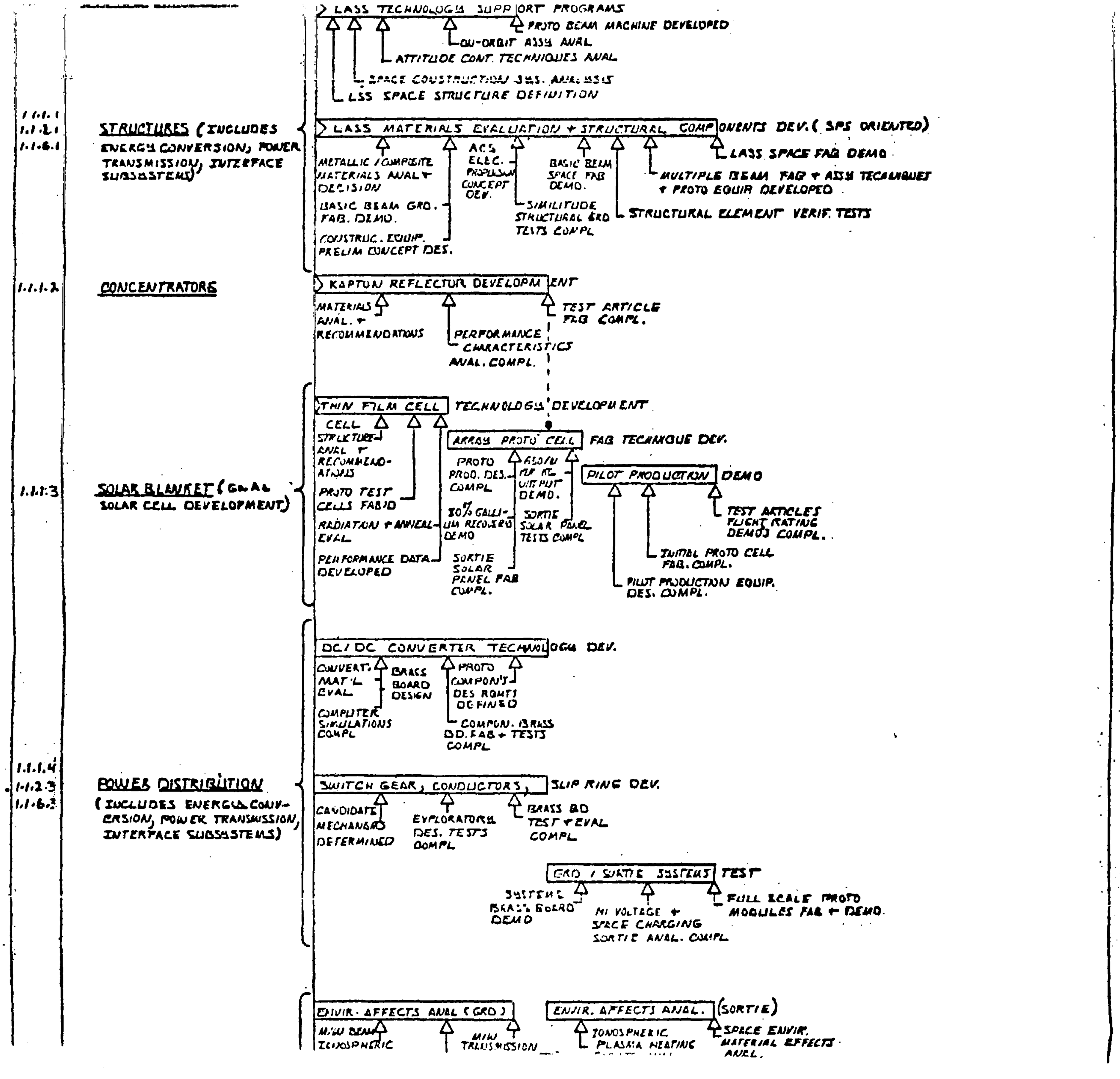
2. *DDT&E/TFU—Full-Scale Development Program*

The objective of this program phase is to produce and operate a full-scale prototype 5-GW satellite power generating system whose performance characteristics will be the basis of justification for continued satellite power systems commercial development. Therefore, the schedule of Figure 1-4 addresses only those tasks and program elements which directly impact development of prototype operational power system hardware/software plus development of equipment and facilities which directly support tasks aimed at this objective.

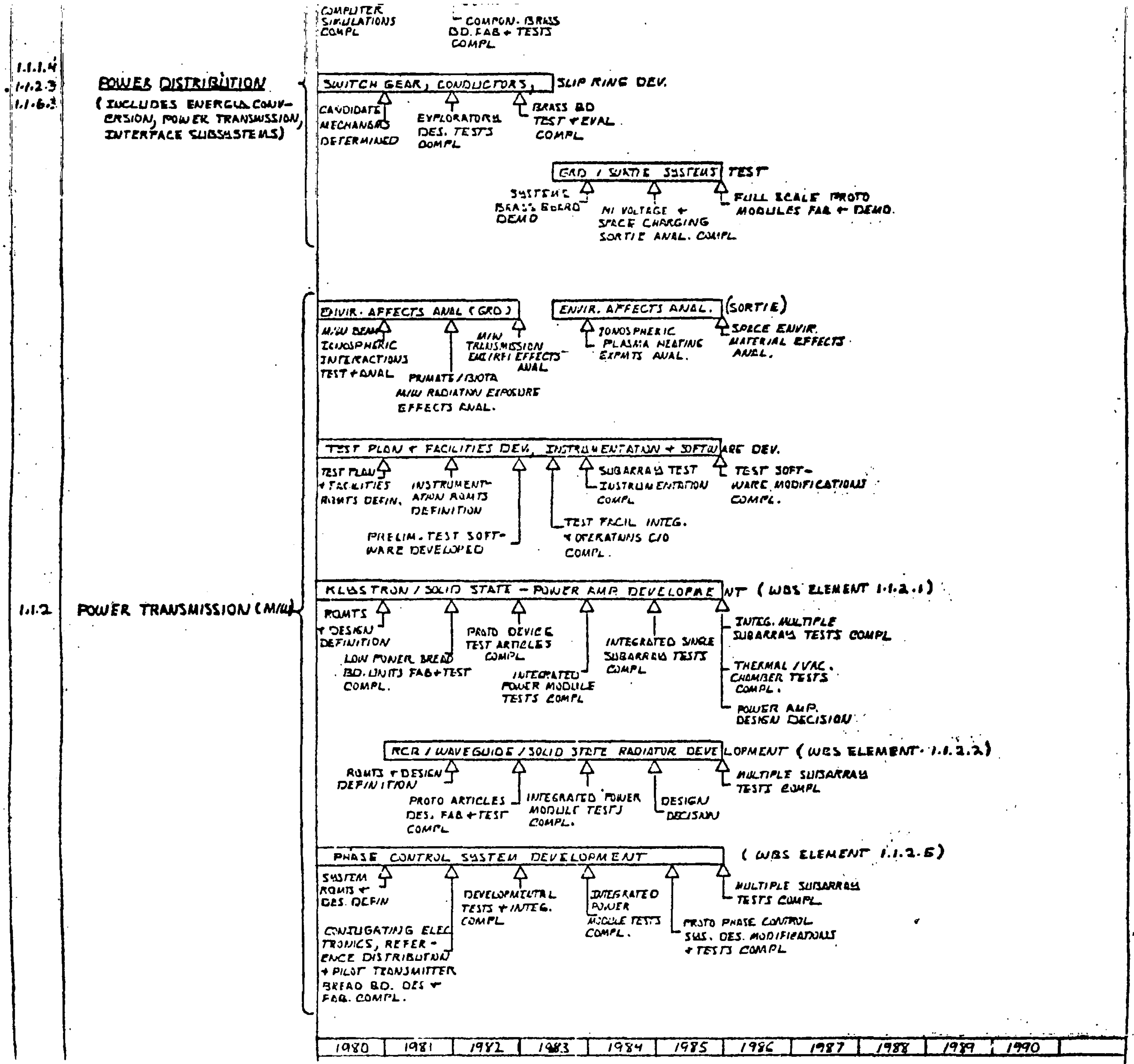
Included in this schedule are broad-based iterations of (1) designs and definitions of subsystem production hardware (based upon data, specifications, and experimental hardware developed during the technology verification program phase); (2) manufacturing technology, equipment, and facilities that need

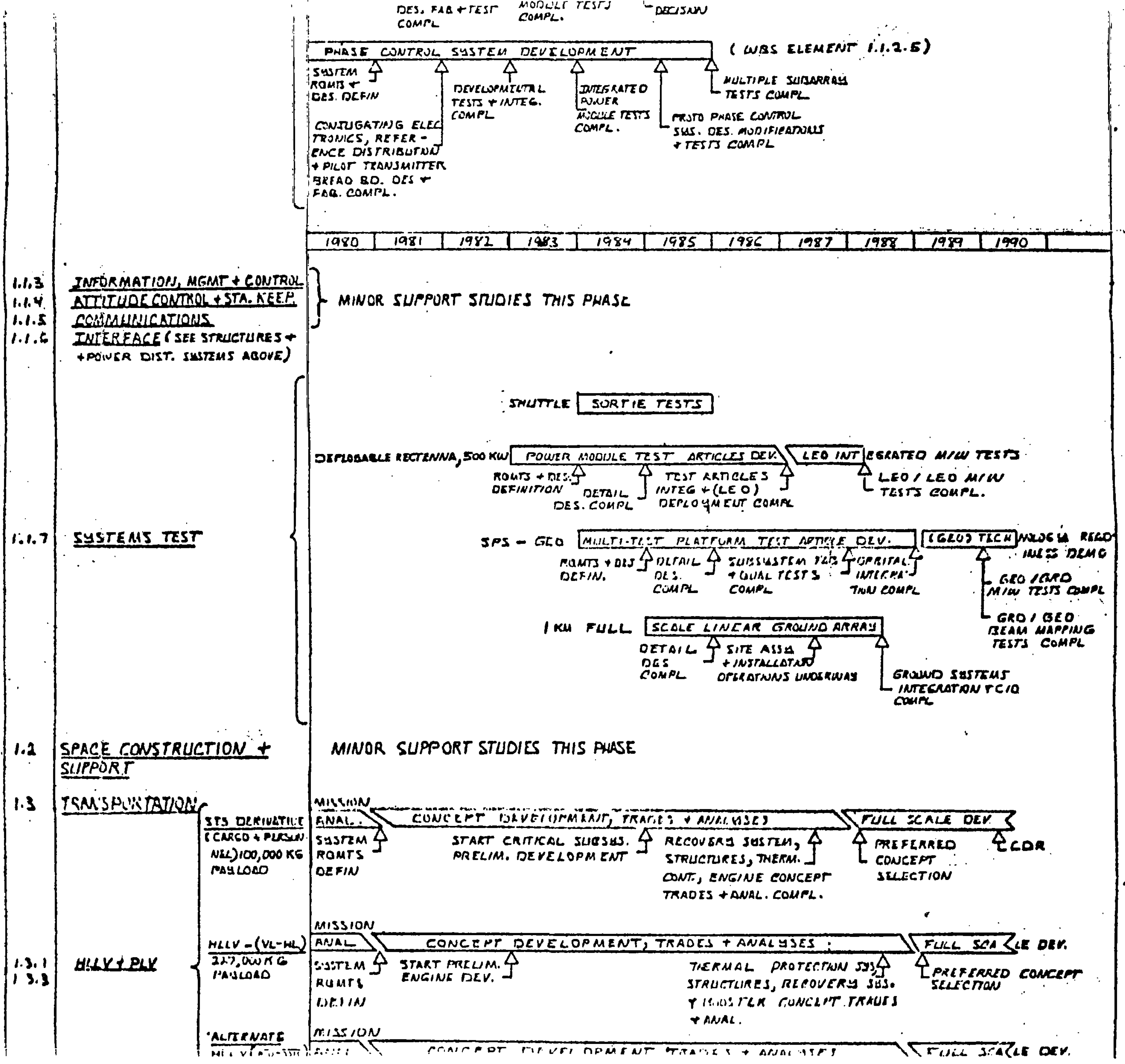
SPS
DDT+E PROGRAM SCHEDULE
(TECHNOLOGY ADVANCEMENT PHASE)





1.1.1.1
1.1.2.1
1.1.6.1
STRUCTURES (INCLUDES ENERGY CONVERSION, POWER TRANSMISSION, INTERFACE SUBSYSTEMS)
LASS TECHNOLOGY SUPPORT PROGRAMS
PROTO BEAM MACHINE DEVELOPED
ON-ORBIT ASSY ANAL
ATTITUDE CONT. TECHNIQUES ANAL
SPACE CONSTRUCTION SYS. ANALYSIS
LSS SPACE STRUCTURE DEFINITION
LASS MATERIALS EVALUATION + STRUCTURAL COMPONENTS DEV. (SPS ORIENTED)
METALLIC/COMPOSITE MATERIALS ANAL + DECISION
BASIC BEAM GRD. FAB. DEMO.
CONSTRUC. EQUIP. PRELIM CONCEPT DES.
ACS ELEC. PROPULSION CONCEPT DEV.
BASIC BEAM SPACE FAB DEMO.
SIMILITUDE STRUCTURAL GRD TESTS COMPL
STRUCTURAL ELEMENT VERIF. TESTS
MULTIPLE BEAM FAB + ASSY TECHNIQUES + PROTO EQUIP DEVELOPED
LASS SPACE FAB DEMO
1.1.1.2
CONCENTRATORS
KAPTON REFLECTOR DEVELOPMENT
MATERIALS ANAL. + RECOMMENDATIONS
PERFORMANCE CHARACTERISTICS ANAL. COMPL.
TEST ARTICLE FAB COMPL.
1.1.1.3
SOLAR BLANKET (GaAs SOLAR CELL DEVELOPMENT)
THIN FILM CELL TECHNOLOGY DEVELOPMENT
CELL STRUCTURE ANAL + RECOMMENDATIONS
PROTO TEST CELLS FAB'D
RADIATION + ANNEAL EVAL
PERFORMANCE DATA DEVELOPED
ARRAY PROTO CELL FAB TECHNIQUE DEV.
PROTO PROD. DES. COMPL
30% GALLIUM RECOVERY DEMO
SORTIE SOLAR PANEL FAB COMPL.
650 W/KG OUTPUT DEMO.
SORTIE SOLAR PANEL TESTS COMPL
PILOT PRODUCTION DEMO
PILOT PRODUCTION EQUIP. DES. COMPL.
INITIAL PROTO CELL FAB. COMPL.
TEST ARTICLES FLIGHT RATING DEMOS COMPL.
DC/DC CONVERTER TECHNOLOGY DEV.
CONVERT. MAT'L EVAL
BRASS BOARD DESIGN
COMPUTER SIMULATIONS COMPL
PROTO COMPONENTS DES RQMTS DEFINED
COMPON. BRASS BD. FAB + TESTS COMPL
1.1.1.4
1.1.2.3
1.1.6.2
POWER DISTRIBUTION (INCLUDES ENERGY CONVERSION, POWER TRANSMISSION, INTERFACE SUBSYSTEMS)
SWITCH GEAR, CONDUCTORS, SLIP RING DEV.
CANDIDATE MECHANISMS DETERMINED
EXPLORATORY DES. TESTS COMPL
BRASS BD TEST + EVAL COMPL
GRD / SORTIE SYSTEMS TEST
SYSTEMS BRASS BOARD DEMO
HI VOLTAGE + SPACE CHARGING SORTIE ANAL. COMPL
FULL SCALE PROTO MODULES FAB + DEMO.
ENVIR. AFFECTS ANAL (GRD)
M/W BEAM IONOSPHERIC
M/W TRANSMISSION
ENVIR. AFFECTS ANAL. (SORTIE)
IONOSPHERIC PLASMA HEATING
SPACE ENVIR. MATERIAL EFFECTS ANAL.


1.1.1.4
1.1.2.3
1.1.6.3
POWER DISTRIBUTION
(INCLUDES ENERGY CONVERSION, POWER TRANSMISSION, INTERFACE SUBSYSTEMS)
COMPUTER SIMULATIONS COMPL
COMPON. BRASS BD. FAB + TESTS COMPL
SWITCH GEAR, CONDUCTORS, SLIP RING DEV.
CANDIDATE MECHANISMS DETERMINED
EXPLORATORY DES. TESTS COMPL
BRASS BD TEST + EVAL COMPL
GRD / SORTIE SYSTEMS TEST
SYSTEMS BRASS BOARD DEMO
HI VOLTAGE + SPACE CHARGING SORTIE ANAL. COMPL
FULL SCALE PROTO MODULES FAB + DEMO.
1.1.2
POWER TRANSMISSION (M/W)
ENVIR. AFFECTS ANAL (GRD)
M/W BEAM IONOSPHERIC INTERACTIONS TEST + ANAL
PRIMATE/BIOTA M/W RADIATION EXPOSURE EFFECTS ANAL.
M/W TRANSMISSION EMI/RFI EFFECTS ANAL
ENVIR. AFFECTS ANAL. (SORTIE)
IONOSPHERIC PLASMA HEATING EXPMTS ANAL.
SPACE ENVIR. MATERIAL EFFECTS ANAL.
TEST PLAN + FACILITIES DEV, INSTRUMENTATION + SOFTWARE DEV.
TEST PLAN + FACILITIES RQMTS DEFIN.
INSTRUMENTATION RQMTS DEFINITION
PRELIM. TEST SOFTWARE DEVELOPED
TEST FACIL. INTEG. + OPERATIONS C/O COMPL.
SUBARRAY TEST INSTRUMENTATION COMPL
TEST SOFTWARE MODIFICATIONS COMPL.
KLYSTRON / SOLID STATE - POWER AMP DEVELOPMENT (WBS ELEMENT 1.1.2.1)
RQMTS + DESIGN DEFINITION
LOW POWER BREAD BD. UNITS FAB + TEST COMPL.
PROTO DEVICE TEST ARTICLES COMPL
INTEGRATED POWER MODULE TESTS COMPL
INTEGRATED SINGLE SUBARRAY TESTS COMPL
INTEG. MULTIPLE SUBARRAY TESTS COMPL
THERMAL / VAC. CHAMBER TESTS COMPL.
POWER AMP. DESIGN DECISION
RCR / WAVEGUIDE / SOLID STATE RADIATOR DEVELOPMENT (WBS ELEMENT 1.1.2.2)
RQMTS + DESIGN DEFINITION
PROTO ARTICLES DES. FAB + TEST COMPL
INTEGRATED POWER MODULE TESTS COMPL.
DESIGN DECISION
MULTIPLE SUBARRAY TESTS COMPL
PHASE CONTROL SYSTEM DEVELOPMENT (WBS ELEMENT 1.1.2.5)
SYSTEM RQMTS + DES. DEFIN
CONJUGATING ELECTRONICS, REFERENCE DISTRIBUTION + PILOT TRANSMITTER BREAD BD. DES + FAB. COMPL.
DEVELOPMENTAL TESTS + INTEG. COMPL
INTEGRATED POWER MODULE TESTS COMPL.
PROTO PHASE CONTROL SYS. DES. MODIFICATIONS + TESTS COMPL
MULTIPLE SUBARRAY TESTS COMPL.
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990


DES. FAB + TEST COMPL
MODULE TESTS COMPL.
DECISION
PHASE CONTROL SYSTEM DEVELOPMENT
(WBS ELEMENT 1.1.2.5)
SYSTEM RQMTS + DES. DEFIN
CONJUGATING ELECTRONICS, REFERENCE DISTRIBUTION + PILOT TRANSMITTER BREAD BD. DES + FAB. COMPL.
DEVELOPMENTAL TESTS + INTEG. COMPL
INTEGRATED POWER MODULE TESTS COMPL.
PROTO PHASE CONTROL SUS. DES. MODIFICATIONS + TESTS COMPL
MULTIPLE SUBARRAY TESTS COMPL
1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990
1.1.3 INFORMATION, MGMT + CONTROL
1.1.4 ATTITUDE CONTROL + STA. KEEP.
1.1.5 COMMUNICATIONS
1.1.6 INTERFACE (SEE STRUCTURES + POWER DIST. SYSTEMS ABOVE)
MINOR SUPPORT STUDIES THIS PHASE
1.1.7 SYSTEMS TEST
SHUTTLE SORTIE TESTS
DEPLOYABLE RECTENNA, 500 KW POWER MODULE TEST ARTICLES DEV.
LEO INTEGRATED M/W TESTS
RQMTS + DES. DEFINITION
DETAIL DES. COMPL
TEST ARTICLES INTEG + (LEO) DEPLOYMENT COMPL
LEO / LEO M/W TESTS COMPL.
SPS – GEO MULTI-TEST PLATFORM TEST ARTICLE DEV.
(GEO) TECHNOLOGY READINESS DEMO
RQMTS + DES DEFIN.
DETAIL DES. COMPL
SUBSYSTEM FAB + QUAL TESTS COMPL
ORBITAL INTEGRATION COMPL
GEO / GRD M/W TESTS COMPL
GRD / GEO BEAM MAPPING TESTS COMPL
1 KM FULL SCALE LINEAR GROUND ARRAY
DETAIL DES COMPL
SITE ASSY + INSTALLATION
OPERATIONS UNDERWAY
GROUND SYSTEMS INTEGRATION + C/O COMPL
1.2 SPACE CONSTRUCTION + SUPPORT
MINOR SUPPORT STUDIES THIS PHASE
1.3 TRANSPORTATION
STS DERIVATIVE (CARGO + PERSONNEL) 100,000 KG PAYLOAD
MISSION ANAL.
CONCEPT DEVELOPMENT, TRADES + ANALYSES
FULL SCALE DEV.
SYSTEM RQMTS DEFIN
START CRITICAL SUBSYS. PRELIM. DEVELOPMENT
RECOVERY SYSTEM, STRUCTURES, THERM. CONT., ENGINE CONCEPT TRADES + ANAL. COMPL.
PREFERRED CONCEPT SELECTION
CDR
1.3.1
1.3.3 HLLV + PLV
HLLV – (VL-HL) 227,000 KG PAYLOAD
MISSION ANAL
CONCEPT DEVELOPMENT, TRADES + ANALYSES
FULL SCALE DEV.
SYSTEM RQMTS DEFIN
START PRELIM. ENGINE DEV.
THERMAL PROTECTION SYS. STRUCTURES, RECOVERY SUS. + BOOSTER CONCEPT TRADES + ANAL.
PREFERRED CONCEPT SELECTION
ALTERNATE
MISSION
FULL SCALE DEV.

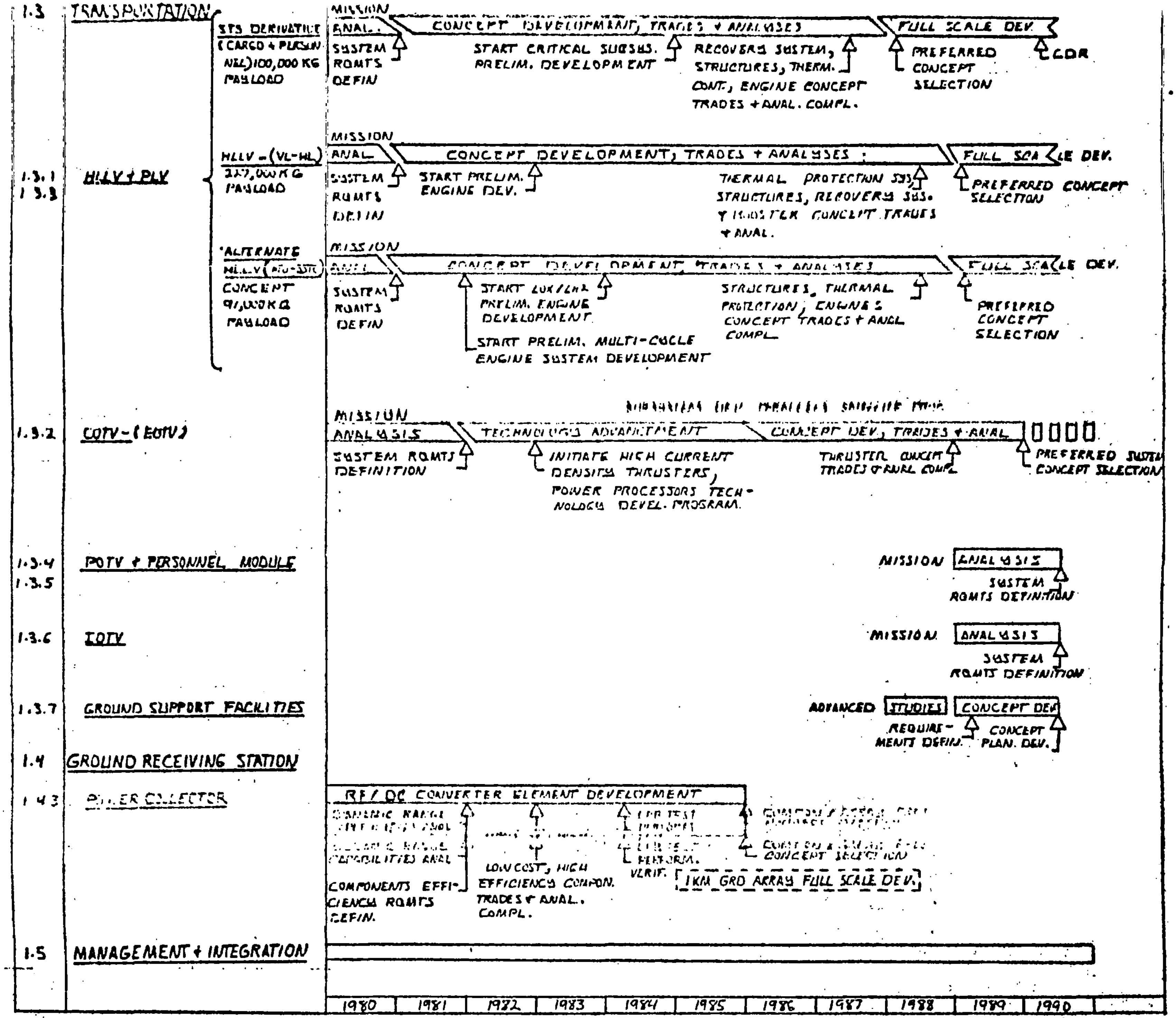
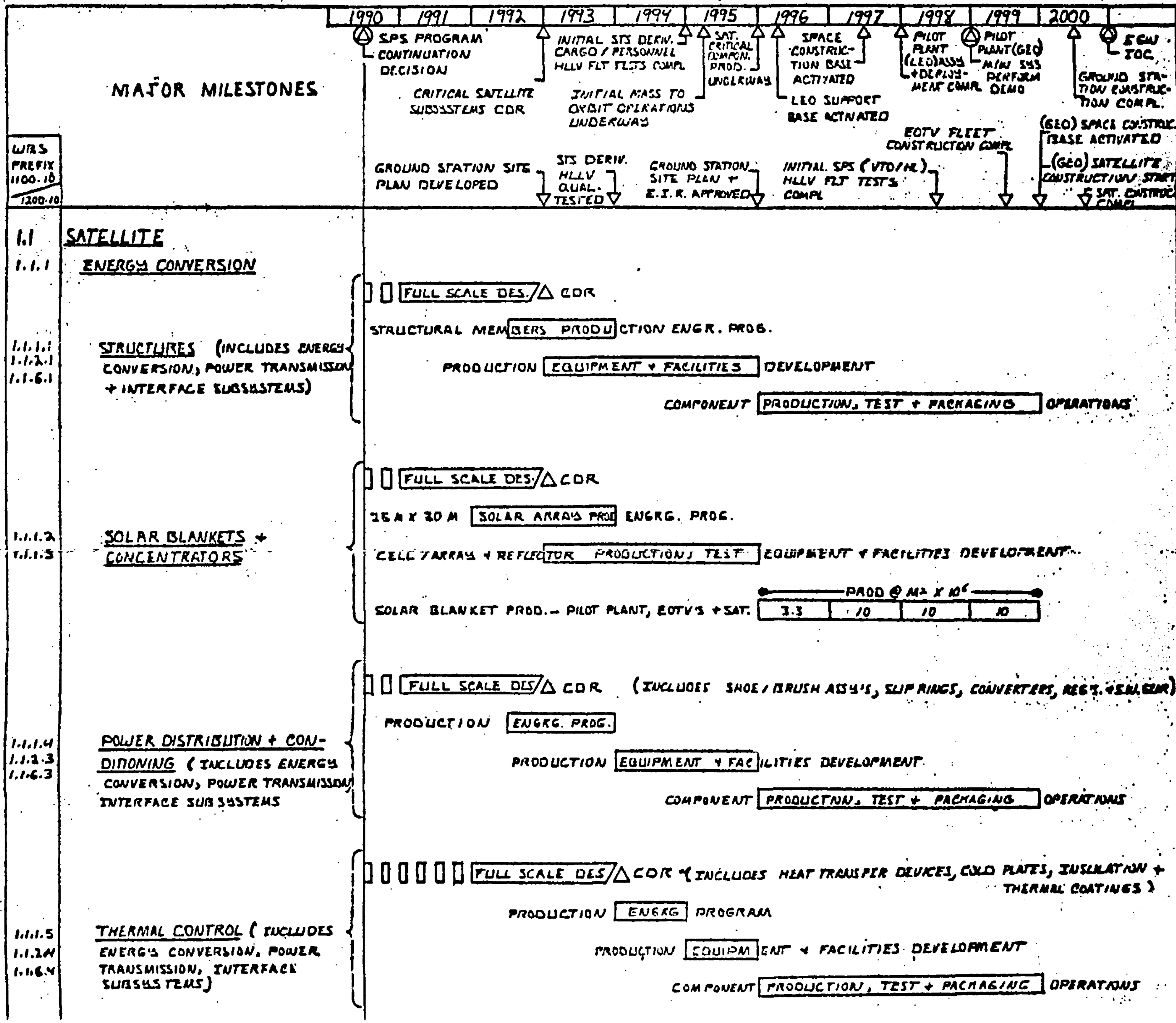
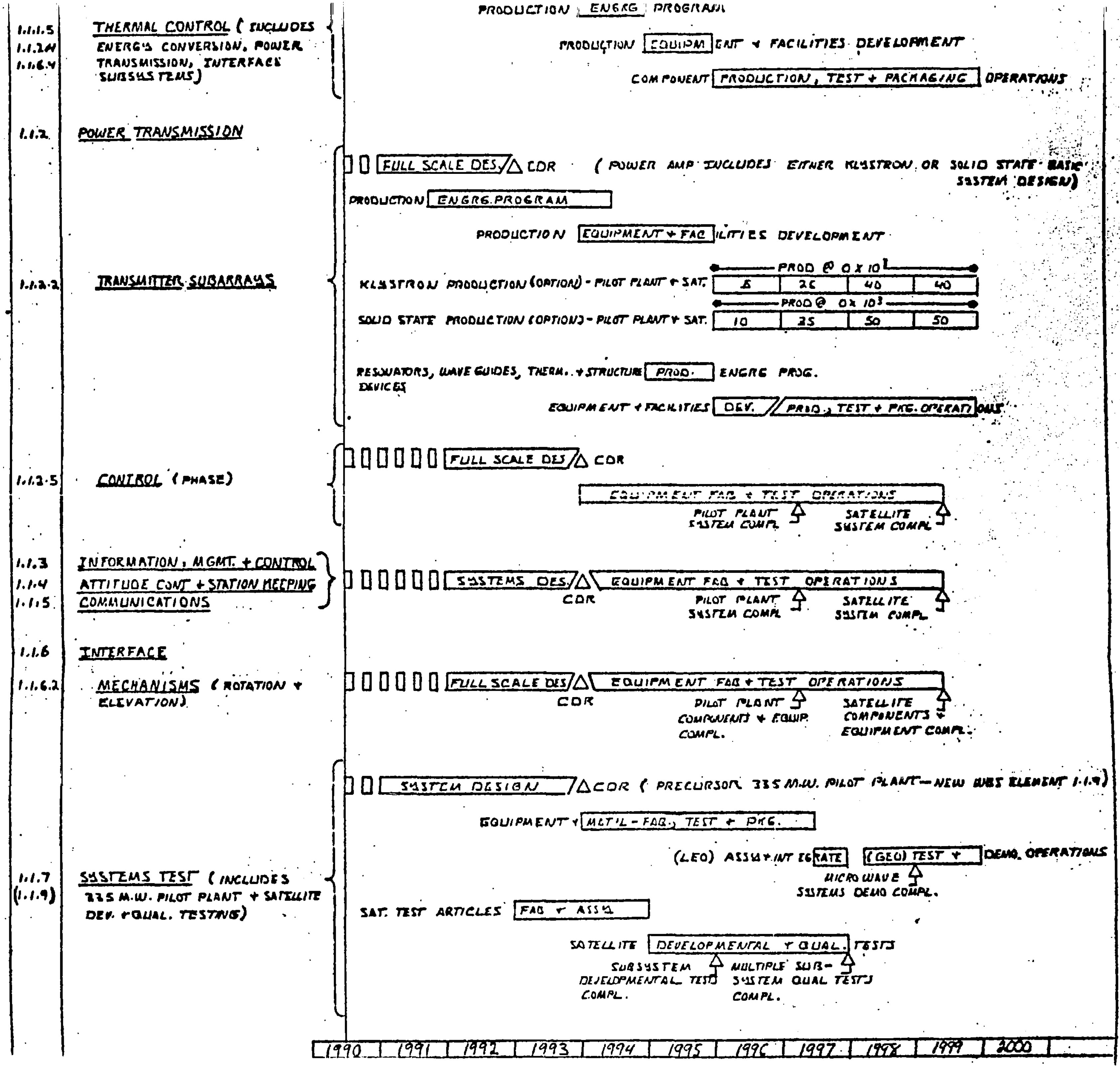


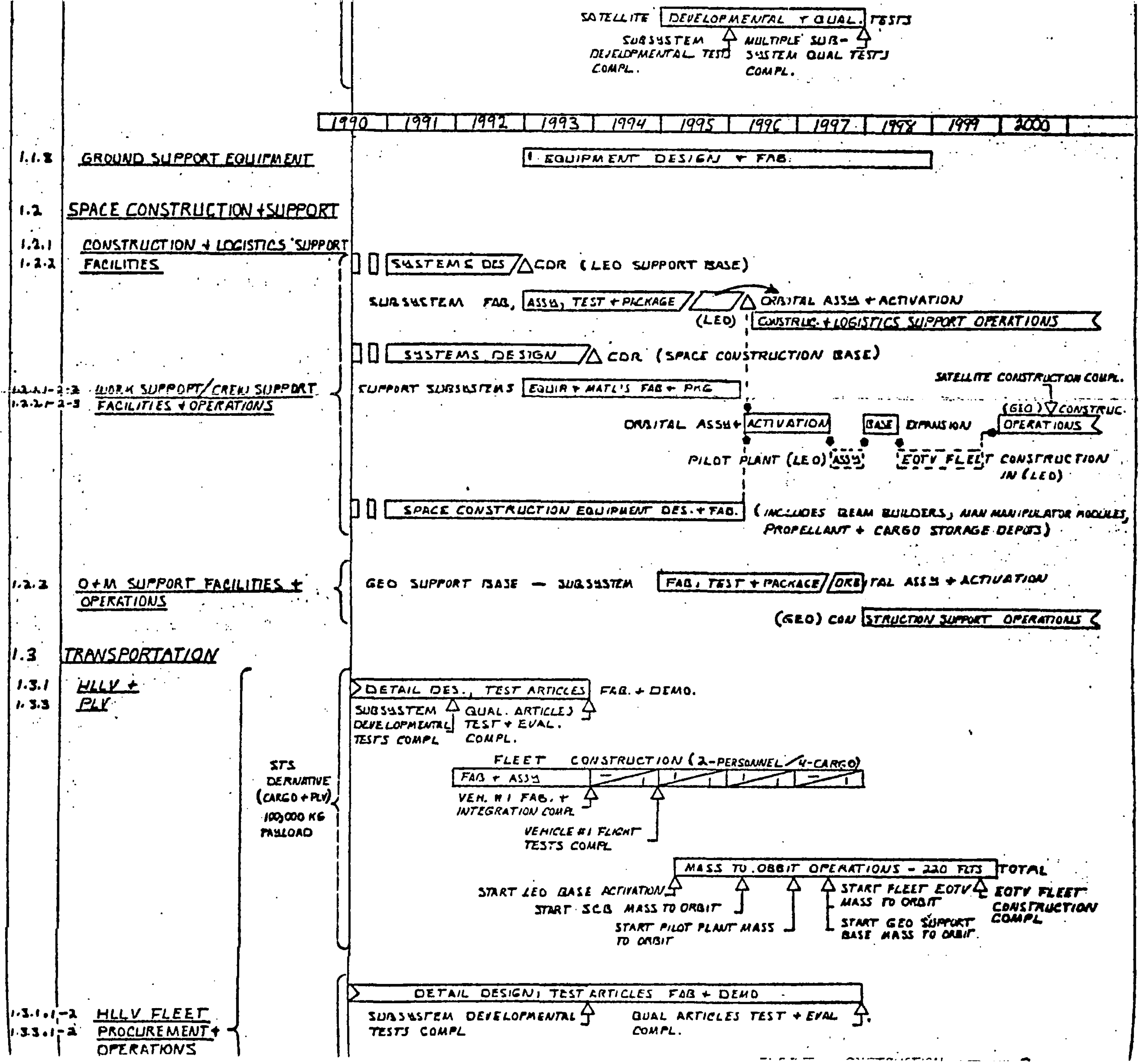
Figure 1-3. SPS DDT&E Program Schedule (Technology Advancement Phase)

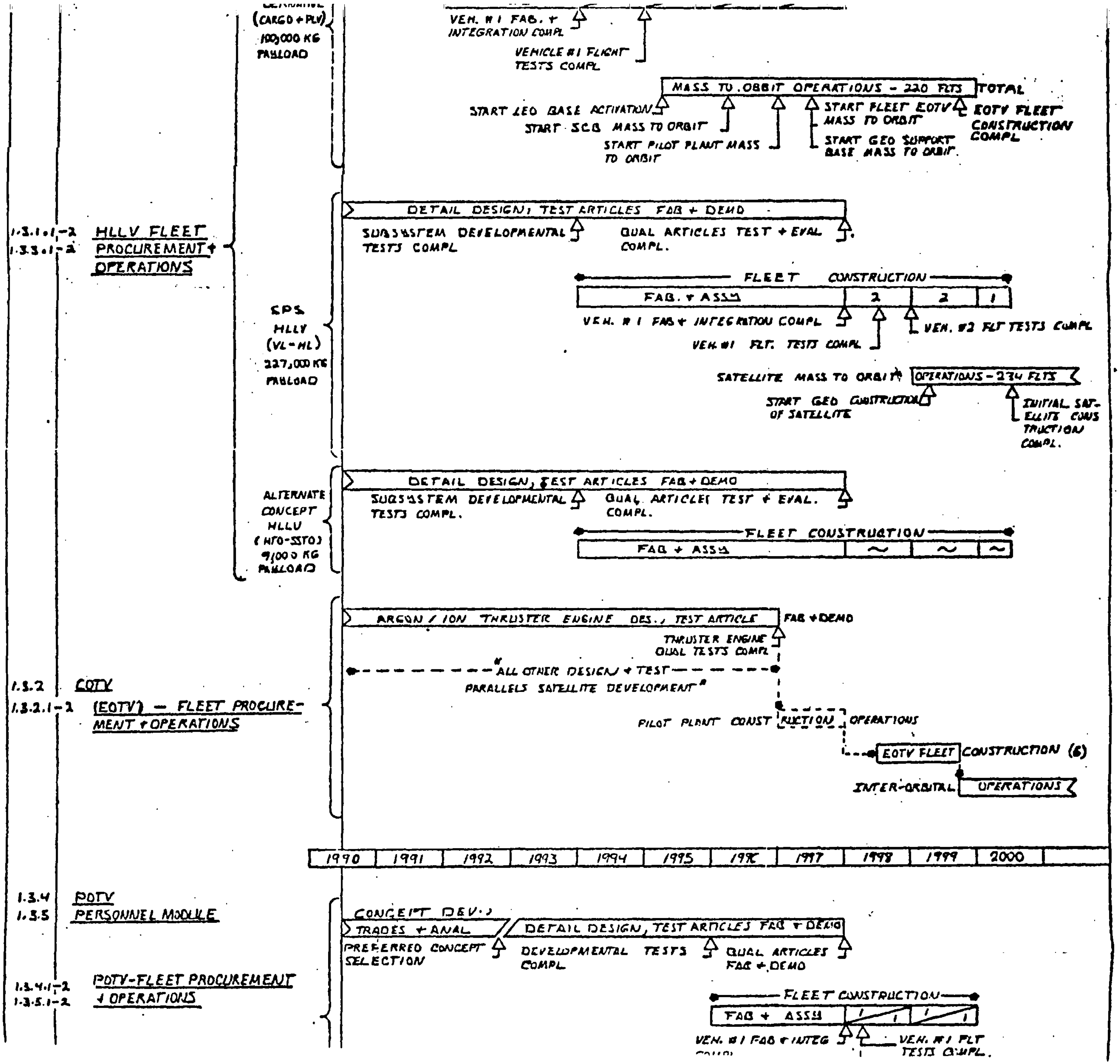
SPS
PROGRAM SCHEDULE
(DDT+E / TFU DEVELOPMENT PHASE)

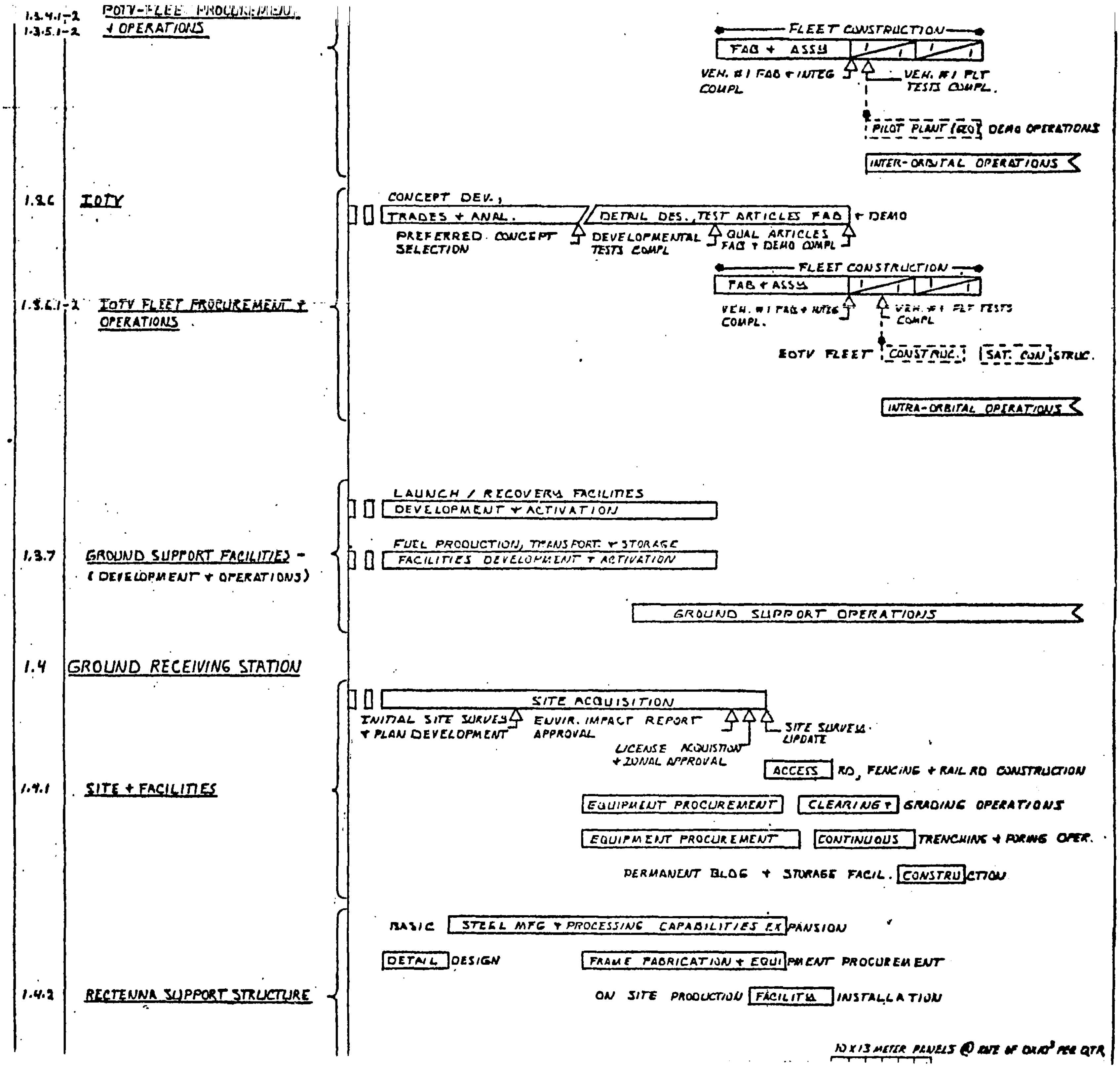




PRODUCTION ENGRG PROGRAM
PRODUCTION EQUIPMENT + FACILITIES DEVELOPMENT
COMPONENT PRODUCTION, TEST + PACKAGING OPERATIONS
1.1.1.5 1.1.2.4 1.1.6.4 THERMAL CONTROL (INCLUDES ENERGY CONVERSION, POWER TRANSMISSION, INTERFACE SUBSYSTEMS)
1.1.2 POWER TRANSMISSION
FULL SCALE DES CDR
(POWER AMP INCLUDES EITHER KLYSTRON OR SOLID STATE BASIC SYSTEM DESIGN)
PRODUCTION ENGRG. PROGRAM
PRODUCTION EQUIPMENT + FACILITIES DEVELOPMENT
1.1.2.2 TRANSMITTER SUBARRAYS
PROD @ 0 x 10
KLYSTRON PRODUCTION (OPTION) - PILOT PLANT + SAT.
5
26
40
40
PROD @ 0 x 10
SOLID STATE PRODUCTION (OPTION) - PILOT PLANT + SAT.
10
25
50
50
RESONATORS, WAVE GUIDES, THERM. + STRUCTURE DEVICES
PROD. ENGRG PROG.
EQUIPMENT + FACILITIES DEV. PROD., TEST + PKG. OPERATIONS
1.1.2.5 CONTROL (PHASE)
FULL SCALE DES CDR
EQUIPMENT FAB + TEST OPERATIONS
PILOT PLANT SYSTEM COMPL.
SATELLITE SYSTEM COMPL.
1.1.3 INFORMATION, MGMT. + CONTROL
1.1.4 ATTITUDE CONT + STATION KEEPING
1.1.5 COMMUNICATIONS
SYSTEMS DES. CDR
EQUIPMENT FAB + TEST OPERATIONS
PILOT PLANT SYSTEM COMPL.
SATELLITE SYSTEM COMPL.
1.1.6 INTERFACE
1.1.6.2 MECHANISMS (ROTATION + ELEVATION)
FULL SCALE DES CDR
EQUIPMENT FAB + TEST OPERATIONS
PILOT PLANT COMPONENTS + EQUIP. COMPL.
SATELLITE COMPONENTS + EQUIPMENT COMPL.
SYSTEM DESIGN
CDR (PRECURSOR 335 M.W. PILOT PLANT — NEW WBS ELEMENT 1.1.9)
EQUIPMENT + MAT'L - FAB., TEST + PKG.
(LEO) ASSY + INTEGRATE (GEO) TEST + DEMO. OPERATIONS
MICROWAVE SYSTEMS DEMO COMPL.
1.1.7 (1.1.9) SYSTEMS TEST (INCLUDES 335 M.W. PILOT PLANT + SATELLITE DEV. + QUAL. TESTING)
SAT. TEST ARTICLES FAB + ASSY
SATELLITE DEVELOPMENTAL + QUAL. TESTS
SUBSYSTEM DEVELOPMENTAL TESTS COMPL.
MULTIPLE SUB-SYSTEM QUAL TESTS COMPL.
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000


SATELLITE DEVELOPMENTAL + QUAL. TESTS
SUBSYSTEM DEVELOPMENTAL TESTS COMPL.
MULTIPLE SUB-SYSTEM QUAL TESTS COMPL.
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000
1.1.8 GROUND SUPPORT EQUIPMENT
EQUIPMENT DESIGN + FAB.
1.2 SPACE CONSTRUCTION + SUPPORT
1.2.1 1.2.2 CONSTRUCTION + LOGISTICS SUPPORT FACILITIES
SYSTEMS DES CDR (LEO SUPPORT BASE)
SUBSYSTEM FAB, ASSY, TEST + PACKAGE
(LEO)
ORBITAL ASSY + ACTIVATION
CONSTRUC. + LOGISTICS SUPPORT OPERATIONS
SYSTEMS DESIGN CDR (SPACE CONSTRUCTION BASE)
1.2.1.1-2.3 1.2.2.1-2.3 WORK SUPPORT/CREW SUPPORT FACILITIES + OPERATIONS
SUPPORT SUBSYSTEMS EQUIP + MATL'S FAB + PKG
SATELLITE CONSTRUCTION COMPL.
(GEO) CONSTRUC. OPERATIONS
ORBITAL ASSY + ACTIVATION
BASE EXPANSION
PILOT PLANT (LEO) ASSY
EOTV FLEET CONSTRUCTION IN (LEO)
SPACE CONSTRUCTION EQUIPMENT DES. + FAB.
(INCLUDES BEAM BUILDERS, MAN MANIPULATOR MODULES, PROPELLANT + CARGO STORAGE DEPOTS)
1.2.3 O+M SUPPORT FACILITIES + OPERATIONS
GEO SUPPORT BASE — SUBSYSTEM FAB, TEST + PACKAGE ORBITAL ASSY + ACTIVATION
(GEO) CONSTRUCTION SUPPORT OPERATIONS
1.3 TRANSPORTATION
1.3.1 1.3.3 HLLV + PLV
STS DERIVATIVE (CARGO + PLV) 100,000 KG PAYLOAD
DETAIL DES., TEST ARTICLES FAB. + DEMO.
SUBSYSTEM DEVELOPMENTAL TESTS COMPL
QUAL. ARTICLES TEST + EVAL. COMPL.
FLEET CONSTRUCTION (2-PERSONNEL/4-CARGO)
FAB + ASSY
VEH. #1 FAB. + INTEGRATION COMPL
VEHICLE #1 FLIGHT TESTS COMPL
MASS TO ORBIT OPERATIONS - 220 FLTS TOTAL
START LEO BASE ACTIVATION
START SCB MASS TO ORBIT
START PILOT PLANT MASS TO ORBIT
START FLEET EOTV MASS TO ORBIT
START GEO SUPPORT BASE MASS TO ORBIT
EOTV FLEET CONSTRUCTION COMPL
1.3.1.1-2 1.3.3.1-2 HLLV FLEET PROCUREMENT + OPERATIONS
DETAIL DESIGN, TEST ARTICLES FAB + DEMO
SUBSYSTEM DEVELOPMENTAL TESTS COMPL
QUAL ARTICLES TEST + EVAL COMPL.


(CARGO + PLV)
100,000 KG
PAYLOAD
VEH. #1 FAB. + INTEGRATION COMPL
VEHICLE #1 FLIGHT TESTS COMPL
MASS TO ORBIT OPERATIONS - 220 FLTS TOTAL
START LEO BASE ACTIVATION
START SCB MASS TO ORBIT
START PILOT PLANT MASS TO ORBIT
START FLEET EOTV MASS TO ORBIT
START GEO SUPPORT BASE MASS TO ORBIT
EOTV FLEET CONSTRUCTION COMPL
1.3.1.1-2
1.3.3.1-2
HLLV FLEET PROCUREMENT + OPERATIONS
SPS
HLLV
(VL-HL)
227,000 KG
PAYLOAD
DETAIL DESIGN, TEST ARTICLES FAB + DEMO
SUBSYSTEM DEVELOPMENTAL TESTS COMPL
QUAL ARTICLES TEST + EVAL COMPL.
FLEET CONSTRUCTION
FAB. + ASSY
2
2
1
VEH. #1 FAB + INTEGRATION COMPL
VEH. #1 FLT. TESTS COMPL
VEH. #2 FLT TESTS COMPL
SATELLITE MASS TO ORBIT
OPERATIONS - 234 FLTS
START GEO CONSTRUCTION OF SATELLITE
INITIAL SATELLITE CONSTRUCTION COMPL.
ALTERNATE CONCEPT HLLV (HTO-SSTO) 91,000 KG PAYLOAD
DETAIL DESIGN, TEST ARTICLES FAB + DEMO
SUBSYSTEM DEVELOPMENTAL TESTS COMPL.
QUAL. ARTICLES TEST + EVAL. COMPL.
FLEET CONSTRUCTION
FAB + ASSY
ARGON / ION THRUSTER ENGINE DES., TEST ARTICLE FAB + DEMO
THRUSTER ENGINE QUAL TESTS COMPL
ALL OTHER DESIGN + TEST
PARALLELS SATELLITE DEVELOPMENT
1.3.2 COTV
1.3.2.1-2 (EOTV) — FLEET PROCUREMENT + OPERATIONS
PILOT PLANT CONSTRUCTION OPERATIONS
EOTV FLEET CONSTRUCTION (6)
INTER-ORBITAL OPERATIONS
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
1.3.4 POTV
1.3.5 PERSONNEL MODULE
CONCEPT DEV.
TRADES + ANAL
PREFERRED CONCEPT SELECTION
DETAIL DESIGN, TEST ARTICLES FAB + DEMO
DEVELOPMENTAL TESTS COMPL
QUAL ARTICLES FAB + DEMO
1.3.4.1-2
1.3.5.1-2
POTV-FLEET PROCUREMENT + OPERATIONS
FLEET CONSTRUCTION
FAB + ASSY
1
1
1
1
VEH. #1 FAB + INTEG COMPL
VEH. #1 FLT TESTS COMPL.


1.3.4.1-2
1.3.5.1-2
+ OPERATIONS
FLEET CONSTRUCTION
FAB + ASSY
VEH. #1 FAB + INTEG COMPL
VEH. #1 FLT TESTS COMPL.
PILOT PLANT DEMO OPERATIONS
INTER-ORBITAL OPERATIONS
1.3.6
IOTV
CONCEPT DEV.,
TRADES + ANAL.
PREFERRED CONCEPT SELECTION
DETAIL DES., TEST ARTICLES FAB + DEMO
DEVELOPMENTAL TESTS COMPL
QUAL ARTICLES FAB + DEMO COMPL
1.3.6.1-2
IOTV FLEET PROCUREMENT + OPERATIONS
FLEET CONSTRUCTION
FAB + ASSY
VEH. #1 FAB + INTEG COMPL.
VEH. #1 FLT TESTS COMPL
EOTV FLEET
CONSTRUC.
SAT. CONSTRUC.
INTRA-ORBITAL OPERATIONS
LAUNCH / RECOVERY FACILITIES
DEVELOPMENT + ACTIVATION
1.3.7
GROUND SUPPORT FACILITIES -
(DEVELOPMENT + OPERATIONS)
FUEL PRODUCTION, TRANSPORT + STORAGE
FACILITIES DEVELOPMENT + ACTIVATION
GROUND SUPPORT OPERATIONS
1.4
GROUND RECEIVING STATION
SITE ACQUISITION
INITIAL SITE SURVEY + PLAN DEVELOPMENT
ENVIR. IMPACT REPORT APPROVAL
LICENSE ACQUISITION + ZONAL APPROVAL
SITE SURVEY UPDATE
1.4.1
SITE + FACILITIES
ACCESS RD, FENCING + RAIL RD CONSTRUCTION
EQUIPMENT PROCUREMENT
CLEARING + GRADING OPERATIONS
EQUIPMENT PROCUREMENT
CONTINUOUS TRENCHING + FORMING OPER.
PERMANENT BLDG + STORAGE FACIL. CONSTRUCTION
BASIC STEEL MFG + PROCESSING CAPABILITIES EXPANSION
DETAIL DESIGN
FRAME FABRICATION + EQUIPMENT PROCUREMENT
1.4.2
RECTENNA SUPPORT STRUCTURE
ON SITE PRODUCTION FACILITY INSTALLATION
10 X 13 METER PANELS

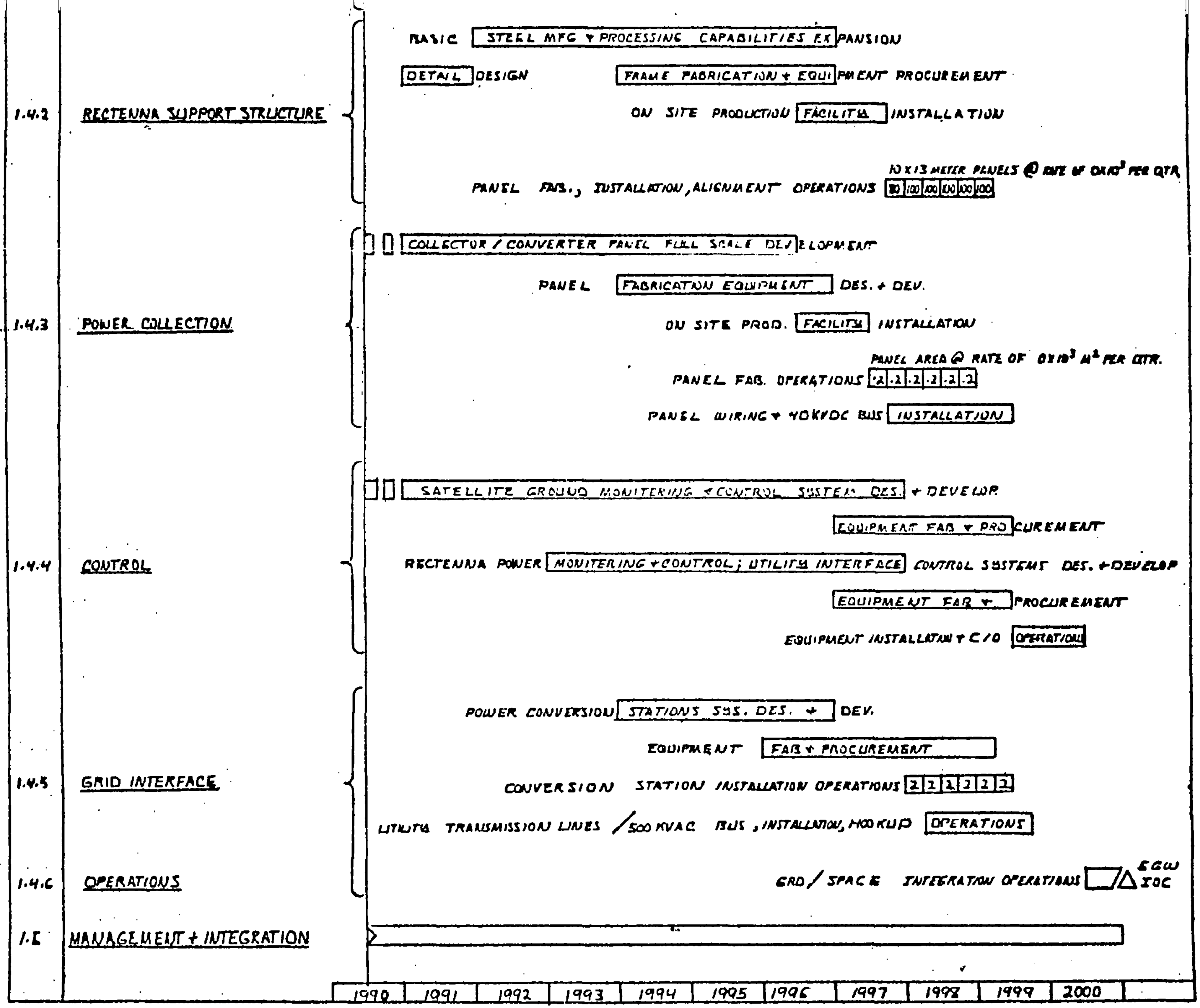


Figure 1-4. SPS Program Schedule (DDT&E/TFU Development Phase)

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
1	PROGRAM MANAGEMENT (Cont.)

development; and (3) the prototype production operations and sequences. Emphasis in this schedule is also placed upon ground/space power system assembly and integration operations and the major equipment and facility development programs required to support these operations. The transportation schedule section is confined to those vehicles needing development for mission use during this particular program phase. It describes the phasing of (1) STS growth/derivative HLLV's which will be used to transport the mass to orbit, facilities, equipment, and personnel to LEO in support of the satellite construction base and its activation; (2) SPS-dedicated HLLV's (VTO-HL) to transport the main satellite construction mass to LEO; (3) the COTV (EOTV) which will be used for large interoribtal cargo mass transfer; and (4) the personnel and high-priority cargo-carrying space vehicles (IOTV, POTV. and PM). The ground station system/subsystem design, development, and construction scenario has been addressed as it will support the overall program. WBS numbers and titles are referenced in the margin, and have been used to provide the basic structure and layout for this schedule.

