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Satellite Power System (SPS) Societal Assessment

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DOE/NASA
Satellite Power System
Concept Development
and
Evaluation Program

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FOREWORD

The Department of Energy (DOE) is considering several options for generating electrical power to meet future energy needs. The Satellite Power System (SPS), one of these options, would collect solar energy through a system of satellites in space and transfer this energy to earth. A Reference System has been described that would use photovoltaic cells to collect the solar energy, convert it to microwaves, and transmit the microwave energy via directive antennas to large receiving/rectifying antennas (rectennas) on earth. At the rectennas, the microwave energy would be converted into electricity. The potential societal impacts of constructing and operating the Satellite Power System have been assessed as a part of the Department of Energy's SPS Concept Development and Evaluation Program.

This is a report of that assessment. It has been preceded by Satellite Power System (SPS) Preliminary Societal Assessment, published in May 1979. The preliminary assessment summarized the results of fourteen individual studies of specific issues in four general areas: resources, institutions, international considerations, and public concerns. This report incorporates the earlier results and extends them on the basis of thirteen additional studies in the same general areas. It outlines the state of knowledge with respect to the issues addressed, delineates SPS-related problems and makes recommendations for further studies.

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ABSTRACT

Construction and operation of a 60-unit (300 GW) domestic SPS over the period 2000-2030 would stress many segments of U.S. society. A significant commitment of resources (land, energy, materials) would be required, and a substantial proportion of them would have to be committed prior to the production of any SPS electricity. Estimated resource demands, however, seem to be within U.S. capabilities. Modifications will be required of institutions called upon to deal with SPS. These include financial, managerial and regulatory entities and, most particularly, the utility industry. Again, the required changes, while certainly profound, seem to be well within the realm of possibility. Enhanced cooperation in international affairs will be necessary to accommodate development and operation of the SPS. To remove its potential as a military threat and to reduce its vulnerability, either the SPS itself must become an international enterprise, or it must be subject to unrestricted international inspection. Now either of these objectives could, in fact, be achieved, or which is preferable, remains unclear. Forty-four concerns about the SPS were identified via a public outreach experiment involving 5,000 individuals from three special interest organizations. The concerns focused on environmental impacts (particularly the effects of microwave radiation) and the centralizing tendency of the SPS on society. The interim results of the public outreach experiment influenced the scope and direction of the CDEP; the final results will be instrumental in refining further societal assessment efforts.

TABLE OF CONTENTS

| | <u>Page</u> |
|---|-------------|
| FOREWORD | 11 |
| ACKNOWLEDGEMENTS | iii |
| ABSTRACT | v |
| LIST OF ABBREVIATIONS | viii |
| I. INTRODUCTION | 1 |
| II. ASSESSMENT RESULTS | 4 |
| A. RESOURCE AVAILABILITY | 4 |
| 1. Land Use-Rectenna Siting | 4 |
| 2. Prototype Environmental Impact Statement | 8 |
| 3. Energy Requirements | 11 |
| 4. Materials Requirements | 12 |
| B. INSTITUTIONAL ISSUES | 13 |
| 1. Financial and Management Scenarios | 13 |
| 2. Regulatory Issues | 14 |
| a. State and Local Regulation | 14 |
| b. Regulation of Microwave Standards | 15 |
| 3. Utility Integration | 17 |
| 4. Insurance | 19 |
| C. INTERNATIONAL IMPLICATIONS | 21 |
| 1. International Agreements | 21 |
| 2. Organizational Considerations | 25 |
| 3. Military Implications and Vulnerability | 26 |
| a. Threats Posed by the SPS | 27 |
| b. SPS Vulnerabilities | 27 |
| c. Safeguards Against Threats and Vulnerabilities | 28 |
| D. PUBLIC CONCERNS | 28 |
| 1. Public Involvement | 29 |
| a. Review of other Government Programs for Public Involvement | 31 |
| b. SPS Public Outreach Experiment | 33 |
| (1) Citizens Energy Project | 35 |
| (2) Forum for the Advancement of Students in Science and Technology | 36 |
| (3) L-5 Society | 37 |
| 2. Public Concerns | 38 |
| III. CONCLUSIONS | 41 |
| IV. RECOMMENDATIONS | 43 |
| BIBLIOGRAPHY OF SOCIETAL ASSESSMENT REPORTS | 45 |

LIST OF EXHIBITS

| | <u>Page</u> |
|---|--------------------|
| 1 Categories of Mapped Variables | 6 |
| 2 Summary Map of Absolute Exclusion Variables | 7 |
| 3 Site of Prototype Environment Assessment | 10 |
| 4 Density of 2.45 GHZ Microwave Beam at Rectenna Location | 16 |
| 5 SPS Utility Integration | 20 |
| 6 SPS Participatory Technology Process | 30 |
| 7 Public Outreach Experiment | 34 |

LIST OF ABBREVIATIONS

| | |
|-----------------|--|
| ANSI | American National Standards Institute |
| BLM | Bureau of Land Management |
| CDEP | Concept Development and Evaluation Program |
| CEP | Citizens' Energy Project |
| COMSAT | Communications Satellite Organization |
| CONUS | Continental United States |
| DOE | Department of Energy |
| DOL | Department of Labor |
| EMC | Electromagnetic Compatibility |
| EPA | Environmental Protection Agency |
| FASST | Forum for the Advancement of Students in Science and Technology |
| FDA | Food and Drug Administration |
| FLPMA | Federal Land Policy Management Act |
| GEO | Geostationary Orbit |
| GW | Gigawatts (1 GW=1000 megawatts) |
| H&HS | Health and Human Services |
| IEA | International Energy Agency |
| INMARSAT | International Maritime Satellite Organization |
| INTELSAT | International Telecommunications Satellite Organization |
| ITU | International Telecommunications Union |
| L-5 | L-5 Society |
| LEO | Low Earth Orbit |
| mW | Milliwatts (1 mW = 1/1000 W) |
| MPTS | Microwave Power Transmission System |
| NASA | National Aeronautics and Space Administration |
| NIOSH | National Institute for Occupational Safety & Health |
| OSHA | Occupational Safety and Health Administration |
| RF | Radio Frequency |
| SPS | Satellite Power System |
| U.N. | United Nations |
| USGS | United States Geological Survey |
| WARC | World Administrative Radio Conference |

I. INTRODUCTION

CONCEPT DEVELOPMENT AND EVALUATION PROGRAM (CDEP)

The possibility of collecting solar energy in space, converting it to a form suitable for transmission to earth, and then converting the received energy to electricity has been studied by the U.S. Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA). A three-year joint program,^{26*} of which this report is one result, has generated information to be used in making decisions regarding development of the Satellite Power System (SPS) after 1980. NASA defined the engineering and operating characteristics of the SPS. DOE evaluated the system's health, safety, and ecological impacts; examined economic, international, and institutional issues; and developed comparative assessments of the SPS and alternative future power sources.

An SPS "Reference System" developed by NASA²⁷ provided the technical and operational information DOE needed to conduct its environmental, societal and comparative assessments. An SPS satellite, as specified in the Reference System, would be a flat solar-cell array of about 50 km² built on a graphite-fiber-reinforced structure. A microwave transmitting antenna 1 km in diameter would be mounted on one end of the satellite. The satellites would be constructed in geostationary earth orbit; a 150-km² ground receiving station (rectenna) for each satellite would be built at the same time. The Reference System presumes that 60 satellites, each delivering 5,000 megawatts of electricity to the utility grid, would be constructed over a 30-year period, beginning in the year 2000.

SOCIETAL ASSESSMENT

The SPS Societal Assessment had two objectives during CDEP. The first was to determine if there were societal ramifications which, in themselves, would suggest termination or redirection of any work beyond CDEP. The second objective was to establish an information base regarding SPS societal issues from which work beyond CDEP could proceed, if warranted. These objectives, in

* The superscript numbers correspond to listings in the Bibliography of Societal Assessment Reports.

conjunction with the Reference System studies, provided the rationale for focusing on four major issue areas--resource availability, institutional and international issues, and public concerns.

Relevant societal issues are created by the interplay between the SPS and its external environment. Those components of the external environment which clearly exert control or influence over SPS and those which are most directly impacted by SPS were given primary consideration. The SPS requires large inputs of resources, the allocation of which depends on various decision making bodies or institutions. Other institutional mechanisms are required to manage program activities and control interfaces between the SPS and its external environment. International bodies would exert control over SPS because of financial interest, its space-based nature, and the need for agreements to allocate space frequencies and orbital slots and to set exposure standards for microwave radiation. Because of its global significance, the SPS would, in turn, influence international relations. Public concerns over potential social change resulting from the implementation of the program are also important components of the external environment.

The studies were not intended to be exhaustive treatments of the issues addressed; rather, they provide estimates of SPS impacts commensurate with its stage of development and the needs of decision makers. Of the four major issue areas addressed in the Societal Assessment, the greatest degree of confidence can be placed in the findings regarding resource availability. The resource studies benefitted from the existence of a Reference System which provided focus and definition to the studies, as well as the availability of tested methodologies for quantitative analyses. Studies of institutional and international issues and public concerns benefit much less from the existence of a defined SPS Reference System or quantitative methodologies and rely more on understanding the complexities of consensus decision making, an undertaking which routinely requires research over a longer period of time.

The Societal Assessment was carried out in two phases. Key issues were defined, and a preliminary assessment was conducted.⁶ On the basis of the results, a final assessment was undertaken to pursue the preliminary studies further or to undertake new initiatives which seemed to be indicated. This process has produced over two dozen issue-related studies in addition to this

final integrated Societal Assessment report. Key findings are reviewed in Section II. Conclusions are surveyed by issue area in Section III. Recommendations for future societal assessment work, if a decision to proceed with SPS development is made, are included in Section IV.

II. ASSESSMENT RESULTS

The Societal Assessment found no single issue or cluster of issues that would preclude the further development of an SPS Reference System for use in the post-2000 time period. Although SPS land requirements are large and the acquisition of the sixty specific rectenna sites needed will be difficult, both problems appear to be manageable. Estimated material and energy resource demands are well within U.S. capabilities. Institutions appear equal to the task of accommodating the SPS even though some of them will require rather profound modification. International implications are extensive and will require complex negotiations and agreements; assurance of geostationary orbit availability will require early consideration. Public concerns about SPS tend to focus on the biological effects of microwave radiation, the tendency it may have to further centralize our energy resources and society in general, the economics of the system, and its international (particularly military) implications.

A. RESOURCE AVAILABILITY

Physical resources considered most critical to SPS are land, energy, and materials. The general objectives of studies addressing these issues were:

- To identify resource requirements based on the SPS Reference System; and
- To identify potential resource availability problems and, where possible, strategies for overcoming them.

A series of preliminary resource assessment studies were conducted. Based on these findings, further analyses pursued the materials and rectenna siting studies and developed a prototype Environmental Impact Statement (EIS) for a hypothetical rectenna site.

