ENVIRONMENTAL ASSESSMENT OVERVIEW

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INTRODUCTION

For the Concept Development and Evaluation Phase (CDEP) of the Satellite Power System (SPS) Program, the environmental assessment program component has as its objectives:

- to identify the environmental issues associated with the SPS Reference System;[1]
- to prepare a preliminary assessment based on existing data;
- to suggest mitigating strategies and provide environmental data and guidance to other components of the program as required;
- to plan long-range research to reduce the uncertainty in the preliminary assessment;
- to initiate research on particularly sensitive issues.

The key environmental issues associated with the satellite power system concern human health and safety, ecosystems, climate, and interaction with electromagnetic systems. Five tasks have been established to address these issues:

Task 1	Microwave Health and Ecological Effects
Task 2	Nonmicrowave Health and Ecological Effects
Task 3	Atmospheric Effects
Task 4	Effects on Communication Systems due to Ionospheric Disturbance
Task 5	Electromagnetic Compatibility

In Task 1 the potential effects of microwave energy on SPS workers, the general public, and ecosystems are evaluated. Other possible health and ecological impacts of the satellite power system are examined in Task 2, including the effects of the space transportation system, ionizing radiation in space, occupational risks due to manufacturing, and air and water pollution. Task 3 comprises characterization of potential atmospheric disturbances due to the SPS and assesses climatic impacts, including the effects of rocket effluents on the atmosphere. The impacts of ionospheric disturbances (caused by microwave heating and space-vehicle effluents) on communications systems which use the ionosphere for radio wave propagation are evaluated in Task 4 and in part in Task 3. The direct effects of the microwave power transmission system on communication and other electromagnetic systems are addressed in Task 5. These include direct and scattered power effects, power at harmonic frequencies, and spurious power sources.

Specific environmental issues have been identified for each of the five tasks and a preliminary assessment has been performed based on existing data. No environmental problem has yet been identified which would preclude the development of the satellite power system technology. To increase the certainty of the assessment, some research has been initiated and long-term research is being planned.

The current environmental assessment has been summarized in the Preliminary Environmental Assessment for SPS.[2] The final revision of the Preliminary Environmental Assessment will be completed later this year.

MICROWAVE HEALTH AND ECOLOGICAL EFFECTS

The Satellite Power Reference System delivers microwave power developed on the solar collecting satellites in geosynchronous orbit to the very large receiving antennas (rectennas) on the earth's surface. The power beam is an unmodulated continuous wave at a frequency of 2.45 GHz. This task is concerned with the effects of this microwave beam on the health of the SPS worker in space and on earth, the health of the general population, and the ecosystem. In the Reference System the power density at the center of the beam near the transmitting antenna in space would be as high as 2200 mW/cm^2. The power density of the beam at the center of the rectenna is 23 mW/cm^2 and the power density as a function of distance from the center of the rectenna is shown in Figure 1. The power density at the edge of the rectenna is 1 mW/cm^2 and 0.1 mW/cm^2

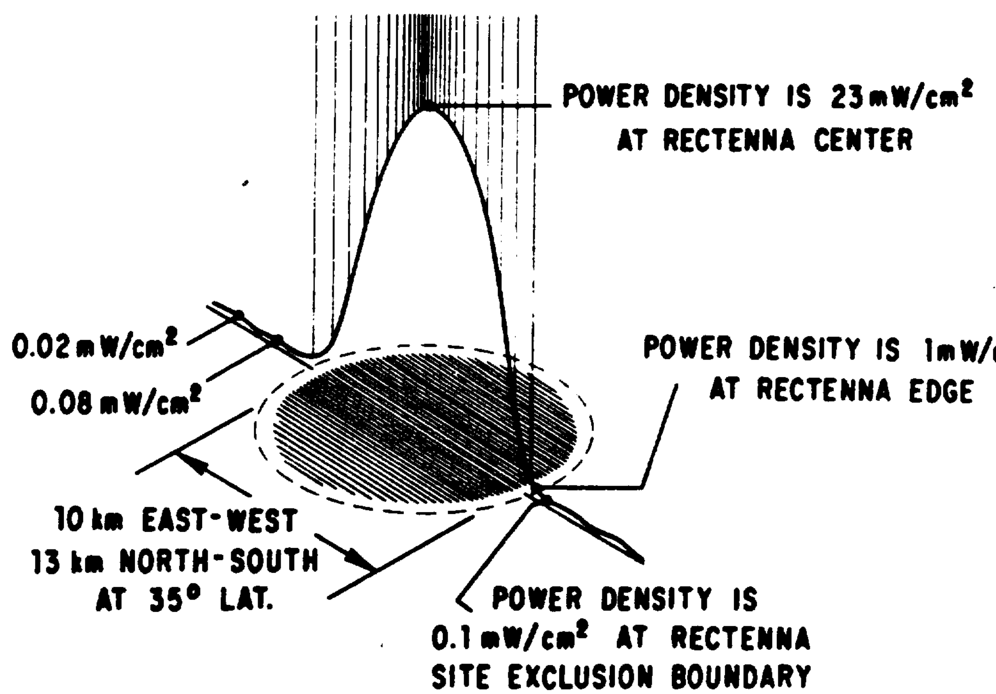

Fig. 1. SPS Microwave Power Density Characteristics at Rectenna Sites

at the exclusion boundary. If there were sixty rectennas in the continental United States spaced an average of 300 km apart, the tails of the power beam patterns would combine and the minimum power density at any point would be about 10^{-4} mW/cm^2.

