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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
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
D. E. Lundin  SPS Schedules/Networks
J. L. Saltz  Taxes and Insurance
K. E. Smith  Program Plans

SPS economics and program planning/analysis tasks were completed under the supervision of F. W. Von Flue, SPS Program Development.

The help and support of representatives from NASA/MSFC and the SPS Program Planning Office is acknowledged as follows:

Engineering Cost Group:

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Program Plans and Requirements Group:

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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.
Figure 1.
SPS Work Breakdown Structure Matrix
(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 con-
sumables, etc.

This account includes costs for all the elements appearing in the hard-
ware 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.
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.)
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.

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

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
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

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.
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

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 satellite 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.
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

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.

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 rectenna.
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 stationkeeping 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.
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.
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 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.
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

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.
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.

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

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
WBS TITLE: TRACING
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 checkout 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.
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.

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.

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.
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.

This element is a subelement of taxes.

This element includes property taxes on the ground station system.

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.)
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); CLR (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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>COST IN MILLIONS OF 1977 DOLLARS</td>
</tr>
<tr>
<td>CD</td>
<td>DDT&amp;E COST</td>
</tr>
<tr>
<td>CD/CER</td>
<td>DDT&amp;E COST ESTIMATING RELATIONSHIP (CER)</td>
</tr>
<tr>
<td>CDEXP</td>
<td>DDT&amp;E SCALING EXPONENT</td>
</tr>
<tr>
<td>CER</td>
<td>COST ESTIMATING RELATIONSHIP</td>
</tr>
<tr>
<td>CF</td>
<td>COMPLEXITY FACTOR</td>
</tr>
<tr>
<td>CICER</td>
<td>INITIAL CAPITAL INVESTMENT COST ESTIMATING RELATIONSHIP (CER)</td>
</tr>
<tr>
<td>CICEXP</td>
<td>INITIAL CAPITAL INVESTMENT COST SCALING EXPONENT</td>
</tr>
<tr>
<td>CIPS</td>
<td>INVESTMENT PER SATELLITE COST</td>
</tr>
<tr>
<td>CLR</td>
<td>LOWEST REPEATING MODULE COST</td>
</tr>
<tr>
<td>C6GM</td>
<td>OPERATIONS AND MAINTENANCE COST PER SATELLITE PER YEAR</td>
</tr>
<tr>
<td>CRCI</td>
<td>REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR</td>
</tr>
<tr>
<td>CTFU</td>
<td>THEORETICAL FIRST UNIT COST</td>
</tr>
<tr>
<td>DDT&amp;E</td>
<td>DESIGN, DEVELOPMENT, TEST AND EVALUATION</td>
</tr>
<tr>
<td>DF</td>
<td>DEVELOPMENT FRACTION</td>
</tr>
<tr>
<td>E</td>
<td>1.0 + LOG (PHI) / LOG (2.0)</td>
</tr>
<tr>
<td>IC</td>
<td>INITIAL CAPITAL INVESTMENT</td>
</tr>
<tr>
<td>INV. PER SAT.</td>
<td>AVERAGE UNIT INVESTMENT COST (2 THRU N)</td>
</tr>
<tr>
<td>M</td>
<td>MASS POWER, AREA OF LOWEST REPEATING MODULE</td>
</tr>
<tr>
<td>#RM</td>
<td>NUMBER OF REPEATING MODULES</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>OPERATIONS</td>
</tr>
<tr>
<td>#O&amp;M</td>
<td>OPERATIONS &amp; MAINTENANCE COST PER SATELLITE PER YEAR</td>
</tr>
<tr>
<td>PHI</td>
<td>PROGRESS FRACTION</td>
</tr>
<tr>
<td>R</td>
<td>ANNUAL SPARES FRACTION</td>
</tr>
<tr>
<td>RCI</td>
<td>REPLACEMENT CAPITAL INVESTMENT COST PER SATELLITE PER YEAR</td>
</tr>
<tr>
<td>T</td>
<td>TOTAL (MASS, POWER, AREA) PER SATELLITE</td>
</tr>
<tr>
<td>TF</td>
<td>TOOLING FACTOR</td>
</tr>
<tr>
<td>TFU</td>
<td>THEORETICAL FIRST UNIT</td>
</tr>
<tr>
<td>Z1</td>
<td>TFU REQUIREMENT</td>
</tr>
<tr>
<td>Z2</td>
<td>SPS OPTION QUANTITY</td>
</tr>
<tr>
<td>Z3</td>
<td>TOTAL SPS REQUIREMENT</td>
</tr>
</tbody>
</table>
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:
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. 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

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Table B-2. SPS Tooling Factors

<table>
<thead>
<tr>
<th>AVERAGE ANNUAL PRODUCTION RATE (AAPR)</th>
<th>TOOLING FACTOR (TF)</th>
<th>PROGRESS FRACTION (θ)</th>
</tr>
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<tbody>
<tr>
<td>1-2</td>
<td>1.0</td>
<td>0.80</td>
</tr>
<tr>
<td>3-5</td>
<td>0.9</td>
<td>0.80</td>
</tr>
<tr>
<td>6-9</td>
<td>0.8</td>
<td>0.80</td>
</tr>
<tr>
<td>10-19</td>
<td>0.7</td>
<td>0.85</td>
</tr>
<tr>
<td>20-39</td>
<td>0.6</td>
<td>0.85</td>
</tr>
<tr>
<td>40-69</td>
<td>0.5</td>
<td>0.85</td>
</tr>
<tr>
<td>70-109</td>
<td>0.4</td>
<td>0.85</td>
</tr>
<tr>
<td>110-159</td>
<td>0.3</td>
<td>0.90</td>
</tr>
<tr>
<td>160-219</td>
<td>0.2</td>
<td>0.90</td>
</tr>
<tr>
<td>220-999</td>
<td>(AAPR)-0.35</td>
<td>0.90</td>
</tr>
<tr>
<td>1000-9999</td>
<td>(AAPR)-0.35</td>
<td>0.95</td>
</tr>
<tr>
<td>10,000</td>
<td>(AAPR)-0.35</td>
<td>0.98</td>
</tr>
</tbody>
</table>

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.

8.3 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 (COM) per satellite per year. Figure B-1 shows a comparison of the cost relationship of the summary WBS elements for each of the above.

8.3.1 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

(UPDATED JUNE 12, 1978)
<table>
<thead>
<tr>
<th>WBS #</th>
<th>DESCRIPTION</th>
<th>EST.</th>
<th>DEVEL.</th>
<th>TOTAL</th>
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(UPDATED JUNE 12, 1978)
Table B-4. Satellite Power System Project Average Cost

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**ORIGINAL PAGE IS POCKETashire QUALITY**
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<th>Description</th>
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<th>Project 2</th>
<th>Project 3</th>
<th>Total</th>
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</tbody>
</table>

(updated June 12, 1976)

SD 78-AP-0023-7
B-9, B-10
**Figure B-1. SPS WBS Cost Relationships**

**DDT&E**
- PM & SE&E, 5.7%
- GRD STA., 0.4%
- FACIL. 9.2%
- SPACE TRANSP. 25.7%
- SPACE ASSY & S/E 28.2%

**TFU**
- PM & SE&E, 3%
- GRD STA. 9.1%
- FACIL. 12.8%
- SPACE TRANSP. 14%
- SPACE ASSY & S/E 37.7%
- SATELLITE 23.4%

**INVESTMENT PER SAT. SYS.**
- PM & SE&E, 3%
- FACILITIES, 0.7%
- SPACE ASSY & S/E, 9.2%
- SPACE TRANSP. 13.6%
- GROUND STATION 23.1%
- SATELLITE 50.4%

**REPL. CAPITAL/OPS & MAINT.**
- PM & SE&E, 2.3%
- FACILITIES, 0.6%
- SPACE ASSY & S/E, 4.7%
- TAXES & INS. 10.6%
- GRD STATION 14.9%
- SPACE TRANSP. 20%
- SATELLITE 46.9%

**Investment per Sat. Sys.**

**Repl. Capital/Ops & Maint.**

**Cost Breakdown**
- $34.70B
- $25.34B
- $9.78B
- $0.309B/SAT-YR
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 subsytems.

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/GEO 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 $30.9 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.

(UPDATED JUNE 12, 1978)
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 RC1 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
#### 56W Photovoltaic CR=2

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<th>Input Coefficients</th>
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<tr>
<td>DF</td>
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**Calculated Values**

- \( CD = \text{CUCER} \times (1 \times DF) \times X \times (\text{CDEXP}) \times CF \)
- \( \text{CLRM} = \text{CUCER} \times (M) \times X \times (\text{CILEXP}) \times CF \times TF \)
- \( \#RM = T / M \)
- \( E = 1.0 \times \log(\text{PHI}) / \log(2.0) \)
- \( \text{CTF} = (\text{CLRM} / E) \times ((\#RM \times Z1 + 0.5) \times X \times (E) - 0.5 \times X \times (E)) \)
- \( \text{CIPS} = ((\text{CLRM} / E) \times ((\#RM \times Z3 + 0.5) \times X \times (E) - 0.5 \times X \times (E)) / Z2 \)
- \( \text{CRCI} = \text{CIPS} \times R \)
- \( \text{O&M} = \text{O&M} \)
- \( \text{COMMENTS} \quad 51 \)

**Input Coefficients**

- \( \text{CUCER} = 0.010000 \)
- \( \text{CDEXP} = 0.010000 \)
- \( \text{CICEF} = 0.010000 \)
- \( \text{CILEXP} = 0.010000 \)

**56 Millions**

- \( CD = 341.399 \)
- \( CLRM = 0.0 \)
- \( CTF = 262.364 \)
- \( CIPS = 100.710 \)
- \( CRCI = 1.166 \)
- \( O&M = 16.069 \)
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 efforts 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 TFU 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
02-00-00-00 5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

CALCULATED VALUES

INPUT COEFFICIENTS

SPACE DIVISION
Rockwell International
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 management, see Table B-7.

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

- $CD = \text{Satellite System DDT\&E Cost} (03-00-00 \text{ thru } 03-13-00) \text{ plus SE\&I Cost}$
- $CTFU = \text{Satellite System TFU Cost} (03-03-00 \text{ thru } 03-13-00) \text{ plus SE\&I Cost}$
- $CIPS = \text{Satellite System Inv. per Sat. Cost} (03-03-00 \text{ thru } 03-13-00) \text{ plus SE\&I Cost}$
- $CRCI = \text{Satellite System RCI Cost per Satellite per year} (03-03-00 \text{ thru } 03-13-00) \text{ plus SE\&I Cost}$
- $CO&M = \text{Satellite System O&M Cost per Satellite per year}$
# TABLE B-7. 03-01-00 PROGRAM MANAGEMENT
5GW PHOTOVOLTAIC CR=2

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</table>

## CALCULATED VALUES

\[ CD = CDCEI \times (T \times DF) \times (CDEFX \times CF) \]

\[ CLR = CICLFX \times (M) \times (CILXPE \times CF \times TF) \]

\[ #RM = T / M \]

\[ E = 1.0 \times \log(\text{PHI}) / \log(2.0) \]

\[ CTF = (CLR / E) \times ( (#RM \times Z1 \times 5) \times (E) - 0.5 \times 5 (E)) \]

\[ CIPE = ( (CLR / E) \times ( (#RM \times Z3 \times 0.5) \times (E) - 0.5 \times 5 (E)) ) / Z2 \]

\[ CRCCI = CIPE \times R \]

\[ CDM = D&M \]

\[ COMMENTS = 54 \]

\[ 5,\text{MILLIONS} \]

\[ 205,564 \]

\[ 0.0 \]

\[ 0.0 \]

\[ 56,936 \]

\[ 49,028 \]

\[ 0.519 \]

\[ 0.293 \]
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:

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<th>Satellite System DDT&amp;E (03-03-00 thru 03-13-00)</th>
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<td>CTFU</td>
<td>Satellite System TFU Cost (03-03-00 thru 03-13-00)</td>
</tr>
<tr>
<td>CIPS</td>
<td>Satellite System Inv. per Sat. Cost (03-03-00 thru 03-13-00)</td>
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<tr>
<td>CRCI</td>
<td>Satellite System RCI Cost per Satellite per year (03-03-00 thru 03-13-00)</td>
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TABLE B-8. 03-02-00 SENI
SGW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 0.0</td>
<td>T= 0.0</td>
</tr>
<tr>
<td>M= 0.0</td>
<td>M= 0.0</td>
</tr>
<tr>
<td>CF= 0.0</td>
<td>CF= 0.0</td>
</tr>
<tr>
<td>PHI= 0.0</td>
<td>PHI= 0.0</td>
</tr>
<tr>
<td>R= 0.0</td>
<td>R= 0.0</td>
</tr>
<tr>
<td>DF= 0.0</td>
<td>DF= 0.0</td>
</tr>
</tbody>
</table>

CALCULATED VALUES

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

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

#RM = 1 / N

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

CTFU=(CLRM / E)X((#RM X 0.5)XX(E) -0.5XX(E)) 372.479

CIPS=((CLRM/E)X((#RM X 0.5)XX(E) -0.5XX(E)) 320.744

CRCI = CIPS X R

COSH = 0.0

COMMENTS 55

5 * MILLIONS

934.380

0.0

0.0

3.393

0.0
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 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 8-9.

Range of Data

<table>
<thead>
<tr>
<th>DDT&amp;E</th>
<th>30,0 to 2000,0Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICI</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>

Input parameters T&M are in kilograms of mass.
<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 0.77740, 0.062</td>
<td>CDCER = 0.023000</td>
</tr>
<tr>
<td>M = 3250, 0.00024</td>
<td>CDEXP = 0.600000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICER = 0.000050</td>
</tr>
<tr>
<td>PHI = 1.000000</td>
<td>C1EXP = 1.000000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 0.500000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

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

CLRM = CICER X (M) X (C1EXP) X CF X TF

\[ \#RM = T / M \]

\[ E = 1.0 \times \log(PHI) / \log(2.0) \]

CTFU = (CLRM / E) X ((\#RM X Z1 X 0.5) X (E) - 0.5 X (E))

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

CHCI = CIPS X R

CDEXP = D & M

COMMENTS: 1
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 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
- Apollo Lunar Module
- Apollo Service Module
- Apollo SLA
- ATS-A
- ATS-B
- ATS-E
- ATS-F
- B-70
- C-5A
- Centaur
- DSCS-II
- Gemini
- HEAO-B
- IUE
- Mariner 1964
- OAO-A1/A2
- OSO-1
- Pioneer-F
- Saturn V
- S-IC
- S-II
- S-IVB
- Skylab-AM
- Skylab-OWS
- TACSAT
- Tiros-M
- VELA IV
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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>371200.00</td>
</tr>
<tr>
<td>M</td>
<td>3250.00024</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>P</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.200000</td>
</tr>
<tr>
<td>TF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**Output Coefficients**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEKH</td>
<td>0.234000</td>
</tr>
<tr>
<td>CDTEXP</td>
<td>0.653000</td>
</tr>
<tr>
<td>CICEKH</td>
<td>0.000005</td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**Calculated Values**

\[
CD = CDCEKH \times (T \times DF) \times (CDTEXP) \times CF
\]

\[
CLRM = CIKEH \times (M) \times (CIEXP) \times CF \times TF
\]

\[
#RM = T / M
\]

\[
E = 1.0 + \log(\text{PHI}) / \log(2.0)
\]

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))) / \pi^2

CMCI = CIPS \times R

COM & M = 0 & M

**Comments**

2
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:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly-Scientific</td>
<td>High Energy</td>
</tr>
<tr>
<td>Poly-Scientific</td>
<td>Radar</td>
</tr>
<tr>
<td>Electro-Tec</td>
<td>Navy Destroyer Propeller System</td>
</tr>
<tr>
<td>Electro-Tec</td>
<td>Satellite Solar Array</td>
</tr>
<tr>
<td>I.E.C.</td>
<td>Navy Shipboard Hoist</td>
</tr>
</tbody>
</table>

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

\[
\begin{align*}
\text{Complexity Factor} & \times 3 \\
\text{Specification Uprating Factor} & \times 3 \\
\text{Total} & \times 9
\end{align*}
\]

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
50W Photovoltaic CR=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I</strong> = 559000.062</td>
<td><strong>COCEH</strong> = 0.156000</td>
</tr>
<tr>
<td><strong>M</strong> = 559.000000</td>
<td><strong>CIF</strong> = 0.511000</td>
</tr>
<tr>
<td><strong>CF</strong> = 1.000000</td>
<td><strong>CICEH</strong> = 0.000764</td>
</tr>
<tr>
<td><strong>PHI</strong> = 0.950000</td>
<td><strong>CIE</strong> = 0.950000</td>
</tr>
<tr>
<td><strong>R</strong> = 0.100000</td>
<td></td>
</tr>
<tr>
<td><strong>DF</strong> = 0.200000</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

\[ CD = CDCEP \times (I \times DF) \times (CDEXP) \times CF \]

\[ CM = CICEH \times (M) \times (CIEEXP) \times CF \times TF \]

\[ #RM = I / M \]

\[ E = 1.0 \times \log(\text{PHI}) / \log(2,0) \]

\[ CTFU = (CM / E) \times ((#RM \times Z2 + .5) \times (E) - 0.5 \times (E)) \]

\[ CIPS = ((CM / E) \times ((#RM \times (Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2 \]

\[ CCLI = CIPS \times R \]

\[ CORE = O&M \]

**Comments** 4
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.

<table>
<thead>
<tr>
<th>Element description</th>
<th>Mass Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-IVB Interstage</td>
<td>6.0 to 15,000.0Kg</td>
</tr>
<tr>
<td>S-IC Forward Skirt</td>
<td>6.0 to 15,000.0Kg</td>
</tr>
<tr>
<td>S-IC Interank</td>
<td></td>
</tr>
<tr>
<td>Solar Telescope Housing Assembly (ASM)</td>
<td></td>
</tr>
<tr>
<td>Common Mount Assembly (ASM)</td>
<td></td>
</tr>
<tr>
<td>Telescope Gimbal Assembly (ASM)</td>
<td></td>
</tr>
<tr>
<td>Common Mount Actuators (ASM)</td>
<td></td>
</tr>
<tr>
<td>Telescope Gimbal Actuators (ASM)</td>
<td></td>
</tr>
<tr>
<td>Array Platform Elevation Pointing Actuator (ASM)</td>
<td></td>
</tr>
<tr>
<td>UV Gr.ival Mount Actuators (ASM)</td>
<td></td>
</tr>
<tr>
<td>Solar Array and Boom Structure (ATS-F)</td>
<td></td>
</tr>
<tr>
<td>Squib Interface Unit (ATS-F)</td>
<td></td>
</tr>
<tr>
<td>Interstage (Centaur)</td>
<td></td>
</tr>
<tr>
<td>Nose Shroud (Centaur)</td>
<td></td>
</tr>
<tr>
<td>Fixed Airlock Shroud (Skylab)</td>
<td></td>
</tr>
<tr>
<td>Payload Shroud (Skylab)</td>
<td></td>
</tr>
<tr>
<td>Pallet Segment (Spacelab)</td>
<td></td>
</tr>
<tr>
<td>OSO-1</td>
<td></td>
</tr>
<tr>
<td>ATS-F</td>
<td></td>
</tr>
<tr>
<td>S-H</td>
<td></td>
</tr>
</tbody>
</table>

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

Range of Data:

<table>
<thead>
<tr>
<th>Range of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT&amp;E: 6.0 to 15,000.0Kg</td>
</tr>
<tr>
<td>ICI: 6.0 to 15,000.0Kg</td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>TF</th>
<th>0.007300</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>2051400.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>6.5000001</td>
<td>C&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
<td>Z1</td>
<td>1.0000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.9800000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0100000</td>
<td>Z3</td>
<td>120.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.2000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ CD = CDCER \times (T \times DF) \times (CDEXP) \times CF \]
\[ CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF \]
\[ #RM = T / M \]
\[ E = 1.0 + \log(\text{PHI}) / \log(2.0) \]
\[ CTFU = (CLRM / F) \times ( (#RM \times 21.5) \times (E) - 0.5 \times (E) ) \]
\[ \text{CIPS} = ((\text{CLRM} / E) \times ( (#RM \times 23 \times 0.5) \times (E) - 0.5 \times (E) ) ) / Z2 \]
\[ \text{CPIC} = \text{CIPS} \times R \]
\[ \text{C&M} = \text{C&M} \]

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCER</td>
<td>0.156000</td>
</tr>
<tr>
<td>CDEXP</td>
<td>0.511000</td>
</tr>
<tr>
<td>CICER</td>
<td>0.101000</td>
</tr>
<tr>
<td>CIEXP</td>
<td>0.355000</td>
</tr>
</tbody>
</table>

\[ 5 \times \text{MILLIONS} \]

\[ 115.180 \]

\[ 0.001 \]

\[ 215599.937 \]

\[ 0.971 \]

\[ 322.056 \]

\[ 280.109 \]

\[ 7.401 \]

\[ 0.0 \]

**COMMENTS**

5
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 thermosetting 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 (OWS)
Skylab (ATM)
FRUSA
SEPS (Est.)

The cost of array structure and mechanisms was not included so that the data would be compatible with the SPS concept of on-orbit structure fabrication and assembly. Although there is a large difference in size between the above arrays and the SPS array, the SPS array will consist of a large number of smaller units. The development fraction (DF) was utilized to normalize the CD cost to reflect cost of only that portion of the total solar array area required to develop the power system.
The initial capital investment CER (CI) to estimate the production cost is based upon an engineering "Grass Roots" projected estimate of average cost of \$60.00/M^2 for the GaAlAs solar cell array. The engineering estimate reflects 1977 dollars and assumes 1985 technology. The average cost per M^2 was converted to TFU cost \$71.60/M^2 in order to exercise the CI cost equation.

