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The Sunsat Act - Transforming our Energy, Economy and Environment

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Abstract

Our global economy depends on low cost energy. In reaction to peaking oil prices, our economy is "in a shambles." We must rebuild our energy supply. Many energy alternatives have been explored and subsidized since the Arab Oil embargo shock of 1973, yet our oil, gas and energy dependency has grown. Our energy security is declining. Rebuilding our primary energy supply is hard. Fortunately, technology has opened the door to a clean new baseload energy player, Space Solar Power (SSP). The difference between communication satellites (comsats) now in use and the power satellites (sunsats) we need, is that sunsats would optimize for efficient power transfer, while comsats have optimized their signal to noise ratio. Just as the Comsat Act of 1962 created our robust commercial satellite communications industry, the key legislation that would enable SSP to become a major energy source is entitled the Sunsat Act. The Sunsat Act would create a commercial power satellite industry.

Our Energy Economy

Our global economy and wealth is strongly tied to the price of energy and our efficiency in using that energy to create value (exergy).[1] About 60% of world primary energy supply comes from oil and gas, which is in, or near, declining supply. World oil production may have peaked in 2008.[2] Other experts, defining "oil" more broadly, project the peak year to be 2012-2013.[3] Charlie Maxwell, dean of world oil analysts who correctly predicted the oil crash of 2008, forecasts a peak of all liquid fuels, including biofuels, in 2015.[4] A group led by David Rutledge, who chairs Caltech's Division of Engineering and Applied Science, has been working to evaluate all global fossil fuel reserve equivalents. Its projection shows a peak in world fossil fuel energy production - oil, gas and coal - in just 10 years.[5]

The rising cost of energy over the last fifteen or twenty years has our global economy "in a shambles," to use Warren Buffet's words.[6] Overextended on debt, the public been squeezed by rising costs and flat or declining wages. Triggered by record oil prices,[7] the world is in the worst economic crisis since the Great Depression. For the first time since WW II, world electric power demand, the surest measure of standard of living, is expected to be 3.5% lower in 2009 than 2008.[8]

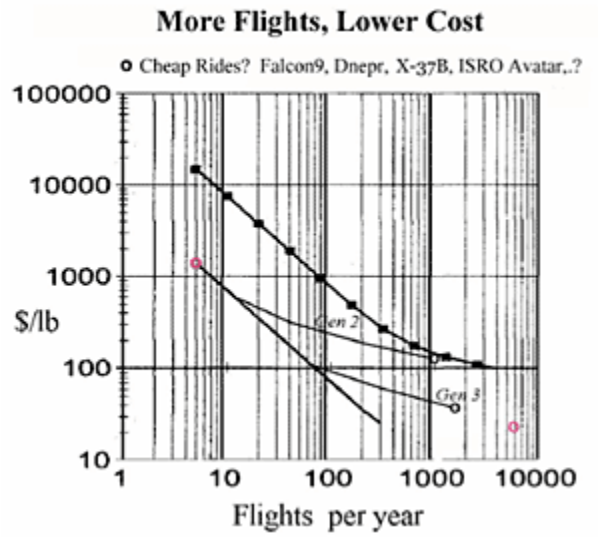
What Technology Now Enables SSP?

Patented in 1968, the potential of SSP was first examined in depth in "The Reference Study" of 1979-1980. This analysis found SSP to be technically just out of reach. Major technical advances have since transformed the business outlook for SSP to "within reach."

What has changed since 1980 to make SSP possible? Besides soaring terrestrial energy prices, here are five SSP transformation enablers:

- Space transportation - The first major financial hurdle in building an SSP system is lowering launch cost to GSO. Only an SSP system provides the huge market volume required to enable the low-cost space transportation system necessary for a successful SSP business case. Low cost transportation to orbit to GSO is critical; launch costs to space must be reduced from thousands of dollars per pound to about $150/lb.

  Led by SpaceX, private orbital commercial transportation could cut that cost with reusable spacecraft. SpaceX, for example, plans to add the necessary thermal protection to allow for first stage recovery on Falcon 9's fifth flight.