1. Land Use-Rectenna Siting⁵

The approach to the land availability problem has been to identify those areas of the contiguous U.S. that cannot be used for siting SPS rectennas. These areas, in the continental United States (CONUS), have been identified

using a series of computer-generated maps which show areas of land excluded on the basis of certain criteria represented by the "exclusion variables" of Exhibit 1. Areas not identified with exclusion variables have been determined to be "eligible" for rectenna siting, pending further analysis. It has also been assumed that the eligible areas must be close enough to major electrical utility load centers to represent a reasonable solution to utility integration concerns. Thus, the need to find sufficient land for all 60 rectennas in the Reference System is one factor; suitably-located land is another.

In addition to those exclusion variables which absolutely preclude rectenna siting (e.g., land traversed by interstate highways), land potentially can be excluded due to a high probability of some adverse effect arising from the siting of a rectenna (e.g., if the given piece of land being mapped contains Indian reservations). Since too little is known currently about the biological effects of SPS microwave power transmission on avian species, another category of variable, "Potential Exclusion--Impact Unknown," was created. This variable specifically excludes the flyways of migratory waterfowl, flyways which are well known and easily identified. Design/cost variables also represent possible exclusion, depending upon rectenna design/cost trade-offs.

The absolute exclusion variables were plotted on USGS 7.5 minute quad maps, as shown in Exhibit 2. Each grid cell measures 13 km on a side, roughly the size of a rectenna site. After mapping the full set of 15 absolute exclusion variables, 60 percent of CONUS was found to be nominally ineligible for rectenna siting. Of the 40 percent of the U.S. considered "eligible," large areas are in the Great Basin of the West and in the Plains states. There are, however, areas of eligible cells throughout the United States; only three states, Rhode Island, Connecticut and New Jersey are without a single eligible cell. Further, an analysis of the nine electric power planning regions within CONUS indicates an apparently adequate number of nominally eligible sites in all regions in comparison to projected electrical generation through the year 2000.

Adding potential exclusion variables, 19 percent of the U.S. land area is eligible for rectenna siting. Waterfowl flyways have only a minor residual impact on the number of eligible areas in CONUS. However, the exclusion of

EXHIBIT 1: CATEGORIES OF MAPPED VARIABLES

ABSOLUTE EXCLUSION VARIABLES

Inland Water
Military Reservations
DOE Atomic Energy Research and Testing Lands
National Recreation Areas
Standard Metropolitan Statistical Areas
Adjusted Population Density
Marshland Vegetation
Perennially Flooded Areas
Endangered Species
Interstate Highways
Navigable Waterways
Topography Unacceptable
EMC-A150* (Electromagnetic Compatibility)
EMC-A100 (Electromagnetic Compatibility)
EMC-A50 (Electromagnetic Compatibility)

POTENTIAL EXCLUSION VARIABLES - HIGH PROBABILITY OF IMPACT

Indian Reservations
National Forests and Grasslands
Wild and Scenic Rivers
Agricultural Lands - Mostly Cropland
Agricultural Lands - Irrigated
EMC-P150 (Electromagnetic Compatibility)
EMC-P100 (Electromagnetic Compatibility)
EMC-P60 (Electromagnetic Compatibility)
EMC-50 (Electromagnetic Compatibility)

POTENTIAL EXCLUSION VARIABLES - IMPACT UNKNOWN

Flyways of Migratory Waterfowl - Ducks
Flyways of Migratory Waterfowl - Geese

DESIGN/COST VARIABLES

Tornado Occurrence
Acid Rainfall
Snowfall
Freezing Rain
Sheet Rainfall
Wind
Lightning Density
Hail
Seismic Risk
Timbered Areas
Water Availability

*Numbers refer to minimum separation, in kilometers, from the nearest rec-
tenna.

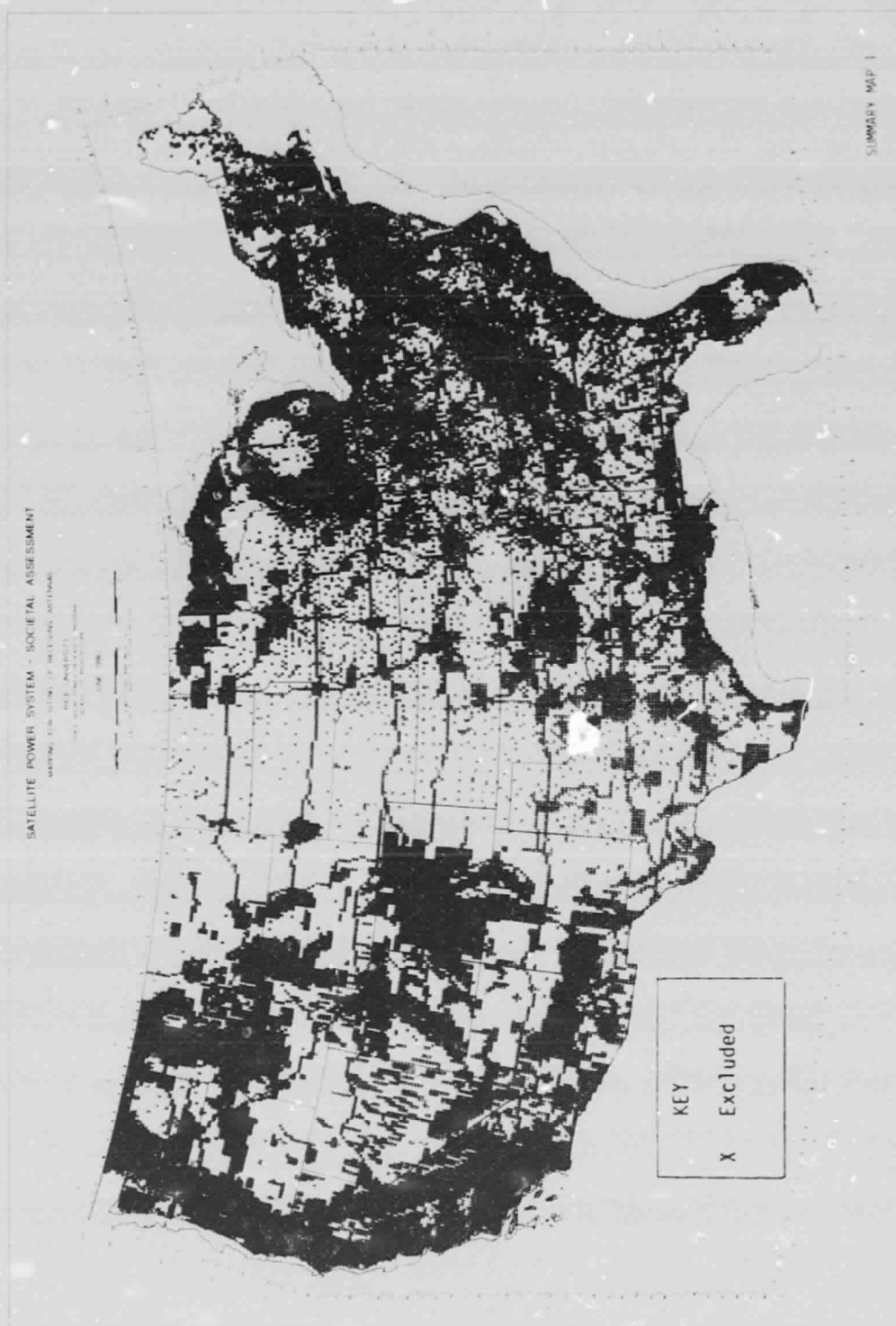


Exhibit 2. Summary Map of Absolute Exclusion Variables

land under the flyways of the other 400 species of U.S. migratory birds could seriously deplete the remaining eligible areas. Such exclusion depends on two currently unknown factors: (1) the effect of microwave radiation on these species, and (2) the precise locations and densities of their flyways.

Both eligible and ineligible areas were validated, and sensitivity analyses were conducted to better gauge the relationship among exclusion variables and between eligible and ineligible areas. The validation indicated that all excluded areas had been properly excluded. However, of the nominally eligible areas, the validation effort indicated that 47 percent pose potentially costly topographic problems and that 24 percent might be excluded for reasons other than topography. This implies that approximately 15 percent of the U.S. remains eligible after validation. Site specific studies and incorporation of potential exclusions would further reduce the percentage.

Sensitivity analyses indicated that reduction of the rectenna area by one-fourth or one-half would provide a very minor net increase (less than 30 percent) in the number of eligible cells. Reduction of rectenna size would, however, ease the problem of site acquisition.

Where land sites are unavailable, offshore sites may be an alternative. However, since no preferred design for an offshore rectenna was available, studies consisted only of mapping and analyzing those variables that would be applicable regardless of design. On this basis about half of the relatively narrow West Coast continental shelf is excluded but only about one-fourth of the Gulf and East Coast shelves are manifestly unsuitable for rectenna sites.

2. Prototype Environmental Assessment¹⁴

Preliminary studies indicated a need to assess the impacts of rectenna construction and operation at a specific site. Therefore, a prototype environmental assessment was prepared for a site in the California desert about 250 kilometers north of Los Angeles. This site was selected because background data had recently been assembled and analyses performed as part of the Environmental Impact Statement for a geothermal project in the same area. Thus the rectenna environmental assessment required only the hypothetical placement of a rectenna in the area and alteration of the analyses to make the work

applicable to the SPS Societal Assessment. Among the socioeconomic considerations addressed were land use, demography, government/social services, economic impact, and cultural resources.

The Rose Valley/Coso area (see Exhibit 3) was selected for this prototype study, because it has many characteristics suitable for an SPS rectenna site. It offers reasonably suitable terrain, and it is located in a sparsely populated rural area not far from a major electrical load center. In general, the area is typical of physical, natural and socioeconomic conditions throughout the Basin and Range Physiographic Province, which encompasses much of the southwestern United States. It should be noted, however, that selection of the study site is not the result of SPS program screening efforts. In fact, Rose Valley has some serious drawbacks as a potential rectenna site. For example, it is partly within the boundaries of the China Lake Naval Weapons Center, a critical defense facility. This would make it difficult to obtain the site for SPS use and would pose communications interference problems. For this study, these incompatible features were ignored, and the assessment proceeded as if the site were, in fact, totally suitable for an SPS rectenna.

Foremost among the critical parameters revealed in this prototype assessment is the size--roughly 150 km²--and intensity of use of the contiguous land area required by an SPS rectenna. The land area required would be an ellipse with a length of 13.4 km north-south and a width of 10.0 km east-west (36° N latitude). Surrounding the rectenna field would be a fenced buffer zone to prevent people and animals from inadvertently entering the low-intensity fringes of the microwave beam.

Preparation of the land area would require total modification of the environment. Further, once the coordinates of the rectenna field boundaries are established, there is essentially no flexibility in siting individual rectenna structures to avoid specific sensitive areas (e.g., an important archaeological site). The inflexibility of rectenna land-use requirements suggests that SPS site selection activities should focus on identifying sites that are larger than the minimum rectenna requirements. A larger site would preserve a measure of flexibility in rectenna field placement that would be unavailable in a site of barely sufficient size.