These values have been compared to standards and guidelines for exposure to radio frequency power. In the USSR, the official maximum permissible average power densities for people occupationally exposed to radio frequency power in the frequency range from 300 MHz to 300 GHz emitted from stationary antennas are 10^{-2} mW/cm^2 for a full working day, 10^{-1} mW/cm^2 for two hours, and 1 mW/cm^2 for 20 minutes. The maximum value for continuous (24 hour) exposure of the general population is 10^{-3} mW/cm^2. The United States has no official maximum permissible exposure limit for radio frequency power for the general population. The Occupational Safety and Health Administration (OSHA) has promulgated a protection guideline of 10 mW/cm^2 for persons occupationally exposed for greater than six minutes to power in the frequency range from 10 MHz to 100 GHz based on the same guideline value of the American National Standards Institute, and this guideline has been adopted by a number of organizations, including the DOD.

SPS power density levels can be indirectly compared with background or ambient radio-frequency power densities. The EPA is measuring environmental field intensities at selected locations within various U.S. cities to permit estimations of cumulative fractions of the total population being exposed at or below various power density levels. A recent report[3] presents the results for 15 cities, a total of 486 sites. The report concludes that, of the population group studied representing 20 percent of the total U.S. population, a median exposure value of about 5×10^{-6} mW/cm^2 time averaged power density exists and less than 1 percent of the population is potentially exposed at levels above 10^{-3} mW/cm^2. It was observed that the FM radio broadcast service (88-108 MHz) is responsible for most of the continuous illumination of the general population. Direct comparison with SPS cannot be made because of the frequency difference. Nevertheless, these data provide us with a measure of the ambient nonionizing radiation.

The SPS workers within the rectenna area would not need to be exposed to levels exceeding current U.S. guidelines if precautions are taken and protective clothing used in some areas. The public near a rectenna would be exposed to levels in excess of the USSR standard and nearly all of the general population would be exposed to levels greater than the current background. Before this is done, a quantitative assessment of the risk associated with this exposure must be developed. Currently, the data necessary to make a quantitative assessment is not available. Furthermore, controversy exists over whether or not adverse biological effects should be expected for low level (less than 0.1 mW/cm^2) power densities.

For these reasons, as well as the fact that there is only a limited amount of data applicable to the SPS, conclusions regarding the potential biological implications of the SPS microwave power transmission system remain tentative and qualitative at this time. Additional substantive, pertinent data are required before a decision can be made to deploy the SPS.

The following list summarizes present knowledge (based on conventional scientific interpretation of existing data) of the potential effects of SPS microwave energy on biological systems in space, at rectenna sites, and outside rectenna sites.

- Immunology and Hematology

  Effects in space largely unknown
  Effects at rectenna sites possible
  Effects beyond rectenna sites unlikely

- Mutation

  Effects unlikely in space or terrestrial environments

- Cancer

  No effects expected

- Reproduction

  Potential effects unknown in space and on rectenna sites
  Small risk of effects elsewhere

- Development

  Effects unlikely except for species inhabiting rectenna sites

- Growth

  Effects unlikely

- Behavior

  Effects on SPS workers and other species endemic to rectenna sites possible
  Effects beyond rectenna sites uncertain

- Physiology and Integrative Processes

  Effects in space and at rectenna sites possible
  Effects beyond rectenna sites unlikely

- Interactive Situations, Medications, and Special Populations

  Possible adverse but largely unpredictable implications

On the basis of this qualitative assessment public health effects appear unlikely; however, there is some small risk concerning human reproductive processes and an uncertainty about behavioral effects. Risks for persons in poor health, receiving medications, or under stress may be somewhat higher than for other members of the public, but this likelihood cannot be assessed with confidence at this time.

Workers at SPS rectenna sites would be exposed to higher levels of microwave energy than the public, with a proportionately higher risk of health effects. If health effects were to occur, they probably would affect the body's immune and blood systems, reproduction, general physiology, or behavior. The effects on spaceworkers of an accidental exposure to the relatively strong microwave energy in space are practically unknown, as there is almost no experience to which the SPS situation can be related. Undesirable effects might be possible.

Microwave energy beams in the lower atmosphere and at rectenna sites have the potential to affect airborne and terrestrial animals that reside at or pass through rectenna sites. The greatest potential effects would be expected on immune or blood systems, reproduction processes, physiology, and behavior.

In the current assessment of SPS almost all of the microwave exposure effects are ascribed to the biological effects of the heating produced by microwave energy. It is conceivable that levels of microwave energy too low to increase body temperatures measurably may nevertheless cause subtle, possibly important, changes in biological processes. The open question of nonheating effects thus increases the uncertainties in this assessment.

Because of the lack of data on microwave biological effects, research is being started on airborne biota and immunology and hematology, teratology, and behavioral effects in animals. Airborne species are of high priority since some can be expected to inhabit or pass through typical rectenna sites.

Extensive research is required to support a quantitative assessment of microwave effects on human health and the ecosystem. The assessment is needed to estimate the impacts of the SPS system, guide the design of an SPS microwave transmission system, and provide a base for international standards of microwave exposure.

NONMICROWAVE HEALTH AND ECOLOGICAL EFFECTS

Development of the satellite power system would require extracting certain natural resources, shipping those resources to factories for processing and manufacturing, transporting finished products to a launch site, and launching the products (and construction workers) into space for orbital assembly of the satellites. Relatively large areas of land also would need to be cleared so that SPS rectennas could be built; manufacturers would ship rectenna components to these sites. Space transportation vehicles would have to be built, either in manufacturing plants or at SPS launch sites.

