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April 1978

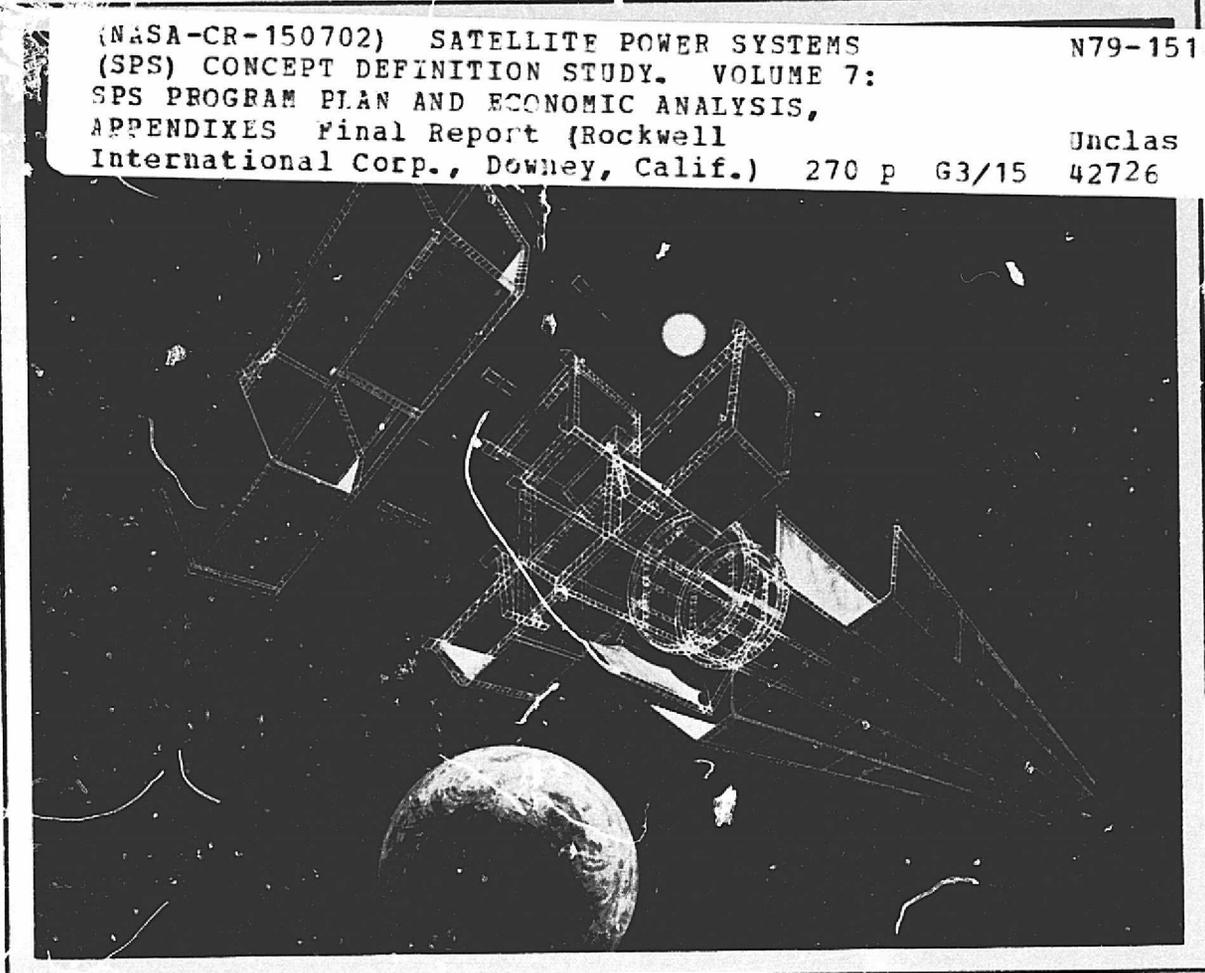
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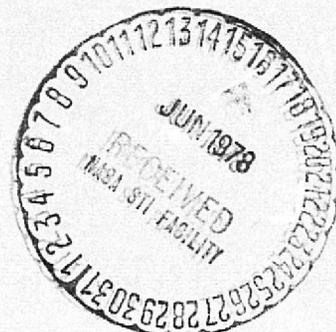
FINAL REPORT
VOLUME VII

**SPS PROGRAM PLAN AND ECONOMIC
ANALYSIS
APPENDIXES**



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Satellite Power Systems (SPS) Concept Definition Study

FINAL REPORT
VOLUME VII

SPS PROGRAM PLAN AND ECONOMIC ANALYSIS APPENDIXES

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FOREWORD

Three appendixes in support of Volume VII - *SPS Program Plan and Economic Analysis*, are contained in this document. This work was completed under the SPS Concept Definition Study (Contract NAS8-32475), Exhibits A and B. The three appendixes are:

Appendix A - Satellite Power System Work Breakdown Structure Dictionary

Appendix B - SPS Cost Estimating Relationships

Appendix C - Financial and Operational Concept

Other volumes of the final report that provide additional detail are listed below.

Volume

I	Executive Summary
II	SPS System Requirements
III	SPS Concept Evolution
IV	SPS Point Design Definition
V	Transportation and Operations Analysis
VI	SPS Technology Requirements and Verification



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ACKNOWLEDGMENTS

The treatment of Satellite Power Systems economic and program planning definitions in this report represent the results of many hours of work by a number of professionals in each of the required areas. They have applied their individual skills in the analysis, evaluation, and documentation of results and conclusions as related to the particular economic or programmatic task. Therefore some acknowledgment is required.

Substantial support was received from each member of the SPS programs team and their management. This furthered the objective of providing sound economic and programmatic conclusions as presented in this volume and its appendixes. The Rockwell - Space Division SPS Program Development team that contributed significantly to the completion of this work is listed as follows:

Dr. L. R. Blue	Cost/Risk Programming
W. Cooper	Cost Analysis
Dr. I. E. Cornelius	SPS Economics
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K. E. Smith	Program Plans

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Engineering Cost Group:

W. S. Rutledge
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APPENDIX A

SATELLITE POWER SYSTEM WORK BREAKDOWN
STRUCTURE DICTIONARY

Solar Photovoltaic,
Concentration Ratio (CR)=2



SATELLITE POWER SYSTEM WORK BREAKDOWN STRUCTURE DICTIONARY

SOLAR PHOTOVOLTAIC, CONCENTRATION RATIO (CR)-2

INTRODUCTION

The Satellite Power System (SPS), because of its magnitude, duration, dollar costs, and interrelationship with other programs and users, is a very complex program. To establish a work breakdown structure (WBS) that properly encompasses the multiple facets of this effort requires some innovative adjustments to the normal WBS display. At the same time it is important that the WBS retain, as nearly as possible, the standard WBS format with which managers are familiar.

Generally a work breakdown structure 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 of a complex program by dividing this program into less complex, more manageable subdivisions or elements. To maximize this effectiveness, the WBS must be consistent and logical.

The greatest shortcoming of a single WBS is its inability to be all things for all people. 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. To do all these things and at the same time meaningfully relate elements of the program in an optical display and define the total work to be accomplished places demands upon the WBS that usually necessitate compromises.

Therefore, the WBS developed and defined herein is primarily tailored to the unique cost, economic, and programmatic requirements of SPS. Other users of the WBS may find some shortcomings with the structure, but it should serve all users reasonably well. This WBS 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 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 costs 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.

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." Entries for taxes and insurance have been provided, and 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 five financial accounts have been established. Research and experimental (R&E) expenditures include the costs for directed supporting research and technology (SRT), advanced studies, and design development, test, and evaluation (DDT&E). 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. Other expenses include the costs of taxes and insurance. 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 terms.

It should be noted that the R&E expenditure account is subdivided into several separate DDT&E accounts. This appears desirable because of the expected long duration of the SPS DDT&E phase and because it will likely be funded in steps. Each of these subdivisions actually constitutes a mini-program in itself and, when viewed in this light, again breaks down into design and development, investment, and operations phases just as the total SPS program does. The number and timing of these steps are not yet known, and the four subdivisions presently designated are meant only to suggest probable development and test programs leading to the full scale SPS development. They undoubtedly will change as the definition of the development program matures. Some of these steps may well be accomplished as a means of developing space-to-space power for NASA and may not then be considered a part of the SPS DDT&E as such.

HARDWARE AND ACTIVITIES WBS DIMENSION

The hardware and activities WBS dimension contains all the presently defined SPS 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 stations, assembly 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 displayed under the SPS banner.

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 work breakdown structure which could be displayed in depth under the SPS WBS if required.

Finally, the hardware and activities WBS dimension also includes the necessary system level and project level activities of program management, systems engineering and integration (SE&I), 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 (Reference Figure 1).
2. The definitions of terms of the accounts and phases dimension.
3. The definitions of terms of the WBS hardware and activities dimension.

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.

In Figure 1 a dot signifies each matrix position that corresponds to an identifiable task that must be completed in the SPS program. Therefore, each dot also corresponds to a cost that will be incurred and must be accounted. Since each dot 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 dotted 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 dotted matrix position is a combination of these two definitions.



DEFINITIONS OF ACCOUNTS

WBS TITLE: SATELLITE POWER SYSTEM
WBS NUMBER: 1000-

This element is the total SPS project including all accounts and phases as well as all hardware and activities.

WBS TITLE: RESEARCH AND EXPERIMENTAL EXPENDITURES
WBS NUMBER: 1100-

This element is an account of the SPS project.

The R&E expenditures account is a summation of those expenditures incident to the research, design, and development of techniques, processes, hardware, systems, etc., that are required and necessary to establish a viable SPS. This account includes costs of SRT efforts directed toward SPS application, costs of advanced studies (prior to Phase C/D), and the DDT&E costs (Phase C/D) of the SPS project. These subaccounts are defined later in this document and are graphically displayed on the WBS matrix (Figure 1). Costs of general supporting research and technology work that would be performed regardless of the SPS project are not included, even though the SPS project may indirectly benefit from that work.

This account includes costs of all the elements appearing in the hardware and activities dimension of the WBS matrix (Figure 1) for which a dot appears in any of the R&E expenditures columns.

For SPS income tax purposes, R&E costs may be deducted in the year incurred in the same manner as business expenses.



WBS TITLE: INITIAL CAPITAL INVESTMENT
WBS NUMBER: 1200-

This element is an account of the SPS project.

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 in 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.

This account includes costs for all the elements appearing in the hardware and activities dimension of the WBS matrix (Figure 1) for which a dot appears in the initial capital investment column.

For SPS income tax purposes, the investment costs in this account are recovered by annual depreciation charges.

WBS TITLE: REPLACEMENT CAPITAL INVESTMENT
WBS NUMBER: 1300-

This element is an account of the SPS project.

The replacement capital investment account is a summation of those plant and equipment expenditures made for capital asset replacement and major maintenance overhauls that are expected to last more than 1 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 rate shares of functional costs. These expenditures begin at the IOC and continue over the life of each SPS.

This account includes costs for all the elements appearing in the hardware and activities dimension of the WBS matrix (Figure 1) for which a dot appears in the replacement capital investment column.

For SPS income tax purposes, the investments in this account are recovered by annual depreciation charges.



WBS TITLE: OPERATIONS AND MAINTENANCE
WBS NUMBER: 1400-

This element is an account of the SPS project.

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.

This account includes costs for all the elements appearing in the hardware and activities dimension of the WBS matrix (Figure 1) for which a dot appears in the O&M column.

For SPS income tax purposes, the costs collected in this account are deductible as business expenses in the year in which they are incurred.

WBS TITLE: OTHER EXPENSES
WBS NUMBER: 1500-

This element is an account of the SPS project.

The other expenses account is a summation of those expenditures incurred for taxes and insurance and casualty losses beginning with the IOC and continuing over the life of each SPS. Examples of costs collected in this account are federal and state income taxes, property taxes, property insurance, payload and launch vehicle losses, etc.

This account includes costs for all the elements in the hardware and activities dimension of the WBS matrix (Figure 1) for which a dot appears in the other expenses column.

For SPS income tax purposes, the costs collected in this account are deductible as business expenses in the year in which they are incurred.



WBS TITLE: DIRECTED SUPPORTING RESEARCH AND TECHNOLOGY
WBS NUMBER: 1110-

This element is a subaccount of the R&E expenditure account.

The directed SRT phase is an SPS discipline-oriented activity very basic and fundamental in nature that is pursued in a step-by-step manner, but is in general not schedule oriented or related. Directed SRT is designed to reveal a fundamental truth or aspect of natural law or an element of a physical science related to the SPS project. The product is usually data rather than hardware. However, the results may be applicable to specific SPS hardware developments and result in improved means of accomplishing the SPS mission.

An example of directed SRT is a study of the likely effect of orbital space debris on the SPS satellite. An example of general SRT not accounted for in the SPS WBS is an Air Force Study to catalog such objects in Earth orbit, if the study would have been undertaken with or without the SPS.

WBS TITLE: ADVANCED STUDIES
WBS NUMBER: 1120-

This element is a subaccount of the R&E expenditure account.

The objective of the advanced studies phase is to conduct efforts and system studies that examine the future direction of the SPS project. New space systems, new operational concepts, and advanced uses of existing systems evolve from these studies in terms of conceptual designs, trade studies, and requirement definitions. Emphasis is given to both the utilization of existing systems that can be used to advance the SPS project capabilities at a minimum cost and studies of potential new systems and operational concepts.

Examples of advanced studies are Pre-Phase A, Phase A, and Phase B studies. Pre-Phase A and Phase A studies are concerned with the analysis of alternate overall SPS project approaches or concepts, the identification of major project elements, and the consideration of the feasibility of the SPS objectives. In these phases, contracted effort is often limited to auxiliary studies in support of in-house activity. Phase B effort involves more detailed study, analysis, and preliminary systems design directed toward facilitating the choice of a single project approach from the alternate approaches selected through Phase A. In Phase B, the major effort is normally accomplished by contracted studies.



WBS TITLE: SPS SUBSYSTEMS DDT&E (AUTOMATED)
WBS NUMBER: 1130-

This element is a subaccount of the R&E expenditure account.

The SPS subsystems DDT&E (automated) subaccount has been included as a generic subaccount only and is subject to modification as the definition of the SPS development program evolves. This subaccount is meant to include any Shuttle automated payload developments defined as part of the overall SPS DDT&E and is subdivided into 3 areas:

- 1) WBS Number 1131 - DDT&E. The DDT&E area consists of one-time costs associated with the design, development, and evaluation of components, subsystems, and systems required in subsystem support of Shuttle automated payload developments defined as a part of the overall SPS-DDT&E phase.
- 2) WBS Number 1132 - INVESTMENT. The investment area consists of one-time post DDT&E efforts required for the initial procurement and installation utilizing Shuttle automated payloads.
- 3) WBS Number 1133 - OPERATIONS. The Operations area consists of the effort required to operate and maintain the SPS project utilizing Shuttle automated payloads over the operational lifetime.

As established, the SPS WBS includes four such generic subaccounts, WBS numbers 1130, 1140, 1150, and 1160. Together, these four subaccounts comprise the DDT&E phase of the entire SPS project.



WBS TITLE: SPS SUBSYSTEMS DDT&E (SORTIE)
WBS NUMBER: 1140-

This element is a subaccount of the R&E expenditure account.

The SPS subsystems DDT&E (sortie) subaccount has been included as a generic subaccount only and is subject to modification as the definition of the SPS development program evolves. This subaccount is meant to include any Shuttle sortie payload developments defined as part of the overall SPS DDT&E and is divided into 3 lower level areas:

- 1) WBS Number 1141 - DDT&E. The DDT&E area consists of one-time costs associated with the design, development, and evaluation of components, subsystems, and systems required in subsystem support of Shuttle sortie payload developments defined as part of the overall SPS-DDT&E phase.
- 2) WBS Number 1142 - INVESTMENT. The investment area consists of one-time post DDT&E effort required for the initial procurement and installation utilizing Shuttle sortie payloads.
- 3) WBS Number 1143 - OPERATIONS. The Operations area consists of the effort required to operate and maintain the SPS Shuttle sortie payloads over the operational lifetime.

As established, the SPS WBS includes four such generic subaccounts, WBS numbers 1130, 1140, 1150, and 1160 that comprise the DDT&E phase of the entire SPS project.



WBS TITLE: SPS DDT&E (SUBSCALE)

WBS NUMBER: 1150-

This element is a subaccount of the R&E expenditure account.

The SPS DDT&E (subscale) subaccount has been included as a generic subaccount only and is subject to modification as the definition of the SPS development program evolves. This subaccount is meant to include any subscale developments (beyond Shuttle) defined as part of the overall SPS DDT&E and is divided into 3 subareas:

- 1) WBS Number 1151 - DDT&E. This DDT&E area consists of one-time costs associated with the design, development, and evaluation of components, subsystems, and systems required in any subscale developments (beyond Shuttle) defined as part of the overall SPS DDT&E phase.
- 2) WBS Number 1152 - INVESTMENT. The investment area consists of one-time post DDT&E effort required for the initial procurement and installation of subscale developments (beyond Shuttle).
- 3) WBS Number 1153 - OPERATIONS. The Operations area of this element is included as a part of SPS-WBS element numbers 1300, 1400, and 1500 within the Operations Phase of the SPS commercialization program.

As established, the SPS WBS includes four such generic subaccounts, WBS numbers 1130, 1140, 1150, and 1160. Together, these four subaccounts comprise the DDT&E phase of the entire SPS project.



WBS TITLE: SPS DDT&E (FULL SCALE)
WBS NUMBER: 1160-

This element is a subaccount of the R&E expenditure account.

The SPS DDT&E (full scale) subaccount has been included as a generic subaccount only and is subject to modification as the definition of the SPS development program evolves. This subaccount is meant to include the developments defined for the operational full scale SPS project and is divided into 3 subareas:

- 1) WBS Number 1161 - DDT&E. The DDT&E area consists of one-time costs associated with the Phase C/D design, development, evaluation and test of components, subsystems, and systems (satellite, ground system, HLLV, etc.) required to complete DDT&E developments as defined for the operational full scale SPS project.
- 2) WBS Number 1162 - INVESTMENT. The investment area consists of one-time post DDT&E effort required for the initial procurement and installation of defined developments (technology advancements) and their validation on an operational full scale SPS project.
- 3) WBS Number 1163 - OPERATIONS. The Operations activity of this element (and associated costs) become a part of SPS-WBS elements (Numbers 1300, 1400, and 1500) within the Operations Phase of the SPS commercialization plan.

As established, the SPS WBS includes four such generic subaccounts, WBS numbers 1130, 1140, 1150, and 1160. Together, these four subaccounts comprise the DDT&E phase of the entire SPS project.



DEFINITIONS OF PHASES

WBS TITLE: DESIGN, DEVELOPMENT, TEST, AND EVALUATION
WBS NUMBER: N/A

This element is a phase of the SPS project.

The DDT&E phase consists of the one-time costs 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 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, assembly and support facilities, 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.

As mentioned earlier in this report, the SPS DDT&E phase is actually composed of several miniprograms. Generic subaccounts have been provided for these miniprograms, and these were defined previously. Some of these miniprograms may materialize for reasons other than SPS and, hence, may not be chargeable to the SPS project.

(For a graphic display of the equivalency of the R&E expenditures account and the DDT&E phase, see the WBS matrix illustrated in Figure 1.)



WBS TITLE: INVESTMENT
WBS NUMBER: N/A

This element is a phase of the SPS project.

The investment phase consists of the one-time post-DDT&E efforts required for the initial procurement and installation of each operational full scale SPS. The costs of this phase are collected in the initial capital investment account (WBS number 1200). (For a graphic display of the equivalency of the initial capital investment account and the investment phase, see the WBS matrix illustrated in Figure 1.)

This element includes plant and equipment expenditures made for the initial procurement and installation of each full scale SPS including costs attributable to the satellite system itself, ground system, space assembly and support facilities, launch vehicle fleets, and supporting functions such as program management and system engineering and integration.

WBS TITLE: OPERATIONS
WBS NUMBER: N/A

This element is a phase of the SPS project.

The operations phase consists of the efforts required to operate and maintain the SPS project over its operational lifetime. This phase includes the recurring provisioning of spare parts for unscheduled repair, refurbishment, and major maintenance operations, the costs of which are collected in the replacement capital investment account (WBS number 1300). Also included in this phase are the day-to-day mission operations, minor maintenance, administration, and other activities such as training required to effect the continuous operation of the SPS, the costs of which are collected in the operations and maintenance account (WBS number 1400). In addition, insurance and taxes are covered in this phase, and the costs are collected in the other expenses account (WBS number 1500). (For a graphic display of the accounts included within the operations phase, see the WBS matrix illustrated in Figure 1.)



DEFINITIONS OF HARDWARE AND ACTIVITIES

WBS TITLE: PROGRAM MANAGEMENT
WBS NUMBER: -01-00-00

This functional element includes efforts and material required to direct, manage, and control the project. This element 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.

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. These element also includes the efforts required in the coordination, gathering, and dissemination of management information.

WBS TITLE: SYSTEMS ENGINEERING AND INTEGRATION
WBS NUMBER: -02-00-00

This functional element includes 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.



WBS TITLE: SATELLITE SYSTEM
WBS NUMBER: -03-00-00.

This element is a system of the SPS project.

This element includes the hardware and activities that comprise the satellite subsystems utilized to convert solar energy to electrical energy and for transmitting this energy by microwave to the ground station system.

The following subsystems are included in this element:

1. Program Management
2. SE&I
3. Structures
4. Power Source
5. Microwave
6. Propulsion
7. Avionics
8. Thermal Control
9. Ground Assembly and Integration
10. System Ground Test Hardware
11. System Ground Test Operations
12. Operations
13. Ground Support Equipment (GSE).



WBS TITLE: PROGRAM MANAGEMENT
WBS NUMBER: -03-01-00

This element is a subsystem of the satellite system.

This functional element includes efforts and material required to direct, manage, and control the project. This element 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.

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.

WBS TITLE: SYSTEMS ENGINEERING AND INTEGRATION
WBS NUMBER: -03-02-00

This element is a subsystem of the satellite system.

This functional element includes 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.



WBS TITLE: STRUCTURES
WBS NUMBER: -03-03-00

This element is a subsystem of the satellite system.

This element includes the mechanical members that form the basic framework for the SPS satellite as well as the secondary structure utilized to mount equipment. Also included in this element are rotary joint structure and mechanisms that allow the antenna to change orientation relative to the main satellite body, and any mechanisms for positioning and actuating that are not an integral part of another subsystem.

The following assemblies are included in this element:

1. Antenna Structure
2. Power Source Structure
3. Rotary Joint
4. Mechanisms
5. Secondary Structure.

WBS TITLE: ANTENNA STRUCTURE
WBS NUMBER: -03-03-01

This element is an assembly of the structures subsystem.

This element includes the basic supporting framework for the microwave antenna from the interface with the rotary joint. The antenna structure provides support and does not include the waveguides or the radio frequency assemblies associated with the microwave subsystem. This element is limited to the primary load carrying elements and does not include secondary structure such as equipment mounts, platforms, and space support equipment supports.



WBS TITLE: POWER SOURCE STRUCTURE
WBS NUMBER: -03-03-02

This element is an assembly of the structures subsystem.

This element includes the basic supporting framework for the energy conversion section of the satellite up to the interface with the rotary joint including the non-rotating inner ring structure that interfaces with the rotary joint. The power source structure provides support and does not include any power source subsystem elements. This element is limited to the primary load carrying elements and does not include secondary structure such as equipment mounts, platforms, and space support equipment supports. This element includes that portion of the power distribution function where the primary structure serves as an electrical conductor.

WBS TITLE: ROTARY JOINT
WBS NUMBER: -03-03-03

This element is an assembly of the structures subsystem.

The rotary joint allows the antenna to rotate relative to the satellites main body so as to maintain a fixed attitude relative to the ground station/rectenna. This element includes the movable interface between the power source structure and the antenna structure excluding brush boxes, brushes, and slip rings as included in WBS element 03-04-03.

WBS TITLE: MECHANISMS
WBS NUMBER: -03-03-04

This element is an assembly of the structures subsystem.

This element includes all mechanical, electromechanical, hydraulic, and pneumatic devices that position, actuate, or articulate elements of the satellite. This element includes the screwjacks that align the microwave antenna subarrays.



WBS TITLE: SECONDARY STRUCTURE
WBS NUMBER: -03-03-05

This element is an assembly of the structures subsystem.

This element includes all structure required as an interface between the primary structure and the mounting attach points of components, assemblies, and subsystems. It also includes any structure required between two or more components or assemblies. Excluded are any mounting brackets that are provided as an integral part of a component, assembly, or subsystem.

WBS TITLE: POWER SOURCE
WBS NUMBER: -03-04-00

This element is a subsystem of the satellite system.

This element includes the components for the generation of electrical power using a solar energy source. This element includes the distribution and conditioning of the electrical power up to the interface with the rotary joint. The following assemblies are included in this element.

1. Solar Cell Blankets
2. Concentrators
3. Power Distribution and Conditioning

WBS TITLE: SOLAR CELL BLANKETS
WBS NUMBER: -03-04-01

This element is an assembly of the power source subsystem.

This element converts solar energy to electrical energy and provides power to the buses in the power distribution and conditioning assembly. It includes the solar cells, cell covers, substrate, interconnects, filters and thermal coatings, integrated power conditioning equipment such as switching diodes, if applicable, and mechanical attachments for mounting to the power source structure. Excluded are the tools and support equipment required for deployment of the blanket.



WBS TITLE: CONCENTRATORS
WBS NUMBER: -03-04-02

This element is an assembly of the power source subsystem.

This element concentrates the solar energy onto the solar cell blanket or solar energy absorber. It includes the reflector substrate and reflective coating, plus any attachments required for mounting to the structure. Excluded are tools and support equipment required for deployment.

WBS TITLE: POWER DISTRIBUTION AND CONDITIONING
WBS NUMBER: -03-04-03

This element is an assembly of the power source subsystem.

This element includes power conductors and switches necessary to transmit electrical power from the power source to the rotary joint. Also included are the slip rings, brushes, and brush boxes required to conduct power across the rotary (movable) joint; and energy storage provisions such as those provided by batteries. The slip ring/brush serves two functions: 1) to transmit power across the movable joint and 2) to act as a bearing for loads from the stationary to the rotating structure. Conductors that would be an integral part of another assembly or subsystem, such as in the case of structures, are not included.



WBS TITLE: MICROWAVE
WBS NUMBER: -03-05-00

This element is a subsystem of the satellite system.

This element includes the components of the microwave power transmission subsystem. This subsystem, whose interface begins at the rotary joint, is utilized to convert the power source output to high power microwave energy for transmission to the ground-based receiving station.

The following assemblies are included in this element:

1. Radio Frequency (RF) Generation and Beam Control
2. Waveguides
3. Power Distribution and Conditioning.

WBS TITLE: RF GENERATION AND BEAM CONTROL
WBS NUMBER: -03-05-01

This element is an assembly of the microwave subsystem.

This element includes the electronics necessary to convert the direct current (dc) electric power provided by the power distribution and conditioning assembly to RF microwave power. Included are the high power RF transmitting devices such as klystrons and other related equipment including driver amplifiers, frequency control electronics, and phase control electronics. This element also includes the computer interfaces, software, and electronics equipment for retrodirective beam control.

WBS TITLE: WAVEGUIDE
WBS NUMBER: -03-05-02

This element is an assembly of the microwave subsystem.

This element includes the waveguide that receives the RF power from the RF generation and beam control assembly and radiates it to the ground-based antenna.



WBS TITLE: POWER DISTRIBUTION AND CONDITIONING
WBS NUMBER: -03-05-03

This element is an assembly of the microwave subsystem.

This element includes the power conductors, switches, and conditioning equipment that conduct dc or low frequency alternating current (ac) electric power from the rotary joint and provide regulated dc power to the RF generation and control equipment and any other power consuming equipment located on the antenna.

WBS TITLE: PROPULSION (ATTITUDE CONTROL AND STATIONKEEPING SUBSYSTEM)
WBS NUMBER: -03-06-00

This element is a subsystem of the satellite system.

This element includes all the propulsion components required to effect and maintain the SPS satellite specified position and orientation in space.

The following assemblies are included in this element:

1. Attitude Control
2. Orbital Maneuvering (Stationkeeping).

Hardware which is common to both attitude control and orbital maneuvering shall be included in orbital maneuvering.

WBS TITLE: ATTITUDE CONTROL
WBS NUMBER: -03-06-01

This element is an assembly of the propulsion subsystem.

This element includes the propulsion hardware that provides the torques required to orient the satellite and maintain its required attitude relative to the Sun. Both chemical propulsion and electrical propulsion may be required, and hardware elements include thrusters, tankage, lines and valves, propellants, support structure, and electronics. Excluded are attitude sensors and reaction wheels that are included in the avionics subsystem.



WBS TITLE: ORBITAL MANEUVERING (STATIONKEEPING)
WBS NUMBER: -03-06-02

This element is an assembly of the propulsion subsystem.

This element includes the propulsion hardware that provides the thrust required to transfer the satellite from its assembly orbit to its required operational position in geosynchronous Earth orbit (GEO). Satellite station-keeping is also maintained by this assembly. Both chemical and electrical propulsion may be required, and hardware elements include chemical engines, thrusters, tankage, lines and valves, propellants, support structure, and electronics. This element is required only when the propulsion units are an integral part of the satellite and are not intended for reuse on other SPS satellites.

WBS TITLE: AVIONICS
WBS NUMBER: -03-07-00

This element is a subsystem of the satellite system.

This element includes those electrical and electronic components required for the communications (including telemetry), tracking, data handling, signal formatting, and attitude sensing and control for the satellite.

The following assemblies are included in this element:

1. Data Management
2. Communications and Tracking
3. Instrumentation
4. Attitude Control.

WBS TITLE: DATA MANAGEMENT
WBS NUMBER: -03-07-01

This element is an assembly of the avionics subsystem.

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



WBS TITLE: COMMUNICATIONS AND TRACKING
WBS NUMBER: -03-07-02

This element is an assembly of the avionics subsystem.

This element includes those components of the satellite that transmit signals to and/or receive signals from other orbiting stations and the ground stations.

Included are communications, telemetry, tracking, and command equipment.

WBS TITLE: INSTRUMENTATION
WBS NUMBER: -03-07-03

This element is an assembly of the avionics subsystem.

This element includes those components that measure various parameters on board the satellite such as temperature, voltage, flow rates, etc. This element includes the sensors, remote signal conditioning equipment, and the signal routing and distribution equipment. Excluded from this element are those sensors that measure the attitude of the satellite.

WBS TITLE: ATTITUDE CONTROL
WBS NUMBER: -03-07-04

This element is an assembly of the avionics subsystem.

This element includes any onboard components that sense the attitude of the satellite. This element also includes any control moment gyros (CMG) or reaction wheels that are used for attitude control plus figure control sensors and actuators, but excluding MW figure control actuators (contained in 03-03-04).



WBS TITLE: THERMAL CONTROL
WBS NUMBER: -03-08-00

This element is a subsystem of the satellite system.

This element includes any onboard equipment for dissipating or acquiring heat that is not an integral part of another subsystem. Included in this element are insulation, radiators, heaters, and heat transfer devices such as heat pipes that are used to control the temperature of another subsystem.

WBS TITLE: GROUND ASSEMBLY AND INTEGRATION
WBS NUMBER: -03-09-00

This element is an activity of the satellite system.

This element includes the ground-based assembly and physical integration of flight subsystem and assembly hardware. It includes the assembly, test, and checkout required to integrate assemblies into an accepted flight article. Included are ground assembly and integration of the SPS subsystems development satellites such as the automated, sortie, subscale, and full scale satellites as well as the full scale operational satellite system. The degree of assembly varies with the flight system. For example, the automated payloads and possibly some sortie payloads are completely assembled on the ground; however, because of the large size of the subscale and full scale satellite systems, only certain subsystems and/or assemblies may be assembled prior to launch.

WBS TITLE: SYSTEM GROUND TEST HARDWARE
WBS NUMBER: -03-10-00

This element is a subsystem of the satellite system.

This element includes the satellite system hardware 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 the hardware into a full or partial system test article. This element excludes hardware that will subsequently be used as operational protoflight or flight hardware. This element also excludes test facilities or test fixtures required for the tests.



WBS TITLE: SYSTEMS GROUND TEST OPERATIONS
WBS NUMBER: -03-11-00

This element is a subsystem of the satellite system.

This element includes the effort required for conducting ground-based systems tests including qualification and other development tests involving two or more subsystems or assemblies. It includes the planning, documentation, and actual test operations. This element also includes design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as GSE.

WBS TITLE: OPERATIONS
WBS NUMBER: -03-12-00

This element is an activity of the satellite system.

This element includes the planning, development, and conduct of operational sequences for ground support of assembly and checkout, payload launch, orbital assembly and checkout, and operation of the assembled SPS.

The following subordinate elements are included in this element:

1. Ground Operations
2. Orbital Operations.

WBS TITLE: GROUND OPERATIONS
WBS NUMBER: -03-12-01

This element is a subactivity of operations.

This element includes the planning, development, and conduct of ground operations required in support of the satellite orbital assembly and checkout. Ground operations required in support of satellite orbital transfer and satellite operations and maintenance are included in ground station system operations. For the early DDT&E programs such as automated (WBS number 1100) and sortie (WBS number 1200), this element includes the ground mission operations required to accomplish the orbital tests and evaluations. Excluded are the launch vehicle mission operations that are included in element numbers 1100-08-02 and 1200-08-02.



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WBS TITLE: ORBITAL OPERATIONS
WBS NUMBER: -03-12-02

This element is a subactivity of operations.

This element includes the planning, development, and conduct of the on-orbit operations associated with orbital assembly and checkout, orbital transfer, and the orbital operations and maintenance of the SPS. It includes the on-orbit personnel and expendable maintenance supplies to support these activities, plus the Satellite operations and maintenance base located on the operational satellite.

WBS TITLE: GROUND SUPPORT EQUIPMENT
WBS NUMBER: -03-13-00

This element is a subsystem of the satellite system.

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. Included are the costs for design, development, manufacture, acceptance, qualification, and maintenance of the GSE equipment. 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 purpose. In these instances, the original acquisition cost is charged to the original or first purpose use, and subsequent usage will incur only the recurring operational and maintenance costs.



WBS TITLE: GROUND STATION SYSTEM
WBS NUMBER: -04-00-00

This element is a system of the SPS project.

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.

The following subsystems are included in this element:

1. Program Management
2. SE&I
3. Rectenna
4. Satellite Control
5. Utility Interface
6. Site and Facilities
7. Operations.



WBS TITLE: PROGRAM MANAGEMENT
WBS NUMBER: -04-01-00

This element is a subsystem of the ground station system.

This functional element includes efforts and material required to direct, manage, and control the project. This element 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.

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.



WBS TITLE: SYSTEMS ENGINEERING AND INTEGRATION
WBS NUMBER: -04-02-00

This element is a subsystem of the ground station system.

This functional element includes 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.

WBS TITLE: RECTENNA
WBS NUMBER: -04-03-00

This element is a subsystem of the ground station system.

This element includes those assemblies that receive the microwave power radiated from the satellite systems to the ground. This element consists of the antenna array elements, the power busses and switching elements, and the supporting structure and ground plane.

The following assemblies are included in this element:

1. Dipole Rectifiers
2. Power Distribution and Conditioning
3. Support and Ground Plane Structure.

WBS TITLE: DIPOLE RECTIFIER ELEMENTS
WBS NUMBER: -04-03-01

This element is an assembly of the rectenna subsystem.

This element includes the dipoles that are 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 desired output voltage.



WBS TITLE: POWER DISTRIBUTION AND CONDITIONING
WBS NUMBER: -04-03-02

This element is an assembly of the rectenna subsystem.

This element includes those components that accept the dc signals from the dipoles and route, control, and switch this power which includes power conditioning and power boosting. This element, therefore, covers those components that process information within the Rectenna perimeter including signal conditioning, formatting, computations, and signal routing.

WBS TITLE: SUPPORT AND GROUND PLANE STRUCTURE
WBS NUMBER: -04-03-03

This element is an assembly of the rectenna subsystem.

This element includes the components that provide the physical support to the rectenna elements and form an electrical ground plane for the antenna elements.

WBS TITLE: SATELLITE CONTROL
WBS NUMBER: -04-04-00

This element is a subsystem of the ground station system.

This element includes the hardware that will be used to monitor and control the satellite from the ground. The subsystem will track the satellite and monitor the microwave beam characteristics, compute phase corrections and provide frequency standard signals for the satellite, and communicate with the GEO space station crew.

The following assemblies are included in this element:

1. Tracking
2. Beam Monitoring and Control
3. Data Management
4. Communications



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WBS TITLE: TRACKING
WBS NUMBER: -04-04-01

This element is an assembly of the satellite control subsystem.

This element will include the ground-based radars or lasers employed to monitor the orbital stability of the satellite.

WBS TITLE: BEAM MONITORING AND CONTROL
WBS NUMBER: -04-04-02

This element is an assembly of the satellite control subsystem.

This element includes the ground equipment for adaptive or command control of the satellite microwave beam.

WBS TITLE: DATA MANAGEMENT
WBS NUMBER: -04-04-03

This element is an assembly of the satellite control subsystem.

This element includes the equipment needed to analyze signals and data from the satellite and ground-based systems to compute control signals and correction data to maintain safe and optimum performance. This excludes rectenna power distribution monitoring and signal routing (see 04-03-02).



WBS TITLE: COMMUNICATIONS
WBS NUMBER: -04-04-04

This element is an assembly of the satellite control subsystem.

This element includes the ground-based equipment required to maintain communications between the ground station and the SPS satellite. Included are the communications with the space station crew, and telemetry and command equipment not included in the beam monitoring and control assembly.

WBS TITLE: UTILITY INTERFACE
WBS NUMBER: -04-05-00

This element is a subsystem of the ground station system.

This element includes the power conversion equipment that receives the energy from the rectenna and conditions it for input into the electrical power distribution networks.

WBS TITLE: SITE AND FACILITIES
WBS NUMBER: -04-06-00

This element is a subsystem of the ground station system.

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



WBS TITLE: OPERATIONS
WBS NUMBER: -04-07-00

This element is a subactivity of the ground station system.

This element includes the planning, development, and conduct of all operations associated with the ground station system activities. Included are the personnel required for satellite system support and for operation and maintenance of the rectenna, satellite control subsystem, utility interface, and site and facilities. This element also includes the expendable maintenance supplies required to accomplish these activities.

WBS TITLE: SPACE ASSEMBLY & SUPPORT FACILITY
WBS NUMBER: -05-00-00

This element is the space assembly and support facility project.

This element includes the space base and construction facilities required to assemble, check out, operate and maintain the satellite system through IOC. The following subordinate elements are included in this element:

1. LEO Base
2. GEO Construction Base

WBS TITLE: LEO BASE
WBS NUMBER: -05-01-00

This element is a system of the space assembly and support facility project.

This element includes the DDT&E, investment, and operations of the base (power, crew/hab, operations, and support modules) located in low earth orbit (LEO). Included are crew life support facilities, the central control/staging facility, and power generation facilities, required supervisory activities for the direct transfer of crew and equipment between the HLLV and OTV's for up and down payload traffic. Excluded are facilities and equipment unique to the assembly of the SPS, since these are included in the assembly and support equipment project.



WBS TITLE: GEO CONSTRUCTION BASE
WBS NUMBER: -05-02-00

This element is a system of the space assembly and support facility project.

This element includes the DDT&E, investment, and operation of the construction base required in GEO to support the assembly, fabrication, and construction activity and to provide safe crew habitability/support provisions for resident crew members. Excluded are the facilities and equipment that are unique assembly and support equipment, since these are included in WBS element 06-00-00.

WBS TITLE: ASSEMBLY AND SUPPORT EQUIPMENT PROJECT
WBS NUMBER: -06-00-00

This element is the assembly and support equipment project.

This element includes the DDT&E, investment, and operations of all SPS unique assembly and support equipment. Included are beam machines, assembly jigs, manipulators, teleoperators, cargo handling equipment, propellant depots, maintenance and repair facilities, and other special equipment required in the assembly, checkout, orbit transfer, and operation and maintenance of the satellite system. This element excludes equipment provided by the space assembly and support facility project (WBS Element 05-00-00).

WBS TITLE: HEAVY LIFT LAUNCH VEHICLE (HLLV) PROJECT
WBS NUMBER: -07-00-00

This element is the HLLV project.