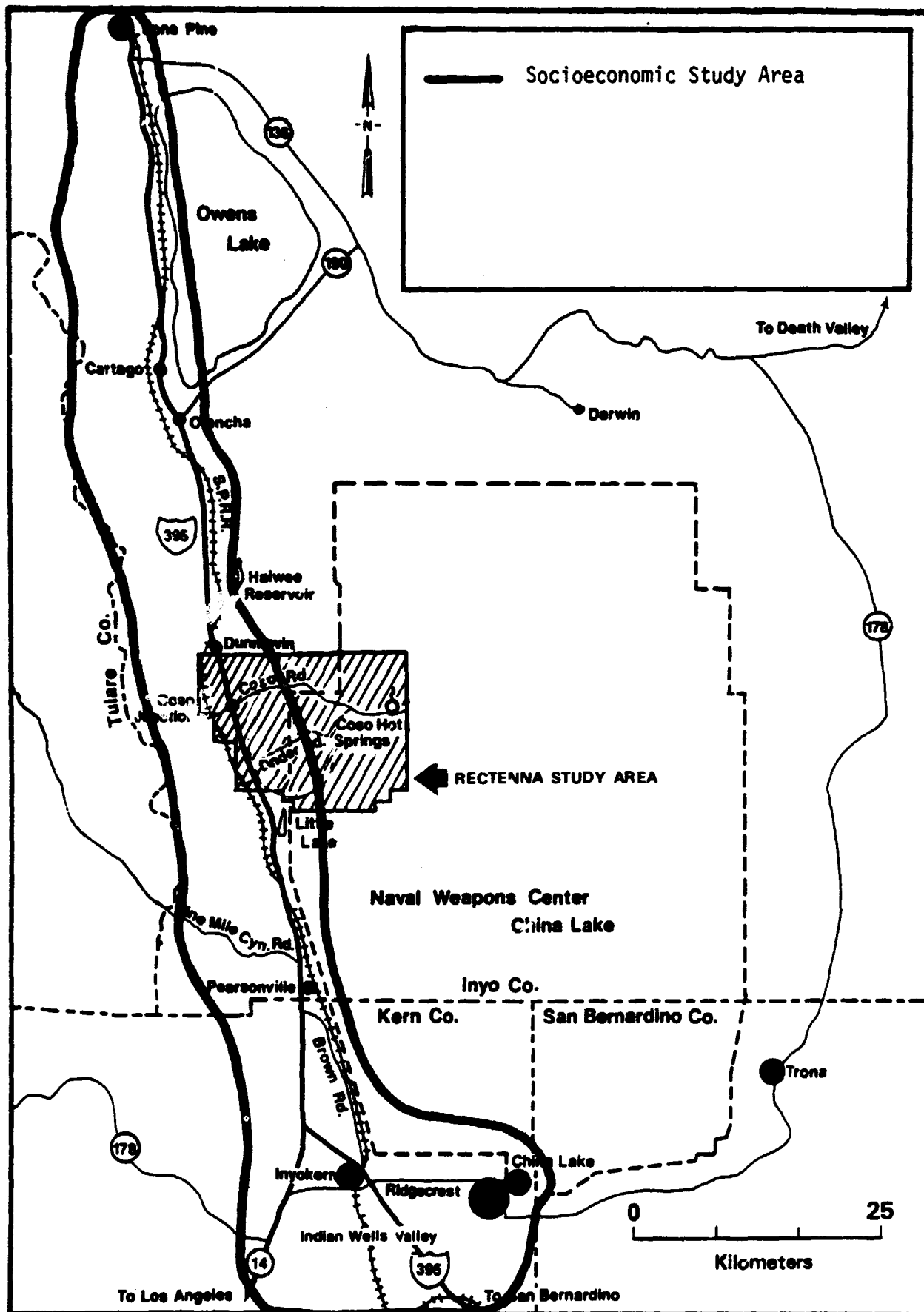


Exhibit 3. Site of Prototype Environment Assessment

The two-year rectenna construction schedule called for in the Reference System has a number of potentially significant implications relating to socioeconomic impacts on the siting region. The peak construction phase would seriously impact air quality, water supplies, and biological resources. The annual level of in-migration of construction workers, not including dependents and secondary employees associated with rectenna development, averages 2,500; with a peak of 3,200. There are also possible logistical problems, particularly with regard to the delivery to the site of enormous quantities of construction materials during the peak construction period. The delivery of 10 million tons of aggregate, 1.4 million tons of cement, and 370,000 tons of steel would require 2,400 heavy truck trips per day or six 100-car unit trains per day. An extended construction period would reduce the volume of deliveries at any one time and contribute to a diminution of all construction impacts, except the length of time they are present.

3. Energy Requirements¹⁹

Several energy analyses of the SPS have been conducted. In general, energy analysis attempts to determine the energy efficiency of a power plant. Other things being equal, it is better to build plants that require less energy for construction and maintenance. Two common measures of energy efficiency are energy ratio and payback period. The former is the net energy derived from a plant over its lifetime divided by the energy required to construct and maintain the plant. The payback period is the length of time the plant would be required to operate to generate the energy used in its construction and maintenance. It is customary to exclude the operating fuel when making these calculations and to restrict the energy requirements to non-renewable sources.

Under these conditions the SPS energy ratio is favorable, although usually less than coal and nuclear plants, depending on the specific assumptions used. Including nonrenewable fuel in the calculation makes SPS much better than coal or nuclear, since SPS is based on renewable energy. Energy payback periods for SPS have been calculated in the range of 1 to 6 years. Equivalent energy ratios would be 5 to 30. Coal and nuclear plants typically have energy ratios in the 5 to 15 range, excluding fuel. Uncertainties are larger for SPS

and stem from the relative lack of definition in the constituent materials, uncertainties regarding their energy intensities and the variety of models available for deriving the energy ratio or payback period.

4. Materials Requirements^{9 29}

Materials assessment studies resulted in both a methodology for performing an assessment and actual assessment results. The heart of the methodology is a computerized materials screening process using a data base containing information on raw and bulk materials--including energy consumption--from which new systems, as well as their components and subsystems, are manufactured. The data base currently contains about 2,000 entries covering more than 260 materials as well as estimates of present and future U.S. and world consumption, prices, U.S. imports, and dominant non-U.S. suppliers.

The screening program tells planners how much expansion in capacity will be needed to produce the projected quantities of each material, how much of the material comes from abroad, and its cost per unit of electricity produced. Materials that exceed critical threshold values are flagged to assure that they will be studied more closely. Thresholds can be changed and the analysis rapidly rerun to determine sensitivities.

Quantities of basic materials required for the SPS were estimated and compared against projected supplies, production capabilities and sources. Assessment of these SPS material requirements indicated a number of potential supply problems. The more serious of these were solar cell materials (gallium, gallium arsenide, sapphire, and solar grade silicon), and the graphite fiber required for the satellite structure and space construction facilities. Two options for solar cell material (silicon and gallium arsenide) are part of the Reference System. In general, the gallium arsenide SPS option exhibits more serious problems than the silicon option, possibly because gallium arsenide technology is not as well developed as that for silicon.

The only problems of serious concern involving a material that appears in both SPS reference concepts are those associated with graphite fiber production. The annual production growth rate to meet the combined requirements of the SPS and the automobile industry could be in the 20-30 percent range sustained for a decade or more. Also, depending on the type of fiber selected,

graphite fiber could become one of the highest material cost contributors to the SPS.

Although no insurmountable materials problems are currently evident, materials definition for the SPS (both as to quantities and specific kinds) is in a fairly primitive state. Similar analyses will be required as the detailed materials requirements become better defined.

B. INSTITUTIONAL ISSUES

The objectives in assessing institutional issues related to SPS have been to (1) define key institutional interfaces, (2) determine how institutional mechanisms would have to change to permit SPS development and (3) establish an information base on these issues. Four major issue areas -- financial and management scenarios, regulatory issues, utility integration and insurance for development and operations--were identified as reflecting major institutional interfaces which would clearly influence the SPS, or which would be most directly impacted by SPS.

1. Financial and Management Scenarios^{16 30}

The financial attractiveness of a project depends on the relationship between anticipated rewards and expected risks. Potential problems, or the downside risk, would play a major role in SPS project financing, and at this time is considered high. Four categories of downside risk that have been considered are:

- SPS malfunction
- Potential international repercussions
- Opportunity costs associated with alternative systems
- Engineering costs/overruns

The SPS Reference System scenario assumes implementation of 60 units in the 2000-2030 time period. Cash flow analyses under several sets of assumptions (including power demand and availability, price of electricity, and R&D costs) produced preliminary "best estimate" returns on investment ranging between four and fifteen percent. The cost of electricity at the entry point

to the utility grid has been determined to be the most important factor determining cash flow and the rate of return. The cost of electricity would primarily determine the extent of private participation in SPS financing. However, the large capital requirements for SPS through R&D and initial operation tend to favor some form of public sector financing. The federal government, or a consortium of governments, may in fact be the only viable source of financing during start-up operations. The private sector, nevertheless, would participate from the beginning in a supplier/contractor role.

Financial and management requirements for the SPS will differ markedly for each of its stages of growth and according to the degree of international involvement. A joint venture partnership between government and the private sector is possible if it is compatible with the interests of international parties. Alternatively, private sector finance mechanisms, compatible with international private sector involvement, provide other potential finance models. The Communications Satellite Corporation (COMSAT) has been identified as a likely model for a national endeavor, while the International Telecommunications Satellite Organization (INTELSAT), the International Maritime Satellite Organization (INMARSAT) and the International Energy Agency (IEA), have been identified as operating models for an international SPS.

2. Regulatory Issues

Regulation covers a broad spectrum of concerns. Two were selected for emphasis in CDEP. In the first, state and local regulations applicable to the construction and operation of power plants were analyzed to see how they might apply to SPS rectennas. In the second, the historical background and likely future of the regulation of microwave radiation was established.

a. State and Local Regulation²⁰

Regulation of power plant siting, construction and operation falls primarily under the jurisdiction of state and local government entities. Currently, state and local regulation is in a state of flux and inadequate to deal with the SPS. The state Public Utility Commissions' approval of utilities' precommitment to the SPS may be conditional on government guarantees regarding electric power pricing. States want and are asserting increasing control over powerplant planning.

Many states are creating a de facto trend toward decentralization in energy policy. SPS, however, is inherently a centralized power source and will require regional coordination of powerplant regulation and transmission interties. And, while there is increasing regionalization of utility planning for generation and transmission, there is no corresponding regional coordination of regulations. Land-intensive SPS rectennas may require federally mandated, state coordinated land use and energy planning. Where federal pre-emption of certain state and local regulatory authority exists (as could be the case with microwave radiation regulation), state and local policies may conflict with federal policies on the SPS, with state and local regulations generally being more restrictive.

