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REFERENCE SYSTEM CHARACTERIZATION AND COST OVERVIEW

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Studies conducted during the Solar Power Satellite Concept Evaluation Program have considered a variety of system design approaches. Each of these design approaches has advantages and disadvantages. Considerable additional work would be required before a final or preferred system can be defined. For the immediate purposes of the evaluation program, however, a reference system has been defined to provide a basis for assessing alternate technical approaches, environmental factors and to serve as a basis for preliminary cost studies.

Reference System Description

A description of the system is presented in reference 1. Major elements of the system are depicted in figure 1. They include a cargo launch vehicle, a low earth orbit staging base, a cargo orbital transfer vehicle, a geosynchronous construction base, and the energy system consisting of the satellite and a ground receiving station or rectenna. Additional program elements include personnel launch and orbital transfer vehicles, launch and recovery facilities, and industrial production facilities. More detailed characteristics of the satellite and rectenna are presented in figure 2. The satellite consists of the solar array and the microwave transmitting antenna. The solar array includes a graphite composite truss structure and a blanket of silicon solar cells. An alternate reference option involves the use of gallium aluminum arsenide solar cells in a trough-like structure. A yoke arrangement provides the interface between the solar array and the transmitting antenna. Its mechanization allows the solar array to track the sun while the antenna tracks the rectenna at a fixed position on the earth. The antenna consists of a primary and a secondary structure, on which are mounted approximately 7000, 10 meter by 10 meter, subarrays. The subarrays include 100,000 DC-RF power amplifiers and wave guides. The rectenna consists of a series of panels, oriented toward the satellite, consisting of an open-screen ground plane, on which are mounted a large number of half-wave dipole antennas. The power, collected by the antennas, is fed to Schottky barrier diodes for conversion to D.C. power. The dimensions of the satellite and rectenna are shown in the figure. The satellite weighs 51,000 metric tons.

Cost Overview

The detailed definitions of the satellite, rectenna and other program elements have provided basic information necessary for preliminary cost estimates. A number of estimates have been developed during the Concept Evaluation Program; however, the concept has not matured sufficiently to establish an official estimate. The estimates presented, however, are illustrative, and have been found to be useful in establishing the relative importance of the various program elements from a cost standpoint.

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Figure 1

NASA Solar Power Satellite

Major Program Elements

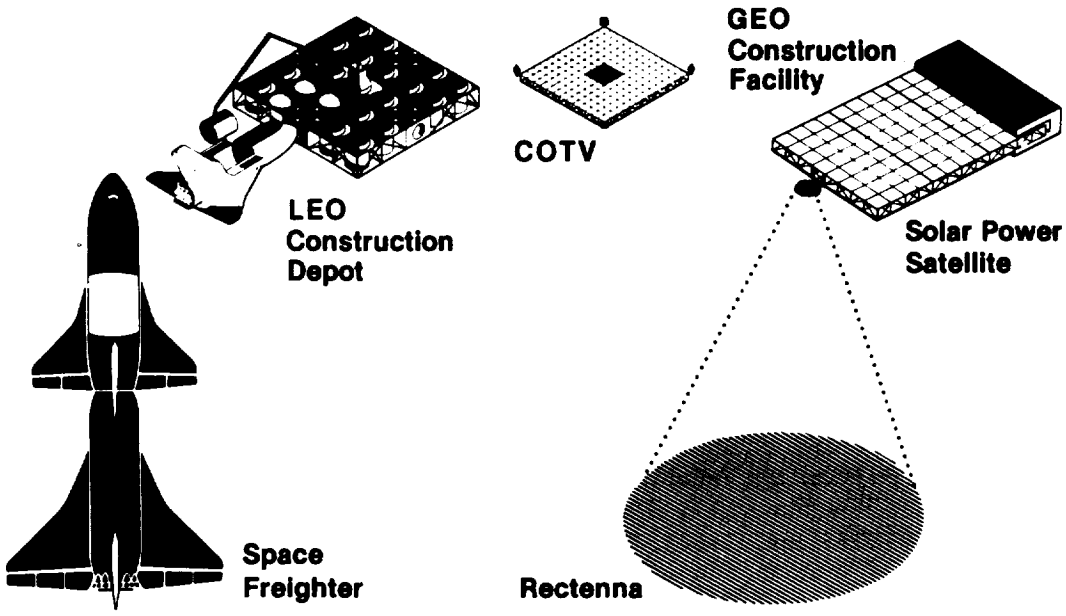
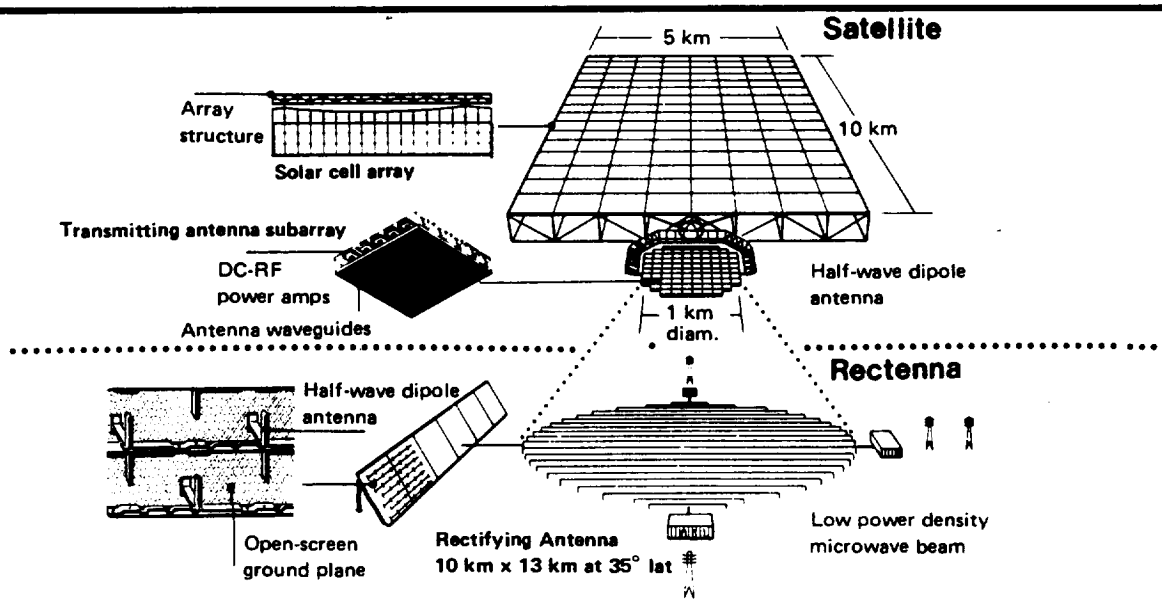