3. *Special-Emphasis Network—Microwave Technology*

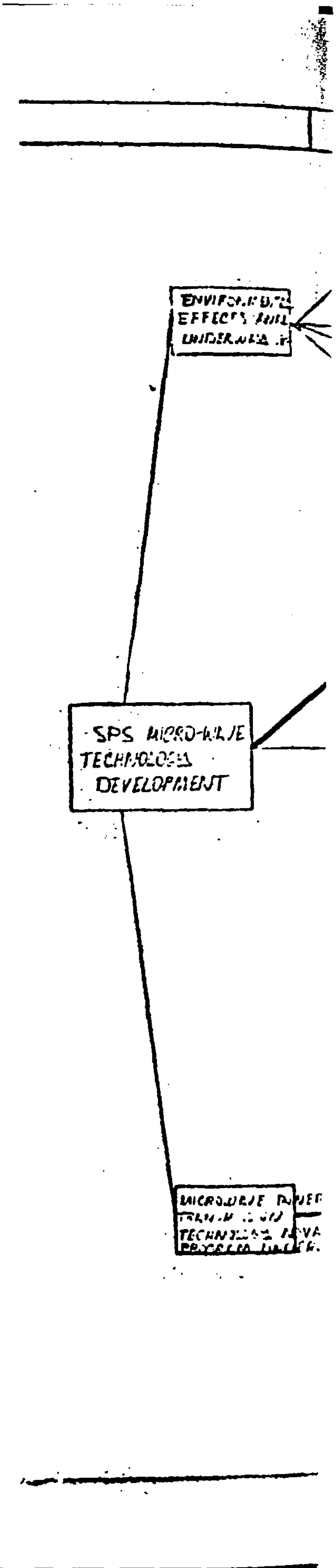
Current technology exploration studies indicate that microwave technology advancement will be a single most-significant pacer in total program development. In order to illustrate the need for early resource allocation directed toward near-term technology exploration and test verification of the concepts now under consideration, a time-oriented logic network was developed as shown in Figure 1-5. It traces the full microwave scope of this effort and highlights program continuation decision gates at critical junctures.

Phase I (1980 through 1985) describes the tasks (including their timing and interrelationships) needed to define requirements, develop concepts, perform trades, conduct analysis on alternate designs, perform tests and evaluations on these alternative concepts and, finally, make a concept selection which will be the baseline for full-scale development.

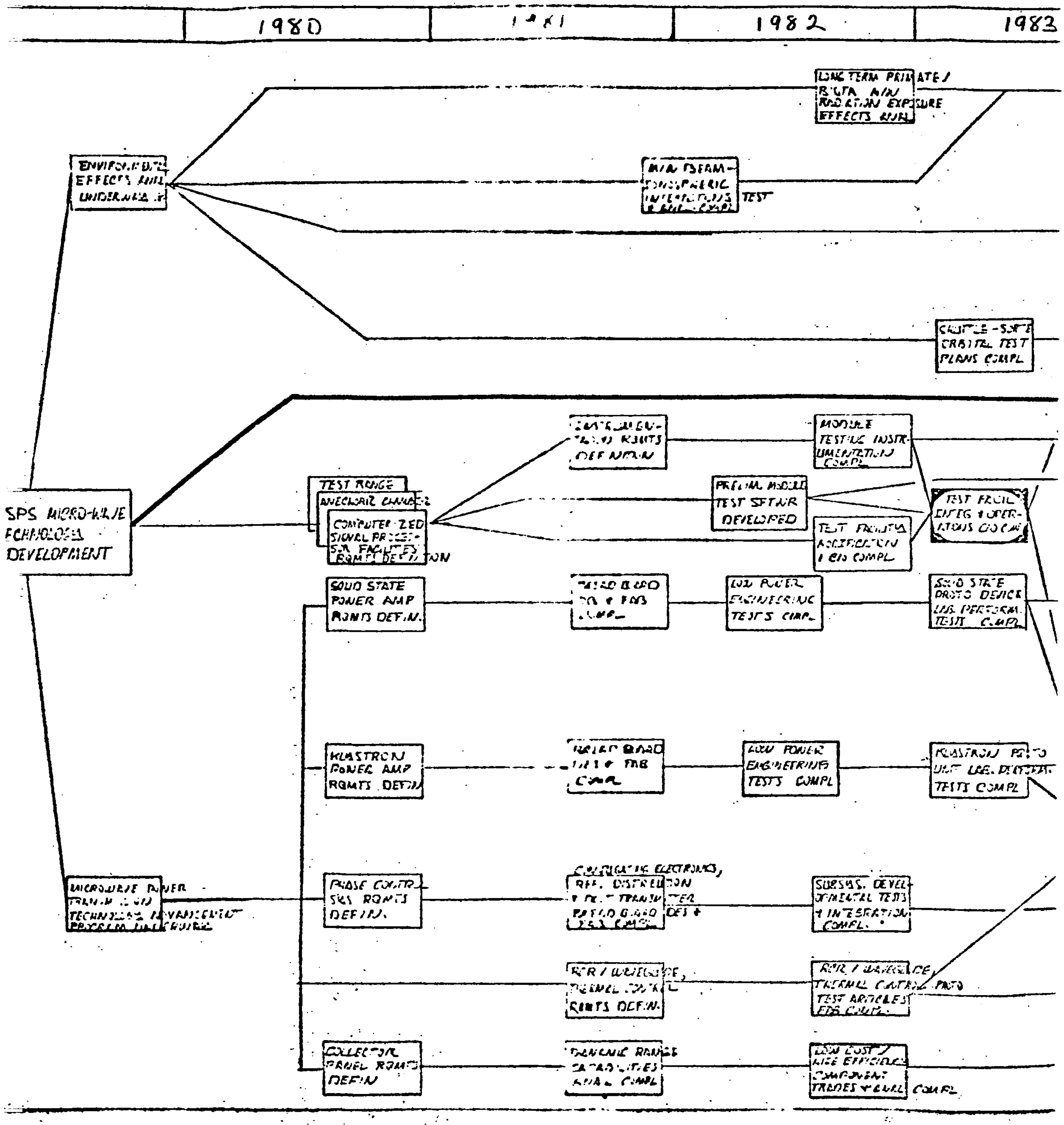
The network also describes parallel development programs on ground test facilities, equipment, instrumentation, and software needed to support the engineering development process.

Phase II (1986 through 1989) describes the development of equipment and test articles needed to provide performance verification of the complete microwave system alone, and the microwave system integrated with key elements of the multi-test platform program for a complete earth/ground-based technology demonstration scheduled for late 1989.

Phase III (1990 through 2000) describes the full-scale development of the subsystem along with the parallel development of all other satellite subsytems. The program culminates with a performance demonstration of multiple subarrays as integrated with other systems in the precursor pilot plant and, finally,

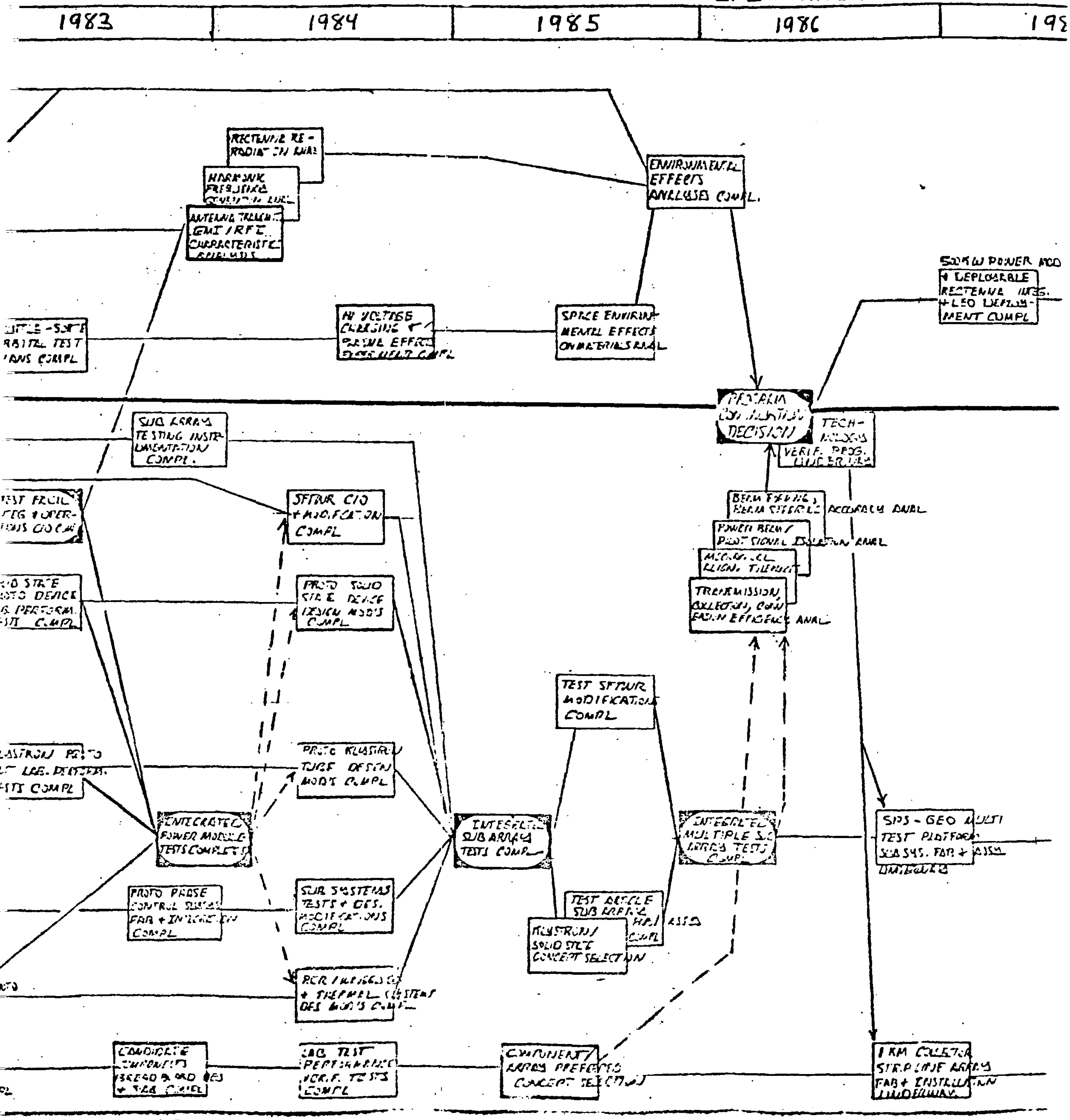


SPS MICRO-WAVE
TECHNOLOGY
DEVELOPMENT

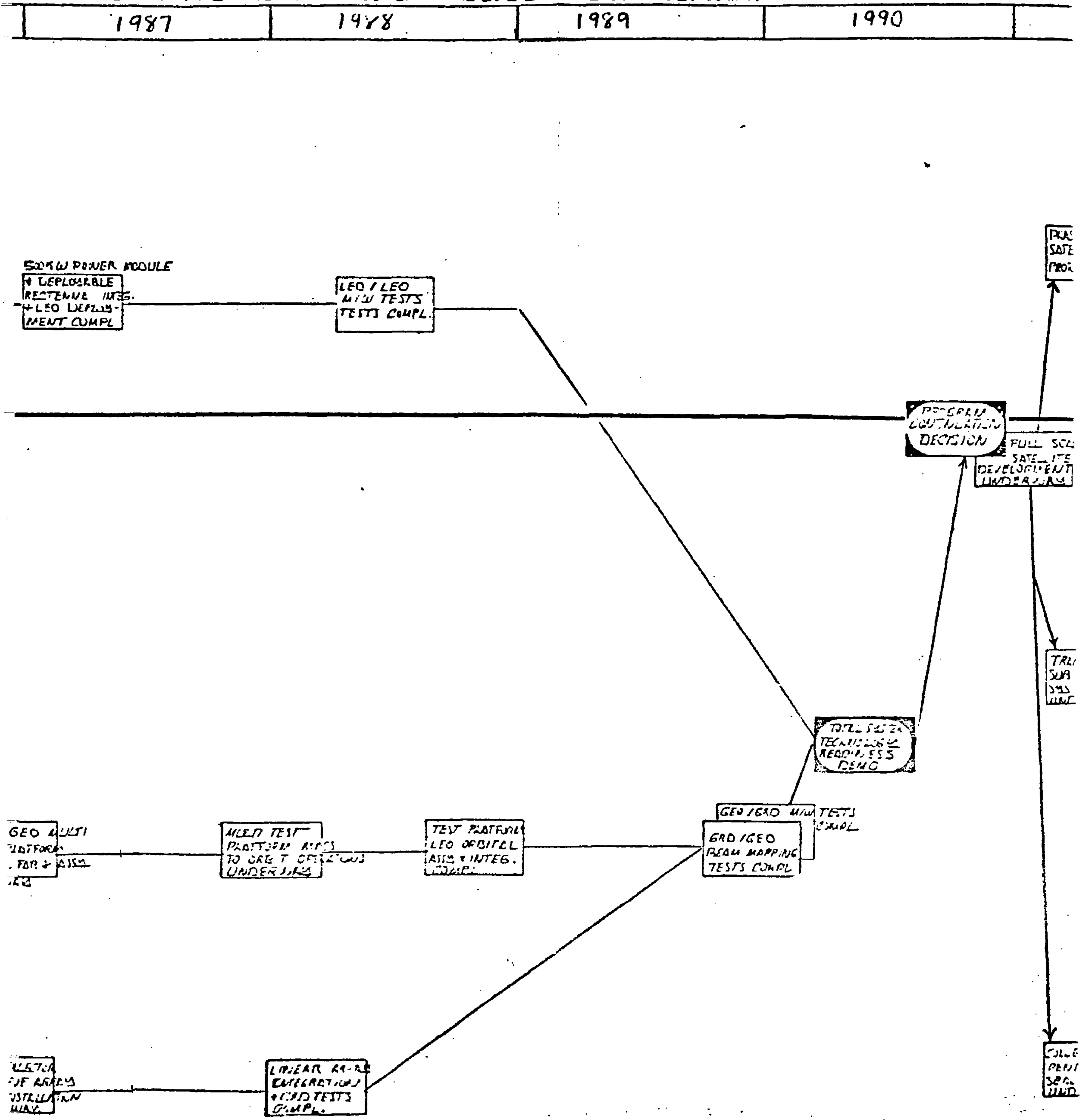


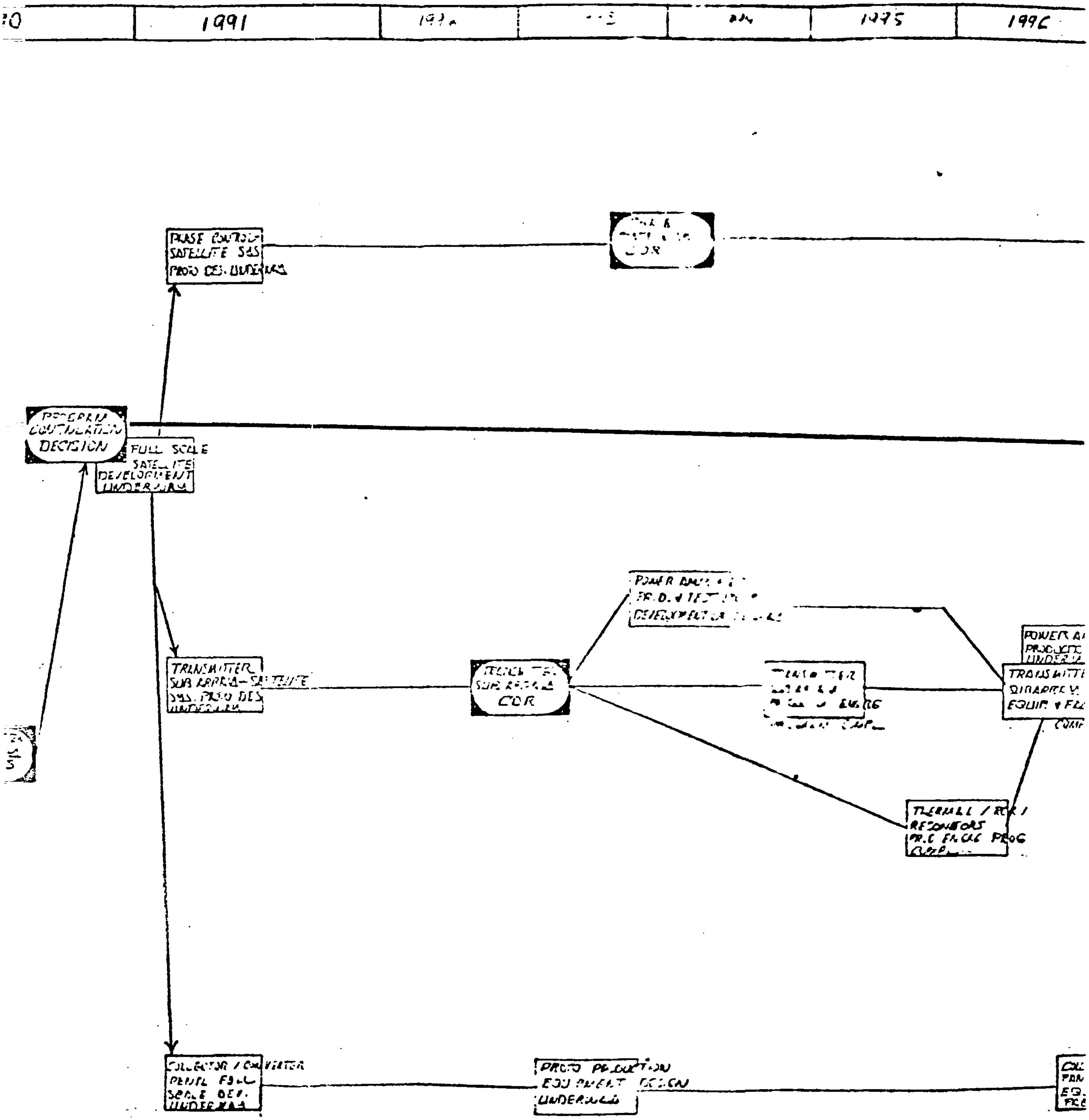
1980
1982
1983
LONG TERM PRIMATE / BIOTA M/W RADIATION EXPOSURE EFFECTS ANAL
ENVIRONMENTAL EFFECTS ANAL
M/W BEAM-IONOSPHERIC INTERACTIONS
TEST
SHUTTLE-SORTIE ORBITAL TEST PLANS COMPL
SPS MICRO-WAVE TECHNOLOGY DEVELOPMENT
TEST RANGE
ANECHOIC CHAMBER
COMPUTERIZED SIGNAL PROCESSOR FACILITIES RQMTS DEFINITION
MODULE TESTING INSTRUMENTATION COMPL
PRELIM MODEL TEST SETUP DEVELOPED
TEST FACILITIES ACQUISITION COMPL
SOLID STATE POWER AMP RQMTS DEFIN.
LOW POWER ENGINEERING TESTS COMPL
SOLID STATE PROTO DEVICE LAB PERFORM. TESTS COMPL
KLYSTRON POWER AMP RQMTS DEFIN
BREAD BOARD DES & FAB COMPL
LOW POWER ENGINEERING TESTS COMPL
KLYSTRON PROTO UNIT LAB. PERFORM TESTS COMPL
MICROWAVE POWER TRANSMISSION TECHNOLOGY ADVANCEMENT PROGRAM DEFINITION
PHASE CONTROL SYS RQMTS DEFIN.
SUBSYS. DEVELOPMENTAL TESTS & INTEGRATION COMPL.
RQMTS DEFIN.
PROTO
COLLECTOR PANEL RQMTS DEFIN
TRADES & ANAL COMPL

SPS - MICROWAVE POWER



VE POWER TRANSMISSION SYSTEM - DEVELOPMENT NETWORK





1991
1995
PROGRAM CONTINUATION DECISION
FULL SCALE SATELLITE DEVELOPMENT UNDERWAY
COR

Figure 1-5.

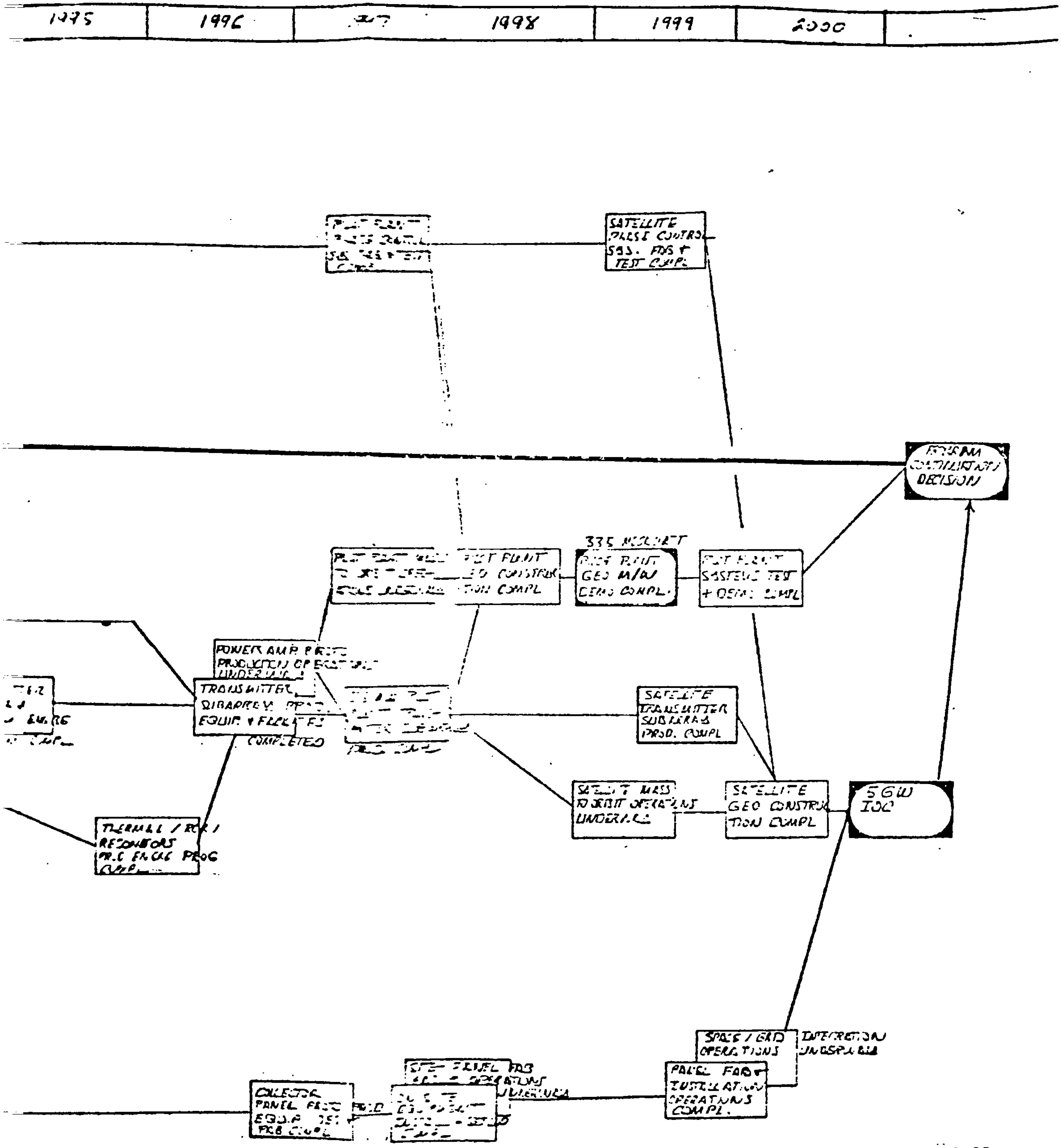


Figure 1-5. SPS Microwave Power Transmission System
—Development Network

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 1 | TITLE

PROGRAM MANAGEMENT (Cont.)

in the all-up systems test of the 5-GW initial satellite. To reiterate, the results of earlier ground-based microwave technology development and performance verification activities will be a most significant factor in evaluating the feasibility of continued total system development.

4. *GRS Site Activation Schedule*

A series of detail phasing schedules were developed on the activation of each of the first four ground station receiving sites (Figure 1-6). Operational sequences were identified for site survey, ground preparation, panel fabrication, concrete placement, facilities installation, and checkout activities. Contacts with A&E, equipment manufacturing, concrete, and construction firms provided additional information on the duration and sequence of operations from their experience on programs of this size. Figure 1-7 is an integrated summary schedule of major events in constructing the ground receiving station and emphasizes the utilization of construction equipment and its transfer from site to site as required to maintain the build-rate of two rectennas per year. It was concluded that the equipment from Site 1 would be available for use on Site 3. This information on equipment utilization, site sequencing, and equipment lifetimes was used to establish total resource requirements and cost estimates for the program.

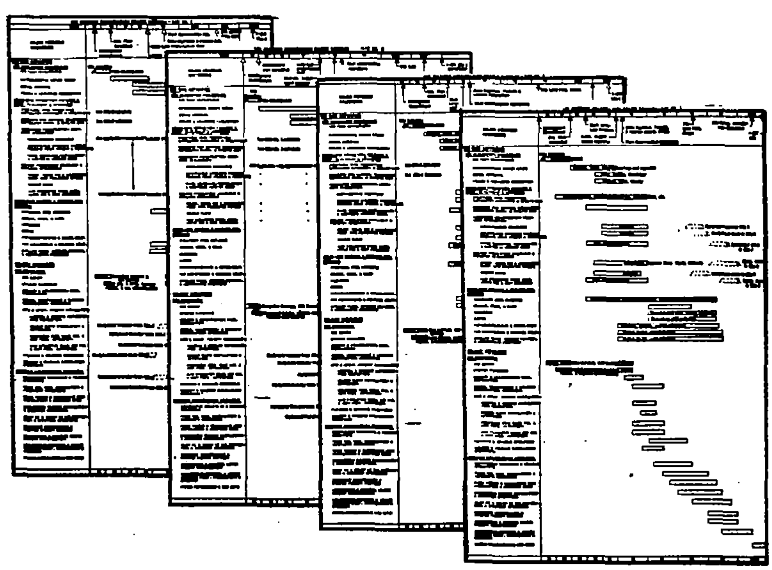


Figure 1-6. GRS Phasing Schedules

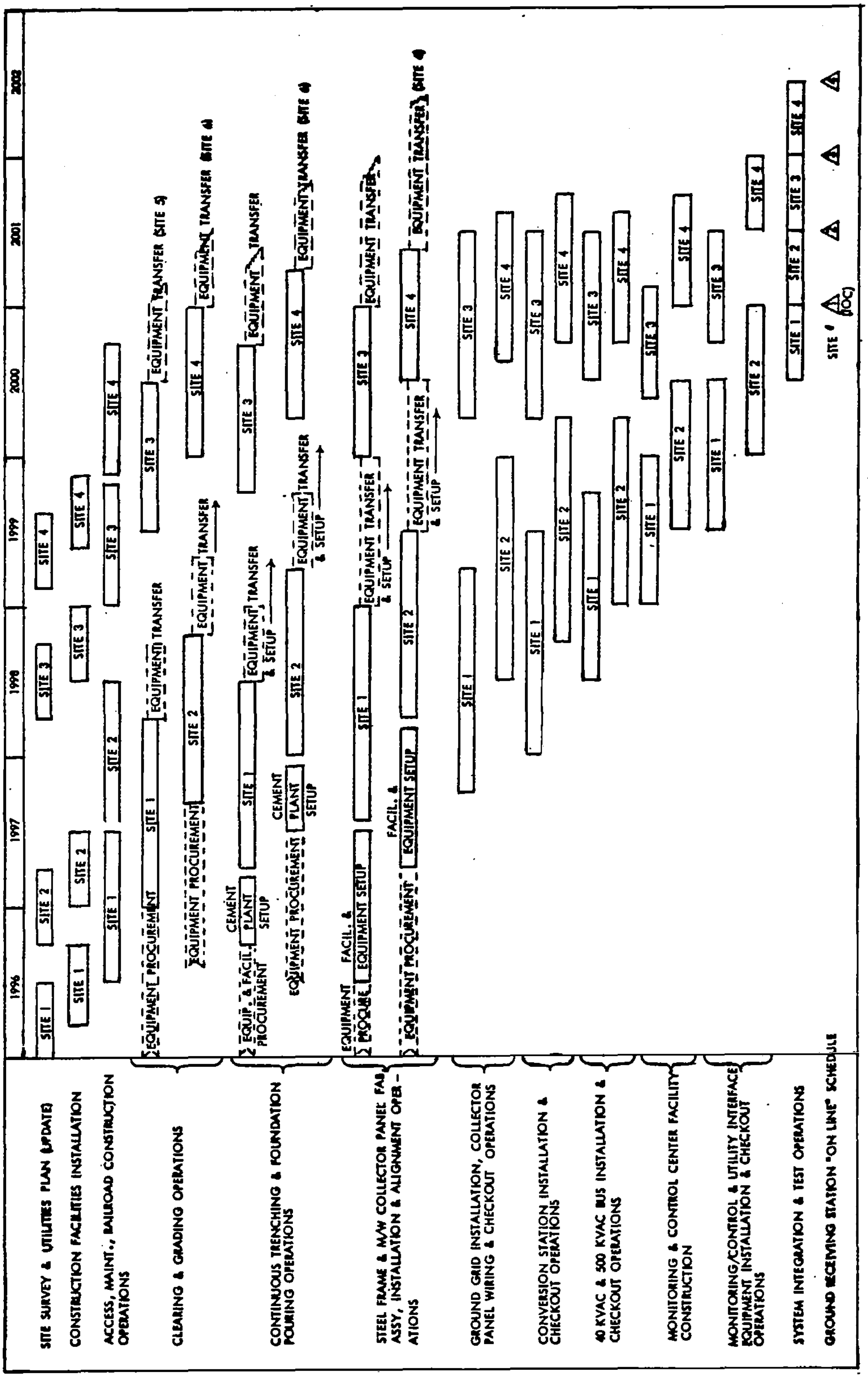


Figure 1-7. SPS Rectenna Construction Sequence Summary Schedule Flow

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 2 | TITLE

SYSTEM ENGINEERING AND INTEGRATION

PROGRAM PLAN DESCRIPTION

This plan shall address the planning for the systems engineering and integration functions to include items such as mission planning, system and subsystem requirements, interfaces (ICD's), verification testing requirements, and payload integration. Costs shall be a major consideration in this planning.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- System and Subsystem Requirements
- Mission Planning
- Interface Control Documents
- Verification Test Definition Requirements
- Payload Integration
- Systems Development and Operations Monitoring
- SPS Cost/Economics

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
  - Engineering Management
  - Safety
  - Reliability
  - Maintainability
  - Support Management
- Support Materials/Equipment and Facilities

DISCUSSION

This plan deals with many software items which must be carried through the entire program. Typical are the definition of hardware requirements verification testing, mission planning, ICD's, payload integration, and costs. Each of these elements may affect hardware design and development in the conceptual stages. Major systems are assigned to Category C under this plan since system requirements must be established, interfaces defined, and continuous updating performed from the earliest stages of the program. Perhaps most importantly, this plan will provide for the development of all cost data, CER's, and costing. These data will form the basis for establishing long-range budgeting for economic projections.

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
3	DESIGN AND DEVELOPMENT

PROGRAM PLAN DESCRIPTION

This plan shall address the design and development of the system and subsystems, including design engineering, development and qualification testing. The hardware and software to carry out these activities shall be identified. The technology and/or development status of each subsystem shall be discussed in sufficient detail to allow for a management assessment of program development risks.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- System and Subsystem Drawing/Specification Requirements
- Supporting Software and Hardware Requirements
- Development Program Definitions and Design Requirements
  - Structural elements—joining and stiffening
  - Beam machine development
  - Solar blanket design efficiency and reliability
  - Microwave reliability and efficiency requirements
  - Rectenna design optimization
  - Utility interface design requirements
- Qualification Test Procedures and Requirements
- Design Interfaces of Systems/Subsystems

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
  - Design, development, and qualification testing manpower
- Supporting Hardware and Software
- Support Materials/Equipment and Facilities

DISCUSSION

This plan provides for all design and, as such, produces drawings, specifications, and other software. It is a major engineering effort and therefore will have significant impact in terms of manpower requirements. However, there is reason to believe that these resources can be made available from existing technical labor markets, such as the aerospace industry, as needed. The same can be said for technology needs in terms of analytical tools, computer software, etc. Two areas are of present concern. First of all, the status of technology and development related to key subsystems and components must be determined and extrapolated to the time frame where needed for the SPS prototype. (Examples are klystrons and GaAs solar cells.) This will permit a risk assessment to be made and justify the allocation of resources to most critical developmental areas. For example, stockpiling of solar cells for the SPS prototype will require a production rate of about 500 MW per year

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
3	DESIGN AND DEVELOPMENT (Cont.)

starting in the late 1980's. Risk assessments under this plan would be a basis for implementing major developmental effort on GaAs to provide thin-film, high-efficiency cells.

Secondly, developmental programs must be identified, planned, and carried out to assure that proof-of-concept will actually take place as scheduled. This effort assumes that the resolution of key issues or research activities will have been completed under technology development projects. It may, however, include development of equipment such as beam machines, development of large-scale, in-space life support and operational capability, and development of critical components or modules such as prototype solar blankets. Several critical long-range areas of concern are identified in Table 3-1.

Table 3-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 2

PLAN NO. 3	TITLE: DESIGN AND DEVELOPMENT	
WBS ELEMENT	IMPACT	CATEGORY
1.1 Satellite System	Satellite design and supporting development will be a major undertaking due to size and complexity well beyond anything previously attempted in space.	A
1.1.1.1, 1.1.2.1, 1.1.6.1 Structure	The methods of designing the satellite construction base (SCB) and EOTV test article structure will evolve as smaller structural platforms for demonstration projects as designed and developed during earlier phases. The design approach must be closely coordinated with the development of in-space processes and manufacturing equipment throughout the program. This will assure that the design of the structural elements, their joining and stiffening will be compatible with the most effective approach to manufacturing. Design and development of beam machines and fixtures specific to the SCB and EOTV are included under WBS 1.2. Capability for producing large structures in space must be developed.	B
1.1.1.4, 1.1.6.2, 1.1.6.3 Rotary Joint, Mechanisms	Special consideration must be given to design and development to provide high reliability of the slip rings and brushes. Parts replacement must be considered.	B
1.1.1 Energy Conversion	Design and development of solar blankets must address the integrated power source at this level although most hardware-related effort will be at a lower level. Energy conversion is among the most critical subsystems requiring extensive development and long lead times. The design and development of the solar blanket will be, perhaps, the most critical item in the SPS. Considerable development will be required, extending over a long period before a suitable design evolves which combines the essential features of lightweight, high efficiency, high reliability, high proton damage resistance, satisfactory handling, and high production and low cost.	A

Table 3-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 2 of 2

PLAN NO. 3 TITLE: DESIGN AND DEVELOPMENT

WBS ELEMENT	IMPACT	CATEGORY
1.1.2, 1.1.2.2 Power Transmission/Subarrays	Design and development of regulators, switch gear, circuit breakers, klystrons, beam control, etc., cathode structure will be extensive to assure high efficiency and reliability. Considerable investigations of alternate PDC subsystem and component approaches are foreseen.	A
1.1.7 Systems Test	Comprehensive overall effort involving two or more systems tests including hardware and operations plus design of all STE and facilities not included elsewhere. A major planning effort is required for development and qualification testing.	B
1.2 Space Construction and Support	Design and development of SCB, LEO base, satellite O&M base, and support equipment is a major task involving such items as assembly fixtures, beam machines, teleoperators, etc. This is one of the most critical areas of development. ICD's must be considered throughout design and development. Concerns include life support, logistics, docking, flight control, personnel/cargo transfer, etc.	A
1.3 Transportation	Major parallel programs on HLLV, EOTV, PLV, POTV, PM, and IOTV. Therefore, ICD's must be considered throughout design. Engine development and vehicle design critical for multimission use.	B
1.4 Ground Receiving Station, Dipole/Rectifier Elements, Power Distribution and Conditioning, Utility Interface	Because of large overall size and number of elements, must emphasize minimum use of materials; high reliability and low maintenance must be emphasized in overall design. Power collector design must permit mass production at minimum cost with on-site fabrication of dipole panels. Converter stations require long-term planning and reliability in design. As the ultimate user, the utilities will have requirements for regulation and reliability. The value of SPS-generated power to the utility must be addressed by taking margin requirements, load factor, etc., into account. Power value and requirements can be expected to vary for each grid network with which an interface is contemplated.	C A

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
4	SYSTEMS TESTING

PROGRAM PLAN DEFINITION

This section shall address the approach to systems verification testing with supporting rationale. Also, the system test hardware and any unusual or unique facilities required to carry out the program shall be identified.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
  - Solar blankets— $27 \times 10^6 \, m^2$ per satellite
  - Power distribution and control
  - Rotary joint
  - Microwave power
  - Rectenna
  - Space transportation
- System and Subsystem Verification Test Requirements
- System Test Hardware/Software Definition
- Unique Test Facilities—Ground and Space

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Operational/Support Personnel
- Supporting Hardware and Software
- Support Materials/Equipment and Facilities
- Special/Unique Test Equipment

DISCUSSION

The overall testing hierarchy for Phase C/D consists of:

- Development
- Production
- Qualification
- Verification
- Operations

This plan addresses system verification and includes any tests which involve two or more subsystems and are for the purpose of verifying that the systems will perform to specifications. Verification tests may be performed on either end-item prototype hardware or on hardware specifically designated for verification purposes. For example, the first flight tests of the EOTV will be in orbit and presumably will be of short duration to verify performance prior to actual use of the vehicle for interorbital transfer. The EOTV in this case is a deliverable operational end item. On the other hand, verification tests of beam accuracy, control, and safety interlocks may be conducted during final phases of the GEOSAT, as shown in Figure 4-1. These tests are critical to SPS acceptance and will be conducted on an interim test platform.

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 4	TITLE SYSTEMS TESTING (Cont.)

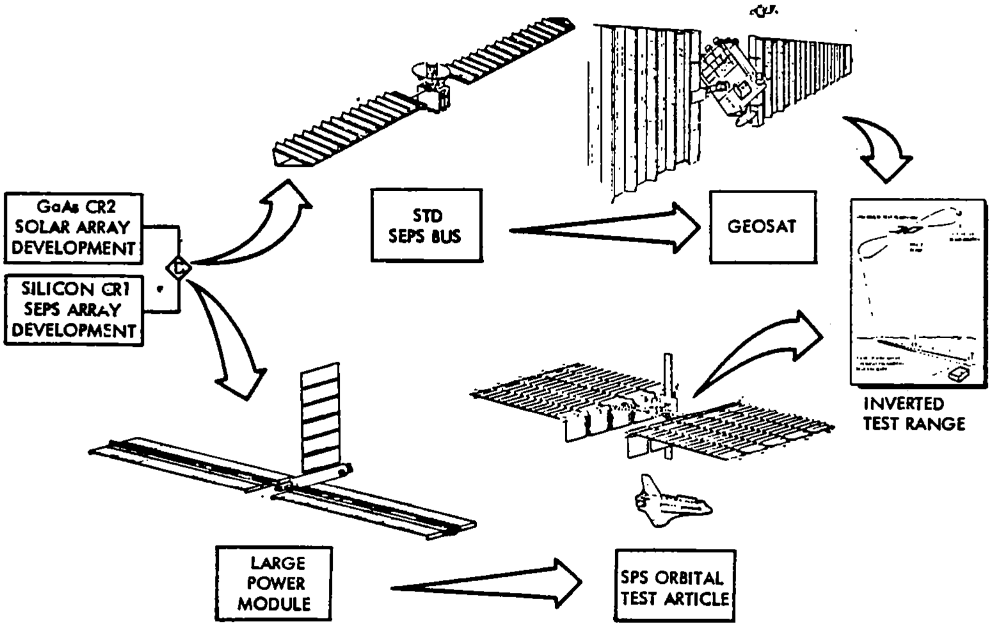


Figure 4-1. SPS Multi-Test Platform Evolution

It remains to be resolved at what levels of assembly actual systems tests will take place and what scope these tests will assume. However, Table 4-1 identifies several areas of concern for reference at this point in time as they apply to main elements of the SPS program.

Table 4-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 3

PLAN NO. 4	TITLE: SYSTEMS TESTING	
WBS ELEMENT	IMPACT	CATEGORY
1.1 Satellite System, Rotary Joint, Mechanisms	Certain tests can only be performed at the satellite level. It is assumed that combined power source/MWPTS/attitude control, etc., would be accomplished as an integrated test program. Systems-level tests will be preceded by component checkout, interface verification, and subsystem testing. Questions which must be answered include: In what increments will a satellite be brought on line? How much of the antenna must be installed before first blanket is activated? Must blankets be covered during installation? (They will be "hot" whenever exposed to direct sunlight.) Should reflectors be installed for checkout, or later after total blankets in each bay are installed? Rectenna converters, switch gear, etc., must be brought to readiness before any blanket can be connected. In addition, are there stability, control, switching, etc., tests which must be performed at this level without ground station interface?	A
	All moving parts such as the rotary joint should have extensive long-term test data to assure reliability. While each of these items may not be of major magnitude relative to the systems programs they may, in total, represent a substantial testing effort. Due to the long lead time involved on the SPS, the opportunity exists to develop the necessary test data provided planning is started early.	B
1.1.1 Energy Conversion	Similar questions arise. What is the testing concept and sequence? For test purposes, will the smallest unit be a single blanket (say, 750×25 m)? How will power source modules include switch gear, regulators, etc., for testing purposes?	A
1.1.1.3 Solar Blankets	The SPS will require approximately 27×10^6 m^2 of solar blankets starting in 1996 for delivery and installation through 2000. Buildup will require average production of 675×10^6 m^2/year for four years starting in 1996. Testing will require ten or more "blimp hangar" size test stands capable of testing blankets on a three-shift basis. Testing of each solar blanket would be done	A

Table 4-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 2 of 3

PLAN NO. 4 TITLE: SYSTEMS TESTING

WBS ELEMENT	IMPACT	CATEGORY
	on test stands adjacent to the factory. These stands would each have solar spectrum simulation capability. Test stands will be located at factory sites.	
1.1.1.4 Power Distribution and Conditioning	High-rate, high-voltage (45 kV) testing of equipment will be involved. Question: What special problems and requirements are involved in high-voltage testing of regulators and switch gear and dc/dc converters?	A
1.1.2 Power Transmission, RF Generation & Beam Control, Power Distribution & Cond.	Verification tests must satisfy beam control and interlock capability relative to safety concerns. High-rate, high-voltage testing at component level for klystrons, driver amplifiers, etc. High-rate, high-voltage testing of conduction network at subsystem level and at component level of switch gear, conditioning electronics.	B
1.1.7 Systems Test & Operations	Comprehensive test requirements needed. Includes all ground systems tests involving two or more subsystems for purposes of qualification and development. Does not include individual component tests such as solar blankets, klystrons, etc. Does not include flight hardware.	A
1.3.7 Facilities	Large facilities will be required for systems tests, particularly those in conjunction with energy conversion and STS.	A
1.4 Ground Receiving Station	Tests must verify 580,500 dipole subarrays plus distribution and conditioning system. Coordination of rectenna construction and operation with the satellite power source and/or MPTS must assure the phased buildup of an integrated power system. What systems level tests must be conducted?	A
1.4.5 Utility Interface	Utility must be prepared to accept interim and incremental power as part of systems testing.	B

Table 4-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 3 of 3

PLAN NO. 4 TITLE: SYSTEMS TESTING

WBS ELEMENT	IMPACT	CATEGORY
1.5 Program Management	This level brings together major systems and requirements, a substantial long-term commitment for systems testing. The satellite/rectenna, for example, will undergo combined testing at various times during phased buildup of the prototype which will take place over a period of years. STS, OTV, and control interfaces must be tested and verified at this level.	A

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
5	GROUND SUPPORT EQUIPMENT (GSE) DESIGN AND DEVELOPMENT

PROGRAM PLAN DEFINITIONS

This plan shall address the design and development of the GSE and its associated software required for checkout of the systems and subsystems at the various locations, i.e., factory, launch site, etc. The hardware required in the design and development of the GSE shall be identified.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- GSE Design/Drawing and Specification Requirements
- Supporting Software and Hardware Checkout Requirements

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Supporting Hardware and Software
- Support Materials/Equipment and Facilities

DISCUSSION

In total, GSE requirements will be substantial, particularly in support of launch and transport vehicles. Individual support equipment for satellite/rectenna systems, however, should not require major expenditure of resources percentagewise. Long-range planning should be a natural fallout of the design process which must consider those items that are larger in size or quantity, such as the solar blankets or rectenna dipole panels, methods of transporting, servicing, and handling (Table 5-1).

Table 5-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 5	TITLE: GSE DESIGN AND DEVELOPMENT	
WBS ELEMENT	IMPACT	CATEGORY
1.1.1.3 Solar Blankets	Equipment to handle, transport, deploy, and service solar blankets after manufacture may be critical due to large size and fragile nature of blankets.	C
1.3 Transportation	Major system program/major support equipment	C
1.3.7 Facilities	Heavy investment required for solar blanket and high-voltage testing.	C
1.4 Ground Receiving Station	Checkout, maintenance, repair, and replacement of large number of dipole panels in place may require special support equipment exclusive of test gear.	C
	Note. Although GSE will represent a substantial investment, neither the resource allocation and planning nor technology appear to be of sufficient criticality for consideration at this time.	

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
6	MANUFACTURING PLAN

PROGRAM PLAN DESCRIPTION

This plan shall address the manufacturing requirements for all the development and deliverable hardware (flight systems and GSE) required in the program. Included shall be a compilation of all the hardware and software requirements from other sections. The major make-or-buy assumptions identified in the section on program management shall be used as a basis for developing the manufacturing requirements. Particular emphasis shall be placed on any unusual or unique facilities, tooling, and STE required to support the manufacturing activities and any advancements in the manufacturing processes and related technology that could impact the program. Quality control requirements shall also be assessed.

SPS POINT DESIGN PROGRAM REQUIREMENTS

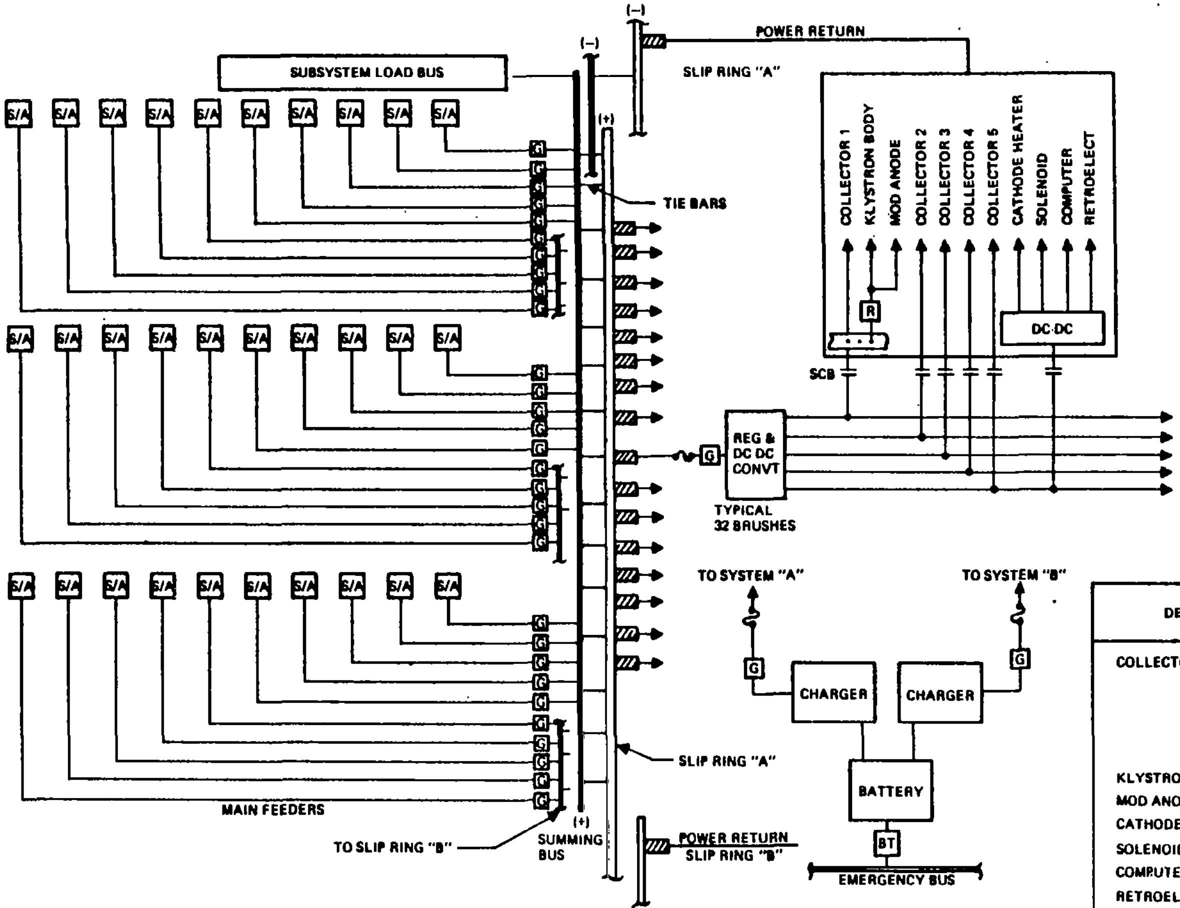
- Solar Photovoltaic CR-2 Concept Definition
  - Structure
  - Solar blankets, 27×10^6 m^2 per satellite
  - Power distribution and conditioning
  - Microwave power
  - Rectenna
- Flight and Ground System Manufacturing Requirements and Producibility Rates
- Unique Manufacturing Facilities—Ground and Space
- Special Test Equipment and Support Tooling
- Quality Control Support Requirements

RESOURCE CONSIDERATIONS

- Technical and management personnel
- Operational/support personnel
- Supporting hardware and software
- Support materials/equipment and facilities
- Special/unique test equipment

DISCUSSION

This plan covers all deliverable hardware. As such it includes ground systems, flight systems, and GSE. Make-or-buy assumptions of the program management plan will be used to develop detailed manufacturing plans which relate to a particular supplier of specific hardware. Such plans obviously are strongly dependent on having a firm design concept established. Unique facilities, tooling, and STE required to support manufacturing activities must be identified. High-voltage test equipment, for example, must be developed for use in manufacturing the multitude of items, indicated in Figure 6-1, at the component level (such as switch gear, regulator, and circuit breakers). Quality control requirements and procedures must be identified and developed. Again, these are strongly dependent on the design concept.



S/A SOLAR ARRAY
G SWITCH GEAR
SCB SOLID STATE CRK BRKR.
R REGULATOR
BT BATTERY TIE CONTACTOR

KLYSTRON REQUIREMENTS

DEVICE	VOLTAGE	POWER KW	REGULATION
COLLECTOR 1	40 KV	11·2	
2	32 KV	11·2	
3	24 KV	11·2	
4	16 KV	11·2	
5	8 KV	11·2	
KLYSTRON BODY	40 KV	3·2	1%
MOD ANODE	20 KV		1%
CATHODE HEATER	20 V	0·1	10%
SOLENOID	20 V	0·6	10%
COMPUTER	20 V	0·1	10%
RETROELECT	20 V	0·1	10%
TOTAL		59.8	

Figure 6-1. SPS Power Distribution

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
6	MANUFACTURING PLAN (Cont.)

Development of high-production, thin-film GaAs technology is probably the most critical item and will require a long-term, well-funded program. An equivalent amount of GaAs production will be required in the same time frame to support buildup of a prototype stockpile and continuation in support of the operational SPS fabrication.

Large investments will also be required to manufacture power distribution, conditioning, and transmission components. Examples are switch gears, converters, and klystrons. (Assembly of the satellite as a power station would be covered under Plan 10, Space Operations.) Such items as beam machine complexes, templates, etc., must be developed specific to the prototype. These may differ considerably from those necessary to support construction of the Nth satellite due to the longer period permitted for staged fabrication of the former. A multitude of special assembly, fabrication, inspection, and test techniques must be developed which pertain to manufacturing in orbit. Some items may be partially fabricated and assembled under this plan with completion under Plan 10 (Space Operations). "Waveguides" is an example. These may be built as full box sections or in half-sections to save volume. The latter would then be transported to the satellite and assembled. Manufacturing and product assurance techniques must be such that waveguides can be placed into operation with "zero" defects since internal arcing due to burrs or whiskers would result in early failure of the guide.

An assumed buildup for one of the most critical items (solar blankets) is presented in Figure 6-2 in order to provide some perspective for the scope of the required manufacturing effort. It should be noted that production will peak at 1145 m per hour in 1997, and will need to increase in subsequent years to support the mature commercial program. Table 6-1 broadly addresses some of the manufacturing facilities development tasks needed to support subsystem production for planned prototype and commercial space operations.

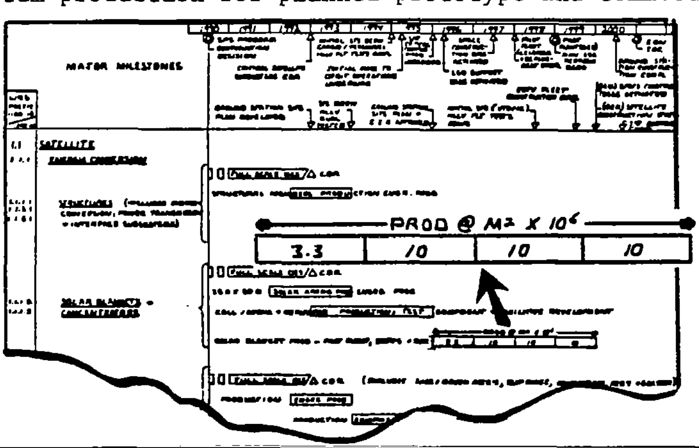


Figure 6-2. SPS Program Schedule (DDT&E/TFU Development Phase)

Table 6-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 2

PLAN NO. 6 TITLE: MANUFACTURING

WBS ELEMENT	IMPACT	CATEGORY
1.1 Satellite System	Once point design is firm, an overall satellite manufacturing plan must be provided in detail.	B
1.1.1.3 Solar Blankets	For the prototype SPS alone, a 27×10^6 m^2 area of solar blankets is required. Starting in 1996 it is suggested that a production rate be developed to support test, TFU, and follow-on production. Average production during 1996 would be 3.3×10^6 m^2 per year. The development of GaAs solar blankets meeting production, reliability, efficiency, and weight goals will be a major SPS technical challenge.	A
1.1.1.4 Power Distribution and Conditioning	Problems relate to the large quantity of high-voltage, highly reliable components which must be produced. Figure 6-1 provided some idea of the complexity of the power distribution subsystem. High-rate, automatic production of 1-mil aluminum wire junctions with zero defects is required. Large numbers of regulators, switch gears, and dc/dc converters will be involved, plus system complexity with IMS control for array regulation, load control, and associated interfaces.	A
1.1.2.2 Microwave Subarrays	Comments similar to the above apply to the MWPTS. If a decision were made to fabricate microwave resonant cavity radiators of ten types at the launch site, a manufacturing facility of approximately 150,000 m^2 must be provided. It is envisioned that the facility will have ten automated lines for cutting, perforating, and corner-welding of power modules. To achieve maximum payload density objectives, consideration is being given to packaging these panels and all other requisite components into appropriate payload configuration for further assembly into klystron power modules, subarrays, and mechanical modules for final installation in the antenna. There are 135,864 power modules, 6993 subarrays, and 777 mechanical modules per each antenna. The manufacturing plan for actual installation, connection, and checkout of this equipment will be covered under Plan 10 (Space Operations).	B

Table 6-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 2 of 2

PLAN NO. 6	TITLE: MANUFACTURING	
WBS ELEMENT	IMPACT	CATEGORY
1.1.7 System Test Hardware	Test articles for all components and subsystems will be built for qualification testing. This does not include flight or operational hardware.	B
1.2 Space Construction and Support	Includes all special support equipment (teleoperators, beam machines, etc.) to assemble, check out and maintain the satellite system.	C
1.3 Transportation	Each transportation element requires a separate manufacturing plan as part of the individual program effort.	C
1.3.7 Facilities	Manufacturing requirements for solar blankets, power conditioning and distribution components and rectenna modules will require extensive facilities.	A
1.4.2 Support Structures	Arrays will require roughly 4 million pedestals plus provisions for mounting switch gear, dc/dc connectors and cable runs. Large undertaking for planning purposes but not a technical problem.	C
1.4.3 Dipole/Rectivier Elements (Power Collection)	Similar technology could be used as for the solar blankets. However, modules could be of more manageable size. Weight will not be a problem but strength/weatherability will be factors not encountered in space. High-rate production must be accomplished on site for production of over 11,400,000 multilayered panels of four types assembled into 580,500 subarrays.	A

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
7	PRODUCT ASSURANCE

PROGRAM PLAN DEFINITION

This plan shall address the program requirements for quality assurance, reliability assurance, and systems safety. NHB 5300.4 (ID-1) shall be used as a guide in developing these requirements.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- Quality Assurance Requirements—NHB 5300.4 (ID-1)
- Reliability Assurance Requirements—NHB 5300.4 (ID-1)
- Systems Safety Requirements—NHB 5300.4 (ID-1)

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Support Equipment/Facilities and Software

DISCUSSION

Product assurance plans, comprising the disciplines of safety, reliability, and quality assurance, will provide direction for the overall satellite system. These plans will be applicable to vehicle contractors (SPS, HLLV, COTV, STS, and support equipment) and site contractors (ground receiving station). The plans, reflecting NHB 5300.4 (ID-1) requirements and associated data reporting requirements, will provide the basis for more detailed plans at the various vehicle and site levels during design/development, manufacturing, test, and operations. Subsequently, plans will be required from the industrial subcontractors. The scope of these plans will vary, depending on the type of procurement.