Range of Data

DDT&E: 10 to 300 square meters
IC1: Unlimited

Input parameters T&M are in square meters, see table B-13.
### Table B-13: 03-04-01 Solar Blankets
50W Photovoltaic CH=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 30376000.0</td>
<td>CUCER= 0.151400</td>
</tr>
<tr>
<td>M= 16250.0000</td>
<td>CUEXP= 0.394000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CICEP= 0.000072</td>
</tr>
<tr>
<td>PHI= 0.9990000</td>
<td>CIEXP= 1.000000</td>
</tr>
<tr>
<td>HR= 0.0100000</td>
<td></td>
</tr>
<tr>
<td>DF= 0.2000000</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

- CD = CUCER × (T × DF) × (CUEXP) × CF
- CLRM = CICER × (M) × (CICEP) × CF × TF
- NR = T / M
- E = 1.0 + LOG(PHI) / LOG(2.0)
- CTF = (CLRM / E) × ((NR × Z1 + 0.5) × XX(E) - 0.5 × XX(E))
- CIPS = ((CLRM / E) × ((NR × Z3 + 0.5) × XX(E) - 0.5 × XX(E))) / Z2
- CRCI = CIPS × M
- CUEM = 0 & M

**Comments**

- Page is of poor quality.
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/m² 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

<table>
<thead>
<tr>
<th>DDT&amp;E:</th>
<th>100</th>
<th>M</th>
<th>100,000M²</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICI:</td>
<td>Unlimited</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Input parameters T&M are in square meters, see table B-14.
### TABLE B-14. 03-04-92 CONCENTRATOPS
SGW PHOTONVLAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>T= 647400000.0</td>
<td>CD=CD(T)X(TDF)XX(CDEXP)XCF</td>
</tr>
<tr>
<td>M= 16250.0000</td>
<td></td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td></td>
</tr>
<tr>
<td>PHI= 0.950000</td>
<td></td>
</tr>
<tr>
<td>K= 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF= 0.200000</td>
<td></td>
</tr>
<tr>
<td>TF= 1.000000</td>
<td>CD(T)F= 0.027000</td>
</tr>
<tr>
<td>0&amp;H= 0.0</td>
<td>CD(U)EXP= 0.394000</td>
</tr>
<tr>
<td>Z1= 1.000000</td>
<td>CD(C)ER= 0.000003</td>
</tr>
<tr>
<td>Z2= 120.000000</td>
<td>CD(C)I(E)F= 0.950000</td>
</tr>
<tr>
<td>Z3= 120.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ \text{CD} = \text{CDER} \times (T \times DF) \times (CDEXP) \times CF \]
\[ \text{CLRM} = \text{CICER} \times (M) \times (CIEXF) \times CF \times TF \]
\[ \#\text{RM} = \frac{T}{M} \]
\[ E = 1.0 + \log(PHI) / \log(2.0) \]
\[ \text{CTFU} = (\text{CLRM} / E) \times (\#\text{RM} \times Z1 + 0.5) \times (E) - 0.5 \times (E) \]
\[ CIPS = (\#\text{CLRM} / E) \times (\#\text{RM} \times Z3 + 0.5) \times (E) - 0.5 \times (E) \]
\[ \text{CRCI} = \text{CIPS} \times R \]
\[ \text{CUGM} = \text{O&M} \]

**COMMENTS**

7

**mILLIONS**

- 17.123
- 0.030
- 3964.000
- 0.971
- 96.748
- R4.151
- 0.842
- 0.0
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
- OSO-1
- 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 microwave 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 CM². The slip-ring diameter is 1.13 KM. Length is 3.55 KM. Each slip-ring weighs $0.0403 \times 10^6$ Kg. A total of (4) slip-rings are required per satellite.

The shoe brush assembly material consist of 75% MoSz, 25% Mo + Ta. Each shoe brush assembly has 868 CM² 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 \( \times 3 \)
- Specification Uprating Factor \( \times 3 \)
- Total \( \times 9 \)

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

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly - Scientific</td>
<td>High Energy</td>
</tr>
<tr>
<td>Poly - Scientific</td>
<td>Radar</td>
</tr>
<tr>
<td>Electro - Tec</td>
<td>Navy Destroyer Propeller System</td>
</tr>
<tr>
<td>Electro - Tec</td>
<td>Satellite Solar Array</td>
</tr>
<tr>
<td>I.E.C.</td>
<td>Navy Shipboard Hoist</td>
</tr>
</tbody>
</table>

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
- APOLLO Lunar Rover
- ATS-E
- ATS-F

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
- APOLLO Lunar Rover
- ATS-E
- ATS-F
- GEMINI
- HAWKEYE
- OSO-1

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
| SGW PHOTOVOLTAIC CR=2 |

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>910000.125</td>
</tr>
<tr>
<td>M</td>
<td>1263.6001G</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>H</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- \( CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF \)
- \( CLRM = CI\text{CER} \times (M) \times (CIEXP) \times CF \times TF \)
- \( #RM = T / M \)
- \( E = 1.0 \times \text{LOG}(PHI) / \text{LOG}(2.0) \)
- \( CTFU = (CLRM / E) \times ( (#RM \times Z1 \times 5) \times (E) - 0.5 \times (E) ) \)
- \( CIPS = ( (CLRM / E) \times ( (#RM \times Z3 \times 0.5) \times (E) - 0.5 \times (E) ) ) / 2 \)
- \( CRCI = CIPS \times R \)
- \( CD\&M = O\&M \)
- **COMMENTS**: 0

**INPUT COEFFICIENTS**

- \( CDCEP = 0.156000 \)
- \( CDEXP = 0.297000 \)
- \( CI\text{CFF} = 0.000064 \)
- \( CIEXP = 1.000000 \)

**DOLLAR MILLIONS**

- 5.766
- 0.005
- 720.165
- 1.000
- 3.640
- 3.640
- 0.034
- 0.0

**Original Page is of Poor Quality**
### TABLE B-1E. 03-04-03 POWER DIST. & COND. -SLIP RINGS
5GW PHOTOVOLTAIC CN=2

#### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>451100.062</td>
</tr>
<tr>
<td>M</td>
<td>780.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.500000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.900000</td>
</tr>
<tr>
<td>R</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

#### INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCER</td>
<td>0.156000</td>
</tr>
<tr>
<td>CUEXP</td>
<td>0.511000</td>
</tr>
<tr>
<td>CICLP</td>
<td>0.000754</td>
</tr>
<tr>
<td>CITf</td>
<td>0.950000</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

\[
CD = CDCER \times (T \times DF) \times (CUEXP) \times CF
\]

\[
CLRM = CICER \times (M) \times (CITf) \times CF \times TF
\]

\[
#RM = T / M
\]

\[
E = 1.0 + \log(\text{PHI}) / \log(2.0)
\]

\[
\text{CTFU} = (\text{CLRM} / E) \times ((#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E))
\]

\[
\text{CIPS} = ((\text{CLRM} / E) \times ((#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2
\]

\[
\text{CRC1} = \text{CIPS} \times \text{R}
\]

\[
\text{R&M} = \text{R&M}
\]

#### COMMENTS

9
TABLE B-15. 03-04-03 POWER DIST. & COND. SWITCHING SGW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 297700.000</td>
<td>TF = 1.000000</td>
</tr>
<tr>
<td>M = 1263.60010</td>
<td>OM = 0.0</td>
</tr>
<tr>
<td>CF = 1.45000000</td>
<td>Z1 = 1.000000</td>
</tr>
<tr>
<td>PHI = 0.9500000</td>
<td>Z2 = 120.000000</td>
</tr>
<tr>
<td>R = 0.01000000</td>
<td>Z3 = 120.000000</td>
</tr>
<tr>
<td>DF = 0.20000000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INPUT COEFFICIENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CIUCEL = 0.15E0000</td>
<td></td>
</tr>
<tr>
<td>CIUEF = 0.79700000</td>
<td></td>
</tr>
<tr>
<td>CIEEF = 0.00040000</td>
<td></td>
</tr>
<tr>
<td>CIEEP = 1.00000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF \]

\[ CLRM = CIREEP \times (M) \times (CIEEP) \times CF \times TF \]

\[ RRM = T / M \]

\[ E = 1.0 \times \log(PHI) / \log(2.0) \]

\[ CTFU = (CLRM / E) \times ((RRM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \]

\[ CIPS = ((CLRM / E) \times ((RRM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) \times CIEEP) / CE \]

\[ CPEC = CIPS \times R \]

\[ GFW = OM \]

**COMMENTS**

10
### TABLE B-15. 03-04-03 POWER DIST. & COND. -BATTERIES

50W PHOTOVOLTAIC CR#2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>CALCULATED VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 26000.000</td>
<td>CD = CUCER X (T X DF) X (CUEXP) X CF</td>
</tr>
<tr>
<td>M = 65.000000</td>
<td>CLRM = CUCER X (M) X (CUEXP) X CF X TF</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>#RM = T / M</td>
</tr>
<tr>
<td>PHI = 0.950000</td>
<td>E = 1.0 + LOG(PHI) / LOG(2.0)</td>
</tr>
<tr>
<td>R = 0.066170</td>
<td>CFU = (CLRM / E) X ((#RM X ZI + 5)) X (E) - 0.5 X (E)</td>
</tr>
<tr>
<td>DF = 0.200000</td>
<td>CPS = ((CLRM/E) X ((#RM X Z3 + 0.5)) X (E) - 0.5 X L)</td>
</tr>
<tr>
<td></td>
<td>CRCI = CPS X R</td>
</tr>
<tr>
<td></td>
<td>C00M = 00M</td>
</tr>
<tr>
<td></td>
<td>COMMENTS 11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INPUT COEFFICIENT</th>
<th>$, MILLIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUCER = 0.037/000</td>
<td>19.754</td>
</tr>
<tr>
<td>CDFXP = 2.73/4.00</td>
<td>0.006</td>
</tr>
<tr>
<td>CICEL = 0.021/000</td>
<td>400.000</td>
</tr>
<tr>
<td>CILAF = 0.2&lt;1000</td>
<td>0.926</td>
</tr>
</tbody>
</table>

$7.87/000$
### Table B-15

**03-04-03 Power Unit: A Condenser Battery Power**

50% Photovoltaic CR=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=</td>
<td>13000.0000</td>
</tr>
<tr>
<td>M=</td>
<td>56.5000001</td>
</tr>
<tr>
<td>CF=</td>
<td>1.0000000</td>
</tr>
<tr>
<td>PHI=</td>
<td>0.9500000</td>
</tr>
<tr>
<td>R=</td>
<td>0.0100000</td>
</tr>
<tr>
<td>DF=</td>
<td>0.5000000</td>
</tr>
<tr>
<td>TF=</td>
<td>0.0030000</td>
</tr>
</tbody>
</table>

#### Calculated Values

- \( CD = CDCEP \times (T \times DF) \times (CIELXP) \times CF \) ~ 131,150
- \( CLRM = CICER \times (M) \times (CIELXP) \times CF \times TF \) ~ 0.003
- \( #RM = T / M \) ~ 20,000,000
- \( E = 1.0 + \log(PHI) / \log(2.0) \) ~ 0.926
- \( CTFU = (CLRM / E) \times ((#RM \times Z1 \times 5) \times (E) - 0.5 \times (E)) \) ~ 3,169
- \( CIPS = ((CLRM / E) \times ((#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) \times 1 / Z2 \) ~ 2,224

- \( CCLI = CIPS \times P \)
- \( CODM = O&M \)

**Comments** 12
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 2.4M² was assumed to 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 8-16. 03-05-MICROWAVE HEAT PIPES
5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I = 1106300.00</td>
<td>COCER = 0.156000</td>
</tr>
<tr>
<td>M = 8.0034001</td>
<td>COEXP = 0.511000</td>
</tr>
<tr>
<td>CF = 1.500000</td>
<td>CICER = 0.000500</td>
</tr>
<tr>
<td>PHI = 0.090000</td>
<td>CLEXP = 1.000000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 0.200000</td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

\[ CD = \text{COCER} \times (T \times DF) \times (COEXP) \times CF \]

\[ CLRM = \text{CICER} \times (M) \times (CLEXP) \times CF \times TF \]

\[ #RM = I / M \]

\[ E = 1.0 \times \log\text{(PHI) / log}(2,0) \]

\[ CTFU = (CLRM / E) \times ((#RM \times Z1 \times 5) \times X(E) - 0.5 \times X(E)) \]

\[ CIPS = (CLRM/E) \times ((#RM \times Z3 + 0.5) \times X(E) - 0.5 \times X(F)) \]

\[ CCRCI = CIPS \times W \]

\[ COTM = O&M \]

**COMMENTS:** 14
<table>
<thead>
<tr>
<th>TABLE B-16, 03-05-02 MICROWAVE ANTENNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5SW PHOTOVOLTAIC CR=2</td>
</tr>
</tbody>
</table>

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>T</th>
<th>80,000,000.00</th>
<th>T = 1,000,000.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>120,000,000.00</td>
<td>M = 0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1,000,000.00</td>
<td>CF = 1,000,000.00</td>
</tr>
<tr>
<td>PHI</td>
<td>0.980000.00</td>
<td>PHI = 120,000,000.00</td>
</tr>
<tr>
<td>R</td>
<td>0.010000.00</td>
<td>R = 0.0</td>
</tr>
<tr>
<td>DF</td>
<td>0.400000.00</td>
<td>DF = 0.0</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

CD = CDCER X (T X DF)^2 X (CINDEX) X DF

CLRM = CICER X (M) X (CINDEX) X CF X T

HARM = T / M

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

CTFU = (CLRM / E) X ((HARM X 21 + 5) X X(E) - 0.5 X X(L))

CIPS = ((CLRM / E) X ((HARM X 23 + 0.5) X X(E) - 0.5 X X(E))) / 12

CRCC = CIPS X H

COM = 0 & M

COMMENTS 15

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>CD</th>
<th>0.205690</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDX</td>
<td>0.067088</td>
</tr>
<tr>
<td>CICER</td>
<td>0.006130</td>
</tr>
<tr>
<td>CTX</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**ORIGINAL PAGE IS POOR QUALITY & MILLIONS**

127.152

0.376

666.664

0.971

1795.335

1735.509

17.355

0.0
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
- SEPS (Rockwell) Study
- SERT-M
- ATS-F (Ion Experiment)
- Rockwell SPS Study
- SERT-C Study

Range of Data:

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

Input parameters T&M are in kilograms, see table B-17.
### TABLE B-17. 03-06-00 ATTITUDE CONTROL AND ORBS, MAN.
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 39390.8039</td>
<td>CDCEP= 1.122000</td>
</tr>
<tr>
<td>M= 390.000000</td>
<td>CDEXP= 0.194000</td>
</tr>
<tr>
<td>CF= 1.1000000</td>
<td>CICER= 0.057000</td>
</tr>
<tr>
<td>PHI= 0.9000000</td>
<td>CIExp= 0.729000</td>
</tr>
<tr>
<td>R= 0.2000000</td>
<td></td>
</tr>
<tr>
<td>DF= 0.3000000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATED VALUES</th>
<th>$\text{MILLIONS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD=CDCEP X (T X DF) X (CDEXP) X CF</td>
<td>7.331</td>
</tr>
<tr>
<td>CLRM=CICER X (M) X (CIExp) X CF X TF</td>
<td>0.514</td>
</tr>
<tr>
<td>NRM = T / M</td>
<td>101.000</td>
</tr>
<tr>
<td>E = 1.0 * LOG(PHI) / LOG(2.0)</td>
<td>0.848</td>
</tr>
<tr>
<td>CTFU=(CLRM / E) X ((NRM X Z1 + 0.5) X (E) - 0.5 X (E))</td>
<td>30.151</td>
</tr>
<tr>
<td>GIPS=((CLRM / E) X ((NRM X Z3 + 0.5) X (E) - 0.5 X (E)) / Z2</td>
<td>14.662</td>
</tr>
<tr>
<td>CRC1 = GIPS X R</td>
<td>2.932</td>
</tr>
<tr>
<td>C0&amp;M = 0&amp;M</td>
<td>0.047</td>
</tr>
<tr>
<td>COMMENTS</td>
<td>16</td>
</tr>
</tbody>
</table>
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
- Minuteman
- Skylab
- Viking Lander
- MOL
- HEAO

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

Range of Data

DDT&E and ICI: 1.8 to 75.7 kilograms

ELECTRONIC COMPONENTS

The electronic components associated with Avionics include the Submultiplexors, Remote Acquisition Units, 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:

<table>
<thead>
<tr>
<th>ATS-F</th>
<th>OSO-8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aux. Digital Sun Sensors</td>
<td>Solar Power Supply</td>
</tr>
<tr>
<td>Monopulse Unit</td>
<td>Power Supply</td>
</tr>
<tr>
<td>Wide Band Data Unit</td>
<td>Control Decoder/Demodulator</td>
</tr>
<tr>
<td>C Band Data Unit</td>
<td>Remote Decoder</td>
</tr>
<tr>
<td>S/L Band Transmitter</td>
<td>PCM Decoder</td>
</tr>
<tr>
<td>VHF Receiver</td>
<td>Format Generator</td>
</tr>
<tr>
<td>Command Decoder</td>
<td>Wheel Clock</td>
</tr>
<tr>
<td>Data Acq. &amp; Control Unit</td>
<td>Sat Clock</td>
</tr>
<tr>
<td>Data Switching Unit</td>
<td>S Band Transmitter</td>
</tr>
<tr>
<td></td>
<td>VHF Transmitter</td>
</tr>
<tr>
<td></td>
<td>B-51</td>
</tr>
</tbody>
</table>

SD 78-AP-0023-7
Range of Data

DDT&E and ICI: 1.1 to 19.6 kilograms

DATA BUS

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

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

FIBER OPTICS:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Type</th>
<th>Characteristics</th>
<th>Cost per Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITT Electro-Optical Products Division</td>
<td>GG-02</td>
<td>Single Fiber (1-10 km)</td>
<td>$3.25</td>
</tr>
<tr>
<td></td>
<td>GS-02</td>
<td>Single Fiber 50 M Dia.</td>
<td>$2.50</td>
</tr>
<tr>
<td>Valtec Fiberoptics Division</td>
<td>MG-05</td>
<td>Single Fiber 65 M Dia.</td>
<td>$2.25</td>
</tr>
<tr>
<td>Galileo Electro-Optics</td>
<td>-</td>
<td>Single Fiber 88 M Dia.</td>
<td>$1.58</td>
</tr>
<tr>
<td>Optics Corporation</td>
<td></td>
<td>Average cost per meter</td>
<td>$2.40</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Characteristics</th>
<th>Cost per Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dearborn Wire &amp; Cable</td>
<td>22 gage stranded silver plate</td>
<td>$0.807</td>
</tr>
<tr>
<td>Standard Wire &amp; Cable</td>
<td>22 gage stranded Silver plate</td>
<td>$0.705</td>
</tr>
<tr>
<td>Karen, Inc.</td>
<td>22 gage, 2 conductor silver plate</td>
<td>$0.807</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Product Description</td>
<td>Price/Unit</td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Mil-Spec Wire &amp; Cable Corporation</td>
<td>22 gage, 19-30 stranded</td>
<td>$0.610</td>
</tr>
</tbody>
</table>

Average cost per meter: $0.732

*Instrumentation input parameters T&M are in kilograms.*
### TABLE B-10.  03-07-01 AVI(C NICS-MCC)  
SUN PHOTOVOLTAIC CH=2

#### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1300.0000</td>
<td>Tf</td>
<td>0.900000</td>
</tr>
<tr>
<td>M</td>
<td>650.000000</td>
<td>(M/r)</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.800000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0100000</td>
<td>Z3</td>
<td>120.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.500000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

CD = CD_CER X (T X DF) X (CD_EXP) X CF

CLRM = CICER X (M) X (C EXP) X CF X TF

#RM = T / M

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

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

CIPS = (1 CLRM / E X (#RM X Z3 + 0.5) X (E) - 0.5 X (E)) / 2

CHLI = CIPS X R

CD & M = 0 & M

COMMENTS: 17

INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD_CER</td>
<td>0.634600</td>
</tr>
<tr>
<td>CD_EXP</td>
<td>0.521900</td>
</tr>
<tr>
<td>CICER</td>
<td>0.172000</td>
</tr>
<tr>
<td>C EXP</td>
<td>0.535000</td>
</tr>
</tbody>
</table>

$\$ MILLIONS

18.490

4.951

2.000

0.678

9.027

2.417

0.025

0.0
TABLE B-19. 03-07-02 AVIUNICS-0 AND C
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 260.000000</td>
<td>CuCEk = 1.102000</td>
</tr>
<tr>
<td>M= 260.000000</td>
<td>CuEXP = 0.870000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CiCFR = 0.069000</td>
</tr>
<tr>
<td>PHI= 0.800000</td>
<td>CiFXP = 0.557000</td>
</tr>
<tr>
<td>R= 0.910000</td>
<td></td>
</tr>
<tr>
<td>DF= 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

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

CLRM=CiCER X (M) X (CiEXP) X CF X TF

#RM = T / M

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

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

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

CRCI = CIPS X R

CWM = O&M

COMMENTS 1B
<table>
<thead>
<tr>
<th>TABLE 8-20. 03-07-03 AVIONICS-SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>5Gw PHOTOVOLTAIC CR=2</td>
</tr>
</tbody>
</table>

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>T</th>
<th>109.200012</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>18.199997</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.550000</td>
</tr>
<tr>
<td>R</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