This element includes the DDT&E, investment, and operations of the HLLV vehicles required to support the satellite system assembly and operation. Included is the HLLV cost per flight which covers the launch to LEO of all space assembly and support facilities, space assembly and support equipment, satellite system hardware, orbital transfer vehicles, propellants, and other consumables required throughout the satellite lifetime. Also included are the payload launch operations that consist of the physical integration of the payload into the HLLV payload bay and any payload unique repair and/or check-out activity at the launch site during launch preparations. The following systems are included in this element:

1. HLLV Fleet
2. HLLV Operations.



WBS TITLE: HLLV FLEET
WBS NUMBER: -07-01-00

This element is a system of the HLLV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary HLLV DDT&E and fleet (vehicle) procurement required to support the SPS project. HLLV DDT&E is charged against the account or subaccount dimension column that corresponds to the first user. That is, for example, if the SPS DDT&E (full scale) has the first requirement for the HLLV, the HLLV DDT&E is charged against the WBS matrix position that corresponds to the HLLV fleet row and the DDT&E column of the SPS DDT&E (full scale) subaccount. Similarly, the HLLV vehicle inventory required by the SPS DDT&E (full scale) is charged against the matrix position that corresponds to the HLLV fleet row and the investment column of the SPS DDT&E (full scale) subaccount.

WBS TITLE: HLLV OPERATIONS
WBS NUMBER: -07-02-00

This element is an activity of the HLLV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary HLLV operations (user charge per flight including payload integration) required to support the SPS project. HLLV operations are charged against the matrix position that corresponds to the HLLV operations row and the operations column of the account or subaccount for which the operations were incurred.

WBS TITLE: SPACE TRANSPORTATION SYSTEM (STS) PROJECT
WBS NUMBER: -08-00-00

This element is the SPS peculiar portion of the STS project.

This element includes the operations of the STS vehicles (shuttle and upper stages) required to support the SPS project. Included are the STS vehicles costs per flight which cover transportation to orbit of all personnel and critical hardware items. Also included are the payload launch operations which consist of the physical integration of the payload into the shuttle payload bay and any payload unique repair and/or checkout activity at the launch site during launch preparations.

The following systems are included in this element:

1. STS Fleet
2. STS Operations.



WBS TITLE: STS FLEET
WBS NUMBER: -08-01-00

This element is a system of the STS project.

This element provides a hardware and activities dimension row line item against which to charge the necessary STS fleet (vehicle) procurement. For example, vehicle inventory required by the SPS DDT&E (full scale) is charged against the matrix position that corresponds to the STS fleet row and the investment column of the SPS DDT&E (full scale) subaccount.

WBS TITLE: STS OPERATIONS
WBS NUMBER: -08-02-00

This element is an activity of the STS project.

This element provides a hardware and activities dimension row line item against which to charge the necessary STS operation (user charge per flight including payload integration) required to support the SPS project. STS operations are charged against the matrix position that corresponds to the STS operations row and the operations column of the account or subaccount for which the operations were incurred.

WBS TITLE: CARGO ORBITAL TRANSFER VEHICLE (COTV) PROJECT
WBS NUMBER: -09-00-00

This element is the COTV project.

This element includes the DDT&E, investment, and operation of the COTV vehicles required to support the assembly (if assembled in GEO) and the operations and maintenance of the SPS project. Included are the COTV costs per flight which cover the LEO to GEO transfer of replacement hardware (spares), propellants, and consumables required throughout the SPS project lifetime.

The following systems are included in this element:

1. COTV Fleet
2. COTV Operations.



WBS TITLE: COTV FLEET
WBS NUMBER: -09-01-00

This element is a system of the COTV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary COTV DDT&E and fleet (vehicle) procurement required to support the SPS project. COTV DDT&E is charged against the account or subaccount dimension column that corresponds to the first user. That is, for example, if the SPS DDT&E (full scale) has the first requirement for the COTV, the COTV DDT&E is charged against the WBS matrix position that corresponds to the COTV fleet row and the SPS DDT&E (full scale) subaccount DDT&E column. Similarly, the COTV vehicle inventory required by the SPS DDT&E (full scale) is charged against the matrix position that corresponds to the COTV fleet row and the investment column of the SPS DDT&E (full scale) subaccount.

WBS TITLE: COTV OPERATIONS
WBS NUMBER: -09-02-00

This element is an activity of the COTV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary COTV operation (user charge per flight including payload integration) required to support the SPS project. COTV operations are charged against the matrix position that corresponds to the COTV operations row and the operations column of the account or subaccount for which the operations were incurred.

WBS TITLE: PERSONNEL ORBITAL TRANSFER VEHICLE (POTV) PROJECT
WBS NUMBER: -10-00-00

This element is the POTV project.

This element includes the DDT&E, investment, and operation of the POTV vehicles required to support the checkout and the operations and maintenance of the SPS project. Included are the POTV costs per flight which cover the LEO to GEO transfer of all personnel and critical hardware items required throughout the SPS project lifetime.

The following systems are included in this element:

1. POTV Fleet
2. POTV Operations.



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WBS TITLE: POTV FLEET
WBS NUMBER: -10-01-00

This element is a system of the POTV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary POTV DDT&E and fleet (vehicle) procurement required to support the SPS project. POTV DDT&E is charged against the account or subaccount dimension column that corresponds to the first user. That is, for example, if the SPS DDT&E (full scale) has the first requirement for the POTV, the POTV DDT&E is charged against the WBS matrix position that corresponds to the POTV fleet row and the SPS DDT&E (full scale) sub-account DDT&E column. Similarly, the POTV vehicle inventory required by the SPS DDT&E (full scale) is charged against the matrix position that corresponds to the POTV fleet and the Investment column of the SPS DDT&E (full scale) sub-account.

WBS TITLE: POTV OPERATIONS
WBS NUMBER: -10-02-00

This element is an activity of the POTV project.

This element provides a hardware and activities dimension row line item against which to charge the necessary POTV operations (user charge per flight including payload integration) required to support the SPS project. POTV operations are charged against the matrix position that corresponds to the POTV operations row and the operations column of the account or subaccount for which the operations were incurred.

WBS TITLE: FACILITIES
WBS NUMBER: -11-00-00

This element is the facilities project.

This element includes major ground facilities required to support DDT&E, production and assembly, and operations of the SPS project systems. Included in this element are the HLLV launch and recovery facility, the space construction base ground support facility, major test facilities such as test stands, and major production facilities required specifically for the SPS project. Excluded are facilities that are included in other systems such as the ground station system site and facilities.



WBS TITLE: TAXES
WBS NUMBER: -12-00-00

This element is a system level cost of the SPS project.

This element includes the taxes that are directly paid by the SPS owner and passed on as part of the SPS electricity generation costs. The tax charges that are included are those that are SPS concept dependent. Both property taxes and income taxes may vary between SPS concepts. Sales taxes, on the other hand, are not concept dependent and, therefore, need not be considered.

The following subelements are included in this element:

1. Property Taxes
2. Income Taxes.

WBS TITLE: PROPERTY TAXES
WBS NUMBER: -12-01-00

This element is a subelement of taxes.

This element includes property taxes on the ground station system.

WBS TITLE: INCOME TAXES
WBS NUMBER: -12-02-00

This element is a subelement of taxes.

This element includes the state and federal corporation income taxes on the revenue from the SPS electricity generation.



WBS TITLE: INSURANCE
WBS NUMBER: -13-00-00

This element is a system element cost of the SPS project.

This element includes the insurance directly paid by the SPS owner on SPS property and space transportation of that property, and passed on as part of the SPS electricity generation costs.

The following subelements are included in this element:

1. Property Insurance
2. Launch Insurance (Losses).

WBS TITLE: PROPERTY INSURANCE
WBS NUMBER: -13-01-00

This element is a subelement of insurance.

This element includes casualty and liability property insurance on the ground station system and the operating satellite system (not including launch insurance).

WBS TITLE: LAUNCH INSURANCE (LOSSES)
WBS NUMBER: -13-02-00

This element is a subelement of insurance.

This element includes casualty and liability insurance on payloads and space transportation vehicles during transfer from the Earth's surface to LEO or GEO and return. (Casualty losses resulting from transportation vehicle failure may be assumed to be absorbed by the SPS owner. These losses can be calculated from vehicle reliability estimates.)



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**APPENDIX B
SPS COST ESTIMATING RELATIONSHIPS (CER'S)**



APPENDIX B

SPS COST ESTIMATING RELATIONSHIPS (CER'S)

B.0 INTRODUCTION

This section provides a brief narrative description of each CER utilized in the SPS computer cost module, its application, input parameters, and computer calculated cost for CD (DDT&E); CLRM (cost of lowest repeating module); CTFU (cost of theoretical first unit); CIPS (investment cost per satellite); CRI (replacement capital investment cost), and CO&M (operations and maintenance cost). Also included are the costing ground rules and assumptions, costing methodology and detailed cost breakdowns. Table B-1 provides definitions of computer cost model elements.

Table B-1. 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
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	= $1.0 + \text{LOG}(\text{PHI}) \div \text{LOG}(2.0)$
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 & 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



B.1 COSTING GROUND RULES AND ASSUMPTIONS

The following major ground rules and assumptions were considered in developing SPS cost data during the study:

1. Cost estimates are in constant mid-1977 dollars.
2. Costs are reported by 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. 120)
 - c. Replacement capital investment (RCI) cost and operations and maintenance cost (O&M) per satellite per year (assumed SPS operational lifetime of 30 years with maintenance)
3. Assumed 1985 technology base and resources supply/demand conditions.
4. Assumed 90% launch vehicle load factor in calculating cost of mass flow to LEO.
5. A 30-percent satellite mass contingency is reflected in only those satellite costs with mass dependent cost calculations.

B.2 COSTING METHODOLOGY

The satellite and ground station costs were developed utilizing the NASA/MSFC computer cost model with certain CER variations. Costing of the remaining WBS elements such as the space station elements, launch vehicles, orbital vehicles, space equipment, facilities, taxes, and insurance utilized the MSFC model but with slight modifications in some areas in order to exercise a more simplified direct function. Therefore, much of the methodology discussion and the CER rationale and descriptions are based upon that developed by MSFC for the computer cost model.

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 DDT&E equation (CD) estimates the cost of the design, development test and evaluation, non-recurring (excluding ground test hardware), ground test operations, program management (PM), and systems engineering and integration (SE&I). Program management and SE&I are shown as separate line items in the WBS at project level and at system level. Separate factors are provided for calculating the project and system program management and SE&I costs. In view of the gross nature of the level of information available at this time on the ground test hardware and the ground test operations, the cost of these two WBS items has been assumed to be the equivalent of one-half the satellite system first-unit costs.

The appropriate inputs for the DDT&E CER's 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 three different forms—CLRM, CTFU 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 then input the satellite TFU cost into a progress (learning) function for the quantity of satellites required to calculate the average unit costs (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. It automatically takes into account the progress over production quantities required when calculating CIPS. In some ICI cost equations, such as avionics—display and control and space station elements, the appropriate input for the CLRM cost calculation is the total mass per satellite/module. In these cases the cost equation calculates the value of one LRM and exercises this LRM value in the normal manner as the TFU value to calculate the IPS.

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

Operations and maintenance costs (O&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. O&M costs are reflected in the following WBS items:



03-06-00	Propulsion
03-12-00	Satellite System Operations
04-07-00	Ground Station System Operations
07-02-00	STS/HLLV Operations
08-02-00	IOV Operations
09-02-00	COTV Operations
10-02-00	POTV Operations

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 based 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 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 Table B-2. 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 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 therefore would experience learning. (Technically distinguishable from learning, but still predictable with

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



Table B-2. SPS Tooling Factors

AVERAGE ANNUAL PRODUCTION RATE (AAPR)	TOOLING FACTOR (TF)	PROGRESS FRACTION (θ)
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 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 as given in Table B-2.

As required by the costing ground rules and assumptions, all CER's are in terms of 1977 dollars. The study did assume 1985 technology and 1985 supply/demand conditions which, in some cases, resulted in differential (non-general) price inflation or deflation between 1977 and 1985 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 the antenna structure CER, the power source structure CER, and the microwave antenna CER.

B.3 COST BREAKDOWNS

Tables B-3 and B-4 reflect detail cost data at SPS-WBS system, subsystem, and assembly levels as developed since the submittal of the SPS Final Report (April 1978). Table B-3 shows SPS project-related development-DDT&E cost (CD) through the first full 5-GW satellite (TFU) including space transportation fleets (HLLV's and OTV's); initial space assembly and support requirements; and the facilities needed to establish the SPS operational capability of building more than one SPS system. Table B-4 details the investment cost per satellite (CIPS); and the replacement capital investment cost (CRCI) and operations and maintenance cost (CO&M) per satellite per year. Figure B-1 shows a comparison of the cost relationship of the summary WBS elements for each of the above.

B.3.1 Development Cost (DDT&E)

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

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Table B-3. Satellite Power System Project Development Cost
SGW PHOTOVOLTAIC CR=2

WBS #	DESCRIPTION	DDTCL	DEVELOPMENT TRD	TOTAL
01-00-00	PROGRAM MANAGEMENT	345.611	250.906	594.524
02-00-00	SECI	1636.275	491.972	2128.248
03-00-00	SATELLITE SYSTEM	10666.852	5921.391	16618.242
03-01-00	PROGRAM MANAGEMENT	209.546	56.697	266.243
03-02-00	SECI	952.483	383.999	1336.482
03-03-00	STRUCTURE	2451.048	390.554	2841.602
03-03-01	ANTENNA STRUCTURE	681.427	38.870	720.297
03-03-02	POWER SOURCE STRUCTURE	1595.157	18.564	1613.721
03-03-04	MECHANISMS	59.276	11.664	70.940
03-03-05	SECONDARY STRUCTURE	115.188	32.056	147.244
03-04-00	POWER SOURCE	335.449	2375.827	2710.276
03-04-01	SOLAR BLANKETS	75.907	1976.461	2054.448
03-04-02	CONCENTRATORS	17.123	96.748	113.871
03-04-03	POWER DIST. & COND. -SUN TRACKING	79.685	165.890	245.574
03-04-03	POWER DIST. & COND. -SLIP RINGS	6.000	124.295	130.295
03-04-03	POWER DIST. & COND. -SWITCHING	19.756	1.604	21.360
03-04-03	POWER DIST. & COND. -BATTERIES	131.150	3.169	134.319
03-04-03	POWER DIST. & COND. -BATTERY POWER	253.179	2001.268	2254.446
03-05-00	MICROWAVE	126.026	5.932	131.959
03-05-01	MICROWAVE -HEAT PIPES	127.152	1995.335	2122.487
03-05-02	MICROWAVE -ANTENNA	7.331	30.151	37.482
03-06-00	PROPULSION	7.331	30.151	37.482
03-06-00	ATTITUDE CONTROL AND ORB. MAN.	68.034	239.945	327.979
03-07-00	AVIONICS	18.450	9.027	27.477
03-07-01	AVIONICS-MCC	13.532	1.402	14.934
03-07-02	AVIONICS-D AND C	3.156	2.076	5.232
03-07-03	AVIONICS-SC			

03-03-01	ANTENNA STRUCTURE	681.427	38.870	720.297
03-03-02	POWER SOURCE STRUCTURE	1595.157	18.584	1613.741
03-03-04	MECHANISMS	59.276	11.064	70.340
03-03-05	SECONDARY STRUCTURE	115.188	322.056	437.244
03-04-00	POWER SOURCE	335.449	2373.827	2709.276
03-04-01	SOLAR BLANKETS	75.967	1978.461	2054.448
03-04-02	CONCENTRATORS	17.123	98.748	115.871
03-04-03	POWER DIST. & COND. -SLIP RINGS	49.885	165.890	215.775
03-04-03	POWER DIST. & COND. -SWITCHING	6.000	124.295	130.295
03-04-03	POWER DIST. & COND. -BATTERIES	49.758	1.604	51.362
03-04-03	POWER DIST. & COND. -BATTERY POWER	131.150	3.169	134.320
03-05-00	MICROWAVE	253.179	2001.268	2254.446
03-05-01	MICROWAVE -HEAT PIPES	126.026	5.932	131.959
03-05-02	MICROWAVE -ANTENNA	127.152	1995.335	2122.487
03-06-00	PROPULSION	7.331	30.151	37.482
03-06-00	ATTITUDE CONTROL AND ORB. MAN.	7.331	30.151	37.482
03-07-00	AVIONICS	68.034	239.943	327.976
03-07-01	AVIONICS-MCC	18.490	9.027	27.517
03-07-02	AVIONICS-D AND C	13.532	1.402	14.934
03-07-03	AVIONICS-SC	3.156	2.676	5.832
03-07-04	AVIONICS-RC	3.043	6.554	9.597
03-07-05	AVIONICS-BUS CONTROL UNIT	0.522	6.032	6.554
03-07-06	AVIONICS-MICROPROCESSORS	0.533	7.824	8.357
03-07-07	AVIONICS-RA AND C	0.522	6.622	7.144
03-07-08	AVIONICS-SUBMULTIPLEXORS	0.335	76.523	76.858
03-07-09	AVIONICS-INSTRUMENTATION	38.270	95.363	133.633
03-07-10	AVIONICS-OPTICAL FIBER	0.673	0.675	1.348
03-07-10	AVIONICS-CABLES/HARNESS	18.771	23.076	41.847
03-08-00	THERMAL CONTROL	38.204	77.159	115.363

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03-08-03	THERMAL CONTROL -INSULATION	38.204	77.159	115.363
03-09-00	GROUND ASSEMBLY & INTEGRATION	0.0	107.563	107.563
03-10-00	SYSTEM GROUND TEST HARDWARE	2742.650	0.0	2742.650
03-11-00	SYSTEM GROUND TEST OPERATIONS	2742.650	0.0	2742.650
03-12-00	OPERATIONS	0.0	265.269	265.269
03-12-01	GROUND OPERATIONS	0.0	68.349	68.349
03-12-01	GROUND SUPPORT, CONSTRUCTION	0.0	65.000	65.000
03-12-01	LOGISTICS	0.0	3.349	3.349
03-12-02	ORBITAL OPERATIONS	0.0	196.921	196.921
03-12-02	ORBITAL OPERATIONS, CONSTRUCTION CREW	0.0	169.726	169.726
03-12-02	ORBITAL OPERATIONS, OPERATIONS CREW	0.0	0.0	0.0
03-12-02	ORBITAL OPERATIONS, CONST. PROV.	0.0	19.747	19.747
03-12-02	ORBITAL OPERATIONS, OPS. PROV.	0.0	0.0	0.0
03-12-02	ORBITAL OPERATIONS, CONST. EMS	0.0	7.446	7.446
03-12-02	ORBITAL OPERATIONS, OPS. EMS	0.0	0.0	0.0
03-13-00	GROUND SUPPORT EQUIPMENT	665.694	0.0	665.694
03-00-00	GROUND STATION SYSTEM, GSS	132.364	2310.914	2443.278

03-12-02	ORBITAL OPERATIONS, CONST. PROV.	0.0	19,747	19,747
03-12-02	ORBITAL OPERATIONS, OPS. PROV.	0.0	0.0	0.0
03-12-02	ORBITAL OPERATIONS, CONST. EMS	0.0	7,446	7,446
03-12-02	ORBITAL OPERATIONS, OPS. EMS	0.0	0.0	0.0
03-13-00	GROUND SUPPORT EQUIPMENT	865.294	0.0	865.294
04-00-00	GROUND STATION SYSTEM, GSS	132.364	2310.914	2443.278
04-01-00	GSS-PROGRAM MANAGEMENT	2,595	22,880	25,476
04-02-00	GSS-SE AND I	11,797	149,064	161,482
04-03-00	GSS-RECTENNA	8,152	1591.614	1599,765
04-03-01	RECTENNA, DIPOLE/RECTIFIER	0.0	645,474	645,474
04-03-02	RECTENNA, POWER DIST. & COND.	0.0	51,069	51,069
04-03-03	RECTENNA, SUPPORT AND GROUND PLANE	0.0	695,071	695,071
04-03-04	RECTENNA, DDTCL	8,152	0.0	8,152
04-04-00	GSS-SATELLITE CONTROL	10,000	50,000	60,000
04-05-00	GSS-UTILITY INTERFACE	99,820	332,423	432,242
04-06-00	GSS-SITE AND FACILITIES	0.0	164,245	164,245
04-06-01	GSS-LAND AND PREPARATION	0.0	105,345	105,345
04-06-02	GSS-ROADS AND FENCES	0.0	8,900	8,900
04-06-03	GSS-UTILITIES	0.0	10,000	10,000
04-06-04	GSS-BUILDINGS	0.0	36,000	36,000
04-06-05	GSS-MAINTENANCE EQPT	0.0	4,000	4,000
04-07-00	GSS-OPERATIONS AND MAINTENANCE	0.0	0.0	0.0
04-07-01	GSS-OPERATIONS AND MAINT. PERSONNEL	0.0	0.0	0.0
04-07-02	GSS-MAINTENANCE MATERIAL	0.0	0.0	0.0
05-00-00	SPACE STATION	918,422	8807,328	18005,750
05-01-00	SPACE STATION-LEO	4165,957	715,703	4885,660
05-01-01	LEO - CHM	262,278	101,790	364,068
05-01-02	LEO - CSM/EVA	335,664	156,546	492,210
05-01-03	LEO - COM	2464,993	310,392	2775,385
05-01-04	LEO - PM	38,000	142,500	180,500
05-02-00	SPACE STATION-GEO CONSTRUCTION BASE	5032,473	8087,629	13120,102
05-02-01	GEO - ADM	31,152	557,187	588,339

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05-02-02	GEO - CHM	262,278	2466,487	2728,765
05-02-03	GEO - CLM	265,000	910,522	1175,522
05-02-04	GEO - COM	2464,993	1448,660	3913,653
05-02-05	GEO - CSM/EVA	335,664	157,112	492,776
05-02-06	GEO - PM	38,000	1039,323	1365,322
05-02-07	GEO - PSM	793,710	1141,934	1935,645
05-02-08	GEO - SHD	343,200	31,426	374,626
05-02-09	GEO - SM	185,480	328,691	514,171
05-02-10	AESE FAB FIXTURE	1065,027	8,475	1073,502
06-00-00	ASSEMBLY & SUPPORT EQPT.	582,300	749,731	1332,031
06-00-01	AESE - BEAM MACHINE	6,020	83,987	90,007
06-00-02	AESE - CASSETTES	0,300	0,438	1,238
06-00-03	AESE - CABLE ATT MACHINE	4,300	47,491	51,791
06-00-04	AESE - REMOTE MANIPULATOR	6,880	35,563	42,443
06-00-05	AESE - BLANKET DISPENSER	8,000	11,873	19,873

05-02-02	GEO - CHM	252.278	2466.487	2728.765
05-02-03	GEO - CLM	265.000	910.622	1101.622
05-02-04	GEO - COM	2464.993	1448.600	3913.653
05-02-05	GEO - CSM/EPA	330.664	157.112	492.776
05-02-06	GEO - PM	350.000	1039.323	1389.323
05-02-07	GEO - PSM	793.710	1141.934	1935.645
05-02-08	GEO - SHD	343.200	31.426	374.626
05-02-09	GEO - SM	188.480	328.691	515.171
05-02-10	AESE FAB MIXTURE	1065.027	8.475	1073.502
06-00-00	ASSEMBLY & SUPPORT EQPT.	582.300	749.731	1332.031
06-00-01	AESE - BEAM MACHINE	0.020	83.987	90.007
06-00-02	AESE - CASSETTES	0.300	0.938	1.238
06-00-03	AESE - CABLE ATT MACHINE	4.300	47.491	51.791
06-00-04	AESE - REMOTE MANIPULATOR	0.850	35.503	42.443
06-00-05	AESE - BLANKET DISPENSER	8.000	11.873	19.873
06-00-06	AESE - REFLECTOR DISPENSER	40.000	5.543	45.543
06-00-07	AESE - CABLE DISPENSER	0.800	4.335	5.135
06-00-08	AESE - ANTENNA PANEL INS. EQPT.	516.000	560.001	1076.001
07-00-00	STS - HLLV	7921.199	2714.803	10636.000
07-01-00	STS - HLLV FLEET PROCUREMENT	7921.199	2090.803	10012.000
07-02-00	STS - HLLV OPERATIONS	0.0	624.000	624.000
08-00-00	INTRA ORBIT VEHICLE	100.000	10.878	110.878
08-01-00	IDV-FLEET PROCUREMENT	100.000	9.878	109.878
08-02-00	IDV-OPERATIONS	0.0	1.000	1.000
09-00-00	CARGO ORBITAL TRANSFER VEHICLE	394.383	703.582	1097.965
09-01-00	COTV-FLEET PROCUREMENT	394.383	689.382	1083.765
09-01-01	COTVFP-POWER SOURCE STRUCTURE	323.085	8.047	331.132
09-01-03	COTVFP-SILAR BLANKET	35.794	373.606	409.400
09-01-04	COTVFP-CONCENTRATOR	11.017	19.440	30.458
09-01-05	COTVFP-ELECTRIC PROPULSION SYSTEM	8.399	263.831	272.230
09-01-06	COTVFP-AVIONICS	11.020	60.794	72.422
09-01-06	COTVFP-AVIONICS, SUPERVISOR COMPUTER	1.082	2.001	3.083
09-01-06	COTVFP-AVIONICS, COMMAND AND CONTROL	4.001	2.391	6.391
09-01-06	COTVFP-AVIONICS, MICROPROCESSORS	0.037	2.320	2.357
09-01-06	COTVFP-AVIONICS, BUS CONTROL UNIT	0.037	2.431	2.468
09-01-06	COTVFP-AVIONICS, REMOTE ACQ & CONTROL	0.040	2.818	2.858
09-01-06	COTVFP-AVIONICS, SUBMULTIPLEXER	0.021	19.019	19.040
09-01-06	COTVFP-AVIONICS, OPTICAL FIBER	0.363	0.207	0.570
09-01-06	COTVFP-AVIONICS, CABLES & HARNESS	4.222	4.829	9.051
09-01-06	COTVFP-AVIONICS, INSTRUMENTATION	1.824	24.776	26.602
09-01-07	COTVFP-THERMAL CONTROL	0.033	0.384	0.417
09-01-08	COTVFP-POWER DISTRIBUTION	4.421	2.781	7.202
09-02-00	COTV-OPERATIONS	0.0	14.200	14.200

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10-00-00 PERSONNEL ORBITAL TRANSFER VEHICLE

500.000 123.010 623.010

10-00-00	PERSONNEL ORBITAL TRANSFER VEHICLE	500.000	123.010	623.010
10-01-00	POTV-FLEET PROCUREMENT	500.000	120.310	620.310
10-02-00	POTV-OPERATIONS	0.0	2.700	2.700
11-00-00	FACILITIES	3210.000	3250.000	6460.000
11-02-00	FACILITIES - GROUND SUPPORT	0.0	1500.000	1500.000
11-03-00	FACILITIES - MAJOR GROUND TEST	0.0	750.000	750.000
11-04-00	FACILITIES - GROUND LAUNCH & RECOVERY	3210.000	1000.000	4210.000
12-00-00	TAXES	0.0	0.0	0.0
12-01-00	TAXES-PROPERTY	0.0	0.0	0.0
13-00-00	INSURANCE	0.0	0.0	0.0
13-01-00	INSURANCE-PROPERTY	0.0	0.0	0.0
	TOTAL	34705.402	25341.500	60046.902

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(UPDATED JUNE 12, 1978)

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Table B-4. Satellite Power System Project Average Cost
 5GW PHOTOVOLTAIC CR=2

WBS #	DESCRIPTION	INV PER SAT	** UPS COST PER SAT PER YEAR ** FCI	UCM	TOTAL UPS	TOTAL
01-00-00	PROGRAM MANAGEMENT	46.836	2.052	1.006	3.059	99.895
02-00-00	SELT	189.874	4.024	0.0	4.024	193.898
03-00-00	SATELLITE SYSTEM	4937.027	136.722	0.111	144.833	5081.859
03-01-00	PROGRAM MANAGEMENT	46.881	1.354	0.080	1.434	50.315
03-02-00	SELT	319.785	8.856	0.0	8.856	328.641
03-03-00	STRUCTURE	345.309	0.753	0.078	0.831	346.140
03-03-01	ANTENNA STRUCTURE	38.870	0.078	0.0	0.078	38.948
03-03-02	POWER SOURCE STRUCTURE	18.564	0.037	0.0	0.037	18.601
03-03-04	MECHANISMS	7.767	0.074	0.078	0.156	7.922
03-03-05	SECONDARY STRUCTURE	280.109	0.560	0.0	0.560	280.669
03-04-00	POWER SOURCE	2104.522	5.625	0.664	6.512	2111.034
03-04-01	SOLAR BLANKETS	1845.868	3.692	0.0	3.692	1849.559
03-04-02	CONCENTRATORS	84.151	0.168	0.0	0.168	84.319
03-04-03	POWER DIST. & COND. -CONDUCTORS	3.640	0.0	0.0	0.0	3.640
03-04-03	POWER DIST. & COND. -SLIP RINGS	80.268	0.803	0.0	0.803	81.070
03-04-03	POWER DIST. & COND. -SWITCHING	87.334	0.873	0.273	1.746	89.080
03-04-03	POWER DIST. & COND. -BATTERIES	1.036	0.069	0.011	0.080	1.119
03-04-03	POWER DIST. & COND. -BATTERY POWER	2.224	0.022	0.0	0.022	2.247
03-05-00	MICROWAVE	1685.977	112.107	0.0	112.107	1798.084
03-05-01	MICROWAVE -HEAT PIPES	5.160	0.052	0.0	0.052	5.211
03-05-02	MICROWAVE -ANTENNA	1680.818	112.055	0.0	112.055	1792.673
03-06-00	PROPULSION	14.662	2.932	0.047	2.979	17.641
03-06-00	ATTITUDE CONTROL AND ORB. MAN.	14.662	2.932	0.047	2.979	17.641
03-07-00	AVIONICS	194.097	1.941	0.0	1.941	196.038
03-07-01	AVIONICS-MCC	2.467	0.025	0.0	0.025	2.492
03-07-02	AVIONICS-D AND C	0.425	0.004	0.0	0.004	0.429
03-07-03	AVIONICS-SC	0.950	0.009	0.0	0.009	0.959
03-07-04	AVIONICS-RC	2.190	0.022	0.0	0.022	2.212
03-07-05	AVIONICS-BUS CONTROL UNIT	5.638	0.056	0.0	0.056	5.695
03-07-06	AVIONICS-MICROPROCESSORS	5.493	0.055	0.0	0.055	5.548
03-07-07	AVIONICS-RA AND C	6.053	0.061	0.0	0.061	6.113
03-07-08	AVIONICS-SUBMULTIPLEXERS	66.557	0.666	0.0	0.666	67.223
03-07-09	AVIONICS-INSTRUMENTATION	82.960	0.830	0.0	0.830	83.790
03-07-10	AVIONICS-OPTICAL FIBER	0.737	0.007	0.0	0.007	0.745
03-07-10	AVIONICS-CABLES/HARNESS	20.627	0.206	0.0	0.206	20.834
03-08-00	THERMAL CONTROL	67.189	0.671	0.0	0.671	67.860

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03-04-03	POWER DIST. & COND. -SWITCHING	87.334	0.873	0.073	1.746	89.080
03-04-03	POWER DIST. & COND. -BATTERIES	1.036	0.009	0.011	0.080	1.119
03-04-03	POWER DIST. & COND. -BATTERY POWER	2.224	0.022	0.0	0.022	2.247
03-05-00	MICROWAVE	1685.977	112.107	0.0	112.107	1798.084
03-05-01	MICROWAVE -HEAT PIPES	5.160	0.052	0.0	0.052	5.211
03-05-02	MICROWAVE -ANTENNA	1680.818	112.055	0.0	112.055	1792.673
03-06-00	PROPULSION	14.662	2.932	0.047	2.979	17.641
03-06-00	ATTITUDE CONTROL AND ORB. MAN.	14.662	2.932	0.047	2.979	17.641
03-07-00	AVIONICS	194.097	1.941	0.0	1.941	196.038
03-07-01	AVIONICS-MCC	2.467	0.025	0.0	0.025	2.492
03-07-02	AVIONICS-D AND C	0.425	0.00	0.0	0.004	0.429
03-07-03	AVIONICS-SC	0.950	0.00	0.0	0.009	0.959
03-07-04	AVIONICS-RC	2.190	0.022	0.0	0.022	2.212
03-07-05	AVIONICS-BUS CONTROL UNIT	5.638	0.056	0.0	0.056	5.695
03-07-06	AVIONICS-MICROPROCESSORS	5.493	0.055	0.0	0.055	5.548
03-07-07	AVIONICS-RA AND C	6.053	0.061	0.0	0.061	6.113
03-07-08	AVIONICS-SUBMULTIPLEXORS	66.557	0.666	0.0	0.666	67.223
03-07-09	AVIONICS-INSTRUMENTATION	82.960	0.830	0.0	0.830	83.790
03-07-10	AVIONICS-OPTICAL FIBER	0.737	0.007	0.0	0.007	0.745
03-07-10	AVIONICS-CABLES/HARNESS	20.627	0.206	0.0	0.206	20.834
03-08-00	THERMAL CONTROL	67.109	0.671	0.0	0.671	67.780

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03-08-03	THERMAL CONTROL -INSULATION	67.109	0.671	0.0	0.671	67.780
03-09-00	GROUND ASSEMBLY & INTEGRATION	89.576	2.481	0.0	2.481	92.056
03-10-00	SYSTEM GROUND TEST HARDWARE	0.0	0.0	0.0	0.0	0.0
03-11-00	SYSTEM GROUND TEST OPERATIONS	0.0	0.0	0.0	0.0	0.0
03-12-00	OPERATIONS	67.145	0.0	7.022	7.022	74.167
03-12-01	GROUND OPERATIONS	16.684	0.0	0.072	0.072	16.756
03-12-01	GROUND SUPPORT , CONSTRUCTION	16.656	0.0	0.072	0.072	16.728
03-12-01	LOGISTICS	0.025	0.0	0.0	0.0	0.028
03-12-02	ORBITAL OPERATIONS	50.461	0.0	6.950	6.950	57.411
03-12-02	ORBITAL OPERATIONS, CONSTRUCTION CREW	43.493	0.0	0.0	0.0	43.493
03-12-02	ORBITAL OPERATIONS, OPERATIONS CREW	0.0	0.0	5.990	5.990	5.990
03-12-02	ORBITAL OPERATIONS, CONST. PROV.	5.060	0.0	0.0	0.0	5.060
03-12-02	ORBITAL OPERATIONS, OPS. PROV.	0.0	0.0	0.697	0.697	0.697
03-12-02	ORBITAL OPERATIONS, CONST. EMS	1.908	0.0	0.0	0.0	1.908
03-12-02	ORBITAL OPERATIONS, OPS. EMS	0.0	0.0	0.263	0.263	0.263
03-13-00	GROUND SUPPORT EQUIPMENT	0.0	0.0	0.0	0.0	0.0
04-00-00	GROUND STATION SYSTEM, GSS	2261.201	21.053	25.013	46.066	2307.266
04-01-00	GSS-PROGRAM MANAGEMENT	22.388	0.208	0.248	0.456	22.644
04-02-00	GSS-SC AND I	146.464	1.364	0.0	1.364	147.828
04-03-00	GSS-RECTENNA	1586.195	15.862	0.0	15.862	1602.057
04-03-01	RECTENNA, DIPOLE/RECTIFIER	845.473	8.455	0.0	8.455	853.928
04-03-02	RECTENNA, POWER DIST.& COND.	45.651	0.457	0.0	0.457	46.107
04-03-03	RECTENNA, SUPPORT AND GROUND PLANE	695.071	6.951	0.0	6.951	702.022
04-03-04	RECTENNA, DDTCE	0.0	0.0	0.0	0.0	0.0
04-04-00	GSS-SATELLITE CONTROL	44.756	0.448	0.448	0.896	45.651
04-05-00	GSS-UTILITY INTERFACE	297.153	2.972	0.0	2.972	300.124

04-05-00	GSS-UTILITY INTERFACE	297.153	2.972	0.000	2.972	297.153
04-06-00	GSS-SITE AND FACILITIES	164.245	0.200	0.569	0.769	165.034
04-06-01	GSS-LAND AND PREPARATION	105.345	0.0	0.0	0.0	105.345
04-06-02	GSS-ROADS AND FENCES	6.900	0.0	0.089	0.089	6.989
04-06-03	GSS-UTILITIES	10.000	0.0	0.100	0.100	10.100
04-06-04	GSS-BUILDINGS	36.000	0.0	0.360	0.360	36.360
04-06-05	GSS-MAINTENANCE EQPT	4.000	0.200	0.040	0.240	4.240
04-07-00	GSS-OPERATIONS AND MAINTENANCE	0.0	0.0	23.728	23.728	23.728
04-07-01	GSS-OPERATIONS AND MAINT. PERSONNEL	0.0	0.0	13.728	13.728	13.728
04-07-02	GSS-MAINTENANCE MATERIAL	0.0	0.0	10.000	10.000	10.000
05-00-00	SPACE STATION	886.378	14.717	0.0	14.717	901.095
05-01-00	SPACE STATION-LED	5.927	0.119	0.0	0.119	6.045
05-01-01	LED - CHM	0.048	0.017	0.0	0.017	0.065
05-01-02	LED - CSM/EVA	1.305	0.026	0.0	0.026	1.331
05-01-03	LED - COM	2.567	0.052	0.0	0.052	2.638
05-01-04	LED - PM	1.166	0.024	0.0	0.024	1.211
05-02-00	SPACE STATION-GEO CONSTRUCTION BASE	860.451	14.599	0.0	14.599	895.050
05-02-01	GEO - ADM	55.697	1.114	0.0	1.114	56.811

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05-02-02	GEO - CHM	95.475	1.870	0.0	1.870	95.545
05-02-03	GEO - CLM	58.621	1.172	0.0	1.172	59.793
05-02-04	GEO - COM	241.867	4.838	0.0	4.838	246.725
05-02-05	GEO - CSM/EVA	118.340	2.367	0.0	2.367	120.706
05-02-06	GEO - PM	8.661	0.173	0.0	0.173	8.834
05-02-07	GEO - PSM	300.770	3.008	0.0	3.008	303.777
05-02-08	GEO - SHD	0.262	0.003	0.0	0.003	0.265
05-02-09	GEO - SM	2.739	0.055	0.0	0.055	2.794
05-02-10	ALSE FAB FIXTURE	0.071	0.0	0.0	0.0	0.071
06-00-00	ASSEMBLY & SUPPORT EQPT.	16.369	0.0	0.0	0.0	16.369
06-00-01	ALSE - BEAM MACHINE	1.780	0.0	0.0	0.0	1.780
06-00-02	ALSE - CASSETTES	0.026	0.0	0.0	0.0	0.026
06-00-03	ALSE - CABLE ATT MACHINE	0.753	0.0	0.0	0.0	0.753
06-00-04	ALSE - REMOTE MANIPULATOR	0.823	0.0	0.0	0.0	0.823
06-00-05	ALSE - BLANKET DISPENSER	0.549	0.0	0.0	0.0	0.549
06-00-06	ALSE - REFLECTOR DISPENSER	0.247	0.0	0.0	0.0	0.247
06-00-07	ALSE - CARTRIDGE DISPENSER	0.053	0.0	0.0	0.0	0.053
06-00-08	ALSE - ANTENNA PANEL INS-EQPT.	12.139	0.0	0.0	0.0	12.139
07-00-00	STS - HLLV	1235.565	21.104	34.163	55.267	1290.832
07-01-00	STS - HLLV FLEET PROCUREMENT	611.565	21.104	0.0	21.104	632.669
07-02-00	STS - HLLV OPERATIONS	624.000	0.0	34.163	34.163	658.163
08-00-00	INTRA ORBIT VEHICLE	3.285	0.103	0.023	0.125	3.411
08-01-00	IDV-FLEET PROCUREMENT	2.265	0.103	0.0	0.103	2.368
08-02-00	IDV-OPERATIONS	1.000	0.0	0.023	0.023	1.023
09-00-00	CARGO ORBITAL TRANSFER VEHICLE	79.896	5.046	0.363	5.409	85.305
09-01-00	COTV-FLEET PROCUREMENT	65.696	5.046	0.0	5.046	70.741
09-01-01	COTVFP-POWER SOURCE STRUCTURE	0.912	0.022	0.0	0.022	0.934
09-01-03	COTVFP-SOLAR BLANKET	39.255	0.964	0.0	0.964	40.220
09-01-04	COTVFP-CONCENTRATOR	2.095	0.051	0.0	0.051	2.146