Another regulatory problem not unique to SPS, but which could impact its rate of development and deployment, is the time required to gain regulatory approvals for powerplant siting and operations. The effects of the time required, now estimated to be at least a decade, could be more severe for SPS than for other technologies because of the greater number of regulatory entities likely to be involved. The establishment of a national power grid, currently under study at the federal level, may alleviate or solve some of these problems.

b. Regulation of Microwave Radiation¹¹

Currently there are no federal standards protecting the worker and/or the general public from the potential hazards of nonionizing microwave radiation exposure. The SPS power transmission system would transmit power to the rectenna via a microwave energy beam. The configuration of microwave density in the vicinity of the rectenna is shown in Exhibit 4. The U.S. "voluntary" guideline of $10/\text{mW}/\text{cm}^2$ is a recommended value for occupational exposure set at a value 10 times below the known threshold for biological damage and was established by the American National Standards Institute (ANSI) in 1966. It has been adopted by most of the Western World.

Soviet and Eastern European microwave exposure standards are three to four orders of magnitude lower than comparable U.S. values. To a large degree, discrepancies between Eastern and Western standards are due to contrasting philosophies. For the U.S. and a majority of western countries, the concept of a risk/benefit criterion has been accepted in setting standards. This involves the use of an adequate safety margin below a known threshold of hazard.

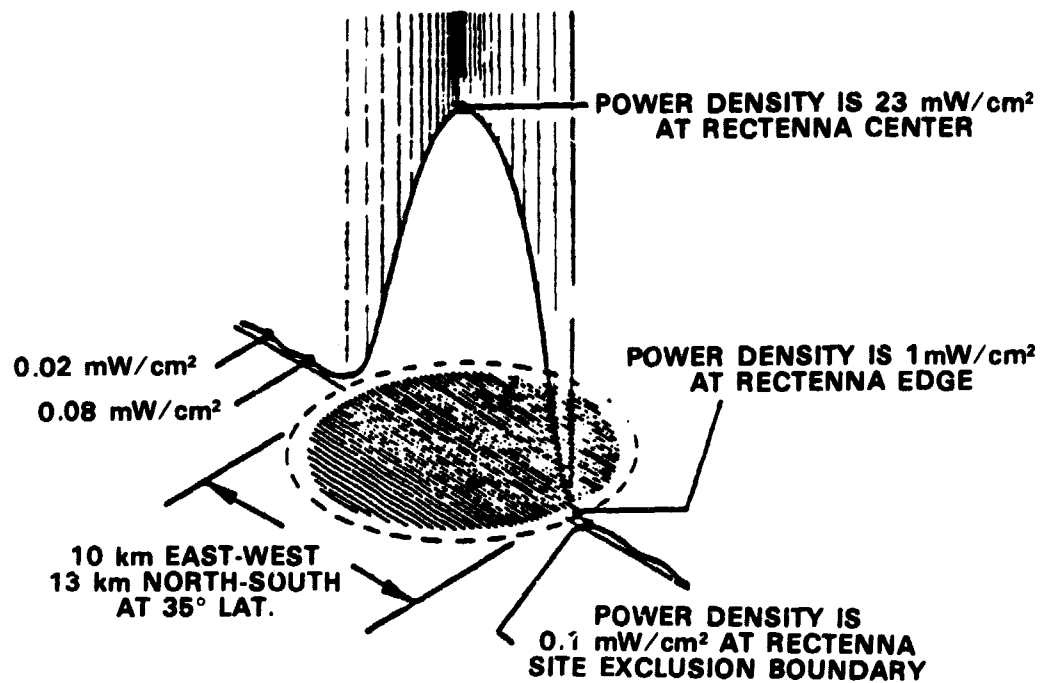


Exhibit 4. Density of 2.45 GHZ Microwave Beam at Rectenna Location

On the other hand, Soviet and most East European microwave standards are based on a "no effect" philosophy--all deviations from normal are hazardous. Yet to be determined are definitions of what connotes a "hazard" or an "adequate" safety margin in terms of exposure to microwave radiation.

At this time, there is no single agency interface on microwave radiation standards. The lead federal agencies with regulatory responsibilities for microwave radiation are the Department of Health and Human Services (H&HS), the Department of Labor (DOL), and the Environmental Protection Agency (EPA). Each of these agencies contains specialized research or advisory bureaus to assist in establishing and enforcing microwave regulations. However, the federal regulatory process is now under review by the recently formed Federal Council on Radiation Protection, chaired by the Administrator of EPA.

A trend toward stricter microwave radiation standards, particularly those pertaining to public health, has been observed. The need for additional research is central to adopting public and workplace standards. Of particular relevance to SPS is the initiation of programs of long-term, low-level microwave exposure. Coupled with new developments in instrumentation and dosimetry, the results from chronic exposure programs and population exposure studies could be expected within the next five to ten years.

3. Utility Integration⁷

An examination of the potential for utility ownership of SPS ground facilities suggests that institutional problems would inhibit utilities from bulk power purchase or ground station ownership at least until the SPS is successfully demonstrated. Ownership of both ground stations and satellites by U.S. utilities or utility consortia would be unlikely until a number of satellite-rectenna pairs are successfully operating and until the risk of system uncertainties (cost, reliability, etc.) are significantly reduced. Also, no regulatory framework currently exists at interstate levels; therefore, regional problems of consortium-owned power plants or utilities serving several states will not be easily resolved. State regulatory, rate, and siting procedures would make it difficult for utilities to own SPS ground stations.

Ways to mitigate the lack of interstate coordination are to: (1) form interstate planning compacts; (2) form regional utility corporations with

federal pre-emption for rate and siting regulation; or (3) have federal ownership of ground stations, and sale of bulk power to local utilities. Considering the financing, risk and lead time for the SPS, as well as the contractual and planning time that is involved, utilities would require strong incentives for early involvement in the SPS. Guarantees and long-lived contracts on SPS development scheduling, pricing, and legal liability are critical to successful integration with utilities, especially to solicit them as rectenna owners.

It is clear that the SPS poses special problems with regard to technical integration issues. Among these are power fluctuations, power level control, stability, reliability, generation size (5 GW) and utility mix requirements. However, a mapping exercise incorporating the probable distribution of demand load centers and rectenna sites determined that these obstacles could be overcome. Sites were limited to "eligible" areas, as defined in the parallel rectenna siting study,⁵ and further constrained by key proxies for critical utility planning and operations integration considerations. These key proxies are:

- That the rectennas be allocated to each region in the proportions indicated by the 1995-2000 electric generation capacity.
- That each rectenna be sited within the ERC region served or, at worst, within 100 km of that regional boundary.
- That SPS power provide no more than 25 percent of the peakload power of any load center.
- That each rectenna distribute its power along five transmission corridors, each carrying approximately 1000 megawatts (MW).
- That no transmission corridor exceed 500 km (approximately 300 miles).

It was found that even with these rather severe constraints, 60 SPS units could be integrated into projected utility networks using state-of-the-art transmission and generation technology. Few technical/operational disincentives exist in the integration of 5 GW increments of SPS power. As long as SPS represents less than roughly 15 percent of a system's capacity (25 percent baseload), few problems arise with regard to system reliability. However,

locating suitable eligible areas in the East to support this constraint could be a problem. Transmission distance problems (greater than 500 km) could be encountered in the West; however, power is already being transmitted much farther by the electric utilities with no intractable technical problems.

What may have greater significance is that transmission corridors would consistently cross state lines, electrical power service area lines, and National Electric Reliability Council boundaries as shown in Exhibit 5. This raises again many of the institutional considerations discussed earlier and confirms that the utility integration problem is more institutional than technical.

4. Insurance²³

The SPS concept poses many exposures to both financial loss and liability to third parties. As with more traditional risks, insurance could be provided to protect against certain of these exposures during both pre-operational and operational phases. The international underwriting community has shown a willingness to insure the sizeable risks associated with today's telecommunications satellites. This precedent could serve as a basis for the acceptance of SPS ground and space-related exposure.

The major risks associated with the program stem from both the financial losses that could be incurred and the liability exposures presented by extensive launch, recovery and space-construction activities. The possible environmental effects of both the ground and space segments also present a substantial degree of risk. The interrelation of so many participants, combined with the need for a continuous flow of resources into space and to launch/rectenna sites, forms a dynamic system that could be severely damaged by catastrophic loss at a number of key points.

The effects of the overall SPS effort, moreover, will extend into an international realm that today does not provide for the sharing of liability exposures among what would be a consortium of diverse countries. Even if constructed as a domestic effort, the exposure to international lawsuits is not clear at this time.

Underwriters do not presently have a basis for assessing either the possible origins of claims or their severity. However, maintaining a close