Quality assurance plans relate primarily to the vehicles; site (facility) operations normally are administrated through quality procedural manuals covering all quality aspects of site operations. These manuals will be compatible with overall program quality requirements.

While the implementation of product assurance plans will entail a relatively small expenditure of resources, the consideration entailed in product assurance may have far reaching effects in terms of providing for reliability and safety of equipment and personnel.

NHB 5300.4 (ID-1) provides guidelines for development of product assurance plans relative to the Space Shuttle. These plans encompass the areas of safety, reliability, maintainability, and quality assurance. While each of these will require planning unique to the SPS, the area overriding concern is safety. The logistics, fabrication, operation, and maintenance activities associated with the satellite system will require manned space activity well beyond any previous space endeavor. Due to the large size of the satellite,

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
7	PRODUCT ASSURANCE (Cont.)

rapid means of transporting men and materials to the most remote areas must be developed. This, along with associated inspection and maintenance must be accomplished safely with minimal need to shut down any portion of the high-voltage grid. Replacement of certain items might be scheduled for periods of eclipse; however, most activities will take place aboard a fully operating power station.

Ground safety will also be of concern. Consider the rectenna site, for example. Besides the microwave potential hazard, the high ac or dc voltage conditioning equipment represents potential lethal voltages to maintenance personnel required to repair or service that equipment. The heights of the various equipments represent an occupational hazard relative to falls or tool droppage. Also, lightning strike potential is affected by the heights, conductors, and array size.

Considerations for other major systems and subsystems are similar in scope. Routine in-orbital operations, for example, will be undertaken on a large scale. Life support and safety will be major drivers in the design of each space system. The more significant product assurance considerations are summarized in Table 7-1.

Table 7.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 7 TITLE: PRODUCT ASSURANCE

WBS ELEMENT	IMPACT	CAT-EGORY
1.1 Satellite System	Product assurance elements must be established which apply to daily operations in the major manufacturing, installation, and operations in space. Safety aspects must consider protection of personnel and equipment during inspection, maintenance, repair, and replacement operations in the midst of an operating antenna or solar blanket field.	C
1.1.1 Energy Conversion	System safety and reliability will be addressed at the system level since inspection, M/R, etc., must be performed on equipment with the photovoltaics and concentrators operating in combination.	C
1.1.1.3 Solar Blankets	27,500 m^2 or more of solar blankets will be produced each day with associated checkout, inspection and repair. This element includes product assurance considerations on the ground and in orbit.	C
1.1.2 Power Transmission	Verification of pointing accuracy and interlock capability will be essential to public acceptance of SPS. Quality assurance considerations will relate to producing zero-defect waveguide assemblies in orbit.	B
1.1.4 ACS	Safety aspects of fueling and performance M&R, etc., of multiple thrusters of the attitude control and stationkeeping system.	C
1.5 Program Management	The product assurance plan will not entail substantial financial commitment in itself relative to some other plans. However, it is assigned to a high category at the summary level to emphasize the critical impact of safety and reliability on the SPS. Requirements established by the product assurance plan will have a strong influence on design and may result in considerable budgetary impact in testing, manufacturing, and operations.	B

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 8 | TITLE

FACILITIES

PROGRAM PLAN DEFINITION

This plan shall provide a compilation of the facility requirements (identified in other sections) for the total program, including development, testing, manufacturing, checkout, and operations. Budgetary estimates shall be provided for the major/critical new facilities and/or major modifications. Options shall be described which will assist in determining whether these costs shall be contractor capital equipment or government facilities. Usage schedules shall be determined and any known conflicts shall be identified.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
  - Development facilities requirements
  - Testing facilities requirements
  - Manufacturing facilities requirements
  - Checkout and operations facilities requirements
  - Ground support requirements
- Requirements for Major/Critical New Facilities
  - Financial and organizational concept financing
    - Space segment
    - Ground segment

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Architectural and Engineering Capability
- Maintenance and Operational Workers
- Site and Facilities Availability
- Materials and Support Equipment
- Heavy Construction/Industrial Equipment

DISCUSSION

Major facilities will be required for manufacturing, testing, ground support, and warehousing—such as those related to power generation and transmission. The same will apply to major systems such as STS and HLLV which must include launch, recovery, and refurbishment facilities (Table 8-1).

Table 8.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 8 TITLE: FACILITIES

WBS ELEMENT	IMPACT	CATEGORY
1.1.1.3 Solar Blankets	Production, test, storage facilities	A
1.1.1.4, 1.1.2.3, 1.1.6.3 Power Distribution and Conditioning	Production and high-voltage test facilities	A
1.1.2 Power Transmission	Production and high-voltage test facilities	B
1.3.7 Facilities	This will provide facilities resulting from requirements generated under other plans. Of particular concern are STS launch/recovery and logistics/payload integration facilities.	A
1.4 Ground Receiving Station	Production facilities for rectenna support structures and power collectors Includes all land, site preparation, buildings, access, and utilities interface for rectenna and other elements of ground station. Site may encompass over 150 km^2. Several thousand workers must be accommodated during construction, with considerable reduction when the site is placed into operation.	B
1.5 Program Management	Top-level planning function; major cost commitment required in subordinate areas indicated.	A

SPS DDT&E PROGRAM.PLANNING SUMMARY

PLAN 9a | TITLE

GROUND OPERATIONS—Ground Integration

PROGRAM PLAN DEFINITION

This plan will cover integration of equipment and instruments into payloads. (Launch site integration of payloads into vehicle carriers will be covered under Space Operations, Plan 10.) An assessment of the manpower, facilities, equipment, and hardware to support these ground integration activities is required.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
  - Operational instruments and payload integration requirements
  - Launch site/vehicle carrier definitions
  - Supporting equipment and facility requirements
  - Test and verification requirements

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Supporting Hardware and Software
- Test Equipment and Facilities

DISCUSSION

Ground integration will have no major impact; however, early consideration should influence certain designs (i.e., waveguides) to assure optimum mix of payloads for STS. Table 9a-1 identifies ground assembly and integration considerations relative to its programmatic impact.

Table 9a-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 9a	TITLE: Ground Operations—Ground Integration	
WBS ELEMENT	IMPACT	CATEGORY
1.1.7 Systems Test Operations	The integration task is comprehensive involving all aspects of assembly, test, and checkout of components, subsystems, etc., into payloads. This includes automated and, in some cases, sortie payloads. Integration aspects must be considered in all phases of design to assure optimum combination of payload space and weight resulting in minimum flights to orbit.	C
1.5 Management and Integration	Provides consideration for policy and procedure required to conduct operations and integration.	C

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
9b	GROUND OPERATIONS—Maintenance and Refurbishment

PROGRAM PLAN DEFINITION

This plan will provide identification of expected maintenance and refurbishment requirements, assessment of how these activities would be accomplished and the resources required, i.e., manpower, facilities, and equipment.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
  - Rectenna maintenance and refurbishment requirements
  - Shuttle-derived HLLV maintenance/refurbishment requirements
  - Launch site operations

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Operations and Maintenance Personnel
- Support Equipment and Facilities
- Special/Unique Refurbishment Equipment
  - Rectenna panel checkout
  - Shuttle-derived HLLV

DISCUSSION

This plan will entail major effort primarily in the areas of rectenna and STS. The 5-GW rectenna site will, for example, contain 580,500 rectenna dipole panels (9.33 m high by 14.69 m long) covering an area of 78.5 million square meters.

Refurbishment techniques for STS should derive directly from the Shuttle. The STS M&R plan area, while substantial will evolve over several years as the prototype ground station and launch/transportation system are being developed and brought up to operational status.

The requirements for inspection, cleaning, maintenance, and some replacement of failed panels will require a sizeable direct labor force and supporting equipment to maintain the operational antenna once installed (Table 9b-1).

Table 9b-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 9b TITLE: GROUND OPERATIONS—Maintenance and Refurbishment

WBS ELEMENT	IMPACT	CATEGORY
1.4.6 Operation	Maintenance and refurbishment will cover all areas of ground stations including dipole subarrays and all associated power conditioning, distribution, and interface equipment.	C
1.5 Management and Integration	Policy and procedural requirements necessary for maintenance and refurbishment are included.	C

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
9c	GROUND OPERATIONS—Logistics

PROGRAM PLAN DESCRIPTION

This plan will address logistic requirements to include planning, warehousing, facilities and equipment, transportation, training, manpower, operations supply and maintenance, etc., utilizing the spare parts requirements identified in other sections.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- SPS Training Requirements
- Warehousing Operations—Spares
- Logistic Support Definitions—Provisioning
- Facilities and Equipment Requirements—Spares Depots
- Logistics and Transportation Requirements—Spares
- Operational Supplies and Maintenance

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
  - Logistics Planners
  - Training Personnel
  - Operational/Support Personnel
- Transportation Systems
- Support Materials/Equipment and Facilities

DISCUSSION

While logistics for the purpose of supporting the SPS alone will be fairly extensive, the major impact of the Phase C/D logistics plan is that it be prototypical of the plan for the following operational phase. This approach is essential since the plan must provide for rapid, orderly expansion toward the end of Phase C/D. Considerations include such items as land transportation networks, training schools and planning facilities for stockpiling and warehousing of materials. Figure 9c-1 provides some indication of the scope of the logistics activities for the launch site, for example. Key elements will include the final selection and design of launch and transport vehicles, all of which must be supplied with trained flight and support crews, fuel, and spare parts. Similar flow charts must be developed for the rectenna site and for the overall logistics ground network. Subplans for space logistics would be a part of Plan 10, Space Operations.

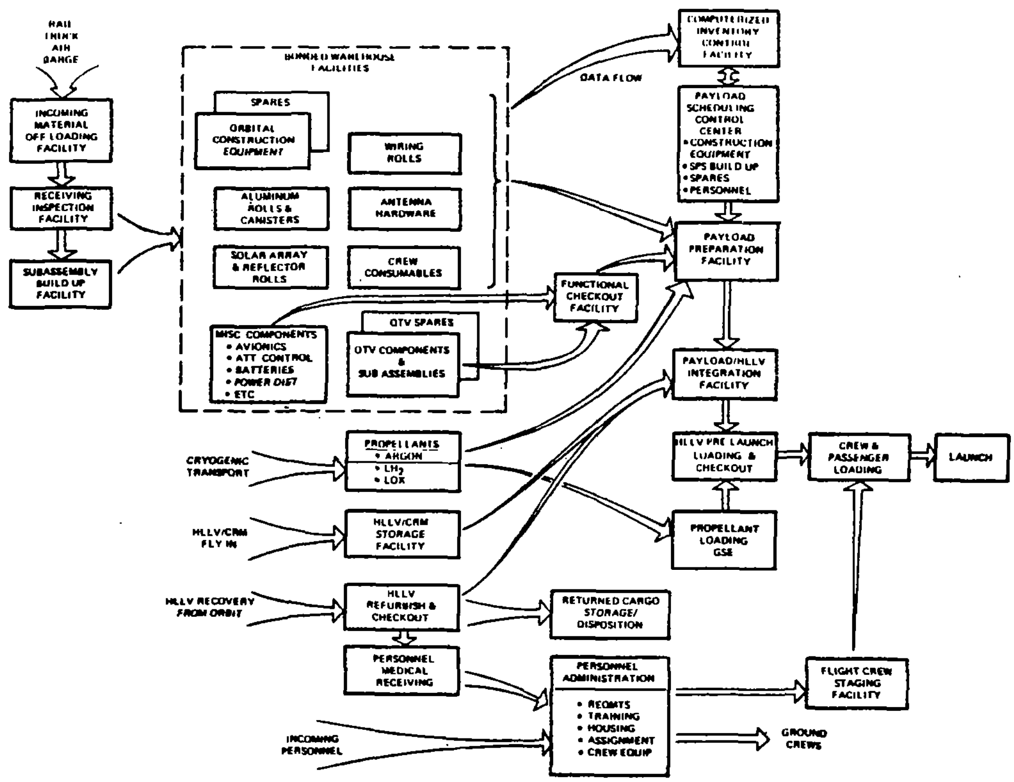


Figure 9c-1. Launch Site Logistics

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
10	SPACE OPERATIONS

PROGRAM PLAN DESCRIPTION

This plan shall address all of the activities associated with space/mission operations. Mission operations cover those activities from liftoff through on-line operations including ground operations, and shall include the requirements for manpower, facilities, and equipment to support the various ground and orbital on-site operations. (Actual procurement and training of manpower, construction of facilities, etc., will take place under the respective plans such as 9c (Logistics) and 8 (Facilities).

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- Mission Planning Definitions (Plan 2)
- Transportation System Definitions
- Orbital Operations Definitions
- Space/Ground Operational Interfaces
- Operational Hardware/Software Requirements

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Operational and Support Personnel
- Supporting Hardware and Software
- Materials/Equipment and Facilities

DISCUSSION

The conduct of large-scale space operations leading to routine construction operation and maintenance of space complexes such as SPS represents, perhaps, the major challenge in space for the remainder of this century. To fully exploit the potential that space provides will require devoting extensive resources and long-range planning to space programs of which SPS is the major one foreseen. The Space Operations Plan will require a breakdown into sub-plans which could include the following:

- Construction (Manufacturing)
- Space Base
- Logistics (including Life Support)
- Maintenance and Refurbishment
- Interstation/Interorbital Transportation
- Product Assurance (including Safety)
- Ground Support (i.e., operations, not logistics/facilities planning and operation, not construction)

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 10 | TITLE

SPACE OPERATIONS (Cont.)

Some of the above such as construction, manufacturing and product assurance are now incorporated as part of existing plans. Consideration might be given to including these unique facets of the Space Operations Plan.

Operational control will include both on-station operations, such as satellite construction, and control of transportation vehicle and construction bases. Planning considerations of space operations are shown in Table 10-1.

Table 10-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 2

PLAN NO. 10	TITLE: SPACE OPERATIONS	
WBS ELEMENT	IMPACT	CATEGORY
1.1 Satellite System	Operations performed on the satellite as a power-generating and transmitting station. Does not include checkout of satellite proper or its subsystems.	A
1.1.1.1, 1.1.2.1, 1.1.6.1 Structure	Manufacturing of the production satellites is based on orientation of beam machines in a complex, spatially controlled by a full cross-section template, as shown in Figure 10-1. The resulting manufacturing sequence provides for full construction in a total elapsed time and requires supporting several hundred men in orbit. The EOTV, on the other hand, will be assembled to permit wide flexibility in sequencing and rate of assembly. Considerable study will be required to identify an optimum approach to continuous manufacturing. This must be followed by development and demonstration on the ground and in space of equipment (i.e., beam machines) and operations (i.e., joining) applicable to the prototype.	A

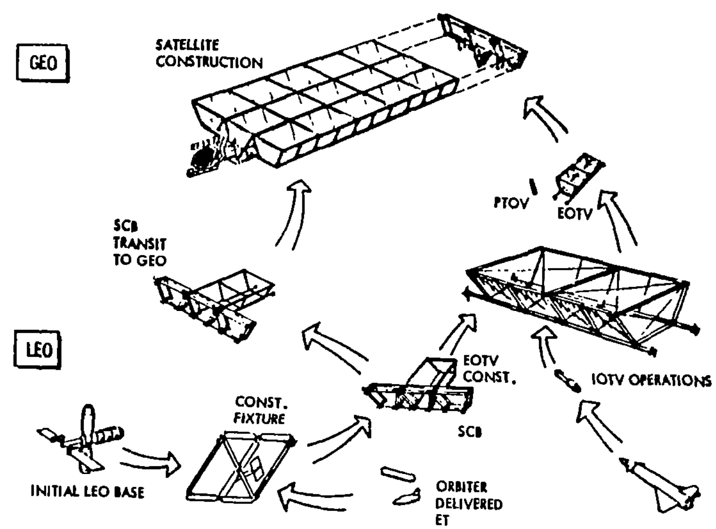


Figure 10-1. Overall Satellite Construction Scenario

Table 10-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 2 of 2

PLAN NO. 10 TITLE: SPACE OPERATIONS

WBS ELEMENT	IMPACT	CAT-EGORY
1.2 Space Construction & Support	Solar blankets operational capability for larger-scale assembly, checkout, and maintenance in orbit represents the significant challenge to SPS. Included also are the power transmission system elements.	C
1.3 Transportation	Operational requirement planning and control.	C
1.5 Program Management	Summary planning functions integrating all major flight and supporting ground systems.	A

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
11	LAUNCH OPERATIONS

PROGRAM PLAN DESCRIPTIONS

This plan shall address all the activities associated with launch operations. Launch operations cover those activities from arrival of the payload at the launch site until liftoff. This shall include, but not be limited to, handling, inspection, assembly/integration/installation, checkout, calibration, etc.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic Cr-2 Concept Definition
- Launch Site Payload Integration Definitions (Plan 9a)
- Transportation System Definitions
- Launch Site Facility Definition (Plan 8)
- Launch Site Support Equipment Utilization
- Test and Verification Definition (Plan 4)

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Operations and Maintenance Personnel
- Support Equipment and Facilities
- Special/Unique Processing Equipment/Facilities

DISCUSSION

Launch operations will involve expanding the capability already developed under the basic Shuttle program. Because of the number and frequency of launches, this will require considerable expansion of current launch facilities. As with the Logistics Plan, however, the major impact is to incorporate within the plan and its implementation the tremendous capability needed for multiple daily flights of HLLV's and provisions for rapid turnaround needed during post-IOC period. Important considerations are shown in Table 11-1.

Table 11-1.
SPS DDT&E Program Planning Considerations (Phase C/D) Impact Sheet

Sheet 1 of 1

PLAN NO. 11 TITLE: LAUNCH OPERATIONS

WBS ELEMENT	IMPACT	CATEGORY
1.3 Transportation Operations	Operational policy and procedure planning required for the handling of STS and VTO/HL HLLV vehicle turnaround.	C
1.3.7 Facilities	Facilities planning requirements will be needed to support STS and VTO/HL HLLV operations. Included are facilities for launch, recovery, fuel, logistics support, and operations.	B
1.5 Management and Integration	Due to the large number of launches and long period over which launch operations will take place the development of routine, rapid turnaround capability will be a major undertaking. Estimates are that in the order of 200 launches of a Shuttle-derived HLLV will be required to support precursor/prototype assembly over the period 1996 through 1008. This is an average of almost two launches per week.	B

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN 12 | TITLE

SPECIFICATION TREE

PROGRAM PLAN DESCRIPTIONS

A specification tree shall be developed, beginning with the project level at the top.

SPS POINT DESIGN PROGRAM REQUIREMENTS

- Solar Photovoltaic CR-2 Concept Definition
- System and Subsystem Definitions
- Make-or-Buy Decisions (Plan 1)
- Development and Procurement Definitions

RESOURCE CONSIDERATIONS

- Technical and Management Personnel
- Support Materials/Equipment and Facilities

DISCUSSION

This plan might be incorporated under Plan 1 or 2 and should be maintained as a natural part of the top-level planning function.

SPS DDT&E PROGRAM PLANNING SUMMARY

PLAN	TITLE
13	NATURAL RESOURCES ANALYSIS

PROGRAM PLAN DESCRIPTION

This plan assesses the degree and rate of consumption of critical materials, the degree of utilization of both material extraction and production plants, and the sensitivity of this consumption toward meeting the program objectives, major milestones, and the initial operational capability of the Satellite Power System (SPS). It expressly covers a natural resource analysis of only the first Rockwell SPS reference configuration.

SPS PROGRAM REQUIREMENTS

Program requirements and detail system definitions are based on the SPS reference configuration of a three trough planar array with an end mounted tension web antenna. Programmatic ground rules and guidelines are:

- Key dates for program planning:

  1981-1987 - Key Technology Program Activities

  1990 - Decision Point for SPS Commercialization (Phase C/D)

  2000 - IOC of First SPS including Ground Receiving Station

- SPS build rate at two nominally 5 GW SPS's/year for 30 years to provide a 60 system capability by 2030.

The resource analysis considered these ground rules and SPS program schedules to identify the timing of system acquisitions and main operational elements. The following paragraphs summarize the analyses for use in identifying potential impact on U.S. productive capacity.

SPS PROGRAM ELEMENTS

Main elements of the SPS program include the satellite; space construction bases and support assembly equipment; space transportation and ground facilities; the ground receiving station; and management/integration activities. Principal resource requirements of the satellite, space construction, ground receiving station, and transportation elements are discussed in the following paragraphs.

Satellite System

The elements/systems of a space satellite are grouped into the categories of - energy conversion, power transmission/antenna, information management and control, attitude control and stationkeeping, and communications. Each of these items were analyzed and researched for its major resource requirement that focused on structures, concentrators, solar blankets, power distribution and conditioning, and the klystron power module. A 25% weight growth factor was added to the basic system design weight statement for resource calculations. This is equivalent to the normal factor used in calculating the total mass to provide for contingency.

Structure. The primary structure which supports the solar array and antenna segment is composed of graphite impregnated composites. The total weight of the composites is 1.028×10^6 kg or 2,265,000 lb. Approximately 30% by weight would be graphite (0.309×10^6 kg/681,200 lb); 15% by weight would be glass fibers (0.154×10^6 kg/339,570 lb); and 55% resin (0.565×10^6 kg/1,246,000 lb). The secondary structure/mechanisms of the solar arrays and antenna segments are considered mainly of aluminum and weighs 1.769×10^6 kg or 3,900,000 lb.

Concentrators. The concentrators (reflectors) consist of aluminum coated 0.5 mil Kapton - Type H sheet. The total weight is 1.296×10^6 kg or 2,857,000 lb of which 1.283×10^6 kg or 2,828,000 lb is Kapton and $.013\times10^6$ kg or 29,000 lb is aluminum.

Solar Blanket. The solar blanket consists of a variety of materials as listed in Table 13-1. The total amounts required are factored from the work completed under Arthur D. Little contract with NASA (NAS9-15294).

Table 13-1. Solar Blanket Material Mass

MATERIAL	AMOUNT REQUIRED 10^6 kg	AMOUNT REQUIRED $\times 10^6$ lb
ALUMINUM	0.008	0.018
GALLIUM	0.432	0.952
ARSENIC (99.999%)	0.465	1.025
SELENIUM (00.999%)	34 kg	75 lb
ZINC (99.999%)	11 kg	24 lb
ALUMINUM (99.999%)	0.005	0.011
SILVER	0.172	0.379
GOLD	1.640	3.615
TIN	0.488	1.076
SAPPHIRE (Al_2O_3)	2.700	5.952
COPPER	0.476	1.049
TEFLON	0.915	2.017
KAPTON	1.219	2.687
TOTAL	8.518	18.781

Power Distribution and Conditioning. This category includes the power conditioning equipment and conductors in both the solar array and the antenna. Also included are the power-transmitting slip rings. The total weight of power distribution and conditioning equipment, etc., amounts to 8.884×10^6 kg, or 19.585×10^6 lb and consists of the following materials (Table 13-2):

Table 13-2. PD&C Materials

MATERIAL	AMOUNT REQUIRED × 10^6 kg	AMOUNT REQUIRED × 10^6 lb
ALUMINUM	6.824	15.044
STEEL	0.506	1.115
TITANIUM	0.028	0.062
COPPER	0.839	1.850
PLASTICS	0.681	1.501
SILVER	0.006	0.013
TOTAL	8.884	19.585

Power Modules (Klystrons). The weight of klystrons required on the SPS is estimated to be 5.206×10^6 kg or $11,477 \times 10^6$ lb. The materials required for their construction are listed in Table 13-3.

Table 13-3. Power Module Composition

MATERIAL	AMOUNT REQUIRED × 10^6 kg	AMOUNT REQUIRED × 10^6 lb
ALUMINUM	0.265	0.584
STEEL	0.690	1.521
COPPER	2.550	5.621
ALNICO-V	1.010	2.227
54% Fe	0.545	1.201
24% Co	0.242	0.533
14% Ni	0.141	0.311
8% Al	0.081	0.179
ALUMINUM OXIDE	0.531	1.171
GRAPHITE EPOXY	0.160	0.353
30% GRAPHITE	0.048	0.106
15% GLASS FIBER	0.024	0.053
55% RESIN	0.088	0.194
TOTAL	5.206	11.477

Material Requirements for Main Elements of the Satellite System. A tabulation of satellite system material requirements in each of the study areas is presented in Table 13-4. The total weight of 26.700×10^6 kg or 58.873×10^6 lb is distributed over 22 materials as listed.

Ground Receiving Station (GRS) Definition

Key elements of the ground receiving station that might impact resource availability consists of the site and facilities requirements, the rectenna support structure, and the power collection system requirements. Other elements such as conversion stations, the grid interface and the operations requirements are basically identical to those required by conventional power

Table 13-4. Material Requirements for Main Satellite System Elements

MATERIAL	STRUCTURE/ MECHANISMS x 10^6 KG	CONCEN-TRATORS x 10^6 KG	SOLAR BLANKET x 10^6 KG	POWER DISTR. & COND. x 10^6 KG	POWER MODULE (KLYSTRONS) x 10^6 KG	TOTAL WEIGHT KG x 10^6	TOTAL WEIGHT LB x 10^6
ALUMINUM	1.769	0.013	0.013	6.824	0.346	8.965	19.768
ALUMINUM OXIDE					0.531	0.531	1.171
ARSENIC			0.465			0.465	1.025
COBALT					0.242	0.242	0.533
COPPER			0.476	0.839	2.550	3.865	8.520
GALLIUM			0.432			0.432	0.952
GLASS FIBER	0.154				0.024	0.178	0.392
GOLD			1.640*			1.640	3.615
GRAPHITE	0.309				0.048	0.357	0.787
IRON					0.545	0.545	1.201
KAPTON		1.283	1.219			2.502	5.517
NICKEL					0.141	0.141	0.311
PLASTIC				0.681		0.681	1.501
RESIN	0.565				0.088	0.653	1.440
SAPPHIRE			2.700			2.700	5.952
SELENIUM			(34 KG)			(34 KG)	(75 LB)
SILVER			0.172	0.006		0.178	0.392
STEEL				0.506	0.690	1.196	2.637
TEFLON			0.915			0.915	2.017
TIN			0.488			0.488	1.076
TITANIUM				0.028		0.028	0.062
ZINC			(11 KG)			(11 KG)	(24 LB)
SUBTOTAL	2.797	1.296	8.518	8.884	5.205	26.700	58.873
OTHER (ACS & THERMAL)						6.318	13.931
					TOTAL WEIGHT	33.018	72.804

*Not economically feasible—Assume the use of an aluminum base material.

generating systems and are not anticipated to impose significant resource re-requirements. Likewise, the control system, while unique to the GRS concept, is not anticipated to require either unusual types or large quantities of natural resources.

Site and Facilities. The ground receiving station will require an area of approximately 35,000 acres. The rectenna field will occupy approximately 25,000 acres with a surrounding buffer zone of 10,000 acres. The land will need to be cleared and leveled and a rainfall run-off system would need to be constructed. Several alternative layouts were examined, however, the amount of excavation and concrete was found to be relatively insensitive to the layout alternatives. Concrete footings (2 parallel rows) would need to be poured for each row of antenna panels. Concrete requirements for GRS rectenna panel footings and for the water channels were translated into the constituent materials (see Table 13-5).

Table 13-5. Cement/Aggregate Requirements

CEMENT	949,000 TONS
SAND	2,827,000
ROCK (APPROX. 1" - 1-1/2")	3,695,000
WATER	606,000
	8,077,000 TONS
REINFORCING ROD	19,000 TONS

It was assumed that the access road between panels would consist of a 6 inch deep layer of gravel. The gravel requirements for the access roads would be 9,791,000 yd^3 or approximately 13,707,000 tons. Requirements associated with construction of 10 miles of access roads and 23 miles of perimeter roads plus 20 miles of access railroad, and 25 miles of perimeter railroad were not considered to impose abnormal requirements on natural resources or production capacities.

Rectenna Support Structure. The rectenna support structure consists of steel hat sections, I beams, tube braces, fittings and hardware along with miscellaneous items. The total weight of steel required for rectenna support was calculated to be 1666.7 kg or 3674 lb per panel, or a total of 967.5×10^6 kg or 2132.9×10^6 lb for the 580,500 panels in the rectenna array.

Power Collection. The power collection occurs in the panel array elements mounted on the rectenna panels. The elements consist of three 0.5" layers of a dielectric (plastic compound) that separates four layers of 0.0039 inches of copper, clad to 0.001 inches of Mylar. Interspersed within each panel are 735 diodes, or a total of 426.67×10^6 diodes in the total array of 580,500 panels. The one ounce diodes consist of 44% tungsten, 40% copper, 15% gallium arsenide and 1% gold and other exotic materials. Consequently, the total material requirements for the power collection portion of a single rectenna are itemized in Table 13-6. Miscellaneous materials such as copper wiring, J-boxes, etc., were not considered to severely impact either material availability or production capacity.

Table 13-6. Diode Materials per Rectenna

MATERIAL	AMOUNT REQUIRED	
	$kg\times10^6$	$lb\times10^6$
PLASTIC DIELECTRIC	169.96	374.68
MYLAR	11.32	24.95
COPPER (COATED OR MYLAR)	46.13	101.70
DIODES		
TUNGSTEN	5.32	11.73
COPPER	4.84	10.67
GALLIUM ARSENIDE	1.81	4.00
GOLD/EXOTICS	0.12	.27

Space Transportation System Definition

The SPS program will require six new vehicle or growth developments. The listing of vehicles needed to complete the first satellite for an initial operating capability is shown in Table 13-7.

Table 13-7. SPS Fleet/Operations for First Satellite

	NO. OF VEHICLES	NO. OF FLTS.
PERSONNEL LAUNCH VEHICLE (PLV) SHUTTLE GROWTH	2	60
HEAVY LIFT LAUNCH VEHICLE (HLLV)	5	234
PERSONAL ORBITAL TRANSFER VEHICLE (POTV)	4	45
INTERORBITAL TRANSFER VEHICLE (IOTV)	4	408
CARGO ORBITAL TRANSFER VEHICLE-ELECTRICAL (EOTV)	6	7
PERSONAL MODULE (PM - USED WITH POTV)	4	60

In order to be available when required, the development times for the six vehicles would overlap. The vehicles will require large quantities of propellants and possibly the construction of new propellant production facilities. The total annual propellant quantity estimated to be required in support of the construction of the first SPS is shown in Table 13-8. The actual quantities required would be somewhat larger than the amounts shown because losses due to boil-off, evaporation, etc., have not been included.

SPS PROGRAMMATIC DEFINITION

Quantities of natural resources required for construction of the SPS, while significant in themselves, may nevertheless be misleading because it is the rate of resource requirements that governs their impact. The elements required for the satellite system (i.e., transportation systems, bases, etc.) will be constructed over a number of years. Thus, the resource requirements

Table 13-8. Propellant Requirements for First Satellite

VEHICLE	$\times 10^6$ kg LOX	LH_2	RP	ARGON
PLV	69.960	11.640		
HLLV	990.288	80.028	201.006	
POTV	2.526	0.421		
IOTV	0.105	0.018		
EOTV				4.690
TOTAL	1062.879	92.107	201.006	4.690
MILLIONS OF LB	2343.117	203.050	443.118	10.339

can be spread over a commensurate period. On the other hand, the ground receiving station is scheduled for IOC approximately four to five years after start of site preparation on the first GRS. Examination of the domestic availability of many of the resources required by the SPS can readily result in the identification of those resource requirements that would not present substantial problems. Similarly, those resource requirements that might tax the current productive capacity of the U.S. can at least be flagged for more detailed analyses in light of the schedules of GRS requirements as shown in Figure 13-1.

RESOURCE REQUIREMENTS

Basic resources considered were: 1) material requirements (i.e., mineral, metal, plastic, etc.); 2) production capacity for processing the materials; and 3) manpower - principal areas of skilled manpower essential for the development and implementation of main elements that comprise the SPS program.

Materials

In assessing the material resources, primary emphasis is placed on the indigenous U.S. supply. However, in some cases such as bauxite which is the basic source of aluminum, the annual U.S. imports from diverse sources are judged to be a more accurate measure of aluminum availability than U.S. bauxite production alone. In other cases, the SPS mineral requirements are assessed in terms of their impact on U.S. government stockpiles.

Production Capacity

The production capacity is assessed in terms of the SPS demand versus the U.S. ability to readily expand its productive capacity to meet new requirements. A major impediment to ready expansion centers is based on the availability of relatively low cost energy sources. New industry may have difficulty in finding readily available locations with low cost energy sources. This is particularly true for production of energy intensive materials such as aluminum or sapphire.

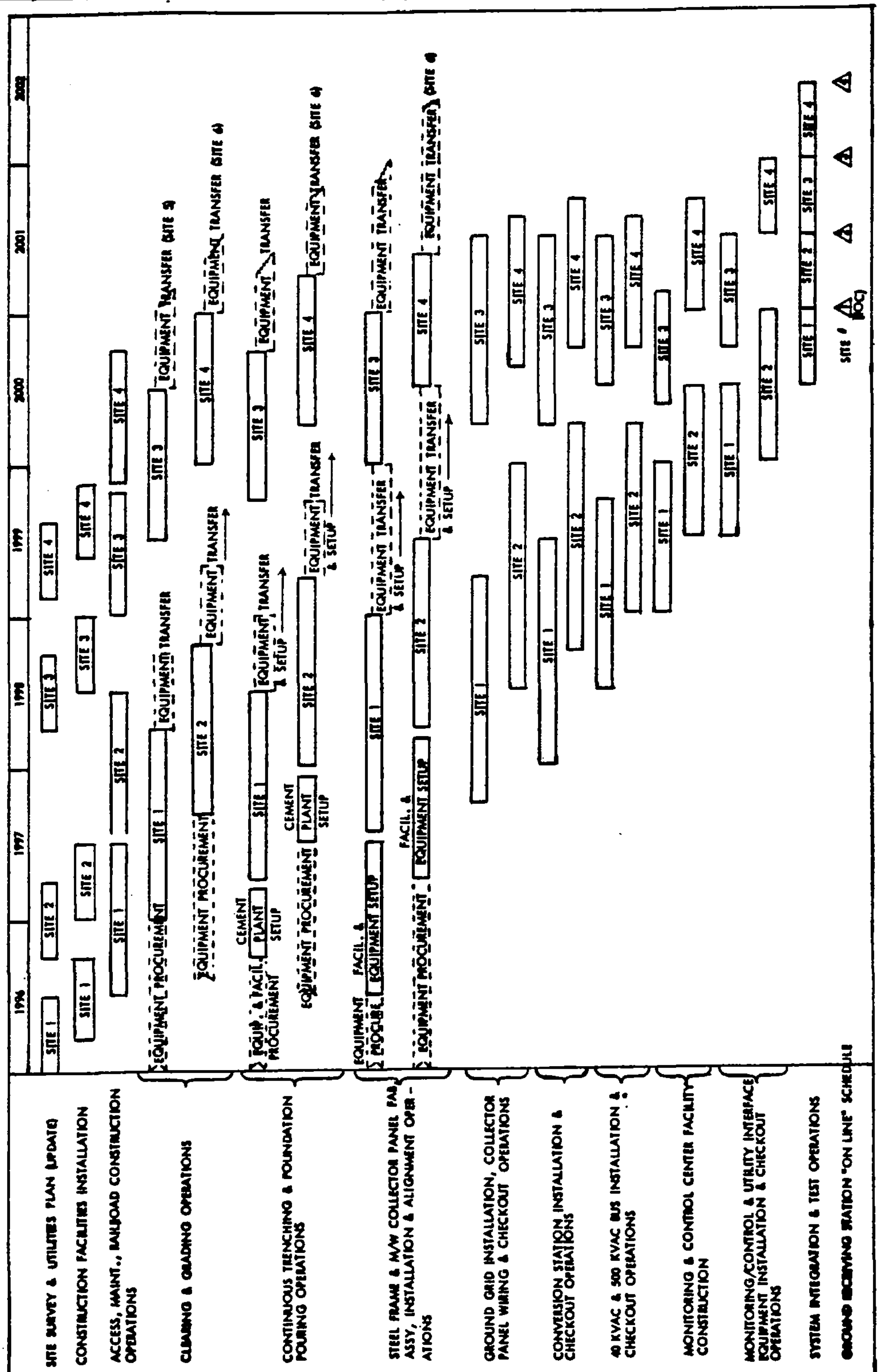


Figure 13-1. SPS Rectenna Construction Sequence Summary Schedule

Manpower

Requirements for skilled manpower can impose constraints on major developments based on the magnitude of SPS and its required disciplines. Two categories of important manpower considerations have been recognized. The first is the engineering manpower necessary for the concurrent development of five new major transportation systems in addition to the simultaneous development of the space bases and the satellite system. The second potential manpower constraint stems from the radiation exposure limitations on the satellite system construction crew. Two crews of 317 each will be required to man the SCB during construction of the first SPS. A work cycle of 3 months in orbit and 6 months on earth is planned for the construction period. This requires 3 full construction crews, plus a complete crew replacement every 3 years without attrition on the basis that five 3-month tours in orbit will result in a maximum lifetime radiation exposure. Consequently, hundreds of satellite construction workers will need to be recruited and trained continuously.

RESOURCE CONSIDERATIONS

Manpower and material requirements imposed by the development and construction of the SPS were identified and analyzed in terms of appropriate manpower and material availability within the U.S. Several potential problem areas were identified.

TECHNICAL AND MANAGEMENT PERSONNEL

Development of eight major systems are required for SPS transportation and space base requirements. These are:

1. Personnel Launch Vehicle/Shuttle Growth Vehicle
2. Heavy Lift Launch Vehicle (VTO/HL)
3. Personnel Orbital Transfer Vehicle (POTV)
4. Interorbital Transfer Vehicle (IOTV)
5. Cargo Orbital Transfer Vehicle (COTV)
6. Space Construction Base (SCB)
7. Low Earth Orbit Base
8. Satellite O&M Base

Three major bases are required in the development and implementation of the SPS, namely the Space Construction Base (SCB), a Low Earth Orbit (LEO) Base and the Satellite O&M Base. The SCB, located in geosynchronous orbit, contains 33 tribeam fabricators (198 beam machines) as well as solar blanket and reflector dispensing areas. It also contains a central and auxiliary habitats, landing area, and warehouse facilities. All of the basic elements of the satellite are constructed through the use of the SCB. The LEO Base is basically a supporting facility for staging cargo and propellants for transfer to GEO. The O&M Base is primarily the maintenance facility for the operational satellite. It contains maintenance supplies as well as a habitat for the maintenance/operations personnel.

Each of these developments constitutes a major program, requiring thousands of skilled engineers. The development schedules for most of these programs will overlap. In view of the current tight supply of skilled aerospace engineers, the unavailability of technical personnel may constitute a major impediment to the establishment of an SPS in accord with the planned schedules.

Another manpower consideration is the manning level for satellite construction. Required crew rotations to support construction of 60 satellites total 120, which results in 24 crews or 14,400 men. Applying a 20% attrition factor (resignations, etc.) raises this figure to 17,280. Similarly, 3,660 maintenance crew rotations at 30 men per crew and including attrition generate a requirement for 26,352 men. An additional 691 men are needed to operate one LEO facility for 30 years.

The need to recruit and train personnel and to develop the required facilities and materials for the programs/courses represent an important aspect of this overall activity.

MATERIALS

A review of materials required for construction of the satellite system and ground receiving station identifies several potential problem areas of material availability. Table 13-9 summarizes eight materials that can pose limitations on SPS requirements. Considerations on material availability are presented in the following paragraphs.

Table 13-9. Significant Satellite and GRS Resource Needs

1.	COBALT:	533,000 lb REQUIRED. IMPORTS FROM PRIMARY SOURCE - ZAIRE - SUSCEPTIBLE TO INTERRUPTION.
2.	GALLIUM:	2,878,000 lb REQUIRED
3.	GOLD	3,750,000 lb REQUIRED
4.	KAPTON:	5,517,000 lb REQUIRED
5.	SAPPHIRE:	5,952,000 lb REQUIRED
6.	SILVER:	392,000 lb REQUIRED
7.	TEFLON:	2,017,000 lb REQUIRED
8.	TUNGSTEN:	11,730,000 lb REQUIRED

DISCUSSION

COBALT

Klystron magnets are assumed to be made of AlNico-V which consists of 24% cobalt. This translates into a cobalt requirement of 533,000 lb. Over 60% of world cobalt production comes from Zaire, principally from Shaba Province. Military conflicts in that region have significantly reduced cobalt production. In 1977, the U.S. imported 17.7 million lb of cobalt. Another 624,000 lb were reclaimed from recycled alloys. The government stockpiles contain approximately 40 million lb of cobalt. There has been no domestic mining of cobalt since 1970. If the price increased from the current $20 per lb to approximately $60 to $80 per lb, then it is expected that domestic production would be quite likely (in limited quantities). Inasmuch as cobalt is in short supply and the SPS would require approximately 3% of the total annual import or 1.33% of the stockpiled amount (if 40 million pounds still remain), cobalt availability should be monitored to track its possible impact on the SPS program.

GALLIUM

Approximately 2,878,000 lb of gallium are required by the SPS program. Gallium is obtained as a by-product of the processing of bauxite into alumina. Sufficient gallium is extracted to meet the demand. The current potential supply of gallium from domestically processed bauxite is over 2 million lb annually. By projecting the anticipated growth of the U.S. aluminum industry to the mid-1990's, the domestically processed bauxite would yield over 5 million lb of gallium annually. However, at present, it appears that the SPS gallium requirements will support program requirements and greater production/recovery is projected for the 1990 gallium production capacity.

GOLD

The 3,750,000 lb of gold required exceeds recent U.S. annual gold production. Approximately 45% of the gold produced in the U.S. is obtained as a by-product from other metal production, primarily copper. In 1977, approximately 75,000 lb of gold were produced domestically, at a value of $148 per troy ounce. With gold currently selling at about $240 per troy ounce, some increased production can be expected, but far short of the SPS requirements. The U.S. Treasury stockpile currently contains approximately 18.5 million lb of gold. Thus, the SPS requirement would constitute approximately 20% of our gold reserve. A substitute material will likely need to be developed to replace the gold requirements of the solar blanket.

KAPTON (POLYAMIDE)

The current U.S. production of polyamides is estimated to be between 4.0 and 5.0 million lb and expanding. In order to supply the 5,517,000 lb required by the SPS, the production capacity would need to be doubled or stockpiles built up. This could readily be accomplished given sufficient lead time.

SAPPHIRE

The aluminum oxide necessary to produce 5,952,000 lb of sapphire ribbon is readily available. The sapphire ribbon availability problem stems primarily from the technology requirements. The crystal growth is a relatively slow process. Considerable research is being performed to resolve the problems associated with sapphire ribbon production. Sapphire ribbon production associated with sapphire ribbon production. Sapphire ribbon production advances should be monitored so that sufficient production facilities will be available to meet the demand.

SILVER

In 1977, the U.S. production of silver amounted to 2,617,000 lb. The 392,000 lb of silver required by the SPS thus constitutes 15% of the annual U.S. production. Silver usage in the United States amounted to approximately 11.0 million lb in 1978. The U.S. government holds a reserve of silver in the strategic stockpile on the order of 8,800,000 lb. The SPS requirement constitutes only 4.5% of the stockpiled amount. Approximately 70% of the silver produced in the U.S. is a by-product or co-product of other metal production -- chiefly copper, lead, and zinc. The 40% increase in the value of silver during the past year will serve to stimulate additional production, both domestically and world-wide.

TEFLON

The SPS requirement for Teflon was established at 2,017,000 lb or 34% of the 6 million pounds estimated to have been produced in 1977. Productive capacity is readily expandable, given sufficient lead time.

TUNGSTEN

The 11,730,000 lb of tungsten required by the SPS constitutes approximately 14% of the annual world production, or 50% more than the total U.S. production of tungsten in 1974. The total annual U.S. consumption of tungsten is on the order of 15 million pounds. U.S. Government stockpiles contain about 110 million pounds of tungsten or 9.4 times the SPS requirement. Consequently, the tungsten requirement of the SPS could present a major problem. Use of alternative materials for the tungsten in the panel diodes should be investigated.

SUMMARY

The above analyses have been based on the construction of one SPS. A construction rate of two SPS per year, for even several years, could substantially compound the material resources availability problems described. A list of data sources used in this analysis are presented in Table 13-10.

Table 13-10. Key Data References

BATTELLE—PACIFIC NORTHWEST LABS DOCUMENTATION
MINERAL FACTS AND PROBLEMS, 1975 EDITION, U.S. DEPARTMENT OF INTERIOR
SURVEY OF AVAILABILITY AND ECONOMICAL EXTRACTABILITY OF GALLIUM FROM EARTH RESOURCES, ALUMINUM COMPANY OF AMERICA, 1 OCTOBER 1976
STATISTICAL ABSTRACT OF THE UNITED STATES 1976, U.S. DEPARTMENT OF COMMERCE
THE WORLD ALMANAC AND BOOK OF FACTS, 1979, GROSSET AND DUNLAP
STATISTICAL ABSTRACTS OF THE UNITED STATES - 1976
MINERAL FACTS AND PROBLEMS (1975), U.S. DEPARTMENT OF INTERIOR
UNITED STATES MINERAL RESOURCES, U.S. DEPARTMENT OF INTERIOR (1973)
CHEMICAL INFORMATION SERVICE S.R.I.
SOCIETY OF THE PLASTICS INDUSTRY
TYCO LABORATORIES, INC. - SAPHIKON DIVISION
UNION CARBIDE CORP. - ELECTRONICS DIVISION
UCLA REFERENCE LIBRARY
CHEMICAL ENGINEERING
LIBRARY OF CONGRESS
AVIATION WEEK AND SPACE TECHNOLOGY
CHEMPLAST INC.
ALUMINUM COMPANY OF AMERICA REPORT
MODERN PLASTICS

4.0 CONCLUSIONS/RECOMMENDATIONS

This section presents summary comments on the methods and rationale followed in arriving at the results documented in this report. Suggestions are also provided in those areas where further analysis or evaluation will enhance SPS cost and programmatic definitions.

4.1 SPS COST ESTIMATES

✓ The costing approach in this study considered an SPS option of 60 units with an IOC in the year 2000 and the full 300-GW capability to become operational at the rate of two SPS's or 10 GW per year.

✓ Cost estimates developed in this report are the extended products of a Rockwell cost data base uniquely formed for the SPS program. Main elements are categorized into (1) satellite (using MSFC and Rockwell CER's), (2) space construction and assembly (Rockwell CER's with space station backup), (3) transportation (Space Shuttle, company-sponsored studies, Boeing cost data), and (4) the ground receiving station (a grass roots analysis). This same data base was expanded to incorporate cost and programmatic information from discussions with business and industry leaders. These discussions were supplemented by the use of selected literature and periodicals to obtain supporting data. Business/industry and literature sources are listed in Table 4.1-1.

✓ The Rockwell cost model and computer program can be used to calculate the costs for differing options in conjunction with an appropriate technical definition, traffic model projection, and operations scenario.

✓ A special factor was used when calculating the development cost of a system/subsystem and was based on the overall program scenario of that particular system. For example, crew and work support modules of the LEO, SCB, or satellite operations and maintenance base are of a common design, although required at differing times in accordance with the program schedule. Appropriately then, development factors were used to project costs at a 100-percent factor for the first module—whereas a lesser factor was used for subsequent requirements of the same modules to cover any revised development or integration need when being used in other applications. This represents a realistic programmatic approach to costing. Other areas should be studied for the use of this same logic.

✓ TFU costs projected for an SPS operational capability of the ground and space segments include estimates for initial space transportation fleets, satellite construction, operations, and the ground receiving station plus electric utility grid interface and supporting facilities. As such, all cost estimates for the TFU include the full cost of systems, equipment, facilities, and machinery that may have a service life capable of building more than one SPS. Therefore, the TFU cost represents a level of investment that can be expected when building a single-unit SPS option.

Table 4.1-1. Business/Industry and Literature Sources

Organization	Purpose
American Bridge—A division of U.S. Steel	To develop steel requirements, costs, and operations definition for procurement and installation of rectenna support structure.
Riverside Cement—A division of American Cement Corporation; and C. S. Johnson Co.	Provide consultation on cement/concrete specification operational methods; processing/handling equipment.
Townsend & Bottum, Inc., (construction manager) 10-MW Solar Plant—Barstown, CA	Discuss site preparation, construction operations/sequencing, plus activation requirements.
Southern California Edison	To discuss dc/ac power distribution and conversion requirements and obtain cost estimates on installation of lines/towers.
Modern Alloys, Inc.; and Miller Formless Co.	To discuss use and application of equipment/crew for continuous concrete pour of rectenna support structure footing.
Caterpillar; International Harvester; and JETCO, Inc.	Obtain prices on earth moving, grading, and trenching equipment
Literature Sources	
The Richardson Rapid System 1978-1979 Edition	Construction labor and operations prices
Engineering News Record—1977, a weekly McGraw-Hill publication	Cement, aggregate and labor prices
National Construction Estimating Guide (NCE)	Construction operations

√ SPS investment (ICI) costs in this study represent the average of a 60-unit option covering the cost of production, assembly, installation, transportation, and testing needed to produce individual satellites, transportation systems, and ground receiving stations—including required support. SPS operations costs consist of the effort required to operate and maintain the SPS program (including replacement capital items) over its operational lifetime of 30 years.

√ Further study is required to identify and analyze SPS cost drivers. This should be an integrated process where technical and program development activities confirm and optimize SPS designs, or technical approaches, for cost-effective results.

√ Several ground receiving station issues require further design definition. These include rectenna lightning protection, support structure optimization, and the rectenna drainage approach. In addition, the space transportation (HLLV) concept needs further definition.

4.2 ROCKWELL COST MODEL

√ The Rockwell SPS cost model was expanded from its earlier version (Exhibit A/B) to (1) provide for newly added input requirements, (2) handle these new requirements when making cost calculations, and (3) provide a more versatile model. There are now six basic input categories: (1) line item name and units; (2) estimating relationships (CDCER, CICER); (3) design parameters such as CF, DF, and TF; (4) programmatic definitions (Z_1 to Z_5); (5) summing information; and (6) the addition of a "comments" section on each cost sheet to document unique technical or estimating characteristics of the line item. Although not required at this time, it is possible to expand the model with an input for use when calculating the complexity of development cost estimates (CFD) as compared with the complexity factor (CFI) as may be needed to calculate investment costs.

√ Changes to the cost model and computer program have simplified the approach when making inputs to the computer. Previously, fixed locations required careful input preparations on a line item by line item basis. This approach was revised to provide the computer with a simplified input procedure and table that will automatically accept and organize the input by WBS hierarchy. This change has resulted in a more flexible computer program and has significantly reduced the time previously required to organize and prepare input sheets.

√ The addition of a CTB (cost to build) capability in the cost model provides individual system/subsystem costs, with learning, over the total quantity to be produced under the option. This base figure is then used to calculate the average unit cost and the replacement capital cost per SPS if attrition prevails. An additional feature of the program categorizes the cost to construct a satellite option (Z_4) and that needed to support O&M requirements of a satellite option (Z_5) when making calculations affecting each area.

4.3 RESOURCES ANALYSIS

A review of materials required for the construction of the satellite system and ground receiving station identified areas for potential investigation of material availability. These requirements should be more closely analyzed in conjunction with the characteristics of design and potential system improvements. The solar blankets and RF devices are typical examples of resource sensitive items.

4.4 SPS PROGRAMMATICS

Ground-based experimental research and technology advancement programs require further definition as they relate to the Rockwell SPS reference configuration. An overall view of critical technology items should result in a technical definition, interface requirements, expected results, and an integrated schedule/network of the steps required for ultimate resolution. These "planning packages" of data should incorporate NASA decision points and coincide with NASA budget inputs.

APPENDIX A

SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

SOLAR PHOTOVOLTAIC GaAlAs
CONCENTRATION RATIO (CR) - 2
THREE-TROUGH COPLANAR
END-MOUNTED ANTENNA

APPENDIX A
SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

INTRODUCTION

Generally a work breakdown structure (WBS) is thought to be a product-oriented family tree composed of all the hardware, software, services, and other tasks necessary to define the program. It offers visual display, relates project elements, and defines the work to be accomplished. The WBS is then a tool for facilitating communications and understanding a complex program by dividing this program into less complex, more manageable subdivisions or elements. It is most desirable that the WBS provide a uniform basis for management and control, cost estimating, budgeting and reporting, scheduling activities, organizational structuring, specification tree generation, weight allocation and control, procurement and contracting activities, and serve as a tool for program evaluation. Therefore, the WBS developed and defined herein is primarily tailored to the unique cost, economic, and programmatic requirements of the Satellite Power System (SPS). It is designed to allow a standard and logical format for estimating SPS project cost, while at the same time permitting cost and economic comparisons of SPS to alternate and competitive candidates for producing power.

WBS MATRIX

The total WBS matrix shown in Figure A-1 is a three-dimensional structure that shows the interrelationship of (1) the hardware and activities dimension, (2) the accounts and phases dimension, and (3) the elements of cost dimension. This latter dimension is not further developed at this time, but is provided to show the overall expansion capability built into the WBS matrix. This dimension will become more important in later years when the SPS program approaches a Phase C/D start and is defined to the extent that the elements of cost can be planned and estimated with realism.

There is, of course, the fourth dimension of time which cannot be graphically shown but must be considered also. Each entry on the other three dimensions varies with time, and it is necessary to know these cost values by year for budget planning and approval, and to establish cost streams for discounting purposes.

While a multiple-dimensional approach may at first appear unduly complex, it actually provides benefits that far outweigh any such concern. This structural interrelationship provides the capability to view and analyze the SPS from a number of different financial and management aspects. Costs may be summed by hardware groupings, phases, functions, etc. The WBS may be used in a number of three-dimensional, two-dimensional, or single-listing format applications.

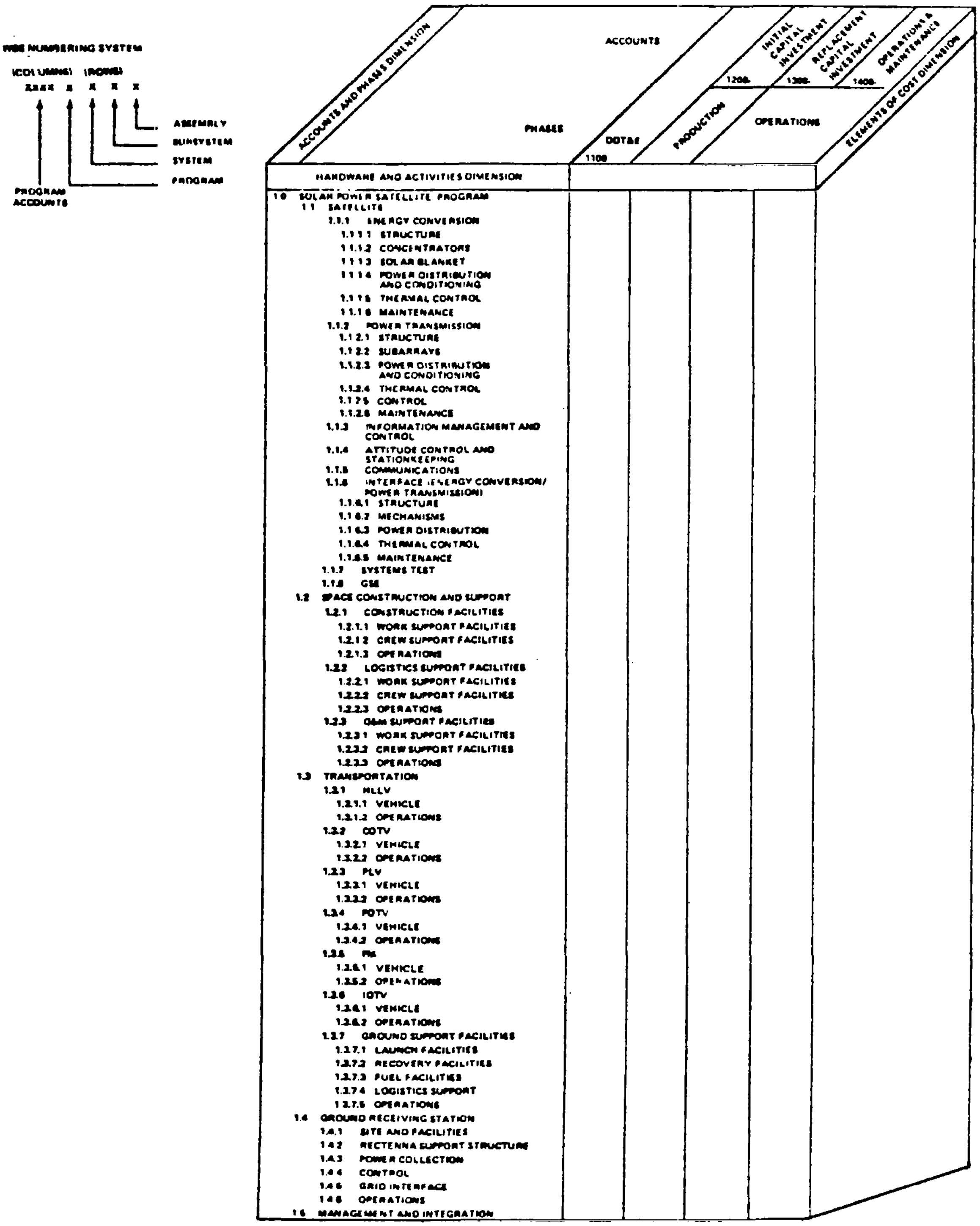


Figure A-1. Satellite Power System Work Breakdown Structure

ACCOUNTS AND PHASES DIMENSION

The accounts and phases dimension differs somewhat from the typical breakout for government aerospace programs in that it has been developed to also accommodate the financial involvement of the private sector, hence, the inclusion of the breakout of financial divisions or "accounts." Distinctions have been made between capital expenditures, which are recoverable by annual depreciation charges and are not deductible as expenses, and operation and maintenance charges against income, which are deductible as expenses in the year incurred.