**Calculated Values**

- CD = CDCEH X (T X DF) X (CDEXP) X CF
- CLRM = CICER X (M) X (CICEXP) X CF X TF
- RM = T / M
- E = 1.0 + LOG(PHI) / LOG(20)
- CTFU = (CLRM / E) X ((#RM X 21 + 1.5) X (E) - 0.5 X (E))
- CIPS = (CICER / E) X ((#RM X 23 + 0.5 X (E) - 0.5 X (F)) / 2)
- CHCI = CIPS X R
- GOAM = OAM
- COMMENTS 19

<table>
<thead>
<tr>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEH = 6.33800</td>
</tr>
<tr>
<td>CDEXP = 0.52100</td>
</tr>
<tr>
<td>CICER = 0.17200</td>
</tr>
<tr>
<td>CICEXP = 0.53500</td>
</tr>
</tbody>
</table>

5, MILLIONS

<table>
<thead>
<tr>
<th>E</th>
<th>3.156</th>
</tr>
</thead>
<tbody>
<tr>
<td>RM</td>
<td>0.569</td>
</tr>
<tr>
<td>E</td>
<td>6.008</td>
</tr>
<tr>
<td>E</td>
<td>0.766</td>
</tr>
<tr>
<td>E</td>
<td>2.676</td>
</tr>
<tr>
<td>E</td>
<td>0.950</td>
</tr>
<tr>
<td>E</td>
<td>0.989</td>
</tr>
<tr>
<td>E</td>
<td>0.6</td>
</tr>
</tbody>
</table>
TABLE B-21.  03-07-04 AVILNICS-VC
55W PHOTOVOLTAIC CH=2

INPUT PARAMETERS

\[ \begin{align*}
T &= 673.399902 \\
M &= 15.199997 \\
CF &= 1.600000 \\
PHI &= 0.650000 \\
P &= 0.010000 \\
DF &= 0.030000
\end{align*} \]

INPUT COEFFICIENTS

\[ \begin{align*}
T &= 6.400000 \\
M &= 0.0 \\
Z1 &= 1.000000 \\
Z2 &= 120.000000 \\
CF &= 0.633000 \\
P &= 0.521000 \\
Z3 &= 0.172000 \\
PHI &= 0.535000
\end{align*} \]

CALCULATED VALUES

\[ \begin{align*}
CD &= CUCER \times (T \times DF) \times (CLEXP \times CF) \\
CCLM &= CICER \times (M) \times (CLEXP) \times CF \times TF \\
\#RM &= T / M \\
E &= 1.0 + \log(PHI) / LCR(2.0) \\
CTFU &= (CLRM / E) \times (\#RM \times 71+0.5) \times (E) -0.5 \times (E) \\
CIPS &= ((CLRM/E) \times ((\#RM \times \bar{Z} + 0.5) \times (E) -0.5 \times (E))) / 22 \\
CCHI &= CIPS / M \\
CDBH &= D&M \\
COMMENTS &= 20
\end{align*} \]
### TABLE B-22. 03-07-05 AVIONICS-HUS CONTROL UNIT

5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETER</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 5343.00000</td>
<td>CDCEF = 0.102800</td>
</tr>
<tr>
<td>M = 5.500001</td>
<td>CLEAF = 11.179800</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CIERR = 1.1669400</td>
</tr>
<tr>
<td>PHI = 0.500000</td>
<td>CIEXL = 0.557000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 0.001200</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\begin{align*}
CD &= CDCEF \times (T \times DF)^X(CDCEF)^X CF \\
CLRM &= CICER \times (M)^X(CIECF)^X CF \times TI \\
\#RM &= T \div M \\
E &= 1.0 + \log(PHI) \div \log(2.0) \\
CTFU &= (CLRM / E) \times ((\#RM \times 2 + \#RM) \times (E) - 0.5 \times (E)) \\
CIPS &= ((CLRM / E) \times ((\#RM \times 2 + 0.5) \times (E) - 0.5 \times (E))) / 22 \\
CCH = CIPS \times R \\
CBBM &= \#BM \\
COMMENTS &= 21
\end{align*}
\]
### TABLE B-23. 3-07-06 AVIONICS-MICROPROCESSORS

**5GW PHOTOVOLTAIC CM=2**

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tm</td>
<td>5050.50000</td>
</tr>
<tr>
<td>Mx</td>
<td>5.500000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>R</td>
<td>0.010800</td>
</tr>
<tr>
<td>DF</td>
<td>0.000300</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ \text{CALCULATED VALUES} \]

<table>
<thead>
<tr>
<th>Equation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD = CDCEP \times (T \times DF) \times (CD EXP) \times CF</td>
<td>8.533</td>
</tr>
<tr>
<td>CLRM = CIFE \times (M) \times (CIFE) \times CF \times TF</td>
<td>0.015</td>
</tr>
<tr>
<td>#RM = -1 / K</td>
<td>177.000</td>
</tr>
<tr>
<td>E = -1.0 + LOG(PHI) / LOG(2.0)</td>
<td>0.926</td>
</tr>
<tr>
<td>CTFU = (CLRM / E) \times ((#RM \times Z1 + 0.5) \times A(E) - 0.5 \times X(E))</td>
<td>7.424</td>
</tr>
<tr>
<td>CIPS = ((CLRM / E) \times ((#RM \times Z3 \times (A(E) - 0.5 \times X(E)))</td>
<td>5.943</td>
</tr>
<tr>
<td>CKCI = CIPS \times P</td>
<td>0.055</td>
</tr>
<tr>
<td>CO&amp;M = Q&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>COMMENTS</td>
<td>22</td>
</tr>
</tbody>
</table>

**5GW PHOTOVOLTAIC CM=2**

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tm</td>
<td>5050.50000</td>
</tr>
<tr>
<td>Mx</td>
<td>5.500000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>R</td>
<td>0.010800</td>
</tr>
<tr>
<td>DF</td>
<td>0.000300</td>
</tr>
</tbody>
</table>

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEP</td>
<td>0.102000</td>
</tr>
<tr>
<td>CIFE</td>
<td>0.079000</td>
</tr>
<tr>
<td>CILEP</td>
<td>0.069000</td>
</tr>
<tr>
<td>CILEP</td>
<td>0.557000</td>
</tr>
</tbody>
</table>

**5GW PHOTOVOLTAIC CM=2**

**CALCULATED VALUES**

<table>
<thead>
<tr>
<th>Value</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8.533</td>
<td></td>
</tr>
<tr>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>177.000</td>
<td></td>
</tr>
<tr>
<td>0.926</td>
<td></td>
</tr>
<tr>
<td>7.424</td>
<td></td>
</tr>
<tr>
<td>5.943</td>
<td></td>
</tr>
<tr>
<td>0.055</td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>
## TABLE B-24. 03-07-81 AVIONICS-RA ANL C
### 5GM PHOTOVOLTAIC CH=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>CF</th>
<th>Value</th>
<th>CD</th>
<th>Value</th>
<th>CD</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>6402.50000</td>
<td></td>
<td>1F</td>
<td>0.069900</td>
<td>CDCEP</td>
<td>0.102000</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>0.5000001</td>
<td></td>
<td>0.6</td>
<td></td>
<td>0.6</td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
<td></td>
<td>Z1</td>
<td>1.000000</td>
<td>CEXP</td>
<td>0.069000</td>
<td></td>
</tr>
<tr>
<td>PHI</td>
<td>0.9500000</td>
<td></td>
<td>Z2</td>
<td>120.000000</td>
<td>CILX1</td>
<td>0.557000</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>0.0100000</td>
<td></td>
<td>Z3</td>
<td>120.000000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>0.0010000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- \( CD = CDCEP \times (T \times DF) \times (CD \times CF) \times CF \)
- \( CLRM = CICER \times (M) \times (CIC \times CF) \times CF \times CF \)
- \( \#RM = T / M \)
- \( E = 1.0 + \log(\PhiI) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times ((\#RM / Z1 + 0.5) \times (E) - 0.5 \times (E)) \)
- \( CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \)
- \( CRCI = CIPS \times \Phi \)
- \( CILM = \#RM \times \Phi \)
- \( COMMENTS = 23 \)

**INPUT COEFFICIENTS**
### TABLE B-25: AVIONICS-SUI MULTIPLEXORS

<table>
<thead>
<tr>
<th>SGW PHOTOVOLTAIC CR=2</th>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 120900.000</td>
<td>TF = 0.822000</td>
<td>CDCEC = 0.102000</td>
</tr>
<tr>
<td>M = 3.900001</td>
<td>D&amp;M = 0.0</td>
<td>CDUFXP = 0.879000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>21 = 1.000000</td>
<td>CICEK = 0.869000</td>
</tr>
<tr>
<td>PHI = 0.980000</td>
<td>22 = 120.000000</td>
<td>CIEXF = 0.557000</td>
</tr>
<tr>
<td>N = 0.000000</td>
<td>23 = 120.000000</td>
<td></td>
</tr>
<tr>
<td>QF = 0.000032</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\begin{align*}
\text{CD} &= \text{CDCEC} \times (T \times DF) \times (\text{CDUFXP} \times CF) \\
\text{CLRM} &= \text{CICEK} \times (M) \times (\text{CIEXF}) \times CF \times TF \\
\text{RM} &= T / M \\
E &= 1.0 \times \text{LOG(PHI)} / \text{LOG(2.0)} \\
\text{CFU} &= (\text{CLRM} / E) \times ((\text{RM} \times 21 + 5) \times (E) - 0.5 \times (E)) \\
\text{CIPS} &= ((\text{CLRM} / E) \times ((\text{RM} \times 7.3 + 0.5) \times (E) - 0.5 \times (E))) / (E) \\
\text{CRCI} &= \text{CIPS} \times \alpha \\
\text{CD&M} &= \text{D&M} \\
\text{COMMENTS} &= 24
\end{align*}
\]

\[5 \times \text{BILLIONS}\]

\[0.335\]

\[0.003\]

\[30999.997\]

\[0.971\]

\[16.523\]

\[66.557\]

\[0.666\]

\[0.0\]
TABLE B-26. 03-07-09 AVIONICS-INSTRUMENTATION
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tff= 362700.000</td>
<td>CDCEP= 0.000100</td>
</tr>
<tr>
<td>N= 0.074100</td>
<td>CDEXP= 1.000000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CICEP= 0.0000400</td>
</tr>
<tr>
<td>PHI= 0.980000</td>
<td>CILXP= 1.000000</td>
</tr>
<tr>
<td>R= 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF= 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATED VALUES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CD=CDCEP X (T X DF) X X(CDEXP) X CF</td>
<td>36.270</td>
</tr>
<tr>
<td>CLRM=CICER X (M) X X(CIEXP) X CF X Tff</td>
<td>0.000</td>
</tr>
<tr>
<td>RRM = T / M</td>
<td>4694739.00</td>
</tr>
<tr>
<td>E = 1.0 * LOG(PHI) / LOG(2.0)</td>
<td>0.971</td>
</tr>
<tr>
<td>CTFU=(CLRM / E) X ((RRM X 21 + 5) X X(E) - 0.5 X X(E))</td>
<td>95.383</td>
</tr>
<tr>
<td>CIPS=((CLRM/E) X ((RRM X 23 + 0.5) X X(E) - 0.5 X X(E)) / 27</td>
<td>82.960</td>
</tr>
<tr>
<td>CMCI = CIPS X R</td>
<td>0.930</td>
</tr>
<tr>
<td>CO&amp;M = O&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>COMMENTS 25</td>
<td></td>
</tr>
</tbody>
</table>

5 MILLIONS
### TABLE B-27. 03-07-10 AVIONICS-OPTICAL FILTER

**5Gw PHOTOVOLTAIC CH=2**

#### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>80.600006</td>
<td>T1 = 1.000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>80.600006</td>
<td>0A = 0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1 = 1.000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHI</td>
<td>0.956000</td>
<td>Z2 = 120.000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0.010000</td>
<td>Z3 = 120.000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- **CO** = **CDGER** x (T x DF) x (CI x EXP) x CF
- **CLRM** = **CICER** x (M x (CIC x EXP) x CF x TF
- **#RM** = T / M
- **E** = 1.0 + LOG(PHI) / LOG(2.0)
- **CFU** = (**CLRM** / E) x ((#RM x Z1 + 5) x (E - 0.5 x (E))
- **CIPS** = ((**CLRM** / E) x (0.5 x (E - 0.5 x (E)) / 2

#### Input Coefficients

- **CICER** = 6.237000
- **CIFX1** = 6.010219
- **CIFX1** = 1.000000
- **#RM** = T / M
- **E** = 1.0 + LOG(PHI) / LOG(2.0)
- **CFU** = (**CLRM** / E) x ((#RM x Z1 + 5) x (E - 0.5 x (E))
- **CIPS** = ((**CLRM** / E) x (0.5 x (E - 0.5 x (E)) / 2
<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T = 380900.00$</td>
<td>$CUCER = 0.237000$</td>
</tr>
<tr>
<td>$M = 380900.00$</td>
<td>$CUEXP = 0.297000$</td>
</tr>
<tr>
<td>$CF = 1.000000$</td>
<td>$CICEK = 0.000000$</td>
</tr>
<tr>
<td>$PHI = 0.980000$</td>
<td>$CIEKP = 1.000000$</td>
</tr>
<tr>
<td>$R = 0.900000$</td>
<td></td>
</tr>
<tr>
<td>$DF = 1.000000$</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

\[
CD = CUCER \times (T \times DF) \times (CUEXP) \times CF
\]

\[
CLRM = CICEK \times (M) \times (CIEKP) \times CF \times TF
\]

\[
#RM = T / M
\]

\[
E = 1.0 \times \log(PHI) / \log(2.0)
\]

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

\[
CIPS = ((CLRM / E) \times ((#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) \times 2
\]

CRCI = CIPS \times R

CUHM = 0.0M

COMMENTS 27
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
55W Photovoltaic CR=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>M = 724100.062, TF = 0.0009700, CF = 5.25001, N&amp;k = 0.0, PHI = 1.000000, Z1 = 1.000000, PHI = 0.980000, Z2 = 120.000000, PHI = 0.010000, Z3 = 120.000000, PHI = 0.200000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calculated Values</th>
<th>Millions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD = CDCEP X (T X DF)X(CDEXP) X CF</td>
<td>34.264</td>
</tr>
<tr>
<td>CLRM = CICEP X (M)X(CIEXP) X CF X if</td>
<td>0.001</td>
</tr>
<tr>
<td>#RM = T / M</td>
<td>134245.937</td>
</tr>
<tr>
<td>E = 1.0 * LOG(PHI) / LOG(2.0)</td>
<td>0.971</td>
</tr>
<tr>
<td>CTFU = (CLRM / E)X((#RM X Z1+.5)X(E) - 0.5X(E))</td>
<td>77.159</td>
</tr>
<tr>
<td>CIPS = ((CLRM/E)X((#RM X Z3 + .5)X(E) - 0.5X(E))) ^ 1 / Z2</td>
<td>67.109</td>
</tr>
<tr>
<td>CRCI = CIPS X M</td>
<td>0.671</td>
</tr>
<tr>
<td>C0mb = 0.0M</td>
<td>0.0</td>
</tr>
<tr>
<td>Comments</td>
<td>30</td>
</tr>
</tbody>
</table>
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 soneties 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 of extrapolating the percentage trend of the historical data to the SPS base.

The programs used as the baseline are listed below:

- ATS A-E
- ATS-F
- DSCS II
- HEAO B
- IDCSP/A
- Lunar Orbiter
- Mariner 1964
- Mariner 1969
- OAO A1/A2
- OSO II
- Pioneer F
- Tiros M
- Vela IV
- 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. 03-09-80 GROUND ASSEMBLY & INTEGRATION
5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 0.0</td>
<td>CDCEP= 0.0</td>
</tr>
<tr>
<td>M= 0.0</td>
<td>CUTFXP= 0.020000</td>
</tr>
<tr>
<td>CF= 0.0</td>
<td>CICEP= 0.020000</td>
</tr>
<tr>
<td>PHI= 0.0</td>
<td>C1EXP= 0.0</td>
</tr>
<tr>
<td>R= 0.0</td>
<td></td>
</tr>
<tr>
<td>DF= 0.0</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\begin{align*}
CD &= CDCEP \times (T \times DF) \times (CUTFXP) \times CF \\
CLRM &= CICEP \times (M) \times (C1EXP) \times CF \times T \\
#RM &= T \div M \\
E &= 1.0 \times \log(PHI) \div \log(2.0) \\
CTFU &= (CLRM \div E) \times ((#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \\
CIPS &= ((CLRM/E) \times (#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \\
CFC1 &= CIPS \times R \\
C0&M &= O&M \\
COMMENTS &= 61
\end{align*}
\]

$\Sigma$ MILLIONS

0.0

0.0

0.0

104,326

89,844

0.954

0.0
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
SGW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TE = 0.0</td>
<td>CDCEK = 0.506800</td>
</tr>
<tr>
<td>M = 0.0</td>
<td>CuEF.XP = 0.0</td>
</tr>
<tr>
<td>CF = 0.0</td>
<td>CIEXF = 0.0</td>
</tr>
<tr>
<td>PHI = 0.0</td>
<td></td>
</tr>
<tr>
<td>R = 0.0</td>
<td></td>
</tr>
<tr>
<td>DF = 0.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATED VALUES</th>
<th>5X MILLIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO=CDCEK X (T X DF) X (CDCEXP) X CF</td>
<td>266 48.362</td>
</tr>
<tr>
<td>CLRM=CIEXR X (M) X (CIEXP) X CF X TF</td>
<td>0.0</td>
</tr>
<tr>
<td>#RM = T / M</td>
<td>0.0</td>
</tr>
<tr>
<td>E = 1.0 + LOG(PHI) / LOG(2.0)</td>
<td>0.0</td>
</tr>
<tr>
<td>CTFU=(CLRM / E)x((#RM x Z1+0.5)x(E) -0.5x(E) / 22</td>
<td>0.0</td>
</tr>
<tr>
<td>CIFS=((CLRM/E)x((#RM x Z3 + 0.5)x(E) -0.5x(E)) / 22</td>
<td>0.0</td>
</tr>
<tr>
<td>CRC1 = CIFS x #</td>
<td>0.0</td>
</tr>
<tr>
<td>CD&amp;M = B&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>COMMENTS 62</td>
<td>0.0</td>
</tr>
</tbody>
</table>
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. 03-11-60 System Ground Test Operations
5GW Photovoltaic CR=2

#### Input Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>0.0</td>
</tr>
<tr>
<td>M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>0.0</td>
</tr>
<tr>
<td>PHI</td>
<td>0.0</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
</tr>
<tr>
<td>DF</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Input Coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCER</td>
<td>1.000000</td>
</tr>
<tr>
<td>CIEXP</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### Calculated Values

\[
CD = CDCER \times (T \times DF) \times (CDCEXP) \times CF
\]

\[
CLRM = CIEXP \times (M) \times (CIEXP) \times CF \times TF
\]

\[
\#RM = T / M
\]

\[
E = 1.0 \times \log(\Phi) / \log(2.0)
\]

\[
CTFU = (CLRM / E) \times ((\#RM \times Z1 \times 1.5) \times (E) - 0.5 \times (E))
\]

\[
CIPS = ((CLRM / E) \times ((\#RM \times Z3 \times 0.5) \times (E) - 0.5 \times (E))) / 2P
\]

\[
CRCI = CIPS \times R
\]

\[
CD\&M = CD\&M
\]

Comments: 63

Original page is of poor quality.
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

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 0.0</td>
<td>CDCEP = 0.0</td>
</tr>
<tr>
<td>M = 0.0</td>
<td>CDEXP = 1.000000</td>
</tr>
<tr>
<td>CF = 0.0</td>
<td>CICEP = 0.0</td>
</tr>
<tr>
<td>PHI = 0.0</td>
<td>C1LAP = 1.000000</td>
</tr>
<tr>
<td>R = 0.0</td>
<td></td>
</tr>
<tr>
<td>DF = 0.0</td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- **CD** = CDCEP * (T * DF) * X(CDEXP) * X CF
- **CLRM** = CICER * (M) * X(CICEXP) * X CF * X TF

- **ERM** = T / M
- **E** = 1.0 + LOG(PHI) / LOG(2.0)
- **CTFU** = (CLRM / E) * ((ERM X Z1 + 0.5) X(X(E) - 0.5X(E))

- **CIPS** = ((CLRM/E) X((ERM X Z3 + 0.5) X(X(E) - 0.5X(E))) / Z2

- **CHCI** = CIPS X R
- **CU&M** = O&M
- **COMMENTS** = 31

---

Input Coefficients:

- **CDCEP** = 0.0
- **CDEXP** = 1.000000
- **CICEP** = 0.0
- **C1LAP** = 1.000000

---

5 MILLIONS

- **ERM** = 0.0
- **E** = 0.0
- **CTFU** = 69.349

- **CIPS** = 16.644
- **CHCI** = 0.0
- **CU&M** = 0.072
### TABLE B-33: 03-12-81 GROUND SUPPORT, CONSTRUCTION 53W PHOTOVOLTAIC CN=2

**Input Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1250.0000</td>
</tr>
<tr>
<td>M</td>
<td>1250.0000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>H</td>
<td>0.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0CEP</td>
<td>0.8</td>
</tr>
<tr>
<td>C0EXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CICEP</td>
<td>0.013000</td>
</tr>
<tr>
<td>CICEXP</td>
<td>1.864000</td>
</tr>
</tbody>
</table>