Most of these activites would be conventional processes normally associated with mining, manufacturing, and transportation. Their environmental consequences also may be regarded as conventional, and potential SPS-related impacts can be assessed on the basis of experience with closely-related activities. Many of these conventional impacts would occur even if the SPS is not developed, as a result of the development of other new power sources.

However, the space activities associated with the satellite power system must be given special consideration. The scope of SPS activities--especially if a large number of satellites were placed in orbit--would greatly exceed the extent of other space activities to date. Thus an analysis of environmental impacts resulting from SPS space activities is a formidable task. Because of the limitations of the existing data base, much of the present analysis is still qualitative rather than quantitative.

SPS depletion of resources, conventional air and water pollutants and waste products could be locally significant and noticeable to the public near industrial centers and SPS rectenna and launch sites. None of these impacts is peculiar to the satellite power system, with the exception of noise generated by SPS rocket launches. All effects could be controlled to some degree by conventional strategies.

Workers in industries supporting SPS development would be exposed to the same kinds of environmental effects as the public but their level of exposure would often be greater. They also would risk conventional occupational illnesses and injuries. Available industrial safety measures appear to be adequate to maintain SPS-related risks at generally-accepted levels.

The principal risks to space workers, as depicted in Figure 2, have been identified based on present knowledge and experience.

Space workers could be injured in SPS launch accidents and during space travel. To date these risks have been faced by only a few people who have been intensively trained for space travel. For SPS, many more individuals would be exposed to these risks, and the level of training might be different than that possible for small groups of people.

One of the principal issues is the ability of humans to work efficiently in space for extended periods of times without undue risk of life shortening or persistent disability. The Apollo and Skylab programs have provided data relevant to this issue. This data has been studied and the conclusion has been reached that there is no substantial evidence to indicate that unpreventable or noncorrective adverse effects will be

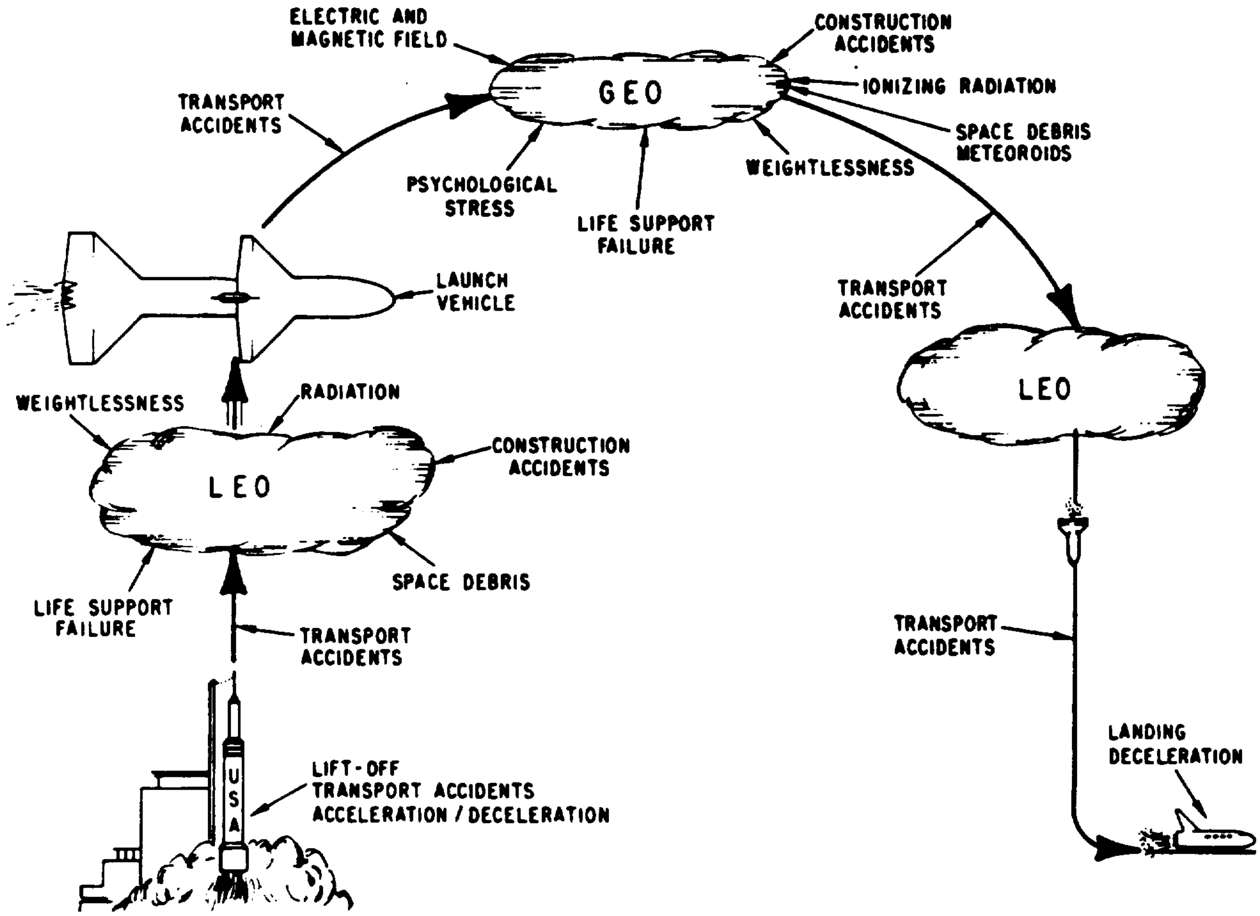

Fig. 2. SPS Environmental Effects on Space Workers

experienced by SPS space workers. Furthermore, although additional potentially adverse effects may be identified in the future, counteracting or ameliorating measures can probably be developed to avoid these effects.

