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EVALUATION OF SOLAR CELL MATERIALS FOR A SOLAR POWER SATELLITE[1]

Dr. Peter E. Glaser - Dr. David W. Almgren - Ms. Katinka I. Csigi
Arthur D. Little, Inc. - Cambridge, Massachusetts

As originally conceived, a solar power satellite (SPS) can utilize current approaches to solar energy conversion, e.g., photovoltaic, thermal electric, and others, which may be developed in the future. Among these conversion processes, photovoltaic conversion represents a useful starting point because solar cells already are in wide use in satellites. An added incentive is the substantial progress being made in the development of low-cost reliable photovoltaic systems for terrestrial applications, the increasing confidence in the capabilities to achieve the required production volumes to sustain expanded markets. Figure 1 projects the cost reduction of silicon solar cells and the necessary transition to thin-film solar cells which will have to be developed to meet projected terrestrial photovoltaic system production and cost goals.

Several photovoltaic energy conversion systems applicable to the SPS concept have been evaluated. Two alternative photovoltaic systems—one employing single-crystal silicon, and the other, gallium arsenide—have been selected for the SPS reference system. The silicon photovoltaic system utilized 50 μm thick, single-crystal, silicon solar cells sandwiched between layers of 75 μm and 50 μm thick borosilicate glass, while the alternative design utilizes 5 μm thick, single-crystal heteroface gallium arsenide solar cells formed by a chemical vapor-deposition process on a 20 μm layer of sapphire as the substrate/cover glass for the solar cell. The array is then encapsulated with 13 μm of Teflon bonding the solar cell to a 25 μm Kapton cover. The gallium arsenide solar cells are integrated with thin-film Kapton solar reflectors with a concentration ratio of 2 to reduce the required solar cell area. The mass of the photovoltaic systems represents 40% of the mass of the SPS reference system.

The beginning of life (BOL) and end of life (EOL) conversion efficiencies of the SPS solar cells has a significant impact on the total size of an SPS and the total mass that has to be carried to geosynchronous orbit.

The SPS system studies have been primarily concerned with such photovoltaic factors as:

- Beginning of life solar cell efficiency;

- Rate of degradation of output on
  - orbit
  - solar cell/array/system performance:
- Photovoltaic efficiency recovery techniques;
- Cell/array cost;
- Mass; and
- Availability of photovoltaic materials.

In addition to these parameters, consideration has to be given to the cell/array manufacturing processes to meet SPS production requirements and cost goals.

Silicon is presently the only photovoltaic material that is being considered for mass production as part of the U. S. Department of Energy (DOE) Photovoltaic Program.[2] Single-crystal silicon solar cells could meet the projected needs of the ground-based exploratory development and space technology verification during the period 1980 to 1985, and is the most likely photovoltaic material for use in SPS pilot and prototype systems. Gallium arsenide is a promising photovoltaic material, however, gallium arsenide solar cells in suitable form, sufficient quantity, having reproducible characteristics and an acceptable cost are unlikely to be available before 1985 unless there is a near-term significant R&D program commitment. Furthermore, other advanced photovoltaic materials, e.g., amorphous silicon, are being investigated as part of the DOE Photovoltaic Program which may deserve consideration as candidates for SPS solar cell arrays if they could be mass produced at low cost.

The industrial capability needed to manufacture the SPS solar cells and arrays will require the development of large-volume production technology which could serve both the SPS and terrestrial PV system requirements. Figure 2 presents a solar cell/array production scenario based on the deployment of one 10 GW on two 5 GW SPS's per year including inventory accumulation. This implies that the selection of solar cell materials and array designs will be completed by 1985, and that a long-term on-orbit solar cell array test program will provide data on the performance of candidate solar cell arrays in the space environment prior to commitment to a pilot-plant program.

The scale of commitment of capital material and labor resources to construct large-scale manufacturing facilities will require that the risks and uncertainties in achieving required solar cell/array performance and cost goals have been evaluated and that they are acceptably low. Funding commitments for gallium arsenide, or other promising photovoltaic materials, would have to approach the present level of funding for silicon solar cells in the next several years so that they could be considered for an operational SPS in the 2000 time frame.