**Calculated Values**

- \( CD = C0CEP \times (T \times DF)^2 \times (C0EXP) \times CF \)
- \( CLRM = CICEP \times (M)^2 \times (CICEXP) \times CF \times TF \)
- \( #RM = T / M \)
- \( E = 1.0 \times \log(\text{PHI}) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times ((#RM \times Z1 + 5)^{2} \times (E) - 0.5 \times (E)) \)
- \( CIPS = ((CLRM / E) \times ((#RM \times Z3 + 0.5)^{2} \times (E) - 0.5 \times (E))) / Z2 \)

**Comments**

- CHCI = CIPS \times H
- CD&M = D&M
- Comments 141
TABLE B-33, 03-12-01 LOGISTICS
SGW PHOTOVOLTAICS, CN=2

INPUT PARAMETERS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>33489000B,0</td>
<td>TF</td>
</tr>
<tr>
<td>M</td>
<td>33489000B,0</td>
<td>Ob/M</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
<td>Z2</td>
</tr>
<tr>
<td>M</td>
<td>0.0</td>
<td>Z3</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

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

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

#RM = T / M

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

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

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

CRCI = CIPS x F

COMMENTS 142

INPUT COEFFICIENTS

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDEEP</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>CDEXP</td>
<td>1.000000</td>
<td></td>
</tr>
<tr>
<td>CICER</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
<td></td>
</tr>
</tbody>
</table>

$MILLIONS
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: 03-12-62 UHITAL OPERATIONS, CONSTRUCTION CHEM
5GW PHOTOLHULTAIC CHEM

#### INPUT PARAMETERS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>160.000000</td>
</tr>
<tr>
<td>M</td>
<td>160.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
<tr>
<td>T9</td>
<td>1.000000</td>
</tr>
<tr>
<td>Z1</td>
<td>4.000000</td>
</tr>
<tr>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>Z3</td>
<td>123.000000</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

\[ CD = CDCEF \times (T \times DF) \times (CDEXP) \times CF \]
\[ CLR = CICER \times (M) \times (CICEXP) \times CF \times TF \]
\[ CRM = T / M \]
\[ E = 1.0 + \log(PHI) / \log(2.0) \]
\[ CTFU = (CLR / E) \times ((CRM \times Z1 + 0.5) \times X(E) - 0.5 \times X(E)) \]
\[ CIPS = ((CLR / E) \times ((CRM \times Z3 + 0.5) \times X(E) - 0.5 \times X(E))) / Z2 \]

### INPUT COEFFICIENTS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEF</td>
<td>0.0</td>
</tr>
<tr>
<td>CICER</td>
<td>1.000000</td>
</tr>
<tr>
<td>CDEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CLR</td>
<td>0.015600</td>
</tr>
<tr>
<td>CICEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CICP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

#### MILLIONS

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEF</td>
<td>0.0</td>
</tr>
<tr>
<td>CICER</td>
<td>2.496</td>
</tr>
<tr>
<td>CRM</td>
<td>1.000</td>
</tr>
<tr>
<td>E</td>
<td>1.000</td>
</tr>
<tr>
<td>CTFU</td>
<td>9.944</td>
</tr>
<tr>
<td>CIPS</td>
<td>2.55R</td>
</tr>
</tbody>
</table>

#### COMMENTS

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>143</td>
</tr>
</tbody>
</table>
TABLE B-35  03-12-02 UNRITAL OPERATIONS: OPERATIONS CHECK
50W PHOTOVOLTAIC CH=2

INPUT PARAMETERS   INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>T</th>
<th>1140.000000</th>
<th>TF</th>
<th>1.000000</th>
<th>CUCER</th>
<th>0.0</th>
<th>CUFAP</th>
<th>1.000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>1140.000000</td>
<td>OIK</td>
<td>17.78397</td>
<td>CUCER</td>
<td>0.0</td>
<td>CUFAP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.00000000</td>
<td>ZI</td>
<td>1.000000</td>
<td>CICER</td>
<td>0.0</td>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.00000000</td>
<td>Z2</td>
<td>120.000000</td>
<td>CICER</td>
<td>0.0</td>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.00000000</td>
<td>Z3</td>
<td>120.000000</td>
<td>CICER</td>
<td>0.0</td>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.00000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD = CUCER X (T X DF) X X (CDEXP) X CF
CLRM = CICER X (M) X X (CIEXP) X CF X TF

RM = T / M

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

CTFU = (CLRM / E) X ((#RM X ZI + 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)) / 2

CMCI = CIPS X R

COMMENTS 144
### TABLE B-36. 03-12-02 DIGITAL OPERATIONS: CONST. PHIV.
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_w ) = 210250.000</td>
<td>( T_f = 2.000000 )</td>
</tr>
<tr>
<td>( M = 210250.000 )</td>
<td>( \phi = 0.0 )</td>
</tr>
<tr>
<td>( CF = 1.000000 )</td>
<td>( \psi F = 1.000000 )</td>
</tr>
<tr>
<td>( PHI = 1.000000 )</td>
<td>( \psi I = 0.000622 )</td>
</tr>
<tr>
<td>( R = 0.0 )</td>
<td>( \psi II = 1.000000 )</td>
</tr>
<tr>
<td>( DF = 1.000000 )</td>
<td>( \psi III = 1.000000 )</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

\[ CD = CDCER \times (T \times DF) \times (CL \times EXP) \times CF \]
\[ CLR M = ICER \times (M) \times (CL \times EXP) \times CF \times \psi F \]
\[ RM = T / M \]
\[ E = 1.0 + \log(PHI) / \log(2.0) \]
\[ CIFU = (CLRM / E) \times ((RM \times 2) \times \psi (E) - 0.5 \times \psi (E)) \]
\[ CIPS = ((CLRM/E) \times ((RM \times 2 + 0.5) \times \psi (E) - 0.5 \times \psi (E))) / 72 \]
\[ CRCI = CIPS \times R \]
\[ CLRM = OAM \]

**COMMENTS** 145

\[ # MILLIONS \]
\[ 0.0 \]
\[ 4.647 \]
\[ 1.000 \]
\[ 1.000 \]
\[ 18.546 \]
\[ 4.763 \]
\[ 0.0 \]
\[ 0.0 \]
### Table B-37. 03-12-02 Optical Operations, OPS. Proc.

<table>
<thead>
<tr>
<th>SBW Photovoltaic Cn=2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input Parameters</strong></td>
</tr>
<tr>
<td>( T ) = 1490000.00</td>
</tr>
<tr>
<td>( M ) = 1490000.00</td>
</tr>
<tr>
<td>( CF ) = 1.000000</td>
</tr>
<tr>
<td>( PHI ) = 1.000000</td>
</tr>
<tr>
<td>( \Omega ) = 0.0</td>
</tr>
<tr>
<td>( DF ) = 1.000000</td>
</tr>
<tr>
<td>( z_1 ) = 120.000000</td>
</tr>
<tr>
<td>( z_2 ) = 120.000000</td>
</tr>
</tbody>
</table>

**Calculated Values**

\[
CD = CDGEX \times (T \times DF) \times (C1E1 \times CF) \\
C1RM = C1CER \times (M) \times (C1E1 \times CF) \times T \\
\#RM = T / M \\
E = 1.0 + \log(\text{PHI}) / \log(2.0) \\
CTFV = (C1RM / E) \times ((\#RM \times Z1+5) \times (E) - 0.5 \times (E)) \\
CIPS = ((C1RM/E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / 2 \%
\]

**Comments**

146
TABLE B-38. 03-12-02 ORBITAL OPERATIONS; CONST. E = MS
5GWP PHOTONI IC C#2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 116800.000</td>
<td>CDCE# = 0.0</td>
</tr>
<tr>
<td>M = 116800.000</td>
<td>CF# = 1.6800000000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CI# = 0.00015</td>
</tr>
<tr>
<td>PHI = 1.000000</td>
<td>CIEX# = 1.000000</td>
</tr>
<tr>
<td>R = 0.0</td>
<td></td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD=CDCE# x (T x DF) x (CIEX#) x CF

CLRM=CI# x (M) x (CIEX#) x CF x TF

#RM = T / M

E = 1.0 x 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)) / X(E))

CHCI = CIPS x H

CO&M = O&M

COMMENTS 147
### Table B-39: 03-12-02 orbital operations, ops. EMS

5GW photovoltaic cr=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 832200.000</td>
<td>CURET = 0.0</td>
</tr>
<tr>
<td>M = 832200.000</td>
<td>CDF = 1.000000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CDF XIP = 1.000000</td>
</tr>
<tr>
<td>PHI = 1.000000</td>
<td>C1CEF = 0.0</td>
</tr>
<tr>
<td>R = 0.0</td>
<td>C1EXP = 1.000000</td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATED VALUES</th>
<th>MILLIONS</th>
</tr>
</thead>
</table>

\[ CD = CDFX \times (T \times DF) \times (CDFX) \times CF \]
\[ CLRM = CDFX \times (M) \times (CDFX) \times CF \times TF \]
\[ \#RM = T / M \]
\[ E = 1.0 + \log(\text{PHI}) / \log(2.0) \]
\[ CTFU = (CLRM / E) \times ([\#RM \times Z1 \times 0.5] \times (E) - 0.5 \times (E)) \]
\[ CIPE = ([CLRM/E] \times ([\#RM \times Z3 \times 0.5] \times (E) - 0.5 \times (E)) \] / Z2

CFIC = CIPE \times R

CDFM = 0.0

COMMENTS 14B
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 CH=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>T</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>0.0</td>
</tr>
<tr>
<td>PHI</td>
<td>0.0</td>
</tr>
<tr>
<td>P</td>
<td>0.0</td>
</tr>
<tr>
<td>DF</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- \( CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF \)
- \( CLRM = CICEP \times (M) \times (CIEXP) \times CF \times TF \)
- \( #RM = T / M \)
- \( E = 1.0 + \log(\Phi) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times ((#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \)
- \( CIPS = ((CLRM / E) \times ((#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \)

**INPUT COEFFICIENTS**

- \( CDCEP = 0.10 \times 10^{00} \)
- \( CDEXP = 0.0 \)
- \( CICEP = 0.0 \)
- \( CIEXP = 0.0 \)

\( %, MILLIONS \)

- \( CD = 849.437 \)
- \( CLRM = 0.0 \)
- \( #RM = 0.0 \)
- \( E = 0.0 \)
- \( CTFU = 0.0 \)
- \( CIPS = 0.0 \)
- \( CRCI = CIPS \times R \)
- \( CD\&M = CD\&M \)

**COMMENTS**

65
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:

\[
\begin{align*}
CD &= \text{Ground Station System DDT&E Cost (04-03-00 thru 04-07-00) plus SE&I Cost} \\
CTFU &= \text{Ground Station System TFU Cost (04-03-00 thru 04-07-00) plus SE&I Cost} \\
CIPS &= \text{Ground Station System Inv. per Sat. Cost (04-03-00 thru 04-07-00) plus SE&I Cost} \\
CRCI &= \text{Ground Station System Cost (04-03-00 thru 04-07-00) plus SE&I Cost} \\
CO&M &= \text{Ground Station System O&M Cost (04-03-00 thru 04-07-00)}
\end{align*}
\]

B-86
<table>
<thead>
<tr>
<th>I = 0.0</th>
<th>TF = 0.0</th>
<th>CDCEP = 0.020000</th>
</tr>
</thead>
<tbody>
<tr>
<td>M = 0.0</td>
<td>D&amp;K = 0.0</td>
<td>CLXR = 0.010000</td>
</tr>
<tr>
<td>CF = 0.0</td>
<td>Z1 = 1.000000</td>
<td>CICRE = 0.010000</td>
</tr>
<tr>
<td>PHI = 0.0</td>
<td>Z2 = 120.000000</td>
<td>CIFAP = 0.010000</td>
</tr>
<tr>
<td>R = 0.0</td>
<td>Z3 = 120.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
C_D = CDCEP \times (T \times DF) \times (CDFXP) \times CF
\]

\[
C_{LRM} = CICRE \times (M) \times (CIFXP) \times CF \times TF
\]

\[
RM = \frac{T}{M}
\]

\[
E = 1.0 \times \frac{\log(\Phi)}{\log(2.0)}
\]

\[
CTFU = \frac{(CLRM/E)}{\left(\frac{(RM \times Z1 + 0.5) \times E}{-0.5 \times E}\right)}
\]

\[
CIPS = \left(\frac{(CLRM/E)}{\left(\frac{(RM \times Z3 + 0.5) \times E}{-0.5 \times E}\right)}\right) / Z2
\]

\[
CSCI = CIPS \times R
\]

\[
CUM = RM \times CDF
\]

**COMMENTS**

70
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 8-42.

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

\[\begin{align*}
\text{CD} & = \text{Ground Station System DDT&E Cost (04-03-00 thru 04-07-00)} \\
\text{CTFU} & = \text{Ground Station System TFU Cost (04-03-00 thru 04-07-00)} \\
\text{CIIPS} & = \text{Ground Station System INV per Satellite cost (04-03-00 thru 04-07-00)} \\
\text{CRCI} & = \text{Ground Station System Cost (04-03-00 thru 04-07-00)}
\end{align*}\]
### Table 8-42. 04-02-00 555-SF and 1 SGW Photovoltaic CR=2

#### INPUT PARAMETERS

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>0.0</td>
<td>TF</td>
<td>0.0</td>
</tr>
<tr>
<td>M</td>
<td>0.0</td>
<td>CM</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>0.0</td>
<td>71</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.0</td>
<td>22</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
<td>Z3</td>
<td>120.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- \( CD = C Peters \times (T \times DF) \times (C Peters) \times CF \)
- \( CLRM = C Peters \times (M) \times (C Peters) \times CF \times TF \)
- \( E = 1.0 \times \log (PHI) / \log (2.0) \)
- \( CTFU = CLRM / E \times (\#RM \times 21 \times 5) \times (E) = 0.5 \times (E) \)
- \( CIPS = (CLRM / E) \times (\#RM \times 23 \times 0.5) \times (E) = 0.5 \times (E) \)
- \( CRCI = CIPS \times R \)
- \( C0 \& M = 0 \& M \)
- COMMENTS: 7

#### INPUT COEFFICIENTS

- \( CUEC = 0.100000 \)
- \( CUEC = 0.070000 \)
- \( CIEF = 0.070000 \)
- \( CIEF = 0.0 \)

**3 MILLIONS**

- 11.747
- 0.0
- 0.0
- 0.0

**169.998**

- 156.778
- 0.755
- 0.0
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 till-faced array structures. The concept selected was one which employs thin-sheet (.020 inches) preformed hat sections; standard sized (8-inch) l-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 l-beams which, in turn, are bolted to the tubular braces. The l-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 weighs approximately 2,200 kilograms (4,800 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. "Steps" 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 HEC Tenna, Dipole/Rectifier 53W Photovoltaic CR=2

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<table>
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#### CALCULATED VALUES

- **CD** = CJCER X (T X DF) X X (CDEXP) X CF
- **CLRM** = CICEP X (M) X X (CIEXP) X CF X TF

- **RMM** = T / M
- **E** = 1.0 + LOG(PHI) / LOG(2.0)
- **CTFUM** = (CLRM / E) X ((RMM X Z1 + 0.5) X X (E) - 0.5X(E))
- **CIPS** = ((CLRM/E) X ((RMM X Z3 + 0.5) X X (E) - 0.5X(E))) / Z2
- **RCRI** = CIPS X R
- **C00M** = 0.0

#### COMMENTS

176
### Table B-44: 04-03-02 Rectenna, Power Dist. Cond.
5% Photovoltaic Cr=2

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<tr>
<td>CIEXP</td>
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#### CALCULATED VALUES

- $CD = CDGCER \times (T \times DF) \times (CDEXP) \times CF$
- $CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF$
- $\#RM = T / M$
- $E = 1.0 \times \log(PHI) / \log(2.0)$
- $CTFU = (CLRM / E) \times ((\#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$
- $CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2$
- $CHCI = CIPS \times R$
- $CD\&M = D\&M$
- COMMENTS 177
### Table B-45. 04-03-03 Hectenna, Support and Ground Plane 53w Photovoltaic Cm=2

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<tr>
<td>DF</td>
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### Calculated Values

C0 = CUCER X (T X DF) X (CIEXP) X CF

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

#RM = T / M

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

CTFU = (CLRM / E) X ((#RM X Z1 + 0.5) 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)) / 22

CRCI = CIPS X R

CD&M = O&M

Comments 17b
### TABLE B-46.  04-03-94 RECENTNA, DOYLE
50W PHOTOVOLTAIC CH=2

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<tr>
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<tr>
<td>OF=</td>
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</table>

#### CALCULATED VALUES

- CD=CDCER X (T X OF) X X(CDEXP) X CF
- CLRM=CICER X (M) X X(CIEXP) X CF X TF
- #RM = T / M
- E = 1.0 + LOG(PHI) / LOG(2.0)
- CTFU = (CLRM / E) X ((#RM X Z1 + 0.5 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
- CULM = D&M

**COMMENTS**: 179
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>
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<tr>
<td>T_ = 1.000000</td>
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<td>M_ = 1.000000</td>
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<tr>
<td>CF_ = 1.000000</td>
<td>CIEXP = 50.000000</td>
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<tr>
<td>PHI_ = 0.980000</td>
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</tr>
<tr>
<td>R_ = 0.010000</td>
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<tr>
<td>DF_ = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

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

CLRME = CIEXP X (M) X (CIEXP) X CF X CF

NRM = T / M

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

CTFU = (CLRME / E) X ((NRM X (1+5) X X(E) - 0.5 X X(E))

CIPS = ((CLRME/E) X ((NRM X Z3 + 0.5) X X(E) - 0.5 X X(E)) / Z2

CRCI = CIPS X M

CQ&M = O&M

COMMENTS 42
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 8-48.

Range of Data

DDT&E and ICI: 1.44 and 2.2 gigawatts
<table>
<thead>
<tr>
<th>TABLE B-48. 04-05-00 GSS-UTILITY INTERFACE</th>
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<tr>
<td>5GW PHOTOVOLTAIC CR=2</td>
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**INPUT PARAMETERS**

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**INPUT COEFFICIENTS**

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**CALCULATED VALUES**

- \[ CD = CD_{CICER} \times (T \times DF) \times (CI_{EXP}) \times CF \]
- \[ CLRM = CI_{CICER} \times (M) \times (CI_{EXP}) \times CF \times TF \]
- \[ \#RM = T / M \]
- \[ E = 1.0 + \log(PHI) / \log(2.0) \]
- \[ CFU = (CLRM / E) \times ((\#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \]
- \[ CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2 \]
- \[ CR_CICER = CIPS \times R \]
- \[ CDLM = DLM \]
- **COMMENTS** 43

**UNIT MILLIONS**

- \[ 99.820 \]
- \[ 311.972 \]
- \[ 1.000 \]
- \[ 0.971 \]
- \[ 332.923 \]
- \[ 297.153 \]
- \[ 2.972 \]
- \[ 2.072 \]
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. 04-06-01 655-LAND AND PREPARATION
5GW PHOTOVOLTAIC CH=2

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<td>OF: 1.000000</td>
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**CALCULATED VALUES**

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

CLR = CICER X (M) X (CIEXP) X CF X £F

WR = T / M

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

CTFU = (CLR / E) X (((WRM X Z1 + 0.5) X (E) - 0.5) X (E))

CIPS = (((CLR / E) X (((WRM X Z3 + 0.5) X (E) - 0.5) X (E))) / Z2

CRCl = CIPS X R

CD£M = D£M

**COMMENTS**

44
### Table B-50.  04-06-02 GSS-ROADS AND FENCEs
5Gw PHOTOVOLTAIC: CR=2

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**CALCULATED VALUES**

- $CD = C\ C\ CE\ R\ \ X\ (T\ \ DF)\ \ X\ \ (C\ \ EXP)\ \ X\ \ CF$
- $CLRM = G\ C\ E\ R\ X\ (M)\ \ X\ \ (C\ \ EXP)\ \ X\ \ CF\ \ X\ \ TF$
- $RM = T / M$
- $E = 1.0 + \log(PHI) / \log(2.0)$
- $CTFU = (CLRM / E) \times ((RM \times Z1 + 0.5) \times (E) - 0.5 \times (E))$
- $CIPS = ((CLRM / E) \times ((RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2$
- $CRCI = CIPS \times R$
- $CD&M = D&M$
- $COMMENTS = 45$
TABLE B-51. 04-06-03 GSU-UTILITIES
50W PHOTOVOLTAIC CH=2

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INPUT COEFFICIENTS

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<td>CDEXP</td>
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<td>1.000000</td>
</tr>
<tr>
<td>CICER</td>
<td>331.399982</td>
<td>331.399982</td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD=CDCER X (T X DF)XX(CDEXP)X CF
CLRM=CICER X (M)XX(CIEXP)X CF X TF
RM = T / M
E = 1.0 + LOG(PHI) / LOG(2.0)
CTF = (CLRM / E)X((RM X Z1+.5)X(E) - 0.5X(E))
CIPS=((CLRM/E)X((RM X Z3 + 0.5)X(E) - 0.5X(E)) / Z2
CRCI = CIPS X M
C0&M = 0&M
COMMENTS 45
### TABLE B-52: 04-06-04 G55-BUILDINGS
5GW PHOTOVOLTAIC CH2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 120000.000</td>
<td>CDGER = 0.0</td>
</tr>
<tr>
<td>M = 120000.000</td>
<td>CUF XP = 1.000000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICER = 0.060000</td>
</tr>
<tr>
<td>PHI = 1.000000</td>
<td>C1 XP = 1.000000</td>
</tr>
<tr>
<td>R = 0.0</td>
<td></td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- CD = CDGER X (T X DF) X (CD EXP) X CF
- CLR M = CICER X (M) X (C1 EXP) X CF X TF
- #RM = T / M
- E = 1.0 + LOG(PHI) / LOG(2.0)
- CTF U = (CLR M / E) X ((#RM X Z1 + 5) X (E) - 0.5 X (E))
- CIPS = (CLR M / E) X ((#RM X Z3 + 0.5 X (E) - 0.5 X (E)) X Z2
- CR Ci = CIPS X R
- CD & M = D & M
- COMMENTS 47

0.0

$\text{BILLIONS}$

0.8

4.800

1.000

1.000

4.800

4.800

0.0

0.0

0.0

0.0

47
### Table 8-53.