The predominant types of ionizing radiation which occur in space are known. The high-energy heavy ions (known as HZE particles) that would be encountered in space are of particular concern. Preliminary calculations made for HZE and other types of predictable ionizing radiation for SPS space workers indicate that radiation doses might exceed current limits recommended by national and international commissions on radiation protection. Unpredictable radiation, from solar storms for example, are also of concern. The risks from ionizing radiation in space could be minimized through carefully-designed shielding for space vehicles, working and living modules, and solar storm shelters. A warning system could be developed to protect workers from excessive, unpredictable space radiation. In addition, special monitoring systems would be necessary to obtain comprehensive, immediate accounts of radiation conditions in places occupied by space workers. Personnel dosimeters with quick readouts also would be required because of differences in exposure among individuals performing different tasks under varying conditions and work schedules.

Ecosystems might be affected by pollutants from industrial activities supporting SPS development; these effects would be the same as those from activities supporting other energy supply endeavors. The effects of some pollutants on ecosystems are not entirely understood. Site-specific environmental impacts undoubtedly would have some effects on species that normally would inhabit SPS rectenna sites. These impacts might include changes in habitat and natural order of succession. A study of a hypothetical rectenna site in California will quantify representative site-specific impacts. Other principal ecological effects, yet to be quantitatively assessed, might stem from light reflected from power satellites and acoustic noise near launch and landing sites. Both of these, however, can be expected to be either minor perturbations or subject to mitigation by appropriate engineering changes.

SPS EFFECTS ON THE ATMOSPHERE

Every level of the earth's atmosphere would be affected to some extent by the construction and operation of a satellite power system. Atmospheric effects resulting from space transportation and satellite operation are the principal considerations of this task. The effects of rectenna operation are also included. These potential atmospheric effects are illustrated in Figure 3.

Estimates of the local and mesoscale weather and climate effects of waste heat from an SPS rectenna indicate that impacts would generally be small, but would be detectable in some instances. The absorption of microwave power in the troposphere is expected to be worse during rain storms, but even then would have a negligible effect on the weather.

An assessment of the air quality impacts of the HLLV, if launched from Kennedy Space Center has shown that:

- The sulfur dioxide concentration would not be a critical problem.
- Nearly all of the carbon monoxide would be oxidized to carbon dioxide.
- The amount of nitric oxide formed would probably be negligible.
- Acid rain might occur near the launch site if sulfur was present in significant quantities in the fuel. Nitrogen is also a potential source for the formation of acid rain but thus far this possibility has not been evaluated.

Valuable but limited information has been gathered regarding inadvertent weather modification due to rocket launches. Because there