To accomplish this objective, four financial accounts have been established. Design, development, test, and evaluation (DDT&E) includes the one-time costs associated with the development of components, subsystems, and systems required for the SPS project. Initial capital investment includes the costs associated with initial procurement and emplacement of the SPS plant and equipment. Replacement capital investment includes the costs associated with capital asset replacements over the operating life of the SPS (e.g., subsystem spare parts, overhauls, etc.). Operations and maintenance (O&M) includes the costs of expendables (e.g., propellants for the propulsion subsystem thrusters), minor maintenance, repair crews, etc. The interrelationship of the financial accounts to the normal aerospace program phases of DDT&E, investment, and operations are also shown in this dimension of the WBS matrix to permit traceability to these more commonly recognized therms.

HARDWARE AND ACTIVITIES WBS DIMENSION

The hardware and activities WBS dimension contains hardware elements of the satellite system and ground system subdivided into subsystems and assemblies. Inherent within this dimension is the capability for further subdivision to lower levels of detail limited only by the realism of the requirements.

Required support hardware, possibly developed under the sponsorship of other programs, is also displayed here for completeness and includes such items as space construction and support equipment and transportation vehicles. Some or all of these support elements may be developed for multiple project applications. A determination will be made later as to how much, if any, of the development costs of these support elements should be charged against the SPS program.

Each of the elements of support hardware is broken out only at a summary level within the SPS WBS. However, they each have their own detailed WBS which could be displayed in depth under the SPS WBS if required.

Finally, the hardware and activities WBS dimension also includes the necessary activities of management, integration, operations, etc., required to accomplish the overall SPS missions.

DICTIONARY ORGANIZATION

The SPS dictionary is divided into:

(1) A graphic display of the three-dimensional WBS matrix (Figure A-1)

(2) The definitions of terms of the accounts and phases dimension (pages A-5 and A-6)

(3) The definitions of terms of the WBS hardware and activities dimension (pages A-7 through A-16)

A systematic numerical coding system coordinates the rows of the hardware and activities dimension to the columns of the accounts and phases dimension such that all matrix locations are identifiable by WBS number.

Since each matrix position corresponds to one particular row of the hardware and activities dimension and also to one particular column of the accounts and phases dimension, a complete definition of any matrix position is constructed by combining the definitions from the two applicable dimensions. That is, to avoid repetition, definitions are provided only once for each hardware and activities dimension row and only once for each accounts and phases dimension column, and a complete definition for any matrix position is a combination of these two definitions.

DEFINITIONS OF ACCOUNTS AND PHASES

1100—DESIGN, DEVELOPMENT, TEST, AND EVALUATION (DDT&E)

The DDT&E account/phase consists of the one-time costs associated with designing, developing, testing, and evaluating the components, subsystems, and systems required for the SPS project. It includes the development engineering, testing, and support necessary to translate a performance specification into a design. It encompasses the preparation of detailed drawings for system hardware fabrication, system integration, and (depending on the system, subsystem, or component) structural, environmental, and other required tests. It includes all ground tests, sortie tests, subscale and full-scale SPS tests, and all hardware fabrication required for such tests. Also included are the analysis of data and whatever redesign and retest activities are necessary to meet specifications. It also includes ground support equipment, special test equipment, and other program-peculiar costs not associated with repetitive production. All SPS related support systems such as transportation, space construction base, and assembly/support equipment necessary to accomplish the DDT&E phase are included at present for completeness. It may later be determined that some of these support systems will exist with or without SPS; therefore, they may not be chargeable to the SPS project.

1200—INITIAL CAPITAL INVESTMENT

The initial capital investment account is a summation of those plant and equipment expenditures made for the initial procurement and installation of each full-scale SPS. That is, this account collects the production, assembly, installation, transportation, test, etc., costs of each individual satellite and ground station that is associated with, and necessary to, bringing the power plant on-line (in government aerospace terminology, this corresponds to costs in the investment phase). Examples of costs collected in this account are the procurement cost and launch cost of the satellite system itself, the procurement cost of the ground system (including installation), and all other necessary costs to achieve this end such as those attributable to space stations, launch vehicle fleets, etc. Also included is pro rata share of such functional costs as program management, SE&I, etc., related to the foregoing systems. Only costs incurred after the end of the DDT&E phase and prior to the initial operational capability (IOC) of each SPS are collected in this account.

1300—REPLACEMENT CAPITAL INVESTMENT

The replacement capital investment account is a summation of those plant and equipment expenditures made for capital asset replacement and major overhauls that are expected to last more than one year and result in an improvement to the operating system. Examples of costs collected in this account are the costs of spares, their installation and associated launch costs or ground transportation costs, permanent improvements in the system such as rotary joint replacement, installation of improved design satellite control equipment, etc., as well as pro rata shares of functional costs. These expenditures begin at the IOC and continue over the life of each SPS.

1400—OPERATIONS AND MAINTENANCE (O&M)

The O&M account is a summation of those expenditures incurred in the day-to-day operations beginning with the IOC and continuing over the life of each SPS. Examples of costs collected in this account are wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for transfer of on-orbit personnel and resupply of expendables and consumables, etc.

DEFINITIONS OF HARDWARE AND ACTIVITIES

1.0 SATELLITE POWER SYSTEM PROGRAM

The program includes all the elements of hardware, software, and activities required for the design, development, production, assembly, transportation, operations, and maintenance of the SPS program systems. Included are the satellite and ground receiving station systems, as well as the necessary support systems such as space construction and sup- t and transportation.

1.1 SATELLITE

This element includes the hardware and software located in geosynchronous orbit (GEO) for the collection of solar energy, conversion to electrical energy, and transmission of electrical energy in microwave form to earth.

1.1.1 ENERGY CONVERSION

This element includes the components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface wubsystem (WBS No. 1.1.6).

1.1.1.1 STRUCTURE

This element includes all necessary members to support the concentrators, solar blankets, and other energy conversion subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures which are required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems.

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes the photovoltaic conversion cells, coverplates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment and slip rings required to transfer power from the solar blanket to the interface subsystem power distribution elements. Also included are electrical cables and harnesses required to distribute power to equipment located on the energy conversion structure, plus batteries or storage medium for information system and attitude control. Excluded are data buses which are included in the information management and control subsystem (WBS No. 1.1.3).

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes coldplates, heat transfer, and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.2 POWER TRANSMISSION

This element receives dc electrical power from the interface subsystem, conditions the power, converts it to microwave energy, and radiates the energy to the ground receiving station. Included are power distributions from the interface subsystem, dc-to-RF conversion devices, control and monitoring equipment, and antenna radiating elements.

1.1.2.1 STRUCTURE

This element includes all members necessary to support the transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures.

1.1.2.2 TRANSMITTER SUBARRAYS

This element includes all the hardware required for generation, distribution, phase control, and radiation of microwave energy. This includes the subarray structure, waveguides, power amplifiers, phase control electronics, and power harnesses. Also included are thermal control devices and finishes that are manufactured as an integral part of the subarray.

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING

This element includes the power conductors, switch gear, and conditioning equipment required to transfer power from the interface subsystem to the subarray wiring harnesses and to any other power-consuming/storage equipment located on the power transmission structure, such as batteries.

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints and finishes applied to components during their manufacturing sequence and thermal control devices that are an integral part of another component.

1.1.2.5 CONTROL

This element provides the reference phase for all subarray phase conjugating circuits. This includes the reference oscillator signal distribution and frequency conversion equipment plus components that commonly serve all subarrays.

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information on board the satellite. This includes sensing, signal conditioning, formatting, computations, formulation and signal routing.

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes the components required to orient and maintain the satellite's position and attitude in GEO. Included are sensors, reaction wheels, chemical and electric propulsion hardware, and propellants.

1.1.5 COMMUNICATIONS

This element includes the hardware to transmit and receive intelligence among the various SPS elements. This includes communication of both data and voice between the SPS and the control center, as well as among the various cargo and personnel vehicles. Excluded is intravehicular and intrasatellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element provides the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360° rotary joint and an antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structure, mechanisms, power distribution, thermal control, and maintenance hardware.

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmission subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS No. 1.1.6.2).

1.1.6.2 MECHANISMS

This element includes the components required to rotate and elevate the power transmission subsystem. Included are the drive ring, bearings, gear drives and drive motors.

1.1.6.3 POWER DISTRIBUTION

This element provides for the transfer of electrical power through the interface. It includes slip rings, brush assemblies, feeders, and insulation.

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes coldplates, heat transfer and radiator devices, as well as insulation, thermal control coatings, and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.6.5 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems tests including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also includes the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support faciliteis. Also included are the planning, documentation, and actual test operations.

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of the satellite subsystems. It also includes special hardware required for simulations and training.

1.1.9 PRECURSOR TEST ARTICLE

The precursor pilot plan test article and operations are included in this element. It represents a test vehicle that consists of an energy conversion, interface, and power transmission segment.

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities required to assemble, check out, operate, and maintain the satellite system. Included are space stations, construction facilities, support facilities and equipment, and manpower operations.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to assemble and check out the satellite system. Included are crew life support facilities, the central control facility, fabrication and assembly facilities, cargo depots, and operations.

1.2.1.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for satellite assembly and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.

1.2.1.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, center control facilities, recreation facilities, and health facilities of the satellite construction base.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both the direct and support personnel and the expendable maintenance supplies required for satellite assembly and checkout.

1.2.2 LOGISTICS SUPPORT FACILITIES

This element includes the hardware, software, and operations required in low earth orbit (LEO) to support the construction and operations and maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the receiving, storage, and transfer of cargo and personnel destined for a construction base or operational satellite located in GEO.

1.2.2.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required to provide logistics support in LEO. Included are heavy-lift launch vehicle (HLLV) and orbital transfer vehicle (OTV) docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support.

1.2.2.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities of the LEO Base.

1.2.2.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the logistics support facility. It includes both the direct and support personnel and the expendable maintenance supplies required for logistics support.

1.2.3 O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support the operations and maintenance of the satellite system. Included are the on-orbit monitor and control facility and the life support facilities and equipment required to provide comfortable, safe living quarters for the resident crew members.

1.2.3.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for operation and maintenance of the satellite system. Included are satellite monitor and control stations and any centralized repair facilities not included under maintenance (WBS Numbers 1.1.1.6, 1.1.2.6, and 1.1.6.5).

1.2.3.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities.

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It includes both the direct and support personnel and the expendable maintenance supplies required in GEO for satellite operations and maintenance.

1.3 TRANSPORTATION

This element includes all space transportation required to support the satellite system assembly and operation; and the ground support facilities to provide a launch, recovery, propellant, logistics, and operational capability. Included are the launch to LEO and the orbit-to-orbit transfer of all hardware, materials, and personnel required during the construction and lifetime operation of the satellite system.

1.3.1 HEAVY-LIFT LAUNCH VEHICLE (HLLV)

This element includes the HLLV vehicles and operations required to support the satellite system assembly and operation. Included is the launch to LEO of all space construction and support equipment, satellite system hardware, OTV's, propellants, and other consumables required throughout the satellite lifetime.

1.3.1.1 HLLV VEHICLE

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.1.2 HLLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout the satellite lifetime.

1.3.2.1 COTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.2.2 COTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.3 PERSONNEL LAUNCH VEHICLE (PLV)

This element includes the PLV and cargo vehicles of the growth Shuttle and operations required to support the satellite system assembly and operation. Included is the launch to LEO and return of all personnel and priority cargo required throughout the satellite construction period and operational lifetime.

1.3.3.1 PLV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project. Included are the vehicles for personnel transfer from earth to LEO and for cargo transfer as needed to support elements of the precursor phase of program development.

1.3.3.2 PLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes the POTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and priority cargo required throughout the satellite construction and operational periods.

1.3.4.1 POTV VEHICLES

This element includes the vehicle fleet procurement required to support the SPS project.

1.3.4.2 POTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS project.

1.3.5 PERSONNEL MODULE (PM)

This element includes the PM units and operations required to support the satellite system assembly and operation. Included is the LEO to GEO and return transfer of all personnel and critical hardware items required throughout the satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfers of personnel.

1.3.5.1 PM VEHICLES

This element includes the PM unit procurement required to support the SPS project.

1.3.5.2 PM OPERATIONS

This element includes the necessary operations (user charge per flight including payload integration) required to support the SPS project.

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes the IOTV vehicles and operations required to support the satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, COTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV VEHICLES

This element includes the necessary vehicle fleet procurement required to support the SPS project.

1.3.6.2 IOTV OPERATIONS

This element includes the necessary vehicle operations (recurring refurbishment and propellant costs) required to support the SPS project.

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovering, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

1.4 GROUND RECEIVING STATION

This element includes the land, facilities, and equipment that comprise the ground subsystems utilized to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. Also included are the equipment and facilities necessary to provide operational control over the satellite.

1.4.1 SITE AND FACILITIES

This element encompasses the site and facilities for the ground receiving station system which includes the rectenna, grid interface, and satellite control subsystems. Included are the land, site preparation, roads, fences, utilities, lightning protection, buildings, and maintenance equipment required to house and support the other ground station subsystems.

1.4.2 RECTENNA SUPPORT STRUCTURE

This element includes the hardware, materials (steel and concrete), and assembly operations necessary to erect the physical support for the rectenna array elements of WBS No. 1.4.3.

1.4.3 POWER COLLECTION

This element includes the antenna array elements associated with the actual reception and rectification of the microwave radiation. These elements are in series and parallel as required to deliver the required output voltage and current. Also included are those components that accept the dc power from the array elements and route, control, convert, and switch this power for delivery to power conversion stations of the grid interface.

1.4.4 CONTROL

This element includes the hardware that will be used to monitor and control the satellite from the ground. Included are telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and providing frequency standard signals for the satellite. Functional requirements provide for signal conditioning, formatting, software, computations, and signal routing.

1.4.5 GRID INTERFACE

This element includes the power conversion equipment that receives the electrical power from the power collection subsystem and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid. Also included are those components necessary to route, control, and switch this power into the national power grid.

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground station operation and maintenance.

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

a) Program Administration
b) Program Planning and Control
c) Contracts Administration
d) Engineering Management
e) Manufacturing Management
(f) Support Management
(g) Quality Assurance Management
(h) Configuration Management
(i) Data Management
(j) Systems Engineering and Integration

This element sums all of the direct effort required to provide management control, including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay the functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated. This element also includes the efforts required in the coordination, gathering, and dissemination of management information. Also included are the engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. It includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability and maintainability. It also includes those efforts required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

APPENDIX B

SATELLITE POWER SYSTEM COST ESTIMATING RELATIONSHIPS (CERs)

SOLAR PHOTOVOLTAIC GaAlAs
CONCENTRATION RATIO (CR) - 2
THREE-TROUGH COPLANAR
END-MOUNTED ANTENNA
CONFIGURATION

APPENDIX B
SATELLITE POWER SYSTEM
COST ESTIMATING RELATIONSHIPS (CERs)

B.0 INTRODUCTION

This appendix contains the cost analyses and a description of cost elements that comprise the SPS program. Each item is presented in accordance with the work breakdown structure of Appendix A and is responsive to the Rockwell reference configuration defined under Exhibit C of NAS8-32475 -- a 3-trough planar array with an end mounted tension web antenna (Figure B-1).

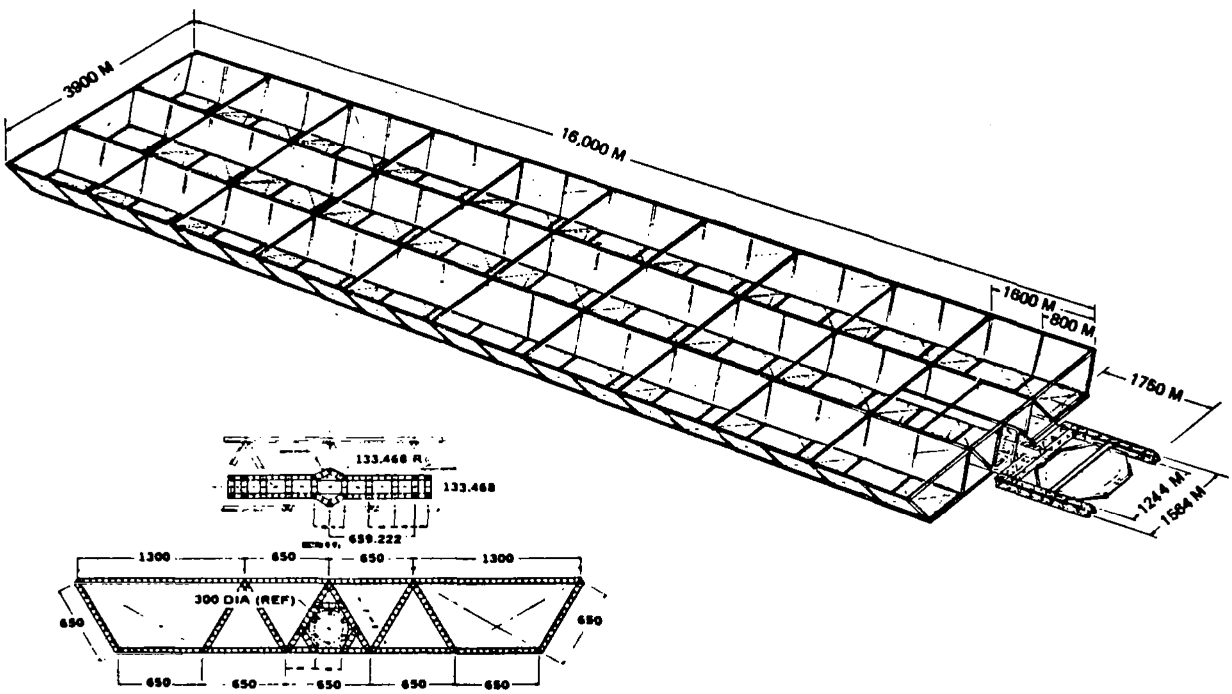


Figure B-1. SPS Reference Configuration

Subsequent sections of this appendix describe the definitions and ground rules used during the cost analysis; the methodology followed in developing estimates and the computer program; plus a detailed discussion of each subsystem, assembly, or component used in the analysis. These descriptions include design input parameters, cost estimates, scaling exponents/factors, and supporting computer program cost model equations for each of the WBS items.

B.1 COSTING GROUND RULES AND GUIDELINES

The following major ground rules and assumptions were used in the performance of this study:

1. The SPS WBS of Appendix A was used as the structure of program hardware, activities and accounts.

2. Key dates of program planning:

1980 - 1985	Ground Based Exploratory Research Activities
1981 - 1987	Key Technology Program Activities
1990	Decision Point for SPS Commercialization (Phase C/D)
2000	IOC of First SPS

3. Costs are reported at WBS level in terms of:

   (a) Development cost and TFU (theoretical first unit).

   (b) Initial capital investment average cost per satellite (Satellites TFU and No. 2 through No. 60).

   (c) Replacement capital investment (RCI) cost and operations and maintenance (O&M) cost per satellite per year.

4. Cost estimates are projected in 1977 dollars and maximum use was made of past SPS studies and other associated data as appropriate.

5. SPS build rate will be two nominal 5 GW SPS systems per year for 30 years to provide a total capacity of 300 GWs by 2030.

6. Overall SPS lifetime will be 30 years with minimum maintenance and no salvage value or disposition costs.

7. Complete construction and assembly will occur at GEO synchronous orbit.

8. Calculations based on 0% launch losses.

9. Program management and SE&I (management and integration) are costed at 5% of all other level 2 costs.

10. 25% mass contingency is costed as a 15% cost contingency on items 1.1, 1.2, and 1.3 of the SPS WBS.

B.2 COSTING METHODOLOGY

The approach followed in developing cost estimates for the SPS Program was based on the maximum use of contract and company sponsored work. The basic Rockwell - NASA/MSFC computer cost model was expanded considerably to incorporate the requirements of a revised WBS structure (Appendix A). The data base of existing and proved CERs was expanded by grass roots analysis and specific engineering estimates on the flight vehicles and ground receiving station to provide cost projections based on industrial/consultant experience and on similar contract effort such as those of the Rockwell Space Shuttle and Space Station programs. Costing of some WBS elements utilized previously developed data with slight modification to incorporate reference systems specifications.

There are a series of equations that were used to deal with the four basic types of cost accounts and phases of the program -- DDT&E, initial capital investment, replacement capital investment, and operations and maintenance.

The DDT&E equation (CD) estimates the cost of the design, development, and test/evaluation of WBS line items for the satellite, space construction and support, transportation, and ground receiving station, plus management and integration support. Management and integration are costed as a separate line item at 5% of all other level two costs of the WBS. Because of the gross nature of the level of information/definition on systems test and GSE (ground support equipment), the cost of system test hardware, and system test operations, has been assumed to be one-half of the satellite system first-unit costs. A 10% factor of satellite DDT&E is used for GSE.

The appropriate inputs for the DDT&E CERs are the applicable total system mass, area, or power. A development factor is provided in the equation (DF) to adjust the cost to reflect only that portion of the total system mass, area or power considered necessary for development of the complete system where it is not required to develop the total mass, area or power. The CD cost equation also allows for the application of a complexity factor (CF) to adjust the cost results when it is determined that the item being estimated is either more or less complex than the CER base data.

The initial capital investment (ICI) cost equations estimate the initial capital investment cost of hardware items as a function of their mass, area or power. The ICI cost equation is expressed in four different forms -- CLRM, CTFU, CTB, and CIPS. The CLRM (cost of lowest repeating module) equation requires that the input correspond to the mass, area or power of the lowest repeating module (M). This is necessary because of the physical scale of the SPS and the production quantities required for many of the hardware elements. It is not reasonable to estimate the SPS initial capital investment cost as a historical function of the entire SPS mass, area or power. Instead, it is desirable to cost the number of repeating modules required per satellite to establish the satellite theoretical first-unit cost (TFU), and to input the satellite TFU cost into a progress (learning) function for the quantity of satellites required to calculate the average unit cost (CTB - cost to build). This calculation involves two steps in the cost equations. The first step (CLRM) is simply the portion of the equation which estimates the theoretical first repeating module cost as discussed above. The second step (CTFU) has the progress function incorporated into the equation for the quantity of repeat modules required for the first satellite. It automatically takes into account the progress over production quantities required when calculating the cost to build an average unit over the total option quantity. This CTB calculation is then the basis of CIPS, where the number of units to construct a satellite option are divided by the option quantity and then multiplied by the

CTB. In some ICI cost equations, such as those of SPS transportation, the space vehicle has a service life that is greater than that needed to construct a single satellite. The CIPS equation provides the cost model with a needed program flexibility.

At the current level of SPS definition, it was difficult to decide just what is a repeating module. It is often impossible to know with any certainty just what portion of the total mass is appropriate to run through the equation as a module. It is just as difficult to identify how many distinct types or designs of modules will be required for any subsystem or assembly. In such cases, the study simply assumed a module mass (or area or power) based on engineering best judgment.

Replacement capital investment (CRCI) CERs simply provide for the multiplication of the annual spares fraction (R) of each system by that system's cost to build in order to arrive at an RCI cost per satellite per year.

Operations and maintenance costs (CO&M) are estimated in terms of O&M cost per satellite per year. O&M costs include those expenditures incurred in day-to-day operations beginning with SPS initial operating capability (IOC) and continuing over the life of each satellite. They consist of wages of operations and maintenance personnel, minor repairs and adjustments to systems to maintain an ordinarily efficient operating condition, expendables and consumables, launch costs for delivery and transfer of on-orbit personnel and cargo resupply of expendables and consumables, etc.

The cost methodology seeks to account for five separate effects which influence SPS cost. These are scaling, specification requirements, complexity, the degree of automation, and production progress. Scaling refers to the relationship in cost between items varying in size, but similar in type. Economies of scale usually assure that such a relationship will not be strictly linear, but rather as size increases, cost per unit of size will decrease. The slope of this relationship is reflected by the equation exponent which results from the regression analysis of the data used to develop the cost estimating relationship.

Specification requirements have been accounted for by normalizing the CER data base to manned spacecraft specification levels using factors from the RCA Price Model.[1] From that model, an average cost factor to adjust MILSPEC to manned spacecraft is around 1.75 for DDT&E and 1.6 for production cost. Under the assumption that some relaxation of Apollo-type specifications can be made for the SPS, a factor of 1.5 was assumed for both DDT&E and production cost. Furthermore, it was assumed that a factor of 3.0 would adjust commercial specifications to SPS requirements. Therefore, military or commercial cost data used in the CERs were adjusted upward by factors of 1.5 and 3.0, respectively.

The cost equations allow a complexity factor input to adjust the cost result when it is determined that the item being estimated is either more or less complex than the listed CER data base.

[1]*Equipment Specification Cost Effect Study*, Phase II Final Report, Nov. 30, 1976, by RCA Government Systems Division

The degree of automation is accounted for in certain cost equations through an adjustment to the CER coefficient by the tooling factors given in Table B-1. The effect of tooling is dependent upon the annual production rate. Higher production rates allow harder tooling and, thus, effect cost reductions. The tooling factors are used only on those CERs which are based on historical aerospace programs with limited annual production rates. Tooling factors are not used on those CERs which are based on data already reflecting automated production techniques (e.g., the commercial electronics data for the microwave antenna CER).

Table B-1. SPS Tooling Factors

AVERAGE ANNUAL PRODUCTION RATE (AAPR)	TOOLING FACTOR (TF)	PROGRESS FRACTION (ϕ)
1-2	1-0	0.80
3-5	0.9	0.80
6-9	0.8	0.80
10-19	0.7	0.85
20-39	0.6	0.85
40-69	0.5	0.85
70-109	0.4	0.85
110-159	0.3	0.90
160-219	0.2	0.90
220-999	$(AAPR)^{-0.35}$	0.90
1000-9999	$(AAPR)^{-0.35}$	0.95
10,000	$(AAPR)^{-0.35}$	0.98

The decreasing cost effects of progress due to production process improvements or direct labor learning are accounted for through standard progress functions. Many SPS components will be mass produced in a capital intensive manner and will experience little labor learning. Other SPS hardware items, however, will be produced at very low annual rates, much in the labor-intensive manner of historical spacecraft programs, and therefore would experience learning. (Technically distinguishable from learning, but still predictable with the same form of exponential function, are the effects of production process improvement. In this model, when progress functions are used, they are meant to account for both of these effects.) A constant relationship has been assumed between the progress fraction and the annual production rate as given in Table B-1.

As required by the costing ground rules and assumptions, all CERs are in terms of 1977 dollars. The study did assume 1990 technology and 1990 supply/demand conditions which, in some cases, resulted in differential (non-general) price inflation or deflation between 1977 and 1990 being included in the CERs. Specifically, it was assumed that composite raw material prices and some electronic component prices will decrease relative to general prices while aluminum coil stock prices will increase relative to general prices. Such effects are allowed for by the CERs, but only to the extent that the expected price changes differ from expected general price changes. The CERs affected are the antenna structure CER, the power source structure CER, and the microwave antenna CER.

Definitions of SPS cost model terms and equation abbreviations are presented in Table B-2.

Table B-2. Definitions of SPS Cost Model Elements

C	= COST IN MILLIONS OF 1977 DOLLARS
CD	= DDT&E COST
CDCER	= DDT&E COST ESTIMATING RELATIONSHIP (CER)
CDEXP	= DDT&E SCALING EXPONENT
CER	= COST ESTIMATING RELATIONSHIP
CF	= COMPLEXITY FACTOR
CICER	= INITIAL CAPITAL INVESTMENT COST ESTIMATING RELATIONSHIP (CER)
CIEXP	= INITIAL CAPITAL INVESTMENT COST SCALING EXPONENT
CTB	= COST TO BUILD AN ITEM
CIPS	= INVESTMENT PER SATELLITE COST
CLRM	= LOWEST REPEATING MODULE COST
CO&M	= OPERATIONS AND MAINTENANCE COST PER SATELLITE PER YEAR
CRCI	= REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR
CTFU	= THEORETICAL FIRST UNIT COST
DDT&E	= DESIGN, DEVELOPMENT, TEST AND EVALUATION
DF	= DEVELOPMENT FRACTION
E	= 1.0 + LOG (PHI) ÷ LOG (2.0)
ICI	= INITIAL CAPITAL INVESTMENT
INV. PER SAT.	= AVERAGE UNIT INVESTMENT COST (2 THRU N)
M	= MASS, POWER, AREA OF LOWEST REPEATING MODULE
#RM	= NUMBER OF REPEATING MODULES
OPS	= OPERATIONS
O&M	= OPERATIONS AND MAINTENANCE COST PER SATELLITE PER YEAR
PHI	= PROGRESS FRACTION
R	= ANNUAL SPARES FRACTION
RCI	= REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR
T	= TOTAL (MASS, POWER, AREA) PER SATELLITE
TF	= TOOLING FACTOR
TFU	= THEORETICAL FIRST UNIT
Z1	= TFU REQUIREMENT
Z2	= SPS OPTION QUANTITY
Z3	= TOTAL SPS REQUIREMENT PER OPTION
Z4	= ITEMS NEEDED TO CONSTRUCT SATELLITE OPTION
Z5	= ITEMS NEEDED FOR O&M OF THE SATELLITE OPTION

B.3 SPS PROGRAM COST BREAKDOWNS

An overall cost relationship for the SPS program is shown in Figure B-2. Principal areas of SPS costing are represented to indicate the emphasis on expenditures as the program moves from one phase to the next.

Subsequent tables summarize the cost data used in developing Figure B-2. They reflect SPS-related development cost DDT&E (CD) data through the first 5-GW satellite (TFU). **Table B-3 includes space construction/support, transportation**

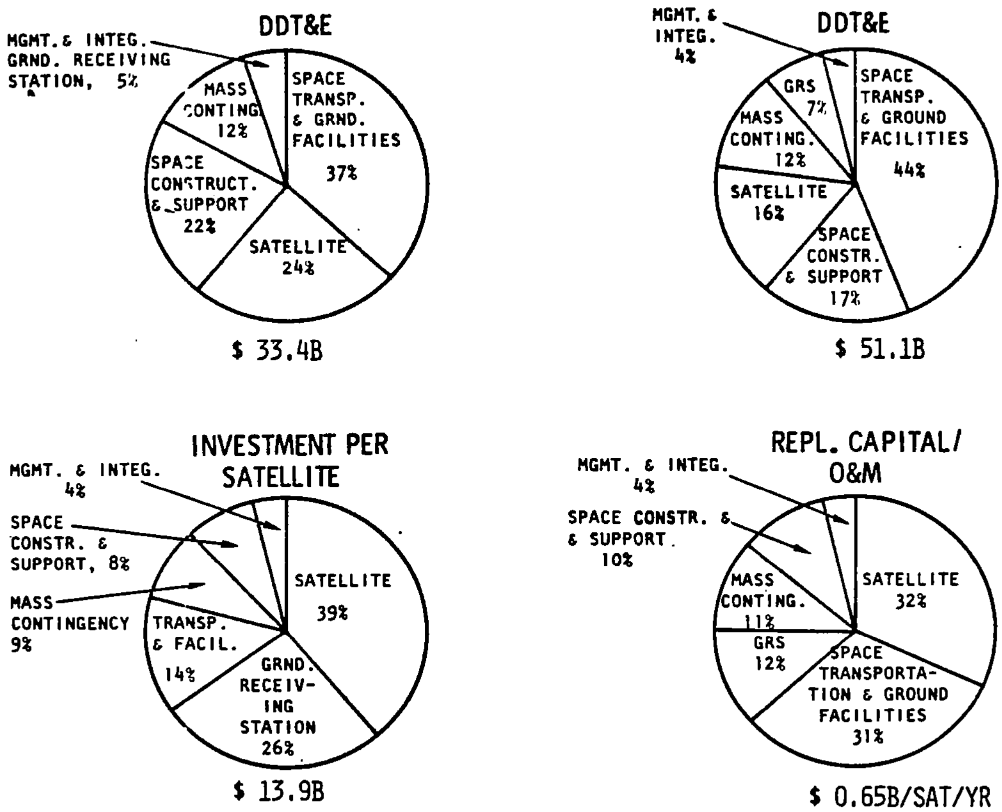


Figure B-2. SPS Cost Relationships

vehicles/operations, and the ground receiving station needed to establish SPS operational capability. This means that the TFU cost includes elements with a lifetime capability of building more than one SPS. Table B-4 summarizes the investment cost per satellite (CIPS) and the replacement capital investment cost (CRCI) plus operations and maintenance (CO&M) per satellite per year.

Table B-3. SPS Program Development Cost

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33401.762	51103.242	84505.000
1.1	SATELLITE SYSTEM	7933.570	7950.922	15884.492
1.2	SPACE CONSTRUCTION & SUPPORT	7331.180	8602.523	15933.703
1.3	TRANSPORTATION	12468.316	22866.199	35335.016
1.4	GROUND RECEIVING STATION	115.699	3618.727	3734.427
1.5	MANAGEMENT AND INTEGRATION	1392.463	2151.918	3544.382
1.6	MASS CONTINGENCY	4160.031	5912.945	10072.977

Table B-4. SPS Program Average Cost

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	13677.068	451.531	193.713	645.244	14522.910
1.1	SATELLITE SYSTEM	5325.422	205.265	0.705	205.970	5531.391
1.2	SPACE CONSTRUCTION & SUPPORT	1148.332	51.428	11.274	62.701	1211.033
1.3	TRANSPORTATION	1949.004	119.343	80.869	200.212	2149.216
1.4	GROUND RECEIVING STATION	3590.822	0.275	78.377	78.652	3669.474
1.5	MANAGEMENT AND INTEGRATION	600.679	18.815	8.561	27.377	628.055
1.6	MASS CONTINGENCY	1263.413	56.405	13.927	70.332	1333.745

B.3.1 DEVELOPMENT COST (DDT&E) AND THEORETICAL FIRST UNIT (TFU)

The total program DDT&E and TFU cost for a first full-up nominal 5-GW SPS system is $84.5 billion. The DDT&E of $33.4 billion and the $51.1 billion for the TFU are detailed by SPS WBS line item in a subsequent table. Detailed DDT&E cost breakdowns show that over 60% of the DDT&E cost is identifiable to transportation and support systems, and the satellite system.

In view of the physical size of the satellite and supportive subsystems and the large quantities required for certain parts and components, it was not considered reasonable to estimate the DDT&E costs as a function of the total mass, area, or power per subsystem—which is generally the method; instead, it was considered desirable to determine the DDT&E costs by application of a development factor (DF). In general, the DF was applied on the basis of a particular system/component in conjunction with the engineering staff and as related to the program development scenario and the usage/availability of the system when needed. For example, the 335-MW EOTV precursor test article is required early in the program for MW verification. The SCB will build this unit first and the DDT&E effort on the many components must be satisfied before items can be made available. Typical items include the structure, concentrators, solar cells, power distribution, and supporting systems that are design verifications of the full-up SPS satellite. As a result of this approach, a 1.0 DF was used on components of the EOTV test article; whereas on other usages of these systems, such as on the EOTV's or similar systems of the satellite itself, a reduced factor was applied in recognition of the earlier completed DDT&E effort. This rationale was also followed in other areas of the SPS program cost analysis.

DDT&E and TFU cost breakdowns are shown in Table B-5. The TFU listing reflects a somewhat different makeup of costs when compared to the DDT&E costs. TFU estimates of $51.1 billion include the full dollar assessment for an initial satellite and ground receiving station, include space transportation fleets; the LEO, SCB, and support assembly equipment; and the facilities needed to establish a 5-GW SPS operational capability. This means that the TFU cost includes elements with a lifetime capability of servicing/building more than one SPS system. In this regard, analysis will show that transportation and space construction and support equipment represent the largest portion of total TFU costs. However, these systems will be used to construct remaining satellites.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	33401.762	51103.242	84505.000
1.1	SATELLITE SYSTEM	7933.570	7950.922	15884.492
1.1.1	ENERGY CONVERSION	118.065	2007.983	2126.048
1.1.1.1	STRUCTURE	71.066	104.608	175.674
1.1.1.1.1	PRIMARY STRUCTURE	47.821	35.100	82.921
1.1.1.1.2	SECONDARY STRUCTURE	23.245	69.508	92.753
1.1.1.2	CONCENTRATORS	0.0	75.637	75.637
1.1.1.3	SOLAR BLANKETS	0.0	1651.832	1651.832
1.1.1.4	POWER DIST. & CONDITIONG	46.999	126.986	173.984
1.1.1.4.1	SWITCH GEAR & CONVERTERS	3.582	89.123	92.704
1.1.1.4.2	CONDUCTORS & INSULATION	6.234	9.468	15.702
1.1.1.4.3	SLIP RINGS	7.392	27.626	35.018
1.1.1.4.4	BATTERIES	5.001	0.338	5.339
1.1.1.4.5	BATTERY PD&C	24.790	0.430	25.220
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	0.0	48.921	48.921
1.1.1.6.1	MAINTENANCE - FREE FLYERS	0.0	29.299	29.299
1.1.1.6.2	MANNED MANIPULATOR	0.0	19.203	19.203
1.1.1.6.3	TRACKS & ACCESS WAYS	0.0	0.420	0.420
1.1.2	POWER TRANSMISSION	883.144	3816.522	4699.664
1.1.2.1	STRUCTURE	26.007	49.349	75.356
1.1.2.1.1	PRIMARY STRUCTURE	7.301	3.350	10.651
1.1.2.1.2	SECONDARY STRUCTURE	18.705	45.999	64.704
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	102.576	2702.309	2804.885
1.1.2.2.1	KLYSTRON DDT&E	102.576	0.0	102.576
1.1.2.2.2	KLYSTRON ICI, R, O&M	0.0	2702.309	2702.309
1.1.2.3	POWER DIST. & CONDITIONING	12.393	769.800	782.193
1.1.2.3.1	SWITCH GEAR & CONVERTERS	7.132	752.336	759.468
1.1.2.3.2	CONDUCTORS & INSULATION	5.262	5.348	10.610
1.1.2.3.3	BATTERIES	0.0	12.115	12.115
1.1.2.4	THERMAL CONTROL - INSULATION	29.136	208.062	237.198
1.1.2.5	CONTROL - PHASE REFERENCE	0.373	20.050	20.423
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.100	0.100	0.200
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	0.203	12.180	12.383
1.1.2.5.3	DIST. SYSTEM, DEVICES	0.070	7.770	7.840

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.1.2.6	MAINTENANCE	712.660	66.953	779.613
1.1.2.6.1	MAINTENANCE - FREE FLYERS	0.0	36.368	36.368
1.1.2.6.2	GANTRY CRANE	91.060	0.220	91.280
1.1.2.6.3	ON-CRANE CONTROL CENTER	621.600	30.305	651.905
1.1.2.6.4	TRACKS & ACCESS WAYS	0.0	0.060	0.060
1.1.3	INFORMATION MGMT. & CONTROL	72.565	196.897	269.462
1.1.3.1	MASTER CONTROL COMPUTER	16.127	7.845	23.972
1.1.3.2	DISPLAYS & CONTROLS	10.745	1.211	11.956
1.1.3.3	SUPERVISORY COMPUTER	2.753	2.325	5.078
1.1.3.4	REMOTE COMPUTER	2.643	5.696	8.339
1.1.3.5	BUS CONTROL UNIT	0.415	6.940	7.354
1.1.3.6	MICROPROCESSORS	0.431	6.881	7.312
1.1.3.7	REMOTE ACQUISITION & CONTROL	0.414	7.450	7.864
1.1.3.8	SUBMULTIPLEXORS	0.266	66.119	66.385
1.1.3.9	INSTRUMENTATION	28.000	74.192	102.192
1.1.3.10	OPTICAL FIBER	0.807	0.634	1.442
1.1.3.11	CABLES/HARNESS	9.963	17.604	27.567
1.1.4	ATTITUDE CONTROL & STATIONKEEPING	8.183	72.488	80.671
1.1.4.1	ACSS HARDWARE	8.183	72.488	80.671
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.0
1.1.5	COMMUNICATIONS	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0
1.1.6	INTERFACE	56.309	118.560	174.869
1.1.6.1	STRUCTURE	35.115	76.827	111.942
1.1.6.1.1	PRIMARY STRUCTURE	11.638	6.000	17.638
1.1.6.1.2	SECONDARY STRUCTURE	23.476	70.827	94.303
1.1.6.2	MECHANISMS - INTERFACE	15.225	7.878	23.103
1.1.6.3	POWER DISTRIBUTION	5.969	7.003	12.972
1.1.6.3.1	CONDUCTOR & INSULATION	5.178	5.068	10.246
1.1.6.3.2	SLIP RING BRUSHES	0.791	1.935	2.726
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	0.0	26.852	26.852
1.1.6.5.1	MAINTENANCE - FREE FLYERS	0.0	7.530	7.530

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.1.6.5.2	MANNED MANIPULATOR	0.0	19.203	19.203
1.1.6.5.3	TRACKS & ACCESS WAYS	0.0	0.120	0.120
1.1.7	SYSTEMS TEST	5325.422	0.0	5325.422
1.1.7.1	SYSTEM GROUND TEST HARDWARE	2662.711	0.0	2662.711
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	2662.711	0.0	2662.711
1.1.8	GROUND SUPPORT EQUIPMENT	721.234	0.0	721.234
1.1.9	COTV - PRECURSOR	748.653	1738.474	2487.127
1.1.9.1	COTV PRECURSOR VEHICLE	748.653	1737.844	2486.497
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	89.863	1.544	91.408
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	21.178	533.576	554.754
1.1.9.1.3	CONCENTRATOR - E.C.	7.869	2.817	10.686
1.1.9.1.4	SOLAR BLANKET -E.C.	47.041	60.300	107.341
1.1.9.1.5	SWITCHGEAR & CONVERTERS -E.C.	3.497	1.725	5.222
1.1.9.1.6	CONDUCTORS & INSULATION - E.C.	7.048	1.431	8.478
1.1.9.1.7	ACS HARDWARE - E.C.	12.190	620.634	632.823
1.1.9.1.8	SLIPRINGS - PRECURSOR	54.565	30.980	85.546
1.1.9.1.9	PRIMARY STRUCTURE - INTERFACE	152.844	6.000	158.844
1.1.9.1.10	SECONDARY STRUCTURE - INTERFACE	15.155	4.047	19.202
1.1.9.1.11	MECHANISMS - INTERFACE	78.868	221.647	300.514
1.1.9.1.12	CONDUCTORS & INSULATION	3.993	0.211	4.204
1.1.9.1.13	SLIPRING BRUSHES - PRECURSOR	2.529	2.268	4.797
1.1.9.1.14	PRIMARY STRUCTURE - POWER TRANS	20.936	0.250	21.186
1.1.9.1.15	SECONDARY STRUCTURE - POWER TRANS	17.041	2.546	19.587
1.1.9.1.16	TRANSMITTER SUBARRAYS - KLYSTRONS ICI	0.0	141.497	141.497
1.1.9.1.17	SWITCHGEAR & CONVERTERS - P.T. PRECURSOR	6.756	47.520	54.276
1.1.9.1.18	CONDUCTORS & INSULATION - P.T. PRECURSOR	4.147	0.240	4.387
1.1.9.1.19	BATTERIES - P.T. PRECURSOR	27.106	11.501	38.607
1.1.9.1.20	THERMAL CONTROL - INSULATION - PRECURSOR	26.539	45.996	72.535
1.1.9.1.21	REFERENCE FREQUENCY GENERATOR - PRECURSOR	0.500	0.100	0.600
1.1.9.1.22	DIST. SYSTEM, COAXIAL CABLE	0.258	0.517	0.775
1.1.9.1.23	DIST. SYSTEM DEVICES	0.022	0.500	0.522
1.1.9.1.24	TRANSMITTER SUBARRAYS - KLYSTRONS DDT&E	148.707	0.0	148.707
1.1.9.2	COTV PRECURSOR OPERATIONS	0.0	0.630	0.630
1.2	SPACE CONSTRUCTION & SUPPORT	7331.180	8602.523	15933.703
1.2.1	CONSTRUCTION FACILITIES	3653.249	6575.176	10228.422

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DDT&E	DEVELOPMENT TFU	TOTAL
1.2.1.1	WORK SUPPORT FACILITIES	3092.417	3956.069	7048.484
1.2.1.1.1	BEAM MACHINE	2.000	83.150	85.150
1.2.1.1.2	BEAM MACHINE CASSETTES	0.800	6.315	7.115
1.2.1.1.3	CABLE ATTACHMENT MACHINE	4.300	28.228	32.528
1.2.1.1.4	REMOTE MANIPULATOR	6.880	60.390	67.270
1.2.1.1.5	BLANKET DISPENSER MACHINE	4.000	26.154	30.154
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.800	9.076	9.876
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	6.000	4.651	10.651
1.2.1.1.8	REFLECTOR CASSETTES	1.000	2.721	3.721
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	2.200	22.786	24.986
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	80.000	200.272	280.272
1.2.1.1.11	GANTRY/CRANES	13.600	85.034	98.634
1.2.1.1.12	CARGO STORAGE DEPOTS	12.000	7.559	19.559
1.2.1.1.13	FAB FIXTURE	2165.128	82.445	2247.573
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	0.0	242.302	242.302
1.2.1.1.15	BASE MGMT. MODULE (BMM)	0.0	1213.870	1213.870
1.2.1.1.16	POWER MODULE (PM)	0.0	1075.459	1075.459
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	793.710	805.657	1599.367
1.2.1.2	CREW SUPPORT FACILITIES-SCB	560.832	2590.290	3151.122
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	31.152	73.413	104.565
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	0.0	1634.456	1634.456
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	604.675	604.675
1.2.1.2.4	SHIELDING	343.200	21.160	364.360
1.2.1.2.5	CREW SUPPORT MODULE-CSM	186.480	256.587	443.067
1.2.1.3	OPERATIONS	0.0	28.819	28.819
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	0.0	19.781	19.781
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	0.0	9.038	9.038
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	3677.934	917.151	4595.082
1.2.2.1	WORK SUPPORT FACILITIES	2814.992	586.187	3401.179
1.2.2.1.1	BASE MGMT. MODULE-BMM	2464.993	310.814	2775.806
1.2.2.1.2	POWER MODULE-PM	350.000	275.373	625.373
1.2.2.2	CREW SUPPORT FACILITIES	862.942	328.782	1191.724
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	262.278	101.928	364.206
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE	265.000	70.095	335.095
1.2.2.2.3	CREW SUPPORT MODULE/EVA	335.664	156.759	492.423

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.2.2.3	OPERATIONS	0.0	2.182	2.182
1.2.2.3.1	LEO OPERATIONS CREW	0.0	1.498	1.498
1.2.2.3.2	LEO CREW PROVISIONS	0.0	0.684	0.684
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	0.0	1110.198	1110.198
1.2.3.1	WORK SUPPORT FACILITIES	0.0	763.578	763.578
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	0.0	44.520	44.520
1.2.3.1.2	BASE MGMT MODULE-BMM	0.0	310.814	310.814
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	0.0	408.244	408.244
1.2.3.2	CREW SUPPORT FACILITIES	0.0	343.893	343.893
1.2.3.2.1	AIRLOCK DOCKING MODULE-ADM	0.0	15.111	15.111
1.2.3.2.2	CREW HABITABILITY MODULE-CHM	0.0	101.928	101.928
1.2.3.2.3	CONSUMABLES LOGISTICS MODULE-CLM	0.0	70.095	70.095
1.2.3.2.4	CREW SUPPORT MODULE/EVA	0.0	156.759	156.759
1.2.3.3	OPERATIONS	0.0	2.727	2.727
1.2.3.3.1	SATELLITE OPERATIONS CREW	0.0	1.872	1.872
1.2.3.3.2	SATELLITE CREW PROVISIONS	0.0	0.855	0.855
1.3	TRANSPORTATION	12468.816	22866.199	35335.016
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	8600.000	9530.492	18130.492
1.3.1.1	SPS-HLLV FLEET	8600.000	8950.176	17550.176
1.3.1.2	SPS-HLLV OPERATIONS	0.0	580.320	580.320
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	31.818	3625.720	3657.538
1.3.2.1	COTV VEHICLES	31.818	3621.310	3653.128
1.3.2.1.1	PRIMARY STRUCTURE	3.930	9.267	13.197
1.3.2.1.2	SECONDARY STRUCTURE	4.582	2478.750	2483.332
1.3.2.1.3	CONCENTRATOR	1.685	15.818	17.503
1.3.2.1.4	SOLAR BLANKET	7.664	338.117	345.781
1.3.2.1.5	SWITCHGEAR AND CONVERTERS	2.054	8.760	10.814
1.3.2.1.6	CONDUCTORS AND INSULATION	2.205	8.584	10.789
1.3.2.1.7	ACS HARDWARE	9.697	762.015	771.712
1.3.2.1.8	INFO. MGMT. AND CONTROL	0.0	0.0	0.0
1.3.2.2	COTV OPERATIONS	0.0	4.410	4.410
1.3.3	PERSONNEL LAUNCH VEHICLE(PLV)	1549.000	6251.230	7800.230
1.3.3.1	STS-PLV FLEET	1549.000	3908.082	5457.082
1.3.3.1.1	STS-PLV ORBITER	0.0	1682.531	1682.531
1.3.3.1.2	STS-PLV EXTERNAL TANK	0.0	606.205	606.205

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.3.3.1.3	STS-PLV LIQ. ROCKET BOOSTER	1304.000	873.985	2177.985
1.3.3.1.4	STS CARGO CARRIER AND EM	245.000	745.362	990.362
1.3.3.2	PLV & STS-HLLV OPERATIONS	0.0	2343.150	2343.150
1.3.3.2.1	PLV OPERATIONS	0.0	1214.400	1214.400
1.3.3.2.2	STS HLLV CARGO OPERATIONS	0.0	1128.750	1128.750
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	350.000	56.282	406.282
1.3.4.1	POTV-FLEET	350.000	54.764	404.764
1.3.4.2	POTV-OPERATIONS	0.0	1.518	1.518
1.3.5	PERSONNEL MODULE(PM)	118.000	201.910	319.910
1.3.5.1	PM FLEET	118.000	198.610	316.610
1.3.5.2	PM OPERATIONS	0.0	3.300	3.300
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	100.000	5.567	105.567
1.3.6.1	IOTV FLEET	100.000	5.476	105.476
1.3.6.2	IOTV OPERATIONS	0.0	0.091	0.091
1.3.7	GROUND SUPPORT FACILITIES	1720.000	3195.000	4915.000
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	115.699	3618.727	3734.427
1.4.1	SITE AND FACILITIES	1.000	195.197	196.197
1.4.1.1	LAND AND PREPARATION	0.0	105.341	105.341
1.4.1.1.1	LAND	0.0	35.000	35.000
1.4.1.1.2	LAND PREPARATION	0.0	70.341	70.341
1.4.1.2	ROADS AND FENCES	0.0	74.180	74.180
1.4.1.2.1	RAILS AND ROADS	0.0	73.710	73.710
1.4.1.2.2	FENCING	0.0	0.470	0.470
1.4.1.3	UTILITIES	0.0	0.200	0.200
1.4.1.4	BUILDINGS	0.0	11.477	11.477
1.4.1.4.1	STORAGE,MAINTENANCE	0.0	1.300	1.300
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	0.0	10.177	10.177
1.4.1.5	MAINTENANCE EQPT.	0.0	4.000	4.000
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DDT&E	1.000	0.0	1.000

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-5. SATELLITE POWER SYSTEM (SPS) PROGRAM DEVELOPMENT COST

WBS #	DESCRIPTION	DEVELOPMENT DDT&E	DEVELOPMENT TFU	TOTAL
1.4.2	RECTENNA SUPPORT STRUCTURE	2.000	1849.629	1851.629
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	0.0	1696.508	1696.508
1.4.2.1.1	HAT SECTIONS	0.0	359.228	359.228
1.4.2.1.2	WIDE FLANGES	0.0	295.173	295.173
1.4.2.1.3	TUBE BRACES & HARDWARE	0.0	431.346	431.346
1.4.2.1.4	ASSEMBLY & INSTALLATION	0.0	610.762	610.762
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	0.0	153.121	153.121
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	0.0	70.821	70.821
1.4.2.2.2	MACHINGERY & EQUIPMENT	0.0	22.360	22.360
1.4.2.2.3	CONSTRUCTION OPERATIONS	0.0	59.940	59.940
1.4.2.3	SUPPORT STRUCTURE DDT&E	2.000	0.0	2.000
1.4.3	POWER COLLECTION	3.000	1353.211	1356.211
1.4.3.1	ANTENNA ARRAY ELEMENTS	0.0	1127.331	1127.331
1.4.3.2	POWER DISTRIBUTION SYSTEM	0.0	69.660	69.660
1.4.3.3	INSTALLATION & CHECKOUT	0.0	156.220	156.220
1.4.3.4	POWER COLLECTION-DDT&E	3.000	0.0	3.000
1.4.4	CONTROL	10.000	75.000	85.000
1.4.4.1	CONTROL CENTER EQUIPMENT	0.0	15.000	15.000
1.4.4.2	CONTROL ELECTRONICS	0.0	60.000	60.000
1.4.4.3	CONTROL DDT&E	10.000	0.0	10.000
1.4.5	GRID INTERFACE	99.699	145.690	245.389
1.4.5.1	ELECTRICAL EQUIPMENT	0.0	145.690	145.690
1.4.5.2	GRID INTERFACE-DDT&E	99.699	0.0	99.699
1.4.6	OPERATIONS	0.0	0.0	0.0
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	0.0
1.4.6.2	MAINT. MATERIAL	0.0	0.0	0.0
1.5	MANAGEMENT AND INTEGRATION	1392.463	2151.918	3544.382
1.6	MASS CONTINGENCY	4160.031	5912.945	10072.977

B.3.2 INVESTMENT AND OPERATIONS

Detailed investment and RCI/O&M cost data are shown in Table B-6. Investment costs were developed at two levels:

(1) Initial capital investment (ICI), which is the cost of production, assembly, installation, transportation, and tests of each individual satellite produced, and the ground station system and associated effort necessary to bring the power satellite on line to a 5-GW operational capability.

(2) Replacement capital investment (RCI), which are those expenditures relating to capital asset replacement and major maintenance overhauls/spares that are expected to last for more than one year or result in an improvement to the operating system.

Costs for the transportation fleet needed to construct the satellites are included in the ICI; whereas, the fleet required for O&M of the satellite over the 30 years is included in the O&M cost. Replacement capital investment is included in the RCI column.