05-02-04	GEO - COM	241.887	4.838	0.0	4.838	246.725
05-02-05	GEO - CSM/EPA	118.340	2.367	0.0	2.367	120.706
05-02-06	GEO - PM	8.661	0.173	0.0	0.173	8.834
05-02-07	GEO - PSM	300.770	3.008	0.0	3.008	303.777
05-02-08	GEO - SHD	0.262	0.003	0.0	0.003	0.265
05-02-09	GEO - SM	2.739	0.055	0.0	0.055	2.794
05-02-10	ALSE FAB FIXTURE	0.071	0.0	0.0	0.0	0.071
06-00-00	ASSEMBLY & SUPPORT EQPT.	16.369	0.0	0.0	0.0	16.369
06-00-01	ALSE - BEAM MACHINE	1.780	0.0	0.0	0.0	1.780
06-00-02	ALSE - CASSETTES	0.026	0.0	0.0	0.0	0.026
06-00-03	ALSE - CABLE ATT MACHINE	0.753	0.0	0.0	0.0	0.753
06-00-04	ALSE - REMOTE MANIPULATOR	0.823	0.0	0.0	0.0	0.823
06-00-05	ALSE - BLANKET DISPENSER	0.549	0.0	0.0	0.0	0.549
06-00-06	ALSE - REFLECTOR DISPENSER	0.247	0.0	0.0	0.0	0.247
06-00-07	ALSE - CABLE DISPENSER	0.053	0.0	0.0	0.0	0.053
06-00-08	ALSE - ANTENNA PANEL INS. EQPT.	12.139	0.0	0.0	0.0	12.139
07-00-00	STS - HLLV	1235.565	21.104	34.163	55.267	1290.832
07-01-00	STS - HLLV FLEET PROCUREMENT	611.565	21.104	0.0	21.104	632.669
07-02-00	STS - HLLV OPERATIONS	624.000	0.0	34.163	34.163	658.163
08-00-00	INTRA ORBIT VEHICLE	3.285	0.103	0.023	0.125	3.411
08-01-00	IOV-FLEET PROCUREMENT	2.215	0.103	0.0	0.103	2.318
08-02-00	IOV-OPERATIONS	1.000	0.0	0.023	0.023	1.023
09-00-00	CARGO ORBITAL TRANSFER VEHICLE	79.896	5.046	0.363	5.409	85.305
09-01-00	COTV-FLEET PROCUREMENT	65.696	5.046	0.0	5.046	70.741
09-01-01	COTVFP-POWER SOURCE STRUCTURE	0.912	0.022	0.0	0.022	0.934
09-01-03	COTVFP-SOLAR BLANKET	39.255	0.964	0.0	0.964	40.220
09-01-04	COTVFP-CONCENTRATOR	2.095	0.051	0.0	0.051	2.146
09-01-05	COTVFP-ELECTRIC PROPULSION SYSTEM	17.074	3.600	0.0	3.600	20.674
09-01-06	COTVFP-AVIONICS	6.108	0.199	0.0	0.199	6.306
09-01-06	COTVFP-AVIONICS, SUPERVISOR COMPUTER	0.134	0.004	0.0	0.004	0.138
09-01-06	COTVFP-AVIONICS, COMMAND AND CONTROL	0.132	0.004	0.0	0.004	0.137
09-01-06	COTVFP-AVIONICS, MICROPROCESSORS	0.217	0.007	0.0	0.007	0.224
09-01-06	COTVFP-AVIONICS, BUS CONTROL UNIT	0.227	0.007	0.0	0.007	0.235
09-01-06	COTVFP-AVIONICS, REMOTE ACQ & CONTROL	0.264	0.009	0.0	0.009	0.272
09-01-06	COTVFP-AVIONICS, SUBMULTIPLIER	1.998	0.065	0.0	0.065	2.063
09-01-06	COTVFP-AVIONICS, OPTICAL FIBER	0.022	0.001	0.0	0.001	0.023
09-01-06	COTVFP-AVIONICS, CABLES & HARNESS	0.512	0.017	0.0	0.017	0.528
09-01-06	COTVFP-AVIONICS, INSTRUMENTATION	2.603	0.085	0.0	0.085	2.687
09-01-07	COTVFP-THERMAL CONTROL	0.040	0.001	0.0	0.001	0.042
09-01-08	COTVFP-POWER DISTRIBUTION	0.212	0.007	0.0	0.007	0.219
09-02-00	COTV-OPERATIONS	14.200	0.0	0.363	0.363	14.563

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10-00-00	PERSONNEL ORBITAL TRANSFER VEHICLE	7.333	0.798	0.180	0.978	8.310
10-01-00	POTV-FLEET PROCUREMENT	5.963	0.798	0.0	0.798	6.760
10-02-00	POTV-OPERATIONS	1.350	0.0	0.180	0.180	1.530
11-00-00	FACILITIES	66.667	1.667	0.0	1.667	68.333
11-02-00	FACILITIES - GROUND SUPPORT	20.833	0.417	0.0	0.417	21.250
11-03-00	FACILITIES - MAJOR GROUND TEST	12.500	0.0	0.0	0.0	12.500

10-00-00	PERSONNEL ORBITAL TRANSFER VEHICLE	7.333	0.798	0.180	0.078	8.310
10-01-00	POTV-FLEET PROCUREMENT	5.983	0.798	0.0	0.798	6.780
10-02-00	POTV-OPERATIONS	1.350	0.0	0.180	0.180	1.530
11-00-00	FACILITIES	66.667	1.667	0.0	1.667	68.333
11-02-00	FACILITIES - GROUND SUPPORT	20.833	0.417	0.0	0.417	21.250
11-03-00	FACILITIES - MAJOR GROUND TEST	12.500	0.250	0.0	0.250	12.750
11-04-00	FACILITIES - GROUND LAUNCH & RECOVERY	33.333	1.000	0.0	1.000	34.333
12-00-00	TAXES	0.0	0.0	31.657	31.657	31.657
12-01-00	TAXES-PROPERTY	0.0	0.0	31.657	31.657	31.657
13-00-00	INSURANCE	0.0	0.0	1.131	1.131	1.131
13-01-00	INSURANCE-PROPERTY	0.0	0.0	1.131	1.131	1.131
	TOTAL	9780.410	207.285	101.644	308.931	10089.340

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(UPDATED JUNE 12, 1978)

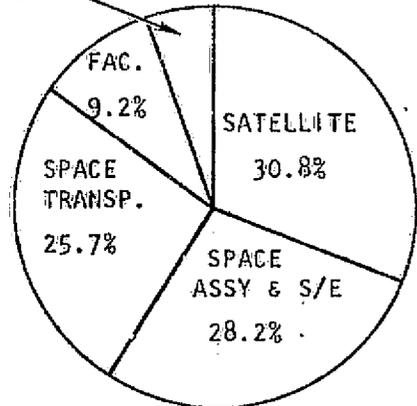
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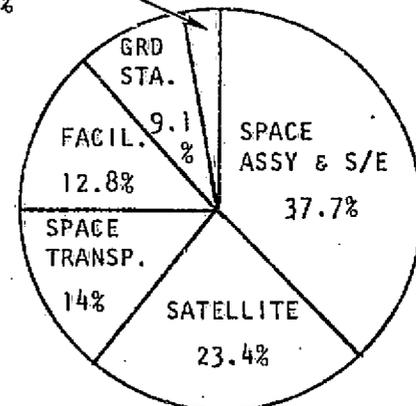
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GRD STA., 0.4%



\$ 34.70B

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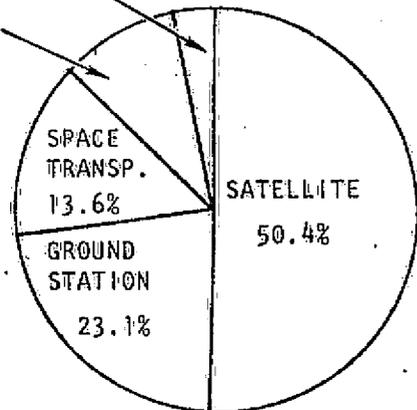
PM & SE&I 3%



\$25.34B

INVESTMENT PER SAT. SYS.

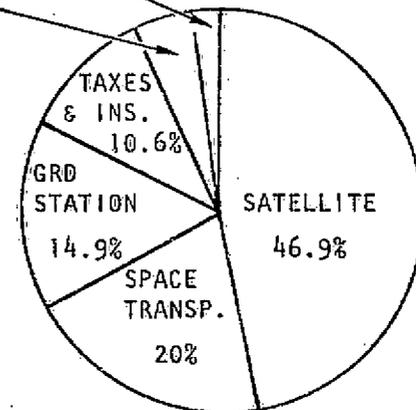
PM & SE&I, 3%
FACILITIES, .7%
SPACE ASSY & S/E, 9.2%



\$ 9.78B

REPL. CAPITAL/ OPS & MAINT.

PM & SE&I, 2.3%
FACILITIES, .6%
SPACE ASSY & S/E, 4.7%



\$ 0.309B/SAT-YR

Figure B-1. SPS WBS Cost Relationships

(UPDATED JUNE 12, 1978)

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SD 78-AP-0023-7



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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 analysis, 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 a 1-GW SPS prototype demonstration satellite which, following demonstrations, will be upgraded to the full 5-GW satellite (TFU). Also included are the analysis of data and whatever design 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 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 are also included.

The total project development cost through the first full 5-GW satellite (TFU) system is \$60.046 billion (DDT&E is \$34.705 billion and TFU is \$25.341 billion). Table B-3 identifies the main areas of cost by WBS category. Figure B-1 reflects this relationship within the DDT&E and TFU cost areas. The satellite portion of the DDT&E cost is \$10.687 billion (30.8%). Cost to develop the space assembly and support equipment is \$9.78 billion (28.2%); and the space transportation DDT&E is \$8.915 billion (25.7%).

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—which is generally the method. Instead, it was considered desirable to determine the satellite subsystem DDT&E costs by the application of a development factor; the development factor was determined by engineering. In general, the development factor was estimated to be 20%, with a few exceptions. This means that it was determined by engineering that the appropriate DDT&E cost necessary to develop the total subsystem would equate to the cost of 20% of the total subsystem mass, area or power per satellite. In some cases, it was determined that the factor should be slightly higher. The development factor for attitude control was estimated to be 30%; the microwave antenna 40%, and the antenna structure at 50%. Some of the avionics component development factors are less than 20%. The computer cost data tables reflect the application of the development factor (DF) for each satellite subsystem.

The detailed DDT&E cost breakdowns show that the structure, ground test hardware and ground test operations make up the largest portion of the satellite system DDT&E cost at about 25% of the total for each. The power source system accounts for only 3.14%; the microwave antenna for 2.37%; attitude control and avionics less than 1%; and thermal control of less than .4%.

Costing of DDT&E for the space station 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.

The TFU cost breakdown shown in Table B-3 and Figure B-1 reflects a somewhat different makeup of costs when compared to DDT&E costs. TFU estimates at \$25.341 billion include the full dollar assessment for the initial satellite and ground station buildup including space transportation fleets (HLLV's and OTV's), initial space assembly and support equipment requirements; 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 space assembly and support equipment represent the largest portion of total TFU costs—\$9.557 billion. Satellite system costs are \$5.928 billion; space transportation, \$3.552 billion; and ground facilities, \$3.250 billion. In the space assembly and support equipment TFU costing, the LEO/GE0 satellite construction base makes up 53% of the total space assembly and support equipment estimate, but will be used to construct the remaining satellites.

B.3.2 Investment and Operations

Table B-4 reflects the detailed investment and operations cost data developed during the study. 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 full 5-GW operational capability; and (2) 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 (initial operating capability) are included in the initial capital investment (CIPS) costs. Costs for the fleet needed to support O&M (operations) is 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 120. This total average cost of \$9.780 billion (Figure B-1) includes \$4.937 billion for the satellite; \$2.261 billion for the ground station (rectenna); \$1.326 billion for space transportation; and \$.902 billion for space assembly and support equipment. The total average (investment) cost per 5-GW satellite yields an investment of \$1956/kW.

SPS replacement capital and operations/maintenance phases have been combined and are estimated at an annual cost of \$.309 billion per satellite-year or for \$9.27 billion over the 30-year operational period. Satellite requirements comprise \$.145 billion of the cost, or 46.9 percent.

01-00-00 PROGRAM MANAGEMENT (PM) CER's

This activity includes project level program management. It 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 activity also includes the efforts required in the coordination, gathering, and dissemination of management information.

Project level program management refers to program management efforts required during the integration and operation of the total SPS Program. This includes those efforts which cannot be charged directly to a system, but which relate to the program as a whole and provide for a viable SPS. This activity encompasses the following functions:

- Program Administration
- Program Planning and Control
- Contracts Administration
- Engineering Management
- Manufacturing Management
- Support Management
- Quality Assurance Management
- Configuration Management
- Data Management

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS project level requirements.

From these data, the CDCER and CECER percentage factors were developed which can be used with project costs to estimate the SPS project level program management, see table B-5.

The cost data bases for application of the factors are as follows:

CD	=	Project DDT&E Cost (03-00-00 thru 13-00-00) plus SE&I Cost.
CTFU	=	Project TFU Cost (03-00-00 thru 13-00-00) plus SE&I Cost.
CIPS	=	Project Inv. per Sat. Cost (03-00-00 thru 13-00-00) plus SE&I Cost.
CRCI	=	Project RCI Cost (03-00-00 thru 13-00-00) plus SE&I Cost
CO&M	=	Project O&M Cost per Satellite per year (03-00-00 thru 13-00-00) plus SE&I Cost.

TABLE B-5. 01-00-00 PROGRAM MANAGEMENT
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

TF=	0.0	TF=	0.0
M=	0.0	O&M=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

CDCER=	0.010000
CDEXP=	0.010000
CICER=	0.010000
CIEXP=	0.010000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (7 X DF)XX(CDEXP) X CF	341.399
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))	262.384
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	100.710
CRCI = CIPS X R	1.160
CO&M = O&M	16.069
COMMENTS 51	

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02-00-00 SYSTEM ENGINEERING & INTEGRATION (SE&I) CER's

This activity includes project level systems engineering and integration. Project level SE&I refers to SE&I efforts required during the integration and operations on the total SPS project. This includes those effort which cannot be charged directly to a system, but which relate to the project as a whole and provide for a viable SPS.

This activity includes the engineering efforts related to the establishment and maintenance of a technical baseline for the program by generation of program configuration parameters, criteria, and requirements. It includes requirements analysis and integration, program definition, program test definition, interfaces, safety, reliability, and maintainability. It also includes those efforts required to monitor the program development and operations to ensure that the design conforms to the baseline specifications.

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS project level requirements. From these data, the CDCER and CECER percentage factors were developed which can be used with project costs to estimate the SPS project level SE&I costs, see table B-6.

The cost data bases for application of the factors are as follows:

CD	=	Project DDT&E Cost (03-00-00 thru 13-00-00)
CTFU	=	Project T&E Cost (03-00-00 thru 13-00-00)
CIPS	=	Project Inv. per Satellite Cost (03-00-00 thru 13-00-00)
CRCI	=	Project RCI Cost per Satellite per year (03-00-00 thru 13-00-00)

TABLE B-6. 02-00-00 SENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T#	0.0	TF#	0.0
M#	0.0	O&M#	0.0
CF#	0.0	Z1#	1.000000
PHI#	0.0	Z2#	120.000000
R#	0.0	Z3#	120.000000
DF#	0.0		

INPUT COEFFICIENTS

CDCER#	0.050000
CDEXP#	0.020000
CICER#	0.020000
CIEXP#	0.020000

CALCULATED VALUES

% MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	1625.710
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))	514.479
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	197.471
CRCI = CIPS X R	2.274
CO&M = O&M	31.508
COMMENTS 52	

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03-01-00 PROGRAM MANAGEMENT (PM) CER's

This activity includes system level program management. Systems level program management includes those management efforts which relate directly to a complete system. Relative to the SPS there are two complete systems. The first is the Satellite system and the second is the Ground Station system. This activity encompasses the following Satellite system functions:

- Program Administration
- Program Planning and Control
- Contract Administration
- Engineering Management
- Manufacturing Management
- Support Management
- Quality Assurance Management
- Configuration Management
- Data Management

This activity also includes the efforts required in the coordination, gathering, and dissemination of management information.

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS system level requirements. From these data, the CDCER and CICER percentage factors were developed which can be used with the satellite system cost to estimate the SPS system level program managements, see table B-7.

The cost data bases for the application of the factors are as follows:

CD	=	Satellite System DDT&E Cost (03-00-00 thru 03-13-00) plus SE&I Cost.
CTFU	=	Satellite System TFU Cost (03-03-00 thru 03-13-00) plus SE&I Cost
CIPS	=	Satellite System Inv. per Sat. Cost (03-03-00 thru 03-13-00) plus SE&I Cost
CRCI	=	Satellite System RCI Cost per Satellite per year (03-03-00 thru 03-13-00) plus SE&I Cost
CO&M	=	Satellite System O&M Cost per Satellite per year

TABLE B-7. 03-01-00 PROGRAM MANAGEMENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	0.0	TF=	0.0
M=	0.0	O&M=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

INPUT COEFFICIENTS

CD CER=	0.020000
CD EXP=	0.010000
CICER=	0.010000
CILEXP=	0.010000

CALCULATED VALUES

\$, MILLIONS

CD=CD CER X (T X DF) X (CD EXP) X CF	205.564
CLRM=CICER X (M) X (CILEXP) 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) X (E) - 0.5 X (E))	56.936
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2	49.028
CRCI = CIPS X R	0.519
COMM = O&M	0.293
COMMENTS 54	

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03-02-00 SYSTEMS ENGINEERING & INTEGRATION (SE&I) CER's

This activity includes system level systems engineering and integration. Systems level SE&I includes those SE&I efforts which relate directly to a complete system. Relative to the SPS there are two complete systems. The first is the Satellite System and the second is the Ground Station System.

This activity includes 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 effort required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS system level requirements. From these data, the CDCER and CICER percentage factors were developed which can be used with the satellite system cost to estimate the SPS system level SE&I costs, see table B-8.

The cost data bases for application of the factors are as follows:

CD	=	Satellite System DDT&E (03-03-00 thru 03-13-00)
CTFU	=	Satellite System TFCU Cost (03-03-00 thru 03-13-00)
CIPS	=	Satellite System Inv. per Sat. Cost (03-03-00 thru 03-13-00)
CRCI	=	Satellite System RCI Cost per Satellite per year (03-03-00 thru 03-13-00)

TABLE B-8. 03-02-00 SENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	0.0	TF=	0.0
M=	0.0	OM=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

INPUT COEFFICIENTS

CDGER=	0.100000
CDEXP=	0.070000
CICER=	0.070000
CIEXP=	0.0

CALCULATED VALUES

CD=CDGER X (T X DF)XX(CDEXP) X CF

5, MILLIONS

934.380

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))

372.479

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))

) / Z2

320.744

CRCI = CIPS X R

3.393

COM = OM

0.0

COMMENTS 55

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03-03-01 MICROWAVE ANTENNA STRUCTURE CER's

This element includes the basic supporting framework for the microwave antenna power transmission subsystem up to its interface with the rotary joint. The structure has three main components; a tension web made from composite wires or tapes, a catenary cable that transfers the web tension to the vertices of the third component which is a hexagonal compression frame. The antenna structure provides a structural support but does not include the waveguides or the radio frequency assemblies associated with the microwave subsystem. This element is limited to primary load carrying elements and does not include other secondary structure such as equipment mounts, platforms, and space support equipment supports.

The antenna structure CD CER was developed using graphite composite data obtained from NASA's Redstar Data Base. 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. The antenna structure ICI cost equation is based on raw composite material stock (prepregnated graphite) cost. These materials cost are based on Engineering cost estimates, see table B-9.

Range of Data

- DDT&E 30,0 to 2000.0Kg
- ICI: Unlimited

Input parameters T&M are in kilograms of mass.

TABLE B-9. 03-03-01 ANTENNA STRUCTURE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	777400.062	TF=	1.000000
M=	3250.00024	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.500000		

INPUT COEFFICIENTS

CDCER=	0.023000
CDEXP=	0.600000
CICER=	0.000050
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	681.427
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.163
#IRM = T / M	239.200
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	38.870
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	39.870
CRCI = CIPS X R	0.389
CO&M = O&M	0.0
COMMENTS 1	

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03-03-02 POWER SOURCE STRUCTURE CER's

This element includes the basic supporting framework for the energy conversion section of the satellite up to the interface with the rotary joint. The power source structure supports, but does not include, power source subsystem elements. This element does not include other secondary structure such as equipment mounts, platforms, and space support equipment supports. This element includes that portion of the power distribution function where the primary structure serves as electrical conductors. The primary function of the power source structure is to provide support for the solar cell blankets and solar concentrators. The structure assemblies are made up, basically, of tri-beam 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 must individually withstand the forces, torques, and dynamics imposed by the construction process. Once built up to an assembly level (e.g., solar array wing, rotary joint, etc.), the structure must have sufficient strength and stiffness to withstand forces, torques, and dynamics generated by the environment (gravity-gradient torques), the attitude control system (forces and frequencies) and the operational equipment (rotary joint torques, microwave induced thermal environment, etc.). The level of strength and stiffness are dictated by other subsystem requirements such as pointing accuracies and ACS bandwidth frequencies

The power source structure CD CER was developed using cost data obtained from NASA's Redstar Data Base. Data from a variety of launch vehicle, manned spacecraft, unmanned satellites and aircraft programs were used and are listed below:

Apollo Command Module	OAO-A1/A2
Apollo Lunar Module	OSO-I
Apollo Service Module	Pioneer-F
Apollo SLA	Saturn V
ATS-A	S-IC
ATS-B	S-II
ATS-E	S-IVB
ATS-F	Skylab-AM
B-70	Skylab-OWS
C-5A	TACSAT
Centaur	Tiros-M
DSCS-II	VELA IV
Gemini	
HEAO-B	
IUE	
Mariner 1964	



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The power source structure ICI CER is the cost of raw materials only since the costs associated with fabrication and assembly are charged against orbital assembly.

The power source structure ICI cost equation is based on raw aluminum coil stock cost plus such ground based processing as cutting to size and application of anodize finish. Material and finishing costs are based on vendor quotes from Reynolds Metals and Alcoa Aluminum companies and Coil Anodizers, see table B-10.

Range of Data

D&D: 40.0 to 100,000 kg

ICI: Unlimited

Input parameters T&M are in kilograms of mass.

TABLE B-10. 03-03-02 POWER SOURCE STRUCTURE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	3712800.00	TF=	1.000000
M=	3250.00024	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCEK=	0.234000
CDEXP=	0.653000
CICER=	0.000005
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDCEK X (T X DF)XX(CDEXP) X CF	1595.157
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.016
#RM = T / M	1142.400
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	18.564
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	18.564
CRCI = CIPS X R	0.186
CO&M = O&M	0.0
COMMENTS 2	

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03-03-04 MECHANISM CER's

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:

<u>Manufacturer</u>	<u>Application</u>
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	x 3
Specification Upgrading Factor	x 3
Total	<u>x 9</u>

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

Range of Data:

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

Input parameters T&M are in Kilograms of mass, see table B-11.

TABLE B-11. 03-03-04 MECHANISMS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	559000.062	TF=	0.054900
M=	559.000000	OBM=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCEP=	0.156000
CDEXP=	0.511000
CICER=	0.000764
CIEXP=	0.950000

CALCULATED VALUES

\$, MILLIONS

CD=CDCEP X (T X DF)XX(CDEXP) X CF	59.276
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.017
#IRM = T / M	1000.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	11.064
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	7.767
CRCI = CIPS X R	0.078
COBM = OBM	0.0
COMMENTS 4	

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03-03-05 SECONDARY STRUCTURE CER's

This element includes all structure, consisting of mounting brackets, clamps and installation structure required as an interface between the primary structure and the 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	UV Instrument Mount Assembly (ASM)
S-IC Forward Skirt	Solar Array and Boom Structure (ATS-F)
S-IC Intertank	Squib Interface Unit (ATS-F)
Solar Telescope Housing Assembly (ASM)	Interstage (Centaur)
Common Mount Assembly (ASM)	Nose Shroud (Centaur)
Telescope Gimbal Assembly (ASM)	Fixed Airlock Shroud (Skylab)
Common Mount Actuators (ASM)	Payload Shroud (Skylab)
Telescope Gimbal Actuators (ASM)	Pallet Segment (Spacelab)
Array Platform Elevation Pointing Actuator (ASM)	OSO-1
UV Gimbal Mount Actuators (ASM)	ATS-F
	S-H

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

Range of Data:

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

Input parameters T&M are in kilograms of mass, see table B-12.

TABLE B-12. 03-03-05 SECONDARY STRUCTURE
50W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	2051400.00	TF=	0.007300
M=	6.500001	Q&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CD CER=	0.156000
CD EXP=	0.511000
CICER=	0.101000
CI EXP=	0.355000

CALCULATED VALUES

\$ MILLIONS

CD=CD CER X (T X DF)XX(CD EXP) X CF	115.188
CLRM=CICER X (M)XX(CI EXP) X CF X TF	0.001
#RM =T / M	315599.937
E =1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	322.056
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	280.109
CPCI = CIPS X R	2.801
Q&M = Q&M	0.0
COMMENTS 5	

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03-04-01 SOLAR BLANKET CER's

This element converts solar energy to electrical energy and provides power to the busses in the power distribution and conditioning assembly. The solar photovoltaic power subsystem consists of the solar cells, blankets, reflector (Concentrator) membranes and attachment devices. 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 1986 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 (QWS)
- 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) to estimate the production cost is based upon an engineering "Grass Roots" projected estimate of average cost of \$60.00/M² for the GaAs solar cell array. The engineering estimate reflects 1977 dollars and assumes 1985 technology. The average cost per M² was converted to TFU cost \$71.60/M² in order to exercise the CI cost equation.

Range of Data

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

Input parameters T&M are in square meters, see table B-13.

TABLE B-13. 03-04-01 SOLAR BLANKETS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	30376000.0	TF=	1.000000
M=	16250.0000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.990000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCEK=	0.161400
CDEXP=	0.394000
CICER=	0.000072
CIEXP=	1.000000

CALCULATED VALUES

5 MILLIONS

CD=CDCEK X (T X DF)XX(CDEXP) X CF 75.967

CLRM=CICER X (M)XX(CIEXP) X CF X TF 1.163

#RM = T / M 1869.292

E = 1.0 + LOG(PHI) / LOG(2.0) 0.986

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E)) 1976.481

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 1845.868

CRCI = CIPS X R 18.459

CO&M = O&M 0.0

COMMENTS 6

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03-04-02 CONCENTRATOR CER

This element concentrates the solar energy onto the solar cell blanket. This 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 membranes 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:	100^2 M	$100,000\text{M}^2$
ICI:	Unlimited	

Input parameters T&M are in square meters, see table B-14.

TABLE B-14. 03-04-02 CONCENTRATORS
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	64740000.0	TF=	1.000000
M=	16250.0000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCER=	0.027000
CDEXP=	0.394000
CICER=	0.000003
CIEXF=	0.950000

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP) X CF

CLRM=CICER X (M)XX(CIEXF) X CF X TF

#RM = T / M

E = 1.0 + LOG(PHI) / LOG(2.0)

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))

CIPS=(CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))

CRCI = CIPS X R

CO&M = O&M

COMMENTS 7

4.9 MILLIONS

17.123

0.030

3964.000

0.971

96.748

84.151

0.842

0.0

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03-04-03 POWER DISTRIBUTION AND CONDITIONING CER'S

This element includes power conductors, rotary joint slip rings and switch gears necessary to transmit electrical power from the power source to the rotary joints. The power converter and conditioners convert the existing bus voltages to the subsystem voltage required for the various subsystem loads. The switch gears are solid-state to reduce the overall mass of switches. The voltages and currents being handled by these switches will be monitored by the IMCS to determine their status and to establish a need for the opening and closing of these switches. The switches are generally held in the closed state during the steady-state mode of operation. During the startup and shutdown operations, the switches will be monitored by the IMCS and when certain voltage levels are reached a command signal will open or close switches as required.

Power obtained at the subarray is transferred to a summing bus through a switch-gear (S/G) and manually-operated circuit-breaker. Power is then transferred from the nonrotating member of the rotating member of the rotary joint through slip-rings and brushes. On the rotating member, power is conducted through switch gears to DC/DC converters which output the 6 primary voltages required by the klystrons. Each voltage is conducted to a summing bus through a switch gear. Subsequently, each voltage is conducted from the summing buses to the 135,864 klystrons.

Batteries and battery power conditioning equipment are included also to provide the power storage required to support satellite station keeping activities during the periods when power is unavailable from the solar array blankets. This storage would be necessary during those infrequent times when the satellite is in shadow or when it is in a charge-orbit mode.

CONDUCTORS & SWITCHES

The power distribution system utilizes flat aluminum 6101/T6 conductors with 1 MM Kapton insulation on both sides. The flat conductors are not considered part of the main structure. They will normally be passively cooled by radiation to free space.

The switch gears are of the Penning design. They are used for isolation of solar array blankets due to array failure and when performing maintenance work. The switch gears are used also to prevent large line transients upon startup and shutdown and during ecliptic periods.



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

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

The ICI CER was based on preprocessed aluminum material cost data and the use of 6101/T-6 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

Slip Rings and Brushes

The slip-rings and brushes located in the rotary joint are utilized to transfer power from the SPS fixed member to the SPS rotating member upon which the micro-wave antenna is located. The power transferred includes both that required to operate antenna-mounted equipment, as well as that to be transmitted to the ground.

The slip-rings consist of an aluminum core with coin silver cladding on each slip-ring. The core cross section is 41.3 CM^2 . The slip-ring diameter is 1.13 KM. Length is 3.55 KM. Each slip-ring weighs $0.0403 \times 10^6 \text{ Kg}$. A total of (4) slip-rings are required per satellite.

The shoe brush assembly material consist of 75% MoS₂, 25% Mo + Ta. Each shoe brush assembly has 868 CM^2 of contact area. There are (64) brushes in each shoe assembly.



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	x 3
Specification Uprating Factor	x 3
	<hr/>
Total	x 9

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

<u>Manufacturer</u>	<u>Application</u>
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

DDT&E:	6 to 15,000 kg
ICI:	11 to 7,300 kg

Batteries

This element consist of sodium chloride batteries. Battery changing, regulation and conditioning equipment are included in the battery power conditioning CER.



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

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

Range of Data

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

Battery Power Conditioning

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. Specifically excluded are conditioning equipment associated with the power source/power conditioning subsystem.

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

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

Range of Data

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

Input parameters T&M are in kilograms of mass, see table B-15.

TABLE B-15. 03-04-03 POWER DIST. & COND. -CONDUCTORS
 .5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 910000.125 TF= 1.000000
 M= 1263.60010 O&M= 0.0
 CF= 1.000000 Z1= 1.000000
 PHI= 1.000000 Z2= 120.000000
 R= 0.010000 Z3= 120.000000
 DF= 0.200000

CDCER= 0.158000
 CDEXP= 0.297000
 CICFP= 0.000004
 CIEXP= 1.000000

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP) X CF

CLRM=CICER X (M)XX(CIEXP) X CF X TF

#IRM =T / M

E =1.0 + LOG(PHI) / LOG(2.0)

CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))

CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2

CRCI = CIPS X R

CO&M = O&M

COMMENTS 8

\$, MILLIONS

5.766

0.005

720.165

1.000

3.640

3.640

0.036

0.0

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TABLE B-1E. 03-04-03 POWER DIST. & COND. -SLIP RINGS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	451100.062	TF=	1.000000	CDCER=	0.156000
M=	780.000000	O&M=	0.0	COEXP=	0.511000
CF=	1.500000	Z1=	1.000000	CICER=	0.000764
PHI=	0.900000	Z2=	120.000000	CIEXP=	0.950000
R=	0.010000	Z3=	120.000000		
DIF=	0.200000				

CALCULATED VALUES

$$CD = CDCER \times (T \times DIF) \times (COEXP) \times CF$$

$$CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$$

$$\#RM = T / M$$

$$E = 1.0 + (\text{LOG}(PHI) / \text{LOG}(2.0))$$

$$CTFU = (CLRM / E) \times ((\#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$$

$$CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2$$

$$CRCI = CIPS \times R$$

$$CO&M = O&M$$

COMMENTS 9

\$, MILLIONS

74.685

0.641

578.333

0.648

165.890

80.268

0.803

0.0

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TABLE B-15. 03-04-03 POWER DIST. & COND. SWITCHING
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	297700.000	TF=	1.000000	CDCER=	0.15E000
M=	1263.60010	OM=	0.0	CDEXF=	0.297000
CF=	1.450000	Z1=	1.000000	CICF=	0.000400
PHI=	0.950000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	0.200000				

CALCULATED VALUES

\$, MILLIONS

CD=	CDCER X (T X DF)XX(CDEXP) X CF	6.000
CLRM=	CICER X (M)XX(CIEXP) X CF X TF	0.733
#IRM =	T / M	235.597
E =	1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=	(CLRM / E) X ((#IRM X Z1+.5)XX(E) -0.5XX(E))	124.295
CIPS=	((CLRM/E) X ((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	97.334
CRCI =	CIPS X R	0.873
CO&M =	OM	0.0
COMMENTS	10	

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TABLE B-15. 03-04-03 POWER DIST. & COND. - BATTERIES
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	26000.0000	TF=	0.075600
M=	65.000000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.066670	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CD CER=	0.037000
CD EXP=	0.700000
CICER=	0.025000
CIEXP=	0.251000

CALCULATED VALUES

\$, MILLIONS

CD = CD CER X (T X DF) X (CD EXP) X CF

19.758

CLRM = CICER X (M) X (CIEXP) X CF X TF

0.006

#IRM = T / M

400.000

E = 1.0 + LOG(PHI) / LOG(2.0)

0.926

CTFU = (CLRM / E) X ((#IRM X Z1 + 0.5) X (E) - 0.5 X (E))

1.604

CIPS = ((CLRM / E) X ((#IRM X Z3 + 0.5) X (E) - 0.5 X (E))) / 72

1.126

CRCI = CIPS X R

0.075

CD&M = O&M

0.0

COMMENTS 11

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C-2

TABLE B-15. 03-04-03 POWER DIST. & COND. -BATTERY POWER
50% PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	13000.0000	TF=	0.043000
M=	6.500001	OLM=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.500000		

INPUT COEFFICIENTS

CDCEF=	0.053000
CDLXP=	0.890000
CICER=	0.012000
CIEXP=	0.850000

CALCULATED VALUES

CD=CDCEF X (T X DF)XX(CIEXP) X CF	131.150
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.003
#RM = T / M	2000.000
E =1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	3.169
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	2.224
CRCI = CIPS X R	0.022
COLM = OLM	0.0
COMMENTS 12	

\$, MILLIONS

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03-05-00 MICROWAVE ANTENNA CER's

This element includes the components of the microwave power transmission subsystem. This subsystem, whose interfaces begins at the rotary joint, is utilized to convert the power source output to high power microwave energy for transmission to the ground-based receiving station.

RF generation and beam control, waveguides and power distribution and conditioning are assemblies of the microwave subsystem. RF generation and beam control include the electronics necessary to convert the direct current (dc) electric power to RF microwave power. Included are 50kw klystrons mounted in the center of a power module which is 1.02M by 2.33M in size. There are 136,000 klystrons located in the satellite microwave antenna. Other related equipment, such as driver amplifiers, frequency control electronics, and phase control electronics are included. Waveguides receive the RF power from the RF generation and beam control assembly, and radiate it to the ground-based rectenna. The power distribution and conditioning assembly includes the power conductors switches, and conditioning equipment that conduct dc or low frequency alternating current (ac) electric power from the rotary joint and provide regulated dc power to the RF generation and beam control equipment and other power consuming equipment located on the antenna.

Also included in this element are the klystrons heat pipes and resonant cavity radiator (RCR). Heat pipes remove heat from the klystrons body and transfer it to the RCR face. The pipes lie between the radiating slots of the RCR. The heat pipes all use water as a working fluid, encased in a copper liner. The outer tube is aluminum to eliminate the single-point contact of dissimilar metals. The spacing of the axial groove heat pipes is 11.4 cum. Any one of the arterial wicked pipes can fail, and the system will still reject the incident heat load and maintain allowable temperature limits.

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 sub-array panels, complete with the radiating elements, waveguides, and cabling.



The sub-arrays were then mounted into the facility framework, sub-array 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 DDT&E 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 CER's. 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 $2.4M^2$ was assumed to be the lowest repeating module (M). In addition, to arrive at an "average" (M), it was necessary to evenly distribute all components over the antenna. 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 microwave antenna, a 20% instrument factor was also applied to the vendor quotes.

Input parameters are as follows:

Antenna

T&M are in square meters

Heat Pipes

T&M are in kilograms

See Table B-16.

TABLE B-16. 03-05-01 MICROWAVE HEAT PIPES
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1106300.00	TF=	0.009000
M=	8.034001	O&M=	0.0
CF=	1.500000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDGER=	0.150000
CDEXP=	0.511000
CICER=	0.000500
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDGER X (T X DF) XX (CDEXP) X CF	126.026
CLRM=CICER X (M) XX (CIEXP) X CF X TF	0.000
#RM = T / M	137702.187
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E) X ((#RM X Z1+.5) XX (E) -0.5 XX (E))	5.932
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) XX (E) -0.5 XX (E))) / Z2	5.160
CRCI = CIPS X R	0.052
CO&M = O&M	0.0
COMMENTS 14	

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TABLE B-16. 03-05-02 MICROWAVE ANTENNA
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	800000.000	TF=	1.000000
M=	120.000000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.400000		

INPUT COEFFICIENTS

CDCER=	0.205690
CDEXP=	0.507000
CICER=	0.003130
CIEXP=	1.000000

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP) X CF

CLRM=CICER X (M)XX(CIEXP) X CF X TF

#IRM =T / M

E =1.0 + LOG(PHI) / LOG(2.0)

CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))

CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))

CRCI = CIPS X R

COMM = O&M

COMMENTS 15

\$ MILLIONS

127.152

0.376

6666.664

0.971

1995.335

1735.509

17.355

0.0

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03-06-00 ATTITUDE CONTROL AND ORBITAL MANEUVERING CER'S

This element includes all the on-board propulsion, attitude control and orbital maneuvering components required to effect and maintain the specified SPS position and orientation in space. The propulsion and orbital maneuvering hardware components provide the necessary torque forces required to orient the satellite and maintain its required attitude relative to the sun. Thrust required to transfer the satellite from its assembly orbit to its required operational orbit is also provided by this element. Hardware elements include Argon Bombardment thrusters, tankage, lines and valves and support structure. The thrusters are located with a ten meter separation to minimize thermal problems when servicing a thruster with a servicing cab and firing an adjacent thruster. The thrusters are serviced by replacing the grids and cathodes annually, thereby reducing the frequency of replacing with new thrusters.

The attitude reference determination system features Charge Coupled Device (CCD), star and sun sensors as well as electrostatic or laser gyros and dedicated microprocessors. Five 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.

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 use Argon propellants with a low thrust but a significantly higher specific impulse, thus reducing propellant re-supply 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 107,500.0kg

Input parameters T&M are in kilograms, see table B-17.

TABLE B-17. 03-06-00 ATTITUDE CONTROL AND ORB. MAN.
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	39390.0039	TF=	0.105900	CDCER=	1.122000
M=	390.000000	OM=	0.046620	CDEXP=	0.190000
CF=	1.100000	Z1=	1.000000	CICER=	0.057000
PHI=	0.900000	Z2=	120.000000	CIEXP=	0.729000
R=	0.200000	Z3=	120.000000		
DF=	0.300000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	7.331
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.514
#IRM = T / M	101.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.848
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	30.151
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	14.662
CRCI = CIPS X R	2.932
COMM = OM	0.047
COMMENTS 16	

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03-07-00 AVIONICS CER's

This element is an assembly of the avionics subsystem and includes those components which process information on-board the satellite. This includes signal conditioning, formatting, computations, and signal routing. This element is separated into three general hardware groups for costing purposes. They are computers, electronics components and data bus.