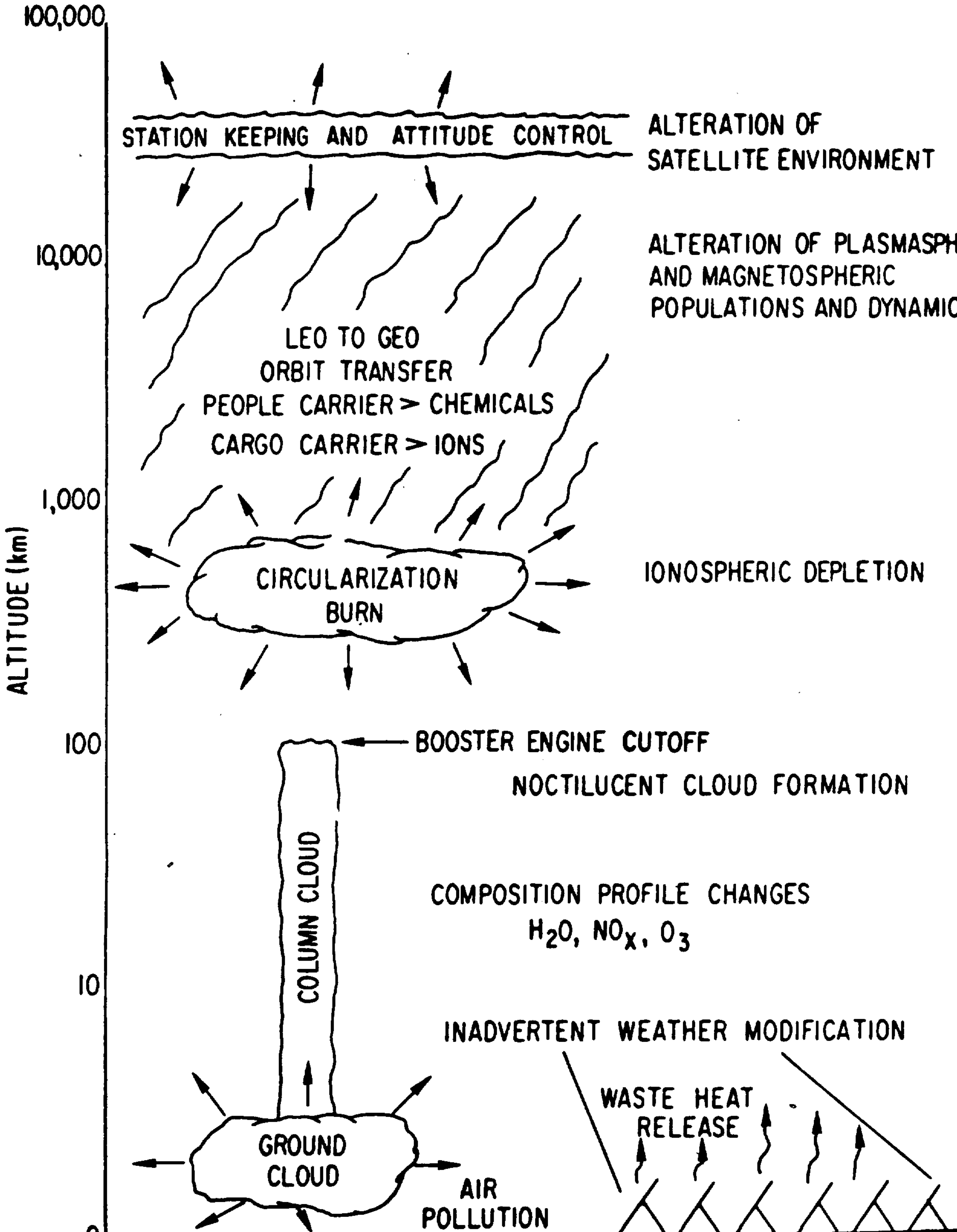

Fig. 3. Illustration of Potential SPS Atmospheric Effects

is a possibility for inadvertent weather modification by the SPS rocket effluents in the troposphere and because cumulative effects would be possible, continuing monitoring of rocket-exhaust ground clouds is needed. Simulations (using computer models) of inadvertent weather modification by HLLV launches under various meteorological conditions are also required to improve the assessment.

Carbon dioxide emissions due to rocket launches would be expected to have no detectable effect in the stratosphere and mesosphere. However, water vapor concentrations could be increased by SPS-related rocket-exhaust emissions. The change in the total (globally averaged) ozone layer due to SPS spaceflights would be expected to be undetectable, as would the effects of nitrogen oxides. The presence of a 0.05% sulfur impurity in the fuel is not considered likely to have any impact, and a similar conclusion may be reached regarding other fuel impurities. Corridor-effect calculations are important to an improved assessment of the SPS perturbations of the composition of the stratosphere and mesosphere.

The globally averaged effect, on the earth's surface, of the anticipated composition perturbation in the stratosphere and mesosphere would be negligible. Reliable assessments of general climatic effects due to SPS perturbations must await model predictions of altitude and latitude dependence. It is probable that transient clouds at stratosphere and mesosphere altitudes would be induced in the vicinity of the launch site but they would not be expected to have a detectable impact on anything else.

The lowest layers of the ionosphere (the D- and E-regions) could be affected by both rocket launches and spacecraft reentry. The effluents from these space operations include water vapor, hydrogen gas, and thermal energy during launch, and ablated materials, oxides of nitrogen, and thermal energy during reentry. These effluents would modify the composition and properties of the ionosphere and might influence climate, satellite-based surveillance systems, radio communications, navigation systems, microwave propagation (SPS power-beam stability) and magnetospheric processes. While the likelihood of altering the electron and ion composition seems to be fairly high, the magnitude of the impacts is uncertain. The effects of nitrogen oxides formed during reentry and the effects of ablated materials do not appear to be important at this time.

Calculations have shown that injection of water and carbon dioxide into the F-region of the ionosphere results in both plasma reduction (electron-ion recombination) and enhanced airglow (visible and IR emissions from excited molecules). These predictions have been verified both inadvertently during the Skylab launch and deliberately during the Lagopedo experiments. Plasma reductions can result in interference with radio communications and navigation systems. Enhanced airglow, while not a serious matter at ground level, can contribute to the noise level of satellite-based surveillance systems.

The issues associated with SPS rocket effluents in the plasmasphere and magnetosphere include the following:

- Injection of Ar+ ions. Effects would be likely and would be expected to be important.
- Generation of plasma instabilities. Possibility of communication interference is unknown.
- Enhancement of airglow. Probability of occurrence and severity of impacts are unknown.
- Disturbance of Van Allen belts and plasma sheet. Probability of occurrence is unknown but potential impacts are important.
- Changes in auroral current systems. Probability of occurrence and severity of impact are unknown.
- Magnetosphere/solar-wind interaction changes. Effects are uncertain but may be important if associated with climate.

EFFECTS OF IONOSPHERIC DISTURBANCE ON TELECOMMUNICATIONS

The ionosphere is the part of the earth's atmosphere beginning at an altitude of about 50 kilometers and extending outward 400 kilometers or more, containing free electrically-charged particles (electrons and ions). The characteristics of the ionosphere vary daily, seasonally, and with the solar cycle.

The ionosphere refracts (deflects) and slows down electromagnetic energy (such as radio waves). The amount of deflection depends on ionospheric electron density, the wave frequency of the electromagnetic energy, the frequency of occurrence of electron collisions, and the strength of the geomagnetic field. The electron density can cause a radio wave to be totally reflected and returned to the earth's surface. This property is used for long-distance propagation of high-frequency radio waves. Radio waves at higher frequencies travel directly through the ionosphere.