  If SpaceX succeeds in recovery and reflight of both stages of a Falcon 9 launch vehicle, it will be the first fully reusable orbital vehicle - a huge advance in space access.

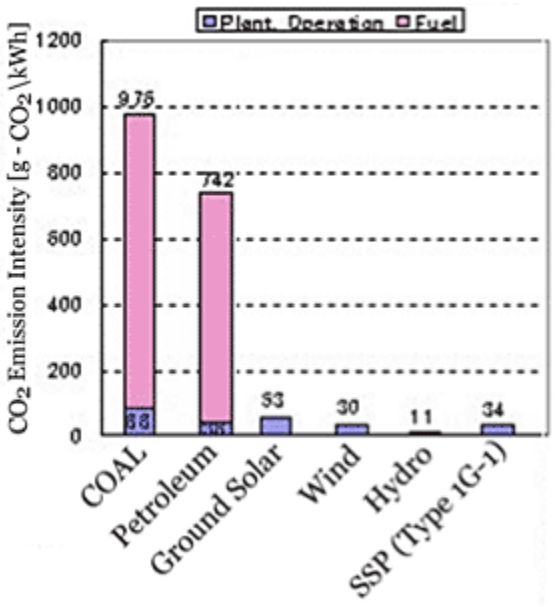
  At $35 million to manufacture, Elon Musk says that an efficient refurbishment and launch operation could bring Falcon 9's per-launch price down to about $1 million, a hundredfold improvement over current costs. The Falcon 9 can place 12,500 kg (27,500 lb) into LEO, so at $1M per flight, that would be $80/kg ($36/lb). To get the launch price to $1M, the amortized manufacturing cost would need to equal refueling costs, or about $200,000. That goal implies reusability for 175 times - within a

short enough time frame that the cost of capital doesn't increase the amortized manufacturing cost.[9] That usage rate exceeds current or projected launch demand.

- Telerobotics - All SSP system construction can and should be done telerobotically and eventually semi-autonomously. Telerobots, operated from Earth, cost a thousand times less than real people working at GSO. Humans also cannot long tolerate the high radiation environment at GSO. Robots can. In 2007, for the first time, a satellite autonomously rendezvoused with and captured another orbiting satellite. ASTRO (Autonomous Space Transport Robotic Operations), part of Boeing's Orbital Express system, demonstrated advanced on-orbit satellite refueling and reconfiguration capabilities docking with NextSat.
- Photovoltaics - The key metric for PV is Kw/kg, not raw efficiency, since transportation cost to GSO forces us to place a premium on weight. Laboratories can now produce PV material that provides 16.8 Kw/kg at GSO (AM0),[10] although its efficiency is only about 10%. This is fully adequate performance for SSP production, although improved materials are expected. The material - amorphous silicon - has been shown to reanneal at operational temperatures, giving it long life.
- Wireless power transfer - Efficiency of microwave power transfer has reached 85%.[11] Overall efficiency from PV output at GSO to grid input on Earth would be about 55%. Much work remains to design and test an array as large as SSP presumes, since efficiency is dependent on large aperture transmitters and rectennas. For spectrum, 5.8 Ghz is a commonly assumed frequency. Laser power transfer is also improving and may become competitive with microwave.
- High Temperature Superconductors (HTS) - these new materials can drastically cut the weight of miles of cabling needed for a Sunsat. At liquid nitrogen temperatures HTS cable has almost no resistance to the flow of electricity enabling it to transmit 150 times as much power as same size copper wires. One vendor's product (AMSC) can "self-heal" by automatically isolating power surges. To obtain the liquid nitrogen temperatures required to be superconducting at GSO is fairly easy - just keep the cable in the sun's shadow and not touching warm parts. This approach will work when the structure is in the shadow of PV materials, which by design will point continuously at the sun.[12]
- Space environment experience - Our understanding of GSO is immensely improved, from the solution of the equations of interaction between the solar wind and earth's magnetosphere[13] for more efficient satellite station keeping (the Westerlund patent and GPS Tensor from Space Systems/Loral- which uses Navstar signals to determine satellite orbital and attitude position and attitude rates[14]). Existing and "retired" comsats could have new lives as communications hubs for SSP telerobotic construction, lowering their cost.