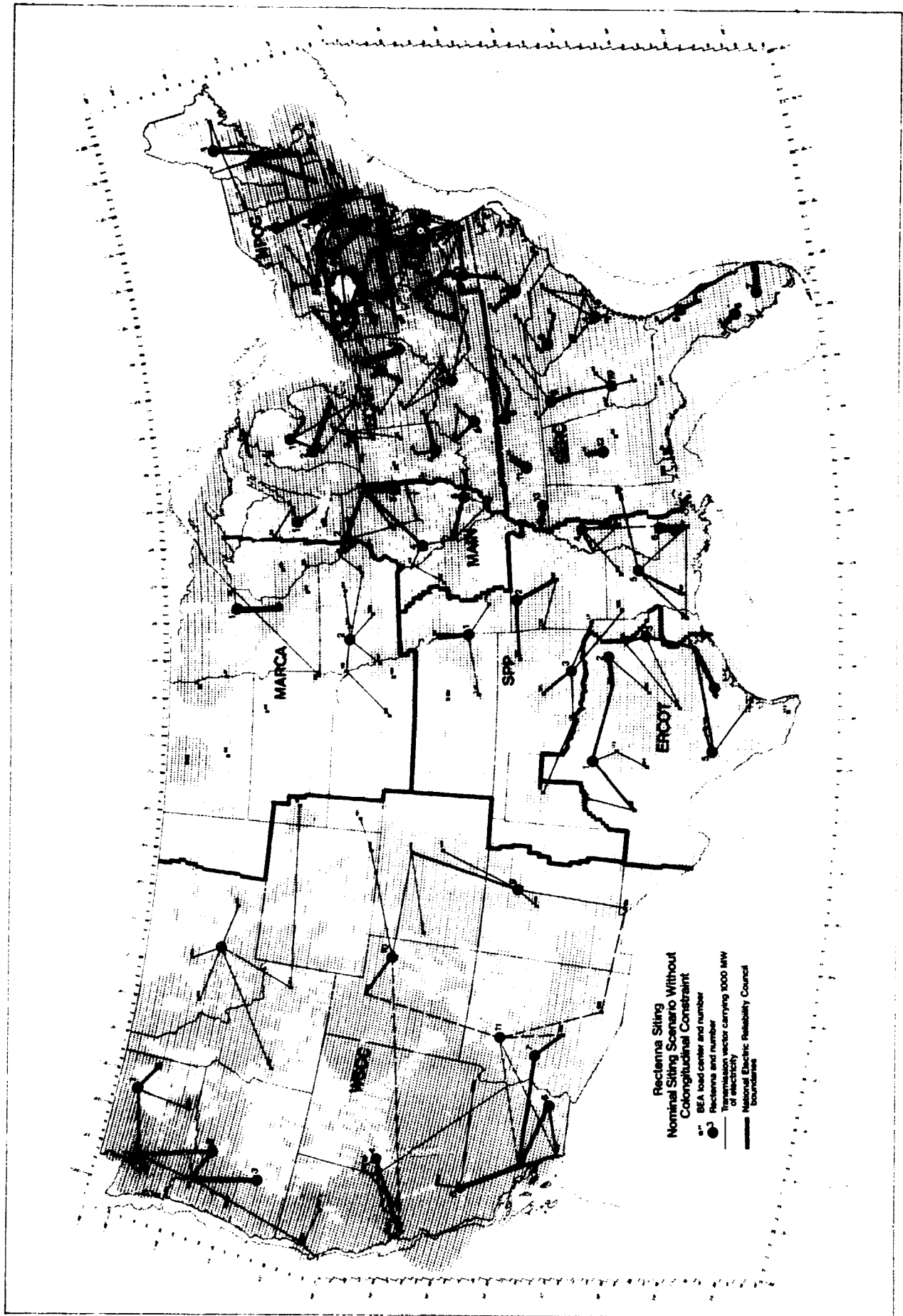


Exhibit 5. SPS Utility Integration

liaison with the world insurance market as the SPS concept is developed could result in coverage for many SPS exposures. A consistent educational process would allow underwriters to identify periods of exposure for which policies could be designed and would allow market capacity for these risks to increase gradually to achieve required levels.

C. INTERNATIONAL IMPLICATIONS

The implications of SPS deployment are international in scope. An SPS would use outer space and radio frequency spectrum resources that are within the international domain. At the same time, energy delivered by the SPS could be shared globally by developed and developing nations alike. International participation in its deployment could contribute to the improvement of international relations with regard to equitable energy distribution and consumption.

Three important international issues were identified: controls expected to be exercised by international organizations through enforcement of treaties governing operations in space and new agreements (e.g., on microwave radiation, geostationary orbit, and radio frequency assignment) that may be required because of the unique aspects of the SPS; international organizational structures to manage the research, development and operations of the SPS; and real or perceived military implications of the SPS.

1. International Agreements^{8 15}

The present legal regime governing activities in outer space, to which the SPS would be subject, encompasses two international organizations and three treaties:

- the U.N. Committee on the Peaceful Uses of Outer Space (UNCOPUOS)
- the International Telecommunications Union (ITU)
- 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (U.N.)
- 1973 Telecommunications Convention and Final Protocol Treaty
- 1972 Convention on International Liability for Damage Caused by Space Objects (U.N.)

Within UNCOPUOS, there has been little direct attention given to the potential importance of collecting and transmitting solar energy from space to earth. The Committee has shown significant interest in outer space, however, as exhibited by the long-running international debate over the draft Treaty Governing the Activities of States on the Moon and Other Celestial Bodies (the Moon Treaty).

Under the 1967 Principles Treaty, the space environment is considered to be open to all who are able to use it. The radio frequency spectrum, the geostationary orbit, and solar energy are considered natural resources of the space environment. As such, they fall within the "province of all mankind" pursuant to the 1967 Principles Treaty. In the case of the SPS, the consideration of space and its environs as the "province of all mankind" raises the question as to who should benefit from the space resource.

The finite geostationary orbit space and increasing competition for its use will influence slot availability for the SPS. Some nations argue that the long-term use of a geostationary orbit slot is the same as appropriating it and is, therefore, in violation of existing international agreements. States with space capabilities have clearly established a customary rule of law, whereby outer space exists beyond the sovereignty of any nation-state. This rule exists in the absence of a formal delimitation between airspace and outer space and in the face of the Bogota Declaration, issued by eight equatorial countries asserting sovereignty over the geostationary orbit above their territory. Attaining SPS orbital slots will, at a minimum, require: (1) some consensus on the first come, first served principle; (2) demonstration of efficient economic use and benefit to all; and (3) recognition that permanent utilization (i.e., ownership) of the orbital slot is not legal.

The International Telecommunications Union (ITU), an autonomous, specialized agency of the United Nations, is now governed by the Telecommunications Convention and Final Protocol. Under this and previous Telecommunications Conventions, the ITU allocates use of radio frequencies, including microwave frequencies. The ITU is also responsible for preventing broadcast interference. There is a trend at ITU to link the radio spectrum with geostationary orbit position. Since 1973, the position of the ITU has consistently been that the geostationary orbit is a limited resource along with

the radio frequency spectrum. However, since the SPS has a power transmission, rather than a communications transmission, function, the ITU may not have authority over it.

The 1972 Liability Convention covers the subject of harm caused by orbiting space objects. The convention also prohibits adverse changes in the environment. Although there is a present lack of knowledge about the health and environmental effects of low-level microwave exposure, clearly, a launching State would be internationally liable for harm produced by microwave radiation emanating from a space object. The U.S., or any organization operating the SPS, must have general international acceptance of microwave exposure standards in order to be safe from potential negligence suits. International agreement on microwave exposure standards may be reached much faster if a framework of bilateral agreements has been established between the U.S. and other countries.

The primary conclusion, after considering the legal regime to which the SPS would be subject, is that there are no unusual prohibitions against SPS deployment which could not be dealt with through international agreements. In terms of liability for operation of the SPS and its component parts, the scope and quality of international tort laws offer encouragement to those who may wish to embark on SPS programs.

A future international regime governing activities in outer space, including SPS, will be influenced by a series of other international activities, including:

- The Law of the Sea negotiations
- The Moon Treaty debate
- World Administrative Radio Conferences
- Deliberations regarding the legal status of the geostationary orbit

The Law of the Sea negotiations are establishing precedents for the management of "common heritage" resources among nations and private parties. The outcome of these negotiations could produce another model of an organizational structure to develop and operate the SPS on an international basis. The concept of an international agency, such as the proposed Seabed Authority,

controlling and equitably disposing of the benefits of resource exploitation on behalf of the world community would be a powerful precedent-setting accomplishment.

The Moon Treaty has been the subject of negotiations within the UNCOPUOS for about 10 years. The main points of contention are possible restrictions placed upon space resource nations (particularly the United States) in the exploitation of the resources of the solar system. If the Moon Treaty should be ratified in its present form, there would be no immediate impact on the SPS in its reference configuration. The geostationary orbit is not covered in the treaty, and only earth resources are contemplated for SPS development. Furthermore, in the interim period (prior to establishment of an international regime to oversee lunar resource utilization) it is clear that the U.S. could construct pilot SPS plants, even those using lunar materials. Since there is so much ambiguity associated with the language of the treaty, these activities would represent a powerful precedent, which legal experts would be unlikely to ignore.

At the 1979 World Administrative Radio Conference (WARC-79), Third World nations were in the majority for the first time. They had been expected to demand a larger share of the radio-frequency spectrum hitherto dominated by the industrialized nations. This expectation was based in part on ideological opposition to some of the U.S. proposals offered at WARC-79. The Third World nations also feared that they were not technologically competent enough to ensure their retention of a fair share of the radio frequency spectrum. The U.S. won support or reduced opposition to its proposals at WARC-79 by being conscientious in explaining their positions and technical issues and by promising to share technology with Third World countries. Questions concerning the use of the geostationary orbit also have been formally considered in this forum at least since the WARC-71 revision of the radio regulations concerning coordination of geostationary satellite positions. The Law of the Sea negotiations and the Moon Treaty debate also indicate a strong Third World desire to share the benefits of applying advanced technology to the problems of resource utilization.

The geostationary orbit debate is a manifestation of an underlying political dispute over the implementation and interpretation of the

principles embodied in the 1967 Outer Space Treaty, as are the claims of the Bogota nations* to segments of the geostationary orbit. It is recognized that as satellite technology advances, the present regulatory regime may not be sufficient to equitably distribute the benefits derived from use of this orbit. Many legal experts are of the opinion that in the near future (apparently well before the SPS is operational), a new agreement for the rational use of the geostationary orbit will be negotiated. The UNCOPUOS is expected to assume an expanded role in this matter.

2. Organizational Considerations¹⁰

The choice of a model upon which to base an SPS organization partly depends on how national in character SPS development would be. COMSAT has been identified as a likely model for a national endeavor. INTELSAT has been cited as an operating model for realizing the global potential of satellite power technology.

An appreciation of the difficulties encountered in establishing these and other international organizations would be helpful in identifying some of the preconditions that would have to be satisfied before SPS development could be internationalized. Consequently, international organizations--COMSAT, INTELSAT, INMARSAT, and IEA--have been investigated with the purpose of identifying: (1) objectives and structure of each organization; (2) how multinational participation and decision making has been accomplished; and (3) the implications of this experience for the SPS.

During the time that an SPS program is a U.S. undertaking, the federal government would have the dominant role in financing and controlling it. The COMSAT experience provides an analogous situation, especially in the event that a debate ensues over the extent to which the private sector participates in SPS decision making. The COMSAT debate in Congress centered around the balance of power between private and public sector voting blocs. Also debated was the effect this power balance would have on decisions affecting national objectives and eventual foreign participation in the satellite communications

*The following are the eight nations traversed by the equator: Brazil, Colombia, Congo, Ecuador, Indonesia, Kenya, Uganda, and Zaire.

system. The ensuing internal organizational friction within the Corporation and the disputes which arose between the Corporation and the State Department during negotiations with foreign nations (i.e., whether to interpret a problem as one of "foreign" or "business" policy) lead to the conclusion that for the SPS, governmental, rather than private, ownership and/or control is to be desired.

As an initially national endeavor, SPS development might be closely tied to the resolution of regulatory problems affecting the internal operating structure of the organization. For instance, federal regulatory agencies might intercede to reduce the effectiveness and accountability of a U.S. "Solar Sat Corporation" with rulings which would enhance the control of private sector participants within the organization. In the case of COMSAT, FCC rulings enhanced private-sector control of corporate operations. This experience indicates the importance of establishing the identity of an SPS organization vis-a-vis the federal government at an early stage in its development. This would also indicate U.S. interest in government-to-government negotiations to encourage international participation.

A real commitment to broad foreign participation in SPS development should be expressed concretely in the structure and operating practices of the organization. The voting structure within INTELSAT, INMARSAT and the IEA provides many mechanisms for participation. Relations between the U.S. and other potential foreign participants could be improved by creating an equitable arrangement for the sharing of SPS technology and manufacturing responsibilities. Voting arrangements, particularly within INMARSAT, provide examples of how the Third World could participate in decision making and the sharing of benefits. A possible first step toward involvement of other nations might be the establishment of a research and development effort under IEA auspices.