Changes in the ionosphere can alter the performance of telecommunication systems whose power is transmitted within and through the ionosphere. Small-scale irregularities (meter to kilometers) in ionospheric electron density can produce radio signal fading and result in loss of information. Ionospheric changes due to the SPS Reference System could result either from interactions between the ionosphere and the SPS microwave beam (heating) or interactions with effluents from SPS space vehicles.

The microwave power density transmitted from solar power satellites to earth might be sufficient to heat the ionosphere, even though only a small fraction of the microwave power would be absorbed by the ionosphere. The heating mechanism is complex, resulting in phenomena such as increased electron temperatures, irregularities in electron density, and focusing of electromagnetic waves. The communications effects of such heating might include absorption or scattering of radio waves (which would disrupt communications systems depending upon the ionosphere as a signal propagation path) and scattering of both the SPS microwave power beam transmitted from space and the beam control signal sent from rectenna to power satellite. Figure 4 illustrates examples of SPS microwave transmission effects on the ionosphere and telecommunications systems.

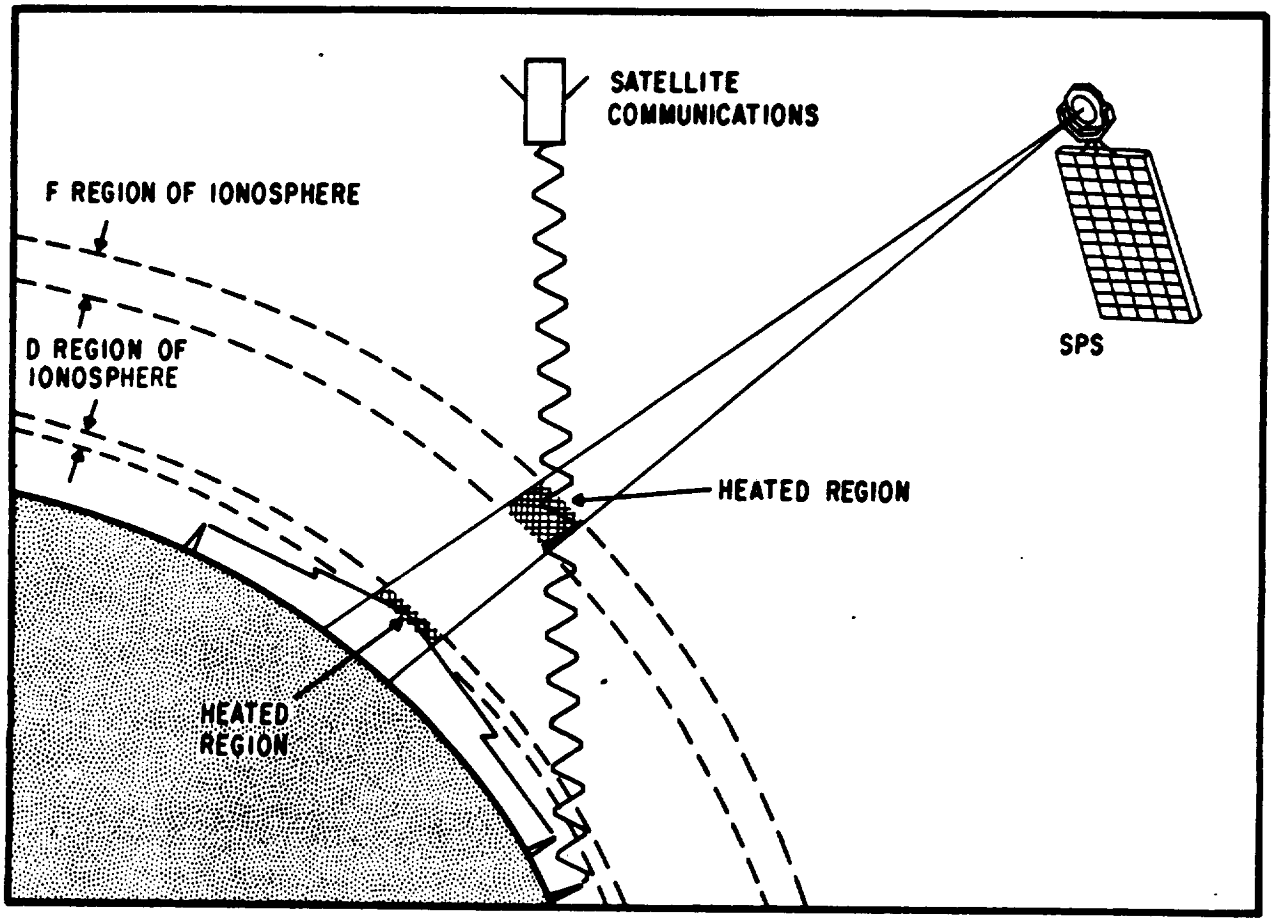

Fig. 4. Examples of SPS Microwave Transmission Effects on the Ionosphere and Telecommunication Systems

A coordinated program of theoretical and experimental work is underway to better understand the impact of SPS heating of the ionosphere. Experimental studies are performed at Arecibo Observatory in Puerto Rico and the Ionospheric Heater Facility in Platteville, Colorado. Both facilities use high-frequency radio-wave transmissions to heat the ionosphere; they can deposit power in the lower ionosphere that is equivalent to the SPS power for ionospheric heating. This is possible because the heating is inversely proportional to the square of the heater frequency.