Climate Change Friendly

Sunsats require no fuel and emit very low CO2, Their receiving antennas (rectenna is the proper term) can have green farms underneath, effectively using no land. Building Sunsats would facilitate a pro-jobs international climate change solution.



CO2 Emission by Plant Type - Credit: USEF.[15]

Wireless microwave power transmission equations show that power transfer efficiency depends on the transmitter and receiver diameters; these must be large for high efficiency. Sunsat transmitters will be about 1 km diameter at GSO, rectennas will be about 5-10 km diameter, for multi-Gigawatt delivery sizes of economic operation. A typical delivery frequency could be 5.8 Ghz.

Terrestrial Solar Farm (left), Illustration of SSP Rectenna (right)
Credit: MAFIC Studios

Why Don't Existing US Utilities or Companies Build SSP?

No company, utility or agency today is prepared to assume the immense business risk involved in creating and launching a space solar power system. The tens of billions in financing required and the painfully slow payback time places SSP in the venture capital "Valley of Death." There are still too many engineering, financial, and regulatory risks. Like building or financing the Hoover Dam or the Transcontinental Railroad, private enterprise will need some help bringing this much needed public utility to operational reality.

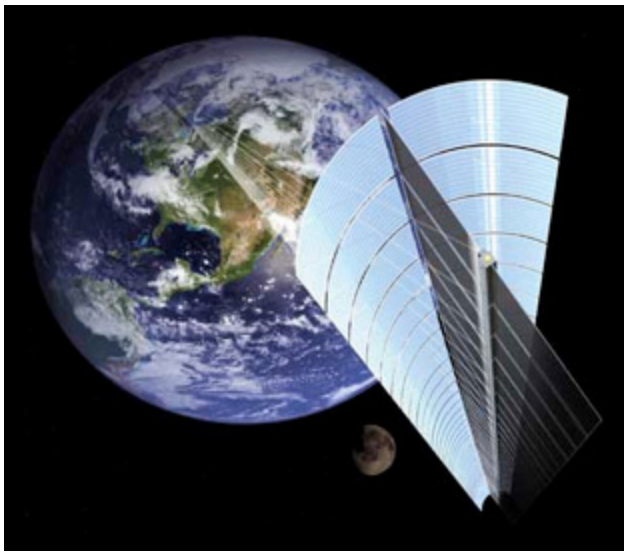
Expecting an individual utility to construct an untested new power source is probably illegal. Since utilities are public trusts, they would not likely engage in

the high-risk work necessary to build the first sunsats. Similarly, requiring utilities to reduce their CO2 footprint would be fruitless unless there is a trustworthy path forward. Wind mills and ground solar, for example, cannot be expected to replace baseload coal and nuclear power plants, which have to be scheduled. Only Congress imagines they can schedule wind or sun. There is also no economic way to store massive quantities of electric power; i.e., California can't be run on "batteries" charged from wind power. To expect it to do so would force its utilities to either destabilize their grid or to greatly increase costs to their customer base. SSP provides a real alternative to cut costs and improve reliability with its unexcelled power generation characteristics, but such an innovation must be scheduled.

No one builds a multi-billion dollar nuclear plant or other baseload plant without being certain of having a customer base. That is why deregulation of energy utilities was such a hoax on the American people. In a deregulated environment new generation capacity and new transmission lines can not be built because the return of the principal and interest can not be assured.[16] To do so would place more debt on the public for needed services than would ever be acceptable. Major electric power utilities are the most capital intensive businesses in the world, meaning they require more dollars to be invested in concrete and steel to earn a dollar that any other business.

Companies in several countries are pursuing SSP, including China, Europe and the United States. In the U.S., Solaren has a contract approved by the California PUC, to provide its PG&E utility with 200 megawatts of space solar power starting in 2016. In a press release, PG&E said the price would exceed 12.9 cents a kilowatt-hour.[17] Note that PG&E has invested nothing and accepted no risk. Solaren is planning for $100 million in first round financing. Expecting private companies to build SSP alone is problematic. Solaren will need to raise ten to forty billion in financing.