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 1.000000</td>
<td>TF = 1.000000</td>
</tr>
<tr>
<td>M = 1.000000</td>
<td>U&amp;M = 0.0</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>Z1 = 1.000000</td>
</tr>
<tr>
<td>PHI = 1.000000</td>
<td>Z2 = 120.000000</td>
</tr>
<tr>
<td>R = 0.0</td>
<td>Z3 = 120.000000</td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- \(\text{CD} = \text{CDECER} \times (T \times DF)\times(CDEXP) \times CF\)
- \(\text{CLRM} = \text{CICEP} \times (M)\times(CIEXP) \times CF \times TF\)
- \(\text{RM} = T / M\)
- \(E = 1.0 \times \log(PHI) / \log(2.0)\)
- \(\text{CTFU} = (\text{CLRM} / E) \times (\text{RM} \times Z1 + 0.5) \times (E) - 0.5XX(E)\)
- \(\text{CIPS} = (\text{CLRM} / E) \times (\text{RM} \times Z3 + 0.5) \times (E) - 0.5XX(E)\) / 22

**COMMENTS** 48
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 MAIN Personnel
5GW PHOTOVOLTAIC. CH=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>1.000000</td>
</tr>
<tr>
<td>M</td>
<td>1.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDECF</td>
<td>0.0</td>
</tr>
<tr>
<td>CDEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CICEF</td>
<td>0.0</td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- CD = CDECF x (T x DF) x (CDEXP) x CF
- CLRM = CICER x (M x CIEXP) x CF x TF
- #RM = T / M
- E = 1.0 + LOG(Phi) / LOG(2.0)
- CTFU = (CLRM / E) x ((#RM x Z1 + 0.5) x (E - 0.5 x (E))
- CIPS = (CLRM / E) x ((#RM x Z3 + 0.5) x (E - 0.5 x (E)) / Z2
- CRCI = CIPS x R
- CD & M = Q&M
- COMMENTS 49

**MONITOR: 0.14**
TABLE B-55. RO-07-02 GSS-MAINTENANCE MATERIAL NO. PHOTOVOLTAIC CH2

SGW PHOTOVOLTAIC CH2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=1.000000</td>
<td>CDCEP=1.000000</td>
</tr>
<tr>
<td>H=1.000000</td>
<td>CDEXP=1.000000</td>
</tr>
<tr>
<td>CF=1.000000</td>
<td>C1ERP=0.000000</td>
</tr>
<tr>
<td>PHI=1.000000</td>
<td>C1EXP=1.000000</td>
</tr>
<tr>
<td>R=0.010000</td>
<td></td>
</tr>
<tr>
<td>DF=1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

\[ CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF \]
\[ CLR = C1ERP \times (H) \times (C1EXP) \times CF \times TF \]
\[ \#RM = T / M \]
\[ E = 1.0 \times \log(\text{PHI}) / \log(2.0) \]
\[ CTFU = (CLR / E) \times (10^{\#RM \times Z1 + 5}) \times 0.5 \times E - 0.5 \times E \]
\[ CIPS = (\text{CLR} / E) \times (10^{\#RM \times Z3 + 0.5}) \times E - 0.5 \times E \]

\[ \text{CRI} = \text{CIPS} \times R \]
\[ \text{CD} & \text{M} = \text{O} & \text{M} \]

COMMENTS: 50
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 R-56. 05-01-01 LE0 = CHM
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

<table>
<thead>
<tr>
<th>T</th>
<th>M</th>
<th>CF</th>
<th>PHI</th>
<th>R</th>
<th>OF</th>
</tr>
</thead>
<tbody>
<tr>
<td>27000.000</td>
<td>27000.000</td>
<td>1.000000</td>
<td>1.000000</td>
<td>0.050000</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>CjCER</th>
<th>CDEXF</th>
<th>CICER</th>
<th>CIEXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.009714</td>
<td>1.000000</td>
<td>0.003770</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

CALCULATED VALUES

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

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

RM = T / M

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

CTFU=(CLRM / E) X ((RM X Z1 + 0.5) X (E) X 0.5 X (E))

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

CRCI = CIPS X R

CD&M = D&M

COMMENTS 151

%.MILLIONS

262.278

101.790

1.000

1.000

101.790

0.848

0.842

0.0
### TABLE B-57. 05-01-02 LEOP CS/VEWA  
5GW PHOTOVOLTAIC CH=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>T</th>
<th>27000.0000</th>
<th>TF</th>
<th>1.000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>27000.0000</td>
<td>D&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>1.000000</td>
</tr>
<tr>
<td>PM</td>
<td>1.000000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.000000</td>
<td>Z3</td>
<td>1.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALculated VALUES**

CD\(=COCER \times (T \times DF)^{\times(CIEXP)} \times CF\)  

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

\(#RM = T / M\)  

E\( = 1.0 + \log(PHI) / \log(2.0)\)  

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

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

CHCI = CIPS \times H  

CD&M = D&M  

COMMENTS 152
### TABLE B-8

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>27000.000</td>
</tr>
<tr>
<td>M</td>
<td>27000.000</td>
</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
</tr>
<tr>
<td>PM</td>
<td>0.0500000</td>
</tr>
<tr>
<td>R</td>
<td>1.0000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.0000000</td>
</tr>
</tbody>
</table>

#### INPUT PARAMETERS

- **T**: Temperature
- **M**: Molecular Weight
- **CF**: Concentration Factor
- **PM**: Pressure
- **R**: Rate
- **DF**: Density Factor

#### INPUT COEFFICIENTS

- **CDEP**: 0.129
- **CID**: 0.0
- **DCEP**: 0.091296
- **CDEXP**: 1.000000

#### CALCULATED VALUES

- **CD**: \( CD = CDEP \times (T \times DF)^{0.5} \times (CDEXP) \times CF \)
- **CLRm**: \( CLRm = CICER \times (M)^{0.5} \times (CIELXP) \times CF \times TF \)
- **E**: \( E = \frac{T}{M} \)
- **E**: \( E = 1.0 + \log(PHI) / \log(2.0) \)
- **CIFU**: \( CIFU = (CLRm/E) \times ((WM \times Z1 + 0.5) \times E) - 0.5 \times E(1) \)
- **CIPS**: \( CIPS = ((CLRm/E) \times ((WM \times Z3 + 0.5) \times E) - 0.5 \times E(1)) \times Z2 \)
- **CRC**: \( CRC = CIPS \times R \)
- **CDM**: \( CDM \times DLM \)

#### Comments

153
### TABLE B-59. 05-01-04 LFO - PM
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 100.000000</td>
<td>CDCCER= 1.900000</td>
</tr>
<tr>
<td>M= 100.000000</td>
<td>CUEXP= 1.000000</td>
</tr>
<tr>
<td>CF= 1,000000</td>
<td>C1CER= 1.425000</td>
</tr>
<tr>
<td>PHI= 1,000000</td>
<td>CICXP= 1.000000</td>
</tr>
<tr>
<td>k= 0.650000</td>
<td>Z1= 1.000000</td>
</tr>
<tr>
<td>DF= 0.200000</td>
<td>Z2= 120.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
CD = CDCCER \times (T \times DF) \times (CDEXP) \times CF
\]

\[
CLRM = C1CER \times (M) \times (CIEXP) \times CF \times TF
\]

\[
RM = \frac{T}{M}
\]

\[
E = 1.0 \times \frac{\log(PHI)}{\log(2.0)}
\]

\[
CTF = (CLRM / E) \times ((RM \times Z1 + 0.5) \times (E) - 0.5 \times (E))
\]

\[
CIPS = ((CLRM / E) \times ((RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2
\]

CRCI = CIPS \times R

C0&M = 0&M

**COMMENTS** 154

**% MILLIONS**

38,000

142.500

1,000

1,000

142.500

1.14

0.059

0.0
This element includes the GEO construction base and the space base onboard 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:

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

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) houses the operational communications and control systems for the base. Power Modules (PM) are photovoltaic power systems (collectors, converters, conditioners and storage) which support all base power requirements. Pressurized Storage Modules (PSM) provide an area for storage and workshop accommodations. Shielding (SHD) is provided in selected modules to protect against solar flare radiation. The Crew Support Module (SM) provides the galley, recreational and medical facilities and support subsystems for 48 to 60 crew members.
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
5GW PHOTOVOLTAIC CR=2

#### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>2500.0000</td>
</tr>
<tr>
<td>M</td>
<td>2500.0000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.980000</td>
</tr>
<tr>
<td>R</td>
<td>0.100000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T_F</td>
<td>1.000000</td>
</tr>
<tr>
<td>U&amp;M</td>
<td>0.000000</td>
</tr>
<tr>
<td>Z1</td>
<td>40.000000</td>
</tr>
<tr>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>Z3</td>
<td>516.000000</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- \( CD = CDCER \times (T \times DF) \times \text{CDEXP} \times \text{CF} \)
- \( CLRM = CICER \times (M) \times \text{CIEXP} \times \text{CF} \times T_F \)
- \( \#RM = T / M \)
- \( E = 1.0 + \log(PHI) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times ((\#RM \times Z1 + \#5) \times (E - 0.5 \times (E)) \)
- \( CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E - 0.5 \times (E))) / Z2 \)
- \( CRI = CIPS \times R \)
- \( CO&M = D&M \)
- **COMMENTS** 155

\( *\text{MILLIONS} \)

<table>
<thead>
<tr>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>31.152</td>
</tr>
<tr>
<td>15.090</td>
</tr>
<tr>
<td>1.000</td>
</tr>
<tr>
<td>0.971</td>
</tr>
<tr>
<td>557.187</td>
</tr>
<tr>
<td>55.697</td>
</tr>
<tr>
<td>5.57n</td>
</tr>
<tr>
<td>0.0</td>
</tr>
</tbody>
</table>
### Table B-67. 05-02-02 GEU - CHM

**5G* PHOTOVOLTAIC CH=2**

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 27000.000</td>
<td>CDCLP= 0.009714</td>
</tr>
<tr>
<td>M= 27000.000</td>
<td>CDLXP= 1.000000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CICER= 0.0003770</td>
</tr>
<tr>
<td>PHI= 0.950000</td>
<td>C1EXF= 1.000000</td>
</tr>
<tr>
<td>R= 0.050000</td>
<td></td>
</tr>
<tr>
<td>DF= 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
CD = CDCLP \times (T \times DF)^{2} \times (CI\cdot EXP) \times CF
\]

\[
CLRM = CICER \times (M)^{2} \times (CI\cdot EXP) \times CF \times T
\]

\[
#RM = T / M
\]

\[
E = 1.0 \times \log\left(\text{PHI}\right) / \log\left(2.0\right)
\]

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

\[
CIPS = ((CLRM / E) \times ((#RM \times Z3 + .5) \times X(E) - 0.5 \times X(E)) \times R)
\]

\[
CRCI = CIPS \times R
\]

\[
CO&M = D&M
\]

**COMMENTS 156**

8,926

2456.487

252.278

181.790

6.000

26.74

93.475

4.674

0.0
**TABLE 8-62. 05-02-03 GEO - CLM**

5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tf</strong> = 1.000000</td>
<td><strong>CDGCR</strong> = 0.053000</td>
</tr>
<tr>
<td><strong>M</strong> = 5000.0000</td>
<td><strong>CDGEX</strong> = 1.000000</td>
</tr>
<tr>
<td><strong>CF</strong> = 1.000000</td>
<td><strong>CDIEX</strong> = 0.014000</td>
</tr>
<tr>
<td><strong>PHI</strong> = 0.950000</td>
<td><strong>P</strong> = 1.000000</td>
</tr>
<tr>
<td><strong>R</strong> = 0.050000</td>
<td><strong>R</strong> = 1.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\text{CD} = \text{CDGCR} \times (T \times DF) \times (CDGEX) \times CF
\]

\[
\text{CLRM} = \text{CLM} \times (M) \times (CDIEX) \times CF \times TF
\]

\[
NRM = T / M
\]

\[
E = 1.0 \times \log(\text{PHI}) / \log(2.0)
\]

\[
\text{CTF} = \left(\text{CLRM} / E\right) \times \left(\left(NRM \times Z1 + 5\right) \times \left(E - 0.5 \times (E)\right)\right)
\]

\[
\text{CIPS} = \left(\left(\text{CLRM} / E\right) \times \left(\#RM \times Z3 + 0.5\right) \times (E) - 0.5 \times (E)\right) / 22
\]

\[
\text{CRCI} = \text{CIPS} \times R
\]

\[
\text{CDGEX} = 0.0\text{M}
\]

**COMMENTS** 157
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>( T )</th>
<th>( M )</th>
<th>( DF )</th>
<th>( C_{\text{DF}} )</th>
<th>( C_{\text{CF}} )</th>
<th>( C_{\text{PHI}} )</th>
<th>( R )</th>
<th>( C_{\text{EI}} )</th>
<th>( C_{\text{EXP}} )</th>
<th>( C_{\text{E}} )</th>
<th>( C_{\text{RM}} )</th>
<th>( C_{\text{TF}} )</th>
<th>( C_{\text{CI}} )</th>
<th>( C_{\text{CM}} )</th>
<th>( C_{\text{COMMENTS}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_f )</td>
<td>1.000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td>158</td>
</tr>
<tr>
<td>( M )</td>
<td>27000.0000</td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>158</td>
</tr>
<tr>
<td>( C_{\text{DF}} )</td>
<td>1.000000</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>158</td>
</tr>
<tr>
<td>( C_{\text{PHI}} )</td>
<td>0.950000</td>
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<td></td>
<td>158</td>
</tr>
<tr>
<td>( R )</td>
<td>0.050000</td>
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<tr>
<td>( C_{\text{EI}} )</td>
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<tr>
<td>( C_{\text{EXP}} )</td>
<td>1.000000</td>
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<tr>
<td>( C_{\text{EI}} )</td>
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<td></td>
<td></td>
<td>158</td>
</tr>
<tr>
<td>( C_{\text{EXP}} )</td>
<td>1.000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>158</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- \( CD = C_{\text{DF}} \times T \times DF \times \left( C_{\text{EI}} \times C_{\text{EXP}} \right) \times CF \)
- \( C_{\text{RM}} = C_{\text{EI}} \times (1.0) \times \left( C_{\text{EI}} \times C_{\text{EXP}} \right) \times CF \times T_f \)
- \( E = 1.0 \times \log(\text{PHI}) / \log(2.0) \)
- \( C_{\text{TFU}} = (C_{\text{RM}} / E) \times (\text{RM} + 0.5) \times (E - 0.5) \times (E) \)
- \( C_{\text{CIP}} = ((\text{CIP} / E) \times (\text{RM} + 0.5) \times (E) - 0.5) \times (E) \)
- \( C_{\text{CRI}} = C_{\text{CIP}} \times H \)
- \( C_{\text{CM}} = C_{\text{CM}} \times H \)

**COMMENTS** 158

- \( 2464.996 \times \text{MILLIONS} \)
- \( 1.000 \times \text{MILLIONS} \)
- \( 0.392 \times \text{MILLIONS} \)
- \( 1448.660 \times \text{MILLIONS} \)
- \( 241.697 \times \text{MILLIONS} \)
- \( 12.994 \times \text{MILLIONS} \)
- \( 0.0 \times \text{MILLIONS} \)
TABLE B-64. 05-02-05 GEU - CSM-EVA
SGW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 27000.000</td>
<td>T= 1.000000</td>
</tr>
<tr>
<td>M= 27000.000</td>
<td>M= 0.000000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CF= 1.000000</td>
</tr>
<tr>
<td>PM1= 0.950000</td>
<td>Z1= 1.000000</td>
</tr>
<tr>
<td>R= 0.050000</td>
<td>Z2= 120.000000</td>
</tr>
<tr>
<td>DF= 1.000000</td>
<td>Z3= 120.000000</td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD = CDCE R X (T X DF) X (CDEXP X CF)

CLRM = CICER X (M) X (CIE XP X CF X T)

#PM = T / M

E = 1.0 + LOG(PM1) / LOG(2.0)

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

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

CRCI = CIPS X R

C0&H = 0&M

COMMENTS 159

$ MILLIONS

335.664
156.546
1.000
0.926
157.112
118.340
5.917
0.0
TABLE 8-65. 05-02-06 GEO - PM  
5GW PHOTOVOLTAIC CR=2

INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>T</td>
<td>250.000000</td>
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<tr>
<td>M</td>
<td>250.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>R</td>
<td>0.050000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CDEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD = CDCEP X (T X DF) X (CDEXP) X CF
CLRM = CIEXP X (M) X (CDEXP) X CF X TF

Here is a calculation example:

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

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

CTF = (CLRM / E) X ((#RM X Z1 + 0.5) X (E) - 0.5 X (E))

CIPS = ((CLRM / E) X ((#RM X Z3 + 0.5) X (E) - 0.5 X (E))) / 2

CRCI = CIPS X R

COMMENTS 160
### TABLE 8-66. 05-02-07 GLO - PSM
5GW PHOTOVOLTAIC CH=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>15000.0000</td>
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<tr>
<td>M</td>
<td>15000.0000</td>
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<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>M</td>
<td>0.050000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
CD = CD_CER \times (T \times DF) \times (CD_EXP) \times CF
\]

\[
CLRM = CICER \times (M) \times (CI_EXP) \times CF \times TF
\]

\[
#RM = T / M
\]

\[
E = 1.0 + \log(PHI) / \log(2.0)
\]

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

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

\[
CRCI = CIPS \times R
\]

\[
CD\&M = O\&M
\]

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD_CER</td>
<td>0.052914</td>
</tr>
<tr>
<td>CD_EXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CI_CER</td>
<td>0.013734</td>
</tr>
<tr>
<td>CI_EXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**$MILLIONS**

<table>
<thead>
<tr>
<th>$MILLIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>793.710</td>
</tr>
<tr>
<td>206.010</td>
</tr>
<tr>
<td>1.040</td>
</tr>
<tr>
<td>0.926</td>
</tr>
<tr>
<td>1141.434</td>
</tr>
<tr>
<td>300.770</td>
</tr>
<tr>
<td>15.038</td>
</tr>
<tr>
<td>0.0</td>
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</tbody>
</table>

**COMMENTS**

161
<table>
<thead>
<tr>
<th>TABLE B-67. 05-02-68 GLO - SHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>5GW PHOTOVOLTAIC CR=2</td>
</tr>
</tbody>
</table>

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>TF</th>
<th>Mu</th>
<th>CF</th>
<th>PHI</th>
<th>R</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>11000.000</td>
<td>11000.000</td>
<td>1.000000</td>
<td>0.900000</td>
<td>0.000000</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>CDGECER</th>
<th>CDEXP</th>
<th>CICER</th>
<th>CILXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.156000</td>
<td>1.000000</td>
<td>0.101000</td>
<td>0.355000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- CD = CDGECER \times (T \times DF) \times (CD\text{EXP}) \times CF
- CLRM = CICER \times (M) \times (C\text{IEXP}) \times CF \times TF
- \#RM = T / M
- E = 1.0 + \log(PHI) / \log(2.0)
- CTFU = (CLRM / E) \times ((\#RM \times Z1 \times 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
- CD\&M = M\&M
- COMMENTS 162
**TABLE B-68. 05-02-09 GEO - SM**
**5GW PHOTOVOLTAIC CR=2**

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tm</td>
<td>15060.0000</td>
</tr>
<tr>
<td>M</td>
<td>15000.0000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>R</td>
<td>0.050000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCER</td>
<td>0.0012432</td>
</tr>
<tr>
<td>CDFEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>CICEP</td>
<td>0.885798</td>
</tr>
<tr>
<td>CIEAP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

- **CD** = CDCER × (T × DF) × (CDFEXP) × CF
- **CLRM** = CICER × (M) × (CIEAP) × CF × TF
- **#RM** = T / M
- **E** = 1.0 + LOG(PHI) / LOG(2.0)
- **CTF** = (CLRM / E) × ((#RM × Z1 + 0.5) × (E) - 0.5X(E))
- **CIPS** = ((CLRM / E) × ((#RM × Z3 + 0.5) × (E) - 0.5X(E)) / 2^2
- **CRCI** = CIPS × M
- **CD&M** = D&M
- **COMMENTS** 163

- **$MILLIONS**
  - CD = 185.480
  - CLRM = 86.970
  - #RM = 1.000
  - E = 0.926
  - CTF = 328.691
  - CIPS = 2.739
  - CRCI = 0.137
  - CD&M = 0.0
### Table B-69: 05-02-1C  FAB FIXTURE