Experiments related to SPS effects on telecommunications have been conducted at Platteville, where the communications environment is representative of environments in which the SPS microwave-beam transmission would typically occur. Many different types of communications signals are monitored while the Platteville facility is heating the ionosphere. Because the current Platteville facility provides SPS comparable power density only to the lower ionosphere, the telecommunications experiments performed so far were directed toward obtaining performance information for those systems whose radio waves are significantly affected by the structure of the lower ionosphere. The telecommunication systems chosen for investigation were representative of those operating in the very low frequency (VLF, 3 kHz-30 kHz), low frequency (LF, 30 kHz-300 kHz), and medium frequency (MF, 300 kHz-3 MHz) portions of the electromagnetic spectrum. The results obtained indicate that the SPS, as currently configured with a peak power density of 23 mW/cm^2, will not adversely impact upon the performance of VLF, LF, and MF telecommunication systems.

The currently available ionospheric heater facilities are limited in power and frequency range and cannot simulate SPS effects in the upper ionosphere. Modified and expanded facilities would be required to simulate SPS heating of the upper ionosphere, verify the frequency scaling theories, and study the limitations on power density in the ionosphere.

The electron density of the ionosphere likely would be decreased by rocket effluents in the vicinity of the SPS launch sites creating "ionospheric holes." Theoretical predictions of electron depletion and data from Skylab and missile launches suggest that a wide range of communications services could be affected following SPS rocket launches.

ELECTROMAGNETIC COMPATIBILITY

Electromagnetic compatibility is achieved when the capabilities of radio, radar, and other electronic systems are maximized with a minimum of interference between systems. The satellite power system would be designed and operated in ways which would satisfy established national and international rules for using the electromagnetic spectrum. Nevertheless, there would be a potential for producing interference because the amount of microwave power transmitted from space to earth for the Reference System would be unprecedented, and the size of the microwave beam would be very large at the earth's surface.

The SPS field intensity would be one volt per meter at a distance of 30 kilometers from the center of a rectenna site. Communications systems generally operate with received-signal strengths of several microvolts per meter so communications systems within about 100 kilometers of an SPS rectenna could receive sizable signals from the satellite power system. Commercial radio and television signals at distances of 1 to 50 kilometers from the transmitter range from several millivolts to several microvolts.

Examples of SPS microwave transmission beam interference mechanisms are illustrated in Figure 5. Electromagnetic systems likely to experience SPS interference would include military systems, public communications, radar, aircraft communications, public utility and transportation system communications, other satellites, and radio and optical astronomy. The interference potential of the SPS would not be especially unusual except in terms of geographic area. Many high-powered radar systems can produce interference of similar electromagnetic intensities, but the influence is generally limited to the immediate geographic area. Mitigating strategies such as cabinet shielding and radio receiver filters are commonly used to avoid interference near radar stations, and these strategies could be adapted, to at least some extent, if interference situations were encountered with the satellite power systems. Equitable distribution of the costs of such strategies would require careful attention.