The largest SSP concern known to exist today is an eighteen-company Japanese consortium, the Institute for Unmanned Space Experiment Free Flyer, with $21 Billion estimated funding.[18] The Japanese group intends to launch a small test satellite in 2015, testing microwave energy beaming through the ionosphere.



A JAXA SSP design. Credit: JAXA.

Its SSP electricity would cost customers eight yen (nine cents) per kilowatt-hour, six times cheaper than its current cost in Japan.[19] The Institute's first 1 Gigawatt satellite is scheduled for 2030 delivery. In 2009, a team at Kyoto University beamed 220W from two phase-controlled magnetrons on an airship.[20]

How Can We Get SSP Built?

When America has faced immense engineering challenges before, the model of a public/private corporation chartered by Congress has been used. The most rapid and effective pathway to assure construction of a new space solar power system is to establish the basis for cooperation between government and private companies. We believe the process for creating this corporation is via a new "SunSat Act." Such an Act has already been proposed to Congress in 2007.[21] A draft of the legislation needed to establish the Sunsat Corporation can be found on the Space Solar Power Institute website.[22] The "Sunsat Corp," as we call it, would be modeled after the "Comsat Corp," a highly successful public/private corporation chartered by Congress in 1962 to launch the beginnings of the communication satellite industry. Anchored by the biddings of successful aerospace companies, for example, the public could also buy shares.

The Sunsat Corp would follow established private company practices. When Boeing, for example, designs jet airplanes it starts with the customer request, asking their priorities for operations, maintenance, fuel efficiency, weight and volume delivery profile. They then design the aircraft to those specifications and schedule deliverables to meet or exceed the customers' expectations.

In 1862, the U.S. Congress had chartered the Union Pacific Railroad Company via the Transcontinental Railroad and Telegraph Act[23] "to aid in the construction of a railroad and telegraph line from the Missouri River to the Pacific Ocean." The greater challenge was the Transcontinental Railroad. What follows is

a page from colorful history showing the grants and subsidies specifically created for the railroad and telegraph line:

The President of the United States received sealed bids on two points: First, within how short a time will the contractors complete the railroad? Second, at what rate per annum will the contractors carry the mails and Government freights for a period of twenty years from the date of the completion of the road?

The government organized and executed surveys from the Mississippi River westward to the Pacific Ocean, to ascertain the most practicable route. The chief engineer, in his 1869 report to the president said: "In 1863 and 1864 surveys were inaugurated, but in 1866 the country was systematically occupied, and day and night, summer and winter, the explorations were pushed forward through dangers and hardships that very few at this date appreciate. Every mile had to be run within range of the musket; there was not a moment's security.

Excursion Train rounding Cape Horn at the Head of the Great American Canon - Frank Leslie's Illustrated Newspaper, April 27, 1878.

"Upon the completion of each 20 consecutive miles of railroad, … title to the granted sections were to be issued."

"It also provided for bond subsidy of $16,000 per mile between the Missouri River and the base of the Rocky Mountains; $48,000 per mile for the distance of 150 miles through the mountain range;"

These bonds were payable thirty years after date, bearing 6 per cent interest, and were in the nature of a loan of credit by the United States, and were made a second-mortgage lien on the railroad, telegraph and all appurtenances, subordinate to bonds which the companies could issue.

In making the surveys some of the ablest and most promising men were killed. During construction our horses and cattle were run off by the hundreds and thousands. Lack of confidence in the project, even in the localities to be the most benefited, was so great that laborers demanded their pay in advance before they would perform a day's work.

How Would Sunsat Corp Operate?

Sunsat will be organized as a super-utility, following the pattern of other successful public/private U.S. corporations. Access to the types of high volume customers a Sunsat is ideally designed to serve, requires contracts with existing utilities (and other high volume users of electricity) to deliver continuous power to designated sites over a long term. Those utilities and companies will be expected to build and own the rectenna system that converts delivered energy into usable power on their grid, which is also physically part of their transmission system hardware.