Investment per satellite is equivalent to the average unit cost of the total SPS requirement—TFU plus satellites and supporting program elements for the 60-SPS option. Total average ICI cost is projected at $13.9 billion. Annual SPS estimates are placed at $0.45 billion for RCI and $0.20 billion for O&M.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS **	TOTAL
1	SATELLITE POWER SYSTEM (SPS) PROGRAM	13877.668	451.531	193.713	645.244	14522.910
1.1	SATELLITE SYSTEM	5325.422	205.265	0.705	205.970	5531.391
1.1.1	ENERGY CONVERSION	1851.622	4.500	0.010	4.510	1856.132
1.1.1.1	STRUCTURE	96.789	0.194	0.0	0.194	96.983
1.1.1.1.1	PRIMARY STRUCTURE	35.100	0.070	0.0	0.070	35.170
1.1.1.1.2	SECONDARY STRUCTURE	61.689	0.123	0.0	0.123	61.812
1.1.1.2	CONCENTRATORS	67.183	0.134	0.0	0.134	67.318
1.1.1.3	SOLAR BLANKETS	1556.692	3.113	0.0	3.113	1559.805
1.1.1.4	POWER DIST. & CONDITIONG	91.948	0.169	0.010	0.179	92.127
1.1.1.4.1	SWITCH GEAR & CONVERTERS	66.093	0.0	0.0	0.0	66.093
1.1.1.4.2	CONDUCTORS & INSULATION	9.468	0.0	0.0	0.0	9.468
1.1.1.4.3	SLIP RINGS	15.825	0.158	0.0	0.158	15.983
1.1.1.4.4	BATTERIES	0.238	0.008	0.010	0.018	0.256
1.1.1.4.5	BATTERY PD&C	0.324	0.003	0.0	0.003	0.327
1.1.1.5	THERMAL CONTROL	0.0	0.0	0.0	0.0	0.0
1.1.1.6	MAINTENANCE	39.010	0.890	0.0	0.890	39.899
1.1.1.6.1	MAINTENANCE - FREE FLYERS	23.392	0.585	0.0	0.585	23.977
1.1.1.6.2	MANNED MANIPULATOR	15.198	0.304	0.0	0.304	15.502
1.1.1.6.3	TRACKS & ACCESS WAYS	0.420	0.001	0.0	0.001	0.421
1.1.2	POWER TRANSMISSION	3153.938	197.438	0.485	197.923	3351.861
1.1.2.1	STRUCTURE	44.175	0.088	0.0	0.088	44.263
1.1.2.1.1	PRIMARY STRUCTURE	3.350	0.007	0.0	0.007	3.357
1.1.2.1.2	SECONDARY STRUCTURE	40.825	0.082	0.0	0.082	40.906
1.1.2.2	TRANSMITTER SUBARRAYS - KLYSTRONS	2322.804	154.854	0.0	154.854	2477.658
1.1.2.2.1	KLYSTRON DDT&E	0.0	0.0	0.0	0.0	0.0
1.1.2.2.2	KLYSTRON ICI, R, O&M	2322.804	154.854	0.0	154.854	2477.658
1.1.2.3	POWER DIST. & CONDITIONING	526.406	34.454	0.475	34.929	561.334
1.1.2.3.1	SWITCH GEAR & CONVERTERS	512.556	34.171	0.0	34.171	546.726
1.1.2.3.2	CONDUCTORS & INSULATION	5.348	0.0	0.0	0.0	5.348
1.1.2.3.3	BATTERIES	8.502	0.283	0.475	0.758	9.261
1.1.2.4	THERMAL CONTROL - INSULATION	184.657	1.847	0.0	1.847	186.504
1.1.2.5	CONTROL - PHASE REFERENCE	20.050	0.262	0.010	0.272	20.322
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	0.100	0.003	0.010	0.013	0.113
1.1.2.5.2	DIST. SYSTEM, COAXIAL CABLE	12.180	0.0	0.0	0.0	12.180
1.1.2.5.3	DIST. SYSTEM, DEVICES	7.770	0.259	0.0	0.259	8.029

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS **	TOTAL
1.1.2.6	MAINTENANCE	55.846	5.933	0.0	5.933	61.779
1.1.2.6.1	MAINTENANCE - FREE FLYERS	28.784	0.576	0.0	0.576	29.360
1.1.2.6.2	GANTRY CRANE	0.220	0.000	0.0	0.000	0.220
1.1.2.6.3	ON-CRANE CONTROL CENTER	26.782	5.356	0.0	5.356	32.139
1.1.2.6.4	TRACKS & ACCESS WAYS	0.060	0.000	0.0	0.000	0.060
1.1.3	INFORMATION MGMT. & CONTROL	163.189	1.632	0.0	1.632	164.821
1.1.3.1	MASTER CONTROL COMPUTER	2.659	0.027	0.0	0.027	2.685
1.1.3.2	DISPLAYS & CONTROLS	0.453	0.005	0.0	0.005	0.458
1.1.3.3	SUPERVISORY COMPUTER	0.969	0.010	0.0	0.010	0.979
1.1.3.4	REMOTE COMPUTER	2.238	0.022	0.0	0.022	2.260
1.1.3.5	BUS CONTROL UNIT	5.128	0.051	0.0	0.051	5.179
1.1.3.6	MICROPROCESSORS	5.085	0.051	0.0	0.051	5.136
1.1.3.7	REMOTE ACQUISITION & CONTROL	5.505	0.055	0.0	0.055	5.560
1.1.3.8	SUBMULTIPLEXORS	58.682	0.587	0.0	0.587	59.268
1.1.3.9	INSTRUMENTATION	65.846	0.658	0.0	0.658	66.504
1.1.3.10	OPTICAL FIBER	0.578	0.006	0.0	0.006	0.584
1.1.3.11	CABLES/HARNESS	16.047	0.160	0.0	0.160	16.207
1.1.4	ATTITUDE CONTROL & STATIONKEEPING	53.746	0.537	0.132	0.669	54.416
1.1.4.1	ACSS HARDWARE	53.746	0.537	0.047	0.584	54.330
1.1.4.2	ACSS PROPELLANT	0.0	0.0	0.085	0.085	0.085
1.1.5	COMMUNICATIONS	0.0	0.0	0.0	0.0	0.0
1.1.5.1	SATELLITE TO GROUND	0.0	0.0	0.0	0.0	0.0
1.1.5.2	SATELLITE TO RESUPPLY VEHICLES	0.0	0.0	0.0	0.0	0.0
1.1.5.3	SATELLITE INTERCOM	0.0	0.0	0.0	0.0	0.0
1.1.6	INTERFACE	102.929	1.157	0.078	1.235	104.163
1.1.6.1	STRUCTURE	68.860	0.138	0.0	0.138	68.998
1.1.6.1.1	PRIMARY STRUCTURE	6.000	0.012	0.0	0.012	6.012
1.1.6.1.2	SECONDARY STRUCTURE	62.860	0.126	0.0	0.126	62.986
1.1.6.2	MECHANISMS - INTERFACE	5.821	0.058	0.078	0.136	5.958
1.1.6.3	POWER DISTRIBUTION	6.510	0.014	0.0	0.014	6.524
1.1.6.3.1	CONDUCTOR & INSULATION	5.068	0.0	0.0	0.0	5.068
1.1.6.3.2	SLIP RING BRUSHES	1.442	0.014	0.0	0.014	1.456
1.1.6.4	THERMAL CONTROL	0.0	0.0	0.0	0.0	0.0
1.1.6.5	MAINTENANCE	21.738	0.946	0.0	0.946	22.684
1.1.6.5.1	MAINTENANCE - FREE FLYERS	6.420	0.642	0.0	0.642	7.062

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS **	TOTAL
1.1.6.5.2	MANNED MANIPULATOR	15.198	0.304	0.0	0.304	15.502
1.1.6.5.3	TRACKS & ACCESS WAYS	0.120	0.000	0.0	0.000	0.120
1.1.7	SYSTEMS TEST	0.0	0.0	0.0	0.0	0.0
1.1.7.1	SYSTEM GROUND TEST HARDWARE	0.0	0.0	0.0	0.0	0.0
1.1.7.2	SYSTEM GROUND TEST OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.1.8	GROUND SUPPORT EQUIPMENT	0.0	0.0	0.0	0.0	0.0
1.1.9	COTV - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1	COTV PRECURSOR VEHICLE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.1	PRIMARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.2	SECONDARY STRUCTURE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.3	CONCENTRATOR - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.4	SOLAR BLANKET -E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.5	SWITCHGEAR & CONVERTERS -E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.6	CONDUCTORS & INSULATION - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.7	ACS HARDWARE - E.C.	0.0	0.0	0.0	0.0	0.0
1.1.9.1.8	SLIPRINGS - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.9	PRIMARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.10	SECONDARY STRUCTURE - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.11	MECHANISMS - INTERFACE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.12	CONDUCTORS & INSULATION	0.0	0.0	0.0	0.0	0.0
1.1.9.1.13	SLIPRING BRUSHES - PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.14	PRIMARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0	0.0
1.1.9.1.15	SECONDARY STRUCTURE - POWER TRANS	0.0	0.0	0.0	0.0	0.0
1.1.9.1.16	TRANSMITTER SUBARRAYS - KLYSTRONS IC	0.0	0.0	0.0	0.0	0.0
1.1.9.1.17	SWITCHGEAR & CONVERTERS - P.T. PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.18	CONDUCTORS & INSULATION - P.T. PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.19	BATTERIES - P.T. PRECURSOR	0.0	0.0	0.0	0.0	0.0
1.1.9.1.20	THERMAL CONTROL - INSULATION - PRECU	0.0	0.0	0.0	0.0	0.0
1.1.9.1.21	REFERENCE FREQUENCY GENERATOR - PREC	0.0	0.0	0.0	0.0	0.0
1.1.9.1.22	DIST. SYSTEM, COAXIAL CABLE	0.0	0.0	0.0	0.0	0.0
1.1.9.1.23	DIST. SYSTEM DEVICES	0.0	0.0	0.0	0.0	0.0
1.1.9.1.24	TRANSMITTER SUBARRAYS - KLYSTRONS DD	0.0	0.0	0.0	0.0	0.0
1.1.9.2	COTV PRECURSOR OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.2	SPACE CONSTRUCTION & SUPPORT	1148.332	51.428	11.274	62.701	1211.033
1.2.1	CONSTRUCTION FACILITIES	123.606	19.081	11.274	30.355	153.961

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.2.1.1	WORK SUPPORT FACILITIES	66.025	13.784	11.274	25.057	91.083
1.2.1.1.1	BEAM MACHINE	1.386	0.0	0.594	0.594	1.980
1.2.1.1.2	BEAM MACHINE CASSETTES	0.097	0.000	0.090	0.091	0.188
1.2.1.1.3	CABLE ATTACHMENT MACHINE	0.470	0.0	0.144	0.144	0.614
1.2.1.1.4	REMOTE MANIPULATOR	0.987	0.036	1.925	1.961	2.948
1.2.1.1.5	BLANKET DISPENSER MACHINE	0.436	0.0	0.180	0.180	0.616
1.2.1.1.6	SOLAR BLANKET CASSETTES	0.273	0.000	0.115	0.116	0.389
1.2.1.1.7	REFLECTOR DISPENSER MACHINE	0.078	0.0	0.048	0.048	0.126
1.2.1.1.8	REFLECTOR CASSETTES	0.042	0.001	0.054	0.055	0.097
1.2.1.1.9	CABLE/CATENARY DISPENSER MACHINES	0.380	0.0	0.168	0.168	0.548
1.2.1.1.10	ANTENNA PANEL INS. EQPT.	3.338	0.0	6.755	6.755	10.093
1.2.1.1.11	GANTRY/CRANES	1.417	0.0	0.600	0.600	2.017
1.2.1.1.12	CARGO STORAGE DEPOTS	0.126	0.0	0.600	0.600	0.726
1.2.1.1.13	FAB FIXTURE	1.374	0.0	0.0	0.0	1.374
1.2.1.1.14	AIRLOCK DOCKING MODULE (ADM)	4.038	0.285	0.0	0.285	4.323
1.2.1.1.15	BASE MGMT. MODULE (BMM)	20.231	6.069	0.0	6.069	26.300
1.2.1.1.16	POWER MODULE (PM)	17.924	5.377	0.0	5.377	23.302
1.2.1.1.17	PRESSURIZED STORAGE MODULE (PSM)	13.428	2.014	0.0	2.014	15.442
1.2.1.2	CREW SUPPORT FACILITIES-SCB	43.171	5.297	0.0	5.297	48.469
1.2.1.2.1	AIRLOCK DOCKING MODULE-ADM	1.224	0.294	0.0	0.294	1.517
1.2.1.2.2	CREW HABITABILITY MODULE-CHM	27.241	1.923	0.0	1.923	29.164
1.2.1.2.3	CONSUMABLES LOGISTICS MODULE-CLM	10.078	1.344	0.0	1.344	11.422
1.2.1.2.4	SHIELDING	0.353	0.026	0.0	0.026	0.379
1.2.1.2.5	CREW SUPPORT MODULE-CSM	4.276	1.711	0.0	1.711	5.987
1.2.1.3	OPERATIONS	14.410	0.0	0.0	0.0	14.410
1.2.1.3.1	OPERATIONS, CONSTRUCTION CREW	9.890	0.0	0.0	0.0	9.890
1.2.1.3.2	ORBITAL OPERATIONS,CONST. PROV.	4.519	0.0	0.0	0.0	4.519
1.2.2	LOGISTICS SUPPORT FACILITIES-LEO	16.340	18.299	0.0	18.299	34.640
1.2.2.1	WORK SUPPORT FACILITIES	9.770	11.724	0.0	11.724	21.494
1.2.2.1.1	BASE MGMT. MODULE-BMM	5.180	6.216	0.0	6.216	11.397
1.2.2.1.2	POWER MODULE-PM	4.590	5.507	0.0	5.507	10.097
1.2.2.2	CREW SUPPORT FACILITIES	5.480	6.576	0.0	6.576	12.055
1.2.2.2.1	CREW HABITABILITY MODULE-CHM	1.699	2.039	0.0	2.039	3.737
1.2.2.2.2	CONSUMABLES LOGISTICS MODULE	1.168	1.402	0.0	1.402	2.570
1.2.2.2.3	CREW SUPPORT MODULE/EVA	2.613	3.135	0.0	3.135	5.748

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.2.2.3	OPERATIONS	1.091	0.0	0.0	0.0	1.091
1.2.2.3.1	LEO OPERATIONS CREW	0.749	0.0	0.0	0.0	0.749
1.2.2.3.2	LEO CREW PROVISIONS	0.342	0.0	0.0	0.0	0.342
1.2.3	O&M SUPPORT FACILITIES - SATELLITE	1008.386	14.047	0.0	14.047	1022.433
1.2.3.1	WORK SUPPORT FACILITIES	692.183	7.778	0.0	7.778	699.960
1.2.3.1.1	AIRLOCK DOCKING MODULE-ADM	40.056	0.267	0.0	0.267	40.323
1.2.3.1.2	BASE MGMT MODULE-BMM	283.322	5.666	0.0	5.666	288.989
1.2.3.1.3	PRESSURIZED STORAGE MODULE-PSM	368.805	1.844	0.0	1.844	370.649
1.2.3.2	CREW SUPPORT FACILITIES	313.476	6.270	0.0	6.270	319.745
1.2.3.2.1	AIRLOCK DOCKING MODULE-ADM	13.774	0.275	0.0	0.275	14.049
1.2.3.2.2	CREW HABITABILITY MODULE-CHM	92.913	1.858	0.0	1.858	94.771
1.2.3.2.3	CONSUMABLES LOGISTICS MODULE-CLM	63.895	1.278	0.0	1.278	65.173
1.2.3.2.4	CREW SUPPORT MODULE/EVA	142.894	2.858	0.0	2.858	145.751
1.2.3.3	OPERATIONS	2.727	0.0	0.0	0.0	2.727
1.2.3.3.1	SATELLITE OPERATIONS CREW	1.872	0.0	0.0	0.0	1.872
1.2.3.3.2	SATELLITE CREW PROVISIONS	0.855	0.0	0.0	0.0	0.855
1.3	TRANSPORTATION	1949.004	119.343	80.869	200.212	2149.216
1.3.1	SPS-HEAVY LIFT LAUNCH VEHICLE(HLLV)	1256.406	99.642	39.372	139.014	1395.420
1.3.1.1	SPS-HLLV FLEET	767.020	99.642	24.256	123.898	890.917
1.3.1.2	SPS-HLLV OPERATIONS	489.387	0.0	15.116	15.116	504.502
1.3.2	CARGO ORBITAL TRANSFER VEHICLE(COTV)	210.343	1.957	6.371	8.328	218.671
1.3.2.1	COTV VEHICLES	205.681	1.957	6.233	8.190	213.871
1.3.2.1.1	PRIMARY STRUCTURE	0.566	0.005	0.017	0.023	0.589
1.3.2.1.2	SECONDARY STRUCTURE	142.934	1.364	4.331	5.696	148.630
1.3.2.1.3	CONCENTRATOR	0.914	0.009	0.028	0.036	0.951
1.3.2.1.4	SOLAR BLANKET	20.077	0.192	0.608	0.800	20.878
1.3.2.1.5	SWITCHGEAR AND CONVERTERS	0.465	0.001	0.014	0.016	0.481
1.3.2.1.6	CONDUCTORS AND INSULATION	0.525	0.002	0.016	0.017	0.542
1.3.2.1.7	ACS HARDWARE	40.199	0.384	1.218	1.602	41.801
1.3.2.1.8	INFO. MGMT. AND CONTROL	0.0	0.0	0.0	0.0	0.0
1.3.2.2	COTV OPERATIONS	4.662	0.0	0.139	0.139	4.801
1.3.3	PERSONNEL LAUNCH VEHICLE(PLV)	423.752	12.995	32.927	45.922	469.674
1.3.3.1	STS-PLV FLEET	188.433	12.995	14.047	27.042	215.474
1.3.3.1.1	STS-PLV ORBITER	100.340	5.797	8.250	14.047	114.387
1.3.3.1.2	STS-PLV EXTERNAL TANK	41.679	0.0	3.330	3.330	45.010

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.3.3.1.3	STS-PLV LIQ. ROCKET BOOSTER	33.991	7.198	2.466	9.664	43.655
1.3.3.1.4	STS CARGO CARRIER AND EM	12.423	0.0	0.0	0.0	12.423
1.3.3.2	PLV & STS-HLLV OPERATIONS	235.319	0.0	18.880	18.880	254.200
1.3.3.2.1	PLV OPERATIONS	216.507	0.0	18.880	18.880	235.387
1.3.3.2.2	STS HLLV CARGO OPERATIONS	18.813	0.0	0.0	0.0	18.813
1.3.4	PERSONNEL ORBITAL TRANS VEHICLE	2.488	0.736	0.254	0.990	3.478
1.3.4.1	POTV-FLEET	1.802	0.736	0.185	0.921	2.723
1.3.4.2	POTV-OPERATIONS	0.686	0.0	0.069	0.069	0.755
1.3.5	PERSONNEL MODULE(PM)	1.294	0.199	0.126	0.324	1.618
1.3.5.1	PM FLEET	0.746	0.199	0.075	0.273	1.019
1.3.5.2	PM OPERATIONS	0.548	0.0	0.051	0.051	0.599
1.3.6	INTRAORBITAL TRANSFER VEHICLE(IOTV)	1.471	0.265	0.045	0.310	1.780
1.3.6.1	IOTV FLEET	1.389	0.265	0.042	0.307	1.697
1.3.6.2	IOTV OPERATIONS	0.081	0.0	0.002	0.002	0.084
1.3.7	GROUND SUPPORT FACILITIES	53.250	3.550	1.775	5.325	58.575
1.3.7.1	LAUNCH FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.2	RECOVERY FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.3	FUEL FACILITIES	0.0	0.0	0.0	0.0	0.0
1.3.7.4	LOGISTICS SUPPORT	0.0	0.0	0.0	0.0	0.0
1.3.7.5	OPERATIONS	0.0	0.0	0.0	0.0	0.0
1.4	GROUND RECEIVING STATION	3590.822	0.275	78.377	78.652	3669.474
1.4.1	SITE AND FACILITIES	188.934	0.200	0.0	0.200	189.134
1.4.1.1	LAND AND PREPARATION	99.119	0.0	0.0	0.0	99.119
1.4.1.1.1	LAND	35.000	0.0	0.0	0.0	35.000
1.4.1.1.2	LAND PREPARATION	64.119	0.0	0.0	0.0	64.119
1.4.1.2	ROADS AND FENCES	74.138	0.0	0.0	0.0	74.138
1.4.1.2.1	RAILS AND ROADS	73.710	0.0	0.0	0.0	73.710
1.4.1.2.2	FENCING	0.428	0.0	0.0	0.0	0.428
1.4.1.3	UTILITIES	0.200	0.0	0.0	0.0	0.200
1.4.1.4	BUILDINGS	11.477	0.0	0.0	0.0	11.477
1.4.1.4.1	STORAGE,MAINTENANCE	1.300	0.0	0.0	0.0	1.300
1.4.1.4.2	CONV. STA. & MONITOR/CONTROL FAC.	10.177	0.0	0.0	0.0	10.177
1.4.1.5	MAINTENANCE EQPT.	4.000	0.200	0.0	0.200	4.200
1.4.1.6	LIGHTNING PROTECTION	0.0	0.0	0.0	0.0	0.0
1.4.1.7	SITE & FACILITIES DUTGE	0.0	0.0	0.0	0.0	0.0

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE B-6. SATELLITE POWER SYSTEM (SPS) PROGRAM AVERAGE COST

WBS #	DESCRIPTION	INV PER SAT	** OPS COST PER SAT PER YEAR ** RCI	O&M	TOTAL OPS	TOTAL
1.4.2	RECTENNA SUPPORT STRUCTURE	1827.999	0.075	0.447	0.522	1828.521
1.4.2.1	STEEL PANEL FAB. & INSTALLATION	1696.493	0.0	0.0	0.0	1696.493
1.4.2.1.1	HAT SECTIONS	359.224	0.0	0.0	0.0	359.224
1.4.2.1.2	WIDE FLANGES	295.170	0.0	0.0	0.0	295.170
1.4.2.1.3	TUBE BRACES & HARDWARE	431.343	0.0	0.0	0.0	431.343
1.4.2.1.4	ASSEMBLY & INSTALLATION	610.756	0.0	0.0	0.0	610.756
1.4.2.2	TRENCHING & CONCRETE INSTALLATION	131.506	0.075	0.447	0.522	132.027
1.4.2.2.1	FOOTING CONCRETE & RE-BAR	70.820	0.0	0.0	0.0	70.820
1.4.2.2.2	MACHINGERY & EQUIPMENT	0.745	0.075	0.447	0.522	1.267
1.4.2.2.3	CONSTRUCTION OPERATIONS	59.940	0.0	0.0	0.0	59.940
1.4.2.3	SUPPORT STRUCTURE DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.3	POWER COLLECTION	1353.200	0.0	0.0	0.0	1353.200
1.4.3.1	ANTENNA ARRAY ELEMENTS	1127.321	0.0	0.0	0.0	1127.321
1.4.3.2	POWER DISTRIBUTION SYSTEM	69.659	0.0	0.0	0.0	69.659
1.4.3.3	INSTALLATION & CHECKOUT	156.220	0.0	0.0	0.0	156.220
1.4.3.4	POWER COLLECTION-DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.4	CONTROL	75.000	0.0	0.0	0.0	75.000
1.4.4.1	CONTROL CENTER EQUIPMENT	15.000	0.0	0.0	0.0	15.000
1.4.4.2	CONTROL ELECTRONICS	60.000	0.0	0.0	0.0	60.000
1.4.4.3	CONTROL DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.5	GRID INTERFACE	145.690	0.0	0.0	0.0	145.690
1.4.5.1	ELECTRICAL EQUIPMENT	145.690	0.0	0.0	0.0	145.690
1.4.5.2	GRID INTERFACE-DDT&E	0.0	0.0	0.0	0.0	0.0
1.4.6	OPERATIONS	0.0	0.0	77.930	77.930	77.930
1.4.6.1	OPER. & MAINT. PERSONNEL	0.0	0.0	64.800	64.800	64.800
1.4.6.2	MAINT. MATERIAL	0.0	0.0	13.130	13.130	13.130
1.5	MANAGEMENT AND INTEGRATION	600.679	18.815	8.561	27.377	628.055
1.6	MASS CONTINGENCY	1263.413	56.405	13.927	70.332	1333.745

1.0 SATELLITE POWER SYSTEM (SPS) PROGRAM

The program elements described in this section include all the elements of hardware, software, and activities required for the design, development, production, assembly, transportation, operations and maintenance of the Satellite Power Systems Program. Included are the satellite and ground receiving station systems as well as the necessary support systems such as space construction and assembly equipment, plus transportation.

Cost estimates are presented for DDT&E, Theoretical First Unit (TFU), investment per satellite, replacement capital investment, and operations/maintenance for SPS program elements in the following categories:

- Satellite
- Space Construction and Support
- Transportation
- Ground Receiving Station
- Management and Integration
- Mass Contingency

1.1 SATELLITE

Elements of the satellite costed in this section include the hardware and software located in geosynchronous orbit for the collection of solar energy, its conversion to electrical energy, and the transmission of this electrical energy in microwave form to earth.

The satellite concept is of a planar array using GaAlAs photovoltaic cells with a solar reflector (concentrator) to provide a concentration ratio of 2.0 suns. The concept consists of 3 main bays with 10 subsections in each of the main bays and is 16,000 meters long by 3900 meters wide with an end mounted antenna adding another 1750 meters to the length (Figure 1.1-1). The total dry weight of the satellite is 26.416×10^6 kg (Table 1.1-1). It has a primary structure of composites, GaAlAs solar cells, and a microwave antenna using the klystron power module as a source for the generation of MW energy.

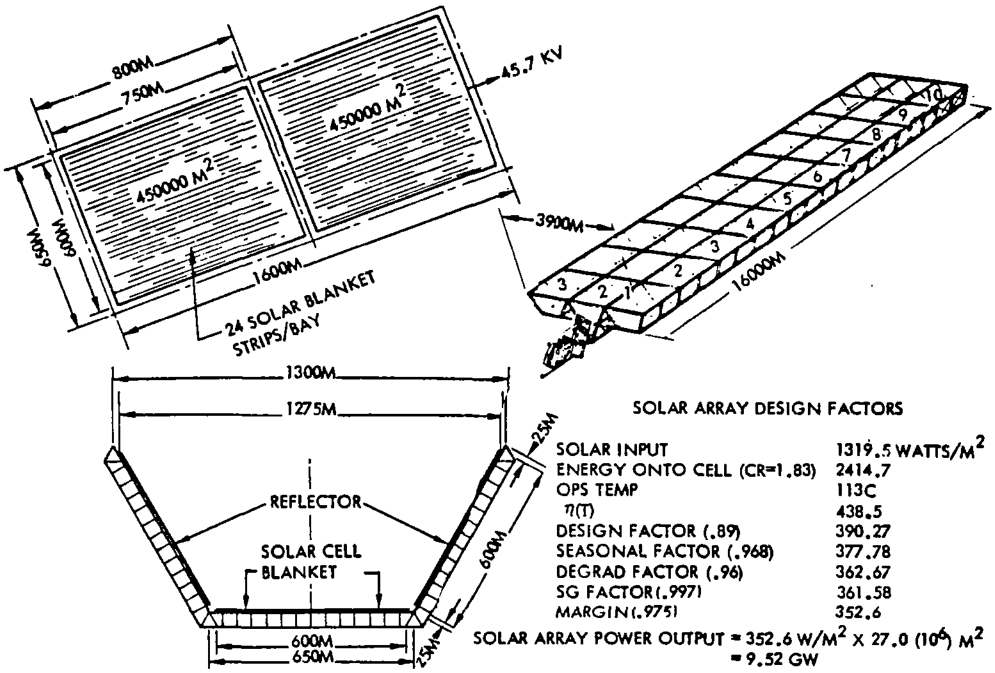


Figure 1.1-1. Solar Array Dimensions

The satellite has been divided into a number of main elements that are included in the following items as described in the SPS-WBS of Appendix A.

1.1.1 Energy Conversion

1.1.2 Power Transmission

1.1.3 Information Management and Control

1.1.4 Attitude Control and Stationkeeping

1.1.5 Communications

1.1.6 Interface

1.1.7 Systems Test

1.1.8 Ground Support Equipment

1.1.9 Precursor Test Article

Table 1.1-1. Solar Photovoltaic Power Conversion Mass Statement - ~10^6 kg End-Mounted Antenna

SUBSYSTEM	CO-PLANAR (3 TROUGH)
COLLECTOR ARRAY	
STRUCTURE AND MECHANISMS	1.260
PRIMARY STRUCTURE	.702
SECONDARY STRUCTURE	.358
MECHANISM	.200
ATTITUDE CONTROL	(0.116)
POWER SOURCE	(7.855)
SOLAR PANELS	6.818
SOLAR REFLECTORS	1.037
POWER DISTRIBUTION AND CONTROL	(2.603)
POWER CONDITIONING EQUIPMENT	(.193)
POWER DISTRIBUTION	(2.410)
CONDUCTORS AND INSULATION	(2.367)
SLIP RINGS	.043
INFORMATION MANAGEMENT & CONTROL	(.050)
DATA PROCESSING	.021
INSTRUMENTATION	.029
TOTAL ARRAY, DRY	11.884
ANTENNA SECTION	
STRUCTURE & MECHANISM	(0.977)
PRIMARY STRUCTURE	.120
SECONDARY STRUCTURE	.599
ANTENNA	.067
MECHANISM	.191
THERMAL CONTROL	1.408
KLYSTRON COOLING	.851
INSULATION	.557
RADIATOR	-
MICROWAVE POWER	(7.012)
KLYSTRONS	4.250
ATT. SEN. ELECTRONICS & PHASE CONTROL	.142
WAVEGUIDES	2.620
POWER DISTRIBUTION & CONTROL	(4.505)
POWER CONDITIONING EQUIPMENT	1.901
POWER DISTRIBUTION	(2.604)
CONDUCTOR & INSULATION	(2.587)
SLIP RING BRUSHES	.017
INFORMATION MANAGEMENT & CONTROL	(.630)
DATA PROCESSING	.380
INSTRUMENTATION	.250
TOTAL ANTENNA SECTION	14.532
TOTAL SPS DRY	26.416

1.1.1 ENERGY CONVERSION

This element includes the components required to collect solar energy, convert the solar energy to electrical energy, condition the electrical energy, and transport it to the interface subsystem (WBS No. 1.1.6).

The satellite structure, solar cells/blankets, concentrators, and power distribution/conditioning subsystems are included in this element plus the necessary maintenance requirements to support operations.

1.1.1.1 STRUCTURE

This element includes all necessary members to support the concentrators, solar blankets, and other energy conversion subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures which are required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems.

1.1.1.1.1 Primary Structure

The primary SPS structure assemblies are made up, basically, of tribeam girders, tension cables, and joints. The fabrication and assembly of these structures are accomplished on orbit by beam machines and supporting auxiliary equipment. These structural elements are made of a graphite fiber reinforced composite that must individually withstand the forces, torques, and dynamics imposed by the construction process. Once built into an assembly level, the structure must have sufficient strength and stiffness to withstand the forces of the environment (gravity-gradient torques), the attitude control system (forces and frequencies), and the operational equipment (rotary jointsk microwave induced thermal environment).

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The energy conversion structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The primary structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.1.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost data contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- X-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass.

1.1.1.1.3 <u>Cost Estimates</u>

Table 1.1.1.1.1 and 1.1.1.1.2 cover cost estimates associated with the primary and secondary structures.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	702000.000	TF=	1.000000	CDCER=	0.023000
M=	11700.0000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			47.821
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.585
#RM =T / M		60.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			35.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			35.100
CIPS=CTB*Z4/Z2			35.100
CRCI =CTB X R			0.070
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	358000.000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.002000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			23.245
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		71600.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			69.508
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			61.689
CIPS=CTB*Z4/Z2			61.689
CRCI =CTB X R			0.123
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.2 CONCENTRATORS

This element concentrates the solar energy onto the solar blanket to increase the energy density on the conversion device. It includes the reflective material and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Concentrator membranes are used to reflect the sun onto the solar cell surfaces and obtain a nominal concentration ratio of 2. The concentrator is made of (0.5-mil) aluminized Kapton. The membrane has a mass of 0.018 kg/m^2 and is mounted on the structure using attachments and tensioning devices. Excluded are tools and support equipment required for deployment.

The DDT&E CER (CD) is based on thin sheet aluminum vendor data. The ICI CER for concentrators is based on Rockwell data for Type H Kapton material with an aluminized coating. As concentrator thickness decreases, cost per unit area decreases due to the diminished material requirements. However, at around 25 microns (1 mil), the cost reductions are cancelled by the increased difficulty of processing thin materials and the overall cost per unit area begins to rise. Rockwell data from Dupont indicates that the current cost of 0.5 mil concentrator for the SPS would be about $4.73 per square meter. At increased demand and increased yields, cost could potentially reach $1.61 per square meter. However, the most likely value, and the value on which the concentrator ICI CER is based, was quoted at $2.58 per square meter. For the purposes of the CER this was rounded to $3.00 per square meter to include sensors and mounting attachments and scaled at a slope of 0.95 to reflect anticipated large array economies.

Range of Data

DDT&E: 100 M^2 - 100,000 M^2
ICI: Unlimited

Input parameters T&M are in square meters, see Table 1.1.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.2 CONCENTRATORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	54000000.0	TF=	1.000000	CDCER=	0.0
M=	450000.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000003
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.950000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M	120.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			75.637
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			67.184
CIPS=CTB*Z4/Z2			67.183
CRCI =CTB X R			0.134
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.3 SOLAR BLANKET

This element converts solar energy to electrical energy and provides power to the power distribution and conditioning buses. It includes the photovoltaic conversion cells, cover-plates, substrate, electrical interconnects, and any integral attach points required for mounting. Excluded are tools and support equipment required for deployment and tensioning.

Gallium aluminum arsenide (GaAlAs) cells have been selected. The cell consists of GaAs junction with a GaAlAs window, substrate, adhesive, current collectors, and an anti-reflective coating. The solar blanket consists of a Kapton membrane upon which the cells are fastened with a thermo-setting FEP adhesive. Also included in the blanket are the interconnects, thermal coating, attachments/tensioning devices, and sensors.

Historical cost data on solar arrays from previous satellite programs were readily available from the Redstar Data Base and were used to develop the CD CER. However, due to the rapidly changing technology, historical data is not applicable for use in estimating the SPS solar blanket production cost. The Department of Energy (DOE) has initiated the U.S. Photovoltaic Conversion Program. Two main objectives of this program are to develop by 1990 the technological and industrial capability to produce silicon solar arrays at a price of less than $500 per peak KWe and to establish by 2000 the viability of even lower-cost ($100 to $300 per KWe) and/or more efficient alternatives utilizing novel materials and devices. Since it is generally believed throughout the photovoltaic industry that low cost solar arrays are achievable and dependent on the demand for high production rates and since some progress toward meeting the DOE goal has already been made, it was decided to base the SPS solar array cost estimates on projected costs rather than historical costs.

The CD CER was based on solar array historical cost data from the following programs.

- Skylab (OWS)
- Skylab (ATM)
- FRUSA
- SEPS (Est.)

The cost of array structure and mechanisms was not included so that the data would be compatible with the SPS concept of on-orbit structure fabrication and assembly. Although there is a large difference in size between the above arrays and the SPS array, the SPS array will consist of a large number of smaller units. The development fraction (DF) was utilized to normalize the CD cost to reflect cost of only that portion of the total solar array area required to develop the power system.

The initial capital investment CER (CI) cost estimate for material and production processing was based upon information contained in the Arthur D. Little report of March 1978 as prepared under Contract NAS9-15294 with NASA/JSC. The materials cost of $\$33/M^2$ and a fabrication cost of $\$34/M^2$ total $\$67/M^2$ for a gallium arsenide solar cell array. This assessment is consistent with work completed under Rockwell company sponsored activity based on 1977 prices and assuming 1990 technology.

Range of Data:

DDT&E: 10-300 square meters
ICI: Unlimited

Cost estimates are shown in Table 1.1.1.3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.3 SOLAR BLANKETS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000000.0	TF=	1.000000	CDCER=	0.0
M=	18750.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000067
PHI=	0.990000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		1440.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.986	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1651.832
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1556.693
CIPS=CTB*Z4/Z2			1556.692
CRCI =CTB X R			3.113
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.4 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes the various power feeders, switching and conditioning equipments necessary to deliver power at the required voltage and power levels throughout the satellite. An energy storage system is included, as a power source, to supply minimum power to the various subsystems during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS No. 1.1.3).

The PD&C system receives power from the solar photovoltaic power generation system and provides for the power conditioning and switching required to deliver the power, through its distribution network, to the satellite power transmission system. Electrical power is transferred from the solar array distribution network through a rotary joint, utilizing slip rings and brushes, to the microwave antenna distribution and conditioning system for the delivery of power at the required levels. The life expectancy of the PD&C is 30 years with the exception of the energy storage system (batteries), which is projected to have a life expectancy of 15 years.

1.1.1.4.1 Switches and Converters

Switches will be used to perform various functions and will be monitored and controlled through the IMCS. Switchgears will:

- Isolate solar array blankets for maintenance work
- Provide voltage regulation of solar array output by selective switching of isolation switchgears
- Control voltage and currents through the IMCS system for short circuit protection
- Prevention of large line transients
- Systematic start-up and shut-down of array during eclipse periods
- Control various loads

The primary switches will be of the Penning cross-field tube design. Functions controlled by these switches will be monitored by the IMCS to determine their status and establish the opening or closing position as required. Basically, the switches are held in a closed state during the operational mode. During start-up and shut-down operations, switches will be monitored by the IMCS, and when certain voltage levels are reached, a command signal will open or close switches as needed.

The power converter and conditioners convert the existing bus voltages to the subsystem voltage required for the various subsystem loads. The output tolerances will be based on the using subsystem interface requirements. The power converters are utilized in the GEO mode of operation.

1.1.1.4.2 Conductors and Insulation

Main feeders are generally sized to minimize the combined mass of itself and the solar array mass, considering power requirements, efficiency, and the variation in resistivity with operating temperature. The power distribution system utilizes flat aluminum (6101/T6) feeders where feasible, and round conductors for those subsystems where flat conductors are not feasible.

The CD CER was based on historical cost data obtained from the Redstar Data Base on the following satellite programs.

- DSCS-II
- ATS-F
- OSO-I
- ATS-B
- ATS-A
- ATS-E
- HEAO

The ICI CER was based on preprocessed aluminum material cost data and the use of 6101/T6 aluminum. Differential aluminum inflation between current prices and expected mid 1986 prices was included. Cost data was obtained from the following manufacturers:

- Reynolds Metals
- Alcoa Aluminum
- Amchem Products, Inc.
- The Yoder Company

Range of Data:

DDT&E: 20 to 150 kilograms
ICI: Unlimited

1.1.1.4.3 Slip Rings

The slip ring portion of the rotary joint is included in the PD&C of the Energy Conversion segment. The slip rings consist of an aluminum core with coin silver cladding on each slip ring. The core cross section is 33.7 cm^2. The slip ring diameter is .3 km with a length of .94 km. Each slip ring weighs 10,715 kg with a total weight of 42,860 kg for the required 4 slip rings.

The cost data for the slip rings cost data are based upon large ground commercial and military slip rings. Since all but one of the base data slip rings were designed for ground application, it was decided that these data should not be used as a basis for estimating DDT&E costs. It was determined that the data should be used only as a basis for estimating ICI production costs and then only after applying complexity and specification uprating factors. The following factors were applied:

Complexity Factor	× 3
Specification Uprating Factor	× 3
Total	× 9

The ICI production cost CER was based on data provided by the following manufacturers.

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the relatively low production rate of 1 to 5 units per year, the tooling factor is assumed to be 1.0.

The DDT&E cost was estimated with a CER developed for secondary structure which consisted of space qualified hardware of approximately the same complexity. See the discussion of the secondary structure CER.

Range of Data.

1.1.1.4.4 Batteries

Batteries will be utilized during ecliptic periods to provide minimum energy required by the energy conversion subsystems. The batteries will be of a sodium chloride design, having a density of at least 200 watt hours/kg.

The DDT&E and the ICI CER's were developed using battery data from the manned/unmanned spacecraft list below:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- ATS-E
- ATS-F
- HAWKEYE
- OSO-I

Range of Data:

DDT&E: 1.0 to 180.0 kg
ICI: 1.0 to 180.0 kg

1.1.1.4.5 Battery PD&C

This element provides the mechanism for the charging of the satellite batteries and the distribution and regulation of power to and from the batteries. Included are the battery chargers, power regulators, power conditioning and power conditioning equipment which directly interface with the battery subsystem.

The DDT&E and the ICI CER's were developed using data from the manned and unmanned spacecraft below:

- APOLLO Lunar Module
- APOLLO Lunar Rover
- GEMINI
- HAWKEYE

- ATS-E
- ATS-F
- OSO-I

Range of Data:

DDT&E: 2.0 to 68.0 kg
ICI: 2.0 to 68.0 kg

1.1.1.4.6 PD&C Cost Estimates

Cost calculations developed from the CER's discussed in the preceding paragraphs are presented in the following tables:

Table	Description
1.1.1.4.1	Switch Gear and Converters
1.1.1.4.2	Conductors and Insulation
1.1.1.4.3	Slip Rings
1.1.1.4.4	Batteries
1.1.1.4.5	Battery PD&C

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.1 SWITCH GEAR & CONVERTERS

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	187000.000	TF=	1.000000		CDCER=	0.158000
M=	3117.00000	O&M=	0.0		CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000		CICER=	0.000400
PHI=	0.950000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	60.000000			
DF=	0.050000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.582
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.870
#RM =T / M		59.994	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			89.123
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			66.093
CIPS=CTB*Z4/Z2			66.093
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.2 CONDUCTORS & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2367000.00	TF=	1.000000	CDCER=	0.158000
M=	19725.0000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.100000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.234
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.079
#RM =T / M		120.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.468
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			9.468
CIPS=CTB*Z4/Z2			9.468
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.3 SLIP RINGS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	43000.0000	TF=	1.000000	CDCER=	0.156000
M=	10750.0000	O&M=	0.0	CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000	CICER=	0.000764
PHI=	0.900000	Z2=	60.000000	CIEXP=	0.950000
R=	0.010000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.392
CLRM=CICER X (M)XX(CIEXP) X CF X TF			7.745
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.848	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			27.626
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.825
CIPS=CTB*Z4/Z2			15.825
CRCI =CTB X R			0.158
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.4 BATTERIES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	4000.00000	TF=	0.075600			CDCER=	0.037000
M=	50.000000	O&M=	0.010000			CDEXP=	0.734000
CF=	1.000000	Z1=	1.000000			CICER=	0.028000
PHI=	0.950000	Z2=	60.000000			CIEXP=	0.241000
R=	0.033333	Z3=	120.000000				
DF=	0.200000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.001
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M		80.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.338
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.238
CIPS=CTB*Z4/Z2			0.238
CRCI =CTB X R			0.008
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.010

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.4.5 BATTERY PD&C

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2000.00000	TF=	0.043000	CDCER=	0.053000
M=	250.000000	O&M=	0.0	CDEXP=	0.890000
CF=	1.000000	Z1=	1.000000	CICER=	0.012000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.859000
R=	0.010000	Z3=	60.000000		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			24.790
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.059
#RM =T / M		8.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.430
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.324
CIPS=CTB*Z4/Z2			0.324
CRCI =CTB X R			0.003
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.1.5 THERMAL CONTROL

This element includes any component used to modify the temperature of the energy conversion subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence.

1.1.1.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and in situ repair equipment.

The maintenance requirements of this element are related to the energy conversion section of the satellite covering the main structure, concentrators, solar blankets, and power distribution/conditioning. Some of the items of maintenance equipment will be commonly used on the satellite power transmission and interface segments. In these cases, the costs have been apportioned to the related WBS element. Maintenance requirements are listed in Table 1.1.1.6 and costs are presented in Tables 1.1.1.6.1, 1.1.1.6.2 and 1.1.1.6.3.

Table 1.1.1.6 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.1.6 ENERGY CONVERSION
1.1.1.6.1	"Free-Flyers" or Barge for Cargo and Personnel (Common Use Item)	0.8 Vehicle Utilization
1.1.1.6.2	Manned Manipulator Module	1 Vehicle
1.1.1.6.3	Tracks and Access Ways	84,000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000	CDCER=	0.0
M=	5000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	0.800000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	48.000000		
DF=	1.000000	Z4=	48.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			29.299
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			29.240
CIPS=CTB*Z4/Z2			23.392
CRCI =CTB X R			0.585
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.2 MANNED MANIPULATOR

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	3000.00000	TF=	1.000000	CDCER=	0.0
M=	3000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.100000	Z1=	1.000000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.133
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.203
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.198
CIPS=CTB*Z4/Z2			15.198
CRCI =CTB X R			0.304
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.1.6.3 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	84000.0000	TF=	1.000000	CDCER=	0.0
M=	84000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.420
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.420
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.420
CIPS=CTB*Z4/Z2			0.420
CRCI =CTB X R			0.001
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2 MW POWER TRANSMISSION

This element receives dc electrical power from the interface subsystem, conditions the power, converts it to microwave energy and radiates the energy to the ground receiving station. Included are power distribution from the interface subsystem, dc to RF conversion devices, control and monitoring equipment, and antenna radiating elements.

Costs in this section include those of the antenna structure and subarrays with their klystrons; the power distribution and conditioning system; thermal control; phase reference system; and maintenance requirements. The MW antenna system is illustrated in Figure 1.1-2 and illustrates the basic configuration, including overall dimensions of the selected antenna structure concept.

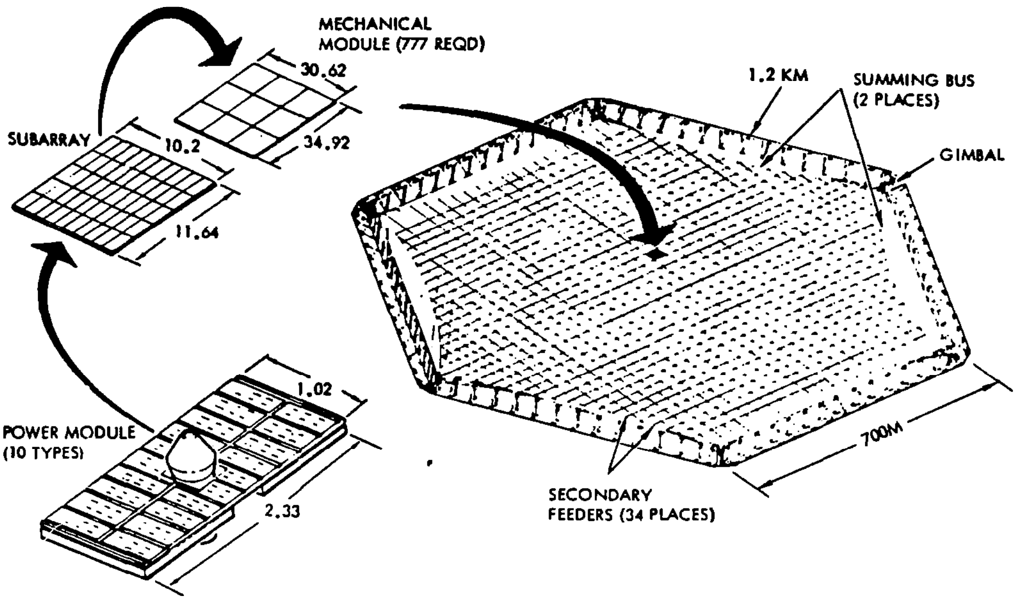


Figure 1.1-2. Microwave Transmission System - Satellite Antenna

The smallest antenna building block is the power module, which varies in size from the one illustrated (which is used at the center portion of the antenna) to 3.40 by 5.82 meters at the periphery of the antenna. Ten different power module sizes are used to comprise the antenna element. Each power module has a klystron located in its center. The power modules are arranged into subarrays measuring 10.2 by 11.64 meters. Each subarray has its own phase control electronics. Nine subarrays are connected to form a mechanical module 30.82 by 34.92 meters.

1.1.2.1 STRUCTURE

This element includes all members necessary to support the transmitter subarrays and other power transmission subsystem hardware. It includes structural beams, beam couplers, cables, tensioning devices, and secondary structures.

1.1.2.1.1 Primary Structure

This element includes the basic supporting framework of the microwave antenna power transmission system up to the interface connection. The antenna primary structure has three main components - a tension web made from composite wires or tapes; a catenary cable that transfers the web tension to the verticies; and the octogonal compression frame. The antenna frame provides a structural support but does not include the wave guides or radio frequency assemblies associated with the microwave subsystem.

This element is limited to primary load carrying structure and does not include other secondary structure such as equipment mounts, platforms, and space equipment supports.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The antenna structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The antenna structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The antenna structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data:

D&D: 30,0 to 2000.0 kg
ICI: Unlimited

1.1.2.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned sate-lite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- S-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly (ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

1.1.2.1.3 <u>Cost Estimates</u>

Input parameters T&M are in kilograms of mass, see Tables 1.1.2.1.1 and 1.1.2.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	67000.0000	TF=	1.000000	CDCER=	0.023000
M=	8375.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.301
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.419
#RM =T / M		8.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			3.350
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			3.350
CIPS=CTB*Z4/Z2			3.350
CRCI =CTB X R			0.007
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	234000.000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.002000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			18.705
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		46800.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			45.999
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			40.825
CIP'S=CTB*Z4/Z2			40.825
CRCI =CTB X R			0.082
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.2 TRANSMITTER SUBARRAY/KLYSTRONS

This element includes all the hardware required for generation, distribution, phase control and radiation of microwave energy. This includes the subarray structure, wave guides, power amplifiers, control devices, and power harnesses. Also included are thermal control devices and finishes that are manufactured as an integral part of the subarray.

RF generators convert the direct current (dc) electric power to RF microwave power. Klystrons are used in this system as the high power RF transmitting devices. Wave guides receive the RF power from the generator and radiate it to the ground-based rectenna.

Historical data for some twenty phased array radars ranging over a period of the last twenty years were extracted from the Redstar Data Base and/or obtained from various contractors. The data were analyzed, normalized and the costs were adjusted to reflect 1977 dollars. In addition, for all costs utilized, the facility receiver subsystem hardware, data subsystem costs and basic facility/housing costs were removed.

The application of phased array radar costs to the development cost estimates of the microwave antenna was pertinent since the design and development of these physically large ground installations was conducted in much the same manner that is being utilized for the SPS. The ground array radiating elements were assembled in subarray panels, complete with the radiating elements, wave guide, and cabling. The subarrays were then mounted into the facility framework, subarray cabling, and plumbing connection completed at system level and confidence testing conducted. The same general assembly philosophy is expected to be followed for the microwave antenna, the difference being that the microwave antenna will be totally assembled in the space environment.

The D&D CER was based on data from four DOD classified projects identified only as Projects 21, 22, 23, and 24 as well as the Cobra Dane, AN/SPS-48 and SAM-D (PATRIOT) radar systems.

A different approach was taken to develop the TFU CERs. After reviewing the various radar systems' cost, it was determined that not enough insight was afforded into the components; therefore, a "grass-roots" approach was undertaken.

For purposes of developing a "grass-roots" estimate for the TFU, a segment of the antenna measuring 2.4 m^2 was assumed to be the Lowest Replaceable Unit (LRU). In addition, to arrive at an "average" LRU, it was necessary to evenly distribute all components over the antenna. Enclosed tables list the components and their estimated cost for both the klystron and amplitron configurations. The required components were determined through analysis. Letters and telephone calls were directed to hardware manufacturers requesting technical data and cost quotes for the specified components. Where multiple quotes were obtained, the average cost was used. In some instances, estimates had to be relied upon. It was further assumed that the components are the same in each configuration with only the power tubes changing with the exception of the klystron configuration where the IRF amplifier is different.

Data contained in the Redstar Data Base were utilized to develop integration factors which were added to the vendor quotes. To account for the cost associated with voltage measurement instrumentation for the microwave antenna, a 20% instrument factor was also applied to the vendor quotes. The individual cost estimates, developed for each type of power tube, were utilized to develop CERs based on the area of one LRU. For the purpose of developing these CERs, three different LRU sizes were assumed - 2.4 m^2, 24 m^2, and 240 m^2. It is necessary for the user to determine the size and number of LRUs required for any given antenna configuration. It is also necessary for the user to consider any learning that may occur.

Range of Data:

D&D: 1000 to 100,000 kilowatts
ICI: Unlimited

Table 1.1.2.2.1 expresses the DDT&E cost estimate [$C_D = .067(P_T)^{0.507}(CF)$] to facilitate the use of antenna power in kilowatts as the input factor. Table 1.1.2.2.2 shows the $C_{I,LRU} = .00327(A_{LRU})^{1.000}$ where A is in square meters. A complexity factor of 1.25 is used to compensate for the klystron kilowatt power rating as used in the data base.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.2.1 KLYSTRON DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	6790000.00	TF=	1.000000	CDCER=	0.205000
M=	6790000.00	O&M=	0.0	CDEXP=	0.507000
CF=	1.250000	Z1=	1.000000	CICER=	0.0
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	180.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			102.576
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.2.2 KLYSTRON ICI, R, O&M

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	830808.000	TF=	1.000000	CDCER=	0.0
M=	118.800003	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	1.000000	CICER=	0.003270
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	180.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.486
#RM =T / M		6993.332	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2702.309
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2322.804
CIPS=CTB*Z4/Z2			2322.804
CRCI =CTB X R			154.854
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.3 POWER DISTRIBUTION AND CONDITIONING (PD&C)

This element includes the various power feeders, switching, and conditioning equipment s necessary to deliver power at the required voltage and power levels for the power transmission section (antenna portion) of the satellite. An energy storage system is included to supply power to keep the power transmission system at a ready state and for housekeeping requirements during eclipse periods. Data buses are not a part of this element as they are included in the information management and control subsystem (WBS No. 1.1.3).

The PD&C system receives power from the interface (Energy Conversion/ Power Transmission) system and provides for the power conditioning and switching required to deliver the power, through the distribution network, to the microwave energy conversion units. On the rotating member, power is conducted through switch gears to dc/dc converters which output the six primary voltages required by the Klystrons. Each voltage is conducted to a summing bus, through switch gears and power feeders and on through switch gear at the mechanical modules for use at the subarrays to provide power at the 135,864 Klystrons.

Batteries and battery conditioning equipment are included also to provide the stored energy to power the heater requirements which keep the Klystrons at a ready mode during the eclipse periods. The batteries will also provide power for the necessary housekeeping activities, i.e., stationkeeping, IMCS, TT&C, etc., during this period.

1.1.2.3.1 Switches and Power Conditioning

Switches will be used to perform operational functions as monitored through the IMCS. Switch gears will:

- Isolate converters, main feeders, secondary feeders, mechanical modules, subarrays and Klystrons for maintenance work

- Provide split bus power feed to offer redundancy to some modules in event of failure of a converter or summing bus

- Control power through the IMCS for:
  - short circuit protection
  - systematic start-up and shut-downs to prevent surges during eclipse periods
  - control various loads

The basic switches will be of the Penning cross-field tube design and monitored and controlled by the IMCS. The IMCS will will determine their status and functionally connect them to the proper feeder and summing bus as conditions may direct.

The power converter and conditioners convert the existing bus voltages to the subsystem voltage required for the various subsystem loads. The output tolerances will be based on using subsystem interface requirements. The power converters are utilized in the GEO mode of operation.

1.1.2.3.2 Conductors and Insulation

The summing buses, main feeders and secondary feeders are generally sized to minimize the combined mass of itself and the satellite mass, considering the power requirements, efficiency, and variation in resistivity with temperature. The PD&C utilized aluminum (6101-T6) conductors.

1.1.2.3.3 Batteries

Batteries will be utilized during the ecliptic periods to provide minimum energy to keep the Klystrons warmed to a ready state and as necessary during the required housekeeping tasks. The batteries will be a sodium chloride type having the capability of providing 200 watt hours/kg.

The battery PD&C costing is included in the earlier sections of 1.1.2.3.2 and 1.1.2.3.1. This element consists of the mechanisms for the charging of batteries and the distribution and regulation of power to and from the battery. This function will be monitored and controlled by the IMCS. Included are the battery chargers, power regulators, diodes, power regulators, and power conditioning equipment that directly interfaces with the battery system.

1.1.2.3.4 PD&C Cost Estimates

The CER's used in this section are the same as those described in Section 1.1.1.4. The following tables itemize the design/cost parameters and identify the cost estimates in each area.

Table	Description
1.1.2.3.1	Switch Gear and Converters
1.1.2.3.2	Conductors and Insulation
1.1.2.3.3	Batteries

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.1 SWITCH GEAR & CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1901000.00	TF=	1.000000	CDCER=	0.158000
M=	2447.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	180.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.132
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.468
#RM =T / M		776.870	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			752.336
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			512.556
CIPS=CTB*Z4/Z2			512.556
CRCI =CTB X R			34.171
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.2 CONDUCTORS & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1337000.00	TF=	1.000000	CDCER=	0.158000
M=	1720.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.100000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.262
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M		777.325	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.348
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.348
CIPS=CTB*Z4/Z2			5.348
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.3.3 BATTERIES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	190000.000	TF=	0.075000	CDCER=	0.0
M=	50.000000	O&M=	0.475000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.028000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.241000
R=	0.033333	Z3=	120.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.005
#RM =T / M	3800.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.926		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			12.115
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			8.502
CIPS=CTB*Z4/Z2			8.502
CRCI =CTB X R			0.283
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.475

COMMENTS

BATTERY PD&C INCLUED IN 1.1.2.3.1 & 1.1.2.3.2

1.1.2.4 THERMAL CONTROL

This element includes any component used to modify the temperature of power transmission subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints and finishes applied to components during during their manufacturing sequence and thermal control devices that are an integral part of another component.

The multi-layer insulation panels are required for the back surface of the resonant cavity radiators to restrict waste heat leaks which could increase temperatures of electronics to unacceptable levels. This insulation is coated externally with low absorptivity/emissivity materials to limit the absorbed solar flux to which the surface is exposed during part of the orbit.

The insulation CER's are based upon secondary structure CER's where the secondary structure CER's were considered comparable to the requirements of insulation in its application on the antenna.

Table 1.1.2.4 presents cost estimates for thermal control.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.4 THERMAL CONTROL - INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	557000.000	TF=	0.012400	CDCER=	0.156000
M=	4.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.010000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			29.136
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.002
#RM =T / M		139250.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			208.062
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			184.657
CIPS=CTB*Z4/Z2			184.657
CRCI =CTB X R			1.847
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.5 CONTROL-PHASE REFERENCE

This element provides the reference phase for all subarray phase conjugating circuits and includes the reference oscillator signal distribution, and frequency conversion equipment. It covers components/equipment that commonly serve all subarrays.

The transmitted signal is formed from the pilot beam by means of the retroelectronics where one circuit is required per subarray. A servo system is needed to transfer the required reference phase from a central point to a mechanical module, where it is distributed to the nine subarrays. The main items included in this subsystem are shown in Table 1.1.2.5.

Table 1.1.2.5 Control-Phase Reference

WBS NO.	ITEM/ DESCRIPTION	QUANTITY PER SATELLITE
1.1.2.5.1	REFERENCE FREQUENCY GENERATOR	1 SET (777 POWER AMPLIFIERS, 1-4 REGULATORS)
1.1.2.5.2	COAX CABLE	777 SETS
1.1.2.5.3	DEVICES FOR USE ON FREQUENCY DISTRIBUTION SYSTEM	777 SETS

Tables 1.1.2.5.1, 1.1.2.5.2 and 1.1.2.5.3 present the engineering estimates for these items.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.1 REFERFNCE FREQUENCY GENERATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.500000
M=	1.000000	O&M=	0.010000	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.100000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	120.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1.2.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.100
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.100
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.100
CIPS=CTB*Z4/Z2		0.100
CRCI =CTB X R		0.003
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.010

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.2 DIST. SYSTEM, COAXIAL CABLE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	203000.000	TF=	1.000000	CDCER=	0.000005
M=	261.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES M SUM TO 1.1.2.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.203
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.016
#RM =T / M	777.778
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	12.180
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	12.180
CIPS=CTB*Z4/Z2	12.180
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.5.3 DIST. SYSTEM, DEVICES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1554.00000	TF=	1.000000	CDCER=	0.000225
M=	2.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.005000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	120.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.070
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		777.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.770
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			7.770
CIPS=CTB*Z4/Z2			7.770
CRCI =CTB X R			0.259
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.2.6 MAINTENANCE

This element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and insitu repair equipment.

Maintenance requirements of this element are related to the power transmission (antenna) section of the satellite covering the structures; subarrays (Klystrons); power distribution/conditioning and energy storage; thermal control, and control elements. Some of the maintenance equipment are multipurpose and are therefore costed against the applicable maintenance items on an apportioned basis.

Maintenance requirements for this element are presented in Table 1.1.2.6 and cost estimates are projected in Tables 1.1.2.6.1, 1.1.2.6.2, 1.1.2.6.3, and 1.1.2.6.4.

Table 1.1.2.6 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.2.6 POWER TRANSMISSION
1.1.2.6.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	1 VEHICLE UTILIZATION
1.1.2.6.2	GANTRY CRANE AT ANTENNA	SET
1.1.2.6.3	ON-CRANE CONTROL CENTER, HOISTS, EQUIPMENT TEST GEAR, ROBOTICALS	SET
1.1.2.6.4	TRACKS AND ACCESSWAYS	12000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000			CDCER=	0.0
M=	5000.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.250000	Z1=	1.000000			CICER=	0.005798
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			36.368
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			28.784
CIPS=CTB*Z4/Z2			28.784
CRCI =CTB X R			0.576
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.2 GANTRY CRANE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	40000.0000	TF=	1.000000	CDCER=	0.234000
M=	40000.0000	O&M=	0.0	CDEXP=	0.653000
CF=	1.100000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			91.060
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.220
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.220
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.220
CIPS=CTB*Z4/Z2			0.220
CRCI =CTB X R			0.000
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.3 ON-CRANE CONTROL CENTER

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	50000.0000	TF=	1.000000		CDCER=	0.012432
M=	50000.0000	O&M=	0.0		CDEXP=	1.000000
CF=	1.000000	Z1=	0.100000		CICER=	0.005798
PHI=	0.950000	Z2=	60.000000		CIEXP=	1.000000
R=	0.020000	Z3=	6.000000			
DF=	1.000000	Z4=	6.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			621.600
CLRM=CICER X (M)XX(CIEXP) X CF X TF			289.900
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			30.305
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			267.824
CIPS=CTB*Z4/Z2			26.782
CRCI =CTB X R			5.356
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.2.6.4 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	12000.0000	TF=	1.000000	CDCER=	0.0
M=	12000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.2.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.060
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.060
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.060
CIPS=CTB*Z4/Z2			0.060
CRCI =CTB X R			0.000
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.3 INFORMATION MANAGEMENT AND CONTROL

This element includes those components that process information onboard the satellite. This includes sensing, signal conditioning, formatting, computations, and signal routing.

The information management and control subsystem (IMCS) provides the interconnecting elements between and within all the various satellites and ground-based operational subsystems. The IMCS also provides operational control of both the satellite and ground systems as well as providing all subsystem processing support for all but very special functions.