COMPUTERS

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

Gemini-3	Viking Lander
Minuteman	MOL
Skylab	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, Micro-processors, 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:

<u>ATS-F</u>	<u>OSO-8</u>
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 consist 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:

<u>Manufacturer</u>	<u>Type</u>	<u>Characteristics</u>	<u>Cost per Meter</u>
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 65M Dia.	\$2.25
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:

<u>Manufacturer</u>	<u>Characteristics</u>	<u>Cost per Meter</u>
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 con- ductor 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.

TABLE B-18. 03-07-01 AVIONICS-MCC
 56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1300.00000	Tf=	0.900000
M=	650.000000	(M)=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.800000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.500000		

INPUT COEFFICIENTS

CDCER=	0.633000
CDEXP=	0.521000
CICER=	0.172000
CIEXP=	0.535000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	18.490
CLRM=CICER X (M)XX(CIEXP) X CF X Tf	4.951
#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))	9.027
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	2.467
CRCI = CIPS X R	0.025
CDLM = CLM	0.0
COMMENTS 17	

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TABLE B-19. 03-07-02 AVIONICS-D AND C
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	260.000000	TF=	0.900000
M=	260.000000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.800000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEK=	0.102000
CDEXP=	0.879000
CICER=	0.069000
CIEXP=	0.557000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	13.532
CLRM=CICER X (M)XX(CIEXP) X CF X TF	1.375
#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))	1.402
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.425
CRCI = CIPS X R	0.004
CO&M = O&M	0.0
COMMENTS 1B	

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TABLE B-20. 03-07-03 AVIONICS-SC
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 109.200012 TF= 0.700000
M= 18.199997 O&M= 0.0
CF= 1.000000 Z1= 1.000000
PHI= 0.850000 Z2= 120.000000
R= 0.010000 Z3= 120.000000
DF= 0.200000

CDCER= 0.633000
CDEXP= 0.521000
CICER= 0.172000
CIEXP= 0.535000

CALCULATED VALUES

\$ MILLIONS

$CD = CDCER \times (T \times DF) \times (CDEXP) \times CF$

3.156

$CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$

0.569

$\#IRM = T / M$

6.000

$E = 1.0 + LOG(PHI) / LOG(2.0)$

0.766

$CTFU = (CLRM / E) \times ((\#IRM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$

2.676

$CIPS = ((CLRM / E) \times ((\#IRM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2$

0.950

$CRCI = CIPS \times R$

0.009

$COMM = O&M$

0.0

COMMENTS 19

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TABLE B-21. 03-07-04 AVIONICS-FC
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	673.399902	TF=	0.400000
M=	18.199997	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.850000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.030000		

INPUT COEFFICIENTS

CDCEP=	0.633000
CDEXP=	0.521000
CICER=	0.172000
CIEXP=	0.535000

CALCULATED VALUES

\$, MILLIONS

CD=CDCEP X (T X DF)XX(CLEXP) X CF	3.030
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.325
#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))	6.554
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	2.190
CRCI = CIPS X R	0.022
CO&M = O&M	0.0
COMMENTS 20	

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TABLE B-22. 03-07-05 AVIONICS-BUS CONTROL UNIT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	5343.00000	TF=	0.076000
M=	5.500001	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.001200		

INPUT COEFFICIENTS

CDCEP=	0.102000
CDEXP=	0.879000
CICER=	0.069000
CIEXP=	0.557000

CALCULATED VALUES

\$, MILLIONS

CD=CDCEP X (T X DF)XX(CDEXP) X CF	0.522
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.015
#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))	8.032
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	5.638
CRC1 = CIPS X R	0.056
CO&M = O&M	0.0
COMMENTS 21	

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TABLE B-23. 3-07-06 AVIONICS-MICROPROCESSORS
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5050.50000	TF=	0.078000	CDCEP=	0.102000
M=	6.500001	GM=	0.0	COEXP=	0.679000
CF=	1.000000	Z1=	1.000000	CICER=	0.069000
PHI=	0.950000	Z2=	120.000000	CIEAP=	0.557000
R=	0.010000	Z3=	120.000000		
DF=	0.001300				

CALCULATED VALUES

	\$, MILLIONS
CD=CDCEP X (T X DF) X X(CDEAP) X CF	0.533
CLRM=CICER X (M) X X(CIEXP) X CF X TF	0.015
#RM = T / M	777.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E) X ((#RM X Z1 + .5) X X(E) - 0.5 X X(E))	7.824
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X X(E) - 0.5 X X(E))) / Z2	5.493
CKCI = CIPS X P	0.055
COMM = 0.6M	0.0
COMMENTS 22	

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TABLE B-24. 03-07-07 AVIONICS-RA AND C
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	6402.50000	TF=	0.069000
M=	6.500001	D&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.001000		

INPUT COEFFICIENTS

CDCER=	0.102000
COEXP=	0.879000
CICER=	0.069000
CILXP=	0.557000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF) X (COEXP) X CF	0.522
CLRM=CICER X (M) X (CIEXP) X CF X TF	0.014
#RM = T / M	965.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E) X ((#RM X Z1 + .5) X (E) - 0.5 X (E))	8.622
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2	4.053
CRCI = CIPS X R	0.061
COMM = D&M	0.0
COMMENTS 23	

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TABLE B-25. 03-07-08 AVIONICS-SUBMULTIPLEXORS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	120900.000	TF=	0.022000
M=	3.900000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	0.000032		

INPUT COEFFICIENTS

CDICER=	0.102000
CDEXP=	0.879000
CICER=	0.069000
CIEXP=	0.557000

CALCULATED VALUES

\$, MILLIONS

CD=CDICER X (T X DF) X (CDEXP) X CF	0.335
CLRM=CICER X (M) X (CIEXP) X CF X TF	0.003
#IRM = T / M	30999.992
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E) X ((#IRM X Z1 + .5) X X(E) - 0.5 X X(E))	76.523
CIPS=((CLRM/E) X ((#IRM X Z3 + 0.5) X X(E) - 0.5 X X(E))) / Z2	66.557
CRCI = CIPS X R	0.666
COLM = O&M	0.0
COMMENTS 24	

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TABLE B-26. 03-07-09 AVIONICS-INSTRUMENTATION
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	362700.000	TF=	1.000000
M=	0.074100	OM=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

COCE=	0.000100
COEX=	1.000000
CICE=	0.000400
CILX=	1.000000

CALCULATED VALUES

5, MILLIONS

CO = COCE * (T * DF) ** (COEX) * CF

36.270

CLRM = CICE * (M) ** (CIE) * CF * TF

0.000

#RM = T / M

4894739.00

E = 1.0 + LOG(PHI) / LOG(2.0)

0.971

CTFU = (CLRM / E) * ((#RM * Z1 + 0.5) ** (E) - 0.5 ** (E))

95.383

CIPS = ((CLRM / E) * ((#RM * Z3 + 0.5) ** (E) - 0.5 ** (E))) / Z2

82.960

CRGI = CIPS * R

0.830

COM = OM

0.0

COMMENTS 25

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TABLE B-27. 03-07-10 AVIONICS-OPTICAL FIBER
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	80.600006	TF=	1.000000	CDCEP=	0.237000
M=	80.600006	ORM=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	1.000000	CICER=	0.010219
PHI=	0.980000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

	\$, MILLIONS
CO=CDCEP X (T X DF)XX(CDEXP) X CF	0.873
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.824
#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))	0.825
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.737
CRCI = CIPS X R	0.007
CO&M = O&M	0.0
COMMENTS 26	

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TABLE B-28. 03-07-10 AVIONICS-CABLES/HARNESS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	380900.000	TF=	1.000000
M=	380900.000	Q&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEP=	0.237000
CDEXP=	0.297000
CICER=	0.000050
CIEXP=	1.000000

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP) X CF	8.4 MILLIONS
CLRM=CICER X (M)XX(CIEXP) X CF X TF	10.771
#RM = T / M	23.044
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	0.971
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	23.076
CRCI = CIPS X R	20.627
CO&M = Q&M	0.206
COMMENTS 27	0.0

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03-08-00 THERMAL CONTROL

This element covers equipment cooling multi-layer insulation blankets. Excluded from this element are the heat pipes and radiators included in the microwave antenna element.

The multi-layer insulation panels are required for the back surface of the resonant activity 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; the secondary structure CER's were normalized to requirements of the insulation by the application of a 1.5 complexity factor.

T&M for insulation are in kilograms, see Table B-29.

TABLE B-29. 03-08-03 THERMAL CONTROL -INSULATION
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	724100.062	TF=	0.009700	CDCER=	0.266000
M=	5.200001	OMM=	0.0	CDIEXP=	0.418000
CF=	1.000000	Z1=	1.000000	CICEP=	0.042000
PHI=	0.980000	Z2=	120.000000	CIEXP=	0.370000
R=	0.010000	Z3=	120.000000		
DF=	0.200000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	38.204
CLIRM=CICEP X (M)XX(CIEXP) X CF X TF	0.001
#IRM = T / M	139249.937
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLIRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(F))	77.159
CIPS=((CLIRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(F))) / Z2	67.109
ORCI = CIPS X R	0.671
COMM = OMM	0.0
COMMENTS 30	

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03-09-00 GROUND ASSEMBLY AND INTEGRATION CER'S

This element includes the ground-based assembly and physical integration of flight subsystem and assembly hardware. It includes the assembly, test, and checkout required to integrate assemblies into an accepted flight article. Also included are ground assembly and integration associated with early SPS technology verification, such as SPS critical component development, integrated ground testing, GEOSAT microwave space tests, shared and dedicated shuttle sorties and all-up full-scale clipped-wing prototype demonstrations.

The degree of assembly varies with the flight system. For example, the automated payloads and possibly some sortie payloads are completely assembled on the ground; however, because of the large size of the subscale and full scale satellite systems, only certain subsystems and/or assemblies may be assembled prior to launch.

The factor used to estimate ground assembly and integration costs was developed from historical spacecraft data. Since these historical data represent programs with a cost base much smaller than that of the SPS, further analysis was required to develop a meaningful factor which could be used to estimate the ground assembly and integration costs of a program the magnitude of the SPS. The methodology consisted to extrapolating the percentage trend of the historical data to the SPS base.

The programs used as the baseline are listed below:

ATS A-E	Mariner 1969
ATS-F	OAO A1/A2
DSCS II	OSO I
HEAO B	Pioneer F
IDCSP/A	Tiros M
Lunar Orbiter	Vela IV
Mariner 1964	Vela V

The cost data base for application of the factor is the satellite system TFU cost for TFU and the satellite system IPS cost for IPS, see table B-30.

TABLE B-30. 03-09-00 GROUND ASSEMBLY & INTEGRATION
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	0.0	CDCER=	0.0
M=	0.0	Q&M=	0.0	CDEXP=	0.020000
CF=	0.0	Z1=	1.000000	CICER=	0.020000
PHI=	0.0	Z2=	120.000000	CLEXP=	0.0
R=	0.0	Z3=	120.000000		
DF=	0.0				
CALCULATED VALUES					\$, MILLIONS
CD=CDCER X (T X DF) X (CDEXP) X CF					0.0
CLRM=CICER X (M) X (CLEXP) 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) X (E) - 0.5 X (E))					104.336
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2					89.844
CFCI = CIPS X R					0.950
CQ&M = Q&M					0.0
COMMENTS 61					

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03-10-00 SYSTEM GROUND TEST HARDWARE CER's

This element includes the satellite system hardware 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 the hardware into a full or partial system test article. This activity excludes hardware that will subsequently be used as operational proto-flight or flight hardware. This activity also excludes test facilities or test fixtures required for the tests.

The cost estimating relationship for this element is a percentage relationship of the total assembled TFU flight unit. Since the SPS will be made up of many standard repeating modules, it is not necessary to construct a full sized SPS for ground testing. The test hardware required will, therefore, be something smaller than the flight unit SPS. It is obvious that many different test items of various subsystems and of various degrees of completeness will be required. An assumption was made, based on analysis of test requirements, that test hardware equal to one-half of an equivalent first flight unit would be required. This analysis formed the basis for the system ground test hardware cost estimating relationship, see table B-31.

TABLE B-31. 03-10-00 SYSTEM GROUND TEST HARDWARE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T#	0.0	TF#	0.0	CDCER#	0.500000
M#	0.0	O&M#	0.0	CDEXP#	0.0
CF#	0.0	Z1#	1.000000	CICER#	0.0
PHI#	0.0	Z2#	120.000000	CIEXP#	0.0
R#	0.0	Z3#	120.000000		
DF#	0.0				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF) X (CDEXP) X CF	2660.562
CLRM=CICER X (M) X (CIEXP) X CF X TF	0.0
#IRM = T / M	0.0
E = 1.0 + LOG(PHI) / LOG(2.0)	0.0
CTFU=(CLRM / E) X ((#IRM X Z1+.5) X (E) -0.5 X (E))	0.0
CIPS=((CLRM/E) X ((#IRM X Z3 + 0.5) X (E) -0.5 X (E))) / Z2	0.0
CRCI = CIPS X R	0.0
CO&M = O&M	0.0
COMMENTS 62	

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03-11-00 SYSTEM GROUND TEST OPERATIONS CER'S

This activity includes the effort required for conducting ground-based systems tests including qualification and other development test involving two or more subsystems or assemblies. It includes the planning, documentation, and actual test operations. This activity also includes design, development, and manufacture of special test equipment, test fixtures, and test facilities that are not included in other elements such as GSE.

Test operation data from several launch vehicles, manned spacecraft and unmanned satellite programs were analyzed to determine a method for estimating the cost of SPS system ground test operations. Based on the ground test hardware envisioned for the SPS and the degree of system testing required, a factor was developed which is equivalent to 100% of the total ground test hardware, see table B-32.

TABLE B-32. 03-11-00 SYSTEM GROUND TEST OPERATIONS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	0.0	TF=	0.0	CDICER=	1.000000
M=	0.0	O&M=	0.0	CDEXP=	9.0
CF=	0.0	Z1=	1.000000	CICER=	0.0
PHI=	0.0	Z2=	120.000000	CIEXP=	0.0
R=	0.0	Z3=	120.000000		
DF=	0.0				

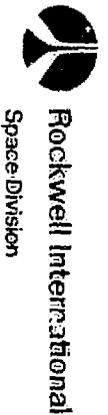
CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	2660.562
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
WRM = T / M	0.0
E = 1.0 + LOG(PHI) / LOG(2.0)	0.0
CIPU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	0.0
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))	0.0
CRGI = CIPS X R	0.0
CO&M = O&M	0.0
COMMENTS 63	

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03-12-01 GROUND OPERATIONS CER's

This element includes the planning, development, and conduct of ground operations required in support of the satellite orbital assembly and checkout, including the ground support personnel and logistics transportation of materials and equipment to the launch site. Also included is the ground support required during mission operations associated with the early SPS technology verification ground and space tests and evaluations. Ground operations required in support of satellite orbital transfer and satellite operations and maintenance are included in ground station system operations. Excluded from this element are the launch vehicle operations. These operations are included in each transportation and launch vehicle element.

Input parameters T&M for construction ground support are in man quarters; input parameters T&M for logistics are in kilograms of mass. See Table B-33.

TABLE B-33. 03-12-01 GROUND OPERATIONS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	0.0	TF=	0.0
M=	0.0	O&M=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	1.000000
CIGER=	0.0
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CIGER X (M)XX(CIEXP) X CF X TF	0.0
NRM = T / M	0.0
E = 1.0 + LOG(PHI) / LOG(2.0)	0.0
CTFU=(CLRM / E)X((NRM X Z1+.5)XX(E) -0.5XX(E))	68.349
CIPS=((CLRM/E)X((NRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	16.684
CRCI = CIPS X R	0.0
CO&M = O&M	0.072
COMMENTS 31	

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TABLE B-33. 03-12-01 GROUND SUPPORT, CONSTRUCTION
5.5W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1250.00000	TF=	1.000000
M=	1250.00000	OBM=	0.072000
CF=	1.000000	Z1=	4.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	123.000000
DF=	1.000000		

INPUT COEFFICIENTS

COCEP=	0.0
COEXP=	1.000000
CICEP=	0.013000
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=COCEP X (T X DF)XX(COEXP) X CF	0.0
CLRM=CICEP X (M)XX(CIEXP) X CF X TF	16.250
#RRH = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#RRH X Z1+.5)XX(E) -0.5XX(E))	65.000
CIPS=((CLRM/E)X((#RRH X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	16.656
CRCI = CIPS X R	0.0
COBM = OBM	0.072
COMMENTS 141	

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TABLE B-33. 03-12-01 LOGISTICS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	33489008.0	TF=	1.000000
M=	33489008.0	OBM=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	1.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEP=	0.0
CDEXP=	1.000000
CICER=	0.000000
CIEXP=	1.000000

CALCULATED VALUES

CD=CDCEP X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	3.349
#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))	3.349
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.028
CRCI = CIPS X P	0.0
COBM = OBM	0.0
COMMENTS 142	

\$ MILLIONS

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03-12-02 ORBITAL OPERATIONS CER's

This element includes the planning, development, and conduct of the on-orbit operations associated with orbital assembly and checkout, orbital transfer, and the orbital operations and maintenance of the SPS. It includes the on-orbit personnel and expendable provisions and maintenance supplies to support these activities.

Input parameters T&M are as follows:

Crew = Man Quarters
Provisions = Kilograms
Expendable Maintenance Supplies (EMS) = Kilograms

See Tables B-34 through B-39.

TABLE B-34. 03-12-02 ORBITAL OPERATIONS, CONSTRUCTION CREW
 SGW PHOTOVOLTAIC CREW

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	160.000000	TF=	1.000000	CDCEP=	0.0
M=	160.000000	ODM=	0.0	CDEAP=	1.000000
CF=	1.000000	Z1=	4.000000	CICEP=	0.015600
PHI=	1.000000	Z2=	120.000000	CDEXP=	1.000000
R=	0.0	Z3=	123.000000		
DF=	1.000000				
CALCULATED VALUES				\$ MILLIONS	
CD=CDCEP X (T X DF)XX(CDEXP) X CF				0.0	
CLRM=CICER X (M)XX(CIEXP) X CF X TF				2.496	
WRM = T / M				1.000	
E = 1.0 + LOG(PHI) / LOG(2.0)				1.000	
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))				9.984	
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2				2.558	
CHCI = CIPS X R				0.0	
COMM = ODM				0.0	
COMMENTS 143					

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TABLE B-35. 03-12-02 ORBITAL OPERATIONS, OPERATIONS CREW
 SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1140.00000	TF=	1.000000	CDGER=	0.0
M=	1140.00000	O&M=	17.783997	CDCAF=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

	\$, 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
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.0
CRCI = CIPS X R	0.0
CO&M = O&M	17.784
COMMENTS 144	

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TABLE B-36. 03-12-02 ORBITAL OPERATIONS, CONST. PROV.
 SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	210250.000	TF=	1.000000	CDCER=	0.0
M=	210250.000	CDM=	0.0	CDXPF=	1.000000
CF=	1.000000	Z1=	4.000000	CICER=	0.000022
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	123.000000		
DF=	1.000000				

CALCULATED VALUES

	\$ MILLIONS
CD=CDCER X (T X DF) X X(CIEXP) X CF	0.0
CLRM=CICER X (M) X X(CIEXP) X CF X TF	4.647
#RM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
GTFU=(CLRM / E) X ((#RM X Z1+.5) X X(E) -0.5 X X(E))	18.586
GIPS=(CLRM/E) X ((#RM X Z3 + 0.5) X X(E) -0.5 X X(E))) / Z2 4.763
CRCI = GIPS X R	0.0
COLM = OLM	0.0
COMMENTS 145	

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TABLE B-37. 03-12-02 ORBITAL OPERATIONS, OPS. PROV.
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T#	1498000.00	TF#	1.000000	CDCEP#	0.0
N#	1498000.00	O&M#	8.275500	CDEXP#	1.000000
CF#	1.000000	Z1#	1.000000	CICEP#	0.0
PHI#	1.000000	Z2#	120.000000	CIEXP#	1.000000
R#	0.0	Z3#	120.000000		
DF#	1.000000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCEP X (T X DF)XX(CIEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#IRM = T / R	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E) X ((#IRM X Z1+.5)XX(E) -0.5XX(E))	0.0
CIPS=((CLRM/E) X ((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.0
CRCI = CIPS X R	0.0
COMM = O&M	8.276
COMMENTS 146	

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TABLE B-38. 03-12-02 ORBITAL OPERATIONS, CONST. EMS
5GW PHOTOVOLTAIC CP=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	116600.000	TF=	1.000000	CDCEK=	0.0
M=	116600.000	O&M=	0.0	CEXP=	1.000000
CF=	1.000000	Z1=	4.000000	CICLP=	0.000015
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	123.000000		
DF=	1.000000				

CALCULATED VALUES

		\$, MILLIONS
CD=	CDCEK X (T X DF) X X (CIEXP) X CF	0.0
CLRM=	CICER X (M) X X (CIEXP) X CF X TF	1.752
#RM =	T / M	1.000
E =	1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=	(CLRM / E) X ((#RM X Z1 + .5) X X (E) - 0.5 X X (E))	7.004
CIPS=	((CLRM/E) X ((#RM X Z3 + 0.5) X X (E) - 0.5 X X (E))) / Z2	1.796
CRCI =	CIPS X R	0.0
COMM =	O&M	0.0
COMMENTS	147	

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TABLE B-39. 03-12-02 ORBITAL OPERATIONS, OPS, EMS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	832200.000	TF=	1.000000	CDCER=	0.0
M=	832200.000	O&M=	3.120800	COEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(COEXP) 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
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.0
CRCI = CIPS X R	0.0
CO&M = O&M	3.121
COMMENTS 140	

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03-13-00 GROUND SUPPORT EQUIPMENT (GSE) CER'S

This activity 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. Included are the costs for design, development, manufacture, acceptance, qualification, and maintenance of the GSE equipment. 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 can be used to estimate SPS ground support equipment costs, see table B-40.

The cost data base for application of this factor is satellite system DDT&E cost (03-00-00).

TABLE B-40. 03-13-00 GROUND SUPPORT EQUIPMENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T =	0.0	Tf =	0.0	CDCEP =	0.100000
M =	0.0	O&M =	0.0	CDEXP =	0.0
CF =	0.0	Z1 =	1.000000	CICER =	0.0
PHI =	0.0	Z2 =	120.000000	CIEXP =	0.0
R =	0.0	Z3 =	120.000000		
DF =	0.0				
CALCULATED VALUES					% MILLIONS
CD = CDCEP X (T X DF) X (CDEXP) X CF					849.437
CLRM = CICER X (M) X (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) X (E) - 0.5 X (E))					0.0
CIPS = ((CLRM / E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2					0.0
CRCI = CIPS X R					0.0
EQ&M = O&M					0.0
COMMENTS 65					

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04-01-00 PROGRAM MANAGEMENT (PM) CER's

This activity includes system level program management. Systems level program management includes those management efforts which relate directly to a complete system. Relative to the SPS there are two complete systems. The first is the Satellite System and the second is the Ground Station System. This activity encompasses the following Ground Station System functions:

- Program Administration
- Program Planning and Control
- Contract Administration
- Engineering Management
- Manufacturing Management
- Support Management
- Quality Assurance Management
- Configuration Management
- Data Management

This activity also includes the effort required in the coordination, gathering, and dissemination of management information.

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS system level requirements. From these data, percentage factors were developed which can be used with the Ground Station System cost to estimate the SPS system level program management, see table B-41.

The cost data bases for the application of these factors are as follows:

CD	=	Ground Station System DDT&E Cost (04-03-00 thru 04-07-00) plus SE&I Cost
CTFU	=	Ground Station System TFU Cost (04-03-00 thru 04-07-00) plus SE&I Cost
CIPS	=	Ground Station System Inv. per Sat. Cost (04-03-00 thru 04-07-00) plus SE&I Cost
CRCI	=	Ground Station System Cost (04-03-00 thru 04-07-00) plus SE&I Cost
CO&M	=	Ground Station System O&M Cost (04-03-00 thru 04-07-00)

TABLE B-41. 04-01-00 GSS-PROGRAM MANAGEMENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	0.0	TF=	0.0	CDCER=	0.020000
M=	0.0	O&M=	0.0	CDEXP=	0.010000
CF=	0.0	Z1=	1.000000	CICER=	0.010000
PHI=	0.0	Z2=	120.000000	CIEXP=	0.010000
R=	0.0	Z3=	120.000000		
Df=	0.0				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	2.595
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))	25.985
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	25.493
CRCI = CIPS X R	0.116
CO&M = O&M	0.002

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04-02-00 SYSTEM ENGINEERING & INTEGRATION (SE&I) CER's

This activity includes system level systems engineering and integration. Systems level SE&I includes those SE&I efforts which relate directly to a complete system. Relative to the SPS there are two complete systems. The first is the satellite systems and the second is the Ground Station system.

This activity includes 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 effort required to monitor the system development and operations to ensure that the design conforms to the baseline specifications.

Data from several launch vehicles, manned spacecraft, and unmanned satellites were analyzed to determine their applicability to the SPS system level requirements. From these data, percentage factors were developed which can be used with the Ground Station system cost to estimate the SPS system level SE&I costs, see table B-42.

The cost data bases for application of the percentage factors are as follows:

CD	=	Ground Station System DDT&E Cost (04-03-00 thru 04-07-00)
CTFU	=	Ground Station System TFU Cost (04-03-00 thru 04-07-00)
CIPS	=	Ground Station System INV per Satellite cost (04-03-00 thru 04-07-00)
CRCI	=	Ground Station System Cost (04-03-00 thru 04-07-00)

TABLE B-42. 04-02-00 GSS-SF AND I
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	0.0	TF=	0.0
M=	0.0	OM=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

INPUT COEFFICIENTS

CDCEH=	0.100000
COEXP=	0.070000
CICER=	0.070000
CIEXP=	0.0

CALCULATED VALUES

$CD = CDCEH \times (T \times DF) \times (COEXP) \times CF$

\$, MILLIONS

11.797

$CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$

0.0

$\#RM = T / M$

0.0

$E = 1.0 + \text{LOG}(PHI) / \text{LOG}(2.0)$

0.0

$CTFU = (CLRM / E) \times (\#RM \times Z1 + .5) \times (E) - 0.5 \times (E)$

169.998

$CIPS = ((CLRM / E) \times (\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) \times 1 / Z2$

166.778

$CRCI = CIPS \times R$

0.758

$COEM = O&M$

0.0

COMMENTS 71

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04-03-00 RECTENNA CER's

The rectenna consists of a dipole network and diode rectifiers which receive/ and rectify the microwave power, a power distribution and conditioning system which collects and delivers to the utility interface the rectified (dc) power, and the support and ground plane structure which provides support for the dipole rectenna panels and components of the distribution system. It also provides a ground plane for the microwave power.

The rectenna farm area of 10 km by 13 km contains 8¹⁴ rows of rectenna panels tilted 40° to the horizontal, providing an active intercept area of 78.54 km². Since an individual panel is 12.24 m by 14.69 m, some 436,805 panels will have to be assembled on site and erected. In order to minimize electrical wiring from the rectenna panel area (i.e., the rectenna "farm"), two electrical switch yards are employed each with its own converter and relay building.

The baseline rectenna panel is 12.24 meters wide by 14.69 meters long. A laminated module of the rectenna panel consists of a stripline pattern of bow-tie dipole antenna etched on a copper faced mylar sheet. The stripline track collects the dipole signals of a common outlet, where it is converted to dc by a diode rectifier. The bow-tie panels offer ease of manufacturing, low diode count, and excellent weather resistance. The concept is designed for ease of mass production. The panel modules are laminated foam and copper-clad mylar solid sheets. A panel module weighs approximately 2 kg/m². The total mass of rectenna panel modules is 157.085 x 10⁶ kg, or approximately 360 kg/rectenna panel. The support structure is designed to withstand high wind loads (90 mph) while holding overall panel deflections to less than 6 centimeters and localized panel deflections to less than 3 centimeters.

Blower and heater equipment which will keep the panels free of ice and snow and power conditioning equipment, such as the DC to AC/DC converter and feeder busses which interface with the panel/rectenna main bus are located underneath the rectenna panels.

The DDT&E costs are considered very small relative to capital costs. They are estimated to be on the order of \$5 million for the rectenna components required for a one gigawatt rectenna. Rectenna DDT&E cost should be relatively insensitive to scale of the rectenna beyond 1 gigawatt. Accordingly a scale effect was assumed equivalent to a 0.3 CER slope as a function of rectenna power output. The technologies involved are state-of-the-art, and have been tested on a small scale.



Near theoretical maximum efficiencies have been demonstrated in microwave to dc conversion. Structural design will involve achievement of high strength to weight ratio and high producibility, however, hundreds of thousands of identical structures will be required for each rectenna system. DDT&E costs for the distribution and conditioning system will be those involved with selection of conducting and insulating materials and optimizing the voltage/current ratios and the configuration of the distribution lines.

The initial capital investment CER's were developed for each element of the rectenna and are discussed below:

Dipole Network/Diode Rectifier

The dipole/rectifier design is a laminated assembly consisting of two layers of foam and three layers of copper clad mylar with a bow-tie dipole network etched on the copper clad mylar. Each dipole network receives enough microwave energy to allow maximum conversion efficiency from microwave to dc through the rectifier diode. Each panel is attached to the support structure. The initial capital investment cost CER's were based upon engineering cost estimates.

Power Distribution and Conditioning System

Based on discussions with TVA and Bonneville personnel, a rule of thumb of \$0.01/watt has tentatively been used for the initial capital investment CER for this element.

Support and Ground Plane

The rectenna support and ground plane consists of 814 rows of tilt-faced array structures. The concept selected was one which employs thin-sheet (.020 inches) preformed hat sections; standard sized (8-inch) I-beams; and 3-1/2-inch diameter, 0.226-inch wall thickness tube braces. The material is galvanized steel. The 24 hat sections are riveted to 4 I-beams which, in turn, are bolted to the tubular braces. The I-beams and braces support the structure on concrete piers. To allow for adjustments, a screw jack is used at the base of the support braces. The entire support structure with rectenna panels weights approximately 2,200 kilograms (4800 lbs.).

This element includes the rectenna construction. As soon as an area of the rectenna site has been partially cleared, graded, survey lines set and the first concrete plants brought into production, the operations of digging holes for pouring footings to support the 436,818 rectenna panels can commence.



It has been estimated that a crew of 2 men can operate and excavate at a rate of 10 panels (80 holes) per 8 hour shift with a 20% time margin. Around-the-clock operations with 20 effective hours per day over a 9-month time period would require crews totaling 260 men for this function. The process of pouring the footings and emplacement of plates of which the rectenna panel structures are attached should take less time than excavation, but to maintain a continuous flow operation, it has been assumed that the times are identical.

The newer concrete trucks can deliver 10 cubic yards of mix per load. Given that an overall average requirement per footing is 6 cubic feet, then the trucks can supply enough mix to provide for 45 footings. In order not to detain the truck or a driver while footings are being poured, the concrete will be delivered from the mix plant to a mobile hopper at the work site. Hoses emanating from the hopper are operated by the two-man crews who are setting the footings. A turnaround cycle for the truck is estimated at 2 hours, thus in an 8-hour shift, a single truck can supply enough concrete to form the piers for 22.5 rectenna panels. If a truck is down for scheduled and unscheduled maintenance for 3-shifts out of the 21 during a week, then 30 10-cubic yard concrete trucks will be the complement required. If a mobile hopper supports the operations of two crews, then only 22 of these machines will be needed.

In order to meet the rectenna site construction schedule, construction masses must be supplied to the assembly and support equipments at rates which meet or exceed their demands. These mass flow demands - millions of kilograms per day - are two in types: delivery to the site demands and intra-site demands. Delivery to site requirements are lower since pre-construction build up will allow, overall, approximately 12 months for satisfying these logistics demands. Intra-site requirements (for the same total masses) must be effected over a nine-month period. Approximately 390 truck trips/day must be handled at the site. In terms of vehicle flow on a good highway, this is a relatively modest demand, but at the site, approximately 40 unloading docks will be required to handle the traffic. Unit trains of 100 cars may be cost-effective in a supplementary role, but the dominate masses must be handled by trucks if the schedule is to be maintained. Although the daily intra-site mass flow demands are higher, they are more easily handled in as much as a truck at the site can make a number of short trips per shift. Estimates have been made for the number of trucks and construction equipments required at the site.



Assembly of rectenna panels represents the major construction time challenge. The large numbers, i.e., 436,805, dictate the need for an assembly and erection concept. Fundamentally, the concept is a mobile assembly jig which, after having completed its share of the construction operations, can be disassembled and transported to a different rectenna site. This particular assembly jig can be loaded to contain 10 "sets" of rectenna panel elements. Each set contains rectenna panels, 24 hat sections and four l-beams with attached tube braces. Since each set weighs 2200 kg (4800 lbs), the 10 sets can be delivered to the jig on a single flat-bed truck trip. After the truck crane lifts off a completed rectenna panel from their loaded locations at the side and end of the jig, the hat sections and l-beam tube braces are conveyed into place. "Stops" are used to ensure exact positioning and alignment. A manned track-mounted crane unit then passes over the jig securing the hat sections to the l-beams and laying down the adhesive for the rectenna panels. The time consumed for these operations is estimated to take 21 minutes. Next the rectenna panel crane moves longitudinally across the jig placing each of the 20 0.74 meter wide panels on to the completed structural frame. A geared eccentric roller on this crane provides the pressure to secure the rectenna panels to the frame. Wiring harnesses are then installed and the hoist sling attached from the truck crane for removal of the completed unit. Ten array panels could be assembled in one eight-hour shift, but the number of required assembly jigs is based on one assembly per hour. Installation of the completed panel on concrete piers is estimated to take about 20 minutes. One truck crane and installation crew should be able to work with two assembly jigs at a time.

The overall rectenna construction time period is estimated to be from 10 to 12 months, excluding site preparation. See Tables B-43 through B-46.

TABLE B-43. 04-03-01 RECTENNA, DIPOLE/RECTIFIER
53W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	78540000.0	TF=	1.000000
M=	78540000.0	OBM=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	1.000000
CICER=	0.000011
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF) X (CDEXP) X CF	0.0
CLRM=CICER X (M) X (CIEXP) X CF X TF	845.474
#IRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E) X ((#IRM X Z1 + .5) X (E) - 0.5 X (E))	845.474
CIPS=((CLRM/E) X ((#IRM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2	845.473
CRCI = CIPS X R	0.0
COBM = OBM	0.0
COMMENTS	176

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TABLE B-44. 04-03-02 RECTENNA, POWER DIST. & COND.
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	5.100000	TF=	1.000000	CDCER=	0.0
M=	5.100000	OLM=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	10.000000
PHI=	0.980000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	51.000
#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))	51.069
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	45.651
CRCI = CIPS X R	0.457
COLM = OLM	0.0
COMMENTS 177	

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TABLE B-45. 04-03-03 RECTENNA, SUPPORT AND GROUND PLANE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS			INPUT COEFFICIENTS		
T=	78540000.0	TF=	1.000000	CDCER=	0.0
M=	78540000.0	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.000009
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	695.071
#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))	695.071
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	695.071
CRCI = CIPS X R	6.951
CO&M = O&M	0.0
COMMENTS 178	

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TABLE B-46. 04-03-04 RECTENNA, DDT&E
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	5.100000	TF=	1.000000	CDCER=	-5.000000
M=	5.100000	DLM=	0.0	CDEXP=	0.300000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	8.152
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.0
#IRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	0.0
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.0
CRCI = CIPS X R	0.0
CDLM = DLM	0.0
COMMENTS 179	

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04-04-00 SATELLITE CONTROL CER's

This element includes the hardware that 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 space station crew, and telemetry and command equipment not included in the beam monitoring and control assembly

Currently, only limited effort has been expended in conducting a detailed analysis to determine the technical and performance requirements for the satellite control subsystem. As a result, a detailed cost analysis has not been performed. Discussions indicate that a rough order of magnitude estimate for both DDT&E and ICI hardware costs are as shown in table B-47.

TABLE B-47. 04-04-00 GSS-SATELLITE CONTROL
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000
M=	1.000000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.010000	Z3=	120.000000
DF=	1.000000		

CDCEK=	10.000000
CDEXP=	1.000000
CICER=	50.000000
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCEK X (T X DF)XX(CDEXP) X CF	10.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	50.000
#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))	50.068
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	44.756
CRCI = CIPS X R	0.448
CO&M = O&M	0.0
COMMENTS 42	

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04-05-00 UTILITY INTERFACE CER's

This element includes the power conversion equipment that receives energy from the rectenna and conditions it for input into the electrical power transmission network. The utility interface converts the output from the ground rectenna to high voltage power for introduction into the national power grid.

The CER's for DDT&E and the ICI for the utility interface were derived from the cost estimates in the "Technical Study Report on Pacific Northwest - Southwest Second DC Intertie," prepared by the Bonneville Power Administration in February 1976. These estimates are based upon six cost estimates which Bonneville Power Administration received on a 1.44 GW and a 2.20 GW intertie. The total cost for the 1.44 GW terminal (\$156.7M) 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, see table B-48.

Range of Data

DDT&E and ICI: 1.44 and 2.2 gigawatts

TABLE B-48. 04-05-00 GSS-UTILITY INTERFACE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	5.010000	TF=	1.000000	CDCER=	37.714996
M=	5.010000	O&M=	0.0	CDEXP=	0.604000
CF=	1.000000	Z1=	1.000000	CICER=	79.367996
PHI=	0.980000	Z2=	120.000000	CIEXP=	0.888000
R=	0.010000	Z3=	120.000000		
DF=	1.000000				
CALCULATED VALUES					\$ MILLIONS
CD=CDCER X (T X DF) X (CDEXP) X CF					99.820
CLRM=CICER X (M) X (CIEXP) X CF X TF					331.972
WRM = T / M					1.000
E = 1.0 + LOG(PHI) / LOG(2.0)					0.971
GTFU=(CLRM / E) X ((WRM X Z1 + .5) X X(E) - 0.5 X X(E))					332.423
CIPS=((CLRM/E) X ((WRM X Z3 + 0.5) X X(E) - 0.5 X X(E))) / Z2					297.153
CROI = CIPS X R					2.972
COLM = O&M					0.0
COMMENTS 43					

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04-06-00 SITE AND FACILITIES CER's

This element includes the site and facilities costs for the ground station system which includes the rectenna, utility interface, and satellite control subsystems. Included are costs of the land, site preparation, roads, fences, utilities, buildings, and maintenance equipment required to house and support the other ground station subsystems, see tables B-49 through B-53.

The site is located at approximately 34° N. latitude and measures 13.0 Km by 10.0 Km, with the long axis oriented north and south

TABLE B-49. 04-06-01 GSS-LAND AND PREPARATION
5GW PHOTOVOLTAIC CRE=2

INPUT PARAMETERS

T=	35115.0000	TF=	1.000000
M=	35115.0000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	1.000000
CICER=	0.003000
CIEXP=	1.000000

CALCULATED VALUES

		\$ MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		105.345
WRM = T / M		1.000
E = 1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))		105.345
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2		105.345
CRCI = CIPS X R		0.0
CO&M = O&M		0.0
COMMENTS	44	

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TABLE B-50. 04-06-02 GSS-ROADS AND FENCES
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	D&M=	0.0	CDFXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	8.900000
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

		\$, MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF		0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF		8.400
#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))		8.900
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	1 / Z2	8.900
CRCI = CIPS X R		0.0
CD&M = D&M		0.0
COMMENTS	45	

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TABLE B-51. 04-06-03 GSS-UTILITIES
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TF=	1.000000
M=	1.000000	0&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	1.000000
CICER=	331.399902
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	331.400
#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))	331.400
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	331.400
CRCI = CIPS X R	0.0
CO&M = 0&M	0.0
COMMENTS 46	

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TABLE B-52. 04-06-04 GSS-BUILDINGS
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	120000.000	TF=	1.000000
M=	120000.000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.0
CUFXP=	1.000000
CICER=	0.000040
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TF	4.800
#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))	4.800
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	4.000
CRCI = CIPS X R	0.0
CO&M = O&M	0.0
COMMENTS 47	

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TABLE B-53. 04-06-05 GSS-MAINTENANCE EQPT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDLER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	4.000000
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	120.000000		
DF=	1.000000				

CALCULATED VALUES

\$ MILLIONS

CD=CDLER 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
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	4.000
CRCI = CIPS X R	0.0
CO&M = O&M	0.0
COMMENTS 48	

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04-07-00 GROUND STATION SYSTEM OPERATIONS CER's

This element includes the cost of planning, development, and conducting all operations associated with the ground station system activities. Included are cost of the personnel required for satellite system support and for operation and maintenance of the rectenna, satellites control subsystem, utility interface, and site and facilities. These CER's also include the expendable maintenance supplies required to accomplish these activities, see tables B-54 and B-55.