Local ownership will thus insure a major financial commitment from the end users, a commitment that would be about $1 Billion for typical 5 GW rectenna installations, actually producing five 1 GW outputs. This will keep the Sunsat Corp focused on the space segment and wireless downlink power transfer. All rectennas will be built in close consultation with Sunsat's earth segment partner, which we call SPARCO. SPARCO is an international association comprised of interested utilities, rectenna owners and an in-house design and development staff. Space Solar Power is precisely the type of power that electric utilities are under pressure to deliver: clean, low cost and reliable.

Sunsat Corp companies will focus on delivering baseload power to large energy users on the ground. They shall not be engaged in the development, construction or marketing of space transportation systems, PV cells, or other space hardware, product or services. These will be purchased on the open market. Just as Comsat had a satellite communications lab, Sunsat will also have a wireless power transfer lab to improve power delivery to their client utility grids.

The Sunsat Corp will provide quarterly reports on its work to Congress as well as to advisories concerning progress toward lower cost, improved performance and reliability. The cost of preparing these reports will be considered part of the developmental design and construction costs of the demonstration power satellites.

The Sunsat Act specifies that the President shall:

1. aid in planning and development and fostering the execution of a national program for the establishment and operation of a global commercial power satellite system;

2. provide for continuous review of all phases of the development and operation of such systems, including the activities of a power satellite corporation authorized under this Act;
3. coordinate the activities of governmental agencies with responsibilities in the field of electric power generation and transmission, so as to insure that there is full and effective compliance at all times with existing policies and policies set forth in this Act;
4. exercise such supervision over relationships of the Sunsat Corp with foreign governments or entities or with international bodies as may be appropriate to assure that such relationships shall be consistent with the national interest and foreign policy of the United States;
5. insure that timely arrangements are made under which there can be foreign participation in the establishment and use of power satellite systems;
6. create a Power Satellite Commission to provide necessary governmental coordination, as required in the national interest, to meet quarterly or as often as required;
7. The Power Satellite Commission shall be composed of members to be named by: The Power Satellite Corporation selected; Federal Energy Regulatory Commission; Federal Communications Commission; Department of Commerce; The Congress; The Department of Defense; Department of Agriculture; Space Transportation Association; and the U.S. Trade Representative.
8. The Chairman of the Power Satellite Commission, named by the Sunsat Corp, will so exercise his authority as to assure coordinated and efficient use of the electromagnetic spectrum and the technical compatibility of the system with existing electric power companies both in the United States and abroad.

Conclusion

As proposed, the Sunsat Corp will be a multinational super-utility created in the manner of such commercial satellite companies as Intelsat and Inmarsat[24] as a result of the Comsat Act. Sample draft legislation for Sunsat Corp is on the Space Solar Power Workshop website[25] at: http://www.sspi.gatech.edu/sunsat-how.pdf.

The energy status quo may feel safe for the moment, but the price to be paid for our continued failure to address our growing global energy, economic and environmental threats is the wasting of the most precious commodity we have, time. Starting now, it will take decades to do the work necessary to build a new SSP system. And it will be costly. As a point of comparison, it is worth noting that, in 2009, the U.S. government stimulus funding for high-speed rail was $8 Billion; China's funding is at $100 Billion.[26]

What can you do? We suggest you study the rationale behind SSP's key points, ask questions about any unclear points and then write your Congressman to request he/she support the Sunsat Act. The Congressional site created for this purpose is: https://writerep.house.gov/writerep/welcome.shtml.

Send an email to your friends and family asking them to send a letter to their Congress men and women, pointing them to that easy link (above) and to this article to be found at: www.spacejournal.org (Issue No.16: Solar power Satellite).

Congress only listens to those who talk to them. Did you know that most Americans have never written their Congress person? A sample letter is on SSPW website at http://www.sspi.gatech.edu. We will place others there. Old fashioned letters get even more attention. Keep the letter or email simple, courteous and to the point. We also encourage you to connect with us and other interested volunteers at the Space Solar Power Workshop through (email: SunsatMinutemen@googlegroups.com) or visit: http://groups.google.com/group/SunsatMinutemen.

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