The satellite IMCS consists of the on-board processing equipment [central processing units (CPU) and memories], the inter- and intra-subsystem data network (data buses), the man-machine interfaces (display/control), and intersystem communication links, including RF, but excepting those specifically provided for the control and transfer of primary power, and all elements provided to accommodate activities related to system security, safety, or any other operation necessary to the continuing operation of the SPS.

Because of the early stage of program analysis, only those requirements imposed upon the IMCS by a limited number of satellite operations have been identified. The identified requirements generally are limited to those associated with the immediate operations of an active satellite. Auxiliary functions such as ground/space communications, display/control, safety, security, etc., will be added when data become available.

The usage and application of IMCS items is identified in Table 1.1-3 and provides direct association with the subsystem functions.

Table 1.1-3. Usage/Application Matrix per Satellite

	INSTRUMENTATION		DATA ACQUISITION		DATA PROCESSING				CONTROL		
ELEMENT DESCRIPTION	SENSORS	SIGNAL CONDITIONING	SOFTWARE	SIGNAL ROUTING	SOFTWARE	FORMATTING	COMPUTATION	DISPLAY GENERATION	DISPLAYS & CONTROLS	SIGNAL CONDITIONING	WBS NO.
MASTER CONTROL COMPUTER					X	X	X	X			1.1.3.1
DISPLAYS CONTROL					X	X	X	X	X		1.1.3.2
SUPERVISORY COMPUTER					X	X	X				1.1.3.3
REMOTE COMPUTER					X	X	X				1.1.3.4
BUS CONTROL UNIT			X	X	X	X	X				1.1.3.5
MICROPROCESSORS					X	X	X				1.1.3.6
REMOTE ACQ. & CONTROL			X	X	X	X	X			X	1.1.3.7
SUB-MULTIPLEXER			X	X	X	X	X				1.1.3.8
INSTRUMENTATION	X	X									1.1.3.9
FIBER OPTICS				X							1.1.3.10
CABLES & HARNESSES	X	X	X	X	X	X	X	X	X	X	1.1.3.11

These items have been separated into general hardware groups for costing purposes.

COMPUTERS

Historical cost data were obtained for computers from the Redstar Data Base system and are listed below:

- Gemini-3
- Minuteman
- Skylab
- Viking Lander
- MOL
- HEAO

A 50% integration factor was included in the DDT&E CER's to allow for subsystem level costs.

Range of Data:

DDT&E and ICI: 1.8 to 75.7 kilograms

ELECTRONIC COMPONENTS

The electronic components associated with Avionics include the Submultiplexors, Remote Acquisition Units, Microprocessors, Bus Control Units and instrumentation.

Development of an electronic components CER was based on the selected components of the ATS-F and OSO-8 spacecraft. These 19 electronic components are listed below:

ATS-F	OSO-8
Aux. Digital Sun Sensors	Solar Power Supply
Monopulse Unit	Power Supply
Wide Band Data Unit	Control Decoder/Demodulator
C Band Data Unit	Remote Decoder
S/L Band Transmitter	PCM Decoder
VHF Receiver	Format Generator
Command Decoder	Wheel Clock
Data Acq. & Control Unit	Sail Clock
Data Switching Unit	S Band Transmitter
	VHF Transmitter

Range of Data:

DDT&E and ICI: 1.1 to 19.6 kilograms

DATA BUS

This element consists of both copper wire and fiber optics. Historical cost data were obtained from the Redstar Data Base to produce the data bus DDT&E CER. Commercial prices were used for the data bus ICI CER.

Production cost information obtained from private industry for "off-the-shelf" fiber optics and copper wire are listed below:

FIBER OPTICS:

Manufacturer	Type	Characteristics	Cost per Meter
ITT Electro-Optical Products Division	GG-02	Single Fiber 50 m Dia.	(1-10 km) $3.25
	GS-02	Single Fiber 50 m Dia.	$2.50
Valtec Fiberoptics Division	MG-05	Single Fiber 65 m Dia.	$2.50
Galileo Electro-Optics Corporation	-	Single Fiber 88 m Dia.	$1.58
	Average cost per meter		$2.40

One industry spokesman estimates that the cost of optical fibers would likely decrease to 40% by 1980. This study assumes a $2.40 per meter average price reduced by 40% to $1.44 per meter.

COPPER WIRE:

Manufacturer	Characteristics	Cost per Meter
Dearborn Wire & Cable	22 gage stranded silver plate	$0.807
Standard Wire & Cable	22 gage stranded silver plate	$0.705
Karen, Inc.	22 gage, 2 conductor silver plate	$0.807
Mil-Spec Wire & Cable Corporation	22 gage, 19-30 stranded	$0.610
Average cost per meter		$0.732

Instrumentation input parameters T&M are in kilograms.

Cost estimates for the items of Table 1.1-3 are presented in Tables 1.1.3.1 through 1.1.3.11 inclusive.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.1 MASTER CONTROL COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1000.00000	TF=	0.900000	CDCER=	0.633000
M=	500.000000	O&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000	CICER=	0.172000
PHI=	0.800000	Z2=	60.000000	CIEXP=	0.535000
R=	0.010000	Z3=	60.000000		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			16.127
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.302
#RM =T / M			2.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.678
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.845
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.659
CIPS=CTB*Z4/Z2			2.659
CRCI =CTB X R			0.027
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.2 DISPLAYS & CONTROLS

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	200.000000	TF=	0.900000		CDCER=	0.102000
M=	200.000000	O&M=	0.0		CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000		CICER=	0.069000
PHI=	0.800000	Z2=	60.000000		CIEXP=	0.557000
R=	0.010000	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			10.745
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.188
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.678	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.211
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.453
CIPS=CTB*Z4/Z2			0.453
CRCI =CTB X R			0.005
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.3 SUPERVISORY COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	84.000000	TF=	0.700000	CDCER=	0.633000
M=	14.000000	O&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000	CICER=	0.172000
PHI=	0.850000	Z2=	60.000000	CIEXP=	0.535000
R=	0.010000	Z3=	60.000000		
DF=	0.200000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.753
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.494
#RM =T / M		6.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.766	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.325
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.969
CIPS=CTB*Z4/Z2			0.969
CRCI =CTB X R			0.010
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.4 REMOTE COMPUTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	518.000000	TF=	0.400000	CDCER=	0.633000
M=	14.000000	O&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	1.000000	CICER=	0.172000
PHI=	0.850000	Z2=	60.000000	CIEXP=	0.535000
R=	0.010000	Z3=	60.000000		
DF=	0.030000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.643
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.282
#RM =T / M		37.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.766	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.696
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.238
CIPS=CTB*Z4/Z2			2.238
CRCI =CTB X R			0.022
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.5 BUS CONTROL UNIT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	4110.00000	TF=	0.076000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001200	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.415
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.013
#RM =T / M		822.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.940
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.128
CIPS=CTB*Z4/Z2			5.128
CRCI =CTB X R			0.051
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.6 MICROPROCESSORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	3960.00000	TF=	0.078000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001300	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.431
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.013
#RM =T / M		792.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.881
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.085
CIPS=CTB*Z4/Z2			5.085
CRCI =CTB X R			0.051
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.7 REMOTE ACQUISITION & CONTROL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	4925.00000	TF=	0.069000	CDCER=	0.102000
M=	5.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.001000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.414
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.012
#RM =T / M	985.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.926		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.450
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.505
CIPS=CTB*Z4/Z2			5.505
CRCI =CTB X R			0.055
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.8 SUBMULTIPLEXORS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	93000.0000	TF=	0.022000	CDCER=	0.102000
M=	3.000000	O&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.557000
R=	0.010000	Z3=	60.000000		
DF=	0.000032	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.266
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.003
#RM =T / M		31000.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			66.119
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			58.682
CIPS=CTB*Z4/Z2			58.682
CRCI =CTB X R			0.587
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.9 INSTRUMENTATION

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	280000.000	TF=	1.000000			CDCER=	0.000100
M=	0.074100	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000			CICER=	0.000400
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.010000	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			28.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.000
#RM =T / M		3778676.00	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			74.192
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			65.846
CIPS=CTB*Z4/Z2			65.846
CRCI =CTB X R			0.658
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.10 OPTICAL FIBER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	62.000000	TF=	1.000000	CDCER=	0.237000
M=	62.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.010219
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.807
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.634
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.634
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.578
CIPS=CTB*Z4/Z2			0.578
CRCI =CTB X R			0.006
CO&M = O&M OR CTB*Z5/Z2/ENYR.			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.3.11 CABLES/HARNESS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	293000.000	TF=	1.000000	CDCER=	0.237000
M=	293000.000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			9.963
CLRM=CICER X (M)XX(CIEXP) X CF X TF			17.580
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			17.604
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			16.047
CIPS=CTB*Z4/Z2			16.047
CRCI =CTB X R			0.160
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.4 ATTITUDE CONTROL AND STATIONKEEPING

This element includes the components required to orient and maintain the satellite's position and attitude in geosynchronous orbit. Included are sensors, reaction wheels, chemical and electric propulsion hardware and propellants.

The baseline ACSS features an argon ion bombardment thruster RCS whose characteristics are:

- Thrusters located in 4 modules at each corner of the satellite
- Each module has 16 thrusters
- Cryogenic propellant storage-electric refrigeration with heat loss makeup
- Hemispherical plume characteristics
- Serviceable in place

The system operates on an average of 36 thrusters. A total of 64 thrusters are included to provide the required redundancy. The redundancy was based on an annual maintenance/servicing interval, 5000 hour thruster grid lifetime and 5-year thruster MTBF. Sixteen thrusters are located on the lower portion of each corner of the spacecraft. Each thruster is gimbaled individually to facilitate thruster servicing, to permit operation of adjacent thrusters during servicing, and to provide the redundancy. The thrusters nominally provide a force approximately in the direction of the sun to counter the solar pressure force (stationkeeping) which is the dominant thruster requirement. The thrusters are gimbaled through small angles (as illustrated) and differentially throttled to provide the remaining forces and torques for attitude control and stationkeeping.

Sensors that make up the attitude reference determination system include:

- CDD Sun Sensor (1/System)
- CCD Star Sensors (2/Systems)
- Electrostatic or laser gyros (3/System)
- Dedicated mini processor

The attitude reference determination system features Charge Coupled Device (CCD), star and sun sensors as well as electrostatic or laser gyros and dedicated microprocessors. Seven attitude reference determination units are located at various locations on the satellite in order to sense thermal and dynamic body bending, and to desensitize the system to these disturbances. The control algorithms will feature statistical estimators for determining principal axis orientation, body bending state observers or estimators, and a quasi-linear propulsion thrust command policy to provide precise control and minimize structural bending excitation.

The mass properties of the ACSS are summarized in Table 1.1-4. This summary includes the mass of individual elements and propellant weight on an annual basis.

Table 1.1-4. ACSS Mass Summary

ITEM	MASS ($\times 10^{+3}$ KG)
ATTITUDE REFERENCE DETERMINATION SYSTEMS (7)	0.32
THRUSTERS—INCLUDING SUPPORT STRUCTURE, 64 @ 120 KG/THRUSTER	7.68
THRUSTER GIMBALS AND MOUNTING	3.98
TANKS, LINES, REFRIGERATION	15.07
POWER PROCESSING EQUIPMENT	88.95
TOTAL (DRY)	116.00
ARGON PROPELLANT—ANNUAL REQUIREMENT	85.39
TOTAL (WITH PROPELLANT)	201.39

Historical cost data were obtained from NASA's Redstar Data Base. Historical data relative to electrical propulsion is limited, consequently, study data have been utilized where necessary. Ion bombardment thrusters are Argon propellants with a low thrust but a significantly higher specific impulse, thus reducing propellant resupply cost.

Development of the propulsion subsystem CER's was based on the spacecraft programs listed below:

SEPS (Boeing) Study	ATS-F (Ion Experiment)
SEPS (Rockwell) Study	Rockwell SPS Study
SERT-II	SERT-C Study

Range of Data:

DDT&E and ICI: 18.0 to 107,500.0 kg

Input parameters T&M are in kilograms.

Tables 1.1.4.1 and 1.1.4.2 contain the costs for this element.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.4.1 ACSS HARDWARE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	116000.000	TF=	0.105900	CDCER=	1.122000
M=	1812.00000	O&M=	0.046620	CDEXP=	0.190000
CF=	1.000000	Z1=	1.000000	CICER=	0.057000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.729000
R=	0.010000	Z3=	60.000000		
DF=	0.300000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			8.183
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.432
#RM =T / M		64.018	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			72.488
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			53.746
CIPS=CTB*Z4/Z2			53.746
CRCI =CTB X R			0.537
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.047

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.4.2 ACSS PROPELLANT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.085390	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.1.4		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.085

COMMENTS

1.1.5 COMMUNICATIONS

This element includes the hardware to transmit and receive intelligence among the various SPS elements. It includes communication of both data and voice between the SPS and the control center, as well as among the various cargo and personnel vehicles. Excluded is intravehicular and intrasatellite communications.

1.1.6 INTERFACE (ENERGY CONVERSION/POWER TRANSMISSION)

This element provides the movable interface between the energy conversion subsystem and the power transmission subsystem. A 360° rotary joint and an antenna elevation mechanism are required to maintain proper alignment of the transmitter with the ground receiving station. Included are structure, mechanisms, power distribution, and maintenance hardware.

The interface is utilized to 1) transfer energy from the slip ring to the antenna via transmission brushes, and 2) act as the structural support member between the main satellite and the antenna. The elements of this movable interface (Figure 1.1-6) are described in the following subsections.

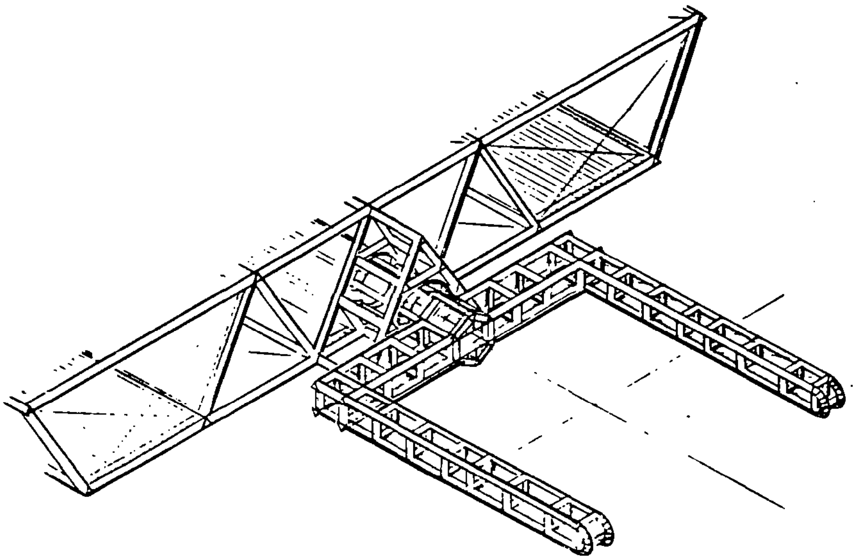


Figure 1.1-6. Energy Conversion/Power Transmission Interface

1.1.6.1 STRUCTURE

This element includes all members necessary to provide a mechanical interface between the primary structures of the energy conversion subsystem and the power transmission subsystem. It includes beams, beam couplers, cables, tensioning devices, and secondary structures. Excluded are elements of the drive assembly which are included in mechanisms (WBS No. 1.1.6.2).

1.1.6.1.1 Primary Structure

The basic supporting structure of the movable interface is included in this element. It is the primary load carrying structure and does not include the secondary structure that is required to support transmission buses or equipment.

The SPS requirement for low thermal distortion, under high thermal stress, dictates the need for a material with a very low coefficient of expansion. The most likely candidate, at this time, is a graphite composite material.

The interface primary structure D&D CER was developed using graphite composite data obtained from NASA's Redstar Data Base. Tooling cost was excluded under the assumption that this cost would be incurred in the development of orbital fabrication equipment. The following data points were used:

- Space Telescope Shell
- ATS-F Truss
- HEAO Optical Bench
- Shuttle Payload Bay Doors

The interface structure ICI is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly and support equipment. The structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These material costs are based on vendor quotes obtained from Hercules, Fiberrite and Union Carbide.

Range of Data:

D&D: 30.0 to 2000.0 kg
ICI: Unlimited

1.1.6.1.2 Secondary Structure

The secondary structure consists of the passive interface attachment between the primary structure and operational subsystems. The structural members are made of aluminum with the ability to articulate, rotate, or otherwise support/allow motion between the primary structure and other subsystem elements.

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface and mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies.

Development of the secondary structure CER for DDT&E was based on cost data contained in the MSFC Redstar Data Base. Data from a variety of launch vehicle and unmanned satellite programs were available and the applicable data points are listed below:

- S-IVB Interstage
- S-IC Forward Skirt
- S-IC Intertank
- Solar Telescope Housing Assembly (ASM)
- Common Mount Assembly (ASM)
- Telescope Gimbal Assembly (ASM)
- Common Mount Actuators (ASM)
- Telescope Gimbal Actuators (ASM)
- Array Platform Elevation Pointing Actuator (ASM)
- UV Gimbal Mount Actuators (ASM)
- UV Instrument Mount Assembly (ASM)
- Solar Array and Boom Structure (ATS-F)
- Squib Interface Unit (ATS-F)
- Interstage (Centaur)
- Nose Shroud (Centaur)
- Fixed Airlock Shroud (Skylab)
- Payload Shroud (Skylab)
- Pallet Segment (Spacelab)
- OSO-1
- ATS-F
- S-II

The ICI production cost CER was based upon an Engineering Cost estimate.

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass.

1.1.6.1.3 <u>Cost Estimates</u>

Primary and secondary structure costs are presented in Table 1.1.6.1.1 and 1.1.6.1.2 respectively.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	120000.000	TF=	1.000000			CDCER=	0.023000
M=	20000.0000	O&M=	0.0			CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000			CICER=	0.000050
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.002000	Z3=	60.000000				
DF=	0.020000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.6.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			11.638
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.000
#RM =T / M		6.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			6.000
CIPS=CTB*Z4/Z2			6.000
CRCI =CTB X R			0.012
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	365000.000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.002000	Z3=	60.000000		
DF=	0.050000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			23.476
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M	73000.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.827
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			62.860
CIPS=CTB*Z4/Z2			62.860
CRCI =CTB X R			0.126
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.6.2 MECHANISMS

This element includes the components required to rotate and elevate the power transmission subsystem. Included are the drive ring, bearings, gear drives, and drive motors.

The structural mechanisms consist of active structural subassemblies that articulate, rotate, or otherwise cause or allow motion between the primary structure and other subsystem elements or between subsystem elements themselves.

The ICI production cost CER was based on data provided by the following manufacturers:

Manufacturer	Application
Poly-Scientific	High energy
Poly-Scientific	Radar
Electro-Tec	Navy destroyer propeller system
Electro-Tec	Satellite solar array
I.E.C.	Navy shipboard hoist

Due to the difference in complexity and the specification requirements differences between ground and space qualified equipment, the following factors were applied.

Complexity Factor	× 3
Specification Uprating Factor	× 3
Total	× 9

Range of Data:

DDT&E: 6.0 to 15,000.0 kg
ICI: 6.0 to 15,000.0 kg

Input parameters T&M are in kilograms of mass, see Table 1.1.6.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.2 MECHANISMS - INTERFACE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	391000.000	TF=	0.054900	CDCER=	0.156000
M=	391.000000	O&M=	0.078000	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.000764
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.950000
R=	0.010000	Z3=	60.000000		
DF=	0.020000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			15.225
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.012
#RM =T / M			1000.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.878
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.821
CIPS=CTB*Z4/Z2			5.821
CRCI =CTB X R			0.058
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.078

COMMENTS

1.1.6.3 POWER DISTRIBUTION

This element transmits the electrical power from the rotary joint to the microwave power transmission system. The PD&C system consists of power risers which are coupled to the pickup shoebrushes on the rotary joint and routed on the antenna support yolk (interface) to the isolation switches on the antenna proper. There are two sets of slip rings. One positive and one negative, at the rotary joint. Sixteen brushes are needed per slip ring. The life expectancy of the PD&C is 30 years with calculated replacements of the slip ring.

1.1.6.3.1 Conductors and Insulation

The power risers are sized to minimize the mass of itself and the satellite mass, considering power requirements, efficiency and variation in resistivity with operating temperature. The power risers are made of multiple round aluminum (6101-T6) conductors with 1 mm kapton insulation.

1.1.6.3.2 Pickup Shoe Brushes

The pickup shoe brush portion of the rotary joint is included in the power distribution of the interface segment. Sixty-four pickup shoe brush assemblies are required per satellite. The brush material is 75% M_0S_2 and 25% M_0tTa with a contact surface area per brush of 863 cm^2. The shoe dimension is 2.72 m × 12.7 am × 19 am with a total weight of 11341 kg for 64 pickup shoe brushes.

1.1.6.3.3 Power Distribution Cost Estimates

The CER presented in section 1.1.1.4.2 was used for the conductors and insulation. An extension of this CER was used for the brushes of section 1.1.6.3.2. The cost estimates for interface power distribution are presented in Tables 1.1.6.3.1 and 1.1.6.3.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.3.1 CONDUCTOR & INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1267000.00	TF=	1.000000	CDCER=	0.158000
M=	39594.0000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	0.100000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			5.178
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.158
#RM =T / M		32.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			5.068
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			5.068
CIPS=CTB*Z4/Z2			5.068
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.3.2 SLIP RING BRUSHES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	11341.0000	TF=	1.000000			CDCER=	0.158000
M=	531.000000	O&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.000200
PHI=	0.950000	Z2=	60.000000			CIEXP=	1.000000
R=	0.010000	Z3=	60.000000				
DF=	0.020000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.6.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.791
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.106
#RM =T / M	21.358		
E =1.0 + LOG(PHI) / LOG(2.0)	0.926		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.935
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.442
CIPS=CTB*Z4/Z2			1.442
CRCI =CTB X R			0.014
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.6.4 THERMAL CONTROL

This element includes any component used to modify the temperature of interface subsystem components. It includes cold plates, heat transfer and radiator devices as well as insulation, thermal control coatings and finishes. Excluded are paints or finishes applied to components during their manufacturing sequence. No thermal control requirements are defined for the interface.

1.1.6.5 MAINTENANCE

THis element provides for in-place repair or replacement of components and includes work stations, tracks, access ways, and insitu repair equipment.

Maintenance requirements are related to the equipment and facilities needed to transport men and material to the work station. Some of the same equipment required for maintenance at the site is used commonly in the performance of work at other sites. The CER's accommodate this usage. Table 1.1.6.5 identifies the requirements, and cost estimates are provided in Tables 1.1.6.5.1, 1.1.6.5.2, and 1.1.6.5.3.

Table 1.1.6.5 Maintenance Requirements

WBS NO.	MAINTENANCE ITEM DESCRIPTION	1.1.6.5 INTERFACE
1.1.6.5.1	"FREE-FLYERS" OR BARGE FOR CARGO AND PERSONNEL (COMMON USE ITEM)	.2 VEHICLE UTILIZATION
1.1.6.5.2	MANNED MANIPULATOR MODULE	1 VEHICLE
1.1.6.5.3	TRACKS AND ACCESS WAYS	24000 kg

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.1 MAINTENANCE - FREE FLYERS

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	5000.00000	TF=	1.000000	CDCER=	0.0
M=	5000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	0.200000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	12.000000		
DF=	1.000000	Z4=	12.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			36.238
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.926		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.530
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			32.098
CIPS=CTB*Z4/Z2			6.420
CRCI =CTB X R			0.642
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.2 MANNED MANIPULATOR

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	3000.00000	TF=	1.000000	CDCER=	0.0
M=	3000.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.100000	Z1=	1.000000	CICER=	0.005798
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.133
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.203
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			15.198
CIPS=CTB*Z4/Z2			15.198
CRCI =CTB X R			0.304
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.6.5.3 TRACKS & ACCESS WAYS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	24000.0000	TF=	1.000000	CDCER=	0.0
M=	24000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000005
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.002000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.6.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.120
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.120
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.120
CIPS=CTB*Z4/Z2			0.120
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.7 SYSTEMS TEST

This element includes the hardware, software, and activities required for ground-based systems test including qualification tests and other development tests involving two or more subsystems or assemblies. It includes the production, assembly, integration, and checkout of satellite system hardware into a full or partial system test article. It also includes the design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as ground support facilities. Also included are the planning, documentation, and actual test operations.

Tables 1.1.7.1 and 1.1.7.2 document DDT&E cost estimates respectively for hardware and operations based on individual calculations equal to 50% of the satellite ICI.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.7.1 SYSTEM GROUND TEST HARDWARE

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1.7		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2662.711
.CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS
DDT&E = 50% OF SATELLITE ICI

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.7.2 SYSTEM GROUND TEST OPERATIONS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1.7		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2662.711
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

DDT&E TEST OPS = 50% OF SATELLITE ICI

1.1.8 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all ground-based hardware required in support of handling, servicing, test, and checkout of the satellite subsystems. It also includes special hardware required for simulations and training.

Costs for design, development, manufacture, acceptance, qualification, and maintenance of the GSE equipment are included. It is recognized that various equipments can serve multipurposes. For example, a developmental mockup may later serve as a training aid after it has served its original purposes. In these instances, the acquisition cost is charged to the original or first purpose use, and subsequent usage will incur only the recurring operations and maintenance costs.

GSE costs from several launch vehicle, manned spacecraft and unmanned satellites were analyzed to determine their applicability to SPS GSE requirements. From these data, a percentage factor was developed which was used to estimate SPS ground support equipment costs. This factor is expressed by the equation $C_D = 0.10\ (C)$; where C = DDT&E cost of the satellite system. See Table 1.1.8.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.8 GROUND SUPPORT EQUIPMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		721.234
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS
DDT&E GSE = 10% OF SATELLITE DDT&E ABOVE

1.1.9 PRECURSOR TEST ARTICLE

The 335 MW pilot plant precursor test article and operations is included in this element. It represents the technology verification space system combining the energy conversion, interface, and power transmission segments of the SPS satellite. The configuration will be constructed by the satellite construction base where the sequence is to build the slip ring/rotary joint housing structure followed by the interface hub and yoke base plus the 1st bay of the solar array. Slip rings are installed and the solar concerter portion is completed as the yoke (interface) arms are fabricated. The antenna construction and maintenance platform is attached to provide facilities for the antenna fabrication and installation of required power modules. The completed EOTV/Demo unit is illustrated in Figure 1.1.9.

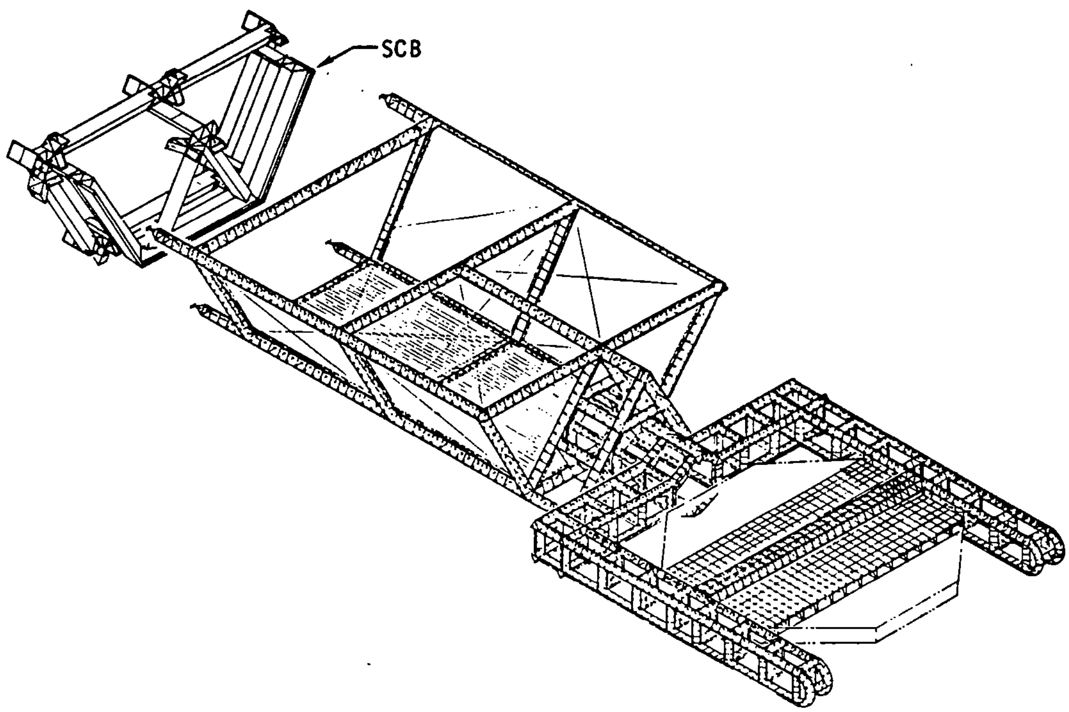


Figure 1.1.9 EOTV Precursor Test Article

1.1.9.1 EOTV PRECURSOR VEHICLE

This element covers the vehicle procurement required to support the integrated test and demonstration program.

The energy conversion segment of the vehicle consists of primary and secondary structure, concentrators, solar blankets, switchgear and converters, conductors/insulation, attitude control and information management subsystems. The interface segment includes the primary and secondary structure, mechanisms, conductors/insulation and slip ring brushes.

The precursor power transmission segment will be representative of the full-up satellite antenna to the extent of using identically available components for the required power levels of the test article. It will include structures, transmitter subarrays, power distribution and conditioning, batteries, insulation, and phase control elements.

CER's used in this section are the same as those used in the particular elements of earlier satellite sections. DDT&E is, however, a main cost item in these categories as the systems/subsystems will require substantial development activities, whereas the other satellite systems/subsystems will capitalize from this development work.

Cost estimates for the precursor test article are presented in the following tables:

Tables	Segment
1.1.9.1.1 thru 1.1.9.1.8	Energy Conversion
1.1.9.1.9 thru 1.1.9.1.13	Interface
1.1.9.1.14 thru 1.1.9.1.24	Power Transmission

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.1 PRIMARY STRUCTURE - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	30890.0000	TF=	1.000000	CDCER=	0.023000
M=	2059.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			89.863
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.103
#RM =T / M		15.002	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.544
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.2 SECONDARY STRUCTURE - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	14918.0000	TF=	1.000000	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			21.178
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.179
#RM =T / M		2983.600	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			533.576
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.3 CONCENTRATOR - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1800000.00	TF=	1.000000	CDCER=	0.027000
M=	450000.000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	1.000000	CICER=	0.000003
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.869
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M	4.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.817
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.4 SOLAR BLANKET -E.C.

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	900000.000	TF=	1.000000	CDCER=	0.161400
M=	18750.0000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	1.000000	CICER=	0.000067
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	2.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			47.041
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		48.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			60.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.5 SWITCHGEAR & CONVERTERS -E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2875.00000	TF=	1.000000	CDCER=	0.158000
M=	719.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000	CICER=	0.000400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	3.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.497
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.431
#RM =T / M		3.999	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.725
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.6 CONDUCTORS & INSULATION - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	357675.000	TF=	1.000000	CDCER=	0.158000
M=	7452.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.048
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.030
#RM =T / M		47.997	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.431
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.7 ACS HARDWARE - E.C.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=.	283557.000	TF=	0.300000	CDCER=	1.122000
M=	1970.00000	O&M=	0.0	CDEXP=	0.190000
CF=	1.000000	Z1=	1.000000	CICER=	0.057000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.729000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			12.190
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.312
#RM =T / M			143.938
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			620.634
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.8 SLIPRINGS - PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	43000.0000	TF=	1.000000	CDCER=	0.156000
M=	10750.0000	O&M=	0.0	CDEXP=	0.511000
CF=	1.500000	Z1=	1.000000	CICER=	0.000764
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			54.565
CLRM=CICER X (M)XX(CIEXP) X CF X TF			7.745
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			30.980
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.9 PRIMARY STRUCTURE - INTERFACE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	120000.000	TF=	1.000000	CDCER=	0.023000
M=	200.000000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			152.844
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M	600.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.10 SECONDARY STRUCTURE - INTERFACE

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	15500.0000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			15.155
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M	3100.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.047
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.11 MECHANISMS - INTERFACE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	391000.000	TF=	1.000000	CDCER=	0.156000
M=	391.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.000764
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.950000
R=	0.0	Z3=	0.0		
DF=	0.500000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			78.868
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.222
#RM =T / M	1000.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			221.647
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.12 CONDUCTORS & INSULATION

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	52790.0000	TF=	1.000000		CDCER=	0.158000
M=	1650.00000	O&M=	0.0		CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000		CICER=	0.000004
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	0.0			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.993
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M		31.994	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.211
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.13 SLIPRING BRUSHES - PRECURSOR

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	11341.0000	TF=	1.000000			CDCER=	0.158000
M=	531.000000	O&M=	0.0			CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000			CICER=	0.000200
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.529
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.106
#RM =T / M		21.358	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.268
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.14 PRIMARY STRUCTURE - POWER TRANS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000			CDCER=	0.023000
M=	1250.00000	O&M=	0.0			CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000			CICER=	0.000050
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			20.936
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.063
#RM =T / M			4.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.250
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.15 SECONDARY STRUCTURE - POWER TRANS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	9750.00000	TF=	0.007300	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000	CICER=	0.101000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.355000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			17.041
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.001
#RM =T / M		1950.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.546
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.16 TRANSMITTER SUBARRAYS - KLYSTRONS ICI

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	34617.0000	TF=	1.000000	CDCER=	0.0
M=	118.800003	O&M=	0.0	CDEXP=	0.0
CF=	1.250000	Z1=	1.000000	CICER=	0.003270
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.486
#RM =T / M		291.389	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			141.497
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.17 SWITCHGEAR & CONVERTERS - P.T. PRECURSOR

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	79200.0000	TF=	1.000000			CDCER=	0.158000
M=	2447.00000	O&M=	0.0			CDEXP=	0.297000
CF=	1.500000	Z1=	1.000000			CICER=	0.000400
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.756
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.468
#RM =T / M		32.366	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			47.520
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.18 CONDUCTORS & INSULATION - P.T. PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	60000.0000	TF=	1.000000	CDCER=	0.158000
M=	1720.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			4.147
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.007
#RM =T / M		34.884	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.240
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.1.9.1.19 BATTERIES - P.T. PRECURSOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	8000.00000	TF=	1.000000	CDCER=	0.037000
M=	50.000000	O&M=	0.0	CDEXP=	0.734000
CF=	1.000000	Z1=	1.000000	CICER=	0.028000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.241000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			27.106
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.072
#RM =T / M		160.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			11.501
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.20 THERMAL CONTROL - INSULATION - PRECURSOR

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	23200.0000	TF=	0.048000		CDCER=	0.156000
M=	4.000000	O&M=	0.0		CDEXP=	0.511000
CF=	1.000000	Z1=	1.000000		CICER=	0.101000
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.355000
R=	0.0	Z3=	0.0			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			26.539
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.008
#RM =T / M	5800.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			45.996
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.21 REFERENCE FREQUENCY GENERATOR - PRECURSOR

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.500000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.100000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.1.9.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.500
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.100
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.100
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.22 DIST. SYSTEM, COAXIAL CABLE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	8613.00000	TF=	1.000000	CDCER=	0.000030
M=	261.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000060
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	0.0		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	M	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.258
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.016
#RM =T / M	33.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.517
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.23 DIST. SYSTEM DEVICES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	100.000000	TF=	1.000000			CDCER=	0.000225
M=	2.000000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000			CICER=	0.005000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.022
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		50.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.500
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.1.24 TRANSMITTER SUBARRAYS - KLYSTRONS DDT&E

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	282500.000	TF=	1.000000			CDCER=	0.205000
M=	282500.000	O&M=	0.0			CDEXP=	0.507000
CF=	1.250000	Z1=	1.000000			CICER=	0.0
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.0
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KW	SUM TO 1.1.9.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			148.707
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.1.9.2 EOTV PRECURSOR OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the precursor test activity.

Cost estimates are presented in Table 1.1.9.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.1.9.2 COTV PRECURSOR OPERATIONS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.630000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	0.0				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES FLIGHT SUM TO 1.1.9		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.630
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.630
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.2 SPACE CONSTRUCTION AND SUPPORT

This element includes all hardware and activities required to assemble, checkout, operate, and maintain the satellite system. Included are space stations, construction facilities, support facilities and equipment, and manpower operations.

The Rockwell reference configuration is used as a baseline for the development of a satellite construction scenario and construction systems/equipment. Precursor operations incident to the establishment of orbital support facilities were identified and the satellite construction sequences and procedures were developed.

The overall scenario leading to establishment of satellite construction support facilities and to satellite construction is shown in Figure 1.2-1. Initial operations entail use of the growth shuttle and the shuttle derived HLLV for transporting men and material to LEO for the precursor phase of the program. Subsequently, during the 30 year satellite construction phase, the sps HLLV will become the primary transportation element for delivering construction mass to LEO and the shuttle HLLV will be used for personnel transfer to LEO.

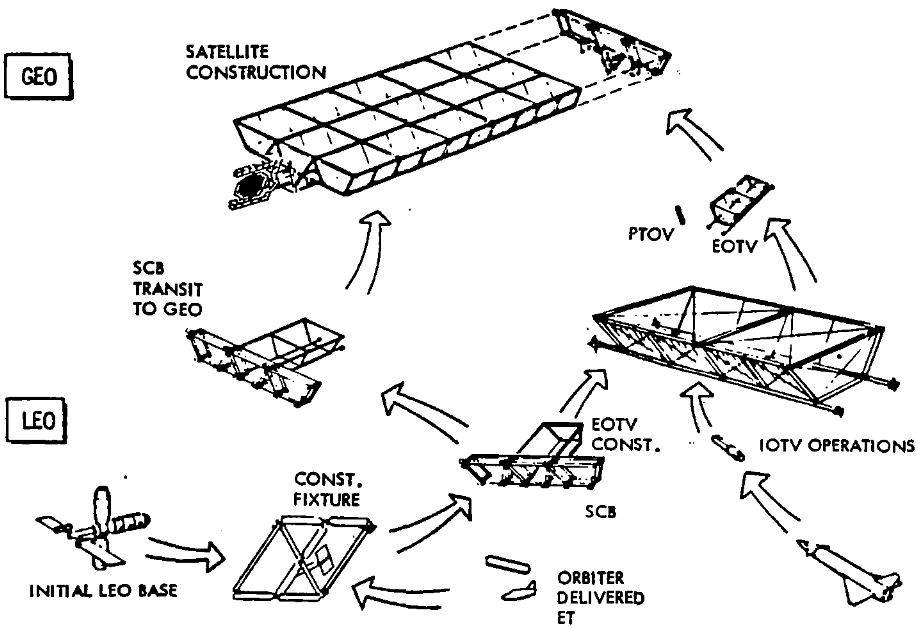


Figure 1.2-1. Overall Satellite Construction Scenario

The initial step in satellite precursor operations is establishment of a LEO base as shown in the lower left of the figure. Crew and power modules are transported to LEO by shuttle derivatives and assembled. When the base is fully operational, shuttle external tanks are delivered and mated to form construction fixtures for the Satellite Construction Base (SCB) construction. The figure shows a completed SCB. Since the more economical SPS HLLV will not be available during this phase of the program, and since overall plans specify an EOTV test article, it is possible that only the center section of the SCB would be constructed initially. This trough would be used to fabricate the pilot plant EOTV test article with an end-mounted antenna. After proof of concept, the remainder of the SCB would be completed along with sufficient EOTVs to support initial satellite construction operations. The SCB will then be transferred to GEO, using one or more EOTVs for propulsion and attitude control. Upon reaching GEO, satellite construction would commence, with the logistics support as shown at the right of the figure.

The energy conversion segment of the satellite structure is constructed by the integrated SCB in a single pass. Satellite longerons of a length sufficient to connect the triangular frames of the slip ring support structure are fabricated, followed by construction of the slip ring interface structure, and the first satellite structure frame. The SCB then proceeds to fabricate/install the remainder of the satellite structure and solar converter. Construction of the slip rings, and yoke (interface) takes place concurrently using free flying fabrication facilities to support this building process (Figure 1.2-2).

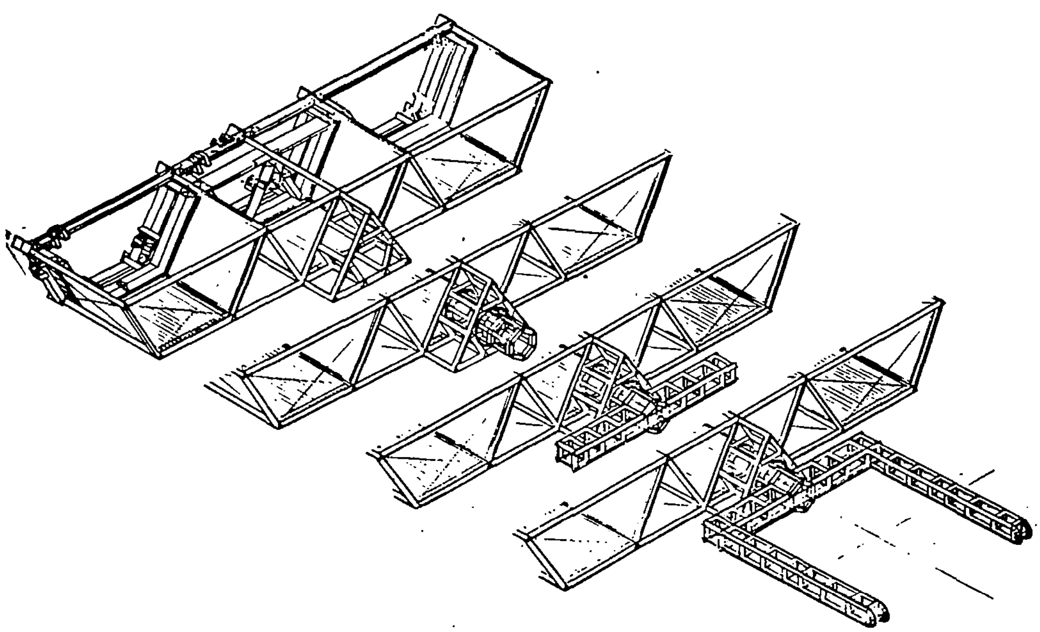


Figure 1.2-2. Antenna Supporting Structure Assembly Sequence

This section addresses the facilities/equipment, and operations required to support SPS work, crew, and operational requirements during the SPS program. Section 1.2.1 deals with the construction facilities; and Section 1.2.2 deals with the work and crew requirements at LEO. Section 1.2.3 covers the requirements in GEO to support operations and maintenance of the satellite.

1.2.1 CONSTRUCTION FACILITIES

This element includes the facilities, equipment, and operations required to assemble and checkout the satellite system. Included are crew life support facilities, the central control facility, fabrication and assembly facilities, cargo depots, and operations.

The satellites are constructed in GEO, each satellite being constructed at its designated longitudinal location. The SCB supports construction of two satellites per year during the program and serves as headquarters for operations and activities necessary to construct such items as the satellite, antenna interface, antenna, and EOTV. The SCB is constructed of composites and consists of the fabrication fixture, construction equipment, and base support facilities.

The construction fixture is in the form of three troughs, corresponding to the satellite configuration, which permits simultaneous construction of all troughs. Additional structural members are located in the middle trough and are used as support for the rotary joint/antenna structure. Figure 1.2-3 illustrates the construction base and shows the location of work and crew facilities.

The SCB fabrication fixture assembly and support equipment, and the crew/work modules on the base are itemized in Table 1.2.1. SCB modules used to support the crew/work activities are of various internal configurations to accommodate specific functional requirements. All modules are of the same diameter and most are of the same length, their dimensions and mass being in compliance with space transportation system constraints. The modules are located on the fab fixture along with the assembly and support equipment.

The Airlock Docking Module (ADM) is used to join the other base modules to provide docking accommodations for other elements such as crew transport modules, consumables logistics modules (CLM) and intra-base logistics vehicles, and for transfer of personnel and equipment between different pressure environments. The Crew Habitability Module (CHM) provides stateroom and personal hygiene facilities, and support systems for 24 to 30 crew members. The Base Management Module (BMM) houses the operational communications and control systems for the base. Power Modules (PM) are photovoltaic power systems (collectors, converters, conditioners, and storage) which support all base power requirements. Pressurized Storage Modules (PSM) provide an area for storage and workshop accommodations. Shielding (SHD) is provided in selected modules to protect against solar flare radiation. The Crew Support Module (SM) provides the galley, recreational and medical facilities and support subsystems. Work support, crew, and operational requirements are discussed in the following paragraphs.

1.2.1.1 WORK SUPPORT FACILITIES - SCB

This element includes work facilities and equipment required for satellite assembly and checkout. Included are beam fabricators, manipulators, assembly jigs, installation and deployment equipment, and cargo storage depots. Excluded are the facilities related to crew support.

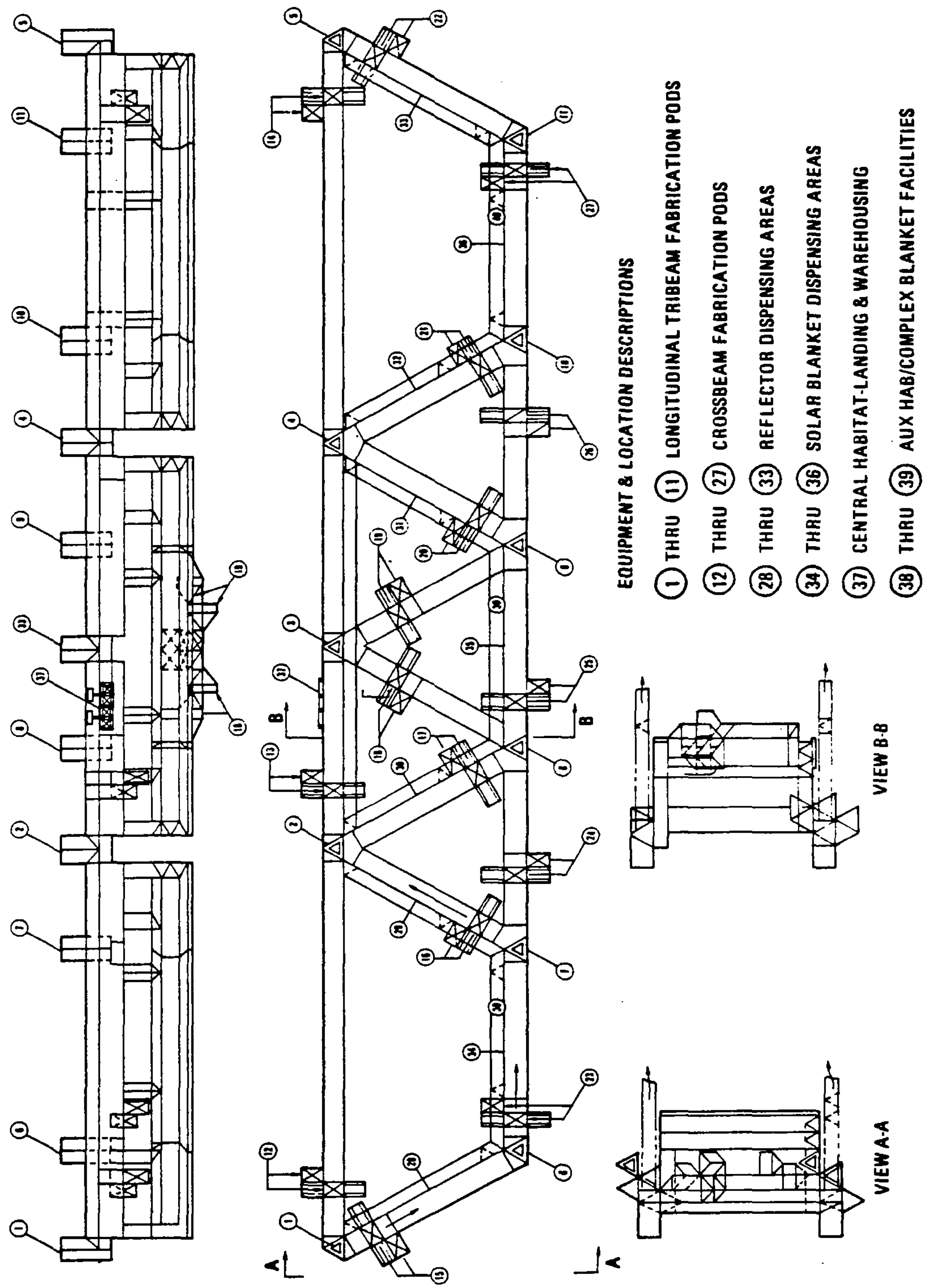


Figure 1.2-3. Satellite Construction Base (SCB)

Table 1.2.1 Total Space Construction and Support Equipment Requirements

SYSTEM DESCRIPTION	ABBREVIATION	SPACE CONSTRUCTION BASE	
		WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
BASE MODULES:			
AIRLOCK DOCKING MODULE	ADM	17	5
CREW HABITABILITY MODULE	CHM		17
CONSUMABLES LOGISTICS MODULE	CLM		9
BASE MANAGEMENT MODULE	BMM	4	
CREW SUPPORT MODULE/EVA	CSM/EVA		
POWER MODULE	PM	4	
PRESSURIZED STORAGE MODULE	PSM	4	
SHIELDING	SHD		8
CREW SUPPORT MODULE	CSM		3
CREW REQUIREMENTS			317 AVG. 504 PEAK
ASSEMBLY AND SUPPORT EQUIPMENT:			
BEAM MACHINES		198	
BEAM MACHINE-CASSETTES		3618	
CABLE ATTACHMENT MACHINES		72	
REMOTE MANIPULATOR		110	
SOLAR BLANKET DISPENSER MACHINE		72	
SOLAR BLANKET CASSETTES		5760	
REFLECTOR DISPENSER MACHINES		6	
REFLECTOR CASSETTES		360	
CABLE/CATENARY DISPENSERS		84	
ANTENNA PANEL INSTALL. EQUIP.		1	
GANTRY/CRANES		12	
CARGO STORAGE DEPOT		4	
SCB FAB FIXTURE		1	

SCB modules used mainly in the support of construction operations include a total of 17 ADMs, 4 BMMs, 4 PMs, and 4 PSMs. The CERs used for these modules were based on Rockwell Space Station studies.

All SPS unique fabrication/orbital construction assembly and support equipment is included in this section (reference Table 1.2.1). Included are the tribeam fabricators, cable attachment machines, solar blanket/concentrator dispensing machines, and antenna panel installation equipment. Each of these requirements were analyzed for equipment usage, replacement factors, O&M, and projected costs based on engineering estimates of design characteristics. The items of assembly and support equipment and base modules remain on the SCB as it transfers from one construction site to another. Cost estimates for these items are presented in Tables 1.2.1.1.1 through 1.2.1.1.17.

1.2.1.2 CREW SUPPORT FACILITIES - SCB

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, central control facilities, recreation facilities, and health facilities of the satellite construction base.

Crew support facilities include 5 ADMs, 17 CHMs, 9 CLMs, 8 SLDs, and 3 CSMs. Detail cost sheets on these components are identified in Tables 1.2.1.2.1 through 1.2.1.2.5.

1.2.1.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the construction facility. It includes both the direct and support personnel and the expendable maintenance supplies for satellite assembly and checkout.

This element has been divided into the subelements of operations (Table 1.2.1.3.1) and consumables (Table 1.2.1.3.2) where an average crew of 317 persons is required to man the SCB over the normal six month fabrication period. A crew rotation is scheduled for every three months. Consumables for the SCB are calculated at 3.6 kg/person/day.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.1 BEAM MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	2.000000
M=	1.000000	O&M=	0.594000	CDEXP=	1.000000
CF=	1.000000	Z1=	198.000000	CICER=	0.700000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	198.000000		
DF=	1.000000	Z4=	198.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.700
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		83.150
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.420
CIPS=CTB*Z4/Z2		1.386
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.594

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.2 BEAM MACHINE CASSETTES

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	1.000000	TF=	1.000000	CDCER=	0.800000
M=	1.000000	O&M=	0.090450	CDEXP=	1.000000
CF=	1.000000	Z1=	1206.00000	CICER=	0.008200
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	3618.00000		
DF=	1.000000	Z4=	1206.00000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.800
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.008
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			6.315
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		0.005
CIPS=CTB*Z4/Z2			0.097
CRCI =CTB X R			0.000
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.090

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.3 CABLE ATTACHMENT MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	4.300000
M=	1.000000	O&M=	0.144000	CDEXP=	1.000000
CF=	1.000000	Z1=	72.000000	CICER=	0.500000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	72.000000		
DF=	1.000000	Z4=	72.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		4.300
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.500
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		28.228
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.392
CIPS=CTB*Z4/Z2		0.470
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.144

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.4 REMOTE MANIPULATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	6.880000
M=	1.000000	O&M=	1.925000	CDEXP=	1.000000
CF=	1.000000	Z1=	55.000000	CICER=	1.200000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.033333	Z3=	110.000000		
DF=	1.000000	Z4=	55.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			6.880
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.200
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			60.390
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		1.077
CIPS=CTB*Z4/Z2			0.987
CRCI =CTB X R			0.036
CO&M = O&M OR CTB*Z5/Z2/ENYR			1.925

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.5 BLANKET DISPENSER MACHINE

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000		CDCER=	4.000000
M=	1.000000	O&M=	0.180000		CDEXP=	1.000000
CF=	1.000000	Z1=	72.000000		CICER=	0.400000
PHI=	0.980000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	72.000000			
DF=	1.000000	Z4=	72.000000	Z5=	0.0	

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			4.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.400
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			26.154
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		0.363
CIPS=CTB*Z4/Z2			0.436
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.180

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.6 SOLAR BLANKET CASSETTES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.800000
M=	1.000000	O&M=	0.115200	CDEXP=	1.000000
CF=	1.000000	Z1=	1440.00000	CICER=	0.010000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	5760.00000		
DF=	1.000000	Z4=	2880.00000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.800
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.010
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.076
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	1 / Z3		0.006
CIPS=CTB*Z4/Z2			0.273
CRCI =CTB X R			0.000
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.115

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.7 REFLECTOR DISPENSER MACHINE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	6.000000
M=	1.000000	O&M=	0.048000	CDEXP=	1.000000
CF=	1.000000	Z1=	6.000000	CICER=	0.800000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	6.000000		
DF=	1.000000	Z4=	6.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		6.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.800
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		4.651
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.775
CIPS=CTB*Z4/Z2		0.078
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.048

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.8 REFLECTOR CASSETTES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1.000000
M=	1.000000	O&M=	0.054000	CDEXP=	1.000000
CF=	1.000000	Z1=	120.000000	CICER=	0.030000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.066667	Z3=	360.000000		
DF=	1.000000	Z4=	120.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.030
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2.721
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		0.021
CIPS=CTB*Z4/Z2			0.042
CRCI =CTB X R			0.001
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.054

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.9 CABLE/CATENARY DISPENSER MACHINES

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	2.200000
M=	1.000000	O&M=	0.168000			CDEXP=	1.000000
CF=	1.000000	Z1=	84.000000			CICER=	0.300000
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	84.000000				
DF=	1.000000	Z4=	84.000000	Z5=	0.0		

CALCULATED VALUES	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2.200
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.300
#RM =T / M		1.000
E =1.0 + LOG(PHI) / LOG(2.0)		0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		22.786
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	0.271
CIPS=CTB*Z4/Z2		0.380
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.168

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.10 ANTENNA PANEL INS. EQPT.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	600.000000
M=	1.000000	O&M=	6.755000	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	200.000000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	1.000000		
DF=	0.133333	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	80.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	200.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLPM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	200.272
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	200.272
CIPS=CTB*Z4/Z2	3.338
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	6.755

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.11 GANTRY/CRANES

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000		CDCER=	17.000000
M=	1.000000	O&M=	0.600000		CDEXP=	1.000000
CF=	1.000000	Z1=	12.000000		CICER=	8.000000
PHI=	0.950000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	12.000000			
DF=	0.800000	Z4=	12.000000	Z5=	0.0	

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			13.600
CLRM=CICER X (M)XX(CIEXP) X CF X TF			8.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			85.034
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		7.086
CIPS=CTB*Z4/Z2			1.417
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.600

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.12 CARGO STORAGE DEPOTS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	15.000000
M=	1.000000	O&M=	0.600000	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	2.000000
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	4.000000		
DF=	0.800000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES	SUM TO 1.2.1.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			12.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			2.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			7.559
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3		1.890
CIPS=CTB*Z4/Z2			0.126
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.600

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.13 FAB FIXTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1648900.00	TF=	1.000000	CDCER=	0.023000
M=	5000.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	1.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2165.128
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.250
#RM =T / M		329.780	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			82.445
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			82.445
CIPS=CTB*Z4/Z2			1.374
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.14 AIRLOCK DOCKING MODULE (ADM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000	CDCER=	0.0
M=	2500.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	17.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	17.000000		
DF=	1.000000	Z4=	17.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			242.302
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			14.253
CIPS=CTB*Z4/Z2			4.038
CRCI =CTB X R			0.285
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.15 BASE MGMT. MODULE (BMM)

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.0
M=	27000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	4.000000			CICER=	0.011496
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	4.000000				
DF=	1.000000	Z4=	4.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1213.870
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			303.467
CIPS=CTB*Z4/Z2			20.231
CRCI =CTB X R			6.069
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.16 POWER MODULE (PM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	250.000000	TF=	1.000000	CDCER=	0.0
M=	250.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	4.000000	CICER=	1.100000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	4.000000		
DF=	1.000000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			275.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1075.459
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			268.865
CIPS=CTB*Z4/Z2			17.924
CRCI =CTB X R			5.377
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.1.17 PRESSURIZED STORAGE MODULE (PSM)

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000	CDCER=	0.052914
M=	15000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	0.013734
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	4.000000		
DF=	1.000000	Z4=	4.000000	Z5=	0.0

CALCULATED VALUES KG SUM TO 1.2.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	793.710
CLRM=CICER X (M)XX(CIEXP) X CF X TF	206.010
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	805.657
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	201.414
CIPS=CTB*Z4/Z2	13.428
CRCI =CTB X R	2.014
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000			CDCER=	0.012461
M=	2500.00000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000			CICER=	0.006036
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	5.000000				
DF=	1.000000	Z4=	5.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			31.152
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			73.413
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			14.683
CIPS=CTB*Z4/Z2			1.224
CRCI =CTB X R			0.294
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.2 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.0
M=	27000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	17.000000			CICER=	0.003770
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	17.000000				
DF=	1.000000	Z4=	17.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1634.456
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			96.144
CIPS=CTB*Z4/Z2			27.241
CRCI =CTB X R			1.923
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.3 CONSUMABLES LOGISTICS MODULE-CLM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000			CDCER=	0.0
M=	5000.00000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	9.000000			CICER=	0.014000
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	9.000000				
DF=	1.000000	Z4=	9.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			604.675
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			67.186
CIPS=CTB*Z4/Z2			10.078
CRCI =CTB X R			1.344
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.4 SHIELDING

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	11000.0000	TF=	1.000000	CDCER=	0.156000
M=	11000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	8.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.010000	Z3=	8.000000		
DF=	0.200000	Z4=	8.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			343.200
CLRM=CICER X (M)XX(CIEXP) X CF X TF			2.748
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			21.160
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.645
CIPS=CTB*Z4/Z2			0.353
CRCI =CTB X R			0.026
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.2.5 CREW SUPPORT MODULE-CSM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000	CDCER=	0.012432
M=	15000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	3.000000	CICER=	0.005798
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	3.000000		
DF=	1.000000	Z4=	3.000000	Z5=	0.0

CALCULATED VALUES KG SUM TO 1.2.1.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		186.480
CLRM=CICER X (M)XX(CIEXP) X CF X TF		86.970
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		256.587
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		85.529
CIPS=CTB*Z4/Z2		4.276
CRCI =CTB X R		1.711
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

(THIS PAGE INTENTIONALLY LEFT BLANK)

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.3.1 OPERATIONS, CONSTRUCTION CREW

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	317.000000	TF=	1.000000	CDCER=	0.0
M=	317.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.062400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	31.000000		
DF=	1.000000	Z4=	30.000000	Z5=	0.0

CALCULATED VALUES	MEN	SUM TO 1.2.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			19.781
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			19.781
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			19.781
CIPS=CTB*Z4/Z2			9.890
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.1.3.2 ORBITAL OPERATIONS,CONST. PROV.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	410832.000	TF=	1.000000	CDCER=	0.0
M=	410832.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000022
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	31.000000		
DF=	1.000000	Z4=	30.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			9.038
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.038
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			9.038
CIPS=CTB*Z4/Z2			4.519
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2 LOGISTICS SUPPORT FACILITIES - LEO

This element includes the hardware, software and operations required in LEO to support the construction and operations and maintenance of the satellite system. Included are crew life support facilities, cargo and propellant depots, and vehicle servicing facilities necessary for the receiving and transfer of cargo and personnel distined for a construction base or operational satellite located in GEO.