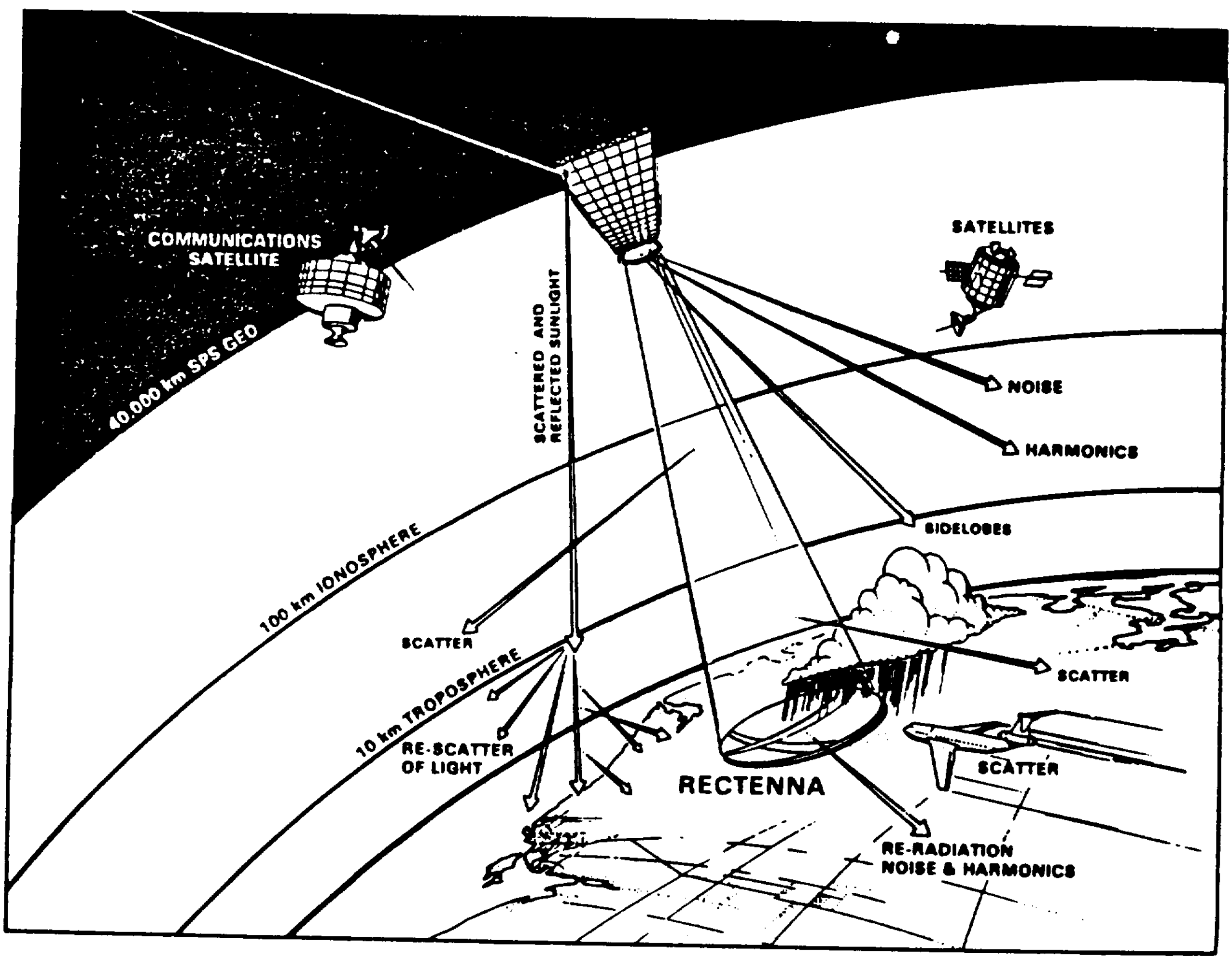

Fig. 5. SPS Electromagnetic Interference Mechanisms

The principal mitigation strategy for preventing SPS interference by direct energy coupling to any class of equipment is a part of the engineering design of the solar power satellite and the rectenna. Interference can be minimized by designing the SPS microwave system to stringent specifications, thereby reducing undesirable emissions at frequencies other than its operating frequency and constraining the size and shape of the transmitted microwave beam. Judicious rectenna siting--including rational tradeoffs between the desire to locate rectennas as near to energy load centers as practical and the need to avoid interference with the maximum number of other users of the radio spectrum--also is an important mitigation strategy.

Military communications equipment is generally complex; uses especially low operating signal levels and therefore is particularly sensitive to electromagnetic interference. Possibilities for modifying the equipment to reduce interference are limited by the nature of its uses. A study has been completed that characterized the potential for SPS interference if a rectenna were located near a large military facility. The China Lake Naval Test Center and two Air Force bases in the Mojave Desert in Southern California were selected for the study. The site selected was especially useful because a wide range of civil telecommunications systems is located nearby and a major electric load center (Los Angeles) is some distance west of the Test Center. Thus the site may be regarded as potentially typical of an actual SPS rectenna site insofar as it conforms to several basic criteria (infrequent cloud cover, near a load center, low population density in the immediate vicinity, etc.). At least 813 government and 685 civil systems were on record as located in a 21,000 square-kilometer area surrounding the hypothetical rectenna and were analyzed.

The study showed there would be a significant potential for the satellite power system to interfere with national defense requirements as represented by large military operational, test, and evaluation facilities. The performance of radar instruments used at airstrips and on test ranges to acquire and track targets might be degraded by 10 to 65 percent. The reception and reliability of command and control communications could be reduced to 5 to 30 percent, and tactical systems performance could be reduced greatly.

Recognizing the constraints inherent in ameliorating interference involving military equipment, the sole mitigation strategy considered in the study was changing the location of the hypothetical SPS rectenna. A relatively minor change in location substantially reduced the impact on national defense facilities without increasing interference effects on civil systems. This scheme may be applicable in other places where large, essentially unoccupied land areas are potentially available as rectenna sites but may be of limited value because of nearby military and civil electromagnetic systems.

Geosynchronous earth orbit (GEO) is currently occupied by a number of space satellites, and undoubtedly will be occupied by others in the future. The SPS also would be located at GEO altitudes. The U.S. INTELSAT satellite has been analyzed as a "worst case" example of potential SPS interference with other GEO satellites. The microwave power which could be delivered to INTELSAT by a solar power satellite was computed and compared with the calculated interference threshold for INTELSAT. The comparison showed that, under maximum-interference conditions, the power delivered by the power satellite would be more than five times lower than that required for interference to occur. Interference thresholds for other commercial GEO satellites are similar to that for INTELSAT, so it can be inferred that the SPS would not be likely to interfere with commercial satellites in GEO. Military satellites are now being analyzed.

Low earth orbit also is occupied by satellites, such as LANDSAT, which is used to monitor earth resources management, and GPS, which is used as a global navigation and position-fixing system. LANDSAT traverses the continental United States six to eight times each day, so it conceivably could encounter an SPS microwave beam. The transit time through the beam would be approximately four seconds; sensor and communications interference could occur during transit. Modifications to the resource satellite to prevent interference appear to be feasible. The GPS satellite is in a higher orbit than LANDSAT and therefore would be exposed to more intense SPS electromagnetic energy and consequently would experience more severe interference. Mitigation strategies are currently being studied for GPS.

Both radio and optical astronomy are used to study the weakest measurable sky signals. Since the satellite power system would contribute power to the radio, infrared, and optical spectrums, there would be significant potential for limiting capabilities for astronomical observations. Radioastronomy could be affected by SPS microwave power beams at distances of hundreds of kilometers from rectenna sites. Additional studies are required to develop a quantitative assessment of these effects.

Power satellites in space would be expected to reflect substantial amounts of light. Even with a coefficient of reflectivity as low as four percent, each power satellite would appear to be brighter than all but the brightest bodies in the sky (the sun and the moon) and would be about as bright as Venus when it is most visible. Multiple satellites would brighten the sky considerably. For example, 60 satellites would provide as much light as the moon between its new and quarter phases across a band 40° long and 10° wide. Earth-based optical observations would be hindered under these conditions.

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