TABLE B-54. 04-07-01 GSS-OPERATIONS AND MAINT. PERSONNEL
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	Q&M=	0.114400	CDEXF=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	0.0
PHI=	1.000000	Z2=	1.000000	CIEXP=	1.000000
R=	0.0	Z3=	1.000000		
DF=	1.000000				

CALCULATED VALUES

	\$, MILLIONS
$CD = CDCER \times (T \times DF) \times (CDEXP) \times CF$	0.0
$CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$	0.0
$NRM = T / M$	1.000
$E = 1.0 + LOG(PHI) / LOG(2.0)$	1.000
$CTFU = (CLRM / E) \times ((NRM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$	0.0
$CIPS = ((CLRM / E) \times ((NRM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2$	0.0
$CRCI = CIPS \times R$	0.0
$COM = Q&M$	0.114
COMMENTS 49	

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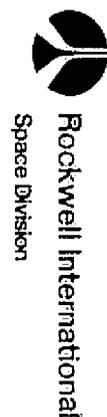


TABLE B-55. 04-07-02 GSS-MAINTENANCE MATERIAL
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TF=	1.000000
M=	1.000000	O&M=	0.100000
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	1.000000
R=	0.010000	Z3=	1.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDGER=	0.0
CDEXP=	1.000000
CICER=	0.0
CIEXP=	1.000000

CALCULATED VALUES

$$CD = CDGER \times (T \times DF)^{XX} (CDEXP) \times CF$$

$$CLRM = CICER \times (M)^{XX} (CIEXP) \times CF \times TF$$

$$\#RM = T / M$$

$$E = 1.0 + \text{LOG}(PHI) / \text{LOG}(2.0)$$

$$CTFU = (CLRM / E) \times ((\#RM \times Z1 + 0.5)^{XX} (E) - 0.5^{XX} (E))$$

$$CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5)^{XX} (E) - 0.5^{XX} (E))) / Z2$$

$$CRCI = CIPS \times R$$

$$COM = O&M$$

COMMENTS 50

%, MILLIONS

0.0

0.0

1.000

1.000

0.0

0.0

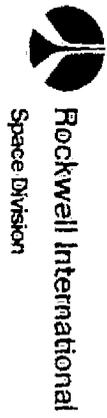
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05-01-00 LEO SPACE BASE CER's

This element includes the space facilities located in low earth orbit (LEO). The LEO base personnel provide supervisory activities for transfer of up and down payloads between the HLLV and the OTV's. They also perform the scheduled maintenance required by the electric propulsion OTV, such as changeout of ion thruster screens. Included are a crew habitability module, an operations control and staging module, a crew support module with airlock and EVA preparation area and a 100kw solar array power module. Excluded are facilities and equipment that are unique to the assembly of the satellite. These facilities and equipment are included in the assembly and support equipment element.

The CER were based upon Rockwell space station studies, see tables B-56 through B-59.

TABLE B-56. 05-01-01 LEO - CHM
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	27000.0000	TF=	1.000000
M=	27000.0000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.050000	Z3=	1.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.009714
CDEXP=	1.000000
CICER=	0.003770
CIEXP=	1.000000

CALCULATED VALUES

\$, 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)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	101.790
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.848
CRCI = CIPS X R	0.042
CO&M = O&M	0.0
COMMENTS 151	

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TABLE B-57. 05-01-02 LEO - CSM/EWA
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T#	27000.0000	TF#	1.000000
M#	27000.0000	DBM#	0.0
CF#	1.000000	Z1#	1.000000
PHI#	1.000000	Z2#	120.000000
R#	0.000000	Z3#	1.000000
DF#	1.000000		

INPUT COEFFICIENTS

CDCEP#	0.012432
CDEXP#	1.000000
CICEP#	0.005798
CIEXP#	1.000000

CALCULATED VALUES

	\$, MILLIONS
CD=CDCEP X (T X DF)XX(CDEXP) X CF	335.664
CLRM=CICEP X (M)XX(CIEXP) X CF X TF	156.546
#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))	156.546
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2
	1.305
CRCI = CIPS X R	0.065
CD&M = DBM	0.0
COMMENTS 152	

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TABLE B-58. 05-01-03 LEO - COM
56 PHOTOVOLTAIC CH=2

INPUT PARAMETERS

T=	27000.0000	TF=	1.000000
M=	27000.0000	D&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.050000	Z3=	1.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.091226
CDEXP=	1.000000
CICER=	0.011495
CIEXP=	1.000000

CALCULATED VALUES

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)	1.000
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	310.392
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	2.587
CRCI = CIPS X R	0.129
CD&M = D&M	0.0
COMMENTS 153	

\$ MILLIONS

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TABLE B-59. 05-01-04 LFO - PM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	100.000000	TF=	1.000000
M=	100.000000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	1.000000	Z2=	120.000000
R=	0.050000	Z3=	1.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCER=	1.900000
CDEXP=	1.000000
CICER=	1.425000
CIEXP=	1.000000

CALCULATED VALUES

$CD = CDCER \times (T \times DF)^{XX} (CDEXP) \times CF$

\$, MILLIONS

38.000

$CLRM = CICER \times (M)^{XX} (CIEXP) \times CF \times TF$

142.500

$\#RM = T / M$

1.000

$E = 1.0 + LOG(PHI) / LOG(2.0)$

1.000

$CTFU = (CLRM / E) \times ((\#RM \times Z1 + .5)^{XX} (E) - 0.5 \times (E))$

142.500

$CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5)^{XX} (E) - 0.5 \times (E))) / Z2$

1 / 22

1.188

$CRCI = CIPS \times R$

0.059

$CD\&M = O\&M$

0.0

COMMENTS 154

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05-02-00 GEO SPACE BASE CER'S

This element includes the GEO construction base and the space base on-board the satellite for operations and maintenance. The GEO construction base serves as the headquarters for operations and activities necessary to construct items such as the satellite, microwave antenna, and cargo orbital transfer vehicle. The physical elements of the GEO base are pressurized modules with various internal configurations to provide specific required functions. All modules are of the same diameter and most are of the same length, their dimensions and mass being in compliance with space transportation systems constraints. The modules are located on the GEO fabrication fixture along with Space Assembly and Support Equipment to build the satellite. The space assembly and support equipment requirements are included in WBS Element 06-00-00.

The GEO construction base consists of various modules as identified in the following tabulation:

WBS #	ACRONYM	DESCRIPTION	QUANTITY	
			GEO CONSTR. BASE	SATELLITE O&M BASE
05-02-01	ADM	AIRLOCK DOCKING MODULE	36	4 ea
05-02-02	CHM	CREW HABITABILITY MODULE	28	1 ea
05-02-03	CLM	CONSUMABLES LOGISTICS MOD	14	1 ea
05-02-04	COM	BASE MANAGEMENT MODULE	4	1 ea
05-02-05	CSM/EVA	CREW SUPPORT MODULE/EVA		1 ea
05-02-06	PM	POWER MODULE	4	
05-02-07	PSM	PRESSURIZED STORAGE MODULE	4	2 ea
05-02-08	SDH	SHIELDING	12	
05-02-09	SM	CREW SUPPORT MODULE	4	
05-02-10	FAB-FIX	FAB FIXTURE	1	

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 (COM/OC&SM) house 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 for 48 to 60 crew members.



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The satellite operations and maintenance base consists of six modules that include the ADM, CHM, CLM, COM and PSM. The combination crew support and EVA module (CSM/EVA) has the same internal function as for the construction base SM but occupies only half of the module. The other half is an integrated multi-crew member EVA preparation area and airlock station. The satellite COM incorporates a health 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 elements for maintenance.

The CER's were based upon Rockwell Space Station studies, See Tables B-60 through B-69.

TABLE B-60. 05-02-01 GEO - ADM
 SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	2500.00000	TF=	1.000000
M=	2500.00000	U&M=	0.0
CF=	1.000000	Z1=	40.000000
PHI=	0.980000	Z2=	120.000000
R=	0.100000	Z3=	516.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.012461
CDEXP=	1.000000
CICER=	0.006036
CIEXP=	1.000000

CALCULATED VALUES

	\$ 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))	557.187
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	55.697
CRCI = CIPS X R	5.570
COLM = D&M	0.0
COMMENTS 155	

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TABLE B-67. 05-02-02 GEO - CHM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T#	27000.0000	TF#	1.000000
M#	27000.0000	O&M#	0.0
CF#	1.000000	Z1#	29.000000
PHI#	0.950000	Z2#	120.000000
R#	0.050000	Z3#	148.000000
DF#	1.000000		

INPUT COEFFICIENTS

COCEP#	0.009714
COEXP#	1.000000
CICEP#	0.003770
CIEXP#	1.000000

CALCULATED VALUES

CD=COCEP X (T X DF)XX(COEXP) X CF	\$, MILLIONS	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)		0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))		2456.487
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	1 / 22	93.475
CRCI = CIPS X R		4.674
CO&M = O&M		0.0
COMMENTS 156		

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TABLE B-62. 05-02-03 GEO - CLM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 5000.00000 TF= 1.000000
M= 5000.00000 O&M= 0.0
CF= 1.000000 Z1= 15.000000
PHI= 0.950000 Z2= 120.000000
R= 0.050000 Z3= 134.000000
DF= 1.000000

CDCER= 0.053000
CDEXP= 1.000000
CICER= 0.014000
CIEXP= 1.000000

CALCULATED VALUES

\$ 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) 0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E)) 916.822
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 58.621
CRCI = CIPS X R 2.931
COLM = O&M 0.0
COMMENTS 157

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TABLE B-63. 05-02-04 GEO - COM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	27000.0000	TF=	1.000000
M=	27000.0000	O&M=	0.0
CF=	1.000000	Z1=	5.000000
PHI=	0.950000	Z2=	120.000000
R=	0.050000	Z3=	124.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.091296
CDEXP=	1.000000
CICER=	0.011496
CIEXP=	1.000000

CALCULATED VALUES

\$, 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)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	1448.660
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	241.887
CRCI = CIPS X R	12.094
COLM = O&M	0.0
COMMENTS 158	

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TABLE B-64. 05-02-05 GEO - CSM-EVA
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	27000.0000	TF=	1.000000
M=	27000.0000	O&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.950000	Z2=	120.000000
R=	0.050000	Z3=	120.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.012432
CWEXP=	1.000000
CICER=	0.005798
CIEXP=	1.000000

CALCULATED VALUES

	\$ 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)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	157.112
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	118.340
ORCI = CIPS X R	5.917
CO&M = O&M	0.0
COMMENTS 159	

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TABLE B-65. 05-02-06 GEO - PM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	250.000000	TF=	1.000000
M=	250.000000	O&M=	0.0
CF=	1.000000	Z1=	4.000000
PHI=	0.950000	Z2=	120.000000
R=	0.050000	Z3=	4.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	1.400000
CDEXF=	1.000000
CICER=	1.100000
CIEXP=	1.000000

CALCULATED VALUES

	\$ 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
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	1039.323
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	8.661
CRCI = CIPS X R	0.433
CO&M = O&M	0.0
COMMENTS 160	

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TABLE B-66. 05-02-07 GEO - PSM
5GW PHOTOVOLTAIC CR#2

INPUT PARAMETERS

T#	15000.0000	TF#	1.000000
M#	15000.0000	O&M#	0.0
CF#	1.000000	Z1#	6.000000
PHI#	0.950000	Z2#	120.000000
R#	0.050000	Z3#	244.000000
DF#	1.000000		

INPUT COEFFICIENTS

CDCER#	0.052914
CDEXP#	1.000000
CICER#	0.013734
CIEXP#	1.000000

CALCULATED VALUES

	\$ 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)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	1141.934
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	300.770
CRCI = CIPS X R	15.038
CO&M = O&M	0.0
COMMENTS 161	

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TABLE B-67. 05-02-08 GEO - SHD
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 11000.0000 TF= 1.000000
M= 11000.0000 O&M= 0.0
CF= 1.000000 Z1= 12.000000
PHI= 0.980000 Z2= 120.000000
R= 0.050000 Z3= 12.000000
DF= 0.200000

CDCER= 0.156000
CDEXP= 1.000000
CICER= 0.101000
CIEXP= 0.355000

CALCULATED VALUES

\$, 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
#IRM = T / M 1.000
E =1.0 + LOG(PHI) / LOG(2.0) 0.971
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E)) 31.426
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 0.262
CRCI = CIPS X R 0.013
CO&M = O&M 0.0
COMMENTS 162

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TABLE B-68. 05-02-09 GEO - SM
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T#	15000.0000	TF#	1.000000	CDCE#	0.012432
M#	15000.0000	Q&M#	0.0	COEXP#	1.000000
CF#	1.000000	Z1#	4.000000	CICEP#	0.005798
PHI#	0.950000	Z2#	120.000000	CIEXP#	1.000000
R#	0.050000	Z3#	4.000000		
DF#	1.000000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCE# X (T X DF)XX(COEXP) X CF	186.480
CLRM=CICE# X (M)XX(CIEXP) X CF X TF	86.970
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	328.691
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E)) / Z2	2.730
CRCI = CIPS X R	0.137
Q&M# = Q&M#	0.0
COMMENTS 163	

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TABLE B-69. 05-02-10 FAB FIXTURE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	2000000.00	TF=	1.000000
M=	2500.00000	D&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.980000	Z2=	120.000000
R=	0.100000	Z3=	1.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCEP=	0.234000
CDEXP=	0.653000
CICER=	0.000005
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCEP X (T X DF)XX(CDEXP) X CF	1065.027	
CLRM=LICER X (M)XX(CIEXP) X CF X TF	0.012	
#RM = T / M	800.000	
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971	
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	8.475	
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) =0.5XX(E))) / Z2	0.071
CRCI = CIPS X R	0.007	
CD&M = D&M	0.0	
COMMENTS 180		

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06-00-00 ASSEMBLY AND SUPPORT EQUIPMENT CER's

The element includes all SPS unique fabrication, orbital construction, assembly and support equipment. Included are the tri-beam builders (beam machines; beam machine material cassettes; cable/catenary attachment machines; remote manipulators; solar array blanket dispensers; reflector (concentrator) dispensers; cable/catenary dispenser; and antenna panel installation equipment. Table B-70 itemizes these components and identifies the initial requirements along with a 30 year replacement schedule for each WBS number.

Table B-70. Space Assembly and Support Equipment

WBS NUMBER	DESCRIPTION	INITIAL REQUIREMENTS	30 YEAR REQUIREMENTS	TOTAL
06-00-01	BEAM MACHINES	234	468	702
06-00-02	CASSETTES	1206	5922	7128
06-00-03	CABLE ATTACH. MACHINE	76	76	152
06-00-04	REMOTE MANIPULATOR	36	-	36
06-00-05	BLANKET DISPENSER	76	406	482
06-00-06	REFLECTOR DISPENSER	6	30	36
06-00-07	CABLE DISPENSER	307	153	460
06-00-08	ANTENNA PANEL INSTALLER	1 (SET)	2 (SETS)	3 (SETS)

Construction is accomplished almost entirely from the GEO Construction Base Fabrication Facility which is included as a part of WBS element 05-02-10. The items of assembly and support equipment are transferred from one construction site to the next as construction is completed on each satellite.

TABLE B-71. 06-00-01 A&SE - BEAM MACHINE
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 700.000000 TF= 1.000000
 M= 700.000000 O&M= 0.0
 CF= 1.000000 Z1= 234.000000
 PHI= 0.900000 Z2= 120.000000
 R= 0.0 Z3= 702.000000
 DF= 1.000000

CDCER= 0.008600
 CDEXP= 1.000000
 CIGER= 0.001000
 CIEXP= 1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF 6.020
 CLRM=CIGER X (M)XX(CIEXP) X CF X TF 0.700
 #IRM = T / M 1.000
 E = 1.0 + LOG(PHI) / LOG(2.0) 0.848
 CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E)) 83.987
 CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 1.780
 CRCI = CIPS X R 0.0
 CO&M = O&M 0.0
 COMMENTS 164

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TABLE B-72. 06-00-02 A&SE - CASSETTES
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	200.000000	TF=	1.000000
M=	200.000000	O&M=	0.0
CF=	1.000000	Z1=	1206.000000
PHI=	0.800000	Z2=	120.000000
R=	0.0	Z3=	7128.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDICR=	0.001500
CDEXP=	1.000000
CICER=	0.000026
CIEXP=	1.000000

CALCULATED VALUES

	\$, MILLIONS
CD=CDICR X (T X DF)XX(CDEXP) X CF	0.300
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.005
#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))	0.938
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.026
CRCI = CIPS X R	0.0
CO&M = O&M.	0.0
COMMENTS 165	

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TABLE B-73. 06-00-03 A6SE - CABLE ATT MACHINE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

I=	500.000000	TF=	1.000000
M=	500.000000	O&M=	0.0
CF=	1.000000	Z1=	76.000000
PHI=	0.950000	Z2=	120.000000
R=	0.0	Z3=	152.000000
DF=	1.000000		

CDCER=	0.008600
CDEXP=	1.000000
CICER=	0.001600
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	4.300
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.800
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	47.491
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.753
CRCI = CIPS X R	0.0
COMM = O&M	0.0
COMMENTS 166	

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TABLE B-74. 06-00-04 A&SE - REMOTE MANIPULATOR
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 800.000000 TF= 1.000000
 M= 800.000000 O&M= 0.0
 CF= 1.000000 Z1= 36.000000
 PHI= 0.950000 Z2= 120.000000
 R= 0.010000 Z3= 36.000000
 DF= 1.000000

CDCER= 0.008600
 CDEXP= 1.000000
 CICER= 0.001500
 CIEXP= 1.000000

CALCULATED VALUES

\$ 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)

0.926

CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))

35.563

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2

0.296

CRCI = CIPS X R

0.003

COLM = O&M

0.0

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TABLE B-75. 06-00-05 A&SE - BLANKET DISPENSER
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	2000.00000	TF=	1.000000
M=	2000.00000	O&M=	0.0
CF=	1.000000	Z1=	76.000000
PHI=	0.950000	Z2=	120.000000
R=	0.0	Z3=	482.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.004000
CDEXP=	1.000000
CICER=	0.000100
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	8.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.200
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	11.873
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))	0.549
CRCI = CIPS X R	0.0
CO&M = O&M	0.0
COMMENTS 168	

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TABLE B-76. 06-00-06 A&SE - REFLECTOR DISPENSER
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	10000.0000	TF=	1.000000	CDCEB=	0.004000
M=	10000.0000	Q&M=	0.0	CUEXP=	1.000000
CF=	1.000000	Z1=	6.000000	CICER=	0.000100
PHI=	0.950000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	36.000000		
DF=	1.000000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCEB X (T X DF)XX(CUEXP) X CF	40.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	1.000
#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))	5.543
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.247
CRCI = CIPS X R	0.0
Q&M = Q&M	0.0
COMMENTS 169	

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TABLE B-77. 06-00-07 A&SE - CABLE DISPENSER
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	200.000000	TF=	1.000000
M=	200.000000	Q&M=	0.0
CF=	1.000000	Z1=	307.000000
PHI=	0.950000	Z2=	120.000000
R=	0.0	Z3=	460.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCER=	0.004000
CDEXP=	1.000000
CICER=	0.000100
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.800
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.020
#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))	4.335
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.053
CRCI = CIPS X R	0.0
COM = O&M	0.0
COMMENTS 170	

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TABLE B-78. 06-00-08 A&SF - ANTENNA PANEL INS.EQF1.
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	450000.000	TF=	1.000000
M=	60000.0000	Q&M=	0.0
CF=	1.000000	Z1=	1.000000
PHI=	0.900000	Z2=	120.000000
R=	0.0	Z3=	3.000000
DF=	0.133333		

INPUT COEFFICIENTS

CD CER=	0.000000
CD EXP=	1.000000
CICER=	0.001500
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF) XX (CDEXP) X CF	516.000
CLRM=CICER X (M) XX (CIEXP) X CF X TF	90.000
#RM = T / M	7.500
E = 1.0 + LOG(PHI) / LOG(2.0)	0.848
CTFU=(CLRM / E) X ((#RM X Z1+.5) XX (E) -0.5XX(E))	560.001
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) XX (E) -0.5XX(E))) / Z2	17.139
CRCI = CIPS X R	0.0
CO&M = Q&M	0.0
COMMENTS 171	

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07-01-00 STS HEAVY LIFT LAUNCH VEHICLE (HLLV) - FLEET PROCUREMENT CER's

The overall SPS transportation system evolution utilized the current baseline space shuttle to satisfy the technology development issues requiring earth to LEO space flights. Shuttle derivatives are employed for the construction of the 1 GW SPS prototype. The SPS operational HLLV transportation system must then be employed to satisfy the high flow requirements from earth to LEO to expand the prototype capability to the operational 5 GW SPS configuration.

The HLLV concept selected is an air-augmented horizontal takeoff single stage to orbit vehicle with a projected service life of about 500 flights per vehicle.

The single stage to orbit configuration utilizes a wet wing concept and multi-cycle air-breathing engines (turbojet/ramjet) from takeoff to $M=7$. Three SSME type engines are employed from $M=6$ to LEO. The vehicle has a cargo bay $6 \times 6 \times 30$ meters and is capable of placing 91,000 kg in a 550 km equatorial orbit. Approximately 500 HLLV flights are required per SPS.

The vehicle will takeoff from KSC, climb to 20,000 ft altitude and cruise to the equator under turbojet power. After turning into the equatorial plane, the vehicle will begin its ascent under augmented turbojet power and transition to ramjet mode at approximately $M=3$. At approximately $M=6$ the SSME engines will be ignited and throttled to maximum power while throttling down the ramjet engines and closing of the variable inlet. During reentry the variable inlet ramp will be reopened and the vehicle will cruise back to the launch site on the air-breathing engine system.

The primary advantages of this concept are ability to achieve the required launch site(s); the method of recovery minimizes risk of damage and enhances turnaround time; minimum facility/equipment requirements; considerably lower acoustic levels and an inherent down-payload capability.

The CER's are based upon engineering estimates, see Table B-79.

TABLE B-79. 07-01-00 STS - MILV FLEET PROCUREMENT
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 1.000000 TF= 1.000000
M= 1.000000 O&M= 0.0
CF= 1.000000 Z1= 3.000000
PHI= 0.800000 Z2= 120.000000
R= 0.0 Z3= 165.000000
DF= 1.000000

CDGER= 7921.19922
CDEXP= 1.000000
CICER= 792.000000
CIEXP= 1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDGER X (T X DF)XX(CDEXP) X CF 7921.199
CLRM=CICER X (M)XX(CIEXP) X CF X TF 792.000
#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)) 2001.271
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 304.925
CRCI = CIPS X R 0.0
CO&M = O&M 0.0
COMMENTS 35

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07-02-00 HEAVY LIFT LAUNCH VEHICLE (HLLV) - OPERATIONS

This element includes the necessary HLLV operations required to support the SPS project. Included are the payload launch operations that consist of the physical integration of the payload into the HLLV payload bay and any payload unique repair and/or checkout activity at the launch site during launch preparations.

A total of 409 HLLV flights are required to transport 37.2×10^6 kg, representing the mass of 1 SPS, to LEO. Ten different payload mixes, averaging 91,000 kg each, have been defined and sequenced to support construction needs. An HLLV launch schedule of 8 flights per day has been postulated. The schedule is within the projected launch rate capability, considering other requirements such as maintenance material and crews. This results in total SPS mass delivery in 51 days, 21 days ahead of the required completion, thus providing considerable margin for contingencies which could slow delivery rate. However, an average of 500 flights per SPS was used in the CER calculations to include operations and maintenance mass to orbit in this instance.

The average number of total HLLV flights per year for transportation of satellite mass, crew, crew provisions, propellants and other maintenance materials, consumables and supplies is approximately 2,500 flights.

The CER's are based upon engineering estimates of the HLLV operations requirements, see Table B-80.

TABLE B-80. 07-02-00 SIS - HLLV OPERATIONS
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TF=	1.000000
M=	1.000000	OSM=	1485.00000
CF=	1.000000	Z1=	500.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	60000.0000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEP=	0.0
CDEXP=	1.000000
CICER=	1.980000
CIEXP=	1.000000

CALCULATED VALUES

CD=CDCEP X (T X DF) X (CDEXP) X CF

CLRM=CICER X (M) X (CIEXP) X CF X TF

#RM = T / R

E = 1.0 + LOG(PHI) / LOG(2.0)

CTFU=(CLRM / E) X ((#RM X Z1+.5) X X(E) - 0.5 X X(E))

CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X X(E) - 0.5 X X(E))) / Z2

CRCI = CIPS X R

OSM = OSM

COMMENTS 36

5 MILLIONS

0.0

1.480

1.000

1.000

990.000

990.000

0.0

1485.000

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08-01-00 INTRA-ORBIT VEHICLE - FLEET PROCUREMENT CER's

This element includes the Intra-Orbit Vehicle (IOV) required to support the SPS project. A single stage chemical (LOX/LH₂) vehicle was selected for use for on-orbit transfers of hazardous cargo (propellants) from the OTV's to the satellite and to the space bases to preclude potential collisions.

The CER's are based upon the upper stage (Stage No. 2) of the two-stage personnel OTV concept, see table B-81.

TABLE B-81. 08-01-00 ICV-FLEET PROCUREMENT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TF=	1.000000
M=	1.000000	DLM=	0.0
CF=	1.000000	Z1=	4.000000
PHI=	0.900000	Z2=	120.000000
R=	0.020000	Z3=	100.000000
DF=	1.000000		

INPUT COEFFICIENTS

CD CER=	97.899994
CD EXP=	1.000000
CICER=	27.169998
CI EXP=	1.000000

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP) X CF	97.900
CLRM=CICER X (M)XX(CIEXP) X CF X TF	27.170
#RM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.648
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	96.914
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	13.167
CRCI = CIPS X R	0.263
COLM = DLM	0.0
COMMENTS	37

*, MILLIONS

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08-02-00 INTRA-ORBIT VEHICLE - OPERATIONS CER'S

This element includes the operations (which is essentially propellant) of Intra-Orbit Vehicles (IOV) required to support the SPS project. It includes the on-orbit transportation cost of operating the vehicle from the OTV's to the satellite and to the space bases to deliver hazardous cargo (Propellants), see Table B-82.

TABLE B-82. 08-02-00 IOV-OPERATIONS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	1.500000	CDEXP=	1.000000
CF=	1.000000	Z1=	1000.00000	CICER=	0.001000
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.0	Z3=	120000.000		
DF=	1.000000				

CALCULATED VALUES

\$, 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
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	1.000
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	1.000
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	1.000
CRCI = CIPS X R	0.0
COLM = O&M	1.500
COMMENTS 38	

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09-01-00 CARGO ORBITAL TRANSFER VEHICLE (COTV) - FLEET PROCUREMENT CER's

This element includes the dedicated electric argon ion thruster OTV for cargo transfer from LEO to GEO. The dedicated electric OTV configuration was sized to accommodate a payload capability of approximately 4×10^6 kg. The structural configuration is essentially the same as employed for the SPS and is sized to produce approximately 270 megawatts.

The thruster array is suspended by cables and located at the vehicle e.g., the thruster array is comprised of six sub arrays (6 x 30 meters) each of which is capable of being packaged in the HTO-HLLV cargo bay. Approximately 270 1 meter electric thrusters are at the structural extremities. Primary thrust vector control is accomplished by a slip-ring joint identical to the type used for SPS antenna orientation.

The dedicated concept was selected over the self-propelled concept because of higher reliability and less risk of damage during orbital transfer.

The COTV CER's are the same as those used for the satellite costing for the same subsystem elements, see tables B-83 through B-97.

TABLE B-83. 09-01-01 COTVFP-POWER SOURCE STRUCTURE
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

I= 321885.000 TF= 1.000000
M= 2500.00000 O&M= 0.0
CF= 1.000000 Z1= 10.000000
PHI= 1.000000 Z2= 120.000000
R= 0.010000 Z3= 45.000000
DF= 0.200000

CDCEP= 0.234000
CDEXP= 0.653000
CICER= 0.000005
CIEXP= 1.000000

CALCULATED VALUES

\$ MILLIONS

$CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF$

323.085

$CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$

0.012

$WRM = T / M$

128.754

$E = 1.0 + \text{LOG}(PHI) / \text{LOG}(2.0)$

1.000

$CTFU = (CLRM / E) \times ((WRM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$

16.094

$CIPS = ((CLRM / E) \times ((WRM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2$

0.604

$CRCI = CIPS \times R$

0.006

$CO&M = O&M$

0.0

COMMENTS B3

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TABLE B-84. 09-01-03 COTVFP-SOLAR BLANKET
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	900000.000	Tf=	1.000000	CDCEK=	0.161400
M=	16250.0000	O&M=	0.0	CDEXP=	0.394000
CF=	1.000000	Z1=	10.000000	CICER=	0.000095
PHI=	0.980000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	45.000000		
DF=	1.000000				
CALCULATED VALUES					\$, MILLIONS
CD=CDCEK X (T X DF)XX(CDEXP) X CF					35.799
CLRM=CICER X (M)XX(CIEXP) X CF X TF					1.544
#IRM = T / M					55.385
E = 1.0 + LOG(PHI) / LOG(2.0)					0.971
CTFU=(CLRM / E) X ((#IRM X Z1+.5)XX(E) -0.5XX(E))					732.405
CIPS=((CLRM/E) X ((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))					26.292
CPCI = CIPS X R					0.263
CO&M = O&M					0.0
COMMENTS BS					

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TABLE B-85. 09-01-04 COTVFP-CONCENTRATOR
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS			INPUT COEFFICIENTS		
T=	1800000.00	TF=	1.000000	CDCER=	0.027000
M=	16250.0000	D&M=	0.0	CDEXP=	0.394000
CF=	1.400000	Z1=	10.000000	CICER=	0.000003
PHI=	0.980000	Z2=	120.000000	CIEXP=	0.950000
R=	0.010000	Z3=	45.000000		
DF=	1.000000				
CALCULATED VALUES					\$, MILLIONS
CD=	CDCER X (T X DF)XX(CDEXP) X CF				11.017
CLRM=	CICER X (M)XX(CIEXP) X CF X TF				0.042
#RM =	T / M				110.769
E =	1.0 + LOG(PHI) / LOG(2.0)				0.971
CTFU=	(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))				39.087
CIPS=	((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2				1.403
CRCI =	CIPS X R				0.014
CD&M =	D&M				0.0
COMMENTS	B6				

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TABLE B-86. 09-01-05 CIVFP-ELECTRIC PROPULSION SYSTEM
53W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	80581.0000	TF=	0.105900
M=	311.000000	OLM=	0.0
CF=	1.100000	Z1=	10.000000
PHI=	0.900000	Z2=	120.000000
R=	0.010000	Z3=	45.000000
DF=	0.300000		

INPUT COEFFICIENTS

CDCER=	1.122000
CDEXP=	0.190000
CICER=	0.057000
CIEXP=	0.729000

CALCULATED VALUES

GD=CDCER X (T X DF)XX(CDEXP) X CF	8.399
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.436
#IRM = T / M	259.103
E = 1.0 + LOG(PHI) / LOG(2.0)	0.848
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	403.059
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	12.030
CRCI = CIPS X R	0.120
COLM = OLM	0.0
COMMENTS	87

% MILLIONS

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TABLE B-87. 09-01-06 COTVFP-AVIONICS, SUPERVISOR COMPUTER
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

I=	14.000000	TF=	0.700000	CDCER=	0.633000
M=	14.000000	Q&M=	0.0	CDEXP=	0.521000
CF=	1.000000	Z1=	10.000000	CICER=	0.172000
PHI=	0.850000	Z2=	120.000000	CIEXP=	0.535000
R=	0.010000	Z3=	45.000000		
DF=	0.200000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	1.082
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.494
WRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.766
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	3.525
CIPS=((CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.097
CRCI = CIPS X R	0.001
CO&M = Q&M	0.0
COMMENTS 101	

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TABLE B-88. 09-01-06 COTVFP-AVIONICS, COMMAND AND CONTROL
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T#	3.000000	TF#	0.900000	CDCER#	0.102000
M#	65.000000	O&M#	0.0	COEXP#	0.879000
CF#	1.000000	Z1#	10.000000	CICER#	0.069000
PHI#	0.800000	Z2#	120.000000	CIEXP#	0.557000
R#	0.010000	Z3#	45.000000		
DF#	1.000000				
CALCULATED VALUES					\$ MILLIONS
CD=CDCER X (T X DF)XX(COEXP) X CF					4.001
CLRM=CICER X (M)XX(CIEXP) X CF X TF					0.635
#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))					4.028
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2					0.099
CRCI = CIPS X R					0.001
CO&M = O&M					0.0
COMMENTS 102					

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TABLE B-89. 09-01-06 CDIVFP-AVIONICS, MICROPROCESSORS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	245.000000	TF=	0.078000	CDCER=	0.102000
M=	5.000000	Q&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	10.000000	CICER=	0.069000
PHI=	0.950000	Z2=	120.000000	CIEXP=	0.557000
R=	0.010000	Z3=	45.000000		
DF=	0.001300				

CALCULATED VALUES

	\$, MILLIONS
CD=CDCER X (T X DF)XX(CIEXP) X CF	0.037
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.013
#IRM = T / M	49.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	4.410
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.148
CRCI = CIPS X R	0.001
CO&M = Q&M	0.0
COMMENTS 103	

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TABLE B-90. 09-01-06 COTVFP-AVIONICS, BUS CONTROL UNIT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	265.000000	TF=	0.076000
M=	5.000000	GM=	0.0
CF=	1.000000	Z1=	10.000000
PHI=	0.950000	Z2=	120.000000
R=	0.010000	Z3=	45.000000
DF=	0.001200		

INPUT COEFFICIENTS

CDCER=	0.102000
CDEXP=	1.879000
CICER=	0.069000
CIEXP=	0.557000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.037
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.013
WRM = T / M	53.000
E = 1.0 + (LOG(PHI) / LOG(2.0))	0.926
CTFU=(CLRM / E)X((WRM X Z1+.5)XX(E) -0.5XX(E))	4.621
CIPS=(CLRM/E)X((WRM X Z3 + 0.5)XX(E) -0.5XX(E))	0.155
CRCI = CIPS X R	0.002
COM = COM	0.0
COMMENTS 104	

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TABLE B-91. 09-01-06 COTVEP-AVIONICS, REMOTE ACN & CONTROL
59W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

I=	345.000000	TF=	0.069000	CDCEK=	0.102000
M=	5.000000	D&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	10.000000	CICER=	0.069000
PHI=	0.950000	Z2=	120.000000	CIEXP=	0.557000
R=	0.010000	Z3=	5.000000		
DF=	0.001000				

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.040
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.012
#RM = T / M	69.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.926
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))	5.357
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.140
CRGI = CIPS X R	0.002
CD&M = D&M	0.0
COMMENTS 105	

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TABLE B-92. 09-71-06 COTVFP-AVIONICS, SUBMULTIPLEXED
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	5154.00000	IF=	0.022000	CDCER=	0.102000
M=	3.000000	Q&M=	0.0	CDEXP=	0.879000
CF=	1.000000	Z1=	10.000000	CICER=	0.069000
PHI=	0.980000	Z2=	120.000000	CIEXP=	0.557000
R=	0.010000	Z3=	45.000000		
DF=	0.000032				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF 0.021

CLRM=CICER X (M)XX(CIEXP) X CF X TF 0.003

#RM = T / M 1718.000

E = 1.0 + LOG(PHI) / LOG(2.0) 0.971

CTIFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E)) 37.278

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 1.338

CRCI = CIPS X R 0.013

COMM = O&M 0.0

COMMENTS 106

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TABLE B-93. 09-01-06 COTVFP-AVIONICS, OPTICAL FIBER
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	4.200000	TF=	1.000000	CDCER=	0.237000
M=	4.200000	Q&M=	0.0	CDEXP=	0.297000
CF=	1.000000	Z1=	10.000000	CICER=	0.010149
PHI=	0.980000	Z2=	120.000000	CIEXP=	1.000000
R=	0.010000	Z3=	45.000000		
DF=	1.000000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	0.363
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.043
NRM = T / M	1.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU=(CLRM / E) X ((NRM X Z1 + .5)XX(E) - 0.5XX(E))	0.408
CIPS=((CLRM/E) X ((NRM X Z3 + 0.5)XX(E) - 0.5XX(E))) / Z2	0.015
CRCI = CIPS X R	0.000
COLM = Q&M	0.0
COMMENTS 107	

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TABLE B-94. 09-01-06 COTVFP-AVIONICS, CABLES & HARNESS
 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 16272.0000 TF= 1.000000
 M= 16272.0000 O&M= 0.0
 CF= 1.000000 Z1= 10.000000
 PHI= 0.980000 Z2= 120.000000
 R= 0.010000 Z3= 45.000000
 DF= 1.000000

CDCER= 0.237000
 CDEXP= 0.297000
 CICEP= 0.000061
 CIEXP= 1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF 4.222

CLRM=CICER X (M)XX(CIEXP) X CF X TF 0.993

#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)) 9.502

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 0.342

CRCI = CIPS X R 0.003

CO&M = O&M 0.0

COMMENTS 108

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TABLE B-95. 09-01-06 COTVEP-AVIONICS, INSTRUMENTATION.
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
I =	18240.0000	TF =	1.000000	CDCER =	0.000100
M =	0.057000	DBM =	0.0	CDEXP =	1.000000
CF =	1.000000	Z1 =	10.000000	CICER =	0.000400
PHI =	0.980000	Z2 =	120.000000	CIEXP =	1.000000
R =	0.010000	Z3 =	45.000000		
DF =	1.000000				

CALCULATED VALUES

\$/MILLIONS

CD = CDCER X (T X DF) X (CDEXP) X CF	1.824
CLRM = CICER X (M) X (CIEXP) X CF X TF	0.000
#RM = T / M	319999.937
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU = (CLRM / E) X ((#RM X Z1 + .5) X (E) - 0.5 X (E))	48.566
CIPS = ((CLRM / E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / Z2	1.743
CRCI = CIPS X R	0.017
CRBM = DBM	0.0
COMMENTS 109	

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TABLE B-96. 09-01-07 COI VFP-THERMAL CONTROL
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T#	22300.0000	TF#	1.000000
M#	4.000000	OLM#	0.0
CF#	1.500000	Z1#	10.000010
PHI#	0.980000	Z2#	120.000000
R#	0.010000	Z3#	45.000000
DF#	1.000000		

INPUT COEFFICIENTS

CDCE#	0.000001
COEXP#	1.000000
CICE#	0.000003
CILXP#	1.000000

CALCULATED VALUES

\$, MILLIONS

CD = CDCE# X (T X DF) XX (COEXP) X CF	0.033
CLRM = CICE# X (M) XX (CIEXP) X CF X TF	0.000
#RM = T / M	5575.000
E = 1.0 + LOG(PHI) / LOG(2.0)	0.971
CTFU = (CLRM / E) X ((#RM X Z1 + .5) XX (E) - 0.5 XX (E))	0.752
CIPS = ((CLRM / E) X ((#RM X Z3 + 0.5) XX (E) - 0.5 XX (E))) / Z2	0.027
CRCI = CIPS X R	0.000
COLM = OLM	0.0
COMMENTS	89

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TABLE B-97. 09-01-08 COTVFP-POWER DISTRIBUTION
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	372109.000	TF=	1.000000
M=	972.000000	CLM=	0.0
CF=	1.000000	Z1=	10.000000
PHI=	0.900000	Z2=	120.000000
R=	0.010000	Z3=	45.000000
DF=	0.200000		

INPUT COEFFICIENTS

CDCER=	0.158000
CDEXP=	0.297000
CICER=	0.000004
CIEXP=	1.000000

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	4.421
CLRM=CICER X (M)XX(CIEXP) X CF X TF	0.004
#IRM = T / M	382.828
E = 1.0 + LOG(PHI) / LOG(2.0)	0.848
CTFU=(CLRM / E)X((#IRM X Z1+.5)XX(E) -0.5XX(E))	5.007
CIPS=((CLRM/E)X((#IRM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	0.149
CRCI = CIPS X R	0.001
COLM = CLM	0.0
COMMENTS 67	

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09-02-00 CARGO ORBITAL TRANSFER VEHICLE
(COTV) - OPERATIONS CER's

This element includes the operations of the dedicated electric OTV for cargo transfer from LEO to GEO. Included are propellant resupply and replacement of thruster grids after each round trip.