3. Military Implications and Vulnerability^{2 25 31}

The location of SPS Reference System elements in both low earth orbit (LEO) and geostationary orbit (GEO) and its power output give rise to three questions: (1) What are the real and perceived military threats of the SPS? (2) Are there unique system vulnerabilities that could inhibit SPS development? and (3) What safeguards can be devised to counter SPS threats and vulnerabilities?

a. Threats posed by the SPS

The present Reference System design of the SPS, without modification, has only modest military support capabilities. The transportation system would be advantageous for military activities involving the transport of large quantities of equipment and personnel. The power satellites, the LEO and GEO bases, and many of the space transportation system vehicles could also be used to support maintenance and repair of military satellites and spacecraft. However, use of SPS elements in these support roles would not be as effective as dedicated military systems designed specifically for these missions.

Other support functions of major tactical or strategic significance could be added: (1) substitution of laser for microwave transmission would turn the satellite into a potential power source for military satellites or allow long-duration flights for high-altitude laser-powered military aircraft; (2) using orbital facilities as laboratories for development or stockpiling of chemical and biological warfare agents; and (3) making large quantities of electrical power available for electronic warfare jammers and direct broadcast (psychological warfare).

Weapons modules, such as directed energy weapons, antisatellite systems or reentry vehicles for earth bombardment, could also be added to the SPS. However, none of these weapons, except for reentry vehicles with nuclear warheads, would pose the same lethal threat as the current strategic arsenals of the nuclear powers. A self-defense capability with appropriate safeguards might ultimately be acceptable, but the addition of any threatening capabilities whatever would be highly destabilizing to international relations.

b. SPS Vulnerabilities

The Reference System satellite would be especially vulnerable to the electromagnetic pulse effects of nuclear detonations. The entire 60-satellite space segment could be destroyed by one well-placed nuclear detonation. However, since other spacecraft (including those of the attacker) would be damaged or destroyed, use of nuclear weapons does not appear to be a likely threat. Since ground-based systems can also be destroyed by nuclear explosions, the satellites' nuclear vulnerability is not unique.

The various elements of the SPS are vulnerable to a variety of types of attack (e.g., attack by non-nuclear weapons, sabotage, mutiny, strikes, electronic warfare), but are inherently no more vulnerable than existing elements

of the economic infrastructure (e.g., electrical generating plants, petroleum refineries, transmission lines, pipelines, railroads, aircraft and airports, communications networks). Since the vulnerability of each SPS subsystem is very sensitive to design details, vulnerability considerations should be integrated with engineering and program management design from the start.

c. Safeguards Against Threats and Vulnerabilities

Numerous safeguards have been identified for the threats which an SPS might pose to other countries and for the vulnerabilities to which the SPS might be prone. Although no combination of safeguards can totally assure that the SPS will not pose a threat to anyone--any more than it is possible to assure that the SPS will be invulnerable to attack--it seems likely that selected safeguards could reduce threat and vulnerability potentials to acceptable levels.

Certain safeguards appear to be necessary as a minimum. These include an international resident inspection organization (RIO), a comprehensive long-range space surveillance (LRSS) system, and various electronic countermeasures to protect SPS from electronic disruption. System design for vulnerability and new international agreements to include proximity rules in space, will be required. Self-defensive weapons might be feasible under permanent resident inspection, since the inspection teams could readily verify the limited purpose of such weapons.

The resolution of threat and vulnerability issues is strongly dependent upon domestic and international acceptance of the proposed safeguards. Thus, the RIO and LRSS safeguard concepts require more intensive investigation. The cost and effectiveness of the proposed safeguards remain uncertain. Final determination of these parameters may require access to classified data, for example, with respect to LRSS capabilities, operational control of defensive armaments, and protective designs for sensitive electrical systems.

Finally, the design of new international agreements regarding proximity rules in space and self-defensive armaments must be examined in depth and given wide discussion in an international context.

D. PUBLIC CONCERNS

There is a substantial public interest in energy. How much will be needed in the future? Where will it come from? What are the environmental and

societal impacts of the various sources? The specific combination of energy sources that end up supplying the energy demand in the coming decade will be based in large part on the answers that the public finds to these questions. Furthermore, the public would like each source to have the least adverse impact possible while contributing its share to the total energy demand. Most importantly, the public would like to be involved in making decisions regarding the selection of energy sources and the acceptability of their impacts.

The SPS is an advanced technological concept with numerous impacts, several of which are international in scope. How can the public be involved at the very earliest phases of a program of this complexity? What are the likely determinants of public acceptability? Which issues are fundamental and which can be resolved?

There are many publics and most of them currently have little or no interest in SPS. Thus, a process is needed to expand awareness and interest. The approach developed for SPS has come to be called the Participatory Technology Process (PTP). A key feature of the PTP is encouragement of public involvement and the identification of public concerns. An outreach experiment was conducted with three public interest organizations. Other studies have confirmed the importance of public involvement in the decision-making process and have examined trends in American society that could influence public attitudes towards SPS.

1. Public Involvement

Public involvement has been an integral part of the SPS Concept Development and Evaluation Program through implementation of the Participatory Technology Process.¹⁸ The major features of this process are shown in Exhibit 6. The activities undertaken and issues addressed in all assessment areas were guided by workshops of nationally known investigators. The studies themselves were conducted by private contractors, universities, government laboratories, or other government agencies; the intent being to get the best possible study and the widest range of thinking about SPS. Every study report was peer reviewed. At least two peers from government (independent of SPS), two from industry and two from the university community were asked to review each report. Often the number of reviews far exceeded the minimum, with each review

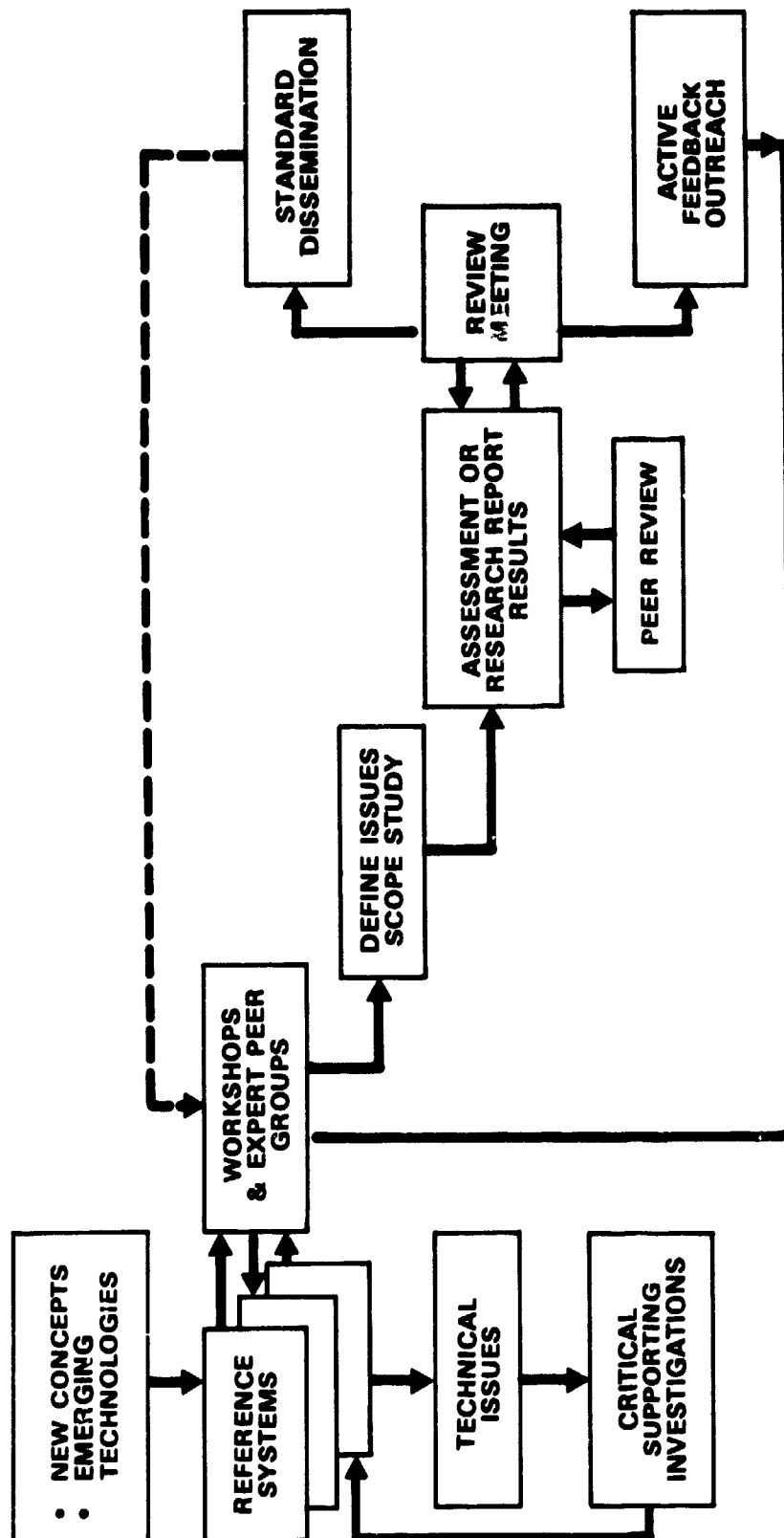


Exhibit 6. SPS Participatory Technology Process

further expanding the participatory process. Study results were reported at open review meetings with time and encouragement given for interaction between presentors and participants. The reports were printed by the Department of Energy and distributed to several thousand recipients, including all major research libraries in the United States.

Although the workshops, peer reviews and wide distribution of research findings succeeded in involving the public with direct interest in SPS development (e.g., government, aerospace contractors, academia, and selected scientific and engineering associations), the Active Feedback Outreach element was designed to involve the general public. This wider public involvement was achieved through a survey of other government public involvement programs and through the preparation and implementation of the Public Outreach Experiment.

a. Review of Other Government Programs for Public Involvement

The frequent use of organized protest and litigation to effect change or challenge policy decisions has encouraged the development and institution of programs for public involvement. Particularly visible with respect to environmental issues, citizens have also confronted the government on the issues of land use, wildlife preservation, energy, economy and growth, health, and the quality of urban life. Where programs to provide the public with opportunities to express their views and preferences have not been available, litigation has been used effectively to contest policy decisions.

Different types of public involvement programs have emerged, in terms of their functions, objectives, and utility. They are visible on local, state, national and international levels and cover a broad scope of content areas, with particular emphasis on environmental issues, controversial technologies, and public safety. There are five general program types: advisory, consultation, education, participation and outreach.

The objectives of advisory programs are to resolve controversies, achieve consensus or ascertain the facts with respect to scientific and technological issues. Attempting to counter the lack of public confidence in technology, a frequent intention is to bring the general public and technical experts together and establish a consensus on scientific and technological controversies.

