TECHNOLOGY ALTERNATIVES FOR THE SPS

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The NASA/DOE reference design adopted for the SPS is based on current technology, with realistic projections for improvements in areas such as the cost and specific mass of photovoltaic cells. It provides a common benchmark for use in assessments of the implications of the SPS in societal, economic, industrial, military, environmental and other areas. However, it is recognized that new technologies are emerging which may offer advantages over those selected for the reference system. It is important to maintain a continuing evaluation of the technological alternatives, so as to exhibit potential improvements in the SPS, permit estimates of the technical and cost risk involved, and develop guidelines for future research.

It is clearly not possible to make an exhaustive list of all conceivable technical innovations which might affect the SPS, but it is nevertheless feasible to develop a systematic methodology for the assessment of technological alternatives, which may be of value both in evaluating new technologies as they are proposed and in identifying high-priority areas for research. Such a methodology involves several components:

1) Variation of Guidelines. There are a number of guidelines underlying the reference design (a build-up rate of 10 GW per year, a design life of 30 years, a microwave power beam with an ionospheric flux limit of 23 mW/cm^2, etc.), which were originally adopted as reasonable but somewhat arbitrary assumptions. These assumptions need to be clearly identified, possible changes in them should be documented, and consideration should be given to the effect of such changes on the optimal design of the SPS, the construction scenario, and the overall cost of the system.

2) Analysis of System Functions. The primary functions which must be performed by the SPS are:

- Collection of solar energy in space.
- Conversion to an intermediate form of energy (thermal and/or electric).
- Conversion to a power beam.
- Reception and conversion to electricity on Earth.

A number of secondary functions are also required, including station-keeping and attitude control, beam control and steering, transportation and construction, etc.

Alternative technical approaches exist for most of the sub-systems required to carry out these functions, and some of them may offer advantages over those assumed in the reference design. However, changes in one sub-system often propagate throughout the design, requiring changes in many other sub-systems as well, and may involve major revision of overall system parameters -- for example, using laser instead of microwave power transmission leads to much lower optimum power output. Fortunately, a relatively elementary analysis of the system effects of sub-system changes will generally suffice for a preliminary assessment of new technologies -- in fact, it appears to be possible to set up a system tree, analogous to a decision tree, in which the branches are different sub-system choices and which explicitly displays the costs and benefits involved. Fig. I shows the first step in the development of such a

tree, in which only the path leading to the reference design is illustrated. The new technologies which appear promising after this simple analysis can then be given more detailed study. This process may itself suggest new approaches, and it must in any case be updated as new technologies are proposed.

3) System Sensitivity Analysis. At the present stage of development of the SPS concept, the highest priority research areas are those where major improvements could be effected in the technical feasibility and/or cost of the system. An important output of the above system analysis is thus a classification of new technologies according to their potential impact on the performance of the system.

4) Technology Status and Risk Analysis. Some alternative technologies are clearly feasible and the costs and benefits which they imply can be estimated with confidence, but others must be regarded as quite speculative. A systematic technique is therefore needed to allow risk to be taken into account in decisions regarding research priorities. As an example, for each new SPS design which is proposed, a measure of the cost risk (e.g., the standard deviation of the cost probability distribution) can in principle be plotted against the nominal cost; in terms of cost, those designs which lie closest to the origin in such a plot are of highest interest. Difficulties may however arise because realistic estimates of cost and cost risk may be unobtainable without detailed analysis.

5) External Costs, Problem Areas and Criticisms of the SPS. Another important dimension in the assessment of new technologies is the effect which they may have in areas outside design engineering. For example, use of laser power transmission might change the military implications of the SPS, simplify or complicate integration with existing utility systems, and affect the societal acceptability of this form of electric power.