The CER's are based upon engineering estimates, see Table B-98.

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TABLE B-98. 09-02-00 CIV-OPERATIONS
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TF=	1.000000
M=	1.000000	CR=	21.300003
CF=	1.000000	Z1=	10.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	1200.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEP=	0.0
CIEXP=	1.000000
CIIEP=	1.420000
CIIEF=	1.000000

CALCULATED VALUES

		8.91111045
CD=CDCEP X (T X DF) X (CIEXP) X CF		0.0
CLRM=CICER X (M) X (CIEXP) X CF X TF		1.420
#RM = T / M		1.000
E = 1.0 + LOG(PHI) / LOG(2.0)		1.000
CTFU=(CLRM / F) X ((#RM X Z + .5) X (E) - 0.5 X (F))		14.200
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (F))) / Zc		14.200
CRCI = CIPS X R		0.0
CCRM = O&M		21.300
COMMENTS	90	

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10-01-00 PERSONNEL OTV - FLEET PROCUREMENT CER's

This element includes the personnel orbital transfer vehicle (POTV) required to support checkout, operations and maintenance of the SPS project. A common chemical (LOX/LH₂) OTV was selected for transfer of personnel and priority cargo from LEO to GEO.

The common stage OTV configuration selected is a scaled version of those concepts presented in the BAC FSTSA studies (Contract NAS 9-24323). The overall length, diameter, tank structures and docking mechanisms are identical. The only significant difference in both stages are the number of engines; 4 for first stage and 2 for second stage. Earth launch in the HLLV consists of an integrated POTV and payload.

Following the LEO-GEO mission, the spent OTV stages would be recovered in LEO by subsequent HLLV vehicles and returned to earth for refueling, refurbishment, and reuse.

The CER's are based upon cost data in the Boeing reports, see Table B-99.

TABLE B-99. 10-01-00 PHOTOVOLT-FLEET PROCUREMENT
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	493.899902
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	2.000000	CICER=	63.139999
PHI=	0.900000	Z2=	120.000000	CIEXP=	1.000000
R=	0.020000	Z3=	16.000000		
DF=	1.000000				
CALCULATED VALUES					\$ MILLIONS
CD=CDCER X (T X DF)XX(CDEXP) X CF					493.900
CLRM=CICER X (M)XX(CIEXP) X CF X TF					63.140
#RM = T / M					1.000
E = 1.0 + LOG(PHI) / LOG(2.0)					0.848
CTFU=(CLRM / E)X((#RM X Z1+.5)XX(E) -0.5XX(E))					120.577
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2					6.341
CROI = CIPS X R					0.127
CO&M = O&M					0.0
COMMENTS 39					

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10-02-00 PERSONNEL OTV - OPERATIONS CER's

This element includes the operations of the POTV required to support the SPS project. It includes the POTV cost per flight to transfer personnel and priority cargo from LEO to GEO. It is estimated that 42 flights will be required per SPS, see Table B-100.

The CER's are based on cost data in the Rockwell SPS Contract (NAS8-32161) and in Boeing reports.

TABLE B-100. 10-02-00 POTV-OPERATIONS
SGW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	1.000000	TE=	1.000000
M=	1.000000	CAF=	0.450000
CF=	1.000000	Z1=	42.000000
PHI=	1.000000	Z2=	120.000000
R=	0.0	Z3=	5040.000000
DF=	1.000000		

INPUT COEFFICIENTS

CDCEP=	0.0
COEXP=	1.000000
CICER=	0.090000
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDCEP X (T X DF)XX(COEXP) X CF	0.0
CLRM=CICER X (M)XX(CIEXP) X CF X TE	0.090
#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))	3.780
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))	3.780
CRCI = CIPS X R	0.0
COM = COM	0.450
COMMENTS 40	

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11-00-00 FACILITIES CER's

This element includes major ground facilities required to support development, production and orbital assembly and operations of the SPS systems. Included are major ground support facilities for orbital construction bases, major ground test facilities and ground launch and recovery facilities. Excluded are facilities that are part of other elements such as the ground station system site and facilities.

Bonded warehousing will provide for SPS and EOTV construction materials and spares. An initial requirement of 190,000 square meters of floor space ultimately will increase to 317,000 square meters. Incoming material (rail, air, etc.) is off loaded, processed through receiving inspection, taken up on the computerized inventory control system and then stored in the appropriate warehouse facility. Maximum rate of incoming railroad traffic required to support construction and maintenance of space-based program elements is approximately 5,500 rail cars annually (excluding propellants) the peak occurs in the 30th year of the program (Santa Fe Rail car specification of 86.5 foot boxcars and 88 foot flatcars with maximum payload capacities of 140,000 kg and 300,000 kg respectively were utilized in establishing requirements).

When scheduled by the payload scheduling control center, construction materials, consumables and spares are transferred to the payload preparation facility for packaging and arranging into payload units on 6x30 meter pallets. Electronic modules and other selected components will be functionally tested prior to packaging. The packaged payloads are then transported to and loaded into the HLLV prior to propellant loading and final HLLV checkout.

Propellant storage facilities provide for cryogenic storage of HLLV propellants and for argon which will be delivered to low earth orbit for use by the EOTV.

The continuous growth in numbers of both base personnel and space crews throughout the 30 year program dictate the requirements for extensive facilities for medical, housing, training and administration. Incoming personnel must be trained and assigned to respective flight or ground crews. Personnel returning from 90 days in orbit must undergo medical processing and then be reassigned to ground activities for a period of time before returning to orbital assignments.

Facilities are also provided for processing and disposing of large amounts of packaging materials, failed and damaged hardware which will be returned from orbit by the HLLV's.



The launch base facilities provide for receiving, storage and processing of material and propellants; storage of ELV's sufficient for initial operations; refurbishment and checkout of returning ELV's and personnel handling and administration. A typical layout of an HTO-HLLV would require an area of less than 20 km². This would provide the necessary runway length plus over-run of km (20,000 ft) and a minimum separation of facilities from readiness area of 1.5 km. Two aircraft type maintenance facilities will be utilized for in-line maintenance and service. Two additional-service buildings will be required for off-line engine replacement and takeoff gear refurbishment. Cargo and propellant loading/off-loading areas are required.

Since initial HLLV flight requirements are substantial, approximately 500 flights during the first year, a fleet build-up will be required prior to initiation of the orbital phase of the program. A facility to store "mothballed" HLLV's during the build-up period will be provided. These facilities will also serve as a refurbishment area for HLLV's returning from orbit.

The facilities costing approach was based on engineering estimates that established values for DDT&E requirements, estimates involving investments for the TFU, and the expansion of facilities to support the selected SPS option of 120 satellites. See Tables B-101 through B-103.

TABLE B-101. 11-02-00 FACILITIES - GROUND SUPPORT
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS				INPUT COEFFICIENTS	
T=	1.000000	TF=	1.000000	CDCER=	0.0
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	1500.00000
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.020000	Z3=	1.666667		
DF=	1.000000				
CALCULATED VALUES				\$ MILLIONS	
CD=CDCER X (T X DF)XX(CDEXP) X CF				0.0	
CLRM=CICER X (M)XX(CIEXP) X CF X TF				1500.000	
#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))				1500.000	
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2				20.433	
CRCI = CIPS X R				0.417	
CO&M = O&M				0.0	
COMMENTS 173					

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TABLE B-102. 11-03-00 FACILITIES - MAJOR GROUND TEST
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 1.000000 TF= 1.000000
M= 1.000000 O&M= 0.0
CF= 1.000000 Z1= 1.000000
PHI= 1.000000 Z2= 120.000000
R= 0.020000 Z3= 2.000000
DF= 1.000000

CDCER= 0.0
CDEXP= 1.000000
CICER= 750.000000
CIEXP= 1.000000

CALCULATED VALUES

\$, MILLIONS

$CD = CDCER \times (T \times DF) \times CDEXP \times CF$

0.0

$CLRM = CICER \times (M) \times CIEXP \times CF \times TF$

750.000

$\#RM = T / M$

1.000

$E = 1.0 + \text{LOG}(PHI) / \text{LOG}(2.0)$

1.000

$CTFU = (CLRM / E) \times (\#RM \times Z1^{1.5}) \times (E - 0.5) \times (E)$

750.000

$CIPS = ((CLRM / E) \times (\#RM \times Z3^{1.5}) \times (E - 0.5) \times (E)) / Z2$

12.500

$CRCI = CIPS \times R$

0.250

$CO&M = O&M$

0.0

COMMENTS 174

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TABLE B-103. 11-04-00 FACILITIES - GROUND LAUNCH & RECOVERY
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T=	1.000000	TF=	1.000000	CDCER=	3210.000000
M=	1.000000	O&M=	0.0	CDEXP=	1.000000
CF=	1.000000	Z1=	1.000000	CICER=	1000.000000
PHI=	1.000000	Z2=	120.000000	CIEXP=	1.000000
R=	0.030000	Z3=	4.000000		
DF=	1.000000				

CALCULATED VALUES

\$, MILLIONS

CD=CDCER X (T X DF)XX(CDEXP) X CF	3210.000
CLRM=CICER X (M)XX(CIEXP) X CF X TF	1000.000
#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))	1000.000
CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2	33.333
CPCI = CIPS X R	1.000
COM = O&M	0.0
COMMENTS 175	

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12-01-00 PROPERTY TAXES CER's

This element includes property taxes related to the ground station system element only. Excluded are ground station system operations.

The CER is based upon Southern California Edison Company planning rates for property taxes, see table B-104.

TABLE B-104. 12-61-00 TAXES-PROPERTY
56W PHOTOVOLTAIC CR=2

INPUT PARAMETERS

INPUT COEFFICIENTS

T= 0.0 TF= 0.0
M= 0.0 O&M= 0.0
CF= 0.0 Z1= 1.000000
PHI= 0.0 Z2= 120.000000
R= 0.0 Z3= 120.000000
DF= 0.0

CDGER= 0.0
CDEXP= 1.000000
CICER= 0.014000
CIEXP= 1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDGER 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

CIPS=((CLRM/E)X((#RM X Z3 + 0.5)XX(E) -0.5XX(E))) / Z2 0.0

CRCI = CIPS X R 0.0

COM = O&M 36.047

COMMENTS 94

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13-01-00 PROPERTY INSURANCE CER's

This element includes property insurance related to the ground station system element only. Excluded are ground station system operations.

The CER is based upon Southern California Edison Company planning rates for insurance, see Table B-105.

TABLE B-105. 13-01-00 INSURANCE-PROPERTY
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

T=	0.0	TF=	0.0
M=	0.0	O&M=	0.0
CF=	0.0	Z1=	1.000000
PHI=	0.0	Z2=	120.000000
R=	0.0	Z3=	120.000000
DF=	0.0		

INPUT COEFFICIENTS

CDCER=	0.0
CDEXP=	1.000000
CICER=	0.000500
CIEXP=	1.000000

CALCULATED VALUES

\$ MILLIONS

CD=CDCER X (T X DF) X (CDEXP) X CF	0.0
CLRM=CICER X (M) X (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) X X(E) -0.5 X X(E))	0.0
CIPS=((CLRM/E) X ((#RM X Z3 + 0.5) X X(E) -0.5 X X(E))) / Z2	0.0
CRCI = CIPS X R	0.0
CO&M = O&M	1.287
COMMENTS 97	

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APPENDIX C

SPS ECONOMIC ANALYSIS
RECOMMENDED FINANCIAL AND OPERATIONAL CONCEPT



APPENDIX C FINANCIAL AND OPERATIONAL CONCEPTS

C.0 INTRODUCTION

This appendix provides a detail description of the technical approach and final results that culminated in a recommended concept for the funding and organizational alignment of the SPS program. Specific information is included on the evolution of various concepts, an analysis of the organizational roles and funding arrangements, data models, evaluation procedures, income statements, returns on investment, and cash flow performances. This appendix is in support of the summarized discussion of the recommended financial and operational concepts as presented in Volume VII (SPS Program Plan and Economic Analysis), Section 3.4.

C.1 GUIDELINES, GROUND RULES, AND ASSUMPTIONS

Pertinent background material and resource information was analyzed to form study guidelines, ground rules, and basic assumptions relative to projects of applicable size and scope that would involve the participation of government, electrical utility industry, and general industry. From this analysis, several important premises were established:

- Financial and operational success of the projected satellite power system will stem, in part, from relevant space projects (space transportation systems, Spacelab, space industrialization programs, etc.)
- Investments in satellite power systems (space and ground segments) would be made after successful demonstration projects have been accomplished under government DDT&E funding of the first fully operational 5-GW system.
- Utilities will form regional consortia to provide funds for satellite power systems offering electrical power on a basis comparable to similar capability and overall costs in competitive power generation.
- Industrial firms will form consortia to provide funds for space projects that present a comparable cost basis for similar capabilities on earth with the added benefits of improved quality, reliability, performance, life, and producibility.

General assumptions and ground rules have been established for the SPS organizational entities, as proposed, based on the following considerations: (1) current views of the economic environment, total U.S. energy consumption and projection, and government funding levels that offer the opportunity to present and sell a well-conceived SPS program; (2) the impact of an SPS-type

program upon estimated Department of Energy, NASA, and other governmental funding levels through 1995, and beyond, warrants the consideration of a selected financial and operational concept over other considered concepts/options; (3) space industrialization projects by the government-NASA, and U.S. industry, are necessary activities and should precede or parallel the SPS operational development; (4) utilities, via consortia funding participation, will be interested and willing to invest in the SPS following demonstrated economic and operational feasibility; and (5) funding data and market/investment data for government, utilities, and industry can be utilized for deriving investment participation between government, utilities and general industry. Additionally, a basic ground rule was established whereby the SPS will be a national corporation—with varying roles, investments, and ownership by the government, electric utilities, general industry, or the public—and that a considered approach would be developed for each contemplated, acceptable operational and financial arrangement.

Figure C.1-1(a), based on Data Resources, Inc. (DRI) data, shows that United States energy consumption is expected to grow at a slower pace than real GNP. The figure compares the energy growth patterns of three scenarios for the next 25 years. Growth in consumption of electrical energy will be much faster than for energy as a whole. Case A is a high-growth scenario that corresponds to the continuation of the conditions, attitudes, and policies that were typical of the 1950's and 1960's. All conditions were generally favorable to growth, and government policies were explicitly aimed at growth. For Case A, the high-growth scenario, this situation is assumed to continue; thus U.S. energy consumption will grow as depicted. In Case B, energy supplies are

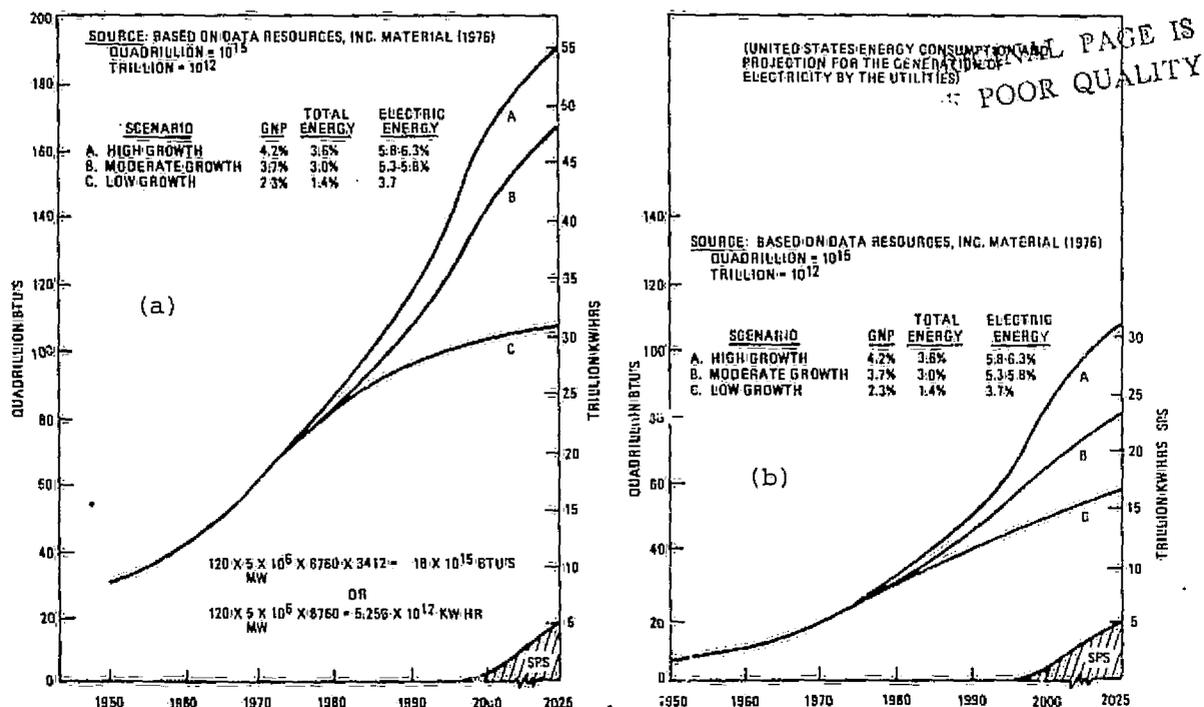


Figure C.1-1. Total U.S. Energy Consumption and Projection



assumed to be less readily available than for Case A. In Case C, it is anticipated that a strong national commitment will be made to allow a steady-state or low-growth society by the late 1980's. A combination of voluntary actions and compulsory legal restraints is assumed to be necessary. Growth rates for GNP, total energy, and electric energy are indicated on the figure. The impact of a 120-SPS satellite program on U.S. energy consumption is readily discernible.

Figure C.1-1(b) shows U.S. energy consumption for electricity under each of the scenarios discussed above for Part (a) of the figure. Growth in consumption of electrical energy will grow faster than energy as a whole; this is due to a continuation of past relationships. The growth in consumption of electricity is because of its superior convenience and versatility, flexibility in being able to use any basic energy source, slower rates of increase than for some competing fuels, and the need for the nation to achieve energy independence. The impact of the 120-SPS satellite program on U.S. electricity consumption is, again, readily discernible.

Figure C.1-2 is a comparison of the DRI energy supply forecast with the Electric Power Institute (EPRI) forecast; this comparison is based on Scenario A only. Significant differences can be seen in the oil and natural gas projections, with EPRI being more optimistic regarding the increase in gas supplies which will result from a removal of well-head prices. EPRI forecasts early decontrol of domestic prices for both oil and natural gas. DRI price projections represent far more stable expansion paths. The impact of the 120-SPS satellite program is shown, arbitrarily, against oil.

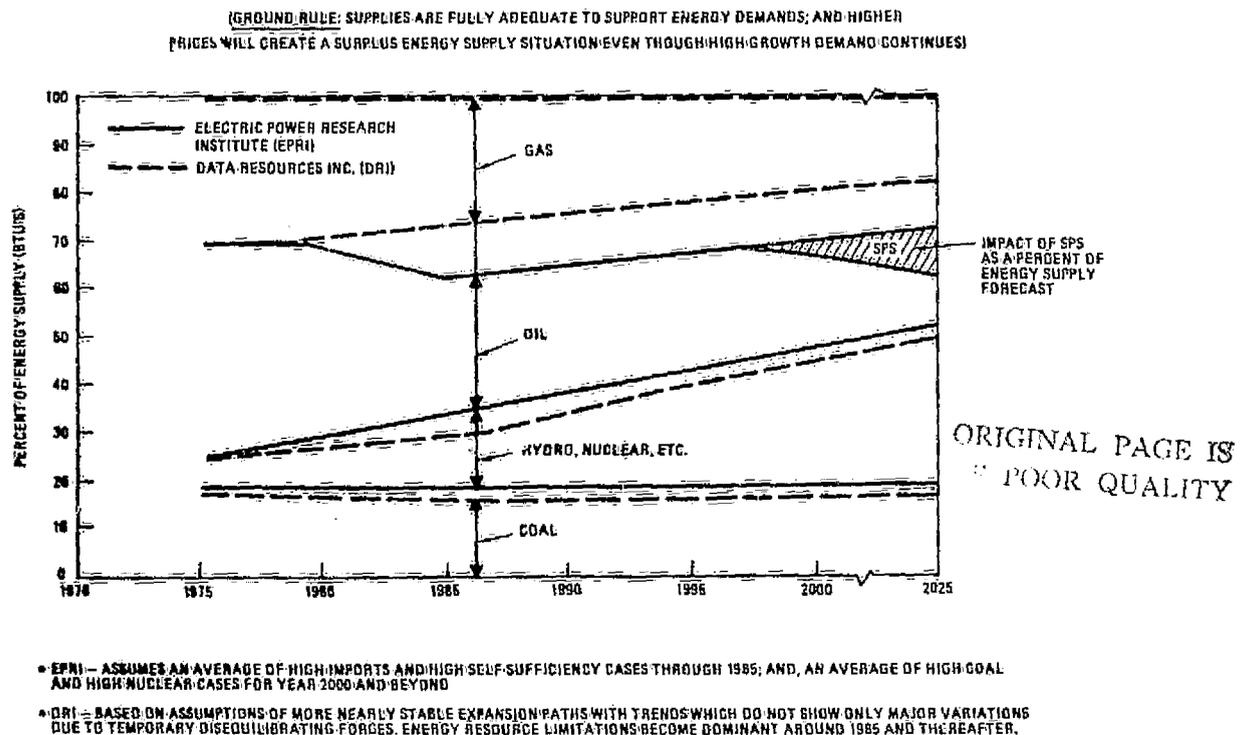


Figure C.1-2. High-Growth Energy Supply Forecast (EPRI Vs. DRI)—Scenario A



C.2 PRELIMINARY FINANCIAL AND OPERATIONAL CONCEPTS

Studies were conducted to identify several financial arrangements and practical approaches for the funding and operation of a satellite power system organization. Important premises, ground rules, and assumptions (as presented in Volume VII) were followed in the development of four preliminary concepts, as summarized in Table C.2-1. Major considerations are listed for (1) a national satellite power system (utility) company—Geographic SPS Utility Consortia, DOE, NASA, etc.; (2) a national satellite power system corporation—based on the COMSAT concept (formed by an Act of Congress, etc.); (3) a national satellite power system corporation—Federalized SPS Corporation (created by an Act of Congress, etc.); and (4) a national utility corporation for electric power via SPS (a variation of Concept 1). Funding projections associated with each organizational approach and the expected sources of funding are also presented in the table.

Table C.2-1. SPS Preliminary Financial and Operational Concepts

FINANCIAL & OPERATIONAL CONCEPT	DESIGN, DEVELOPMENT, TEST & EVALUATION	SPS PHASES		REMARKS
		INITIAL CAPITAL INVESTMENT	OPERATIONS REPLACEMENT CAPITAL INVESTMENT OPERATIONS & MAINTENANCE, TAXES AND INSURANCE	
I -NATIONAL SATELLITE POWER SYSTEM COMPANY	<ul style="list-style-type: none"> 100% FUNDING BY DOE/NASA 	<ul style="list-style-type: none"> 40% FUNDING OF OPERATIONAL SYSTEM BY DOE 60% FUNDING OF OPERATIONAL SYSTEM BY UTILITY CONSORTIA 100% FUNDING OF TRANSPORTATION SYSTEM BY -TBD 100% FUNDING OF LAND AND GROUND SYSTEMS BY UTILITY CONSORTIA 		FIVE GEOGRAPHIC SPS UTILITY CONSORTIA
II -NATIONAL SATELLITE POWER SYSTEM CORPORATION	<ul style="list-style-type: none"> 100% FUNDING BY DOE/NASA 	<ul style="list-style-type: none"> UTILITY CONSORTIA FUNDING/EQUITY PARTICIPATION-TBD INDUSTRIAL CONSORTIA FUNDING/EQUITY PARTICIPATION-TBD POTENTIAL PUBLIC PARTICIPATION VIA PUBLIC STOCK-TBD 100% FUNDING OF TRANSPORTATION SYSTEM BY -TBD 		BASED ON COMSAT CONCEPT - CREATED BY AN ACT OF CONGRESS (PUBLIC LAW)
III-NATIONAL SATELLITE POWER SYSTEM AUTHORITY	<ul style="list-style-type: none"> 100% FUNDING BY DOE/NASA 	<ul style="list-style-type: none"> GOVERNMENT FUNDING OF SPS SYSTEM WITH PARTICIPATION BY UTILITIES AND PUBLIC 100% FUNDING OF TRANSPORTATION SYSTEM BY -TBD UTILITIES/UTILITY CONSORTIA BUY ELECTRIC POWER FROM SPS AUTHORITY 		CREATED BY AN ACT OF CONGRESS (PUBLIC LAW) - FEDERALIZED SPS CORPORATION
IV -NATIONAL UTILITY CORPORATION FOR ELECTRIC POWER VIA SPS	<ul style="list-style-type: none"> 100% FUNDING BY DOE/NASA 	<ul style="list-style-type: none"> UTILITY CONSORTIA 100% FUNDING OF SPS OPERATIONAL SYSTEM WITH PUBLIC PARTICIPATION 100% FUNDING OF TRANSPORTATION SYSTEM BY -TBD 		GEOGRAPHIC SPS UTILITY CONSORTIA - VARIATION OF CONCEPT I

Continued analyses of these preliminary concepts, discussions with SCE (Southern California Edison), NASA/MSFC, and EPRI personnel; and literature studies of DOE, NASA, JPL, and EPRI documentation resulted in the expansion of these basic concept formations and interrelationships of each approach. For example, in the meeting with SCE personnel, discussions were held on the financial and organizational concept/option that would be best suited to the utility; the kind of participatory role that would meet their needs; how such a concept might be implemented; the capital investment approach; the effect of local, state, and federal regulations and considerations on taxes and insurance; cash flow concepts; depreciation factors; and the *pro forma* approach. SCE also described their operations, methods of obtaining funds, and how organizational alignments were formed with other utilities in the generation/distribution of



power. SCE felt that the idea of a utility consortia for the SPS would be more desirable once the SPS concept was proved to be economically and operationally feasible. An analysis was also completed on the TVA (Tennessee Valley Authority) organizational and funding concept. TVA was created by an Act of Congress to advance the economic development of the Tennessee Valley Region, and all functions of the TVA are vested in a Board of Directors appointed by the President with the consent of the Senate. It is wholly owned by the government, and the electric power program is required to be financially self-supporting. TVA finances its capital needs from earnings and bonds.

C.3 PREFERRED CONCEPTS

The investigation and assessment of various elements fundamental to each of the four preliminary options culminated in the identification of preferred concepts. The National Satellite Power System Corporation and the National Utility Corporation for SPS Electric Power represent these two viable approaches of joint ownership and financial and operational alignment. Fundamentally, both concepts are similar in the funding of DDT&E and the transmission/distribution phases for the SPS program. One hundred percent funding of DDT&E is projected for DOE and the NASA with specific charters and responsibilities to be developed relative to the capabilities of each organization. In addition, groups such as the EPRI were planned to participate in the DDT&E activity as a means of being directly involved with the research and development process and the design characteristics of power generation from the SPS. This membership would also facilitate the exchange of technical knowledge with the utilities as the program progresses, and provide a direct interface with participating utility consortia on the subject of power transmission and distribution; 100 percent of the funding for transmission/distribution interfaces and the required facilities would be provided by the utility consortia.

Funding for the SPS capital investment and operations/maintenance phases for each SPS would be provided by the government under the National Satellite Power System Corporation concept. The utilities or utility consortia would then buy electric power from the SPS. Whereas, under the concept of a National Utility Corporation for SPS Electric Power, 100 percent of the funding for earth-based investments, the fabrication and assembly of all SPS's, and the maintenance/operations phases would be provided by a number of utility consortia. These data are summarized in Table C.3-1 for each of the preferred concepts, with additional discussion in Tables C.3-2 and C.3-3.

Criteria for the evaluation of identified financial and operational concepts/options focused on SPS business development planning strategies/formats consistent with the objectives of: (1) maximizing return on investments and other resources; (2) matching expenditures with the SPS operational entity and its business development plan strategies; (3) stability and management/control of funding; and (4) appropriate concern over revenues, returns, probability of successful market penetration, and investments/costs.



Table C.3-1. SPS Preferred Financial and Operational Concepts

PREFERRED CONCEPTS	SPS PHASE		
	DESIGN, DEVELOP., TEST & EVALUATION	INVESTMENT	OPERATIONS
NATIONAL SATELLITE POWER SYST CORP—CREATED BY ACT OF CONGRESS (PUBLIC LAW)	100% FUNDING BY DOE/NASA WITH EPRI PARTICIPATION IN PLANNING	<ul style="list-style-type: none"> • 100% GOVERNMENTAL FUNDING OF SPS CAPITAL INVESTMENT, OPERATIONS AND MAINTENANCE • 100% FUNDING OF SPACE TRANSPORTATION SYSTEM—TBD (E.G., HLLV, OTV) • UTILITIES OR UTILITY CONSORTIA BUY ELECTRIC POWER FROM SPS CORPORATION 	100% FUNDING BY UTILITY CONSORTIA
NATIONAL UTILITY CORPORATION FOR SPS ELECTRIC POWER	100% FUNDING BY DOE/NASA WITH EPRI PARTICIPATION IN PLANNING	<ul style="list-style-type: none"> • 100% FUNDING OF SPS CAPITAL INVESTMENT, OPERATIONS, AND MAINTENANCE BY UTILITY CONSORTIA 	100% FUNDING BY UTILITY CONSORTIA

Table C.3-2. Organizational and Funding Concepts for a National SPS Corporation

<ul style="list-style-type: none"> • CREATED BY AN ACT OF CONGRESS (PUBLIC LAW)—FEDERALIZED NATIONAL SATELLITE POWER SYSTEM CORPORATION • SPS FUNDING <ul style="list-style-type: none"> - DOE/NASA/EPRI, 100% OF DDT&E - SPACE TRANSPORTATION SYSTEMS—TBD - INVESTMENT AND OPERATIONS FUNDING OF SPS BY GOVERNMENT (PUBLIC) <ul style="list-style-type: none"> ✓ GOVERNMENT FUNDING OF THE SPS SYSTEM VIA THE ASSUMPTION THAT SPS CAN BE FUNDED IF NATION'S ECONOMY GROWTH CONTINUES. BASED ON CONTINUED GROWTH AND PRESENT TAXATION POLICIES, MONIES WILL BECOME AVAILABLE AS A RESULT OF OUR NATIONAL REVENUE SYSTEM. FOR EXAMPLE, THE IMPACT OF DEFENSE AND DISARMAMENT POLICIES ON THE NATION MAY RELEASE MONIES FOR OTHER PURPOSES. ✓ UTILITIES OR UTILITY CONSORTIA BUY ELECTRIC POWER FROM THE SPS CORPORATION - TRANSMISSION/DISTRIBUTION FUNDING BY UTILITY CONSORTIA

Table C.3-3. Organizational and Funding Concepts for a National Utility Corporation for Electric Power via SPS

<ul style="list-style-type: none"> • GEOGRAPHIC SPS UTILITY CONSORTIA • SPS FUNDING <ul style="list-style-type: none"> - DOE/NASA/EPRI, 100% FUNDING OF DDT&E - SPACE TRANSPORTATION SYSTEMS—TBD - UTILITY CONSORTIA, 100% FUNDING OF SPS INVESTMENT AND OPERATIONS OF SYSTEM <ul style="list-style-type: none"> ✓ INITIAL SPS FUNDING 100% BY UTILITY CONSORTIA THROUGH 20 SATELLITE SYSTEMS. STOCK IS ISSUED FOR UTILITY EQUITY POSITIONS IN THE NATIONAL UTILITY CORP. ✓ 50 SATELLITE-SPS FUNDING REQUIREMENTS MET BY THE RESPECTIVE GEOGRAPHIC UTILITY CONSORTIA VIA UTILITY CORP. STOCK OFFERING TO THE PUBLIC. ✓ SUBSEQUENT SPS FUNDING REQMTS MET VIA SECONDARY STOCK ISSUES OR LTD ARRANGEMENTS BY THE RESPECTIVE UTILITY CONSORTIA - TRANSMISSION/DISTRIBUTION FUNDING BY UTILITY CONSORTIA



C.4 RECOMMENDED SPS ORGANIZATIONAL AND FUNDING CONCEPT

Of the six financial and operational concepts proposed for consideration, subsequent investigation and evaluation resulted in the selection and refinement of a single concept. The organizational entities that would be formed and funded are summarized below.

National SPS Space Segment Corporation (Federally Owned)

Organizational Roles

The National Satellite Power System Space Segment Corporation (a federally owned corporation) would be created by an Act of Congress (public law) to undertake all DDT&E activities and to demonstrate an operational satellite power system and ground system/rectenna site.

The National SPS Space Segment Corporation would, after a successful operational demonstration, proceed to complete the 120 SPS systems.

Utilities would be asked and expected to form a geographical SPS Ground Segment Utility Consortia Corporation to fund the ground segment—rectenna sites/installations and transmission/distribution roles.

EPRI and TVA would participate with the Department of Energy, NASA, and the utilities in planning and management activities.

SPS Space Segment Funding—Investment and Operations

Funding will be provided by the Department of Energy and NASA, with some participation by the utilities via EPRI for 100 percent of DDT&E through demonstration of a total operational SPS. Funding for Department of Energy will be available via the assumption that SPS can be funded if the nation's economic growth continues. Based on continued growth and present taxation policies, monies will become available as a result of our National Revenue System. Again, the impact of defense and disarmament policies on the nation may release monies for SPS or other purposes.

Funds/revenues will also be provided by utilities or utility consortia purchasing electric power from the National SPS Space Segment Corporation.

The National SPS Segment Corporation will be required to become financially self-supporting. It will be expected to finance its capital needs from earnings and the sale of bonds within the first ten years of operations.

DDT&E costs will not be charged to the SPS Space Segment Corporation's operations since other space programs will also have benefited from this DDT&E, and an appropriate derivation of such an allocation cannot be made at this time.



SPS Ground Segment Utility Consortia Corporation

Organizational Roles

The SPS Ground Segment Utility Consortia Corporation (a national utility corporation formed by geographic SPS utility consortia) would be created to undertake funding of operational rectenna installations and to perform transmission/distribution operations.

The SPS Ground Segment Utility Corporation would participate with the Department of Energy, NASA, TVA, and others (via EPRI) in planning and management activities.

The SPS Ground Segment Utility Corporation would purchase electric power delivered to the rectenna sites of the geographic SPS utility consortia from the SPS Space Segment Corporation.

SPS Ground Segment Funding—Investment and Operations

The SPS Ground Segment Utility Consortia Corporation would participate in SPS DDT&E phases through EPRI. This membership (EPRI) will facilitate the exchange of technical knowledge with the utilities as the program progresses and provide a direct interface with all participating utility consortia with respect to rectenna sites/installations, power transmission and distribution.

All funding of the operational rectenna sites/installations and for transmission and distribution interfaces and the required facilities will be provided by utility consortia via the SPS Ground Segment Utility Consortia Corporation, which is the vehicle for buying electric power from the SPS Space Segment.

Funds for the SPS Ground Segment Utility Consortia Corporation would come via the equity positions taken by utilities in this organizational entity. Participating utilities would raise funds through common stock offerings (secondary issues), preferred stock issues, and long-term debt (issuance of bonds) as necessary to support the extent of their desired/or available electric power participation. Thus, utilities within the SPS consortia would obtain equity in the SPS Ground Segment Corporation based on the degree of their need and ability to provide funding to this entity through the issuance of additional common stock, preferred stock, and/or through long-term debt.

C.5 CRITERIA FOR EVALUATION OF PREFERRED FINANCIAL AND OPERATIONAL CONCEPT

National SPS Space Segment Corporation (Federally Owned)

General Criteria for Financial and Operational Evaluation

Revenues—Revenues should be based on a cost to the electric utilities (SPS Ground Segment Utility Consortia Corporation) that will be sufficient to permit the write-off of capital investments, cover operational expenses, and provide a suitable profit on operations.



Profitability—Profitability of the entity should be a percent of revenues which is high enough to provide a satisfactory return on net assets employed (investment), and permit investment recovery within the planning period (via cumulative net cash flow).

Investments/Costs Funding—The entity should be able, within ten years of operation, to generate sufficient funds via cash flow to finance at least 40 percent of its capital investment requirements. Not more than 60 percent of capital investment shall be obtained by long-term debt (bond issues).

Figures of Merit

Net income divided by average net assets employed should be ≥ 6 percent return on investment; or, percent return on revenues times the net asset turnover = ROI of ≥ 6 percent.

Investment recovery via cumulative net cash flow should be achieved by the year 2029 (120 SPS systems operational).

Returns on revenues should exceed 15 percent in order to provide a satisfactory ROI and permit investment recovery (via cumulative net cash flow).

SPS Ground Segment Utility Consortia Corporation

General Criteria for Financial and Operational Evaluation

Revenues—Revenues should be based on a cost per kilowatt-hour which will be comparable to other forms of competitive power generation systems. Revenues should be sufficient to permit the write-off of capital investments, cover operational expenses, and provide a suitable profit on operations.

Profitability—Profitability of this entity should be a percent of revenues which is high enough to provide a return on investment (ROI) levels for electric utilities, and permit investment recovery within the planning period (via cumulative net cash flow).

Investments/Costs Funding—The entity should be able, within ten years of operations, to generate sufficient funds via cash flow to finance at least 40 percent of its capital investment requirements. Not more than 60 percent of capital investment shall be necessary via common stock, preferred stock, and long-term debt (bond issues) by the participating utility consortia to fund the SPS Ground Segment's capital requirements.

Figures of Merit

Net income divided by average net assets employed (ANAE) should be $\geq 10\%$ return on investment (ROI), or percent return on revenues times net asset turnover = ROI $\geq 10\%$.

Investment recovery via cumulative net cash flow should be achievable within the first 25 years of investment and operations of the 120 SPS operational systems.



Returns on revenues should exceed 15 percent in order to provide a satisfactory ROI and permit investment recovery (via cumulative net cash flow).

C.6 FINANCIAL AND OPERATIONAL DATA MODELS—COMPUTATION METHODOLOGY AND GENERAL EVALUATION OF RESULTS

Computation Assumptions and Financial Data Structures

Limitation of Financial and Operational Data Model

At best, any financial or economic model is only a very approximate reflection of reality. However, such a model as has been utilized herein does provide a structural and internally consistent framework for evaluation of the financial and operational performance of the two proposed entities that could be utilized to implement the SPS program. In that sense, it can be useful in developing alternative views of the future for the SPS Ground Segment Utility Consortia concept and the National SPS Space Segment Corporation (federally owned) concept.

SPS Ground Segment Utility Corporation Concept

The SPS system schedule buildup to 120 satellites was utilized to derive the potential revenues based upon a total cost of 30 mills and 40 mills per kilowatt-hour to the busbar. The electricity charges of 30 mills and 40 mills per kilowatt-hour are utilized in the calculations to determine the extent of amortization possible for the SPS system costs. Overland transmission costs and distribution costs have not been included in the electricity generation cost calculations. Income statements, assets-employed statements, and cash flow performance statements were developed for these two financial models.

Income Statement (based on 30 mills/kWh)—For the SPS Ground Segment Utility Consortia Corporation concept, data were developed using computational methodology applicable to utilities, generally, and then deriving ratios that could be applied to total revenues and thus create an income statement. The elements of the income statement and pertinent ratios (based on 30 mills/kWh) are:

	Without ITC (%)	With ITC (%)
Total revenues	100.00	100.00
Operating expenses	Ratio (% of Revenues)	
Purchased power (purchased from National Space Segment Corporation (federally owned))	61.776	61.776
Operations and maintenance	0.475	0.475
Depreciation and amortization	7.000	7.000
Interim replacement	0.848	0.848
Property insurance	0.098	0.098
State and local taxes	2.743	2.743
Interest costs (imputed)	8.000	8.000
Income taxes	4.000	4.000
Income tax credits	0	(1.290)
Total operating expenses	84.940	83.650



	<u>Without ITC (%)</u>	<u>With ITC (%)</u>
Operating income	15.060	16.350
Other income	TBD	TBD
Research and development costs	TBD	TBD
Total net income	15.060	16.350

These ratios for the income statement have been tested against various utility financial statements and found to be representative of the contents of such statements over a period of years. They have been used in the model to provide a useful financial picture based on preliminary SPS schedule and cost data. Special consideration was given to appropriate SPS elements as necessary to derive useful ratios.