Figure 2

NASA Solar Power Satellite

Reference System Characteristics



Two cost perspectives are necessary for concept evaluation. The first involves the total cost necessary to research, develop, facilitize, and construct the first full-scale system. The program phases involved in achieving this first unit and the associated costs are discussed in reference 2. The second perspective involves the cost of replicating the initial system and thereby increasing the total power available.

The work breakdown structure presented in table 1 has been utilized in developing the cost estimate. The actual structure used involves many more levels of detail than portrayed in the table. Cost estimating procedures have included conventional estimating relationships based on existing data bases coupled with a "mature industry approach" where very large production quantitites are involved.

The satellite costs are those required to produce the 51,000 metric tons of material and components in earth-based facilities. Construction costs include the funds required to maintain and operate the space staging and construction facilities including salaries and supplies for the construction crews. The transportation costs involve the operation of fleets of four types of vehicles ferrying crews and cargo to the space construction facility. The rectenna costs include both the cost of the materials and components and the associated construction costs. Maintenance costs include the crews and components, transportation and facilities necessary to service the satellite and the rectenna, after operations are initiated.

Table 2 presents a summary cost estimate for a particular program scenario, involving the construction of two-five gigawatt systems per year over a thirty-year period. Cost estimates are presented for each program phase leading up to the first full-scale unit and the average cost of the succeeding fifty-nine units. The relative cost of the energy system, construction, transportation, and program management costs are presented.

Concluding Remarks

Accurate cost estimates for any advanced energy systems are very difficult to develop, since such estimates require technology advancement projections over an extended period of time. Nevertheless, such estimates are necessary to the preliminary evaluation of advanced concepts. The primary value of such estimate is to provide an indication of whether the concept should be pursued relative to other concepts, and to evaluate the relative cost importance of the various elements contained within the program.

The estimated costs presented in table 2 were obtained from studies conducted by the Boeing Aerospace Company as part of the SPS System Definition effort.

Reference 1. Reference System Report, Satellite Power System Concept Development and Evaluation Program, Department of Energy and the National Aeronautics and Space Administration, October 1978.

Reference 2. Piland, R.O. SPS Cost Methodology and Sensitivities. Satellite Power System Program Review, Department of Energy and the National Advisory Committee for Aeronautics, April 1980.

Table 1
Work Breakdown Structure

- 1 0 SPS PROGRAM
  - 1 1 Satellite
    - 1.1.1 **Conversion**
    - 1.1.2 **Transmission**
    - 1.1.3-7 **Other**
  - 1 2 Construction
    - 1.2.1 **GEO Base**
    - 1.2.2 **LEO Base**
    - 1.2.3 **Maint. system**
  - 1 3 Transportation
    - 1.3.1 **Cargo launch**
    - 1.3.2 **Cargo OTV**
    - 1.3.3 **Personnel launch**
    - 1.3.4 **Personnel OTV**
    - 1.3.5 **Ground Operations**
  - 1 4 Rectenna
    - 1.4.1 **Site**
    - 1.4.2 **Structure**
    - 1.4.3 **Power collection**
    - 1.4.4 **Control**
    - 1.4.5 **Interface**

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Cost Elements	Major Program Phases						
	Res.	**Eng.**	**Demo.**	**Invest.**	**1st SPS**	**Total**	**Avg. SPS**
Satellite/ Rectenna	.3	.7	7.5	9.5	6.5	24.5	6.5
Construction	.05	2.3	8.8	17.0	1.8	30.0	1.0
Transportation	.05	5.0	6.5	30.0	4.0	45.5	2.8
Mgmt. & Integ.		.1	.2	1.0	1.2	2.5	1.2
Total	**.4**	**8.1**	**23.0**	**57.5**	**13.5**	**102.5**	**11.5**

Table 2
A Program Cost Scenario*

All Costs in Billions of 1977 $

* *No official estimates exist. This is one of several estimates.*