#### 5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 20,000,000,00</td>
<td>CDCEP= 0.234,000</td>
</tr>
<tr>
<td>M= 25,000,000,00</td>
<td>CDEXP= 0.653,000</td>
</tr>
<tr>
<td>CF= 1,000,000</td>
<td>CICL= 0.000,000,05</td>
</tr>
<tr>
<td>PHI= 0.980,000</td>
<td>CIEXP= 1.000,000</td>
</tr>
<tr>
<td>R= 0.100,000</td>
<td></td>
</tr>
<tr>
<td>DF= 0.200,000</td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

\[
CD = CDCEP \times (T \times D^7)^{X \times (CDEXP)} \times CF
\]

\[
CLRHM = CICL \times (M)^{X \times (CIEXP)} \times CF \times TF
\]

\[
#RM = T / M
\]

\[
E = 1.0 \times \log(PHI) / \log(2.0)
\]

\[
CTFU = (CLRHM / E)^{X \times ((#RM \times Z1 + 5)^{X \times E} - 0.5 \times (E))}
\]

\[
CIPS = ((CLRHM / E)^{X \times ((#RM \times Z3 + 0.5)^{X \times E} - 0.5 \times (E)))} / 72
\]

CRCI = CIPS \times R

C0&M = 0&M

COMMENTS = 180

---

### Calculated Values

- \$1,000,000: 1,065,027
- 0,012: 0.012
- 800,000: 0.971
- 4.475: 4.475
- 0.071: 0.071
- 0.077: 0.077
- 0.0: 0.0
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

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

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 AESI - HEAM MACHINE
5GW PHOTOVOLTAIC CR=2

#### INPUT PARAMETERS

<table>
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<tr>
<th>Parameter</th>
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<tr>
<td>M</td>
<td>700.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.900000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.000000</td>
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<tr>
<td>O&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>Z1</td>
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</tr>
<tr>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>Z3</td>
<td>702.000000</td>
</tr>
</tbody>
</table>

#### INPUT COEFFICIENTS

<table>
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<th>Value</th>
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</thead>
<tbody>
<tr>
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<td>0.8000000</td>
</tr>
<tr>
<td>CDEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>C1CEP</td>
<td>0.001000</td>
</tr>
<tr>
<td>C1EXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- $CD = CDCEK \times (T \times DF) \times (CDEXP) \times CF$
- $CLRM = CICER \times (M) \times (C1CEP) \times CF \times TF$
- $\#RM = T / M$
- $E = 1.0 + \log(\text{PHI}) / \log(2.0)$
- $CTF = (CLRM / E) \times ((\#RM \times Z1+0.5) \times (E) - 0.5 \times (E))$
- $CIPS = (CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2$
- $CRCI = CIPS \times R$
- $C0LM = O&M$

**COMMENTS**: 164
**TABLE B-72. 06-00-02 AKSE - Cassettes**

50W PHOTOVOLTAIC CH=2

### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Te</td>
<td>200.0000000</td>
<td>Tf</td>
<td>1.0000000</td>
<td>CDCER#</td>
<td>2.0000000</td>
</tr>
<tr>
<td>M</td>
<td>200.0000000</td>
<td>Q&amp;M</td>
<td>0.0</td>
<td>CDEXP#</td>
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</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
<td>Z1</td>
<td>120.0000000</td>
<td>CICER#</td>
<td>0.0000250</td>
</tr>
<tr>
<td>PHI</td>
<td>0.0000000</td>
<td>Z2</td>
<td>120.0000000</td>
<td>C1EXP#</td>
<td>1.0000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
<td>Z3</td>
<td>720.0000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>1.0000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CALCULATED VALUES

\[
CD = CDCER \times (T \times DF) \times (CDEXP) \times CF
\]

\[
CLRM = CICER \times (M) \times (C1EXP) \times CF \times TF
\]

\[
\#RM = T / M
\]

\[
E = 1.0 \times \log(PHI) / \log(2.0)
\]

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

\[
CIPS = ((CLRM/E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / ZP
\]

CRCI = CIPS \times R

CD&M = Q&M

COMMENTS 165

$\text{MILLIONS}$

- $0.300$
- $0.005$
- $1.000$
- $0.678$
- $0.938$
- $0.026$
- $0.0$
- $3.0$
### Input Parameters

<table>
<thead>
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<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Iתק</td>
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</tr>
<tr>
<td>Mתק</td>
<td>500.00000</td>
</tr>
<tr>
<td>CFתק</td>
<td>1.00000</td>
</tr>
<tr>
<td>PHIתק</td>
<td>0.95000</td>
</tr>
<tr>
<td>Rתק</td>
<td>0.0</td>
</tr>
<tr>
<td>DFתק</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

### Input Coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCEP=</td>
<td>0.00860</td>
</tr>
<tr>
<td>CDCEP=</td>
<td>1.00860</td>
</tr>
<tr>
<td>CIEXP=</td>
<td>0.00160</td>
</tr>
<tr>
<td>CIEXP=</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

### Calculated Values

1. CD = CDCEP * (T * DF) * (CDCEP) * CF
2. CLRM = CIEXP * (M) * (CIEXP) * CF * TF
3. #RM = T / M
4. E = 1.0 + LOG(PHI) / LOG(2.0)
5. CTFU = (CLRM / E) * ((#RM * Z1 + 0.5) * XX(E) - 0.5 * XX(E)) / Z2
6. CIPS = ((CLRM/E) * ((#RM * Z3 + 0.5) * XX(E) - 0.5 * XX(E))) / Z2
7. CRCI = CIPS * P
8. O&M = O&M

### Comments

166
## TABLE 8-74. 06-00-04 AASE - REMOTE MANIPULATOR 5GW PHOTOVOLTAIC CRR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 800,000000</td>
<td>CUCER = 0.000000</td>
</tr>
<tr>
<td>M = 600,000000</td>
<td>CUEXP = 1.000000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICER = 0.001500</td>
</tr>
<tr>
<td>PHI = 0.950000</td>
<td>CIEXP = 1.000000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

### Calculated Values

- **CD** = CUCER \times (T \times DF) \times (CUEXP) \times CF
- **CLRM** = CICER \times (M) \times (CIEXP) \times CF \times TF
- **WRM** = T / M
- **E** = 1.0 + \log(PHI) / \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
- **CQ&M** = Q&M

**COMMENTS** 167

**$\text{BILLIONS}$**

6.880

1.200

1.000

0.926

35.563

0.246

0.003

0.2
### Table B-75: 06-08-05 A&SE - Blanket Dispenser

<table>
<thead>
<tr>
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<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
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<td></td>
</tr>
<tr>
<td>M</td>
<td>2000.0000</td>
<td>0&amp;H</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>76.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
<td>Z3</td>
<td>492.000000</td>
</tr>
</tbody>
</table>

### Calculated Values

- \( CD = CD\text{CER} \times (T \times DF) \times (CD\exp) \times CF \)
- \( CLRM = CIC\text{ER} \times (M) \times (CI\exp) \times CF \times TF \)
- \( WRM = T \times M \)
- \( E = 1.0 \times \log(\text{PHI}) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times (WRM \times Z1 + 0.5) \times (E) - 0.5 \times (E) \)
- \( CPS = ((CLRM / E) \times (WRM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \)

### Comments
- CI\text{RCI} = CPS \times H
- CD\&M = D&H
- Comments: 168
### Table B-76. 06-00-06 ASE - REFLECTOR DISPENSE?
5GWP PHOTOVOLTAIC CR=2

#### Input Parameters

<table>
<thead>
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<th>Parameter</th>
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<tbody>
<tr>
<td>Tw</td>
<td>10000.0000</td>
</tr>
<tr>
<td>M</td>
<td>10000.0000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.950000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF</td>
<td>1.000000</td>
</tr>
<tr>
<td>Q&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>Z1</td>
<td>6.000000</td>
</tr>
<tr>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>Z3</td>
<td>36.000000</td>
</tr>
</tbody>
</table>

#### Calculated Values

1. \( CD = CDCE\times(T\times DF)\times(CUEXP)\times CF \)

2. \( CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF \)

3. \( \#WM = T / M \)

4. \( E = 1.0 + \log(\text{PHI}) / \log(2.0) \)

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

6. \( CIPS = ((CLRM / E) \times ((\#WM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / 12 \)

7. \( CRCI = CIPS \times P \)

8. \( CQ&M = Q&M \)

9. Comments: 169
<table>
<thead>
<tr>
<th>TABLE B-77.  06-00-07 A&amp;SE - CABLE DISPENSER</th>
<th>INPUT COEFFICIENTS</th>
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</thead>
<tbody>
<tr>
<td>5GW PHOTOVOLTAIC CR=2</td>
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</tr>
<tr>
<td><strong>INPUT PARAMETERS</strong></td>
<td></td>
</tr>
<tr>
<td>( T ) = 200.000000</td>
<td>( T F ) = 1.000000</td>
</tr>
<tr>
<td>( M ) = 200.000000</td>
<td>( O &amp; H ) = 0.0</td>
</tr>
<tr>
<td>( C F ) = 1.000000</td>
<td>( Z 1 ) = 307.000000</td>
</tr>
<tr>
<td>( P H I ) = 0.950000</td>
<td>( Z 2 ) = 120.000000</td>
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<tr>
<td>( R ) = 0.0</td>
<td>( Z 3 ) = 460.000000</td>
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<tr>
<td>( D F ) = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\begin{align*}
C D & = C D C E R \times (T \times D F) \times (C D E X P) \times C F \\
C L R M & = C I C E R \times (M) \times (C I E X P) \times C F \times T F \\
\# R M & = T / M \\
E & = 1.0 + \log(\text{PHI}) / \log(2.0) \\
C T F U & = (C L R M / E) \times ((\# R M \times Z 1 + 0.5) \times X(E) + 0.5 \times X(E)) \\
C I P S & = ((C L R M / E) \times ((\# R M \times Z 3 + 0.5) \times X(E) + 0.5 \times X(E))) / Z 2 \\
C R C I & = C I P S \times R \\
C O L M & = O & M \\
C O M M E N T S & = 170
\end{align*}
\]
### TABLE B-78. 06-04-08 A&SF - ANTENNA PANEL INS. EQn 1.
50W PHOTOVOLTAIC CR=2

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>T</td>
<td>450000.000</td>
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<tr>
<td>M</td>
<td>600000.000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.900000</td>
</tr>
<tr>
<td>R</td>
<td>0.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.133333</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

1. \( CD = CD\text{CER} \times (T \times DF) \times (CD\text{EXP}) \times CF \)
2. \( CLRM = CI\text{CER} \times (M) \times (CI\text{EXP}) \times CF \times TF \)
3. \( \#RM = I / M \)
4. \( E = 1.0 + \log(\text{PHI}) / \log(2.0) \)
5. \( CFU = (CLRM / E) \times ((\#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \)
6. \( CIPS = ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2 \)

**INPUT COEFFICIENTS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD\text{CER}</td>
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</tr>
<tr>
<td>CD\text{EXP}</td>
<td>1.000000</td>
</tr>
<tr>
<td>CI\text{CER}</td>
<td>0.001500</td>
</tr>
<tr>
<td>CI\text{EXP}</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

**COMMENTS** 171
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 6x6x30 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 it's 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 acostic levels and an inherent down-payload capability.

The CER's are based upon engineering estimates, see Table B-79.
### Table B-79: 07-01-04 STS - MLLV Fleet Procurement

#### 5GW Photovoltaic DR=2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
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<td>T</td>
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<td>TF</td>
<td>1.000000</td>
</tr>
<tr>
<td>M</td>
<td>1.000000</td>
<td>O&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>3.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.000000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0</td>
<td>Z3</td>
<td>165.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Calculated Values

- **CD**: \(\text{CDCER} \times (T \times DF) \times (\text{CDEXP}) \times CF\)  
  \[7421.199\]  
- **CLRM**: \(\text{CICER} \times (M) \times (\text{CIELXP}) \times CF \times TF\)  
  \[792,000\]  
- **RM**: \(T / M\)  
  \[1.000\]  
- **E**: \(1.0 \times \log(\text{PHI}) / \log(2.0)\)  
  \[0.678\]  
- **CTFU**: \((\text{CLRM} / E) \times ((\text{RM} \times Z1 + 5) \times (E) - 0.5 \times (E))\)  
  \[2081.271\]  
- **CIPS**: \(((\text{CLRM} / E) \times ((\text{RM} \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2\)  
  \[304.925\]  
- **CRCI**: \(\text{CIPS} \times R\)  
  \[0.0\]  
- **C&O&M**: \(\text{O&M}\)  
  \[0.0\]  
- **Comments**: 35

- **Input Coefficients**:  
  \[7921.19922, 1.000000, 792,000000, 1.000000\]
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 \(37.2 \times 10^6\) 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. 97-02-00 SIS - HLV OPERATIONS

SSW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
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<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 1.000000</td>
<td>CDCEP= 0.0</td>
</tr>
<tr>
<td>H= 1.000000</td>
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<tr>
<td>CF= 1.000000</td>
<td>CIEXP= 1.59406000</td>
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<td>CLEAF= 1.000000</td>
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<tr>
<td>R= 0.0</td>
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</tr>
<tr>
<td>DF= 1.000000</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>CALCULATED VALUES</th>
<th>ORIGINAL PAGE IS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD=CDCEP x (T x DF)x(CDXP) x CF</td>
<td>OF POOR QUALITY</td>
</tr>
<tr>
<td>CLRM=CICER x (H)x(CIEXP) x CF x TF</td>
<td>5 MILIONS</td>
</tr>
<tr>
<td>#RM = 1/y / K</td>
<td>0.0</td>
</tr>
<tr>
<td>E = 1.0 * LOG(PHI) / LOG(2.0)</td>
<td>1.480</td>
</tr>
<tr>
<td>CTFU=(CLRM / E)x((#RM x 21.5)x(E) - 0.5x(E))</td>
<td>1.000</td>
</tr>
<tr>
<td>CIPS=((CLRM/E)x((4RM x 73 + 0.5)x(E) - 0.5x(E)) ) / 2p</td>
<td>999,000</td>
</tr>
<tr>
<td>CRC1 = CIPS x R</td>
<td>999,086</td>
</tr>
<tr>
<td>COSM = O&amp;M</td>
<td>9.0</td>
</tr>
<tr>
<td>COMMENTS 36</td>
<td>1485,000</td>
</tr>
</tbody>
</table>
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 3-81. 08-01-00 1GW-Fleet Procurement
5GW Photovoltaic CP=2

<table>
<thead>
<tr>
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</tr>
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<tr>
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<td>CUEXF= 1.000000</td>
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<td>CF=</td>
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</tr>
<tr>
<td>PHI=</td>
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<tr>
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</table>

**Calculated Values**

- CD = CICER X (T X DF) X (CDEXF) X CF
- CLR = CICER X (M) X (CICF) X CF X TF
- RPM = T / M
- E = 1.0 + LOG(PHI) / LOG(2,0)
- CTRF = (CLR / E) X ((#RM X Zl * 5) X X(E) - 0.5 X X(E))
- CIPS = ((CLR / E) X (((#RM X Z3 + 0.5) X X(E) - 0.5 X X(E)) / Z2)
- CRCl = CIPS X R
- CD&M = 0 & M

**Comments**

37
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. 08-02-80 10V-OPERATIONS
5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T= 1.000000</td>
<td>CFCLT= 0.0</td>
</tr>
<tr>
<td>M= 1.000000</td>
<td>CFEXP= 1.000000</td>
</tr>
<tr>
<td>CF= 1.000000</td>
<td>CICLT= 0.001000</td>
</tr>
<tr>
<td>PHI= 1.000000</td>
<td>CICEXP= 1.000000</td>
</tr>
<tr>
<td>R= 0.0</td>
<td></td>
</tr>
<tr>
<td>DF= 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

\[ CD = \text{CDCER} \times (T \times DF) \times (\text{CFEXP}) \times \text{CF} \]
\[ \text{CLRM} = \text{CICER} \times (M) \times (\text{CFEXP}) \times \text{CF} \times \text{TF} \]
\[ \text{CTF} = T / M \]
\[ E = 1.0 \times \log(\text{PHI}) / \log(2.0) \]
\[ \text{CTF} = (\text{CLRM} / E) \times ((\text{RM} \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \]
\[ \text{CIPS} = ((\text{CLRM} / E) \times ((\text{RM} \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \]
\[ \text{CRCI} = \text{CIPS} \times \text{R} \]
\[ \text{CDLM} = \text{RM} \]

COMMENTS 38
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 $4 \times 10^6$ 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>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>321805.000</td>
</tr>
<tr>
<td>M</td>
<td>2500.00000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

CD=CDICER \* (T \* DF) \* (CDF\*5) \* (CTDFEXP) \* CF

CLRM=CICER \* (M) \* (CIELXP) \* CF \* TF

\#RM = T / M

E = 1.0 \* LOG(PHI) / LOG(2.0)

CTFU=(CLRM / E) \* (\#RM \* Z1+5) \* X(E) \* 0.5 \* X(E) \* 0.5 \* X(E)

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

CGCI = CIPS \* H

CDEMP = CDEMP

COMMENTS: B3
<table>
<thead>
<tr>
<th>T</th>
<th>9000000.000</th>
<th>Tf</th>
<th>1.000000</th>
<th>CDCEK</th>
<th>0.151400</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>162500.000</td>
<td>D&amp;H</td>
<td>0.0</td>
<td>CDEXP</td>
<td>0.394000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>10.000000</td>
<td>CIEXP</td>
<td>0.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.980000</td>
<td>Z2</td>
<td>120.000000</td>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
<tr>
<td>H</td>
<td>0.010000</td>
<td>Z3</td>
<td>45.000000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ CD = CDCEK \times (T \times DF) \times (CDEXP) \times CF \]

\[ CLR = CI\times (M) \times (CIEXP) \times CF \times TF \]

\[ #RM = T / M \]

\[ E = 1.0 + \log(\text{PHI}) / \log(2.0) \]

\[ CTFU = (CLR / E) \\times ((#RM \times Z1 + 5) \times (E) - 0.5 \times (E)) \]

\[ CJPS = ((CLRME / E) \\times ((#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E))) \]

\[ CHCI = CJPS \times H \]

\[ CD&H = D&H \]

**COMMENTS**

85
### Table B-85. 09-01-04 GOLVEF-CONCENTRATION
56W PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 1900000.00</td>
<td>CD = CD x T x DF x (T x DF) x (CD x EXP) x CF</td>
</tr>
<tr>
<td>M = 16250.0000</td>
<td>CD = CD x T x DF x (T x DF) x (CD x EXP) x CF</td>
</tr>
<tr>
<td>CF = 1.4000000</td>
<td>CD = CD x T x DF x (T x DF) x (CD x EXP) x CF</td>
</tr>
<tr>
<td>PHI = 0.9800000</td>
<td>CD = CD x T x DF x (T x DF) x (CD x EXP) x CF</td>
</tr>
<tr>
<td>Z = 0.0100000</td>
<td>CD = CD x T x DF x (T x DF) x (CD x EXP) x CF</td>
</tr>
</tbody>
</table>

#### Calculated Values

CD = CD x T x DF x (T x DF) x (CD x EXP) x CF

CLRM = CLRM x (H) x (C x EXP) x CF x T

#RM = T / M

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

CTF = (CLRM / E) x (#RM x Z + 0.5 x (x(E) - 0.5 x (x(E))}

CIPS = ((CLRM / E) x (#RM x Z + 0.5 x (x(E) - 0.5 x (x(E))}

CRCI = CIPS x #M

COMMENTS 86

---

Rockwell International
Space Division

![Logo]
### TABLE 8-86. 09-01-85 CDVFP-ELECTRIC PROPULSION SYSTEM 5GW PHOTOVOLTAIC CP=2

#### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>80581.0000</td>
</tr>
<tr>
<td>M</td>
<td>31.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.100000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.200000</td>
</tr>
<tr>
<td>R</td>
<td>0.010000</td>
</tr>
<tr>
<td>DF</td>
<td>0.300000</td>
</tr>
</tbody>
</table>

#### INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUCER</td>
<td>1.122000</td>
</tr>
<tr>
<td>CDFXP</td>
<td>0.190000</td>
</tr>
<tr>
<td>CICER</td>
<td>0.057000</td>
</tr>
<tr>
<td>CIEAP</td>
<td>0.729000</td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

<table>
<thead>
<tr>
<th>Expression</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD=CUCER X (T X DF) X (CDF XP X CF)</td>
<td>8.399</td>
</tr>
<tr>
<td>CLR=CICER X (M) X (CIE XP X CF X TF)</td>
<td>0.436</td>
</tr>
<tr>
<td>MRN=T / M</td>
<td>289.103</td>
</tr>
<tr>
<td>E = 1.0 + LOG( (PHI) / LOG(2.0) )</td>
<td>0.046</td>
</tr>
<tr>
<td>CTFU=(CLRM / E) X ((MRN X Z1 X 0.5) X (E - 0.5 X (E)))</td>
<td>403.050</td>
</tr>
<tr>
<td>CIPS=((CLRM / E) X ((MRN X (Z3 + 0.5) X (E) - 0.5 X (E))) / Z2</td>
<td>12.030</td>
</tr>
<tr>
<td>CRC1 = CIPS X R</td>
<td>0.120</td>
</tr>
<tr>
<td>CODM = 0 &amp; M</td>
<td>0.0</td>
</tr>
</tbody>
</table>

#### COMMENTS

87
### Table B-87. T&RLE 8-87 COTVFP-AVIDNICS, SUPERVISOR COMPUTER 5GW PHOTOVOLTAIC CR#2

#### Input Parameters

<table>
<thead>
<tr>
<th>I</th>
<th>M</th>
<th>CF</th>
<th>Phi</th>
<th>R</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>14,000000</td>
<td>14,000000</td>
<td>1,000000</td>
<td>0.850000</td>
<td>0.010000</td>
<td>0.200000</td>
</tr>
</tbody>
</table>

#### Calculated Values

- CD = CDCER X (T X DF) X X(CDEXP) X CF
- CLRM = CICER X (M) X X(CIEXP) X CF X TF
- #RM = T / M 
- 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
- CMCI = CIPS X W

