Chapter 2: Mission Perspectives

Background

The National Solar Power Research Institute, Inc. (NSPRI) Summer 97 Solar Academy examined several important questions related to the utilization of humans in space for the construction and maintenance of space-based solar-power systems (SSPS).

These questions fell into three broad categories, human endurance in a microgravity environment, minimized-cost life support for space-based human personnel and utilizing robotics to perform work normally performed by humans in space.

The SSPS Mission

The SSPS mission is to provide bountiful amounts of environmentally safe, economically competitive energy to the Earth. Bountiful amounts of energy include much if not all of the energy presently required to operate human society and preferably as much as is needed to prevent to cost and scarcity of energy from keeping humans in poverty.

Present types of energy used by human society include heat, illumination, mechanical and electromagnetic, among others. Sources of this energy are from fossil fuels, hydroelectric, wind, renewable fuels (e.g. wood and tallow), and nuclear fission.

The sun already provides much energy utilized by humans in the form of illumination (e.g. via windows and skylights). However, utilization of solar power for the production of electricity, while used tactically in remote locations...
Space-based solar power systems have a long history of discussion, beginning with a proposal by mathematician and rocket theorist Oberth to use orbiting reflectors to melt ice in northern shipping lanes to the seminal work by Peter Glaser in 1967 for orbiting electric power stations.

The cost of SSPS is at present uncertain, despite numerous attempts to quantify it. While the cost of unmanned rocket launches is presently well determined, the cost of large-scale SSPS facilities are not.

SSPS is also typically referred to as Solar Power Satellite (SPS) systems, since the solar collectors in most proposals are dedicated satellites orbiting the Earth. However, space-based solar power is presently used on the Mir space station and is planned for the International Space Station, so the broader SSPS acronym is sometimes used in this report.

**System Scenarios**

There are several levels of production and utilization of solar power produced in space.

- Tiny amounts by satellites, most of which are solar-powered.

- Small scale systems such as for Skylab, Mir and the International Space Station.

- Moderate-sized tactical production stations.

- Large, cost-competitive collection and transmission facilities.
At present, none of these scenarios directly provide any Earth-based energy needs. Scenarios of interest in this report are moderate-sized and large system scenarios.

The “tiny” systems are those used by small communications satellites. Such systems involve covering a satellite with photovoltaic cells, so that some of the cells are facing the sun at all times. The output of such systems is often only a few watts.

A good example of a small scale system is that planned for the International Space Station. On the ISS, “the main solar power array is the U.S. built integrated truss; generating a combined 92 kilowatts.” (NASA, 1995). At one point, the ISS provided for “eight solar array ‘wings’, each wing containing 14,592 solar cells to supply power to the station. (NASA, 1989).

An intermediate power system, conceptually, is an early power system proposed for ISS, which was “a hybrid that combines the familiar photovoltaic solar arrays, which convert sunlight directly into electricity, with a new thermal dynamic heat engine. In the latter system, the large dishes at either end of the central boom contain a number of hexagonal mirrors that collect solar heat, which is used to drive an electricity-generating turbine. The combined system will produce 75 kilowatts of electricity. The hybrid was adopted because the heat engine is a more efficient way of generating power and the use of solar panels alone would have required an enormous array, increasing drag and necessitating more frequent adjustment of the Space Station’s orbital position.” (NASA, 1986).

Another example of small scale system is the tethered satellite experiments. “Moving through Earth’s magnetic fields, the satellite will collect electrons and send them through the conducting tether to an electron generator in the Orbiter; the generator’s emission of electrons into space creates a potential difference between the Orbiter and the satellite and completes a circuit that
causes current to flow in the tether. The 12.5 mile tether will generate about four kilowatts; a 60-mile tether could produce about 70 kilowatts, many times the power level of the Shuttle Orbiter. Thus a tether system could be employed as a space power generator, supplying power to spacecraft to supplement other power sources or serving as an emergency backup.” (NASA, 1989).

A moderate-sized system would provide a minimum of a thousand kilowatts of power. This figure is smaller than that used by numerous space activists. Yet, the International Space Station has found that providing even over 100 kilowatts to be a monumental challenge (the presently proposed configuration will utilize 92 watts plus a smaller amount generated by Russian components).