The objective of consultation programs is to provide a medium for the public to express their views on projects where decisions are being made. They attempt to obviate public perceptions of alienation from government, assuming that public opportunities to participate will dispel the notion of a citizen/government gap. Hearings and public meetings are the primary media for consultation programs.

The objective of education programs is to disseminate information to the public. The impetus for these programs has frequently been an assumption that the lack of public consensus and the tendency toward opposition to proposed technologies are due to inadequate information. The passage of legislation at many levels of government, has made it mandatory that information be available to the public in published form.

Limited success of the advisory, consultation and education programs to adequately address public concerns and satisfy public demands in many areas of program development and decisionmaking, has created the need for participation programs. The major objective of participation programs is to provide a mechanism for the public to voice their opinions during the process of program development, with emphasis on the utilization of this information by decision makers. Although the advisory, consultation and education programs have addressed public concerns to some extent, opportunities for public input are limited, frequently co-opted by experts, and the utilization of public input is questionable.

Participation programs offer more opportunities for direct involvement and enhance program development by elevating the rationale for decisions on the basis of information and input from the public. Participation programs are used most frequently in program development and decision making where the public has previously intervened, where decisions are controversial, and where the impact of decisions/programs is visible. They are, therefore, frequently used in the environmental area.

Outreach programs are those which take the participation concept one step further, by reaching out to the public and requesting participation in program development in a circumstance in which the level of participation desired is unlikely without its solicitation. For example, in Community Action and Model Cities programs, outreach programs have been used to attempt to

balance input from individual citizens who are unlikely to participate, with input from organized interest groups, who are likely to participate. In many cases, outreach programs have been successful in obtaining public input to supplement other investigative efforts in the development of government programs and projects.

The Participatory Technology Process, augmented by the outreach experiment described below, has incorporated all these elements of public involvement. The PTP has facilitated the solicitation of information from a broad spectrum of people, diverse in their level of expertise and occupational background.

b. SPS Public Outreach Experiment²²

The outreach experiment was an effort to acquire feedback about the SPS concept from the constituents of three public interest groups. The objectives of the outreach were: (1) to identify public concerns and questions about the SPS and (2) to gain experience in an outreach process for use in the development of future SPS public involvement activities.

The three participating groups were the Citizen's Energy Project (CEP), Forum for the Advancement of Students in Science and Technology (FASST) and the L-5 Society (L-5). CEP is a tax-exempt research and advocacy organization whose primary interests are decentralized energy policy and environmental issues. FASST is a national network of individuals and organizations supporting active student participation in science, policy development, research, and new applications in science. L-5 is an international organization with approximately 3,200 members who advocate space colonization. Prior to the outreach, both L-5 and CEP had demonstrated a position on SPS. L-5 was in favor of the continued development of SPS; CEP was opposed to any development of SPS. With the selection of these two groups for participation, it was felt that public concerns, from both a pro and con perspective, could be identified. FASST had not taken a position on SPS prior to the outreach. The respective positions of each group did not change during the experiment; L-5 remains in favor of SPS; CEP remains opposed and FASST is relatively neutral.

The steps in the outreach program are outlined in Exhibit 7. Each group summarized 20 SPS papers and distributed them to 3,000 of their constituents, with a request for feedback in the form of open-ended comments or answers to

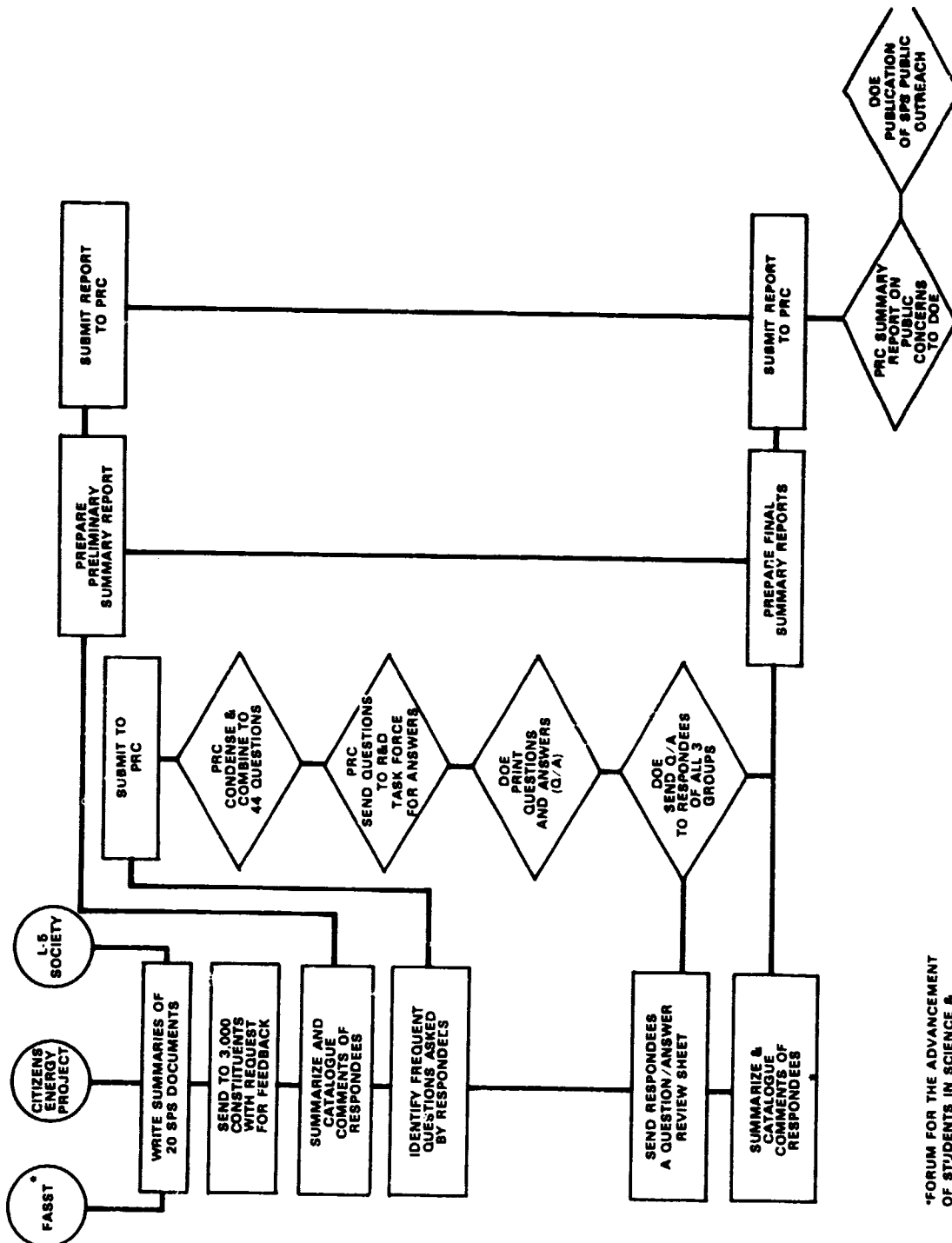


Exhibit 7. Public Outreach Experiment

*FORUM FOR THE ADVANCEMENT OF STUDENTS IN SCIENCE & TECHNOLOGY

specific questions. Since each group worked independently of the other, the responses differ in format and content. A consensus among the three groups determined 44 questions that covered the concerns expressed by the respondents from all three groups. Answers to the questions were prepared by SPSPD field investigators working on the subjects in question. A compilation of the questions and answers was mailed back to respondents in the three groups.²⁸

Success of the outreach experiment is evident in the range and number of questions and concerns provided by the respondents. Two studies (one on SPS insurability and one on satellite orbit degradation) were initiated as a result. Although most concerns had been previously identified through other mechanisms in the Participatory Technology Process, the relative importance of these concerns for each group were identified. Many concerns were common to the three groups, differing only in terms of priority. The most common concerns of members in all three groups were microwave bioeffects, the societal ramifications of centralized power generation, opportunity costs, and military implications.

The outreach also provided considerable information about the communicative process in the early development of an advanced technological concept such as SPS. Through the combined efforts of all three groups, 9200 individuals/organizations received information about the SPS concept, and over 1500 recipients of this information provided feedback. The response to the outreach effort was positive for all three groups, suggesting that the effort extended by the SPS Project Division to encourage information exchange with the public was well received. However, there were some questions raised by respondents in all three groups as to whether or not public input would be utilized.

The outreach effort also generated requests for additional information from the constituents of all three groups, and many respondents have expressed interest in continued involvement.

The following is a more detailed summary of the results obtained by each group.

(1) Citizens Energy Project

Approximately 350 recipients of the SPS summaries responded. The geographic distribution of responses were similar to the population distribution

of the United States, and a broad range of occupational backgrounds was represented. State utility regulatory commissioners and labor representatives were two audiences approached that did not respond in any significant number. The largest number of responses came from anti-nuclear and pro-solar citizen groups.

The response to the outreach effort itself was very positive. A general recommendation by CEP is that DOE should consider similar outreach efforts for other technologies under development--notably synfuels and fusion--as well as other solar technologies. The overall general response to SPS was negative. Eighty seven percent of the CEP responses indicated opposition to SPS, ranging from a sense that better energy options exist to unequivocal hostility. The alternatives most frequently suggested were decentralized energy systems, including terrestrial photovoltaics, low-head hydro, wind power, solar collectors, and biomass energy conversion.

A major concern of the majority of respondents was that SPS is centralized and thus inconsistent with the "inherently decentralized" nature of solar technologies. Relative to this concern was the stated belief that, because of SPS costs, funds would be diverted from development of other, decentralized systems.

The major environmental concern was over the effects of microwave radiation on human health, local ecosystems, and the atmosphere. Other environmental concerns were associated with land use, atmospheric damage, resource availability, and disruption of ecosystems at rectenna sites.

In the international area, respondents expressed concern over the possible use of the SPS as a strategic military weapon. They were strongly opposed to this on the grounds that it would destabilize international relations. The vulnerability of SPS to military action was also a concern.

(2) Forum for the Advancement of Students in Science and Technology

Approximately 300 response forms were received from the recipients of FASST summaries. The majority of respondents were college students; however, both faculty and students from high schools, junior colleges and universities were represented. The respondents' average age was 26, and over 80 percent were male. Approximately 250 respondents sent in personal comments.

No clear majority of either support or opposition to the SPS was evident. Those who supported the concept felt that the program should begin immediately. Many of those in favor also expected to see beneficial spin-offs from SPS technology. Those who opposed the SPS cited numerous problems related to the environment (especially microwave hazards), military applications and vulnerability, and economic considerations (e.g., opportunity costs). Several questions were raised about aspects of the Reference System (e.g., manpower and maintenance requirements, life support for the space workers, use of lunar materials for construction of the satellites). The issue of centralization/decentralization generated many comments and questions. The implication that SPS would rely on a strong centralized system was not favored by many. An international structure for the SPS was endorsed, and although the degree of difficulty involved in an international organization was not overlooked, many nonetheless felt it vital if SPS were to succeed.