One of the strengths of the SPS, as compared with other options for power generation, is the variety of technical alternatives which are available for virtually all the sub-systems and for providing support functions such as transportation. This characteristic increases confidence that the concept will prove feasible, but it greatly complicates the rational allocation of limited resources during the R&D phase. The methodology discussed here is a first step towards creation of a formal decision-analytic framework which can support design choices and program decisions as development proceeds. It provides a common basis for the assessment of alternative approaches which have been proposed or are evolving, it may facilitate innovation by identifying areas where new technologies can be of greatest benefit, and it should eventually allow creation of an extensive data base concerning design options which can be of value to the SPS design engineer as well as to management of the program.
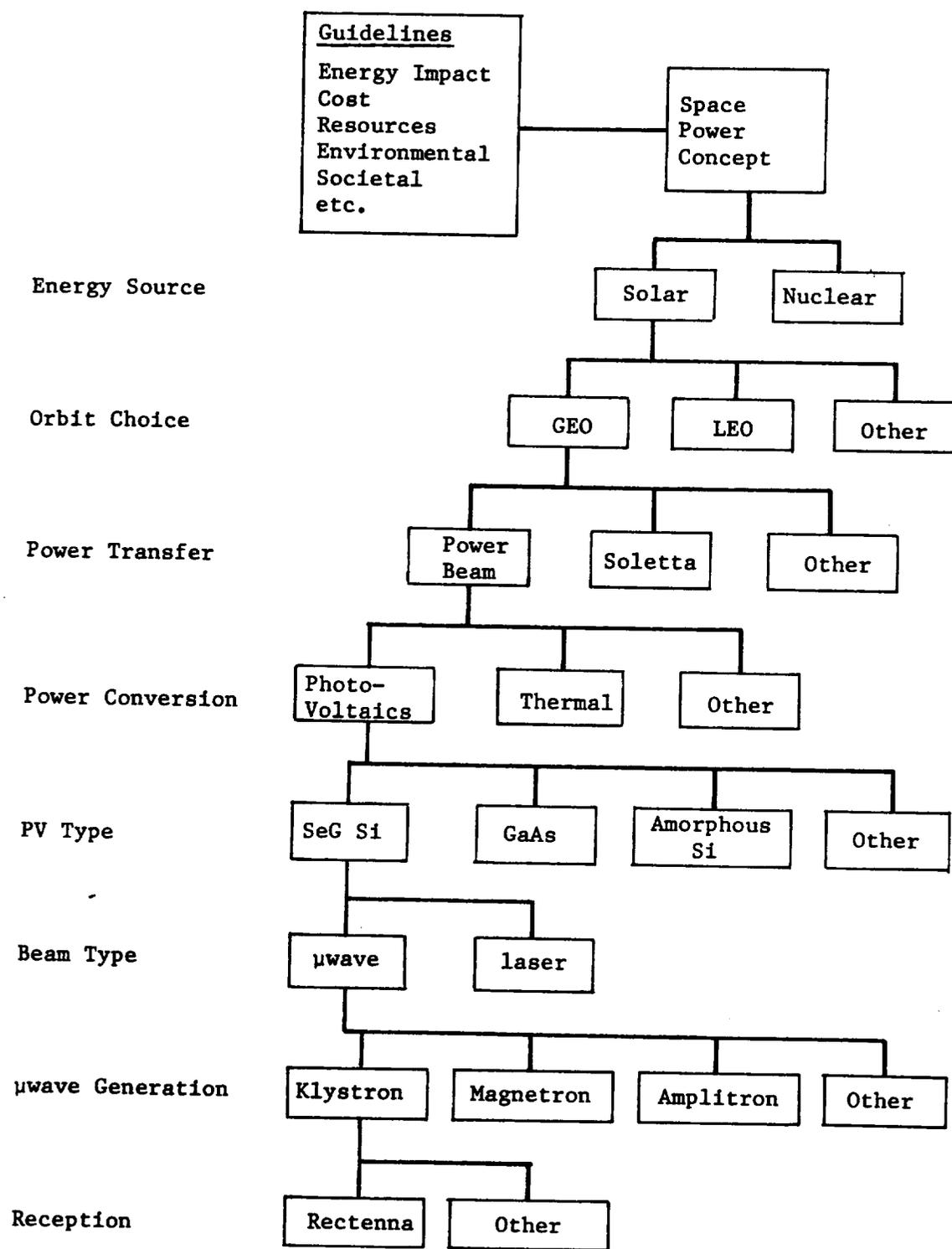
Figure I   Space Power Sub-System Tree

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