Income Statement (based on 40 mills/kWh)

	<u>Without ITC (%)</u>	<u>With ITC (%)</u>
Total revenues	100.00	100.00
Operating expenses	Ratio (% of Revenues)	
Purchased power (purchased from National SPS Space Segment Corp. (federally owned))	66.279	66.279
Operations and maintenance	0.356	0.356
Depreciation and amortization	5.250	5.250
Interim replacement	0.636	0.636
Property insurance	0.073	0.073
State and local taxes	2.057	2.057
Interest costs (imputed)	6.000	6.000
Income taxes	3.800	3.800
Income tax credits	0	(0.968)
Total operating expenses	84.451	83.483
Operating income	15.549	16.517
Other income	TBD	TBD
Research and development costs	TBD	TBD
Total net income	15.549	16.517

In this model, 40 mills/kWh is used to improve revenues and income to the National SPS Segment Corporation from the Ground Segment SPS Utility Corporation concept. Only the cost of purchased power increases for the SPS Ground Segment Utility Corporation concept. All other operating expenses (dollars) are the same, although the ratios (percent of revenues, percent of return or net assets employed) change.

Assets-Employed Statement—The assets-employed statement was developed using a typical electric utility format for total assets: utility plant, other property and investments, and current assets. However, the capitalization and liabilities portion of the statement was designated as "liabilities and investments" and considers only current liabilities and investments—investments consisting of cumulative income (or loss) applied to the investment, and total investment requirements as shown via the cash flow statement. The assets-employed statement is the most useful way to show utility consortia the total



investment picture. From such a statement, plus the cash flow statement, it is relatively easy to determine financing based on common stock, preferred stock, and long-term debt considerations.

Total Assets—The utility plant, other property, and investments were determined from preliminary acquisition cost estimates for this entity. The time-phasing of these capital investments was determined from the SPS rectenna site completion schedule and the use of NASA CER progress factors to arrive at an approximation of the probable, incurred annual costs. Depreciation and amortization reserves for the scheduled investment are those expenses indicated in the income statement.

Current assets were derived as a ratio of total revenues (after a nominal consideration for some current assets acquired prior to receipt of revenues). This overall ratio considered all the elements of cash requirements, receivables, materials and supplies at average cost, prepayments, and other items (taxes, insurance, etc.). This current asset ratio is approximately 25.2 percent of total revenues.

Liabilities and Investment—Current liabilities were derived as a ratio of total revenues (after a nominal consideration for some current liabilities acquired prior to receipt of revenues). This overall ratio considered all the elements of accounts payable, accrued salaries and wages payable, taxes accrued, energy cost adjustment balancing account, interest accrued, and other items. The current liability ratio works out to be approximately 18.2 percent of total revenues (or about 72% of current assets).

Investment is a combination of investment requirements and the cumulative net income (or loss) applied to the investment requirements. The combination of income (or loss) and investment requirements, added algebraically, represents the total investment. This total investment is commonly referred to as the net assets employed. The investment requirements are the cumulative net cash flow summarized in the cash flow performance summary statement.

Current liabilities plus total investment equals total assets. The investment requirements (cash requirements) are normally satisfied via common stock offerings for shareholders' equity, paid-in capital, earnings reinvested in the business, preferred stock issuance, and/or financing agreements with banks via promissory notes payable, first mortgage and collateral trust bonds (long-term debt arrangements).

**Net assets employed* consist of the cumulative utility plant and property investments at acquisition cost, less the accumulated reserve for depreciation and amortization (net plant and property); and net working capital, which is the difference between current assets and current liabilities. NOTE: The ability of an SPS Ground Segment Utility Consortia Corporation to meet its obligations, expand its business volume, and take advantage of increased business opportunities will be tied to its net working capital.

**Return on average net assets employed.* The average net assets employed consists of averaging the net assets employed for the first two years and adding the third year to the second year and averaging again, and so on until completed for the program period. Return on average net assets employed is



computed either by dividing the revenues by the average net assets employed, to determine the turnover ratio, and multiplying the turnover ratio by the percent of profit (return on revenues); or by dividing the profit dollars by the average net assets employed.

Cash Flow Performance Summary Statement—The cash flow performance summary statement is a summary of operating results, investments, and working capital changes ($\Delta\pm$); and presents annual net cash flow data and cumulative net cash flow data.

- *Operating results.* Net income (or loss) added algebraically to depreciation and amortization and other non-cash deductions (if any) provides an annual basic cash in-flow. These funds, generated by operations, are then utilized to offset outlays for capital investments and increases in working capital. These funds are a measure of the ability of the SPS program to help finance its expansion and provide for investment recovery.

- *Investments.* This includes construction expenditures, new capital acquisitions, land and buildings, and other items which must be capitalized and depreciated or amortized (except land). These investments are shown as annual cash outlay requirements.

- *Working capital changes ($\Delta\pm$).* Working capital changes are the increases or decreases between successive years for current assets and current liabilities. Increases between successive planning years of current assets are a minus (-) figures, while decreases are a plus (+) figure. Increases in current liabilities between successive planning years are a (+) figure (i.e., using funds free, owned externally), while decreases are a (-) figure.

- *Annual net cash flow.* This annual figure is the result of the cash inflows applied to the capital investments and the changes ($\Delta\pm$) in working capital. It indicates the amount of financial investment that must be made each year if negative. If a positive figure results, it indicates the cash flow amount that is available to offset previous negative figures; or, to apply to new investment opportunities.

- *Cumulative net cash flow.* The annual net cash flow figures, when added cumulative, indicate the cumulative investment (cash outlay) requirements, the period where cash flow requirements are at a maximum (maximum exposure and risk); the period when, as annual net cash flows become positive, investment recovery begins; and, when investment recovery is accomplished, i.e., the length of time to recover the investment.

National SPS Space Segment Corporation Concept (Federally Owned)

The National SPS Space Segment Corporation schedule buildup was utilized to derive the potential revenues based on a total sales value of 30 mills/kWh and 40 mills/kWh by the SPS Ground Segment Utility Corporation concept. Separate income statements, assets employed statements, and cash flow performance statements were developed for these two financial models.



Income Statement (Based on 18 mills/kWh)—For the National SPS Space Segment Corporation concept, data were developed using computational methodology that would be applicable to such a corporation, wholly owned by the federal government; and, then deriving ratios that could be applied to total revenues and thus create an income statement. The elements of the income statement and the ratios (percent of revenues) for the operating expense items are as follows:

Power sales and revenues	100.00%	(the price to SPS Ground Segment Utility Consortia Corporation concept)
Operating expenses	Ratios (% of Revenues)	
Satellite power production	(24.5995)	
Satellite system interim replacement	(6.1802)	
Satellite system operations and maintenance	(3.7164)	
HLLV space transportation system interim replacement	(0.6653)	
HLLV space transportation system O&M	(2.7777)	
Space station interim replacement	(5.1957)	
Space assembly/support facilities interim replacement	(0.5000)	
Intra-orbit vehicle interim replacement	(0.0304)	
Intra-orbit vehicle O&M	(0.0003)	
Cargo orbiter transfer vehicle expense	(0.0357)	
Personnel orbiter transfer vehicle expense	(0.0103)	
Personnel orbiter transfer vehicle O&M	(0.0554)	
Facilities—interim replacement	(0.2230)	
Depreciation and amortization	(26.1400)	
Payments in lieu of taxes	(5.0000)	
Social security taxes (@ \$1500 per year per employee)	(1.4800)	
Total operating expenses	(76.6099)	
Operating income	(23.3901)	
Other income	TBD	
Total income	(23.3901)	
Research and development expense	TBD	
Income before interest expense	(23.3901)	
Interest expense (imputed)	(8.0000)	
Total net income	(15.3901)	

The ratios for the income statement have been derived from SPS cost data and tested against the program for validity and compared with a variety of electric utility companies including TVA material. These ratios have been used in the models to provide a useful financial picture based on preliminary SPS schedule and cost data. Special consideration was given to appropriate SPS elements as necessary to derive useful ratios.



Income Statement (Based on 27 mills/kWh)

Power sales and revenues	100.00% (the price to SPS Ground Segment Utility Consortia Corporation concept)
Operating expenses	Ratio (% of Revenues)
Satellite power production	(31.2389)
Satellite system interim replacement	(4.3224)
Satellite system operations and maintenance	(2.5992)
HLLV space transportation system interim replacement	(0.4653)
HLLV space transportation O&M	(1.9427)
Space station interim replacement	(3.6338)
Space assembly/support facility interim replacement	(0.3497)
Facilities--interim replacement	(0.1560)
Intra-orbit vehicle interim replacement	(0.0213)
Intra-orbit vehicle O&M	(0.0002)
Cargo orbiter transfer vehicle expense	(0.0250)
Personnel orbiter transfer vehicle expense	(0.0074)
Personnel orbiter transfer vehicle O&M	(0.0388)
Depreciation and amortization	(18.2822)
Payments in lieu of taxes	(3.4970)
Social security taxes	(1.0351)
Total operating expenses	(67.6150)
Operating income	
Other income	TBD
Total income	(32.3850)
Research and development expense	TBD
Income before interest expense	(32.3850)
Interest expense (imputed)	(5.6000)
Total net income	(26.7850)

Assets-Employed Statement—The assets-employed statement for the National SPS Space Segment Corporation (federally owned) was devised from analysis of financial data of various electric utility companies, including TVA. Total assets include all elements of the space segment, other property and investments, and current assets. However, the capitalization and liabilities portion of the assets-employed statement was designated "liabilities and investments" and considers only current liabilities and investments—investments consisting of cumulative income (or loss) applied to investment, and total investment requirements as shown via the cash flow statement. The assets-employed statement is the most useful way for the governmental agencies (DOE and NASA) to view the total investment picture for this federally owned corporation concept, and to determine to what extent it should issue bonds, notes, and other evidences of borrowings/indebtedness, etc., to finance the National SPS Space Segment Corporation concept. NOTE: It is anticipated that the National SPS



Space Segment Corporation concept via an SPS Act would require that such a corporation charge rates for power supplied to the Ground Segment Utility Corporation concept which will produce gross revenues sufficient to provide funds for operation, maintenance, and administration of its power system; payments to states and counties in lieu of taxes; specified fixed charges associated with debt financing and U.S. Treasury payments; and a margin determined by the board for total investment in SPS power system assets. It is anticipated that an SPS Act further would require that rates be set as low as feasible, yet ensure that return on investment be commensurate with a reasonable return for such an electric utility entity owned by the federal government.

Total Assets—The utility plant, other property, and investments were determined from the preliminary cost estimates for this entity. The time-phasing of these capital investments was determined from the SPS Space Segment start and completion schedule and the use of NASA CER progress factors to arrive at an approximation of the probable, incurred annual costs. Depreciation and amortization reserves for this scheduled investment are those expenses indicated in the income statement.

Current assets were derived as a ratio of total revenues (after a nominal consideration for some current assets acquired prior to receipt of revenues). This overall ratio considered all the elements of cash requirements, receivables, supplies and materials, and prepaid expense items. This current asset ratio is calculated as approximately 25.0 percent of total revenues.

Liabilities and Investment—Current liabilities were derived as a ratio of total revenues (after a nominal consideration from some current liabilities acquired prior to receipt of revenues). This overall ratio considered all the elements of accounts payable, accrued salaries and wages payable, accruals for payment to the U.S. Treasury, interest accrued, and other items. The current liability ratio to total revenues has been estimated to be approximately 18.0% of total revenues (or 72% of current assets).

Investment is a combination of investment requirements and the cumulative net income (or loss) applied to the investment requirements. That is, the combination of cumulative income (or loss) and investment requirements, added algebraically, represents the total investment. This total investment is what is known as the net assets employed (net SPS plant and property plus net working capital). The investment requirements are summarized in the cash flow performance summary statement.

Current liabilities plus total investment equals total assets. The investment requirements (cash requirements) for the SPS Space Segment entity, are anticipated as being satisfied initially through governmental appropriations and, subsequently, via proceeds from borrowing. Proceeds would be used to finance that portion of investment or capital outlays in excess of available SPS proceeds after interest, to operations, Treasury payments, and changes in working capital.

Net assets employed consist of the cumulative SPS Space Segment plant and property investments at acquisition cost, less the accumulated reserve for depreciation and amortization (net plant and property value); and, net working



capital, which is the difference between current assets and current liabilities.
NOTE: The ability of the National SPS Space Segment Corporation to meet its obligations, expand its energy services volume, and to become self-supporting and self-financing depends upon its power proceeds and borrowings secured by future revenues.

The average net assets employed are derived by averaging the net assets employed for the first two years, and adding the third year to the second year and averaging again, and so on until completed for the program period.

Return on average net assets employed is computed either by dividing the revenues by the average net assets employed to determine the turnover ratio, and multiplying the turnover ratio by the percent of profit (return as revenues); or, by dividing the profit dollars by the average net assets employed.

Cash Flow Performance Summary Statement—The cash flow performance summary statement is a summary of operating results, investments, and working capital changes ($\Delta\pm$); and presents annual net cash flow data and cumulated net cash flow data.

- *Operating results.* Net income (or loss) added algebraically to depreciation and amortization and other non-cash deductions (if any) provides a basic cash in-flow. These funds, generated by operations, can be used to offset outlays for capitalized property and increased working capital. These funds are a measure of the ability of the SPS program to help finance its expansion and provide for investment recovery.

- *Investments.* This includes construction expenditures, satellite power systems, space transportation systems, space assembly and support facilities, ground launch facilities, landing sites for launch vehicles, and other land and building investments. These items must all be capitalized and depreciated or amortized (except land). These investments are shown as annual cash outlay requirements.

- *Working capital changes ($\Delta\pm$).* Working capital changes are the increases or decreases between successive years for current assets and current liabilities. Increases between successive planning years of current assets are a minus (-) figure while decreases are a plus (+) figure. Increases in current liabilities between successive planning years are a + figure (i.e., using funds free, or externally) while decreases are a - figure.

- *Annual net cash flow.* This annual figure is the result of the cash in-flows applied to the capital investments and the changes ($\Delta\pm$) in working capital. It indicates the amount of financial investment that must be made each year if negative. If a positive figure results, it indicates the cash flow amount that is available to offset previous negative figures; or, to apply to new investment opportunities.

- *Cumulative net cash flow.* The annual net cash flow, when added cumulatively, indicates: the cumulative cash flow requirements, the period where cash flow requirements are at a maximum (maximum exposure and risk); the period



when, as annual net cash flow becomes positive, investment recovery begins; and, when investment recovery is accomplished, the length of time to recover the investment.

C.7 GENERAL EVALUATION OF FINANCIAL AND OPERATIONAL RESULTS

Income Statements for the Two SPS Organizational Entities (Based on 30 mills/kWh)

SPS Ground Segment Utility Consortia Corporation

Income statements based on 30 mills/kWh without investment tax credit will yield an average annual net income of 15.06%. With investment tax credit, annual net income will approximate 16.35% of annual revenues.

Income statements based on 40 mills/kWh without investment tax credit will yield an annual average income of 15.59%. With investment tax credit, annual net income will approximate 16.52%.

Evaluation of income statements for the SPS Ground Segment Utility Consortia Corporation must consider the financial performance of the National SPS Space Segment Corporation. While the income statements for the SPS Ground Segment Utility Consortia Corporation are satisfactory at 30 mills/kWh for return on revenues, return on investment, and cash flow analysis, they are not satisfactory for the National SPS Space Segment Corporation.

National Space Segment Corporation (Federally Owned Entity)

Income statements based on sales of electricity to the SPS Ground Segment at 19 mills/kWh (which would generate its revenues at a rate of 30 mills/kWh) will yield an average net income of 15.39%. However, this is not large enough of a percentage of profit to permit a return on investment comparable to that of the SPS Ground Segment Utility.

Income statements based on an increased cost to the SPS Ground Segment (which would then generate its revenues at a rate of 40 mills/kWh) will provide an annual average income of 26.79%. This percentage of profit is necessary for the SPS Space Segment entity to compare favorably with the SPS Ground Segment entity in return on investment.

Evaluation of income statements for the National SPS Space Segment Corporation should consider the size of the financial investment by the U.S. Government. To achieve a cash flow (income plus depreciation) sufficient to finance up to 70% of its investment requirements, the SPS Space Segment Corporation must sell electric power to the SPS Ground Segment Corporation at a rate of 27 mills/kWh, which will add a cost of 13 mills/kWh, thus making the cost to the busbar 40 mills for its customers.

Summary exhibits of SPS revenues and income statements for the National SPS Space Segment Corporation and the SPS Ground Segment Utility Consortia Corporation are furnished below for useful comparisons of performance at 30 mills/kWh (Table C.7-1) and 40 mills/kWh (Table C.7-2), respectively. Computer printouts with further explicit details were generated and are available.

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Rockwell International
Space Division

Table C.7-1. Summary of SPS Revenues at 30 Mills/kWh

SPS GROUND SEGMENT UTILITY CONSORTIA—INCOME STATEMENT FOR THE YEARS 1991 - 2029		SPS SPACE SEGMENT CORPORATION (FEDERALLY OWNED)—INCOME STATEMENT FOR THE YEARS 1991 - 2029	
REVENUE FROM SALE OF ELECTRICITY	(\$ BILLIONS)	POWER SALES AND REVENUES	(\$ BILLIONS)
TOTAL OPERATING REVENUES (SALES + OTHER)	2,387.536	TOTAL POWER REVENUES (ELECTRIC UTILITIES + OTHER)	1,474.924
ANNUAL kWh SALES (000's)	79,584.562	ANNUAL kWh SALES (000's)	79,584.562
CENTS PER kWh	3c	CENTS PER kWh	1.8c
OPERATING COSTS		OPERATING COSTS	
PURCHASED POWER FROM SPS SPACE SEGMENT CORP.	1,474.924	SATELLITE POWER PRODUCTION	362.706
OPERATIONS AND MAINTENANCE	11.341	SATELLITE INTERIM REPLACEMENT	91.166
DEPRECIATION & AMORTIZATION	167.128	SATELLITE SYSTEM OPERATIONS & MAINTENANCE	54.814
INTERIM REPLACEMENT EXPENSE	20.246	SPACE STATION INTERIM REPLACEMENT	76.632
PROPERTY INSURANCE	2.340	SPACE ASSEMBLY & SUPPORT EQUIPMENT EXPENSE	7.375
STATE & LOCAL TAXES	65.490	HLV INTERIM REPLACEMENT	9.812
INTEREST COSTS	191.003	HLV OPERATIONS & MAINTENANCE	40.969
INCOME TAXES	95.501	INTRA-ORBIT VEHICLE INTERIM REPLACEMENT	0.449
INVESTMENT TAX CREDIT & OTHER	(30.799)	INTRA-ORBIT VEHICLE OPERATIONS & MAINTENANCE	0.004
TOTAL OPERATING COSTS	1,997.184	COTV INTERIM REPLACEMENT EXPENSE	0.527
		POTV INTERIM REPLACEMENT EXPENSE	0.153
		POTV OPERATIONS & MAINTENANCE	0.817
		FACILITIES INTERIM REPLACEMENT	3.289
		DEPRECIATION & AMORTIZATION	385.545
		PAYMENTS IN LIEU OF TAXES	73.746
		SOCIAL SECURITY TAXES	21.829
		TOTAL OPERATING COSTS	1,129.817
OPERATING INCOME	390.351	OPERATING INCOME	345.093
OTHER INCOME	-0-	OTHER INCOME	TBD
INCOME BEFORE R&D EXPENSE	390.351	R&D EXPENSE	TBD
R&D EXPENSE	TBD	INCOME BEFORE INTEREST	345.093
TOTAL INCOME ON REVENUES	390.351	INTEREST EXPENSE	(117.994)
RETURN ON REVENUES (%)	16.35	TOTAL INCOME ON REVENUES	227.086
		RETURN ON REVENUES (%)	15.40

NOTE: NUMBERS SHOWN HAVE BEEN MADE TO ADD PRECISELY AND THEREFORE MAY NOT AGREE EXACTLY ON THE LAST TWO DIGITS WITH THE COMPUTER PRINTOUTS DUE TO COMPUTER ROUNDING OF DATA INPUTS.

Table C.7-2. Summary of SPS Revenues at 40 Mills/kWh

SPS GROUND SEGMENT UTILITY CONSORTIA—INCOME STATEMENT FOR THE YEARS 1991 - 2029		SPS SPACE SEGMENT CORPORATION (FEDERALLY OWNED)—INCOME STATEMENT FOR THE YEARS 1991 - 2029	
REVENUE FROM SALE OF ELECTRICITY	(\$ BILLIONS)	POWER SALES AND REVENUES	(\$ BILLIONS)
TOTAL OPERATING REVENUES (SALES + OTHER)	3,183.379	TOTAL POWER REVENUES (ELECTRIC UTILITIES + OTHER)	2,109.911
ANNUAL kWh SALES (000's)	79,584.424	ANNUAL kWh SALES (000's)	79,584.562
CENTS PER kWh	4c	CENTS PER kWh	2.7c
OPERATING COSTS		OPERATING COSTS	
PURCHASED POWER FROM SPS SPACE SEGMENT CORP.	2,109.911	POWER PRODUCTION	659.111
OPERATIONS & MAINTENANCE	11.341	SATELLITE INTERIM REPLACEMENT	91.212
DEPRECIATION & AMORTIZATION	167.127	SATELLITE SYSTEM OPERATIONS & MAINTENANCE	54.841
INTERIM REPLACEMENT EXPENSE	20.246	SPACE STATION INTERIM REPLACEMENT	76.671
PROPERTY INSURANCE	2.340	SPACE ASSY & SUPPORT EQUIPMENT EXPENSE	7.378
STATE & LOCAL TAXES	65.490	HLV INTERIM REPLACEMENT	9.817
INTEREST COSTS	191.003	HLV OPERATIONS & MAINTENANCE	40.990
INCOME TAXES	120.968	INTRA-ORBIT VEHICLE INTERIM REPLACEMENT	0.449
INVESTMENT TAX CREDIT & OTHER	(30.799)	INTRA-ORBIT VEHICLE OPERATIONS & MAINTENANCE	0.004
TOTAL OPERATING COSTS	2,657.627	COTV INTERIM REPLACEMENT EXPENSE	0.527
		POTV INTERIM REPLACEMENT EXPENSE	0.153
		POTV OPERATIONS & MAINTENANCE	0.818
		FACILITIES INTERIM REPLACEMENT	3.291
		DEPRECIATION & AMORTIZATION	385.739
		PAYMENTS IN LIEU OF TAXES	73.783
		SOCIAL SECURITY TAXES	21.840
		TOTAL OPERATING COSTS	1,426.624
OPERATING INCOME	525.752	OPERATING INCOME	683.287
OTHER INCOME	-0-	OTHER INCOME	TBD
INCOME BEFORE R&D EXPENSE	525.752	INCOME BEFORE R&D	683.287
R&D EXPENSE	TBD	R&D EXPENSE	TBD
TOTAL INCOME ON REVENUES	525.752	INCOME BEFORE INTEREST	683.287
RETURN ON REVENUES (%)	16.52	INTEREST EXPENSE	(118.053)
		TOTAL INCOME ON REVENUES	565.234
		RETURN ON REVENUES (%)	26.79

NOTE: NUMBERS SHOWN HAVE BEEN MADE TO ADD PRECISELY AND THEREFORE MAY NOT AGREE EXACTLY ON THE LAST TWO DIGITS WITH THE COMPUTER PRINTOUTS DUE TO COMPUTER ROUNDING OF DATA INPUTS.



- SPS Ground Segment Utility Consortia at
at 30 mills/kWh and without investment tax credit
in financial computations
 - Income statements
 - Investment and return on investment
 - Cash flow performance summary and
investment recovery schedule
- at 40 mills/kWh with and without investment tax
credit in financial computations
 - Income statements
 - Investment and return on investment
 - Cash flow performance summary and investment
recovery schedule
- SPS Space Segment Corporation (Federally Owned
at 18 mills/kWh cost basis to SPS Ground Segment for
30 mills/kWh total cost
 - Income statements
 - Investment and return on investment
 - Cash flow performance summary and investment
recovery schedule
- at 27 mills/kWh cost basis to SPS Ground Segment for
40 mills/kWh total cost
 - Income statement
 - Investment and return on investment
 - Cash flow performance summary and investment
recovery schedule

Principle of Importance in Evaluation of this Financial Parameter

Percent return on revenues is an important factor in appraisal of financial performance; however, to be further understood and interpreted, it must also be taken and related to the size of the investment (assets employed) which, in large part, made it possible to generate the percent return on revenues. This is discussed below (Assets Employed and Return on Assets Employed).

Assets-Employed Statements and Return of Assets Employed for the Two SPS Entities (based on 30 mills/kWh)

Assets-Employed Statements for the SPS Ground Segment Utility Consortia Corporation

Assets-employed statements based on 30 mills/kWh without investment tax credit will provide an average yield on average net assets employed (ANAE) of 11.2% (Figure C.7-1). With investment tax credit (ITC), the average yield on average net assets employed over the 1991-2029 time period will approach 12.2%.

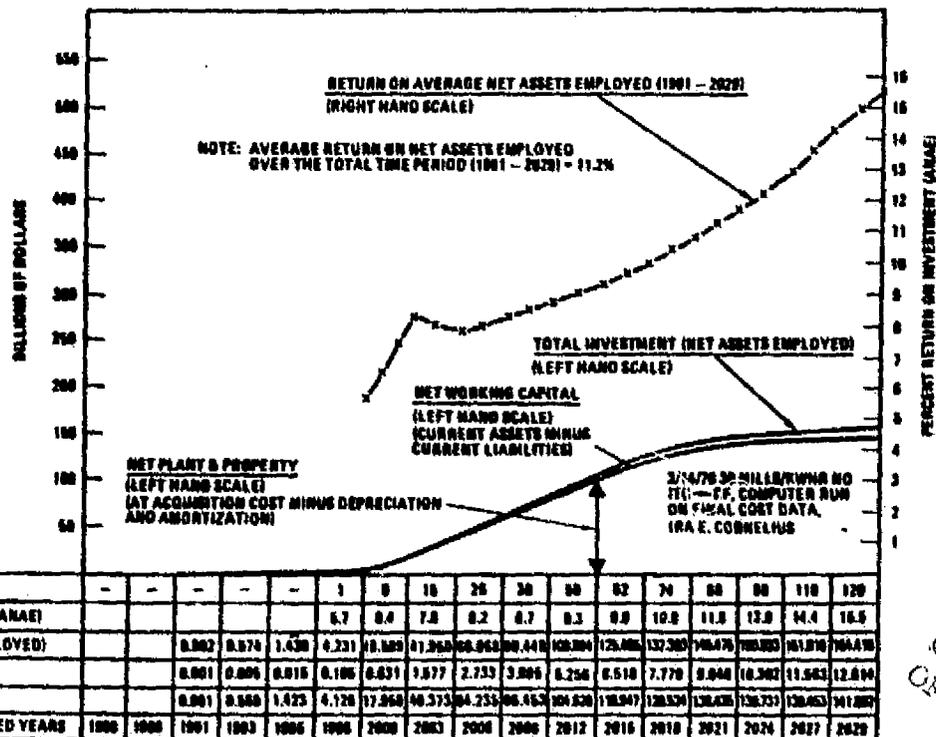


Figure C.7-1.

SPS GROUND SEGMENT UTILITY CORPORATION CONCEPT - INVESTMENT AND RETURN ON INVESTMENT
(AT 30 MILLS PER KILOWATT HOUR, EXCLUDES INVESTMENT TAX CREDIT)

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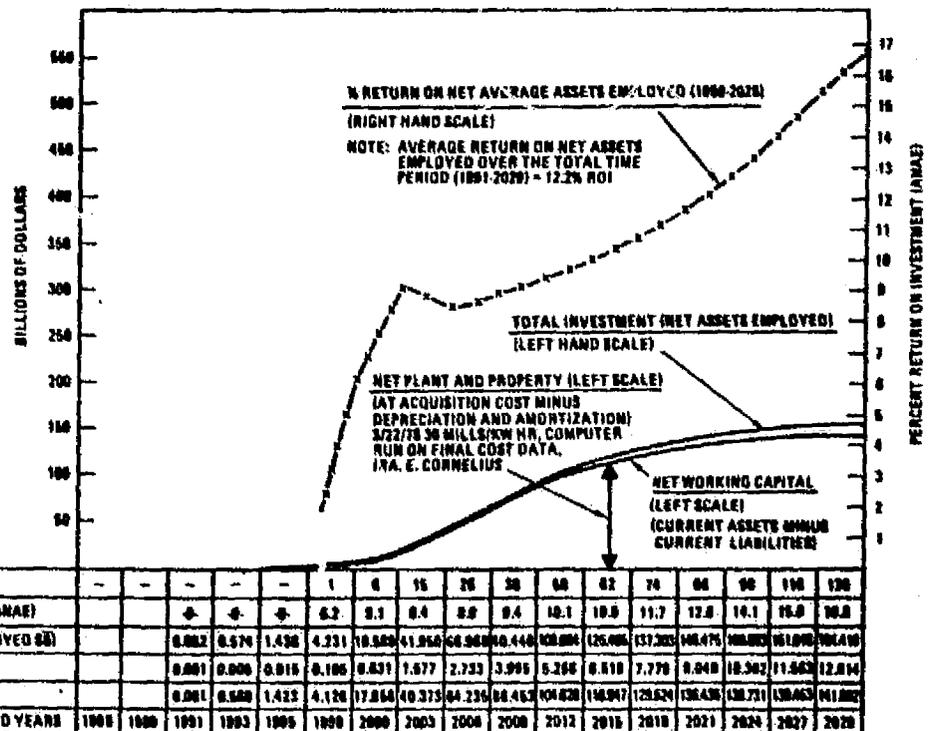


Figure C.7-2.

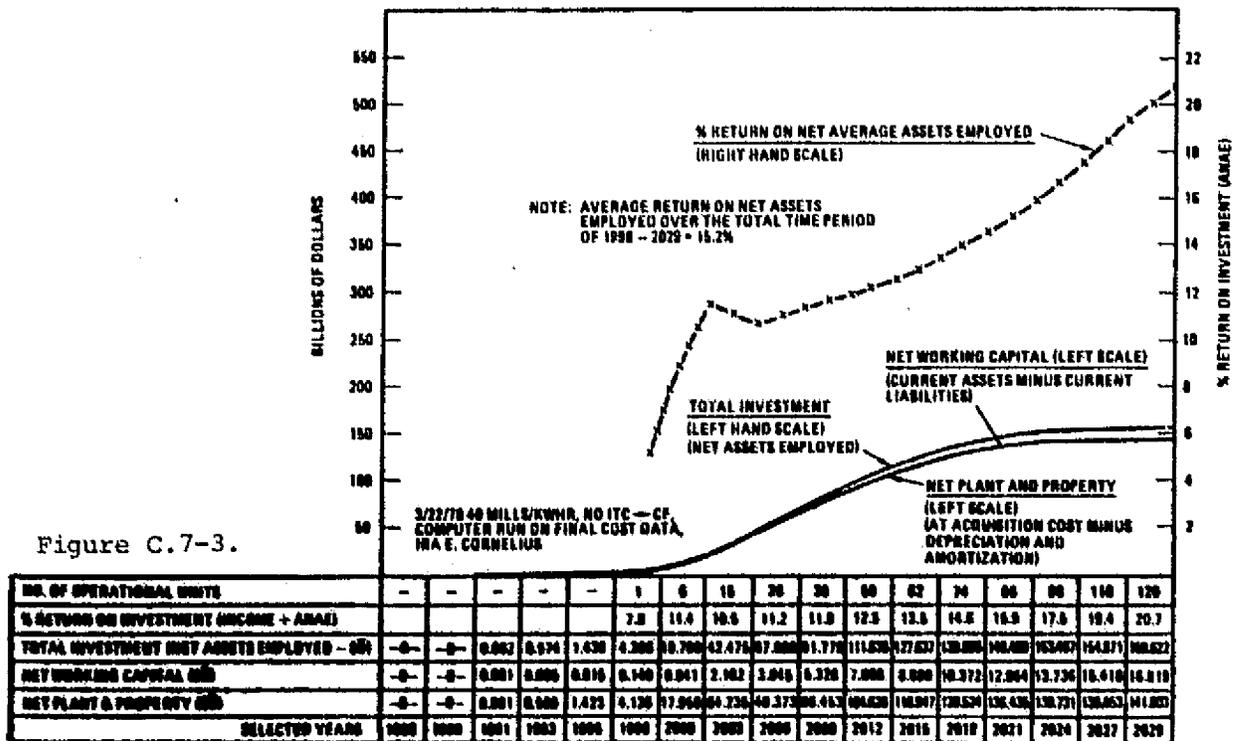
SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION - INVESTMENT AND RETURN ON INVESTMENT
(AT 30 MILLS PER KILOWATT HOUR; INCLUDES INVESTMENT TAX CREDIT)



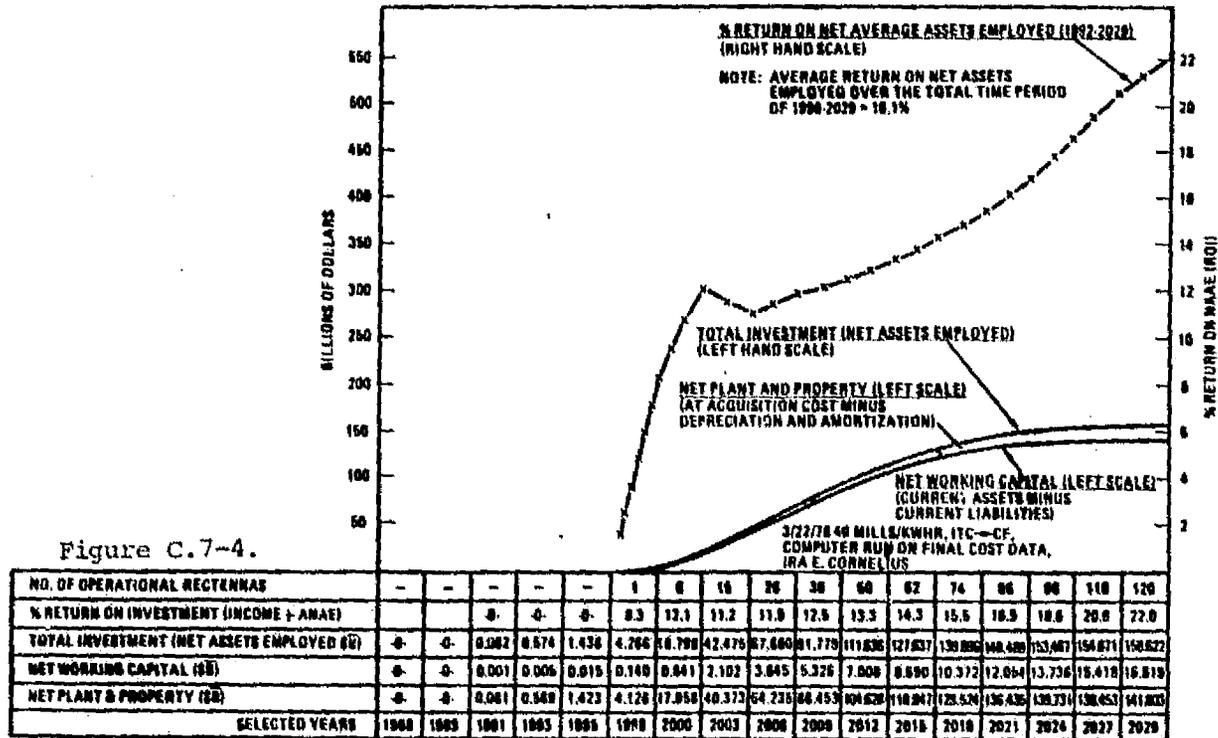
Assets-employed statements based on 40 mills/kWh without investment tax credit will provide an average yield on average net assets employed of 15.2% (Figure C.7-3). With investment tax credit, the average yield on average net assets employed over the 1991-2029 time period will approach 16.1% (Figure C.7-4).

Evaluation of assets-employed statements and return on assets employed is a satisfactory performance in both cases. However, the factors permitting these acceptable performances must also permit acceptable percent returns on assets employed for the SPS Space Segment entity.

Figure C.7-3.



SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION CONCEPT - INVESTMENT AND RETURN ON INVESTMENT (AT 40 MILLS PER KILOWATT HOUR, EXCLUDES INVESTMENT TAX CREDIT)



SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION—INVESTMENT AND RETURN ON INVESTMENT
(AT 40 MILLS PER KWH; INCLUDES INVESTMENT TAX CREDIT)

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**Assets-Employed Statements for the National SPS Space Segment Corporation
 (Federally Owned Entity)**

Assets-employed statements, based on 30 mills/kWh (at a sales price of 19 mills/kWh to the SPS Ground Segment entity) do not permit an adequate return on assets employed. Average return on net assets employed over the total period of 1990-2029 = 2.7% (Figure C.7-5. If 30% of investment requirements are financed by bonds (long-term debt), return on ANAE will improve to approximately 4.0%.

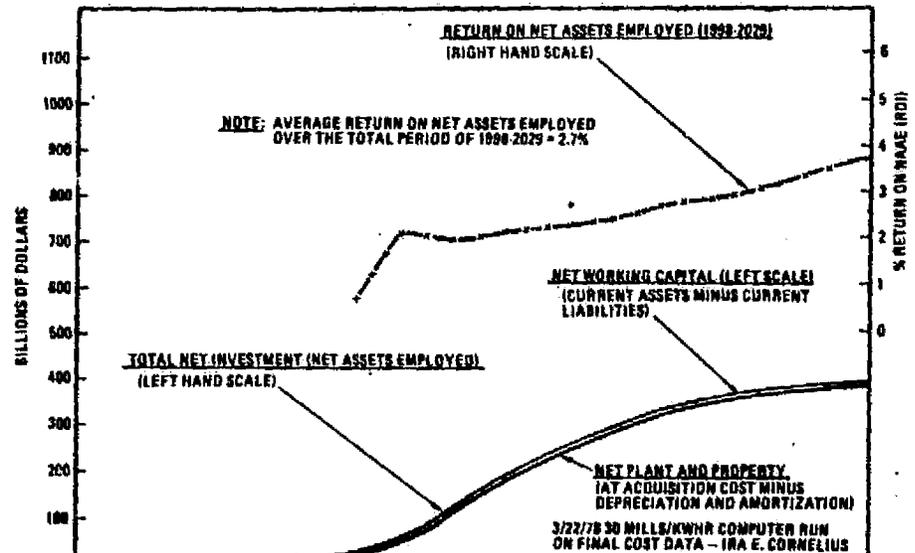


Figure C.7-5.

NO. OF OPERATIONAL RECTENNAS	--	--	--	--	--	1	5	15	25	35	50	65	80	95	110	120	
% RETURN ON INVESTMENT (INCOME + ANAE)	--	--	--	--	--	0.7	2.1	2.0	2.1	2.2	2.3	2.5	2.7	2.9	3.1	3.5	
TOTAL INVESTMENT (NAE \$B)	0.100	0.470	1.750	4.200	8.700	10.453	15.410	22.900	34.000	47.000	62.000	79.000	98.000	119.000	142.000	167.000	
NET WORKING CAPITAL (\$B)	0.001	0.002	0.004	0.017	0.030	0.057	0.140	0.262	0.477	0.780	1.161	1.623	2.065	2.480	2.860	3.210	
NET PROPERTY (\$B)	0.100	0.470	1.750	4.271	8.670	10.396	15.268	22.638	33.523	46.220	60.839	77.377	95.935	116.520	139.190	163.790	
SELECTED YEARS	1988	1990	1991	1993	1996	1998	2000	2003	2005	2008	2012	2015	2018	2021	2024	2027	2029

NATIONAL SPS SPACE SEGMENT CORPORATION CONCEPT (FEDERALLY OWNED)—INVESTMENT AND RETURN ON INVESTMENT (AT 30 MILLS PER KILOWATT HOUR)

Assets employed statements based on 40 mills/kWh (at a sales price of 27 mills/kWh to the SPS Ground Segment entity) will yield 6.7% (Figure C.7-6) on the average net assets employed (ANAE). If 30% of investment requirements are financed by bonds (long-term debt), return on ANAE will improve to approximately 10.0%.