LEO support operations will require a permanent crew of 24 at the LEO facility. These personnel will provide supervisory activities for transfer of up and down payloads between the HLLV and OTVs. They also perform the scheduled maintenance required by the electric propulsion OTV, such as change-out of ion thruster screens. Included are work and crew support facilities (Table 1.2.2) plus required operations.

Table 1.2.2 LEO Base Modules

SYSTEM DESCRIPTION	ABBREVIATION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
CREW HABITABILITY MODULE	CHM		1
CONSUMABLES LOGISTICS MODULE	CLM		1
BASE MANAGEMENT MODULE	BMM	1	
CREW SUPPORT MODULE/EVA	CSM/EVA		1
POWER MODULE	PM	1	

1.2.2.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required to provide logistics support in LEO. Included are HLLV and OTV docking stations, payload handling equipment, and cargo and propellant storage depots. Excluded are facilities related to crew support.

A 100 kW solar array power module and the base management module are work support facilities. Cost estimates contained in Tables 1.2.2.1.1 and 1.2.2.1.2 were based on Rockwell Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.1.1 BASE MGMT. MODULE-BMM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000	CDCER=	0.091296
M=	27000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.011496
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2464.993
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			310.814
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			310.814
CIPS=CTB*Z4/Z2			5.180
CRCI =CTB X R			6.216
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.1.2 POWER MODULE-PM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	250.000000	TF=	1.000000	CDCER=	1.400000
M=	250.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	1.100000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KW	SUM TO 1.2.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			350.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			275.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			275.373
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			275.373
CIPS=CTB*Z4/Z2			4.590
CRCI =CTB X R			5.507
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities at LEO.

The crew habitability module and crew support module/EVA are the same basic configuration as for those on the SCB. However, the crew support module has an airlock and EVA preparation area. A consumables logistics module is the third element of crew support facilities.

CERs used for crew support facilities were based upon Rockwell Space Station studies. See Tables 1.2.2.2.1, 1.2.2.2.2, and 1.2.2.2.3.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.1 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000	CDCER=	0.009714
M=	27000.0000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.003770
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			262.278
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			101.928
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			101.928
CIPS=CTB*Z4/Z2			1.699
CRCI =CTB X R			2.039
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.2 CONSUMABLES LOGISTICS MODULE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000	CDCER=	0.053000
M=	5000.00000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.014000
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			265.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.095
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			70.095
CIPS=CTB*Z4/Z2			1.168
CRCI =CTB X R			1.402
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.2.3 CREW SUPPORT MODULE/EVA

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.012432
M=	27000.0000	O&M=	0.0			CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000			CICER=	0.005798
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	1.000000				
DF=	1.000000	Z4=	1.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			335.664
CLRM=CICER X (M)XX(CIEXP) X CF X TF			156.546
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			156.759
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			156.759
CIPS=CTB*Z4/Z2			2.613
CRCI =CTB X R			3.135
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.2.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the logistics support facility. It includes both the direct and support personnel and the expendable maintenance supplies required for logistics support.

An average of 24 crew members are required at the LEO Base to support orbital operations. Engineering estimates were made of the operations and consumable requirements at LEO. See Tables 1.2.2.3.1 and 1.2.2.3.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.3.1 LEO OPERATIONS CREW

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	24.000000	TF=	1.000000	CDCER=	0.0
M=	24.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.062400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	31.000000		
DF=	1.000000	Z4=	30.000000	Z5=	0.0

CALCULATED VALUES	MEN	SUM TO 1.2.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.498
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.498
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.498
CIPS=CTB*Z4/Z2			0.749
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.2.3.2 LEO CREW PROVISIONS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	31104.0000	TF=	1.000000			CDCER=	0.0
M=	31104.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.000022
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	31.000000				
DF=	1.000000	Z4=	30.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.2.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.684
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.684
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.684
CIPS=CTB*Z4/Z2			0.342
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.2.3 SATELLITE O&M SUPPORT FACILITIES

This element includes the facilities, equipment, and operations required in GEO to support the operations and maintenance of the satellite system. Included are the on-orbit monitor and control facility and the life support facilities and equipment required to provide confortable safe living quarters for the resident crew members.

A permanent satellite operations and maintenance base is installed on each satellite at a location near the antenna to provide best access to all systems of the satellite. The base has facilities for both the crew and for storage of maintenance material, and installation/repair equipment. Table 1.2.3 identifies the supporting facilities.

Table 1.2.3 Satellite O&M Base

SYSTEM DESCRIPTION	ABBREVIATION	WORK SUPPORT FACILITIES	CREW SUPPORT FACILITIES
AIRLOCK DOCKING MODULE	ADM	3	1
CREW HABITABILITY MODULE	CHM		1
CONSUMABLES LOGISTICS MODULE	CLM		1
BASE MANAGEMENT MODULE	BMM	1	
CREW SUPPORT MODULE/EVA	CSM/EVA		1
PRESSURIZED STORAGE MODULE	PSM	2	

1.2.3.1 WORK SUPPORT FACILITIES

This element includes the facilities and equipment required for operation and maintenance of the satellite system. Included are satellite monitor and control stations and any centralized repair facilities not included under maintenance.

The ADM is required at four places for the integration of other modules comprising the satellite O&M base. Three of these modules are to be used primarily for work support operations. The satellite BMM incorporates a monitoring and fault isolation capability for the SPS satellite subsystems as well as the controls required for alternate operational modes and functional isolation of selected subsystems for maintenance. The cost estimates of these modules and the PSM are shown in Tables 1.2.3.1.1, 1.2.3.1.2 and 1.2.3.1.3. The CERs are based on Rockwell Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000	CDCER=	0.0
M=	2500.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	3.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	180.000000		
DF=	1.000000	Z4=	180.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			44.520
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			13.352
CIPS=CTB*Z4/Z2			40.056
CRCI =CTB X R			0.267
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.2 BASE MGMT MODULE-BMM

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.0
M=	27000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.011496
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			310.392
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			310.814
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			283.323
CIPS=CTB*Z4/Z2			283.322
CRCI =CTB X R			5.666
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.1.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.1.3 PRESSURIZED STORAGE MODULE-PSM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	15000.0000	TF=	1.000000	CDCER=	0.0
M=	15000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	2.000000	CICER=	0.013734
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	1.000000	Z4=	120.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			206.010
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			408.244
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			184.403
CIPS=CTB*Z4/Z2			368.805
CRCI =CTB X R			1.844
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.1.1.17 FOR DDT&E

1.2.3.2 CREW SUPPORT FACILITIES

This element includes the facilities and equipment required for the life support and well-being of the crew members. Included are living quarters, recreation facilities, and health facilities.

The combination crew support and EVA module (CSM/EVA) has the same internal function as for the SCB, but occupies only half of the module. The other half is an integrated multi-crew member EVA preparation area and airlock station.

The ADM, CHM, CLM and CSM/EVA modules are costed in Tables 1.2.3.2.1, 1.2.3.2.2, 1.2.3.2.3, and 1.2.3.2.4. The estimates are based on Rockwell's Space Station studies.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.1 AIRLOCK DOCKING MODULE-ADM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2500.00000	TF=	1.000000	CDCER=	0.0
M=	2500.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.006036
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			15.090
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			15.111
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			13.774
CIPS=CTB*Z4/Z2			13.774
CRCI =CTB X R			0.275
CO&M = O&M OR CTB*Z5/Z2/ENYR.			0.0

COMMENTS

SEE 1.2.1.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.2 CREW HABITABILITY MODULE-CHM

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	27000.0000	TF=	1.000000	CDCER=	0.0
M=	27000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.003770
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.020000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			101.790
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			101.928
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			92.913
CIPS=CTB*Z4/Z2			92.913
CRCI =CTB X R			1.858
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS
SEE 1.2.2.2.1 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.3 CONSUMABLES LOGISTICS MODULE-CLM

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	5000.00000	TF=	1.000000		CDCER=	0.0
M=	5000.00000	O&M=	0.0		CDEXP=	0.0
CF=	1.000000	Z1=	1.000000		CICER=	0.014000
PHI=	0.980000	Z2=	60.000000		CIEXP=	1.000000
R=	0.020000	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.095
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			63.895
CIPS=CTB*Z4/Z2			63.895
CRCI =CTB X R			1.278
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.2 FOR DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.2.4 CREW SUPPORT MODULE/EVA

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	27000.0000	TF=	1.000000			CDCER=	0.0
M=	27000.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.005798
PHI=	0.980000	Z2=	60.000000			CIEXP=	1.000000
R=	0.020000	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.3.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			156.546
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			156.759
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			142.894
CIPS=CTB*Z4/Z2			142.894
CRCI =CTB X R			2.858
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

SEE 1.2.2.2.3 FOR DDT&E

1.2.3.3 OPERATIONS

This element includes the planning, development, and conduct of operations at the O&M support facility. It includes both the direct and support personnel and the expendable maintenance supplies required in GEO for satellite operations and maintenance.

The satellite operations base crew is manned by 30 persons on a continuous basis throughout the year. This crew and supporting provisions are costed in Tables 1.2.3.3.1 and 1.2.3.3.2 based on engineering estimates.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.3.1 SATELLITE OPERATIONS CREW

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	30.000000	TF=	1.000000	CDCER=	0.0
M=	30.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.062400
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	MEN	SUM TO 1.2.3.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.872
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.872
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.872
CIPS=CTB*Z4/Z2			1.872
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.2.3.3.2 SATELLITE CREW PROVISIONS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	38880.0000	TF=	1.000000			CDCER=	0.0
M=	38880.0000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.000022
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	KG	SUM TO 1.2.3.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.855
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.855
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.855
CIPS=CTB*Z4/Z2			0.855
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.3 TRANSPORTATION

This element of the costing includes all space transportation required to support the satellite system assembly and operation. Included are transportation requirements supporting the precursor activity, launch to LEO, orbit-to-orbit transfer of all hardware, materials, and personnel, and intra-orbit movement of cargo during the construction and lifetime operation of the satellite system.

The overall scenario for SPS space transportation systems consists of seven major elements -- Space Shuttle derivatives for personnel (PLV) and precursor cargo (STS-HLLV); SPS heavy lift launch vehicle (HLLV); electric orbit transfer vehicle (EOTV); intra-orbit transfer vehicle (IOTV); personnel orbit transfer vehicle (POTV); personnel module (PM); and orbital/ground support facilities. Transportation requirements and concepts for SPS vary as a function of program phase. During the verification planning period (1981 - 1987), the baseline Shuttle is used to conduct sortie missions. Later in the verification program "growth" Shuttle is used to deliver personnel and cargo to LEO. The Shuttle derived HLLV is also employed early in the program for LEO fabrication of the space construction base plus support in building the precursor satellite (EOTV) test model. Figure 1.3-1 illustrates early program systems and identifies the SPS VTO/HL HLLV that will be needed for the fabrication of flight EOTVs and the mass-to-orbit requirements of satellite construction.

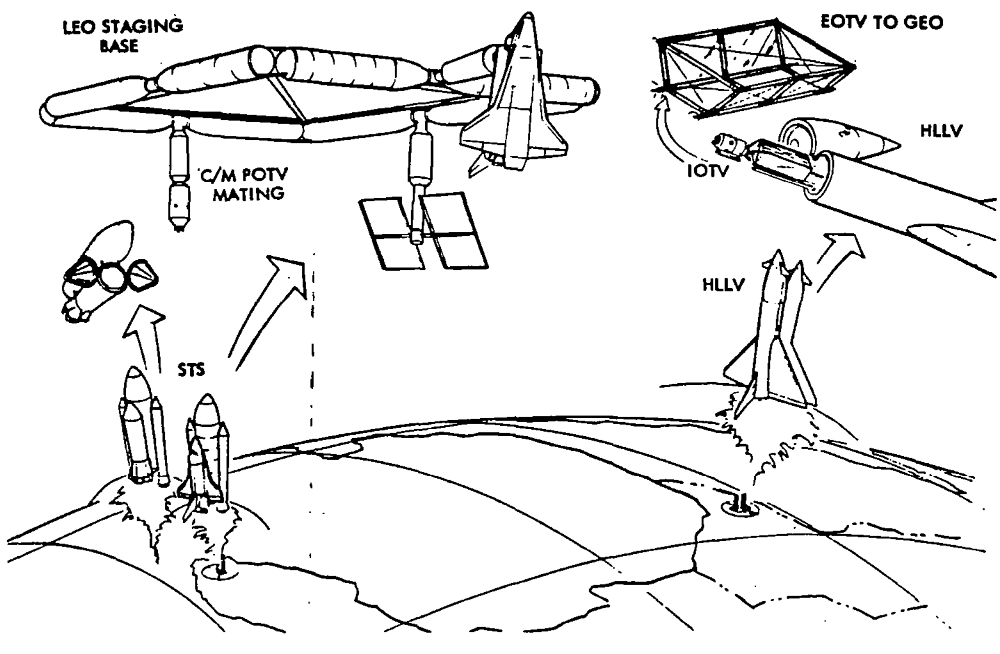


Figure 1.3-1. SPS Transportation System - LEO Operations Operational Program

Geosynchronous orbit is the eventual destination of SPS construction materials/equipment, personnel, and supplies. The crews will be transported from earth to LEO by the growth Shuttle containing the personnel module (PM) where the PM will then be carried to GEO by the POTV. Cargo will be delivered to LEO by the SPS VTO/HL-HLLV configuration, transferred to the EOTV by IOTV's, transported to GEO by the EOTV, and off-loaded by IOTV's. Additional detail on the individual vehicles is presented in later subsections.

Mass-to-orbit requirements for construction, propellant, and operations/maintenance activities were established in accordance with the mission profile and build schedule of two SPS satellites per year with a first unit (TFU) by the end of year 2000. These calculations were based on a round trip vehicle life as shown in Table 1.3-1.

Table 1.3-1. Vehicle Life with Maintenance

VEHICLE	R.T. FLIGHTS PER VEHICLE
STS GROWTH VEHICLE FOR PLV/CARGO	100
SPS-VTO/HL HEAVY LIFT LAUNCH VEHICLE	300
EOTV-CARGO (ELECTRIC) ORBIT TRANSFER VEH.	20
POTV-PERSONNEL ORBIT TRANSFER VEHICLE	100
IOTV-INTRO-ORBIT TRANSFER VEHICLE	200

Table 1.3-2 shows the vehicle fleet and vehicle flight requirements to build the first SPS satellite, LEO construction base, and the EOTV test vehicle. These calculations were based on the mass-to-LEO and GEO for personnel, materials, and supplies identified to each of the transportation modes. Precursor activities can be completed by utilizing (1) the two existing TFU personnel modules (PMs); and (2) an additional PLV over the two needed for the TFU. Two Shuttle launch vehicle sets will be combined with a cargo container/engine module to transport materials to LEO for the precursor activity. TFU vehicle requirements are based on mission timelines, turnaround schedules, and flight profiles.

Table 1.3-3 tabulates the total program transportation requirements and the number of flights per vehicle as needed to construct the satellites and to provide operations and maintenance after IOC. These calculations are the basis for developing overall fleet requirements for a 60-unit SPS program, but do not include the precursor effort identified in Table 1.3-2 nor the additional vehicles needed for attrition/spares or overhaul (replacement capital investment).

Table 1.3-2. TFU Transportation Requirements

	MASS x 10^6 KG		VEHICLE FLIGHTS					
			PLV	HLLV	POTV	EOTV	IOTV	
	LEO	GEO					LEO	GEO
SATELLITE CONST. MAINT. & PACKAGING	37.12	37.12	45	163.5	45	6.5	164	164
CREW CONSUMABLES & PKG.	0.98	0.94	-	4.3	-	0.2	4	4
POTV PROPELLANTS & PKG.	2.91	1.46	-	12.8	-	0.3	13	6
EOTV CONST., MAINT. & PKG.	7.20	-	15	31.7	-	-	32	-
EOTV PROPELLANTS & PKG.	4.79	-	-	21.1	-	-	21	-
IOTV PROPELLANTS & PKG.	0.13	0.06	-	0.6	-	-	1	-
							235	174
TOTAL	53.13	39.58	60	234.0	45	7.0	409	
TFU FLEET VEHICLE REQUIREMENTS			2	5	4	6	4	
GROWTH SHUTTLE VEHICLE/OPERATIONS REQUIREMENTS FOR PRECURSOR ACTIVITIES (LEO BASE, SPACE CONSTRUCTION BASE, AND EOTV TEST VEHICLE - EOTV'S)			72 FLIGHTS 1 VEHICLE PERSONNEL (PLV)			129 FLIGHTS 2 VEHICLES CARGO CARRIER/ENGINE MODULE AND LAUNCH VEHICLE		

Table 1.3-3. Total Program Transportation Requirements

	MASS x 10^6 KG		VEHICLE FLIGHTS					
			PLV	HLLV	POTV	EOTV	IOTV	
	LEO	GEO					LEO	GEO
SATELLITE								
CONSTRUCTION	2197.8	2197.8	1340	9682	1220	425.1	9682	9682
OPERATIONS & MAINTENANCE	1803.0	1803.0	3694	7943	3660	348.7	7943	7943
CREW CONSUMABLES								
CONSTRUCTION	31.5	28.7	-	139	-	5.6	139	126
OPERATIONS & MAINTENANCE	86.8	86.0	-	382	-	16.6	382	379
POTV PROPELLANTS								
CONSTRUCTION	82.7	41.4	-	364	-	8.0	364	182
OPERATIONS & MAINTENANCE	267.8	133.8	-	1180	-	25.9	1180	589
EOTV CONSTRUCTION								
CONSTRUCTION	28.2	24.2	-	124	-	4.7	124	107
OPERATIONS & MAINTENANCE	22.2	19.0	-	98	-	3.7	98	84
EOTV PROPELLANTS								
CONSTRUCTION	340.3	2.0	-	1499	-	0.4	1499	9
OPERATIONS & MAINTENANCE	304.0	-	-	1339	-	-	1339	-
IOTV PROPELLANTS								
CONSTRUCTION	7.2	3.3	-	32	-	0.6	32	15
OPERATIONS & MAINTENANCE	6.6	3.0	-	29	-	0.6	29	13
SUMMARY								
CONSTRUCTION	2687.7	2297.4	1340	11840	1220	444	11840	10121
OPERATIONS & MAINTENANCE	2490.4	2044.8	3694	10971	3660	396	10971	9008
TOTAL	5178.1	4342.2	5034	22811	4880	840	22811	19129
VEHICLE FLEET								
CONSTRUCTION	-	-	14	39	12	22	110	
OPERATIONS & MAINTENANCE	-	-	37	37	37	20	100	
TOTAL	-	-	51	76	49	42	210	

1.3.1 SPS HEAVY LIFT LAUNCH VEHICLE (HLLV)

The SPS HLLV is shown in Figure 1.3-2 and has a payload capability of 227,000 kg with a vertical take-off and horizontal landing feature. The SPS HLLV is used to bring space construction and support equipment payloads, satellite system hardware, OTVs, consumables and crew expendables, and propellants from earth to LEO. This element covers the SPS HLLV vehicles and operations required to support the satellite system assembly and operation during a 30 year life. Ground rules and guidelines applicable to the HLLV are summarized in Table 1.3-4.

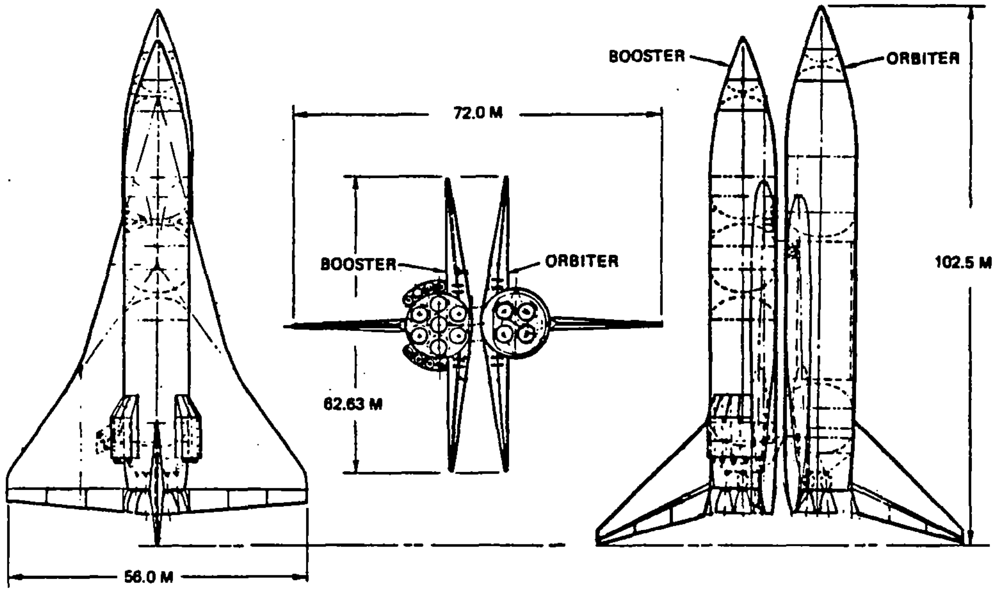


Figure 1.3-2. SPS Transportation System Launch Configuration

Table 1.3-4. HLLV Ground Rules/Assumptions

TWO-STAGE VERTICAL TAKEOFF/HORIZONTAL LANDING (VTO/HL)
FLY BACK CAPABILITY BOTH STAGES - ABES FIRST STAGE ONLY
PARALLEL BURN WITH PROPELLANT CROSSFEED
LOX/RP FIRST STAGE - LOX/LH_2 SECOND STAGE
HI P_c GAS GENERATOR CYCLE ENGINE - FIRST STAGE [I_s (VAC) = 352 SEC.]
HI P_c STAGED COMBUSTION ENGINE - SECOND STAGE [I_s (VAC) = 466 SEC.]
STAGING VELOCITY - HEAT SINK BOOSTER COMPATIBLE
CIRCA 1990 TECHNOLOGY BASE - BAC/MMC WEIGHT REDUCTION DATA
ORBITAL PARAMETERS - 487 KM @ 31.6°
PAYLOAD CAPABILITY - 227×10^3 KG UP/45 KG DOWN
THRUST/WEIGHT - 1.30 LIFTOFF/3.0 MAX
15% WEIGHT GROWTH ALLOWANCE/0.75% ΔV MARGIN

1.3.1.1 SPS HLLV FLEET

A total of 76 HLLV vehicles are required to handle the mass flow requirements throughout the 60 year SPS program. Thirty-nine vehicles are required for the construction of 60 satellites and 37 vehicles are needed for operation and maintenance during the 30 year satellite lifetime.

Data used in projecting estimates for the HLLV and supporting flight costs were factored from the NASA/JSC contract NAS9-15196. Specific changes were made to consider the reference HLLV design configuration; vehicle complexity factors -- engines, ablative shield, propellant valves, and system/subsystem design; plus the greater mass of the Orbiter/booster as compared with current experience and Rockwell Space Shuttle contract work.

HLLV capital asset replacements, major overhaul requirements, spares provisioning, and system lifetimes were projected as being equivalent to two vehicle replacements for each of the SPS fleet vehicles. These calculations are reflected as an annual cost per satellite over the 30 year period.

The DDT&E cost estimate was developed from a careful evaluation of the NAS9-15196 data base and a comparative factoring of these data as compared with data directly applicable to the Space Shuttle program.

See Table 1.3.1.1 for the SPS HLLV cost computer program tabulation.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.1.1 SPS-HLLV FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	8600.00000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000	CICER=	2000.00000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.084440	Z3=	228.000000		
DF=	1.000000	Z4=	39.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	8600.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	2000.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	8950.176
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	1180.031
CIPS=CTB*Z4/Z2	767.020
CRCI =CTB X R	99.642
CO&M = O&M OR CTB*Z5/Z2/ENYR	24.256

COMMENTS

1.3.1.2 SPS HLLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program. The HLLV has a lifetime capability of 300 flights.

There are a total of 22.811 round trip flights required to support the 60 year program where approximately 227,000 kg is delivered per flight. These are grouped into a total of 11840 flights for construction and 10,971 flights for operations and maintenance. The TFU requires a total of 234 flights to carry the necessary mass to orbit. On the average of 60 satellites, approximately 197 flights are needed for satellite construction and 6 flights are required for annual operations and maintenance per satellite.

The projected cost per HLLV flight is based on contract data (reference NAS9-15196) that was factored and revised to arrive at a propellant, payload integration, and supporting operational cost by evaluation against such things as propellant costs versus HLLV requirements. See Table 1.3.1.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.1.2 . SPS-HLLV OPERATIONS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	234.000000			CICER=	2.480000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	22811.0000				
DF=	1.000000	Z4=	11840.0000	Z5=	10971.0000		

CALCULATED VALUES FLIGHT SUM TO 1.3.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		2.480
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		580.320
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		2.480
CIPS=CTB*Z4/Z2		489.387
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		15.116

COMMENTS

1.3.2 CARGO ORBITAL TRANSFER VEHICLE (COTV)

This element includes the COTV vehicle and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO transfer of space construction and support equipment, satellite system hardware, spares, and propellants required throughout the satellite lifetime.

The Rockwell cargo orbital transfer vehicle is a high specific impulse configuration that is possible with electric propulsion. The concept is shown in Figure 1.3-3 and has a payload capability of 5.17×10^6 kg (equivalent to 23 HLLV payloads) with a 6 month round trip time per flight.

COTV fleet procurement and operations are detailed in sections 1.3.2.1 and 1.3.2.2, respectively.

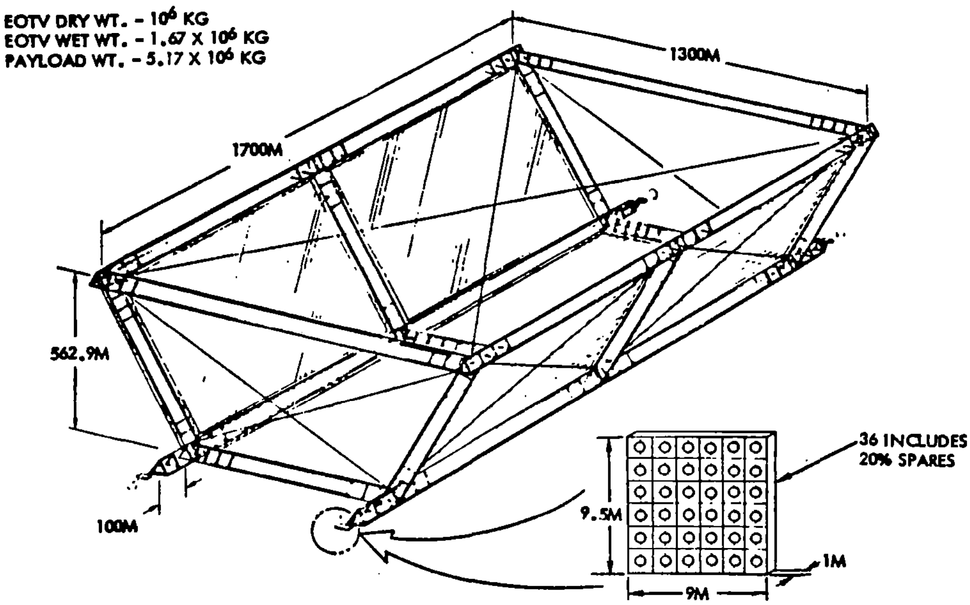


Figure 1.3-3. EOTV Reference Configuration

1.3.2.1 COTV FLEET

This element includes the vehicle fleet procurement required for the SPS.

The electric OTV structural configuration is essentially the same as that employed for the satellite bay. It has a weight of 871,753 kg's. The EOTV weight and payload summary is shown in Table 1.3-5.

Table 1.3-5. EOTV Weight Summary (kg) (GaAlAs)

SOLAR ARRAY		588,196
CELL/STRUCTURE	299,756	
POWER CONDITIONING	288,440	
THRUSTER ARRAY (4)		96,685
THRUSTERS/STRUCTURE	10,979	
CONDUCTORS	4,607	
BEAMS/GIMBALS	2,256	
PROPELLANT TANKS	78,843	
ATTITUDE CONTROL SYSTEM		186,872
POWER SUPPLY (INCL. ENERGY STORAGE)	184,882	
SYSTEM COMPONENTS	274	
PROPELLANT TANKS	1,716	
EOTV INERT WEIGHT		871,753
25% GROWTH		217,938
TOTAL INERT WEIGHT		1,089,691
PROPELLANT WEIGHT		666,660
TRANSFER PROPELLANT	655,219	
ACS PROPELLANT	11,441	
EOTV LOADED WEIGHT		1,756,351
PAYLOAD WEIGHT		5,171,318
LEO DEPARTURE WEIGHT		6,927,669

The thruster array consists of 36 units at four locations for a total of 144 thrusters with a maximum of 64 thrusters operable simultaneously. The total attitude control system and thruster array mass is equal to 283,557 kg's per EOTV.

The EOTV CERs are the same as those used for the satellite costs on the same subsystem elements. The replacement capital investment calculation is based on an attrition factor of 5-6% of each flight vehicle. Table 1.3-6 lists the elements of cost for the EOTV.

Table 1.3-6. EOTV Cost Elements

WBS NO.	DESCRIPTION
1.3.2.1.1	PRIMARY STRUCTURE
1.3.2.1.2	SECONDARY STRUCTURE
1.3.2.1.3	CONCENTRATOR
1.3.2.1.4	SOLAR BLANKET
1.3.2.1.5	SWITCHGEAR AND CONVERTERS
1.3.2.1.6	CONDUCTORS AND INSULATION
1.3.2.1.7	ACS HARDWARE
1.3.2.1.8	INFO MANAGEMENT AND CONTROL

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.1 PRIMARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	30890.0000	TF=	1.000000	CDCER=	0.023000
M=	2059.00000	O&M=	0.0	CDEXP=	0.800000
CF=	1.000000	Z1=	6.000000	CICER=	0.000050
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			3.930
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.103
#RM =T / M		15.002	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			9.267
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.544
CIPS=CTB*Z4/Z2			0.566
CRCI =CTB X R			0.005
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.017

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.2 SECONDARY STRUCTURE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	14918.0000	TF=	1.000000	CDCER=	0.156000
M=	5.000000	O&M=	0.0	CDEXP=	0.511000
CF=	1.000000	Z1=	6.000000	CICER=	0.101000
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.355000
R=	0.003500	Z3=	44.000000		
DF=	0.050000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			4.582
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.179
#RM =T / M	2983.600		
E =1.0 + LOG(PHI) / LOG(2.0)	0.971		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			2478.750
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			389.820
CIPS=CTB*Z4/Z2			142.934
CRCI =CTB X R			1.364
CC&M = O&M OR CTB*Z5/Z2/ENYR			4.331

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.3 CONCENTRATOR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1800000.00	TF=	1.000000	CDCER=	0.027000
M=	450000.000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	6.000000	CICER=	0.000003
PHI=	0.980000	Z2=	60.000000	CIEXP=	0.950000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	SQ M	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.685
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.704
#RM =T / M		4.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			15.818
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			2.494
CIPS=CTB*Z4/Z2			0.914
CRCI =CTB X R			0.009
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.028

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.4 SOLAR BLANKET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	900000.000	TF=	1.000000	CDCER=	0.161400
M=	18750.0000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	6.000000	CICER=	0.000067
PHI=	0.990000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003500	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	SQ M	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			7.664
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.256
#RM =T / M		48.000	
E =1.0 + LOG(PHI) / LOG(2.0)		0.986	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			338.117
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			54.757
CIPS=CTB*Z4/Z2			20.077
CRCI =CTB X R			0.192
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.608

COMMENTS

NASA/ADL NAS 9-15294 MARCH 1978

$67/SQ M

MTLS $33/SQ M & PROCESSING $34/SQ M.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.5 SWITCHGEAR AND CONVERTERS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	2875.00000	TF=	1.000000	CDCER=	0.158000
M=	719.000000	O&M=	0.0	CDEXP=	0.297000
CF=	1.500000	Z1=	6.000000	CICER=	0.000400
PHI=	0.950000	Z2=	60.000000	CIEXP=	1.000000
R=	0.001111	Z3=	44.000000		
DF=	0.500000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.054
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.431
#RM =T / M		3.999	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8.760
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.268
CIPS=CTB*Z4/Z2			0.465
CRCI =CTB X R			0.001
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.014

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.6 CONDUCTORS AND INSULATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	357675.000	TF=	1.000000	CDCER=	0.158000
M=	7452.00000	O&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	6.000000	CICER=	0.000004
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.001111	Z3=	44.000000		
DF=	0.020000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			2.205
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.030
#RM =T / M	47.997		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			8.584
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			1.431
CIPS=CTB*Z4/Z2			0.525
CRCI =CTB X R			0.002
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.016

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.7 ACS HARDWARE

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	283557.000	TF=	0.093800	CDCER=	1.122000
M=	1970.00000	O&M=	0.0	CDEXP=	0.190000
CF=	1.000000	Z1=	6.000000	CICER=	0.057000
PHI=	0.950000	Z2=	60.000000	CIEXP=	0.729000
R=	0.003500	Z3=	44.000000		
DF=	0.300000	Z4=	22.000000	Z5=	20.000000

CALCULATED VALUES	KG	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			9.697
CLRM=CICER X (M)XX(CIEXP) X CF X TF			1.348
#RM =T / M		143.938	
E =1.0 + LOG(PHI) / LOG(2.0)		0.926	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			762.015
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			109.634
CIPS=CTB*Z4/Z2			40.199
CRCI =CTB X R			0.384
CO&M = O&M OR CTB*Z5/Z2/ENYR			1.218

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.1.8 INFO. MGMT. AND CONTROL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	6.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.3.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		0.0	
E =1.0 + LOG(PHI) / LOG(2.0)		0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.3.2.2 COTV OPERATIONS

Necessary vehicle operations (user charge per flight including payload integration) is included in this element.

The flight life of the EOTV is estimated at 20 round trips from LEO to GEO. Four hundred forty-four flights are required for the construction of 60 satellites and an additional 396 flights will maintain the operational satellites for the 30 year period. Seven flights are required to build the first satellite.

The calculations used in this cost estimate are presented in Table 1.3.2.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.2.2 COTV OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	7.000000	CICER=	0.630000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	840.000000		
DF=	1.000000	Z4=	444.000000	Z5=	396.000000

CALCULATED VALUES FLIGHT SUM TO 1.3.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.630
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		4.410
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.630
CIPS=CTB*Z4/Z2		4.662
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.139

COMMENTS

1.3.3 PERSONNEL LAUNCH VEHICLE (PLV)

This element includes the space shuttle growth vehicles and operations required to support the satellite system assembly and operation. Included is the launch to LEO and return of all personnel and priority cargo required throughout the satellite construction period and operational lifetime.

In addition to the earth-to-LEO transfer of personnel during satellite construction and operational periods, the space shuttle growth vehicle will 1) accommodate the transfer of personnel and 2) with the cargo/engine module adaptation, will transfer the cargo/material needed for precursor activities dealing with the LEO Base, Space Construction Base, and the initial EOTV-335 mW precursor test article. Shuttle goowth vehicle and flight requirements for the SPS Grogram are identified in Table 1.3.3.

Table 1.3.3. Shuttle Growth Vehicle and Flight Requirements

VEHICLE/ITEM DESCRIPTION	PRECURSOR PROGRAM	TFU	SATELLITE CONSTRUCTION	SATELLITE O&M	VEHICLE ATTRITION/RCI	TOTAL REQUIREMENTS*	PLV VEHICLE	CARGO VEHICLE
VEHICLE REQUIREMENTS								
SHUTTLE ORBITER (STANDARD VERSION)	(1)	(3)	15	37	26	78	1 EA	
SHUTTLE CARGO CARRIER & MODULE	2				1	3		1 EA
EXTERNAL TANK	(201)	(60)	1541	3694		5235	1 EA	1 EA
LIQUID ROCKET BOOSTER	(6)	(10)	34	74	216	324	2 EA	2 EA
FLIGHT REQUIREMENTS								
PERSONNEL LAUNCH VEHICLE (PLV)	(72)	(60)	1412	3694		5106		
CARGO CARRIER LAUNCH VEH. MODULE	129-					129		

* Precursor & TFU requirements included in satellite construction quantity.

The Personnel Launch Vehicle (PLV) is described in section 1.3.3.1 along with the Shuttle derived cargo carrier and engine module required to support the precursor program. PLV operations are described in section 1.3.3.2. The Personnel Module is covered in section 1.3.5.1.

1.3.3.1 PLV FLEET

This element includes the vehicle fleet procurement required to support the SPS program. Included are the vehicles for personnel transfer from earth to LEO and for cargo as needed to support the precursor phase of SPS program development.

The PLV consists of a standard Shuttle Orbiter, an external tank, and two liquid rocket boosters. The cargo vehicle configuration is achieved by replacing the orbiter with a cargo carrier and engine module. The external tank and liquid rocket booster (Figure 1.3.3) are common systems used on the Shuttle derived personnel and cargo vehicles. The integral, SSME-35 powered concept requires four engines with a thrust-to-weight ratio at lift-off of 1.335, which is adequate for both nominal and abort trajectories.

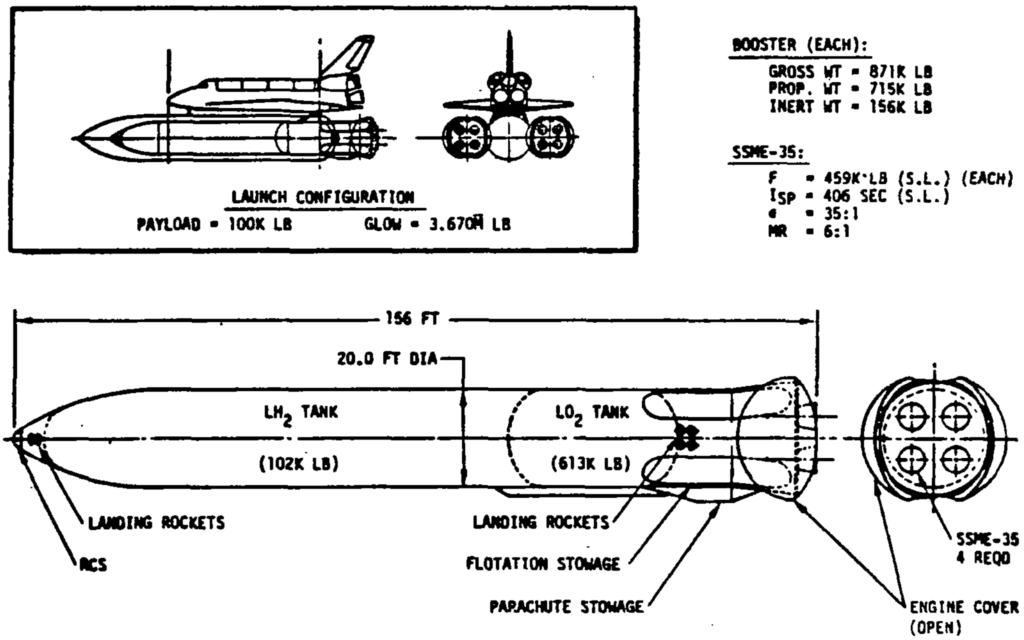


Figure 1.3.3. PLV Configuration

Cost estimates were developed from work produced under the Rockwell Shuttle Growth Study Contract NAS8-32015 of May, 1977. DDT&E, Shuttle Orbiter, external tank, liquid rocket booster, the engine module costs, and projections on operational requirements were identified by comparative evaluation with the Shuttle growth data base. Many different concepts for reducing Shuttle operations costs were examined in the study, but overall cost characteristics clearly reflected the choice of propulsion which lead to the SSME-35 powered LRB as a considered alternative.

Elements of the STS PLV and cargo fleet were individually analyzed on the basis of systems per vehicle, vehicle life, asset rep lacement and operational aspects. A PLV orbiter 30 year replacement factor of 0.5 equivalent vehicles was used for each orbiter in the fleet. The external tank is an expended item after each flight and the LRBs are to be replaced on the basis of two boosters for each one in the fleet. An attrition/spares factof of 0.5 equivalent vehicles is also used for the cargo/engine module.

DDT&E and system cost estimates are identified in the following tables:

Table No.	Item
1.3.3.1.1	STS-PLV Orbiter
1.3.3.1.2	STS-PLV External Tank
1.3.3.1.3	STS-PLV Liquid Rocket Booster
1.3.3.1.4	STS-Cargo Carrier and Engine Module

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.1 STS-PLV ORBITER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	3.000000	CICER=	600.000000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.014444	Z3=	78.000000		
DF=	1.000000	Z4=	15.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.3.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		600.000
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.880	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1682.531
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		401.360
CIPS=CTB*Z4/Z2		100.340
CRCI =CTB X R		5.797
CO&M = O&M OR CTB*Z5/Z2/ENYR		8.250

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.2 STS-PLV EXTERNAL TANK

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	261.000000	CICER=	4.000000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	5235.00000		
DF=	1.000000	Z4=	1541.00000	Z5=	3694.00000

CALCULATED VALUES SET SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	4.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	606.205
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	1.623
CIPS=CTB*Z4/Z2	41.679
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	3.330

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.3 STS-PLV LIQ. ROCKET BOOSTER

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1304.00000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	5.000000	CICER=	195.300003
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.060000	Z3=	162.000000		
DF=	1.000000	Z4=	17.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	1304.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	195.300
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	873.985
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	119.967
CIPS=CTB*Z4/Z2	33.991
CRCI =CTB X R	7.198
CO&M = O&M OR CTB*Z5/Z2/ENYR	2.466

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.1.4 STS CARGO CARRIER AND EM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	245.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	3.000000	CICER=	265.800049
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	3.000000		
DF=	1.000000	Z4=	3.000000	Z5=	0.0

CALCULATED VALUES $ SUM TO 1.3.3.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	245.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	265.800
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	745.362
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	248.454
CIPS=CTB*Z4/Z2	12.423
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.3.3.2 PLV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program.

A total of 5,235 flights are required of the Shuttle derived personnel and cargo vehicle -- 1,412 for construction, 3,694 for operations, and 129 for the precursor program. The 1,412 PLV flights for construction include 72 for the precursor effort and 60 for the TFU satellite.

Cost estimates per flight were projected after an engineering analysis of the operational costs and vehicle elements identified in the Rockwell Shuttle Growth Study (NAS8-32015). Tables 1.3.3.2.1 and 1.3.3.2.2 cover operational cost estimates.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.2.1 PLV OPERATIONS

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000		CDCER=	0.0
M=	1.000000	O&M=	0.0		CDEXP=	0.0
CF=	1.000000	Z1=	132.000000		CICER=	9.200000
PHI=	1.000000	Z2=	60.000000		CIEXP=	1.000000
R=	0.0	Z3=	5106.00000			
DF=	1.000000	Z4=	1412.00000	Z5=	3694.00000	

CALCULATED VALUES FLIGHT SUM TO 1.3.3.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		9.200
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1214.400
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		9.200
CIPS=CTB*Z4/Z2		216.507
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		18.880

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.3.2.2 STS HLLV CARGO OPERATIONS

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	129.000000			CICER=	8.750000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	129.000000				
DF=	1.000000	Z4=	129.000000	Z5=	0.0		

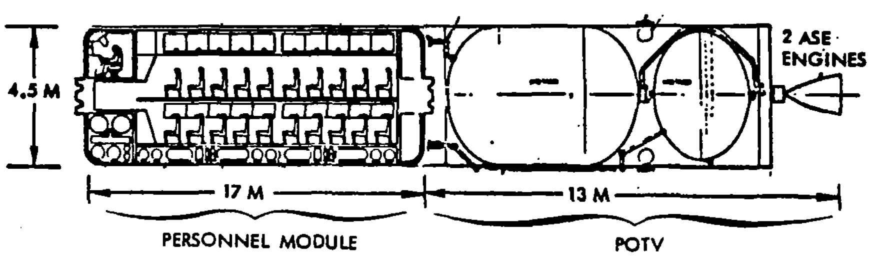
CALCULATED VALUES $ SUM TO 1.3.3.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		8.750
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1128.750
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		8.750
CIPS=CTB*Z4/Z2		18.813
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.3.4 PERSONNEL ORBITAL TRANSFER VEHICLE (POTV)

This element includes the POTV vehicles and operations required to support the satellite system assembly and operation. Included is the LEO-to-GEO and return of all personnel and priority cargo required throughout the satellite construction and operational periods.

All of the POTV options evaluated utilize a single stage propulsive element that is fueled in LEO and refueled in GEO for the return flight. The reference configuration is illustrated in Figure 1.3.4 where the POTV (a propulsive stage) is capable of transporting a 60-man personnel module (PM) of 18,000 kg. The vehicle is costed in section 1.3.4.1 and POTV operations are covered in section 1.3.4.2.



• 60 MAN CREW MODULE	18,000 KG
• SINGLE STAGE OTV (GEO REFUELING)	36,000 KG
• BOTH ELEMENTS CAPABLE OF GROWTH STS LAUNCH	

Figure 1.3.4. POTV Configuration

1.3.4.1 POTV FLEET

The vehicle fleet procurement required to support the SPS program is included in this element. The POTV is a single stage OTV of 36,000 kg with refueling at GEO for the return to LEO. Propellants are carried from LEO to GEO by the EOTV. The SPS HLLV carries the construction, crew expendables, and POTV propellants to LEO. The Shuttle Orbiter carries the crew in a personnel module (PM) to LEO for transfer to the POTV.

The single stage OTV configuration selected is a scaled version of those concepts presented in the BAC FSTSA NAS9-24323 contract and engineering analyses presented in Exhibits A/B of the Rockwell contract NAS8-32475. DDT&E estimates considered fewer engines, a significant difference in mass, and the degree of development required for the engines. Engineering analyses of available vehicle estimates projected a POTV cost based on the design and complexity of the vehicle.

POTV cost estimates are presented in Table 1.3.4.1 for a total fleet of 196 vehicles with: 1) 12 for personnel involved in satellite construction, 2) 37 for SPS operational activities, and 3) an attrition factor of 3 equivalent vehicles to keep the fleet fully operational.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.4.1 POTV-FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	350.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	15.000000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.081667	Z3=	196.000000		
DF=	1.000000	Z4=	12.000000	Z5=	37.000000

CALCULATED VALUES SET SUM TO 1.3.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	350.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	15.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	54.764
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	9.010
CIPS=CTB*Z4/Z2	1.802
CRCI =CTB X R	0.736
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.185

COMMENTS

1.3.4.2 POTV OPERATIONS

This element includes the necessary vehicle operations (user charge per flight including payload integration) required to support the SPS program with required personnel.

The primary operational cost of the POTV is the cost of fuel. A total of 4,880 flights were costed on this basis where 1,220 flights were for satellite construction; 3,660 for operations and maintenance; and 45 of the 1,220 needed to support TFU activities. Table 1.3.4.2 presents the results of this analysis.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.4.2 POTV-OPERATIONS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	45.000000			CICER=	0.033742
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	4880.00000				
DF=	1.000000	Z4=	1220.00000	Z5=	3660.00000		

CALCULATED VALUES	$	SUM TO 1.3.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.034
#RM =T / M	1.000		
E =1.0 + LOG(PHI) / LOG(2.0)	1.000		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			1.518
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.034
CIPS=CTB*Z4/Z2			0.686
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.069

COMMENTS

1.3.5 PERSONNEL MODULE (PM)

This element includes the PM units and operations required to support the satellite system assembly and operation. Included in the earth-to-LEO-to-GEO and return transfer of all personnel and critical hardware items required throughout the satellite construction and operational periods. The PM provides a crew habitat during the orbit-to-orbit transfers of personnel as well as during the trip from earth. An illustration of the PM was shown in Figure 1.3.4. It has a 60-man capacity and is approximately 17 m long by 4.5 m in diameter. The Shuttle is used for the earth-to-LEO transfer and the POTV handles the round trip movement from LEO-GEO-LEO.

1.3.5.1 PM FLEET

Procurement of the PM as required to support the SPS program is covered in this element. The PM is operated by a pilot and co-pilot and contains the major systems of life support, communication, seating, and support facilities. A total of 4 PMs are needed to support the program and 2 equivalent PMs are considered sufficient to provide spares and major overhaul components during the program. Four vehicles will be required to build the satellite TFU and early program supporting elements such as the LEO Base and SCB.

Engineering cost projections were based on Rockwell company-funded studies of 1976 where DDT&E, a pair of 68 passenger modules, and the orbiter modification kits were costed from internal design specifications. PM fleet procurement costs are presented in Table 1.3.5.1.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.5.1 PM FLEET

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	118.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	54.399994
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.004444	Z3=	12.000000		
DF=	1.000000	Z4=	1.000000	Z5=	3.000000

CALCULATED VALUES SET SUM TO 1.3.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	118.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	54.400
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.880
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	198.610
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	44.737
CIPS=CTB*Z4/Z2	0.746
CRCI =CTB X R	0.199
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.075

COMMENTS

1.3.5.2 PM OPERATIONS

This element includes the necessary operations (user charge per flight including payload integration) required to support the SPS program.

A PM crew (pilot and co-pilot) will command the module during earth-to-LEO trips on the Shuttle and complete the procedures of leaving the Shuttle and making the POTV hook-up for transfer to GEO. The crew will monitor passenger off-loading/transfer to and from the LEO Base, SCB, or satellite O&M Base. Two man-days are calculated per trip which includes a rest period at GEO and a day off after the trip. An average of 4,993 round trip flights are projected from earth to GEO and back. A total of 132 flights are needed for the precursor and TFU programs. The engineering estimates of PM operations are presented in Figure 1.3.5.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.5.2 PM OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	132.000000	CICER=	0.025000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	4993.00000		
DF=	1.000000	Z4=	1316.00000	Z5=	3677.00000

CALCULATED VALUES FLIGHT SUM TO 1.3.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.025
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		3.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.025
CIPS=CTB*Z4/Z2		0.548
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.051

COMMENTS

1.3.6 INTRA-ORBITAL TRANSFER VEHICLE (IOTV)

This element includes the IOTV vehicles and operations required to support the satellite system assembly and operation. Included is the intra-orbit transfer of cargo between the HLLV, EOTV, construction facility, logistics support facility, and operational satellites.

1.3.6.1 IOTV FLEET

This element includes the necessary vehicle fleet procurement required to support the SPS program. The IOTV has been synthesized in terms of application and concept only. IOTV elements considered here are powered by a chemical (LOX/LH_2) propulsion system. At least three distinct applications have been identified; (1) the need to transfer cargo from the HLLV to the EOTV in LEO and from the EOTV to the SPS construction base in GEO; (2) the need to move materials about the SPS construction base; and (3) the probable need to move men or materials between operational SPSs. Clearly the POTV, used for transfer of personnel from LEO to GEO and return, is too large to satisfy all intra-orbit requirements. A "free-flyer" teleoperator concept would appear to be a logical solution to the problem. A propulsive element was synthesized to satisfy the cargo transfer application from HLLV-EOTV-SPS base in order to quantify potential on-orbit propellant requirements. Pertinent IOTV parameters are summarized in Table 1.3.6.

Table 1.3.6. IOTV Design Parameters

SUBSYSTEM	WEIGHT (kg)
ENGINE (1 ASE)	245
PROPELLANT TANKS	15
STRUCTURE AND LINES	15
DOCKING RING	100
ATTITUDE CONTROL	50
OTHER	100
SUBTOTAL	525
GROWTH (10%)	53
TOTAL INERT	578
PROPELLANT	300
TOTAL LOADED	878

A total of 840 IOTVs are needed to maintain intra-orbit cargo/operations flow during the program. One hundred ten vehicles will accomplish the construction phase and 100 vehicles are needed for satellite O&M. An attrition/spares fleet of equivalent vehicles was projected on the ratio of 3 units for each of the operational vehicles.

Cost estimates for the IOTV are engineering assessments based on POTV designs and similarities such as those of the common advanced space engine (ASE). Table 1.3.6.1 displays the applicable cost data.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.6.1 IOTV FLEET

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	1.000000	TF=	1.000000	CDCER=	100.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	1.500000
PHI=	0.920000	Z2=	60.000000	CIEXP=	1.000000
R=	0.350000	Z3=	840.000000		
DF=	1.000000	Z4=	110.000000	Z5=	100.000000

CALCULATED VALUES SET SUM TO 1.3.6		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		100.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		1.500
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.880	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		5.476
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.758
CIPS=CTB*Z4/Z2		1.389
CRCI =CTB X R		0.265
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.042

COMMENTS

1.3.6.2 IOTV OPERATIONS

This element includes the necessary vehicle operations and propellant costs required to support the SPS program. It includes the on-orbit operational cost of transferring cargo at LEO and GEO.

A total of 41,940 IOTV flights are planned for LEO and GEO construction and operations/maintenance requirements of the program. The 22,811 flights needed for construction and the 19,979 for operations and maintenance are considered as equal missions for the purpose of costing. The propellant requirements were averaged and calculated at 1977 dollars of \$0.07/kg for LO_2 and \$3.27/kg for LH_2. A 40% mark-up was added per flight for other operational and maintenance charges. See Table 1.3.6.2.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.6.2 IOTV OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	408.000000	CICER=	0.000222
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	41940.0000		
DF=	1.000000	Z4=	21961.0000	Z5=	19979.0000

CALCULATED VALUES FLIGHT SUM TO 1.3.6		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.000
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.091
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.000
CIPS=CTB*Z4/Z2		0.081
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.002

COMMENTS

1.3.7 GROUND SUPPORT FACILITIES

This element includes all land, buildings, roads, shops, etc., required to support the cargo handling, launching, recovering, refurbishment, and operations of the space transportation system.

1.3.7.1 LAUNCH FACILITIES

This element includes the design and construction of the actual launch facility and its associated equipment. Included are land, buildings, and equipment required to support the various crews. It also includes the required control centers and administrative facilities.

1.3.7.2 RECOVERY FACILITIES

This element covers the design, construction, and equipping of the actual recovery facilities.

1.3.7.3 FUEL FACILITIES

This element includes fuel production facilities, storage and handling facilities, transportation, and delivery and safety facilities for both the fuel and the oxidizer. Also included are the facilities for fuels used in the various orbital transfer facilities.

1.3.7.4 LOGISTICS SUPPORT

This element includes the land, buildings, and handling equipment for the receiving, inspection, and storage and packaging of all payloads to be launched except for fuels and oxidizers.

1.3.7.5 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground support facilities. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground support facilities operation and maintenance.

A cost estimate for ground support facilities is projected in Table 1.3.7 based on the Boeing final report, NAS9-14710, dated September 1977, Volume 4, Cost Estimates. It is judged that there is little difference in the cost of facilities in this report as compared with those projected for the transportation and operations requirements of this study.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.3.7 GROUND SUPPORT FACILITIES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1720.00000
M=	1.000000	O&M=	1.775000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	3195.00000
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.001111	Z3=	1.000000		
DF=	1.000000	Z4=	1.000000	Z5=	0.0

CALCULATED VALUES SUM TO 1.3	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	1720.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	3195.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	3195.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	3195.000
CIPS=CTB*Z4/Z2	53.250
CRCI =CTB X R	3.550
CO&M = O&M OR CTB*Z5/Z2/ENYR	1.775

COMMENTS

1.4 GROUND RECEIVING STATION

The ground receiving station (GRS) is designed to accept power from a single satellite and to provide a nominal 5 GW of power to the utility interface. As shown in Figure 1.4-1, a typical receiving station would be located at 34° N latitude with rectenna panels covering an elliptical area of 13 km in the north-south direction and 10 km in the east-west direction. This area is surrounded by another elliptical segment to house the power conversion equipment and to provide for the operational facilities of the receiving station. A summary of point design characteristics are presented in Table 1.4-1.