#### Input Coefficients

<table>
<thead>
<tr>
<th>CDCCR</th>
<th>CDLAP</th>
<th>CICER</th>
<th>CIEXP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.633000</td>
<td>0.521000</td>
<td>0.172000</td>
<td>0.535000</td>
</tr>
</tbody>
</table>

#### Comments

101
### TABLE B-88  09-01-06 COTVEP-AVIONICS, COMMAND AND CONTROL
5GW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=</td>
<td>TF= 0.900000</td>
</tr>
<tr>
<td>Tm</td>
<td>0.900000</td>
</tr>
<tr>
<td>CF</td>
<td>Z1= 10.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>Z2= 120.000000</td>
</tr>
<tr>
<td>X</td>
<td>Z3= 45.000000</td>
</tr>
<tr>
<td>DF</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

- CD = CDCE = (T x DF) x (CLC x EXP) x CF
- CR = CICR x (M) x (CLC x EXP) x CF x TF
- #RM = T / M
- E = 1.0 + LOG(PHI) / LOG(2.0)
- CTFU = (CLRM / E) x ((#RM x Z1 * 0.5) x (E - 0.5 x (L))
- CPS = ((CLRM/E) x ((#RM x Z3 * 0.5) x (E - 0.5 x (L)) / Z2
- CRCI = CPS x @
- CD = 0.102000
- CICR = 0.879000
- CINDEX = 0.069000
- CLC = 0.557000

**Comments**

- 102
<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=245.000000</td>
<td>CDCEK=0.102000</td>
</tr>
<tr>
<td>M=5.000000</td>
<td>CDUE=0.879000</td>
</tr>
<tr>
<td>CF=1.000000</td>
<td>CIEK=0.069000</td>
</tr>
<tr>
<td>PHI=0.950000</td>
<td>CIEXP=0.557000</td>
</tr>
<tr>
<td>R=0.010000</td>
<td></td>
</tr>
<tr>
<td>DF=0.001300</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

\[ CD = CDCEK \times (T \times DF) \times \frac{1}{(CI - EXP)} \times CF \]

\[ CLRM = CICER \times (M) \times \frac{1}{(CI - EXP)} \times CF \times TF \]

\[ WRM = \frac{1}{M} \]

\[ E = 1.0 + \log(\text{PHI}) \times \log(2.0) \]

\[ CTFU = (\text{CLRM} / E) \times \left( (\text{WM} \times Z1 + 5) \times \frac{x(E)}{120} - 0.5 \times x(E) \right) \]

\[ CIPS = (\text{CLRM} / E) \times \left( (\text{PAM} \times Z3 + 0.5) \times \frac{x(E)}{120} - 0.5 \times x(E) \right) \]

\[ CRCI = CIPS \times R \]

\[ CDAM = D&M \]

**Comments** 103
### TABLE 8-30

**09-01-06 COTVP-NAVIONICS; HUS CONTROL UNIT**

**5GW PHOTOMULTIPLIER CR=2**

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF = 266.000000</td>
<td>CDCEM = 0.102000</td>
</tr>
<tr>
<td>M = 5.000000</td>
<td>CDEXP = 1.183000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICEM = 0.069000</td>
</tr>
<tr>
<td>PHI = 0.950000</td>
<td>CIEXP = 0.557000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 0.001200</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ CD = CDCEM \times (T \times DF) \times X(CD EXP) \times CF \]
\[ CICEM = CIC \times (M) \times X(CI EXP) \times CF \times TF \]
\[ DRM = T / M \]
\[ E = \log(PHI) \times \log(2.0) \]
\[ CTFU = (CLRM / E) \times ((DRM \times Z1 + 0.5) \times X(E) - 0.5 \times X(E)) \]
\[ CIPS = (CLRM / E) \times ((DRM \times Z3 + 0.5) \times X(E) - 0.5 \times X(E)) / Z2 \]
\[ CRCI = CIPS \times R \]
\[ CDM = 0 \times M \]

**COMMENTS**

104
### TABLE D-91. 09-01-06 COTVFP-AVIONICS, REMOTE ACU & CONTROL
5GW PHOTOVOLTAIC CR=2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I = 345.000000</td>
<td>CDCEP = 0.102000</td>
</tr>
<tr>
<td>M = 5.000000</td>
<td>CDEXP = 0.479000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICER = 0.069000</td>
</tr>
<tr>
<td>PHI = 0.950000</td>
<td>CIEXP = 0.557000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 0.000100</td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ CD = CDCEP \times (T \times DF) \times (CDEXP) \times CF \]
\[ CER = CIEXP \times (M) \times (CICER) \times CF \times TF \]
\[ \#RM = I / M \]
\[ E = 1.0 \times \log(PHI) / \log(2.0) \]
\[ CTFU = (CER / E) \times ((\#RM \times Z1) + 0.5) \times 0.5 \times (E) \]
\[ 0.5 \times (E) \]
\[ CIPS = ((CER / E) \times ((\#RM \times Z3) \times 0.5) \times 0.5 \times (E) \]
\[ 1 / Z2 \]

**COMMENTS**

1.05
### INPUT PARAMETERS

<table>
<thead>
<tr>
<th>T</th>
<th>5154.000000</th>
<th>TF</th>
<th>0.020000</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>3.0000000</td>
<td>O&amp;M</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
<td>Z1</td>
<td>10.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.9800000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.0100000</td>
<td>Z3</td>
<td>45.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.000032</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### CALCULATED VALUES

\[
CD = CD\text{CER}_X (T \times DF) \times (CDEXP) \times CF
\]

\[
CLRM = CIC\text{ER}_X (M) \times (CIEXP) \times CF \times TF
\]

\[
RM = T / M
\]

\[
E = 1.0 + \log(\text{PHI}) / \log(2.0)
\]

\[
CTFU = (CLRM / E) \times ((RM \times Z1 + 5) \times (E) - 0.5 \times (E))
\]

\[
CIPS = ((CLRM/E) \times ((RM \times (Z3 + 0.5) \times (E) - 0.5 \times (E))) / Z2
\]

\[
CRI = CIPS \times RM
\]

\[
CD\&M = O&M
\]

**COMMENTS**

|   | 106 |

### INPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>CD</th>
<th>0.102000</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDEXP</td>
<td>0.079000</td>
</tr>
<tr>
<td>CICER</td>
<td>0.069000</td>
</tr>
<tr>
<td>CIEXP</td>
<td>0.557000</td>
</tr>
</tbody>
</table>

### MILLIONS

- CD: 0.021
- CLRM: 0.003
- RM: 1715.000
- E: 0.971
- CTFU: 37.276
- CIPS: 1.338
- CRRI: 0.013
- CD\&M: 0.0
<table>
<thead>
<tr>
<th>TABLE 8-93. 09-01-06 CTVFP-AVIONICS, OPTICAL FIBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSW PHOTOVOLTAIC CR=2</td>
</tr>
</tbody>
</table>

**INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>T</th>
<th>4.200000</th>
<th>T/F</th>
<th>1.000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>4.200000</td>
<td>M/T</td>
<td>0.0</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>Z1</td>
<td>10.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.980000</td>
<td>Z2</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.010000</td>
<td>Z3</td>
<td>45.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[ \text{CD = CD_CER} \times (T \times DF) \times (CD_EXP) \times CF \]

\[ \text{CLRM = CL_CER} \times (M) \times (CI_EXP) \times CF \times TF \]

\[ \text{RM} = T / M \]

\[ E = 1.0 + \log(\phi) / \log(2.0) \]

\[ \text{CFU} = (C_{LRM} / E) \times \left( \text{RM} \times Z1 \times 0.5 \times (E) - 0.5 \times (E) \right) \]

\[ \text{CIPS} = \left( \left( \text{CLRM} / E \right) \times \left( \text{RM} \times Z3 \times 0.5 \times (E) - 0.5 \times (E) \right) \right) / Z2 \]

\[ \text{CHCI} = \text{CIPS} \times A \]

\[ \text{CO&M} = 0.0 \]

**COMMENTS**: 10?
### TABLE B-94. 09-01-06 COTVFP-AVIONICS, CABLES & HARNESS
SGW PHOTOVOLTAIC CH=2

<table>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 16272.0000</td>
<td>CDCEX= 0.237000</td>
</tr>
<tr>
<td>H = 16272.0000</td>
<td>CDCEX= 0.247000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CIEX= 0.0000001</td>
</tr>
<tr>
<td>PHI = 0.980000</td>
<td>CIEX= 1.000000</td>
</tr>
<tr>
<td>R = 0.010000</td>
<td></td>
</tr>
<tr>
<td>DF = 1.000000</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

\[ CDM = CDCEX \times (T \times DF) \times (CDCEX) \times CF \]

\[ CLRM = CIEX \times (M) \times (CIEX) \times CF \times TF \]

\[ \#RM = T / M \]

\[ E = 1.0 \times \log(\text{PHI}) / \log(2.0) \]

\[ CTFU = (\text{CLRM} / E) \times ((\#HM \times Z1 + 5) \times (E) - 0.5 \times (E)) \]

\[ CIPS = ((\text{CLRM} / E) \times (\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / Z2 \]

\[ CHCI = CIPS \times R \]

\[ C0&M = D&M \]

**Comments** 108
<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T = 18240.90000</td>
<td>CDCCER = 0.400100</td>
</tr>
<tr>
<td>M = 0.057600</td>
<td>CULIN = 1.000000</td>
</tr>
<tr>
<td>CF = 1.000000</td>
<td>CICER = 0.600400</td>
</tr>
<tr>
<td>PHI = 0.990000</td>
<td>CIEEP = 1.000000</td>
</tr>
<tr>
<td>H = 0.010000</td>
<td>DF = 1.000000</td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
CD = CDCCER \times (T \times DF)^{\times X(CIEEP) \times CF}
\]

\[
CLRM = CICER \times (M)^{\times x(CIEEP) \times CF \times T}
\]

\[
#RM = T / H
\]

\[
E = 1.0 \times \log(PHI) / \log(2.0)
\]

\[
CTFU = (CLRM / E) \times ((#RM \times Z1 + 0.5) \times X(E) - 0.5X(E))
\]

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

\[
CHCI = CIPS \times H
\]

\[
CDRM = D\&M
\]

**COMMENTS** 109
### TABLE B-96. 09-01-87 COVFP- THERMAL CONTROL
55W PHOTOVOLTAIC CN=2

#### INPUT PARAMETERS

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<thead>
<tr>
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<tbody>
<tr>
<td>M</td>
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</tr>
<tr>
<td>CF</td>
<td>1.50000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.98000000</td>
</tr>
<tr>
<td>R</td>
<td>0.01000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.00000000</td>
</tr>
</tbody>
</table>

#### Calculated Values

- \(CD = CD_{CE} \times (T \times DF) \times (CD_{EXP}) \times CF\)
- \(CLRM = CI_{CE} \times (M) \times (CI_{EXP}) \times CF \times TF\)
- \(#RM = T / M\)
- \(E = 1.0 \times \log(\text{PHI}) / \log(2.0)\)
- \(CTFU = (CLRM / E) \times ((#RM \times Z1 + 0.5) \times (E) \times 0.5) \times (E)\)
- \(CIPS = ((CLRM / E) \times ((#RM \times Z3 + 0.5) \times (E) \times 0.5)) / Z2\)
- \(CHCI = CIPS \times H\)
- \(CD & M = O & M\)

#### Comments

89
# TABLE B-97.  09-01-08 CTVFP-POWER DISTRIBUTION

SGW PHOTOVOLTAIC CH=2

## INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
<td>M</td>
<td>972.0000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.0000000</td>
</tr>
<tr>
<td>PHI</td>
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<tr>
<td>R</td>
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</tr>
<tr>
<td>DF</td>
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</table>

## OUTPUT COEFFICIENTS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDCE=</td>
<td>0.1580000</td>
</tr>
<tr>
<td>CDFP=</td>
<td>0.2970000</td>
</tr>
<tr>
<td>CIEF=</td>
<td>0.0400000</td>
</tr>
<tr>
<td>CIEP=</td>
<td>1.0000000</td>
</tr>
</tbody>
</table>

## CALculated VALUES

- \( CD = CDCE = (T \times DF) \times (CD = CF) \times CF \)
- \( CLRM = CICER = (M) \times (CI EXP) \times CF \times TF \)

- \( \#RM = T / M \)
- \( E = 1.0 + \log(\text{PHI}) + \log(2.0) \)
- \( CTFU = (CLRM / E) \times ((\#RM \times Z1 + 5) \times X/E) - 0.5 \times X(E) \)
- \( CIPS = ((CLRM/E) \times (\#RM \times Z3 + 0.5) \times X(E) - 0.5 \times X(E)) \)
- \( CRCI = CIPS \times R \)
- \( CD &= M = 0 \& M \)

**Comments**: 67
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.
**Table B-98. 09-02-60 C114-11ERATIONS**

**GEN PHOTOPHTAIL CR=2**

**INPUT PARAMETERS**

<table>
<thead>
<tr>
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<th>TF</th>
<th>1.000000</th>
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</thead>
<tbody>
<tr>
<td>Me</td>
<td>1.000000</td>
<td>C6E</td>
<td>21.30000</td>
</tr>
<tr>
<td>Lf</td>
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<td>Z1</td>
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</tr>
<tr>
<td>PHI</td>
<td>1.000000</td>
<td>Z2</td>
<td>1.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.000000</td>
<td>Z3</td>
<td>1.000000</td>
</tr>
<tr>
<td>DF</td>
<td>1.000000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CALCULATED VALUES**

CD = CDOEF * (T * DF) * (C1EAF) * CT

CLRM = CICFR * (H) * (C1EXP) * CF * TF

#HM = T / H

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

CTF = (CLRM / F) * (((#HM * Z + 0.5) * X(E) - 0.5 * Z) / F)

CIPS = ((CLRM/E) * ((#HM * Z + 0.5) * X(F) - 0.5 * X(F))) / 32

CHCI = CIPS * H

C6BM = 0 & M

**COMMENTS**

90
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>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Value</th>
</tr>
</thead>
<tbody>
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<td>1.000000</td>
</tr>
<tr>
<td>M</td>
<td>1.000000</td>
<td>0.000000</td>
</tr>
<tr>
<td>CF</td>
<td>1.000000</td>
<td>2.000000</td>
</tr>
<tr>
<td>PHI</td>
<td>0.900000</td>
<td>120.000000</td>
</tr>
<tr>
<td>R</td>
<td>0.020000</td>
<td>16.000000</td>
</tr>
</tbody>
</table>

**Calculated Values**

CD = CDCE + (T x DF) x (CDEXP) x CF

CLRM = CICER x (M) x (CDEXP) x CF x TF

WRM = T / M

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

CTFUR = (CLRM / E) x ((WRM x 21 + 0.5) x (E) - 0.5 x (E))

CIPS = ((CLRM / E) x ((WRM x Z3 + 0.5) x (E) - 0.5 x (E))) / 22

CSCI = CIPS x R

CDM = DMR

Comments: 39

Input Coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Value</th>
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<tbody>
<tr>
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<tr>
<td>CICER</td>
<td>493.899902</td>
</tr>
<tr>
<td>CDEXP</td>
<td>0.139999</td>
</tr>
<tr>
<td>CIEXP</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

$ \text{in millions}$
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.
INPUT PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Z1</td>
<td>1.0</td>
</tr>
<tr>
<td>Z2</td>
<td>2.0</td>
</tr>
<tr>
<td>Z3</td>
<td>0.5</td>
</tr>
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</table>

CALCULATED VALUES

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TF</td>
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</tr>
<tr>
<td>CF</td>
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</tr>
<tr>
<td>CFEXP</td>
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</table>

TABLE 8-100: 10-62-88 PV-ORP Parameters

Input Parameters

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<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>T</td>
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</tr>
<tr>
<td>E</td>
<td>1.00000</td>
</tr>
<tr>
<td>M</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

Input Coefficients

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM</td>
<td>1.00000</td>
</tr>
<tr>
<td>MS</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

Space Division

Rockwell International
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 CH#2

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>INPUT COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>T × 1.0000000</td>
<td>TF × 1.0000000</td>
</tr>
<tr>
<td>M × 1.0000000</td>
<td>0.0000000</td>
</tr>
<tr>
<td>CF × 1.0000000</td>
<td>Z1 × 1.0000000</td>
</tr>
<tr>
<td>PHI × 1.0000000</td>
<td>Z2 × 120.0000000</td>
</tr>
<tr>
<td>R × 0.0200000</td>
<td>Z3 × 1.666667</td>
</tr>
<tr>
<td>DF × 1.0000000</td>
<td></td>
</tr>
</tbody>
</table>

CALCULATED VALUES

CD = CDCER × (T × DF) × (CF × (CF × T × DF))

CLRM = CI × (T × DF) × (CF × T × DF)

#RM = T / M

E = 1.0 × LDG(PHI) / LDG(2.0)

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

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

CRCI = CIPS × R

CD&M = 0.0M

COMMENTS 173

CUT: MILLIONS

0.0

1500.000

1.000

1500.000

20.433

0.417

0.0

SOLAR QUALITY IS
### TABLE B-102. 11-03-80 FACILITIES - MAJOR GROUND TEST
5-GW PHOTOVOLTAIC CR=2

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<td>CUEXP = 1,000,000</td>
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<td>C1EXP = 750,000,000</td>
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<tr>
<td>PHI = 1,000,000</td>
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<tr>
<td>R = 0.020000</td>
<td></td>
</tr>
<tr>
<td>DF = 1,000,000</td>
<td></td>
</tr>
</tbody>
</table>

#### CALCULATED VALUES

- \( CD = CUCER \times (T \times DF) \times (CUEXP) \times CF \)
- \( CLRM = CICER \times (M) \times (CIEXP) \times CF \times TF \)
- \( \#RM = T / M \)
- \( E = 1.0 + \log(\phi_1) / \log(2.0) \)
- \( CTFU = (CLRM / E) \times (\#RM \times Z1+0.5) \times (E) - 0.5X(E) \)
- \( CIPS = ((CLRM/E) \times (\#RM \times Z3+0.5) \times (E) - 0.5X(E)) / Z2 \)
- \( CRCI = CIPS \times R \)
- \( CO&M = 0\&H \)
- \( COMMENTS \) 174

\$ MILLIONS

- 0.0
- 750,000
- 1.000
- 1.000
- 750,000
- 12.500
- 0.250
- 0.0

- 5-GW PHOTOVOLTAIC CR=2
<table>
<thead>
<tr>
<th>TABLE B-103. 11-04-00 FACILITIES - GROUND LAUNCH / RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>56W PHOTOVOLTAIC CH=2</td>
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**INPUT PARAMETERS**

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<tbody>
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<td>R</td>
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<tr>
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**INPUT COEFFICIENTS**

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<tbody>
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<td>CICEP=</td>
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<tr>
<td>CLCXP=</td>
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</tr>
</tbody>
</table>

**CALCULATED VALUES**

\[
\begin{align*}
CD &= CICER \times (T \times DF) \times \text{CDEXP} \times CF \\
CLRM &= CICER \times (M) \times \text{CDEXP} \times CF \times TF \\
\#RM &= T / M \\
E &= 1.0 + \log(PHI) / \log(2.0) \\
CTFU &= (CLRM / E) \times ((\#RM \times Z1 + 0.5) \times X(E) - 0.5 \times X(E)) \\
CIPS &= ((CLRM / E) \times ((\#RM \times Z3 + 0.5) \times X(E) - 0.5 \times X(E))) / Z2 \\
CRCI &= CIPS \times M \\
CDHM &= D\&M \\
COMMENTS &= 175
\end{align*}
\]

\[3210.00000 \text{ MILLIONS} \]
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-G1-00 TaxPS-Property

## 5Gw Photovoltaic CH=2

### Input Parameters

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<th>Parameter</th>
<th>Value</th>
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<tr>
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<td>061</td>
<td>0.0</td>
</tr>
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<td>CF</td>
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<tr>
<td>R</td>
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<td>120.000000</td>
</tr>
<tr>
<td>DF</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Calculated Values

- \( CD = \text{CUCER} \times (T \times DF) \times (\text{CDEXP}) \times \text{CF} \)
- \( \text{CLRM} = \text{CICER} \times (M) \times (\text{CEXP}) \times \text{CF} \times \text{TF} \)
- \( \#RM = T / P \)
- \( E = 1.0 \times \log(\text{PHI}) / \log(2.0) \)
- \( \text{CTFU} = (\text{CLRM} / E) \times ((\#RM \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \)
- \( \text{CIPS} = ((\text{CLRM} / E) \times ((\#RM \times Z3 + 0.5) \times (E) - 0.5 \times (E)) / ZP \)
- \( \text{CRCI} = \text{CIPS} \times \text{P} \)
- \( \text{GPM} = \text{GPM} \)

### Comments

94
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>
<thead>
<tr>
<th>Input Parameters</th>
<th>Input Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>( M ) = 0.0</td>
<td>( E_{DUEX} = 1.0 )</td>
</tr>
<tr>
<td>( CF ) = 0.0</td>
<td>( E_{CERC} = 0.0 )</td>
</tr>
<tr>
<td>( PHI ) = 0.0</td>
<td>( E_{CIEX} = 1.0 )</td>
</tr>
<tr>
<td>( R ) = 0.0</td>
<td></td>
</tr>
<tr>
<td>( DF ) = 0.0</td>
<td></td>
</tr>
</tbody>
</table>

**Calculated Values**

\[ C_D = CD_{EGER} \times (T \times DF) \times (C_D_{EEXP}) \times CF \]

\[ CL_{RM} = C_I_{CER} \times (M) \times (C_I_{EEXP}) \times CF \times TF \]

\[ N_{RM} = T / M \]

\[ E = 1.0 \times \log(PHI) / \log(2.0) \]

\[ CTFU = (CL_{RM} / E) \times ((N_{RM} \times Z1 + 0.5) \times (E) - 0.5 \times (E)) \]

\[ CIPS = ((CL_{RM}/E) \times ((N_{RM} \times (Z3 + 0.5) \times (E) - 0.5 \times (E))) \] / \( Z2 \)

\[ CRCI = CIPS \times R \]

\[ CD_{O6M} = 0.6M \]

**Comments** 97
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
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.