There was almost unanimous support for some form of public discussion on the related issues, regardless of how respondents felt about SPS. Several suggestions were given for alternative methods to use in future projects. Most frequently cited were methods of making use of audio-visual presentations. Others included campus workshops and debates.

(3) The L-5 Society

Approximately 850 responses were received from members of the L-5 Society, the highest response rate of the three groups. Ninety percent of the L-5 respondents were male; the average age was 29. The outreach experiment itself was favorably received. More than three-fourths of the respondents wanted to see a more active dialogue between the government and the public on the SPS, and almost 90 percent wanted to see the DOE more actively involved in informing the public about the SPS. Seventy-two percent of the respondents thought public acceptance of SPS would be difficult.

Over 80 percent of the L-5 respondents thought the SPS had the potential to become a major energy source by the end of the century. Extra-terrestrial solar and terrestrial solar were considered to be the most desirable power systems for the long-term future. Satellite solar power is perceived to have the least environmental impact among the alternatives to conventional power plants. Regarding the cost of SPS, 30 percent thought SPS would be cheap, and

65 percent thought the cost would be tolerable. Respondents were in favor of private business, or combinations of government and private business, to both construct and own the SPS. While interest in the SPS was high, many respondents wanted to see more emphasis on alternatives to the present Reference System incorporated into the system definition work.

In terms of program direction, almost all respondents believed that funding of SPS research should be increased. In terms of current funding emphasis, a plurality of respondents wanted to see more societal research done and, as previously mentioned, many were not entirely satisfied with the scope of the system definition. Over 60 percent saw international cooperation on SPS as a means of improving international relations, although a majority of respondents saw no problem in making the SPS the basis of sophisticated weapons systems.

2. Public Acceptance^{1 17}

Early public involvement increases the probability of determining SPS public acceptability issues. Public values that are inherently incompatible with the SPS concept and which may later develop into effective public opposition to the implementation of SPS may be identified. Public concerns, identified early, can be addressed and integrated into the development of the concept before a specific design or program option becomes fixed.

Public acceptance or rejection of government programs and decisions has become an important issue which demands increasing attention. In areas of controversial technology such as nuclear power, the public has effectively intervened in program development by means of litigation and organized protest, resulting in program delay, postponement and cancellation. Public interest groups have become prominent in the political arena, voicing preferences for decisions and programs which support their respective organizational goals and values. Competing values among organized interests often result in public debate and reflect the variety of public values in need of consideration in program development.

Several recent trends make public involvement mandatory and public acceptance increasingly difficult. These are:

- Realization of limitations in the natural environment's capacity to absorb impacts of an industrial society

- Passage of federal, state and local laws and regulations to control and reverse environmental degradation, such as The Clean Air Act and the National Environmental Policy Act
- Requirements of direct public involvement in project review and approval process in environmental legislation
- Passage of public disclosure legislation, such as the Freedom of Information Act
- Trends in the judicial/regulatory arena which provide adversely affected citizens a legal means to protect their interests
- General decline in trust and goodwill towards government
- Rise and prominence of public interest organizations

There is also an element of risk stemming from the unprecedented nature of early public involvement in the SPS CDEP. It is not known to what extent public involvement at this early stage may complicate or facilitate program development in the future. It is possible that early public involvement may result in a premature polarization of issues. Public confusion and controversy may result from the dissemination of incomplete information derived from early technological, environmental, and societal impact assessments. Furthermore, public involvement programs in the next stage could be expensive and, without any precedent, it is difficult to determine a proper balance between costs and benefits.

In terms of the benefits, public participation may dispel the notion of a powerless public in the hands of elitist decision makers, instead of creating perceptions of a cooperative enterprise. Public participation may also encourage the development of leadership, clarify issues, and substitute issue politics for personality politics. Other benefits include more effective planning and prioritization of objectives, with checks and balances to ensure appropriate and acceptable action.

The paradox of public participation is that as citizen participation increases in terms of both scope and intensity, there is an equal likelihood of an increase in associated risks or benefits. Participation and outreach programs are subject to greater risks and greater potential benefits than other programs which share in a reduced level of public involvement. Unfortunately,

it is not easy to discern a priori, to what extent any given program will mitigate the risks and realize the benefits. Evaluation of public involvement programs is therefore essential in order to establish a data base on which to build more intensive public involvement programs.

Recent trends in public opinion polls suggest that public perceptions of the economy, energy situation and the environment have changed from optimism about an unlimited future towards a new sense of lowered expectations and a limited future. Scientific research and technological developments are perceived as mixed blessings, and the public seems unwilling to sacrifice the environment for high economic or energy growth. Although energy use is expected to increase, the rate of increase is not easily predicted, due to a number of variables which influence the rate of growth.

In general, a trend away from centralization of institutions and decision making in the U.S. is evident.²⁴ States are assuming more power, communities and neighborhoods are increasing their influence and control, and a militant new regionalism is likely to emerge in the 1980s. There is a growing jurisdictional diversity in approaches to problem solving (including those related to energy), reflected in increasing use of referenda or initiative process. There is also a trend toward a multioption society, rather than an either-or society, reflected in the increasing interest in "appropriate scale" technologies rather than technologies based on economies of scale.

At present it is not known whether the SPS will ultimately be acceptable to the public; what is certain is that public acceptance is an essential part of SPS development. Although these studies have found trends in American society which suggest public acceptance of SPS will not be easily obtained; the stability, longevity, and potential influence of these trends with respect to SPS are not clear.

Furthermore, the public's position with respect to SPS is expected to be volatile throughout the development process as more information becomes available from R&D efforts. Fears may be quieted and then refired as the proximity to a go/no decision becomes closer. The political climate of "energy crises" may result in changes of opinion or new concerns. Assessing and obtaining public acceptance are, therefore, long-term processes, requiring a continuing program of public involvement.

III. CONCLUSIONS

Assessments of societal issues in four areas that appeared to be particularly troublesome at the outset of CDEP have been made. The methods and results have been briefly surveyed in the preceding sections. The major conclusions are presented here by issue area.

Resources

The materials and energy requirements for construction and operation of the SPS Reference System, although uncertain, appear to give rise to no insoluble problems or to be greatly out of line with competing systems. There are suitably located areas for rectenna sites throughout the United States. However, acquisition of specific sites promises to be a difficult problem at best, and the location of sites in some of the identified eligible areas will exact a fairly heavy cost penalty to either prepare the site or to modify the rectenna design. Reduction of the critical siting parameter--rectenna area--by even as much as one-half has little effect on the availability of eligible sites.

The siting research has resulted in the development of a methodology for determining eligible areas that is highly automated, and widely applicable, but the further elucidation of the rectenna siting problem will be much more dependent upon site-specific analysis. The site-specific prototype Environmental Assessment indicates the extensive societal impacts of rectenna siting and implies a need for coordination among the elements of the SPS program concerned with design, environmental impacts, and societal concerns.

Institutional and Regulatory Issues

It is concluded that an adequate framework to deal with the many institutional and regulatory issues is achievable; however, intergovernmental and multinational coordination will be required to do so. The issues involved are acceptable microwave radiation standards, workable finance and management schemes, compatible land use and energy planning. The seeming insolubility of some of the regulatory problems is a result of the substantive changes underway in the state and local regulatory environment. This particularly affects

utility integration requirements because financial risks and lead times will vary for state and local participants. However, barriers to utility participation can be removed by appropriate institutional arrangements and coordination. In general, once higher order problems are solved (e.g., system costs compared to alternatives and availability of rectenna sites) institutional and regulatory problems should be more amenable to solution since risks and lead times will have been reduced or at least clarified.

International Issues

International issues confronting SPS development present a complex array of problems requiring significantly more research as well as coordination with other international entities whose inputs are critical. There will be a need for new international treaties, particularly with regard to orbital slot assignments and ensuring the peaceful use of SPS. Since an international organization is strongly indicated for SPS development and commercialization, it is incumbent upon the U.S. to fully understand the stakes which international actors would have in any multinational SPS program. The precise level of international participation must still be weighed in terms of a timely response to U.S. energy needs. To make these judgements will require knowledge of: (1) who potential participants would be; (2) what their interest in an SPS program would be; and (3) how U.S. and foreign interests would mesh.

Public Concerns

It is necessary to involve the public in SPS decision making and to respond to public concerns. In the Societal Assessment a mechanism for exploring the ways and means of involving the public, the Public Outreach Experiment, was implemented. Future studies of public concerns should utilize an outreach mechanism in broadened form to reach a larger representation of public interests.⁴ The results of public acceptability studies suggest that public acceptance of SPS will not be easily obtained. There are elements of the SPS system which are the basis for both opposition and support from the public, and it is possible that controversy and conflict among different public sectors indicative of competing values and perceptions of the SPS system may result.

IV. RECOMMENDATIONS

Since SPS effects on human activities have not been fully explored or defined, the framework and scope of a continuing societal assessment should be established. It should be broadened to look beyond impediments and near-term effects to examine issues which defy easy quantification. For example, two issues which were of greatest concern to the groups in the Public Outreach Experiment--centralization of power (in all its aspects) and opportunity costs--received incommensurate emphasis in the completed Societal Assessment. This broadening of the research approach should yield a more balanced appraisal of SPS, emphasizing those positive aspects of the concept as well as those which may prove to be obstacles.

Further research in the area of resource availability and institutional arrangements is recommended, particularly in the areas of rectenna site acquisition mechanisms and SPS labor and training requirements. Materials availability and net energy analyses should be performed as the SPS materials list and net energy analysis methodologies are updated and improved.

Extending the Participatory Technology Process to include a broader spectrum of participation (domestically and internationally) would greatly enhance the results of future SPS developmental activities.

A regional needs analysis should be conducted to examine SPS from a global and regional perspective, taking into consideration regional and national concerns relative to U.S. interests. Programmatic or policy alternatives could then be defined in order to reduce identified conflicts. This regional effort should determine the capability of Third World countries to participate, and clarify how international financial institutions could assist.

Domestic and foreign institutional barriers to international participation should be identified in order to determine to what extent the SPS would compete with or complement alternative central station electricity technologies of countries whose utilities are nationalized. This study would also be aimed at identifying any controls on the transfer of SPS technology which could hinder international participation as well as identifying agencies of the U.S. federal government with purview over SPS operations abroad. In order

to ensure thoroughness, research should be initiated to explore the possibilities of cooperation and collaboration with those countries which are most advanced in the space technologies required by the SPS.

In order to ensure widespread public involvement, the U.S., in conjunction with countries that wish to participate, should initiate an international public outreach program to encourage the participation of international interest groups. Concurrently, the U.S. public outreach mechanism developed in this Societal Assessment should be expanded in scope to reach additional segments of the general public.

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