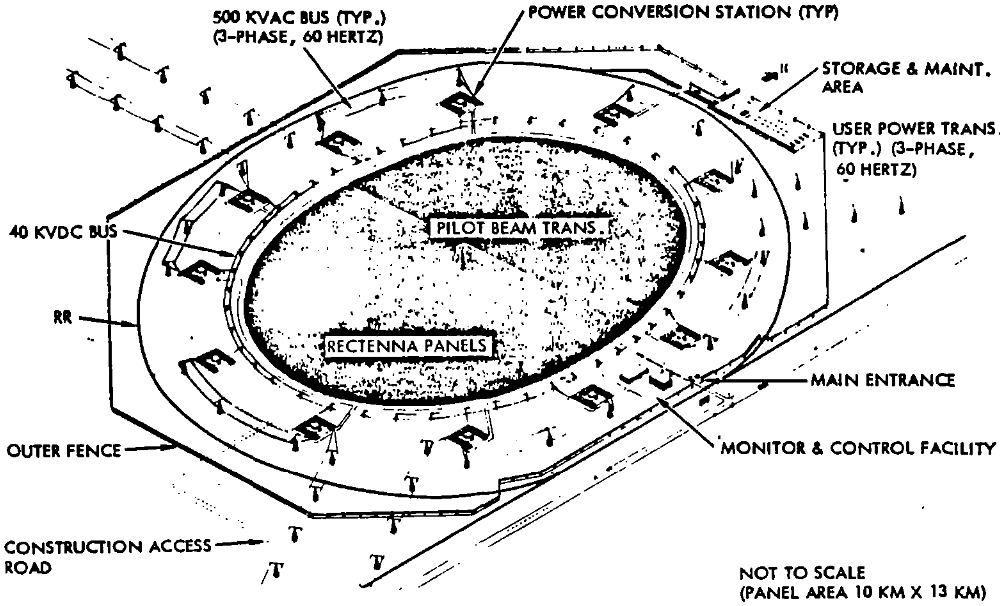


Figure 1.4-1. Operational Ground Receiving Facility (Rectenna) - Typical

Table 1.4-1. System Point Design Characteristics

SIZE (km)	10×13
TOTAL GROUND AREA (km)²	102.1
TOTAL PANEL AREA (km)²	79.53
AREA PER PANEL (9.33×14.69 m)	137.0
NUMBER OF PANELS	580,500
NUMBER OF DIODES	330×10⁶
RECTENNA EFFICIENCY (%)	89
VOLTAGE OUTPUT PER STRING (kV dc)	40+
VOLTAGE OUTPUT TO UTILITY (kV ac)	500
POWER OUTPUT (GW) AT UTILITY INTER-TIE	4.61*
*BASED UPON 5.53 GW INCIDENT RADIATION	

This ground based element of the SPS is comprised of the land, facilities, equipment, and hardware/software systems to receive the radiated microwave power beam and to provide the power at the required voltage and type of current for entry into the national power grid. It also includes the equipment, facilities, and hardware/software necessary to provide operational control over the satellite; and a reliable means of monitoring and controlling ground based systems and equipment.

Major objectives of the SPS ground system design are: (1) to provide low maintenance subsystems and equipment capable of handling the designed power levels; (2) to assure that the overall station will provide dependable service for at least 30 years; (3) to minimize the size of operational crews and costs; and (4) to economically optimize system performance.

There are nine major activities involved in the overall GRS construction process. After the survey and clearing, utilities and supporting facilities are installed while the site is leveled and graded. Trenching and concrete pouring precede the installation of rectenna panels, after which electrical hook-up, converter stations, and monitoring facilities are installed. The 40 kV dc and 500 kV ac buses are then interconnected and procedures take place for system checkout. Cost effective utilization of equipment and personnel was identified after the development and integration of detail phasing schedules on each of the first four ground stations. Contacts with A&E, equipment manufacturers, concrete, and construction firms provided additional information on the duration and sequence of operations based on their experience with programs of this type. Figure 1.4-2 is an integrated summary schedule of major events in constructing the ground receiving station where emphasis is placed on the utilization of construction equipments and their transfer from site to site as required to maintain the build rate of two stations per year. It was concluded that the equipment from Site 1 would be available for use on Site 3. This information on equipment/manpower utilization, site sequencing, and equipment lifetimes is used in this analysis to establish total resource requirements for the program.

The ground receiving station was divided into several main elements for the purpose of associating cost and programmatic definitions. These elements include (1) site and facilities, (2) rectenna support structure, (3) power collection, (4) control, (5) grid interface, and (6) operations. SPS design definitions and specification requirements were analyzed to provide realistic cost estimates and resource definitions for each element as explained in the following sections.

Internal resources, cost estimating relationships, and prior cost analyses were supplemented by: 1) direct contact with business, industry, and institutional organizations, and 2) a literature search of various publications to obtain realistic cost estimates and operational definitions directly applicable to the unique requirements of the GRS. A list of principal organizations and literature sources are presented in Table 1.4-2.

A summary of the costs associated with the GRS is presented in Table 1.4-3. The detail supporting these costs is presented in the subsequent pages of this section.

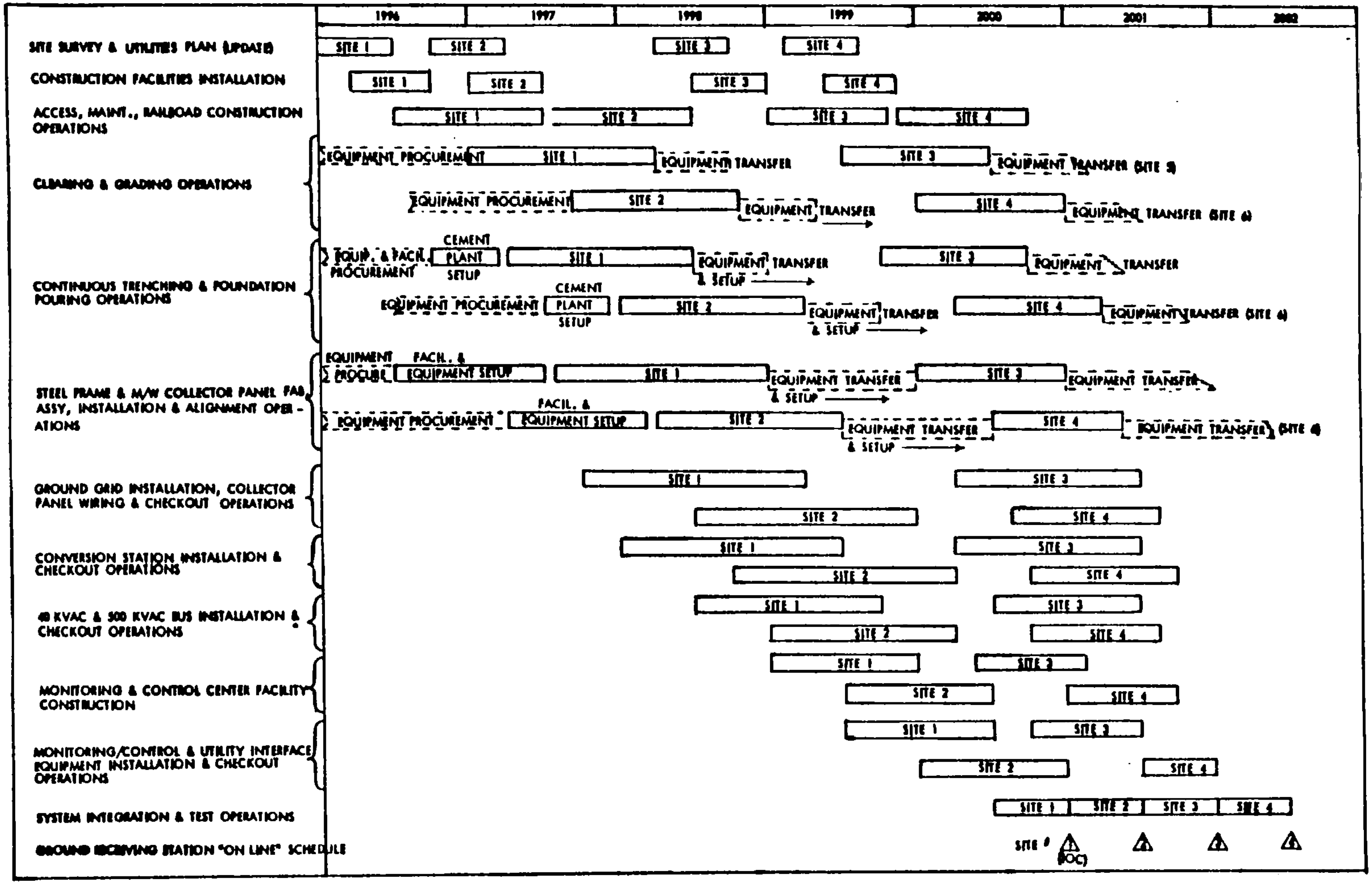


Figure 1.4-2. Rectenna Construction Sequence Summary Schedule

Table 1.4-2. Organizations and Literature Sources Supporting GRS Definition

ORGANIZATION	PURPOSE
• AMERICAN BRIDGE - A DIVISION OF U.S. STEEL	TO DEVELOP STEEL REQUIREMENTS, COSTS AND OPERATIONS DEFINITION FOR PROCUREMENT AND INSTALLATION OF RECTENNA SUPPORT STRUCTURE
• RIVERSIDE CEMENT - A DIVISION OF AMERICAN CEMENT CORPORATION; AND C. S. JOHNSON, CO.	PROVIDE CONSULTATION ON CEMENT/CONCRETE SPECIFICATIONS, OPERATIONAL METHODS, PROCESSING/HANDLING EQUIPMENT, AND CONCRETE PLANT
• TOWNSEND & BOTTUM, INC., CONSTRUCTION MANAGER, TEN MW SOLAR PLANT - BARSTOW, CA.	DISCUSS SITE PREPARATION, CONSTRUCTION OPERATIONS/SEQUENCING, PLUS ACTIVATION REQUIREMENTS
• SOUTHERN CALIFORNIA EDISON	TO DISCUSS DC/AC POWER DISTRIBUTION AND CONVERSION REQUIREMENTS, AND OBTAIN COST ESTIMATES ON INSTALLATION OF LINES/TOWERS
• MODERN ALLOYS, INC.; AND MILLER FORMLESS CO.	TO DISCUSS USE AND APPLICATION OF EQUIPMENT/CREW FOR CONTINUOUS CONCRETE POUR OF RECTENNA SUPPORT STRUCTURE FOOTINGS
• CATERPILLAR; INTERNATIONAL HARVESTER; AND JETCO, INC.	OBTAIN PRICES ON EARTH MOVING, GRADING AND TRENCHING EQUIPMENT
LITERATURE SOURCES	
• THE RICHARDSON RAPID SYSTEM 1978-1979 EDITION	CONSTRUCTION LABOR AND OPERATIONS PRICES
• ENGINEERING NEWS RECORD - 1977 A WEEKLY McGRAW-HILL PUBLICATION	CEMENT, AGGREGATE AND LABOR PRICES
• NATIONAL CONSTRUCTION ESTIMATING GUIDE (NCE)	CONSTRUCTION OPERATIONS

Table 1.4-3. GRS Cost Summary ($ Millions)

WBS NO.		DDT&E	TFU	ICI	RCI/ O&M
1.4.1	SITE AND FACILITIES	1.0	195.2	188.9	.2
1.4.2	RECTENNA SUPPORT STRUCTURE	2.0	1849.6	1828.	.5
1.4.3	POWER COLLECTION	3.0	1353.2	1353.2	-
1.4.4	CONTROL	10.0	75.0	75.0	-
1.4.5	GRID INTERFACE	99.7	145.7	145.7	-
1.4.6	OPERATIONS	-	-	-	77.9

1.4.1 SITE AND FACILITIES

The ground receiving station is located on a site of 35,000 acres where over 25,000 acres of a central ellipse, or 72% of the total acreage, is used for rectenna panels. The area surrounding the inner ellipse is allocated for maintenance/control facilities, access roads, converter stations, and the rows of towers that support the 40 kW dc and 500 kV ac cables. The GRS perimeter is fenced for security reasons.

The sequence of construction operations begins with site identification, environmental impact studies, zoning/permits, surveys, utility/road installation, and supporting facilities. After reference coordinates are established, the site is cleared, leveled, and followed with precise grading for panel foundations, fabrication facilities, installation and GRS site completion. This includes concrete mixing plants, rectenna panel fabrication factories, crew accommodations, warehousing, and support facilities as shown in Figure 1.4-3. The GRS DDT&E effort will be a valuable asset to all GRS sites by providing designs, analyses, and procurement specifications for commonly used buildings and facilities.

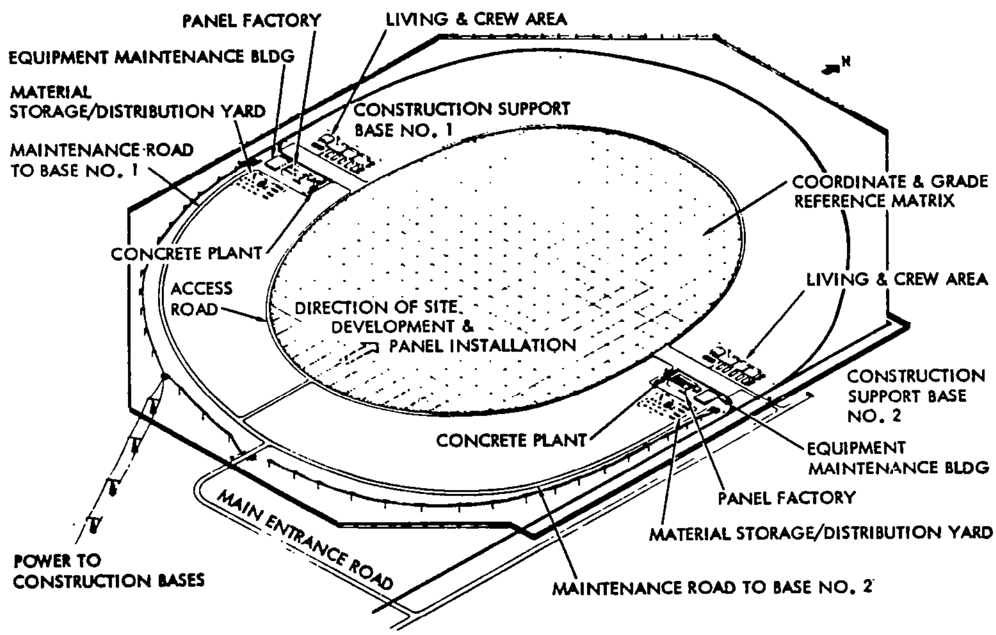


Figure 1.4-3. Support Facilities

Clearing and leveling operations will occur at a number of locations within the panel farm perimeter. These operations consist of tree removal (if required), grading, and leveling the terrain to acceptable slope angles, and removing excess dirt. Sixteen areas of the ellipse would be cleared and leveled simultaneously. Bulldozers will make the initial cut, scrapers will grade to more precise requirements, and an estimate was made of one crew of 13 men to grade eight acres per day. The crew and equipment required to prepare a 35,000 acre site was established based on a single shift that would level 130 acres per day to meet a nine month schedule.

Costs developed for the site and facilities are divided into the elements of land, site preparation, roads and fence, utilities, buildings and facilities, maintenance equipment, lightning protection, and DDT&E. Basic design parameters used in this costing are presented in Table 1.4-4. The DDT&E, investment, and operations cost established for each element are tabulated as follows:

Table 1.4-4. Site and Facilities Requirements

ITEM	UNIT PARAMETER
LAND/FENCING	35,000 ACRES
GRADING/LEVELING	HEAVY EQUIPMENT/CREW SIZE
PREPARATION	SURVEY, EIR, PERMITS, A&E PLANNING
UTILITIES	WATER, ELECTRICITY, GAS, SEWAGE
ROADS/RAILS	ROADS 35 MILES; RAILS 45 MILES
FACILITIES	CONVERSION STATION, MONITOR & CONTROL, MAINTENANCE/STORAGE
DRAINAGE	6" GRAVEL FOR COMBINATION ACCESS-WAY & DRAINAGE BETWEEN PANEL ROWS
LIGHTNING PROTECTION	TBD

Table 1.4.1.1 Land and Preparation (Land - 1.4.1.1.1, Preparation - 1.4.1.1.2)

Table 1.4.1.2 Roads and Rences (Rails & Roads - 1.4.1.2.1, Fencing - 1.4.1.2.2)

Table 1.4.1.3 Utilities

Table 1.4.1.4 Buildings and Facilities (Storage/Maintenance - 1.4.1.4.1, Converter Station - 1.4.1.4.2)

Table 1.4.1.5 Maintenance Equipment

Table 1.4.1.6 Lightning Protection System

Table 1.4.1.7 Site & Facilities DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.1.1 LAND

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	35000.0000	TF=	1.000000	CDCER=	0.0
M=	35000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.001000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	ACRES	SUM TO 1.4.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			35.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			35.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			35.000
CIPS=CTB*Z4/Z2			35.000
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.1.2 LAND PREPARATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=.	35000.0000	TF=	1.000000	CDCER=	0.0
M=	35000.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.002007
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	ACRES	SUM TO 1.4.1.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			70.245
#RM =T / M			1.000
E =1.0 + LOG(PHI) / LOG(2.0)			0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.341
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			64.119
CIPS=CTB*Z4/Z2			64.119
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.2.1 RAILS AND ROADS

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	73.710007
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.1.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	73.710
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	73.710
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	73.710
CIPS=CTB*Z4/Z2	73.710
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.2.2 FENCING

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	42671.0000	TF=	1.000000	CDCER=	0.0
M=	42671.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000011
PHI=	0.980000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES M SUM TO 1.4.1.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.469
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.470
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.428
CIPS=CTB*Z4/Z2		0.428
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.3 UTILITIES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.200000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.200
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.200
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.200
CIPS=CTB*Z4/Z2		0.200
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.4.1 STORAGE,MAINTENANCE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	1.300000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUFS $ SUM TO 1.4.1.4		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		1.300
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1.300
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		1.300
CIPS=CTB*Z4/Z2		1.300
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.4.2 CONV. STA. & MONITOR/CONTROL FAC.

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	21290.0000	TF=	1.000000	CDCER=	0.0
M=	21290.0000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000478
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	SQ M	SUM TO 1.4.1.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			10.177
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			10.177
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			10.177
CIPS=CTB*Z4/Z2			10.177
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.5 MAINTENANCE EQPT.

INPUT PARAMETERS					INPUT COEFFICIENTS
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	4.000000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.050000	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			4.000
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			4.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			4.000
CIPS=CTB*Z4/Z2			4.000
CRCI =CTB X R			0.200
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.6 LIGHTNING PROTECTION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	O&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M	0.0		
E =1.0 + LOG(PHI) / LOG(2.0)	0.0		
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.1.7 SITE & FACILITIES DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	1.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	$	SUM TO 1.4.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			1.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.0
#RM =T / M		1.000	
E =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			0.0
CIPS=CTB*Z4/Z2			0.0
CRCI =CTB X R			0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

1.4.2 RECTENNA SUPPORT STRUCTURE

The rectenna farm area of 102.1 $(km)^2$ is covered by 580,500 panels that have a total mW intercept area of 79.53 $(km)^2$. Each panel (9.33 m × 14.69 m) is tilted at an angle of 40° to the horizontal and is mounted on two continuous ribbons of concrete as shown in Figure 1.4-4. The procurement, fabrication, assembly and installation of the steel rectenna support structure, and the supporting foundation placement are costed in this section and represent the results of consultation and discussions with industrial/construction contacts.

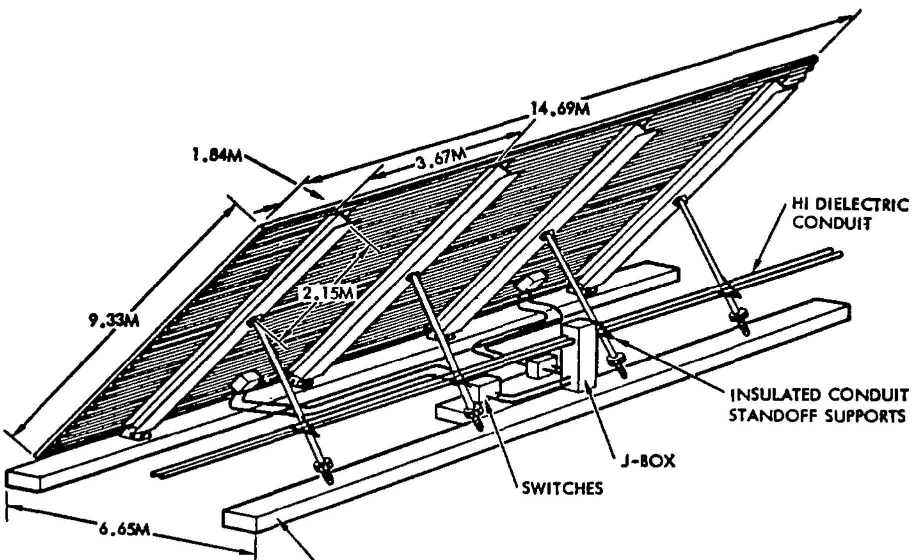


Figure 1.4-4. Panel Installation

1.4.2.1 PANEL STRUCTURE

The rectenna panel structure is comprised of four standard size eight-inch (wide flange) I beams, supporting tube braces, and 18 hat-shaped sections for the mounting of the power collection electronic elements. Tube braces, steel cast fittings and attachment hardware are used to support the panel on the continuous footing as shown in Figure 1.4-5.

A detail analysis of the support structure was completed to identify the amount of material needed; fabrication, operations, assembly, and installation requirements; plus an estimate of manpower and equipments needed to produce the average daily production of 2150 panels over the nine month period. The cost of material for a rectenna panel is shown in 1.4-6.

The rectenna panel hat section serves as a mounting surface for the laminated-copper-clad mylar array elements. (See section 1.4.3, Power Collection). Adhesives will be used to mount the elements to the structure to

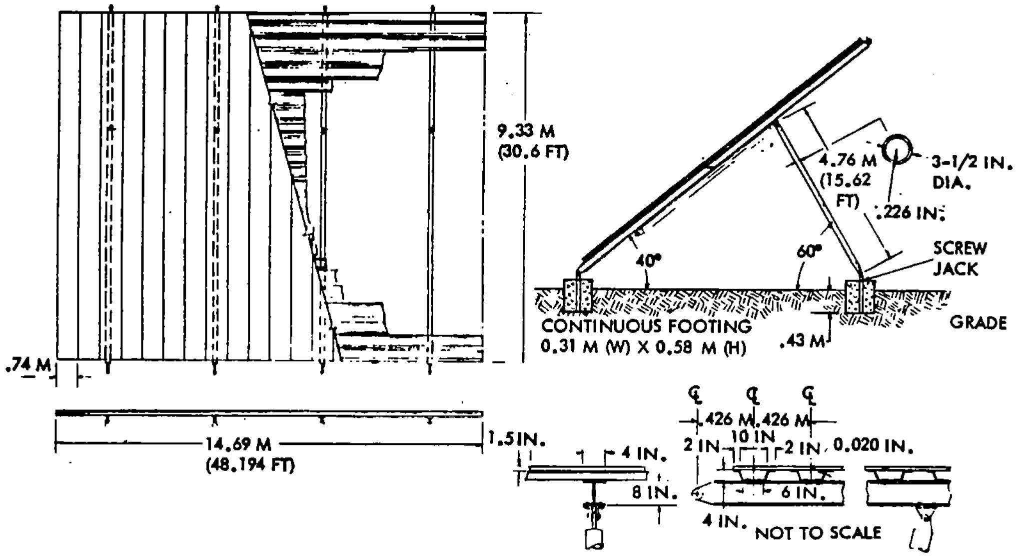


Figure 1.4-5. Rectenna Array Support Structure

ITEM/DESCRIPTION	DIMENSIONAL DATA	NUMBER REQ'D	TOTAL WEIGHT	PREFAB & DELIVERED COST/PANEL (DOLLARS)
HAT SECTIONS	14.69M LONG; 6"; 4"; 2"; .020"	18	1288# 584.25 kg	$618.24
I-BEAMS	9.33M LONG; 3.94"; 0.170; 7.90"; 0.204	4	1589# 720.75 kg	$508.48
TUBE BRACES	4.76M LONG; 0.226"; 3.50"	4	1104# 500.75 kg (tube braces and hardware)	$773.76
HARDWARE FITTINGS & WELDING ROD		4 SETS		
RETURNED SCRAP ALLOWANCE			-307# -139 kg	$30.70
TOTAL MATERIAL PER PANEL			3674# 1666.75 kg	$1869.78

Figure 1.4-6. Rectenna Panel Support Structure

provide continuous support and added strength with a minimum of localized panel deflection.

The basic hat section is formed at the rectenna site from 0.020" galvanized steel sheet stock by processing through a set of forming rollers in a continuous manner. The forming machine (Yoder mill) accommodates widths of rolled mill stock sufficient to produce the finished hat sections ready for assembly to the I-beams.

Four standard wide-flange 8-inch galvanized steel I-beams are required in lengths of 9.33 m for each rectenna panel. This material will be delivered to the site in precut lengths for hole punching and the addition of brackets/machined castings for the support braces and panel mounting.

Four 3.5" diameter tube braces of galvanized steel are cut to a length of 4.76 m and preassembled to the fittings/hardware. Anchors, brackets, clips, hangers, etc., are fabricated or cast of carbon steel material and galvanized prior to machining at the site. All these items are scheduled to combine with the hat sections and I-beams at a centralized facility for assembly. A concept for such a facility is shown in Figure 1.4-7. The factory has multiple assembly lines where each line has a materials feed section, steel assembly facilities, electron ics assembly and checkout section. It was assumed that one line using automated procedures could assemble and checkout a panel in 40 minutes. On this basis, seventy-two assembly lines operating 20 hours per day, seven days a week are required to produce 580,500 panels in the allocated 270 days. Eight additional requirements are summarized in the lower left of the figure.

After the panels have been checked, they are placed on an overhead conveying system and transported to loading stalls, where they are assembled into 9-panel magazines and loaded on specially designed trucks for delivery to the point of installation.

Specialized equipment is required to deliver the panels from the factory to the installation point and to install them because of their large dimensions. After consultation with industrial sources on large equipment handling, a concept for a specialized machine was developed (Figure 1.4-8). The front and rear wheel pairs are each steerable as a unit and have provisions for height adjustment. The panels are transferred in magazines and lifted by means of fixtures mounted in vertical rails. They can be translated laterally and longitudinally for final positioning before attachment to the footings.

1.4.2.2 TRENCHING AND CONCRETE FOOTINGS

A trade-off which considered eight individual footings versus continuous footings was made. A maximum wind force of 90 m/hr was assumed. It was determined that the amount of concrete required for either approach was essentially the same, but that the continuous footing concept was easier to install and required fewer operations and less capital equipment.

Each panel is secured to the footings at eight locations by fixtures which are imbedded in the concrete during the pouring operation. Mounting attachments which provide for longitudinal and lateral adjustment are secured to the fittings. Screw jacks on each of the rear attach points provide for panel adjustment and alignment.

The footings of continuous concrete are 0.43 meters deep, 0.31 meters wide, and project 0.15 meters above ground level. Two footings are excavated simultaneously by trenchers which feed the removed dirt into a truck. Approximately 17×10^6 meters of trenches must be excavated. To accomplish this, 38 trenchers are required, each trencher excavating 90 meters per hour.

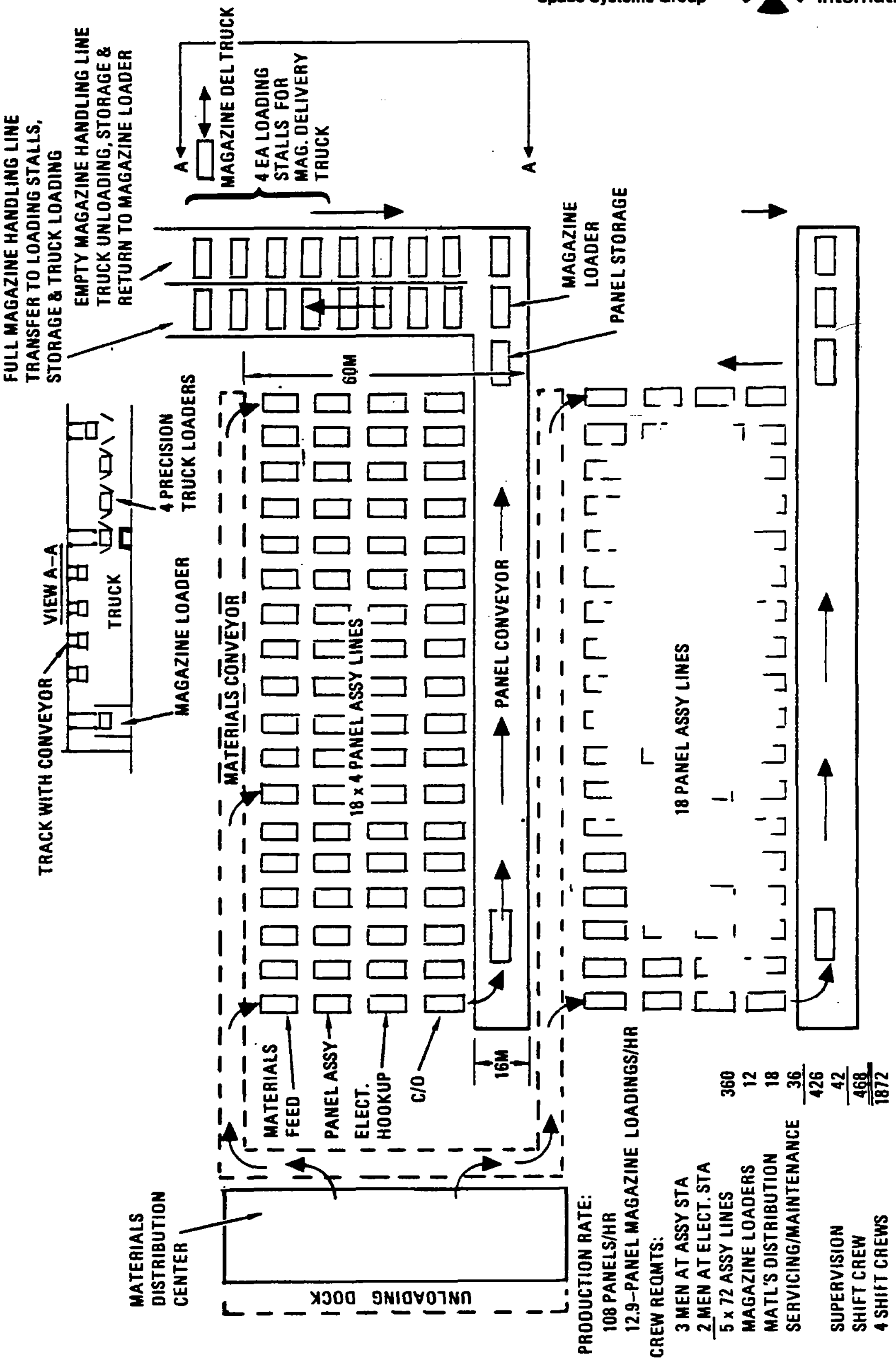


Figure 1.4-7. Central Panel Factory

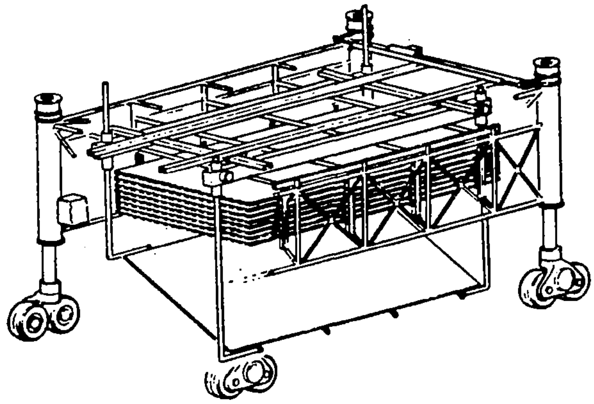


Figure 1.4-8. Panel Loading Sequence

Table 1.4-5 summarizes crew and equipment requirements compatible with the nine month schedule to prepare 1088 panel rows per rectenna.

Table 1.4-5. Concrete Footing Equipment/Crew

ITEM/DESCRIPTION	SITE CONSTRUCTION QUANTITY	1977 UNIT PRICE (DOLLARS)	TOTAL COST
TRENCHERS - JW-2	38	$70,000	$2,660,000
DUMP TRUCKS - 992C	26	$350,000	$9,100,000
CONCRETE DELIVERY VEHICLES - 10 C.Y.	190	$50,000	$9,500,000
CONCRETE FORMING MACHINES	10	$60,000	$600,000
CONCRETE CENTRAL MIX PAVING PLANTS	2	$250,000	$500,000
TOTAL COST			$22,360,000
TRENCHING & CONCRETE CREW PERSONNEL	1480		

Each rectenna panel will be mounted and aligned on 6.8 cu yds of concrete placed by concrete formers such as those commonly used in freeway divider construction. The formers extrude a shaped ribbon at rates of 6 meters per minute. Reinforcing steel and panel attach fittings are inserted as the concrete is vibrated during the extrusion process. Concrete footing requirements for the rectenna panels are shown in Table 1.4-6.

Table 1.4-6. *Concrete Footing Requirements*

ITEM/DESCRIPTION	1977 $ (MILL PRICE DELIVERED)	INGREDIENTS FOR 6.8 CU.YDS.	MATERIAL COST DELIVERED (1977 DOLLARS)
CEMENT (5 SACK) (94# SACK)	$42/TON	3196#	$67.12
SAND	$4.51/TON	9520#	$21.47
ROCK 1"-1½"	$4.39/TON	12444#	$27.31
WATER	-	2040#	Ø
REINFORCING STEEL - #4	$0.10/LB	64#	$6.44
TOTAL/PANEL		27264#	$122.34
DELIVERED 1977 MILL PRICES PER ENGINEERING NEWS RECORD (ENR) - McGRAW HILL, AN INDUSTRY PUBLICATION			

1.4.2.3 COST ESTIMATES

DDT&E, investment, construction/installation, and operations costs of the rectenna support structures (less electronic elements) and the concrete footings are identified in the following tables:

Table 1.4.2.1.1 Hat Sections

Table 1.4.2.1.2 Wide Flanges

Table 1.4.2.1.3 Tube Braces & Hardware

Table 1.4.2.1.4 Assembly & Installation

Table 1.4.2.2.1 Footing Concrete & Rebar

Table 1.4.2.2.2 Machinery & Equipment

Table 1.4.2.2.3 Construction Operations

Table 1.4.2.3 Support Structure DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.1 HAT SECTIONS

INPUT PARAMETERS / **INPUT COEFFICIENTS**

T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000619
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.2.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.001
#RM =T / M	580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		359.228
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		359.224
CIPS=CTB*Z4/Z2		359.224
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

EACH PANEL USES 18 HAT SECTIONS TOTALING 584.25 KG (1288LBS)
WITH COST ESTIMATE(US$) OF
$1.058/KG ($.48/LB).

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.2 WIDE FLANGES

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000508
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL	SUM TO 1.4.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.001
#RM =T / M		580500.000
E =1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		295.173
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	) / Z3	295.170
CIPS=CTB*Z4/Z2		295.170
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.3 TUBE BRACES & HARDWARE

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000743
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.2.1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.001
#RM =T / M	580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		431.346
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		431.343
CIPS=CTB*Z4/Z2		431.343
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS
INCLUDES 4 TUBE BRACES 4.76M LONG,
FRONT & REAR CLEVIS FITTINGS,CAST MOUNTINGS,WELD ROD,
AND PROVIDES FOR OVERALL SCRAP ALLOWANCES.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.1.4 ASSEMBLY & INSTALLATION

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.001052
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES PANEL SUM TO 1.4.2.1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.001
#RM =T / M	580500.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	610.762
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	610.757
CIPS=CTB*Z4/Z2	610.756
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.2.1 FOOTING CONCRETE & RE-BAR

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000122
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	PANEL	SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			0.000
#RM =T / M			580500.000
E =1.0 + LOG(PHI) / LOG(2.0)			1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			70.821
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			70.820
CIPS=CTB*Z4/Z2			70.820
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

CONCRETE ESTIMATED AT 6.8 CU YDS OF 5 SACK CEMENT.
MIX 3196 LBS CEMENT, 9520 LBS SAND,
12444 LBS 1-1.5 INCH ROCK.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.4.2.2.2 MACHINGERY & EQUIPMENT

INPUT PARAMETERS | INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.447200	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	22.360001
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.003333	Z3=	8.000000		
DF=	1.000000	Z4=	2.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	22.360
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	22.360
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	22.360
CIPS=CTB*Z4/Z2	0.745
CRCI =CTB X R	0.075
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.447

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
TABLE 1.4.2.2.3 CONSTRUCTION OPERATIONS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	399600.000	TF=	1.000000	CDCER=	0.0
M=	399600.000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000150
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES	MANDAYS	SUM TO 1.4.2.2	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF			0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF			59.940
#RM =T / M		1.000	
F =1.0 + LOG(PHI) / LOG(2.0)		1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))			59.940
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3			59.940
CIPS=CTB*Z4/Z2			59.940
CRCI =CTB X R			0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR			0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.2.3 SUPPORT STRUCTURE DDT&E

INPUT PARAMETERS					INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000		CDCER=	2.000000
M=	1.000000	O&M=	0.0		CDEXP=	0.300000
CF=	1.000000	Z1=	1.000000		CICER=	0.0
PHI=	1.000000	Z2=	60.000000		CIEXP=	0.0
R=	0.0	Z3=	60.000000			
DF=	1.000000	Z4=	60.000000	Z5=	0.0	

CALCULATED VALUES SET SUM TO 1.4.2		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		2.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.4.3 POWER COLLECTION

This element of the GRS includes the rectenna array elements associated with the actual reception and rectification of the microwave radiation. These elements are in series and parallel as required to deliver the line output voltage and current. Also included are those components that accept the dc power from the array elements and route, control, convert, and switch this power for delivery to the power conversion stations of the grid interface.

The rectifier assembly consists of a GaAs diode and input/output filters. The outputs of the rectifier circuit are series connected to output 40+ kV (Figure 1.4-9). The regulation assembly accepts the voltage from the series connected rectenna diodes and adjusts the voltage output to the power distribution feeders to a value consistent with positive current flow. The rectenna array elements are 0.735×9.33 m in size and 20 elements are combined per panel with diode circuitry equivalent to the mW density pattern. A total of 735 diodes or diode equivalents are required per average panel with a rectenna total of 330×10^6 diodes as shown in Figure 1.4-10.

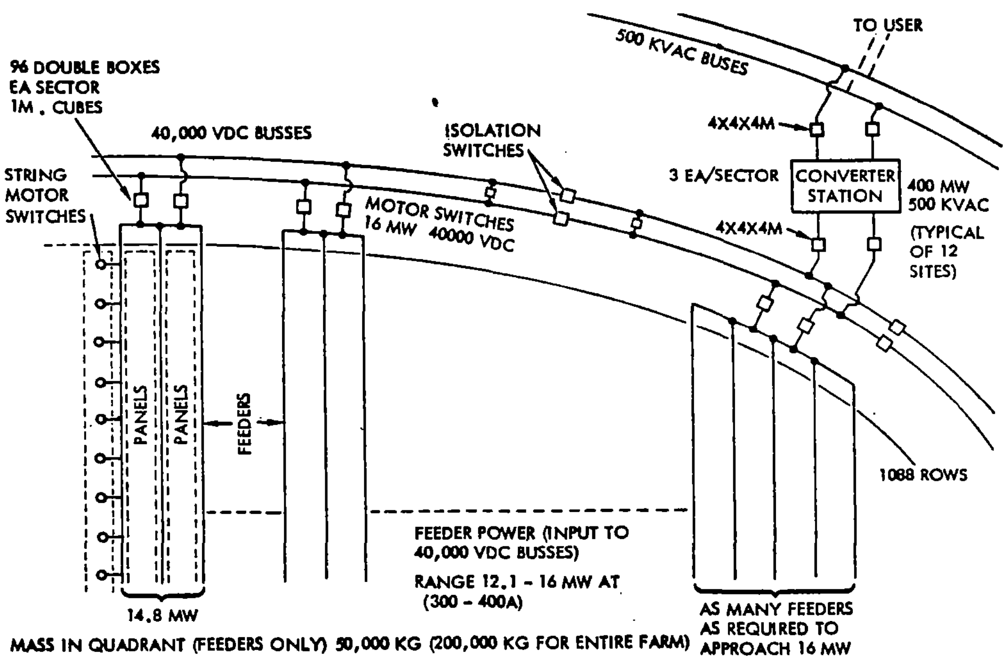


Figure 1.4-9. Rectenna Schematic Block Diagram - Preliminary

The electronic array element of the antenna is a multilayered copper/dielectric sandwich panel material. Resource/mass projections are identified in Table 1.4-7. These calculations were based on the array cross section and panel requirements shown in Figure 1.4-11. Costs were determined from

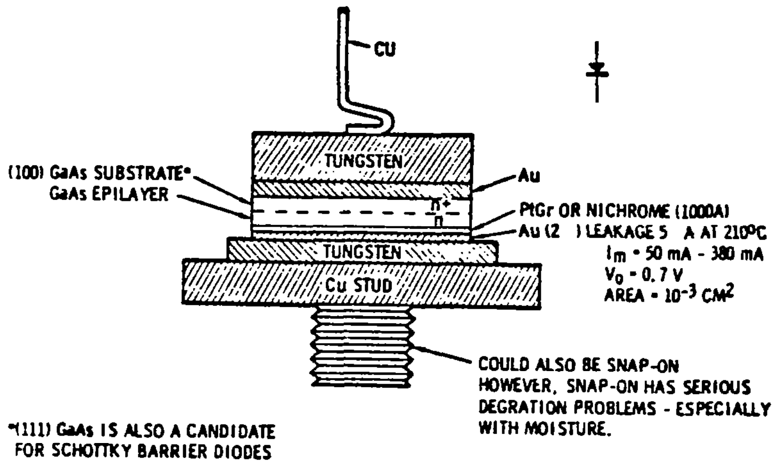


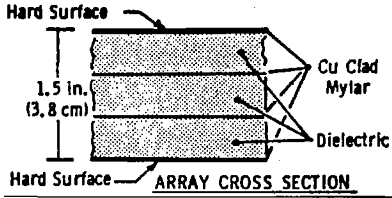
Figure 1.4-10. Diode Concept

Table 1.4-7. Resource Requirements Rectenna Dipole - Bow-Tie - Panel Array Elements

580,500 RECTENNA PANELS	
• DIELECTRIC	
PLASTIC COMPOUND—3.5 LB/FT^3, 0.4375 LB/FT^2 x 856.4 x 10^6 FT^2 -	374.68 x 10^6 LB
• MYLAR	
0.001-IN. THICKNESS AT 87.36 LB/FT^3, 0.02913 LB/FT^2 x 856.4 x 10^6 FT^2 -	24.95 x 10^6 LB
• COPPER	
0.0039 THICKNESS AT 556.6 LB/FT^3, 0.118753 LB/FT^2 x 856.4 x 10^6 FT^2 -	101.70 x 10^6 LB
• DIODES	
1 OZ. PER 426.67 x 10^6 DIODES OR EQUIV. -	26.67 x 10^6 LB
TOTAL	528 x 10^6 LB
	909.6 LB/PANEL 412.6 KG/PANEL

estimating guides/industrial contacts and combined with the cost of switches and regulators needed at each panel to provide a total cost estimate of $1942 for the antenna array elements.

The power collection and distribution system consists of all field feeders (collectors), supporting switchgear, 40 kV dc buses to the power converters, and the towers/footings needed to support the transmission lines. Approximately 330,000 switchgears, 10^7 meters of feeder cables, miscellaneous junction boxes, etc., must be delivered and installed at the panel sites. Tractor/trailer trucks are used for this purpose and proceed through the panel rows,



ARRAY CROSS SECTION

- 20 ARRAY ELEMENTS / PANEL
- 1475 FT^2 (137 M^2) PER PANEL
- 1990 TECHNOLOGY
- 1977 PRICES

• TOTAL PANEL AREA	• 9.33 M x 14.69 M x 580,500 PANELS (30.61 FT x 48.19 FT x 580,500 PANELS	• 79.56 x 10^6 M^2 • 856.4 x 10^6 FT^2)
• DIELECTRIC	0.4375 LB/FT^2 x 856.4 x 10^6 FT^2 @ $0.872/LB	• $326.72 x 10^6
• MYLAR/ SURFACE	4 LAYERS x 856.4 x 10^6 FT^2 @ $0.10 FT^2	• $342.56 x 10^6
• COPPER (PROCESSED / BONDED)	65% COVERAGE x 856.4 x 10^6 FT^2 @ $0.15/$FT^2$	• $ 83.50 x 10^6
• DIODES/EQUIVALENTS/WIRE	426.67 x 10^6 DIODES @ $0.10 EA.	• $ 42.67 x 10^6
• BONDING	6 SURFACES x 856.4 x 10^6 FT^2 @ $0.0262/$FT^2$	• $134.63 x 10^6
	TOTAL	• $930.08 x 10^6 ($1602.20/ PANEL)

Figure 1.4-11. Rectenna Dipole - Bow-Tie - Panel Array Elements

delivering material at each panel. Additional trucks with reels playout the feeders, which then are installed in conduits and spliced to panel connections by the electrical installation crew. Contacts with a utility company indicate a requirement of 8 manhours to hookup one panel. On this basis, the manpower and equipment projections were established for a 20 hour 7 day week.

Equipment for electrical hookup and checkout of completed panels was calculated on the basis of acquisition cost prorated over the service life and utilization period at a particular site. Total crew requirements of 4196 personnel and the schedule period were the basis of calculating man-day requirements of 755,280. The amortized cost of equipment and labor were combined for the total cost factor.

DDT&E power collection costs are associated with the design and verification of bow-tie electronic panels/bonding processes, connectors, and large switchgear to optimize the voltage/current ratios and element/wiring configuration. Cost estimates are provided in the following areas:

Table 1.4.3.1 Antenna Array Elements

Table 1.4.3.2 Power Distribution System

Table 1.4.3.3 Installation and Checkout

Table 1.4.3.4 Power Collection DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.1 ANTENNA ARRAY ELEMENTS

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.001942
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.002
#RM =T / M	580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		1127.331
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		1127.322
CIPS=CTB*Z4/Z2		1127.321
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.2 POWER DISTRIBUTION SYSTEM

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	580500.000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000120
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES PANEL SUM TO 1.4.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.000
#RM =T / M	580500.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		69.660
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		69.659
CIPS=CTB*Z4/Z2		69.659
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.3 INSTALLATION & CHECKOUT

INPUT PARAMETERS / INPUT COEFFICIENTS

T=	781100.000	TF=	1.000000	CDCER=	0.0
M=	4340.00000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.000200
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES MANDAYS SUM TO 1.4.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.868
#RM =T / M	179.977	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		156.220
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		156.220
CIPS=CTB*Z4/Z2		156.220
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.3.4 POWER COLLECTION-DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	3.000000
M=	1.000000	O&M=	0.0	CDEXP=	0.300000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.3		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		3.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.4.4 CONTROL

The telemetry, tracking, communications, monitoring of microwave beam characteristics, computing phase corrections, and the equipment needed to provide frequency standard signals for the satellite are included in this section. This hardware will be used to monitor and control the satellite from the ground.

The following monitor and control functions are performed:

1. Tracking, using ground-based radars to monitor the orbital stability of the satellite.

2. Beam monitoring and control, using ground equipment for adaptive or command control of the satellite microwave beam.

3. Data management, using equipment required to analyze signals and data from the satellite and ground-based systems to compute control signals and corrective data to maintain safe and optimum performance.

4. Communications, using equipment required to maintain communications between the ground station and the SPS satellite. Included are the communications with the crew, and telemetry and command equipment not included in the beam monitoring and control assembly.

At this time, the cost effort is divided into the three categories of control center equipment, beam control electronics, and DDT&E. Two sets of full-up IBM 370, or equivalents, a complete display center, and a manned control room are envisioned as basic elements of the control center. Beam control electronics would consist of control sensors and dual frequency transmitters. The overall DDT&E and hardware costs were projected by engineering. The exacting requirement of this rectenna operation will require further study in future contract activity to define the technical and performance standards. It should also be noted that system and operational requirements are needed to define adequate software/programming considerations.

Cost estimates are presented as follows:

Table 1.4.4.1 Control Center Equipment

Table 1.4.4.2 Control Electronics

Table 1.4.4.3 Control DDT&E

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.1 CONTROL CENTER EQUIPMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	15.000000
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	15.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	15.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	15.000
CIPS=CTB*Z4/Z2	15.000
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.2 CONTROL ELECTRONICS

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000			CDCER=	0.0
M=	1.000000	O&M=	0.0			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	60.000000
PHI=	1.000000	Z2=	60.000000			CIEXP=	1.000000
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	60.000
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	60.000
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	60.000
CIPS=CTB*Z4/Z2	60.000
CRCI =CTB X R	0.0
CC&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.4.3 CONTROL DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	10.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.4	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	10.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	0.0
CIPS=CTB*Z4/Z2	0.0
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

1.4.5 GRID INTERFACE

This element includes the power conversion equipment that receives electrical power from the power collection system and conditions/converts it to a high voltage dc or ac power acceptable for input into the national power grid.

The converter stations accept 40 kV dc power and output 500 kV ac or dc. The concept utilizes a solid-state inversion/step-up concept typified by an existing dc - ac conversion station located in Sylmar, California. Although specific design details of this system await clarification in a future study effort, an analysis and cost estimate was prepared as shown in Table 1.4-8. The CER for DDT&E were derived from cost estimates in the "Technical Study Report on Pacific Northwest-Southwest dc inter-tie," prepared by the Bonneville Power Administration in February, 1976. This DDT&E estimate was based on six cost quotations which Bonneville received on a 1.44 GW and a 2.20 inter-tie. The total cost for the 1.44 GW terminal ($156.7 $\overline{M}$) was allocated as 30% DDT&E and 70% ICI. This judgment was based on the assumption that most of the facility will be a standard design.

Table 1.4-8. Grid Interface (WBS 1.4.5)

ITEM DESCRIPTION	SPECIFICATION	GRS QUANTITY	PROJECTED UNIT COST	TOTAL (1977 $)
CONVERTER STATIONS	400 mW 500 kV ac or kV dc	12 EA.	$\$10 \times 10^6$	$\$120 \times 10^6$
ISOLATION SWITCH-GEAR	4x4x4 m	24 EA	$400,000 EA	$\$0.96 \times 10^6$
FILTER YARDS		12	$100,000 EA	$\$1.2 \times 10^6$
INTERCONNECT TOWERS & FOUNDATION	500 kV ac TOWERS	90 EA		$\$12.741 \times 10^6$
INTERCONNECT TRANSMISSION CABLE		12 LINES	$90,000/MI	$\$10.789 \times 10^6$
TOTAL/GRS				$\$145.69 \times 10^6$

Cost estimates are presented in Table 1.4.5.1 on electrical equipment and in Table 1.4.5.2 on DDT&E.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.5.1 ELECTRICAL EQUIPMENT

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	145.690002
PHI=	1.000000	Z2=	60.000000	CIEXP=	1.000000
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.5	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	145.690
#RM =T / M	1.000
E =1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	145.690
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3	145.690
CIPS=CTB*Z4/Z2	145.690
CRCI =CTB X R	0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR	0.0

COMMENTS

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.5.2 GRID INTERFACE-DDT&E

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5.000000	TF=	1.000000	CDCER=	37.714996
M=	5.000000	O&M=	0.0	CDEXP=	0.604000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES GW SUM TO 1.4.5		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		99.699
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		0.0

COMMENTS

1.4.6 OPERATIONS

This element includes the planning, development, and conduct of operations at the ground receiving station. It includes both the direct and support personnel and the expendable maintenance supplies required for the ground station operation and maintenance.

Operations and maintenance personnel required after IOC are identified as a 300 personnel staff to provide a 24 hour operation, maintenance/repair, security, and administrative support (Table 1.4-9). A cost estimate for maintenance material (expendables, trucks, and equipment); standby auxiliary power; and test/support equipment is also identified in the table.

Table 1.4-9. Operations Requirements

ITEM	SHIFT	NO.	TOTAL	1977 DOLLARS
• OPERATIONS & MAINTENANCE PERSONNEL				
COMMAND & CONTROL CENTER (PERSONNEL + SUPERVISORY)	1	30		
	2	30		
	3	20	80	
CONVERTER STATION (TOTAL FOR 12 STATIONS)	1	36		
	2	36		
	3	36	108	
24-HOUR MAINTENANCE, REPAIR, SECURITY, & G&A/SUPPORT		112	112	
			300	
• MAINTENANCE MATERIAL				$\$13.13\times10^6$
EXPENDABLES, TRUCKS, EQUIP., UTILITIES, TEST/SUPPORT EQUIP.				

Cost estimates are shown in Table 1.4.6.1 for operations and maintenance personnel and in Table 1.4.6.2 for maintenance material.

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.6.1 OPER. & MAINT. PERSONNEL

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	300.000000	TF=	1.000000			CDCER=	0.0
M=	300.000000	O&M=	64.800003			CDEXP=	0.0
CF=	1.000000	Z1=	1.000000			CICER=	0.0
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.0
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	MAN-DAYS SUM TO 1.4.6	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		64.800

COMMENTS
360 DAYS/YR * 3 SHIFTS/DAY * 300 MANDAYS/SHIFT * $200/MANDAY

ROCKWELL SPS CR-2 REFERENCE CONFIGURATION

TABLE 1.4.6.2 MAINT. MATERIAL

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	13.130000	CDEXP=	0.0
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES SET SUM TO 1.4.6		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	1.000	
E =1.0 + LOG(PHI) / LOG(2.0)	1.000	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		0.0
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		0.0
CRCI =CTB X R		0.0
CO&M = O&M OR CTB*Z5/Z2/ENYR		13.130

COMMENTS

1.5 MANAGEMENT AND INTEGRATION

This element includes all efforts and material required for management and integration functions at the systems level and program level. It encompasses the following functions:

1. Program Administration
2. Program Planning and Control
3. Contracts Administration
4. Engineering Management
5. Manufacturing Management
6. Support Management
7. Quality Assurance Management
8. Configuration Management
9. Data Management
10. Systems Engineering and Integration.

This element sums all of the direct effort required to provide management control including planning, organizing, directing, and coordinating the project to ensure that overall project objectives are accomplished. These efforts overlay the functional work areas (e.g., engineering, manufacturing, etc.) and assure that they are properly integrated. This element also includes the efforts required in the coordination, gathering, and dissemination of management information. Also included are the engineering efforts related to the establishment and maintenance of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. It includes requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, and maintainability. It also includes those efforts required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

The management and integration function for DDT&E, TFU :ICI, RCI and O&M are estimated at a cost equal to 5% of the corresponding total dollar estimates for WBS elements 1.1 through 1.4 within each area. Table 1.5 presents this tabulation.

TABLE 1.5 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
MANAGEMENT AND INTEGRATION

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000	CDCER=	0.0
M=	0.0	U&M=	0.0	CDEXP=	0.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	60.000000	CIEXP=	0.0
R=	0.0	Z3=	60.000000		
DF=	1.000000	Z4=	60.000000	Z5=	0.0

CALCULATED VALUES 5% * ALL SUM TO 1		$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		1392.463
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM =T / M	0.0	
E =1.0 + LOG(PHI) / LOG(2.0)	0.0	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		2151.918
CTB =((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		600.679
CRCI =CTB X R		18.815
CO&M = U&M OR CTB*Z5/Z2/ENYR		8.561

COMMENTS
DDT&E,TFU,ICI,RCI, AND O&M ARE
CALCULATED AT 5% OF CORRESPONDING TOTALS
FOR WBS 1.1 THROUGH 1.4

1.6 MASS CONTINGENCY

A cost contingency has been added to the SPS Program to provide for potential growth due to increased weight as a result of design/development activities that would affect the procurement of systems during any phase of the program. This allowance is costed as a 15% bottom line contingency to the DDT&E, TFU, ICI, RCI and O&M elements of the program. Table 1.6 reflects the total amounts in each of these areas based on the totals of items 1.1, 1.2, and 1.3.

TABLE 1.6 ROCKWELL SPS CR-2 REFERENCE CONFIGURATION
MASS CONTINGENCY

INPUT PARAMETERS						INPUT COEFFICIENTS	
T=	0.0	TF=	1.000000			CDCER=	0.0
M=	0.0	O&M=	0.0			CDEXP=	0.0
CF=	0.0	Z1=	1.000000			CICER=	0.0
PHI=	1.000000	Z2=	60.000000			CIEXP=	0.0
R=	0.0	Z3=	60.000000				
DF=	1.000000	Z4=	60.000000	Z5=	0.0		

CALCULATED VALUES	SUM TO 1	$,MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		4160.031
CLRM=CICER X (M)XX(CIEXP) X CF X TF		0.0
#RM = T / M		0.0
E = 1.0 + LOG(PHI) / LOG(2.0)		0.0
CTFU= (CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		5912.945
CTB = ((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z3		0.0
CIPS=CTB*Z4/Z2		1263.413
CRCI = CTB X R		56.405
CO&M = O&M OR CTB*Z5/Z2/ENYR		13.927

COMMENTS
A 25% MASS CONTINGENCY IS COSTED
AS A 15% COST CONTINGENCY ON 1.1, 1.2, 1.3

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA CR-3319		

4. Title and Subtitle	5. Report Date
SATELLITE POWER SYSTEMS (SPS) CONCEPT DEFINITION STUDY VOLUME II, PART 2 - SYSTEM ENGINEERING	September 1980
	6. Performing Organization Code
7. Author(s): G. M. Hanley	8. Performing Organization Report No. SSD 79-0010-2-2
	10. Work Unit No.
9. Performing Organization Name and Address: Rockwell International, 12214 Lakewood Boulevard, Downey, California 90241	11. Contract or Grant No. NAS8-32475
	13. Type of Report and Period Covered: Contractor Report
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, D.C. 20546	14. Sponsoring Agency Code

15. Supplementary Notes

Marshall Technical Monitor: C. H. Guttman
Volume II, Part 2 of Final Report

16. Abstract

Since the publication of earlier Rockwell SPS cost, economic, and programmatic documentation - dating back to 1976 - a continuing effort has resulted in this volume incorporating the latest in technical and programmatic developments, along with expansions of the Rockwell SPS cost model covering each phase of the program through the year 2030. Comparative cost/economic analyses cover elements of the satellite, construction system, space transportation vehicles and operations, and the ground receiving station. System and subsystem cost estimates are detailed along with schedules/networks and SPS program plans to define time-phased costs and planning requirements that support major milestones through the year 2000. Emphasis is placed on the 1980-1990 period of technology advancement and ground/space based exploratory development leading to the first SPS. In addition, a special analysis is included on natural resources required to build the Rockwell SPS reference configuration - a three trough planar array satellite with a supporting ground receiving station. An appendix contains the SPS Work Breakdown Structure and dictionary along with detail cost data sheet on each system and main element of the program. Over 200 line items address DDT&E, theoretical first unit, investment cost per satellite, and operations changes for replacement capital and normal operations and maintenance costs. The Rockwell SPS cost model is both versatile and flexible to incorporate CER's (cost estimation relationships/exponents), complexity factors, development fractions, technical characteristics - mass/volume/power, tooling factors, and other cost/programmatic parameters.

17. Key Words (Suggested by Author(s))		18. Distribution Statement
Rectenna Costing	Rockwell SPS Cost Model	Unclassified - Unlimited
SPS Cost Analyses	Development Logic Network	
Time-Phased Costs	SPS Natural Resources Analysis	
SPS Programmatics	Space Transportation Cost Model	
SPS Program Plans	Space Construction Cost Estimates	
Satellite System Costs		
Satellite Power System		Subject Category 44

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	435	A19

For sale by the National Technical Information Service, Springfield, Virginia 22161

☆ U. S. GOVERNMENT PRINTING OFFICE: 1980—638-044