![Graph showing energy consumption and forecast comparisons](image)

**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

<table>
<thead>
<tr>
<th>FINANCIAL &amp; OPERATIONAL CONCEPT</th>
<th>DESIGN, DEVELOPMENT, TEST &amp; EVALUATION</th>
<th>INITIAL CAPITAL INVESTMENT</th>
<th>REPLACEMENT CAPITAL INVESTMENT</th>
<th>OPERATIONS &amp; MAINTENANCE, TAXES AND INSURANCE</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. NATIONAL SATELLITE POWER SYSTEM COMPANY</td>
<td>100% FUNDING BY DOE/NASA</td>
<td>40% FUNDING OF OPERATIONAL SYSTEM BY DOE</td>
<td>60% FUNDING OF OPERATIONAL SYSTEM BY UTILITY CONSORTIA</td>
<td>100% FUNDING OF TRANSPORTATION SYSTEM BY -TBU</td>
<td>GEOGRAPHIC SPS UTILITY CONSORTIA</td>
</tr>
<tr>
<td>II. NATIONAL SATELLITE POWER SYSTEM CORPORATION</td>
<td>100% FUNDING BY DOE/NASA</td>
<td>UTILIT Y CONSORTIA FUNDING/EQUITY PARTICIPATION-TBD</td>
<td>INDUSTRIAL CONSORTIA FUNDING/EQUITY PARTICIPATION-TBD</td>
<td>POTENTIAL PUBLIC PARTICIPATION VIA PUBLIC STOCK-TBD</td>
<td>BASED ON COMSAT CONCEPT - CREATED BY AN ACT OF CONGRESS (PUBLIC LAW)</td>
</tr>
<tr>
<td>III. NATIONAL SATELLITE POWER SYSTEM AUTHORITY</td>
<td>100% FUNDING BY DOE/NASA</td>
<td>GOVERNMENT FUNDING OF SPS SYSTEM WITH PARTICIPATION BY UTILITIES AND PUBLIC</td>
<td>100% FUNDING OF TRANSPORTATION SYSTEM BY -TBU</td>
<td>UTILITIES/UTILITY CONSORTIA BUY ELECTRIC POWER FROM SPS AUTHORITY</td>
<td>CREATED BY A 40% ACT OF CONGRESS (PUBLIC LAW) - FEDERALIZED SPS CORPORATION</td>
</tr>
<tr>
<td>IV. NATIONAL UTILITY CORPORATION FOR ELECTRIC POWER VIA SPS</td>
<td>100% FUNDING BY DOE/NASA</td>
<td>UTILITY CONSORTIA 100% FUNDING OF SPS OPERATIONAL SYSTEM WITH PUBLIC PARTICIPATION</td>
<td>100% FUNDING OF TRANSPORTATION SYSTEM BY -TBU</td>
<td>GEOGRAPHIC SPS UTILITY CONSORTIA - VARIATION OF CONCEPT 1</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>PREFERRED CONCEPTS</th>
<th>SPS PHASE</th>
<th>TRANSMISSION/DISTRIBUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIONAL SATELLITE POWER SYST CORP—CREATED BY ACT OF CONGRESS (PUBLIC LAW)</td>
<td>DESIGN, DEVELOP., TEST &amp; EVALUATION</td>
<td>INVESTMENT</td>
</tr>
<tr>
<td>NATIONAL UTILITY CORPORATION FOR SPS ELECTRIC POWER</td>
<td>100% FUNDING BY DOE/NASA WITH EPRI PARTICIPATION IN PLANNING</td>
<td>100% FUNDING OF SPACE TRANSPORTATION SYSTEM—TBD (E.G., HLLV, OTV)</td>
</tr>
</tbody>
</table>

Table C.3-2. Organizational and Funding Concepts for a National SPS Corporation

- CREATED BY AN ACT OF CONGRESS (PUBLIC LAW)—FEDERALIZED NATIONAL SATELLITE POWER SYSTEM CORPORATION
- SPS FUNDING
  - DOE/NASA/EPRI, 100% OF DOT6E
  - SPACE TRANSPORTATION SYSTEMS—TBD
  - INVESTMENT AND OPERATIONS FUNDING OF SPS BY GOVERNMENT (PUBLIC)
    - 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

- GEOGRAPHIC SPS UTILITY CONSORTIA
- SPS FUNDING
  - DOE/NASA/EPRI, 100% FUNDING OF DOT6E
  - SPACE TRANSPORTATION SYSTEMS—TBD
  - UTILITY CONSORTIA, 100% FUNDING OF SPS INVESTMENT AND OPERATIONS OF SYSTEM
    - 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 ≥10% return on investment (ROI), or percent return on revenues times net asset turnover = ROI ≥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 Consortium 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 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:

<table>
<thead>
<tr>
<th></th>
<th>Without ITC (%)</th>
<th>With ITC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total revenues</strong></td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td><strong>Operating expenses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchased power (purchased from National Space Segment Corporation (federally owned))</td>
<td>61.776</td>
<td>61.776</td>
</tr>
<tr>
<td>Operations and maintenance</td>
<td>0.475</td>
<td>0.475</td>
</tr>
<tr>
<td>Depreciation and amortization</td>
<td>7.000</td>
<td>7.000</td>
</tr>
<tr>
<td>Interim replacement</td>
<td>0.848</td>
<td>0.848</td>
</tr>
<tr>
<td>Property insurance</td>
<td>0.098</td>
<td>0.098</td>
</tr>
<tr>
<td>State and local taxes</td>
<td>2.743</td>
<td>2.743</td>
</tr>
<tr>
<td>Interest costs (imputed)</td>
<td>8.000</td>
<td>8.000</td>
</tr>
<tr>
<td>Income taxes</td>
<td>4.000</td>
<td>4.000</td>
</tr>
<tr>
<td>Income tax credits</td>
<td>0</td>
<td>(1.290)</td>
</tr>
<tr>
<td><strong>Total operating expenses</strong></td>
<td>84.940</td>
<td>83.650</td>
</tr>
</tbody>
</table>
**Without ITC (%)** | **With ITC (%)**
---|---
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)**

| | **Without ITC (%)** | **With ITC (%)** |
---|---|---|
Total revenues | 100.00 | 100.00 |
Operating expenses | | |
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 | 83.463 |
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 (Δ); 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 (Δ). 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, 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 (Δ) 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:

<table>
<thead>
<tr>
<th>Power sales and revenues</th>
<th>100.00% (the price to SPS Ground Segment Utility Consortia Corporation concept)</th>
</tr>
</thead>
</table>

**Operating expenses**

<table>
<thead>
<tr>
<th>Operating expenses</th>
<th>Ratios (% of Revenues)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite power production</td>
<td>(24.5995)</td>
</tr>
<tr>
<td>Satellite system interim replacement</td>
<td>(6.1802)</td>
</tr>
<tr>
<td>Satellite system operations and maintenance</td>
<td>(3.7164)</td>
</tr>
<tr>
<td>HLLV space transportation system interim replacement</td>
<td>(0.6653)</td>
</tr>
<tr>
<td>HLLV space transportation system O&amp;M</td>
<td>(2.7777)</td>
</tr>
<tr>
<td>Space station interim replacement</td>
<td>(5.1957)</td>
</tr>
<tr>
<td>Space assembly/support facilities interim replacement</td>
<td>(0.5000)</td>
</tr>
<tr>
<td>Intra-orbit vehicle interim replacement</td>
<td>(0.0304)</td>
</tr>
<tr>
<td>Intra-orbit vehicle O&amp;M</td>
<td>(0.0003)</td>
</tr>
<tr>
<td>Cargo orbiter transfer vehicle expense</td>
<td>(0.0357)</td>
</tr>
<tr>
<td>Personnel orbiter transfer vehicle expense</td>
<td>(0.0103)</td>
</tr>
<tr>
<td>Personnel orbiter transfer vehicle O&amp;M</td>
<td>(0.0554)</td>
</tr>
<tr>
<td>Facilities—interim replacement</td>
<td>(0.2230)</td>
</tr>
<tr>
<td>Depreciation and amortization</td>
<td>(26.1400)</td>
</tr>
<tr>
<td>Payments in lieu of taxes</td>
<td>(5.0000)</td>
</tr>
<tr>
<td>Social security taxes (@ $1500 per year per employee)</td>
<td>(1.4800)</td>
</tr>
</tbody>
</table>

**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)**

<table>
<thead>
<tr>
<th>Operating expenses</th>
<th>Ratio (% of Revenues)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite power production</td>
<td>(31.2389)</td>
</tr>
<tr>
<td>Satellite system interim replacement</td>
<td>(4.3224)</td>
</tr>
<tr>
<td>Satellite system operations and maintenance</td>
<td>(2.5992)</td>
</tr>
<tr>
<td>HLLV space transportation system interim replacement</td>
<td>(0.4653)</td>
</tr>
<tr>
<td>HLLV space transportation O&amp;M</td>
<td>(1.9427)</td>
</tr>
<tr>
<td>Space station interim replacement</td>
<td>(3.6338)</td>
</tr>
<tr>
<td>Space assembly/support facility interim replacement</td>
<td>(0.3497)</td>
</tr>
<tr>
<td>Facilities—interim replacement</td>
<td>(0.1560)</td>
</tr>
<tr>
<td>Intra-orbit vehicle interim replacement</td>
<td>(0.0213)</td>
</tr>
<tr>
<td>Intra-orbit vehicle O&amp;M</td>
<td>(0.0002)</td>
</tr>
<tr>
<td>Cargo orbiter transfer vehicle expense</td>
<td>(0.0250)</td>
</tr>
<tr>
<td>Personnel orbiter transfer vehicle expense</td>
<td>(0.0074)</td>
</tr>
<tr>
<td>Personnel orbiter transfer vehicle O&amp;M</td>
<td>(0.0388)</td>
</tr>
<tr>
<td>Depreciation and amortization</td>
<td>(18.2822)</td>
</tr>
<tr>
<td>Payments in lieu of taxes</td>
<td>(3.4970)</td>
</tr>
<tr>
<td>Social security taxes</td>
<td>(1.0351)</td>
</tr>
</tbody>
</table>

**Total operating expenses**

(67.6150)

**Operating income**

Other income

**Total income**

(TBD)

**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 (A±); 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 (A±). 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 inflows applied to the capital investments and the changes (A±) 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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### Table C.7-1. Summary of SPS Revenues at 30 Mills/kWh

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue from Sale of Electricity</strong></td>
<td><strong>(S Billions)</strong></td>
<td><strong>Power Sales and Revenues</strong></td>
<td><strong>(S Billions)</strong></td>
</tr>
<tr>
<td>Total Operating Revenues (SALES + OTHER)</td>
<td>2,387.536</td>
<td>Total Power Revenues (ELECTRIC UTILITIES + OTHER)</td>
<td>1,474.924</td>
</tr>
<tr>
<td>Annual kWh Sales (G000's)</td>
<td>79,584.562</td>
<td>Annual kWh Sales (G000's)</td>
<td>79,584.562</td>
</tr>
<tr>
<td>Cents per kWh</td>
<td>3c</td>
<td>Cents per kWh</td>
<td>1.8c</td>
</tr>
<tr>
<td><strong>Operating Costs</strong></td>
<td></td>
<td><strong>Operating Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Purchased Power from SPS Space Segment Corp.</td>
<td>1,474.924</td>
<td>Satellite Power Production</td>
<td>362.706</td>
</tr>
<tr>
<td>Operations and Maintenance</td>
<td>11.341</td>
<td>Satellite Interim Replacement</td>
<td>51.166</td>
</tr>
<tr>
<td>Depreciation &amp; Amortization</td>
<td>167.128</td>
<td>Satellite System Operations &amp; Maintenance</td>
<td>54.814</td>
</tr>
<tr>
<td>Interim Replacement Expense</td>
<td>20.246</td>
<td>Space Station Interim Replacement</td>
<td>76.633</td>
</tr>
<tr>
<td>Property Insurance</td>
<td>2.340</td>
<td>Space Assembly &amp; Support Equipment Expense</td>
<td>7.375</td>
</tr>
<tr>
<td>State &amp; Local Taxes</td>
<td>65.490</td>
<td>HLV Interim Replacement</td>
<td>9.812</td>
</tr>
<tr>
<td>Interest Costs</td>
<td>191.003</td>
<td>HLV Operations &amp; Maintenance</td>
<td>40.990</td>
</tr>
<tr>
<td>Income Taxes</td>
<td>95.501</td>
<td>Intra-Orbit Vehicle Interim Replacement</td>
<td>0.449</td>
</tr>
<tr>
<td>Investment Tax Credit &amp; Other</td>
<td>(30.793)</td>
<td>Intra-Orbit Vehicle Operations &amp; Maintenance</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Total Operating Costs</strong></td>
<td>1,957.184</td>
<td><strong>Total Power Revenues</strong></td>
<td></td>
</tr>
<tr>
<td>Operating Income</td>
<td>390.351</td>
<td>Operating Income</td>
<td>345.093</td>
</tr>
<tr>
<td>Other Income</td>
<td>0</td>
<td>Other Income</td>
<td>780</td>
</tr>
<tr>
<td>Income Before R&amp;D Expense</td>
<td>390.351</td>
<td>R&amp;D Expense</td>
<td>780</td>
</tr>
<tr>
<td>R&amp;D Expense</td>
<td>180</td>
<td>Income Before Interest</td>
<td>345.093</td>
</tr>
<tr>
<td><strong>Total Income on Revenues</strong></td>
<td>390.351</td>
<td>Interest Expense</td>
<td>(117.994)</td>
</tr>
<tr>
<td>Return on Revenues (%)</td>
<td>16.35</td>
<td><strong>Total Income on Revenues</strong></td>
<td>227.086</td>
</tr>
<tr>
<td><strong>Note:</strong> 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.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table C.7-2. Summary of SPS Revenues at 40 Mills/kWh

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue from Sale of Electricity</strong></td>
<td><strong>(S Billions)</strong></td>
<td><strong>Power Sales and Revenues</strong></td>
<td><strong>(S Billions)</strong></td>
</tr>
<tr>
<td>Total Operating Revenues (SALES + OTHER)</td>
<td>3,183.379</td>
<td>Total Power Revenues (ELECTRIC UTILITIES + OTHER)</td>
<td>2,109.911</td>
</tr>
<tr>
<td>Annual kWh Sales (G000's)</td>
<td>79,584.424</td>
<td>Annual kWh Sales (G000's)</td>
<td>79,584.562</td>
</tr>
<tr>
<td>Cents per kWh</td>
<td>4c</td>
<td>Cents per kWh</td>
<td>2.7c</td>
</tr>
<tr>
<td><strong>Operating Costs</strong></td>
<td></td>
<td><strong>Operating Costs</strong></td>
<td></td>
</tr>
<tr>
<td>Purchased Power from SPS Space Segment Corp.</td>
<td>2,109.911</td>
<td>Power Production</td>
<td>659.111</td>
</tr>
<tr>
<td>Operations and Maintenance</td>
<td>11.341</td>
<td>Satellite Interim Replacement</td>
<td>51.166</td>
</tr>
<tr>
<td>Depreciation &amp; Amortization</td>
<td>167.128</td>
<td>Satellite System Operations &amp; Maintenance</td>
<td>54.814</td>
</tr>
<tr>
<td>Interim Replacement Expense</td>
<td>20.246</td>
<td>Space Station Interim Replacement</td>
<td>76.633</td>
</tr>
<tr>
<td>Property Insurance</td>
<td>2.340</td>
<td>Space Assembly &amp; Support Equipment Expense</td>
<td>7.375</td>
</tr>
<tr>
<td>State &amp; Local Taxes</td>
<td>65.490</td>
<td>HLV Interim Replacement</td>
<td>9.812</td>
</tr>
<tr>
<td>Interest Costs</td>
<td>191.003</td>
<td>HLV Operations &amp; Maintenance</td>
<td>40.990</td>
</tr>
<tr>
<td>Income Taxes</td>
<td>95.501</td>
<td>Intra-Orbit Vehicle Interim Replacement</td>
<td>0.449</td>
</tr>
<tr>
<td>Investment Tax Credit &amp; Other</td>
<td>(30.793)</td>
<td>Intra-Orbit Vehicle Operations &amp; Maintenance</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Total Operating Costs</strong></td>
<td>2,657.627</td>
<td><strong>Total Power Revenues</strong></td>
<td></td>
</tr>
<tr>
<td>Operating Income</td>
<td>525.752</td>
<td>Operating Income</td>
<td>681.287</td>
</tr>
<tr>
<td>Other Income</td>
<td>0</td>
<td>Other Income</td>
<td>780</td>
</tr>
<tr>
<td>Income Before R&amp;D Expense</td>
<td>525.752</td>
<td>R&amp;D Expense</td>
<td>780</td>
</tr>
<tr>
<td>R&amp;D Expense</td>
<td>180</td>
<td>Income Before Interest</td>
<td>681.287</td>
</tr>
<tr>
<td><strong>Total Income on Revenues</strong></td>
<td>525.752</td>
<td>Interest Expenses</td>
<td>(118.053)</td>
</tr>
<tr>
<td>Return on Revenues (%)</td>
<td>16.35</td>
<td><strong>Total Income on Revenues</strong></td>
<td>405.234</td>
</tr>
<tr>
<td><strong>Note:</strong> 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.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
• 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. SC-7.

Figure C.7-2. SC-7-2.

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Rockwell International
Space Division

SD 78-AP-0023-7
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.7-4.

Table: % Return on Net Average Assets Employed (1982-2020)

<table>
<thead>
<tr>
<th>Year</th>
<th>6</th>
<th>10</th>
<th>19</th>
<th>26</th>
<th>30</th>
<th>65</th>
<th>82</th>
<th>94</th>
<th>96</th>
<th>118</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>% RETURN ON NET INCOME</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL INVESTMENT (NET ASSETS EMPLOYED $)</td>
<td>0.082</td>
<td>0.574</td>
<td>1.424</td>
<td>4.784</td>
<td>16.799</td>
<td>27.949</td>
<td>27.949</td>
<td>16.799</td>
<td>0.082</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>NET WORKING CAPITAL (Net Assets)</td>
<td>0.001</td>
<td>0.005</td>
<td>0.011</td>
<td>0.016</td>
<td>0.026</td>
<td>0.041</td>
<td>0.102</td>
<td>0.528</td>
<td>1.509</td>
<td>8.590</td>
<td>13.272</td>
</tr>
<tr>
<td>NET PLANT &amp; PROPERTY (Net Assets)</td>
<td>0.001</td>
<td>0.004</td>
<td>0.003</td>
<td>0.004</td>
<td>0.006</td>
<td>0.011</td>
<td>0.044</td>
<td>0.337</td>
<td>0.648</td>
<td>1.043</td>
<td>1.595</td>
</tr>
</tbody>
</table>


Note: Average return on net assets employed over the total time period of 1982-2020 = 18.1%
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%.

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%.

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SD 78-AP-0023-7
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.
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
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.

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.
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, 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 for 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.

<table>
<thead>
<tr>
<th>CUMULATIVE CASH FLOW PERFORMANCE AND INVESTMENT RECOVERY SCHEDULE FOR THE COMBINED SPS SPACE SEGMENT CORPORATION &amp; THE SPS GROUND SEGMENT UTILITY CONSORTIA CORPORATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL CUMULATIVE NET CASH FLOW</td>
</tr>
<tr>
<td>SPACE SEGMENT</td>
</tr>
<tr>
<td>GROUND SEGMENT</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
<tr>
<td>MILLIONS OF DOLLARS</td>
</tr>
<tr>
<td>0.164</td>
</tr>
<tr>
<td>0.164</td>
</tr>
<tr>
<td>0.164</td>
</tr>
</tbody>
</table>

INVESTMENT RECOVERY PERIOD ~32-1/4 YEARS

BASED ON 3/22/78 40 MILLS/KWH COMPUTER RUN ON THE PROPOSED TWO MAJOR ORGANIZATIONAL ENTITIES - IRA E. CORNELIUS

ORIGINAL PAGE IS OF POOR QUALITY
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:

<table>
<thead>
<tr>
<th>Profit before taxes</th>
<th>$100,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income taxes at 50%</td>
<td>$50,000,000</td>
</tr>
<tr>
<td>Less: Investment tax credit</td>
<td>$ 5,000,000</td>
</tr>
<tr>
<td>Net income (profit after taxes)</td>
<td>$ 45,000,000</td>
</tr>
</tbody>
</table>

Example 2. The corporation could also elect to spread the benefit over a five-year period, for example:

<table>
<thead>
<tr>
<th>Profit before taxes</th>
<th>$100,000,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income taxes at 50%</td>
<td>$50,000,000</td>
</tr>
<tr>
<td>Less: Investment tax credit</td>
<td>$ 1,000,000</td>
</tr>
<tr>
<td>Net income (profit after taxes)</td>
<td>$ 49,000,000</td>
</tr>
</tbody>
</table>

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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.
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 util-
ity. 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 prin-
ciples (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 adden-
dum allowed utilities to treat tax benefts, 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 dif-
ferent 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 circum-
stances 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. How-
ever, 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 elimi-
nated. 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.
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.