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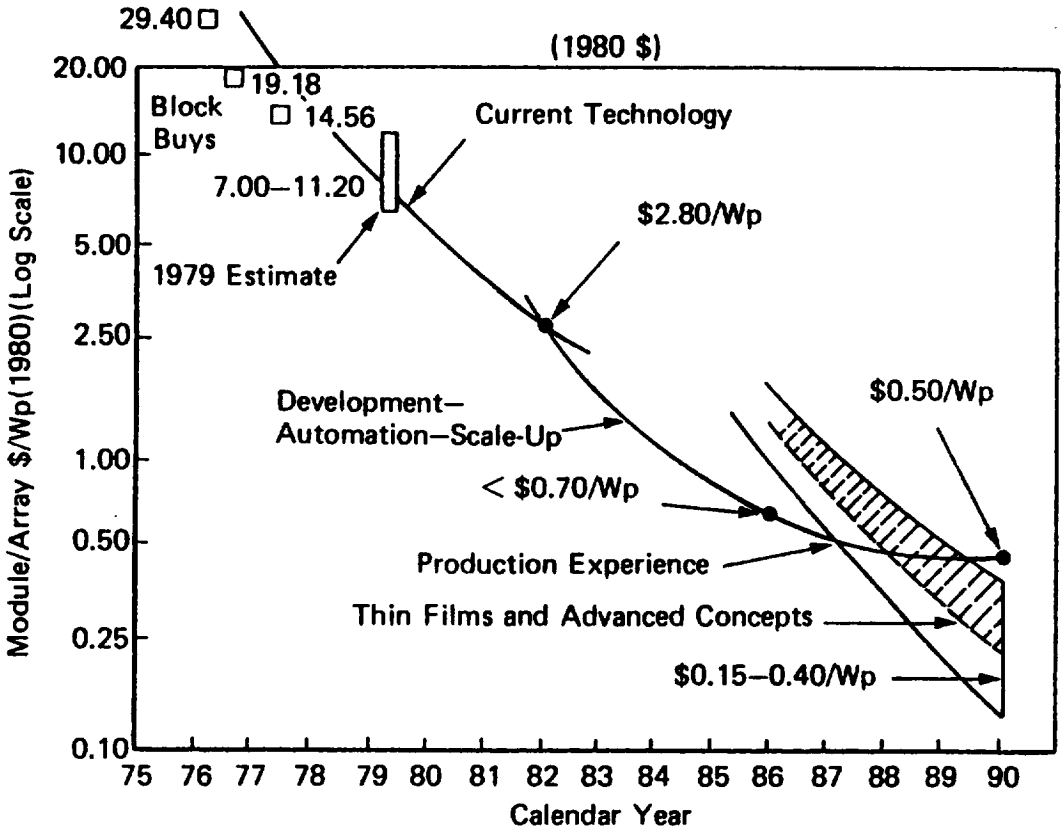
[1]Arthur D. Little, Inc., "Evaluation of Solar Cells and Arrays for Potential Solar Power Satellite Applications." Final Report to NASA Lyndon B. Johnson Space Center, March 1978.

[2]U.S. Department of Energy, National Photovoltaic Program, Multi-Year Program Plan, June 6, 1979. DOE/ET-0105-D.

PHOTOVOLTAIC CELL/ARRAY PRICE GOALS AND HISTORY



Source: Department of Energy, Reference 2.

Figure 1.

SOLAR CELL/ARRAY PRODUCTION SCENARIO FOR YEAR 2000 SPS DEPLOYMENT

(Inventory Accumulation

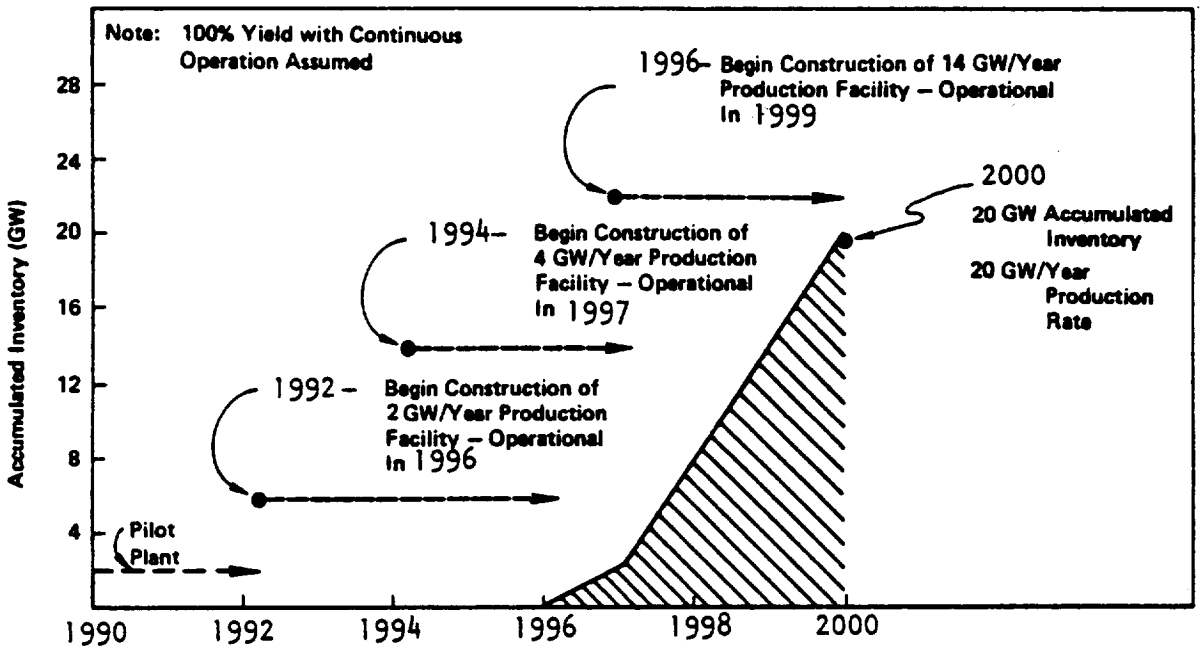


Figure 2.