To provide a power collection system over ten times as large as the configuration used by the International Space Station would require many hours of intelligent, on-site physical labor by either humans or robots, even if all presently known automation techniques are utilized. Such labor in space is terribly expensive, even if the technology exists to produce the components of such a system. If a space shuttle mission costs roughly $250 million, and a crew of two astronauts work 25 hours each on a extravehicular activities, then the cost is $5 million per hour per person! Arguably, significant cost savings can be made in the future, but a present figure of $1 million per hour per person is at this point optimistic. Until the International Space Station can prove that it can produce 92 kilowatts of power from solar energy, even 1000 kW must be considered quite ambitions, in terms of both cost and technical ability.

An initial mission scenario is a small collection and microwave transmitter unit. A small Earth receiving station would receive the microwave transmissions and convert them into electricity. The receiver would be located in an area with low population density and probably in an area where other energy resources are restricted.
Building on this “proof of concept”, larger facilities would be built, each utilizing growing economies of scale to produce increasing inexpensive electric power until, finally, the cost of space-based electric power is not only competitive with Earth-based electric power, but even cheaper.

The traditional constituency which is excited about SSPS is the space activist community, which views SSPS as a means to fund and justify the establishment of a self-sustaining infrastructure in space from which orbiting space communities, innovative space enterprises and further long-term space development would spin off.

Perhaps the original reason for SSPS though was the 1970's energy crisis, spurred by the 1973 oil embargo, leading to a deregulation of energy process, finally leading to staggering prices in the cost of petroleum-based energy. At that time, even quite a few electric generation plants ran off of petroleum fuels. Today, in a society in which energy is for the present extremely abundant, the driving force for resurgent interest by politicians in SSPS is the danger of a runaway greenhouse effect. For the first time in over a decade, there is again some reasonable chance for government funding for investigation into SSPS in the United States.

The primary proposed scenario for giant orbiting solar collectors to microwave energy to receiving devices on Earth appears to create an environment of abundant and potentially inexpensive energy. This was an extremely attractive scenario in the early 1970’s and again in the late 1970’s with another stiff price jolt in the price of petroleum. Since such receivers would convert the microwave energy to electrical power without creating carbon dioxide or nuclear waste nor require the consumption of limited terrestrial fossil fuel reserves, this scenario is again attractive. Surely, this would an extremely attractive possibility to both environmentalists and
business magnates who believe it is possible. For those who do not believe it is possible, SSPS could become a cause against which to rally.

Such devices would be a part of the Earth’s power grid. Most pragmatic estimates have such power providing only a portion of the Earth’s power generation. Optimists suggest that this proportion would be large. This presents another political issue. The attraction of solar energy to many long-time alternative energy activists is the ability to live “off the grid.” Such activists may view large scale electric generation facilities as a monopoly used to support the wealthy as well as big government with disregard to the well-being of the environment.

Additional Considerations

The current and projected cost of electricity is an important factor of whether SSPS should even be utilized in large quantities. However, if the environmental cost of producing greenhouse gasses as a waste product of current electrical generation can be expressed in monetary terms and added with force to the marketplace for electricity, SSPS will certainly become much more competitive than it is presently.

Further, given the increasing need for electrical energy (due to electrical cars and increased global industrialization, among other reasons) and the need to reduce reliance on fuels that produce carbon dioxide when burnt, SSPS certainly has a huge potential market.

Conclusions
To the extent that the construction and operation of space-based solar power systems depend on the activity of humans in space, it is impractical given the present demand and cost environments.

Present life science indicates that humans cannot live in zero or near-zero gravity for much longer than six months without risking permanent health damage, let alone safely reproduce and raise children in space (probably a requirement for long-term space communities). Hence, the cost of replacing a space-based crew must be incurred at least every six months.

However, there are two areas in which future developments may economically justify SSPS. The first is if robotic techniques can be developed to supplement much of the human activity now required. The second is if demand for electricity or special solar-based energy services can justify the cost of an artificial gravity-generating centrifugal facility which could reduce launch costs by allowing crews to space in space for years at a time, and perhaps indefinitely.

References