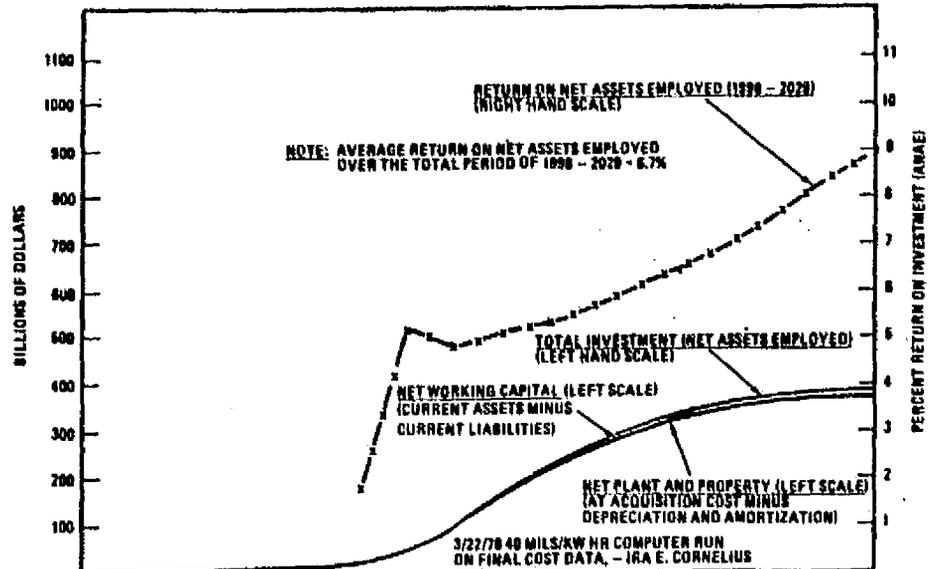


Figure C.7-6.

NO. OF OPERATIONAL UNITS	-	-	-	-	-	1	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	
% RETURN ON INVESTMENT (INCOME + ANAE)			-0-	-0-	-0-	1.8	6.2	4.8	6.1	6.3	6.7	6.1	6.5	7.0	7.7	8.4	8.9					
TOTAL INVESTMENT (NAE - \$B)	0.166	0.478	1.258	4.288	8.708	19.477	45.558	102.961	164.877	223.200	271.847	311.894	342.815	366.408	379.610	386.504	386.784					
NET WORKING CAPITAL (\$B)	0.001	0.002	0.004	0.017	0.038	0.081	0.487	1.218	2.113	3.083	4.064	5.038	6.014	6.991	7.968	8.941	9.764					
NET PROPERTY (\$B)	0.165	0.474	1.264	4.271	8.670	18.386	45.068	101.742	162.564	219.911	267.783	305.865	336.001	358.418	371.646	378.563	386.690					
SELECTED YEARS	1988	1989	1991	1993	1995	1998	2000	2003	2006	2009	2012	2015	2018	2021	2024	2027	2028					

NATIONAL SPS SPACE SEGMENT CORPORATION CONCEPT (FEDERALLY OWNED) - INVESTMENT AND RETURN ON INVESTMENT (AT 40 MILLS PER KILOWATT HOUR)

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Evaluation of assets-employed statements and return on assets employed is not satisfactory based on a sales price of 19 mills/kWh to the SPS Ground Segment entity. Based on a sales price of 27 mills/kWh to the SPS Ground Segment entity, an acceptable return on ANAE is achieved. This figure is further improved and compares favorably with the typical utility return on investment, if it is assumed that 30% of the investment is financed by bonds (long-term debt).

Principle of Importance in Evaluation of this Financial Parameter

Return on average net assets is considered to be the most important parameter for appraisal of financial performance. It measured the effectiveness of the assets employed in generating income and is generally considered an important criterion in measuring the effectiveness of management. However, it too (like return on revenues) must be further understood and interpreted by relating it to asset turnover and to cash flow. The ability of an organizational entity to substantially finance its expansion out of self-generated funds is another important element in any financial evaluation. This is discussed next (Cash Flow Performance Summaries).



Cash Flow Performance Summaries and Investment Recovery Schedules

Cumulative Cash Flow and Investment Schedule Recovery for the SPS Ground Segment Utility Consortia Corporation

Cash flow performance and investment recovery schedules based on 30 mills per kilowatt hour without investment tax credit result in a maximum cumulative cash outlay of \$48.112 billion in the year 2009. Investment recovery occurs in the year 2018. Time to recover investment is approximately 26-3/4 years. Positive cash flows of \$205.135 billion are provided through the year 2029 (Figure C.7-7). Based on 30 mills/kWh, with investment tax credit, maximum cumulative cash outlay is reduced to \$41.021 billion and investment recovery occurs in the first quarter of the year 2018. Time to recover investment is approximately 26-1/4 years (Figure C.7-8). Positive cash flows of \$226.734 billion are achieved through the year 2029 for reinvestment or new investments.

SPS GROUND SEGMENT UTILITY CORPORATION CONCEPT - CUMULATIVE CASH FLOW & INVESTMENT RECOVERY SCHEDULE (AT 30 MILLS PER KILOWATT HOUR, EXCLUDES INVESTMENT TAX CREDIT)

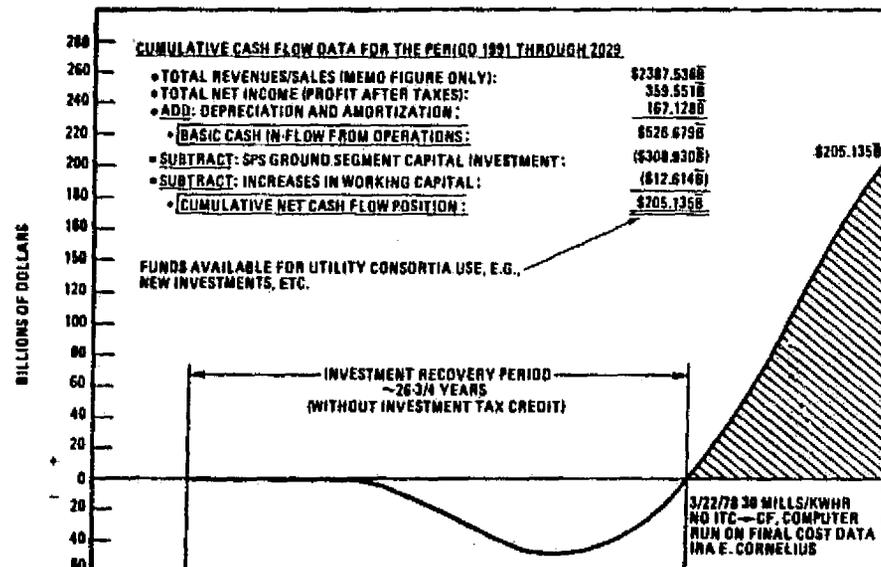


Figure C.7-7.

NO. OF OPERATIONAL UNITS	-	-	-	-	-	1	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120		
CUMULATIVE NET CASH FLOW (\$B)	0	0	10.063	19.578	11.447	14.846	10.823	12.880	14.810	16.122	16.230	12.307	8.331	40.844	100.000	162.822	205.135						
SELECTED YEARS	1990	1990	1991	1993	1996	1999	2000	2003	2006	2009	2012	2015	2018	2021	2024	2027	2029						



SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION CONCEPT - CUMULATIVE CASH FLOW AND INVESTMENT RECOVERY SCHEDULE AT 30 MILLS PER KILOWATT HOUR (INCLUDES INVESTMENT TAX CREDIT)

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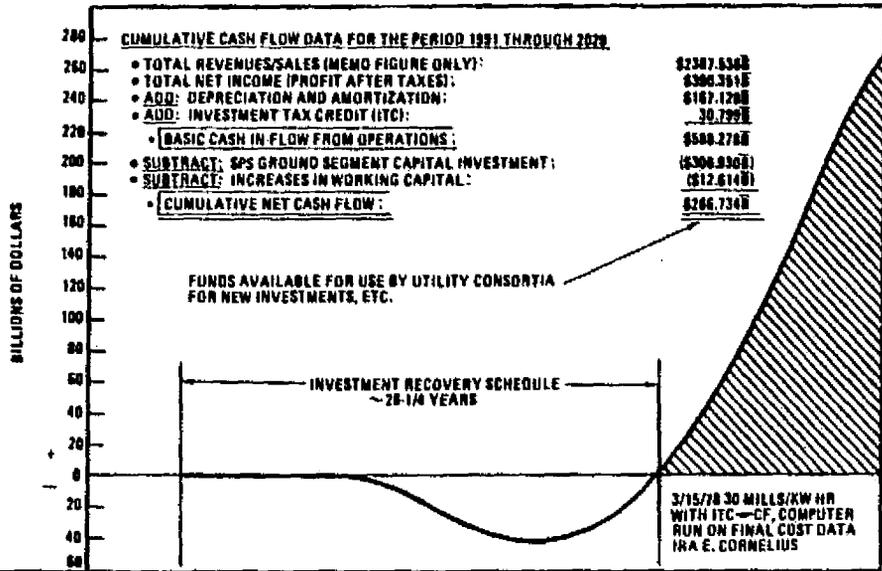


Figure C.7-8.

NO. OF OPERATIONAL UNITS	-	-	-	-	-	1	5	15	25	30	50	62	74	86	98	110	120
CUMULATIVE NET CASH FLOW (\$B)	-	-	10.003	10.578	11.447	14.612	16.204	21.200	41.021	40.057	28.306	13.655	33.263	82.130	142.938	215.664	286.734
SELECTED YEARS	1994	1995	1997	1993	1995	1998	2000	2003	2006	2008	2012	2015	2018	2021	2024	2027	2029

Cash flow performance and investment recovery schedule based on 40 mills per kilowatt hour without investment tax credit results in a maximum cumulative cash outlay of \$37.383 billion in the year 2006. Investment recovery occurs in the year 2015. Positive cash flows of \$336.318 billion are provided through the year 2029 (Figure C.7-9). Based on 40 mills/kWh, with investment tax credit, maximum cumulative cash outlay is reduced to \$33.586 billion. Investment recovery occurs in the first quarter of the year 2015. Positive cash flows of \$397.917 billion are achieved through the year 2029 (Figure C.7-10). Time to recover investment is 23-1/2 years without investment tax credit, and 23-1/4 years with investment tax credit.

Evaluation of the cash flow performances based on 30 mills/kWh and 40 mills/kWh provides suitable performances for the SPS Ground Segment Utility Consortia Corporation in all cases considered. However, the factors resulting in these acceptable performances must also permit acceptable cash flow performance levels for the SPS Space Segment entity with its greater investment requirements.

Since the investment recovery periods may appear to the uninitiated observer/analyst of cash flow methodology to involve long periods of time, a special analysis was undertaken to show a cumulative cash flow performance summary and

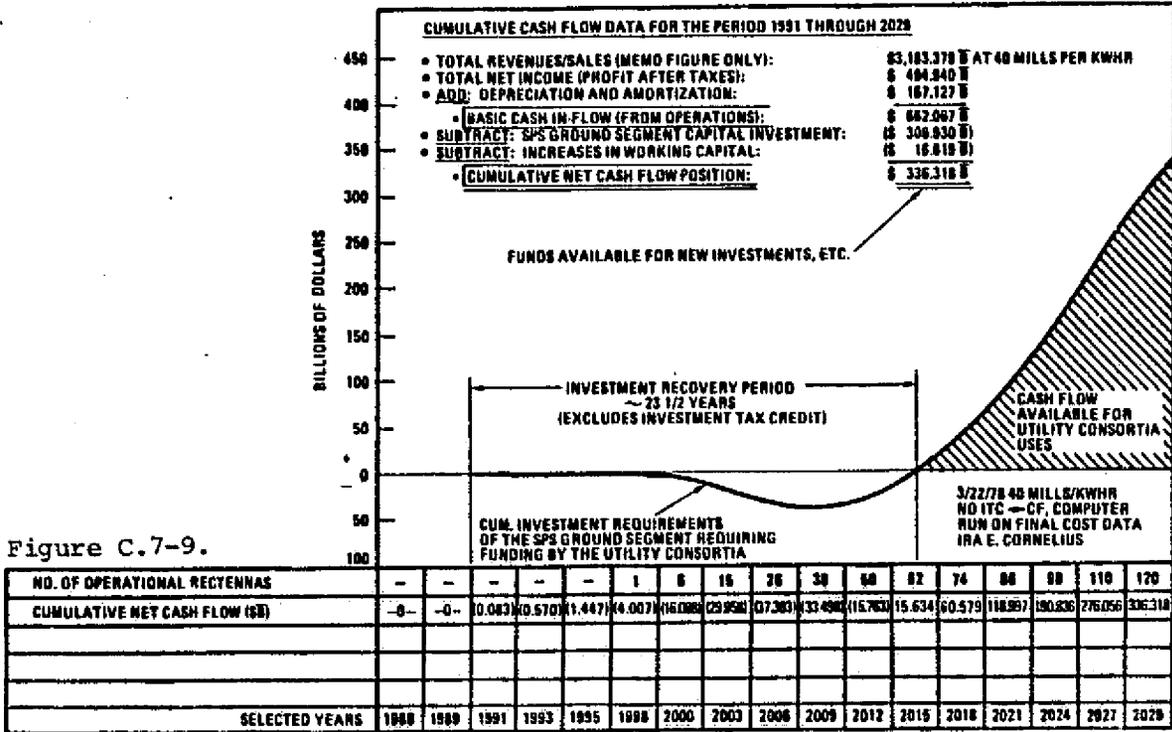


Figure C.7-9.

SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION CONCEPT - CUMULATIVE CASH FLOW & INVESTMENT RECOVERY SCHEDULE AT 40 MILLS PER KWHR (EXCLUDES INVESTMENT TAX CREDIT)

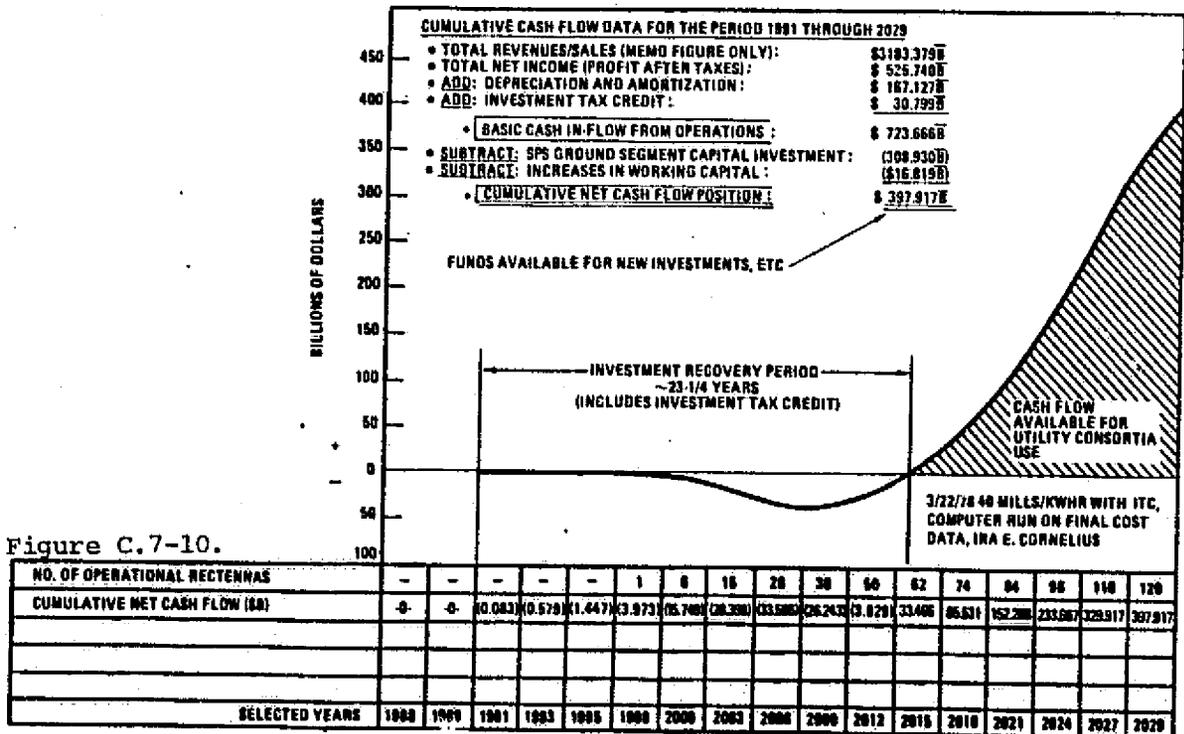


Figure C.7-10.

SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION - CUMULATIVE CASH FLOW AND INVESTMENT RECOVERY SCHEDULE (AT 40 MILLS PER KWHR, INCLUDES INVESTMENT TAX CREDIT)



investment recovery schedule based on a single geographical consortia with a requirement for six SPS installations (Figure C.7-11). Since there are no further capital investments after the installation of six operational rectenna sites (with an operational life of 30 years), the revenues/sales become an annual constant; net working capital also becomes an annual constant, and cash flow results in investment recovery being accomplished in 11-3/4 years. However, the 120 satellites and Ground Segment System, as scheduled, requires continuous annual investments and increases in working capital to satisfy the projected increased demand. Also, it is the financial nature of business investments that revenues and profits will always lag the investments. Ultimately, it is the intent of those investing in any business to plan for a cessation of major capital investments, and a leveling-off of net working capital requirements; and, to anticipate a satisfactory return on revenues/sales, a satisfactory return on investment, and to also anticipate a return of investment via cash flow over a period of time that is commensurate with the size of revenues/sales and profits, rewards, and the risks taken in making the investment.

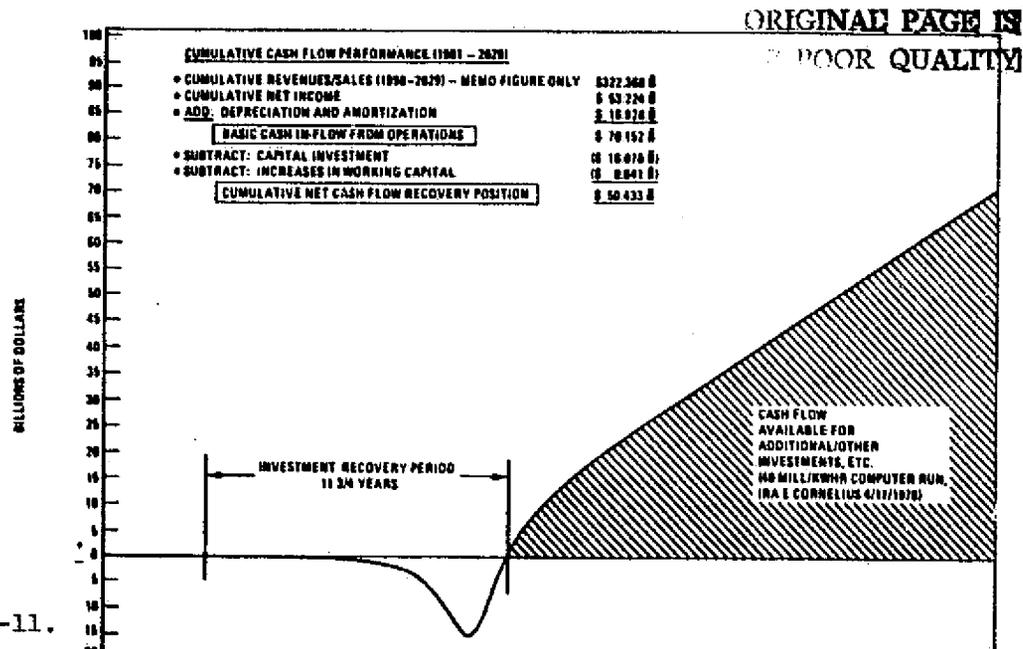


Figure C.7-11.

NO. OF OPERATIONAL UNITS	-	-	-	-	-	1	3	6	6	6	6	6	6	6	6	6	
CUM. NET CASH FLOW	-	-	(6,083)	(6,579)	(2,016)	(3,000)	(6,016)	18,964	14,948	24,382	31,256	38,120	44,984	51,848	58,712	65,576	72,440
SELECTED YEARS	1987	1989	1991	1993	1995	1996	2000	2003	2006	2009	2012	2015	2018	2021	2024	2027	2030

**CASH FLOW SUMMARY DATA FOR AN SPS-GROUND SEGMENT UTILITY CONSORTIA CORPORATION
BASED ON A UTILITY CONSORTIA FORMED FOR SIX RECTENNA OPERATIONAL SITES
(DATA BASED ON 40 MILLS PER KILOWATT-HOUR)**



Cumulative Cash Flow and Investment Schedule Recovery for the National SPS Space Segment (Federally Owned) Corporation

Cash flow performance and investment recovery schedules based on 30 mills per kilowatt hour (a charge of 19 mills/kWh to the SPS Ground Segment Utility Consortia entity) achieves investment recovery of approximately 79% of the investment. Total investment recovery would occur in the year 2034, a time period of approximately 46-1/2 years to recover investment. This is obviously too long a period based on size of the cash outlays. The cumulative cash flow outlay reaches \$249.107 billion in the year 2018 before declining (Figure C.7-12). Cash flow performance and investment schedules based on 40 mills/kWh (a cost of 27 mills/kWh to the SPS Ground Segment Utility Consortia entity) achieves investment recovery in approximately 35-3/4 years. Maximum cumulative cash outlay is \$162.359 billion, occurring in the year 2012 (Figure C.7-13). Investment occurs in the third quarter of the year 2034. This cash flow performance and investment recovery is considered to be acceptable based on the size of the investment and the return on sales/revenues.

NATIONAL SPS SPACE SEGMENT CORPORATION CONCEPT (FEDERALLY OWNED)-CUMULATIVE CASH FLOW & INVESTMENT RECOVERY SCHEDULE AT 30 MILLS PER KWHR

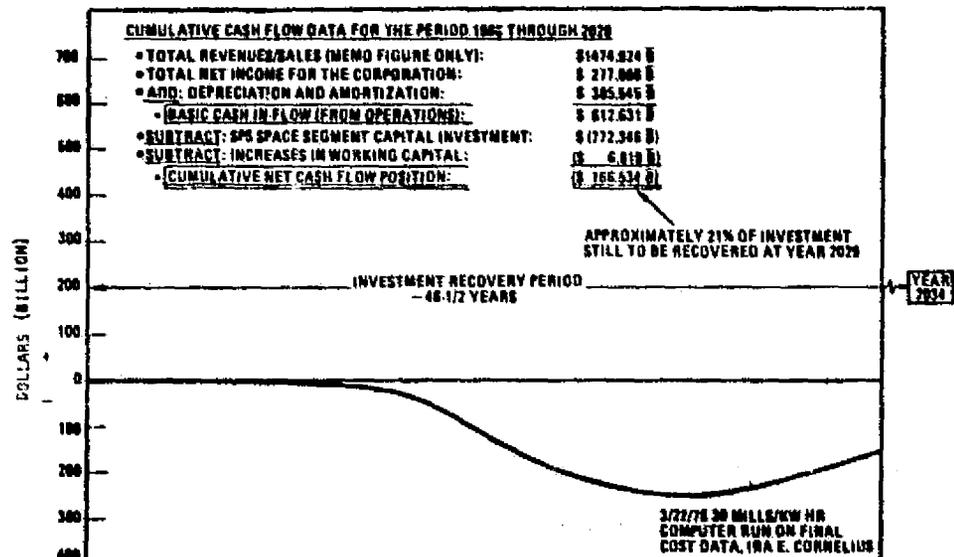


Figure C.7-12.

NO. OF OPERATIONAL RECTENNAS	-	-	-	-	-	1	5	15	25	35	45	55	65	75	85	95	105	115	125	
CUMULATIVE NET CASH FLOW (\$B)	0.106	0.478	1.768	4.293	8.708	14.442	24.174	38.063	54.000	71.988	91.020	111.092	132.204	154.356	177.548	201.780	227.052	253.364	280.716	309.108
SELECTED YEARS	1988	1989	1991	1993	1995	1998	2000	2003	2006	2008	2012	2015	2018	2021	2024	2027	2029			

NATIONAL SPS SPACE SEGMENT CORPORATION CONCEPT (FEDERALLY-OWNED) - CUMULATIVE CASH FLOW & INVESTMENT RECOVERY SCHEDULE AT 40 MILLS PER KILOWATT HOUR

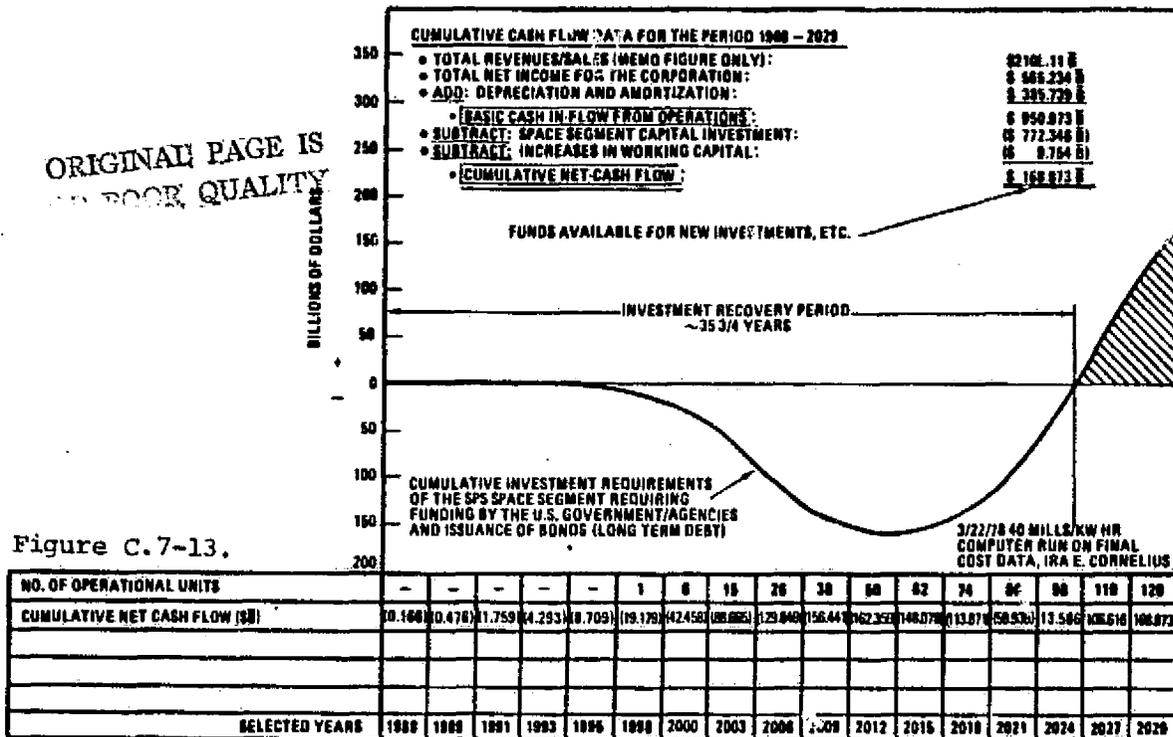


Figure C.7-13.

Principle of Importance in Evaluation of this Financial Parameter

The basic value of a cash flow analysis lies in its ability to provide a useful yardstick for measuring the capability of an operational entity to finance expansion from self-generated cash. Cash flow analysis is useful in determining the value of an opportunity, risks involved, and evaluation of desirable strategies. The basis for conducting a cash flow analysis stems from the size of the penetrable market, and considers the planned sales levels, size of the investment requirements (capital investments and working capital), total expected income to be derived from the investment, and the technological merits of the program, and the strategic timing of the investment. Cash flow analysis provides an evaluation of the risks involved: (1) maximum cash outlay requirements, (2) time to recover investment, (3) appraisal of the likelihood/desirability of proceeding from DDT&E to operational systems/production hardware, and (4) the evaluation of alternative courses of action based on considerations of costs and applicability.



Total Satellite Power System Cumulative Cash Flow Performance and Investment Recovery Schedule for the Combined SPS Space Segment Corporation and the SPS Ground Segment Utility Consortia Corporation

The combined cash flows the the two major entities comprising the SPS program show a satisfactory investment recovery based on 40 mills/kWh. The cumulative cash flow data are given for the years 1988 through 2029. Maximum cumulative investment for the combined entities reaches \$182.684 billion in the year 2009. The investment recovery period is approximately 32-1/4 years (Figure C.7-14). The cumulative net cash flow position at the end of the year 2029 amounts to \$566.790 billion for the combined entities.

TOTAL SATELLITE POWER SYSTEM CUMULATIVE CASH FLOW PERFORMANCE AND INVESTMENT RECOVERY SCHEDULE FOR THE COMBINED SPS-SPACE SEGMENT CORPORATION & THE SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION (AT 40 MILLS PER KILOWATT HOUR, WITH INVESTMENT TAX CREDIT)

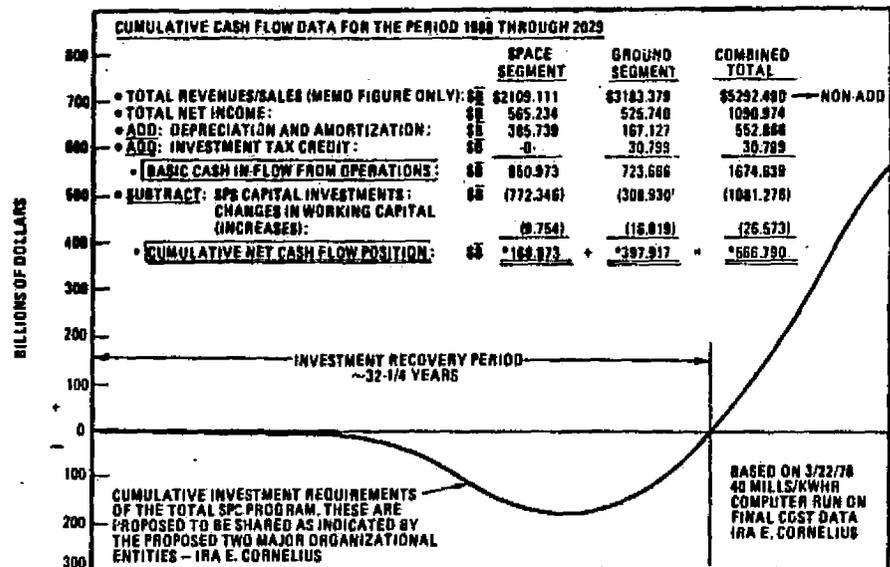


Figure C.7-14.

NO. OF OPERATIONAL UNITS	-	-	-	-	-	1	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	
(1) NATIONAL SPS SPACE SEG CUM NET CASH FLOW \$B	0.166	(0.478)	(1.759)	(4.293)	(8.709)	(13.729)	(18.248)	(22.268)	(25.888)	(29.108)	(31.928)	(34.348)	(36.368)	(38.088)	(39.508)	(40.728)	(41.748)	(42.568)	(43.188)	(43.708)	(44.128)	(44.448)
(2) SPS GROUND SEGMENT UTILITY CONSORTIA CUMULATIVE NET CASH FLOW \$B	-0-	-0-	(0.083)	(0.579)	(1.447)	(2.673)	(4.249)	(6.175)	(8.451)	(11.077)	(14.053)	(17.379)	(21.055)	(25.081)	(29.457)	(34.183)	(39.259)	(44.685)	(50.461)	(56.587)	(63.063)	(70.889)
COMBINED CUMULATIVE NET CASH FLOWS	0.166	(0.478)	(1.842)	(4.872)	(10.156)	(16.402)	(22.497)	(28.543)	(34.589)	(40.635)	(46.681)	(52.727)	(58.773)	(64.819)	(70.865)	(76.911)	(82.957)	(89.003)	(95.049)	(101.095)	(107.141)	(113.187)
SELECTED YEARS	1988	1989	1991	1993	1995	1999	2000	2003	2006	2009	2912	2916	2918	2918	2921	2924	2927	2929				

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Review of Selected Financial Assumptions and/or Explanations

Investment Tax Credit (SPS Ground Segment Utility Consortia Corp. Only)

Investment tax credits (ITC) have been assumed for the SPS Ground Segment Utility under the Tax Reduction Act of 1975. It is presumed that the policies adopted for accounting purposes would also be applied for rate-making purposes by those regulatory authorities exercising jurisdiction over the rates of the utilities participating in the SPS Ground Segment entity. Under the provisions of the Act, it is further presumed that the utility consortia will choose, for accounting and rate-making purposes, to defer the ITC and amortize the credits ratably over the book lives of the SPS Ground Segment properties generating such credits by reducing income tax expense.

It is useful to review the purpose of the ITC and to indicate what it means to the SPS Ground Segment Utility Corporation concept. The U.S. Government, under the Tax Reduction Act of 1975 (originally offered in 1962) offers both industrial and utility corporations a significant incentive to add to their productive assets and earning power on the theory that this aids the economy in a number of ways. Industrial companies have the opportunity to reduce their income tax bills up to a full 10% of the cost of new equipment. Utility companies which purchase, for instance, new generating equipment also get a similar tax credit, although in their case it is limited to 10% of the cost of the assets acquired for power generation.

A company, under most circumstances, must take the full tax credit for tax purposes for the year in which the equipment was first utilized. It can, however, spread the tax benefit over the estimated useful life of the asset for accounting purposes. The following examples show how it might be used for a company.

Example 1. Assume that a corporation has profit before taxes of \$100 million. If income taxes are assumed at a 50% rate, profit after taxes will amount to \$50 million. Now, if the corporation purchased \$50 million in new machinery and equipment in that year for production activities, its income tax bill of \$50 million could be reduced by 10% as follows:

Profit before taxes		\$100,000,000
Income taxes at 50%	\$50,000,000	
Less: Investment tax credit	<u>\$ 5,000,000</u>	<u>\$ 45,000,000</u>
Net income (profit after taxes)		\$ 55,000,000

Example 2. The corporation could also elect to spread the benefit over a five-year period, for example:

Profit before taxes		\$100,000,000
Income taxes at 50%	\$50,000,000	
Less: Investment tax credit	<u>\$ 1,000,000</u>	<u>\$ 49,000,000</u>
Net income (profit after taxes)		\$ 51,000,000



There is considerable evidence that the investment tax credit (ITC) has contributed substantially to an upsurge in capital goods sales. There are few firms to which the tax exemption is not important. Another fact of importance is the broad array of investor-owned companies which have improved their earnings, both through the benefit in lower tax bills and improvement in profitability through the employment of new, improved equipment. For utility companies, the ITC has made it possible to increase power generating capacity without having to drastically increase the cost per kilowatt-hour to its customers to recover its investment.

The use of the ITC for the SPS Ground Segment Utility Consortia has been tested in the conventional manner and then related to revenues as a ratio for ease of computation. The figures shown in the ITC computation include recognition for allowance of funds used during construction (ADC) which is the generally accepted accounting procedure designed to restore profit after taxes to that which would have been experienced without the construction program through the transfer of such costs from the income statement to the balance sheet as utility plan construction work-in-progress. Although ADC is included in ITC, it should not be considered as representative of current cash earnings.

SPS Ground Segment Plant and Property Investments--Government Licenses

It is contemplated that SPS Ground Segment installations will be located in whole or in part on lands of the United States under Government licenses and permits with varying expiration dates. Such licenses and permits will no doubt contain numerous restrictions and obligations, including the right of the United States to acquire the projects, under certain conditions, upon payment of specified compensation.

Leases and Rentals (SPS Ground Segment)

It is assumed that the SPS Ground Segment utility will involve the necessity for renting or leasing automotive equipment, computer equipment, fuel, office space, and other incidental equipment and property. The total annual gross lease expenses has been estimated at less than one percent of operating revenues. (NOTE: A general rule of leasing is that the present value of the minimum commitments of all non-capitalized financing leases should always be less than five percent of capitalization. The majority of expenses under lease commitments is considered as charged to other operating expenses. The impact on profit after taxes, if these commitments were to be capitalized, would not be significant.)

Financial Statements

The financial statements include the accounts of the respective SPS entities and are representative of the uniform systems of the accounts that would be prescribed by the utility regulatory commissions having jurisdiction with respect to accounting matters.



Revenues

Revenues for the SPS Ground Segment entity have been derived on the basis of a ground rule that each SPS installation will provide 5000 megawatts of electrical power for 8760 hours for each year of planned operation. Although transmission and distribution cost factors are not included in financial data, an assumption was made that revenues would be billed to utility customers on a monthly cycle billing. At the end of each month there would be an unbilled electric service which has been rendered from the previous/last month's meter reading to the month-end. It is assumed that the SPS Ground Segment utility will be billed in a related fashion for its purchases of electric power by the SPS Space Segment entity.

Interim Replacement Costs

Interim replacement costs, as used in the financial models, are not considered replacements of retirement units of property. Where there would be additions to utility plant and replacements of retirement units of property, these are capitalized at original cost. Interim replacement costs in the model are charged as expense, similar to maintenance, with the cost of repairs and minor renewals.

Depreciation and Amortization

Traditionally, the annual provisions for depreciation are computed by the use of composite rates applied on the straight-line method for financial accounting and principally on accelerated methods for income tax purposes. The effect of this difference in recording depreciation provides a reduction in income taxes, the benefit of which, effective with respect to additions to the utility facilities, is deferred (normalized) for credit to subsequent years when financial accounting expense exceeds tax expense.

In the model, depreciation and amortization provisions have been developed and re-established as a percent of total revenues to facilitate computations and simplify the construction of the financial statements of the model.

Accounting Changes by the FASB that could Impact Utility Income Statements

Financial Accounting Standards Board (FASB)

Earlier this year (1978), the FASB appointed a special study team to consider whether one key utility accounting practices, i.e., the deferral of major costs for years, is still justified and whether the exception should be extended to other rate-regulated industries. Utility accountants are quite concerned about this effort by the FASB to streamline accounting rules for the utilities.

The FASB has been pressured by the Securities and Exchange Commission, CPA's, and financial analysts to examine utility accounting, which is considered second-class accounting. This is because many accountants do not go along with present utility accounting exceptions and cost deferrals. For



example, a flood or storm damage to an industrial concern would have to be taken out of its current year profit. But the same losses to a utility plant could likely be deferred and written off over several years. It is nearly impossible to quantify the impact of eliminating that difference for a utility. However, it would clearly result in reduced earnings that would be reported by the utility to its share holders. Reported costs also would be higher—at least in the short-run—without an offsetting increase in the revenues rate regulators allow utilities to collect.

Utility accounting has always been unique. In addition to the example of flood damage, regulators routinely mandate that utilities defer such things as research and development costs and write-offs for plants that are closed before being fully depreciated. Under generally accepted accounting principles (GAAP) other companies must treat those items as expenses in the year they are incurred.

Utility accounting methods are viewed as somewhat "fuzzy" by most of the accounting profession. When a particular accounting exception cannot be explained under the GAAP, a problem exists. Most of these accounting problems arise out of a document commonly referred to as "the addendum," which is a vaguely worded paragraph addition to a 1962 ruling by the old Accounting Principles Board, the predecessor of the more sophisticated FASB. The addendum allowed utilities to treat tax benefits, such as investment tax credits or accelerated depreciation, in their shareholder reports in the same manner required by utility regulators for rate-making purposes. The varied approaches by regulators permit utilities to spread tax reduction benefits over the life of the assets, or "normalized," while other regulators demand that they flow immediately to income. But the broadly worded addendum, however, goes even further. When rate regulators require a utility to recognize cost in a different period than GAAP requires for non-regulated companies, the addendum allows the utility to report those costs to the shareholders in the same manner.

Most utilities insist the addendum is not a deviation from the GAAP, but rather a different and necessary application of GAAP to economic circumstances unique to rate regulation. Most companies are free to pass along higher costs when incurred. Utilities, of course, are not permitted to do so until a rate hike has been permitted by the rate regulators. Utilities argue, therefore, that the addendum is essential to their operations. However, other rate-regulated industries such as insurance companies and health-care facilities are not permitted this method of accounting.

Many accountants, including utility accountants, admit that if overall accounting concepts were more carefully defined, the addendum could be eliminated. At the same time, legitimate differences between utility and non-utility accounting could be preserved. Presently, the addendum offers a no-holds-barred out to rationalize just about anything in accounting the utilities want to do; and their earnings seem tainted because they have an exception in the addendum no one else has. The FASB is currently at work to eliminate the addendum.



Rockwell International
Space Division

It is easy to forecast the actions that would be taken by the utilities industry if they lose the benefits of "the addendum." They would seek higher immediate rates to salvage their earnings and competitive position in financial markets. Presently, some utilities are counting on the FASB settling for a better explanation of the addendum's application rather than eliminate it. Others are not so hopeful. At least, the FASB investigation should give more credibility to utility reports.