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SUNSATS: The Next Generation Of COMSATS

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Abstract

No solar power satellites (SunSats) are yet in operation. While all space-based satellites host some type of solar collector for the energy needed to power and control them, no satellites are in orbit today for the primary purpose of gathering energy from the sun and delivering it to earth. Because an abundant and sustainable new source of energy is desperately needed on earth and the current level of technological development will now permit it, a huge new satellite sector is about to emerge relaying energy from space to the ground where it will be used as electricity.

The logical path forward in development of solar power generation plants in space is to go in partnership with the commercial satellite (ComSat) industry, a well-established ($140 billion per year) sector with 30-plus years of expertise in designing, manufacturing, launching and operating spacecraft in orbit above the earth. ComSat stakeholders can be predicted to take the lead in any new SunSat ventures because this is their home territory. Once it is clear that satellites parked in geosynchronous orbit can safely and profitably deliver energy as well as video, voice and data signals, the ComSat industry will be there with the global perspective, the venture capital, the regulatory clout, the managerial experience and the marketing skills to turn such an enterprise into a viable business.

Power Plants in Space

The idea that the sun's rays can be collected in space and beamed to earth from a space-based platform as a source of electrical power has been around even longer than the idea of communication satellites. The entrepreneurs in communications sectors were the first to commit to space because they were quicker to see the advantages in having transmission towers located high above earth for widest reach, coverage and mobility, while the power industry stayed home feeling assured that it could get all its needs met digging for fossil fuels on the ground.

In the 1970s, energy stored within the earth was still readily available, and very cheap. But by 2010, economically available oil and gas reserves were harder to mine and were a lot more expensive. Coal and nuclear fission material were perceived as "dirty energy" sources. Also, by the 21st century, all the unaccounted costs of environmental desecration and atmospheric pollution had finally come due. That scenario has created the context for reconsidering the SunSat option. While initial investment costs may be high, the attraction of clean, abundant and instantly useful energy drawn down from strategically placed solar stations above earth is now too compelling to resist.

Since communication satellites (ComSats) and solar satellites (SunSats) have many similar technological and operational requirements, it is worth considering how their business plans might converge.

In-orbit satellites perform a variety of functions; the most significant are: communication (audio and video broadcasting, mobile telephony, broadband data and Internet); remote sensing (weather, environmental surveillance, mapping), and geo-positioning and navigation. As a platform for doing work beyond earth's atmosphere, the International Space Station (ISS) is also a multipurpose satellite, whose purpose is largely to do research while testing the opportunities and challenges of living and working in space.

Will solar power satellites be radically different from those operating in space today? The answer is yes and no. If one considers the three basic structural elements of communication satellites - that is, the space segment, the earth segment and transport segment, one can see that they have much in common.

Space Segment: The new solar power satellite industry will be positioning above earth a new type of energy infrastructure hosting many of the features of communication platforms, including a satellite bus (physical structure), solar arrays, on-board processing, telemetry control and wireless transmission systems. Unlike the ComSats that also gather a small portion of the Sun's radiation to power their spacecraft, the SunSat antennas will be collecting and concentrating solar thermal or photovoltaic energy for the principal purpose of relaying it to earth where it will be converted into electricity.

While development of the thinner, lighter, cheaper photovoltaic (PV) cells that make terrestrial power production increasingly more efficient is benefitting communication systems in space, the benefits will be much greater for the solar power producers looking to reduce the size and increase the productivity of their antennas while holding down the costs of launching their much larger collector-arrays into space. Also benefitting the SunSat as well as ComSat industry will be promising new developments in remote construction, assembly, repair and replacement.

SunSats will need bigger, more efficient solar panels than are used by current day ComSats, since they will be collecting and processing sun's energy in substantially larger quantities. The principal purpose of their on-board power conversion and transmission systems will be to convert the sun's energy into microwaves and beam them down as a source of electrical power.

Among the more innovative SunSat designs are architectures that consist of more than one satellite, networking them together within a common space orbit, creating a photovoltaic mass of one-kilometer size or more. Multiple clusters of such satellites may one day be operating in space orbit, and these will be linked for global service. While building such structures, launching them and assembling them in space will be a massive undertaking, past space achievements (like the International Space Station, the Hubble Telescope, the Mars rovers and the many spacecraft that operate safely and productively in earth orbit) give us confidence that locating solar stations in space is within our reach.

ComSat architectures in the digital age have greatly improved functionality and performance as a result of on-board computer processing and control and effective use of spot beam technologies. These advance technology spacecraft can direct their communication transmissions to more narrowly defined regions, and increase power levels through cloud cover. Such beams can be moved from one receiver to another on command from earth. While transmitting a communication signal requires quite different operations from those needed in wireless power transmission, these more advanced ComSat designs will help to solve some of the challenges faced by SunSat engineers.

Ground Segment: Rectifying antennas - receiving earth stations - will capture the transmitted signals of the solar satellites and convert them into electrical power. In this respect, SunSat receivers will be somewhat like the passive TVRO (receive only) earth antennas of radio and television, only they capture not information but energy to be relayed to clients and consumers. Except for telemetry, no uplink is needed. The SunSat on-ground receivers will be substantially larger than those of radio/TV.

Solar power rectennas can stretch 1-10 Km across, with networked photovoltaic arrays capable of producing the electrical equivalents of coal fired or nuclear power plants of 1GW (one-gigawatt-per-hour), or larger. To be clear, such collection points can be expected to require a protected area similar in size to that required of coal and nuclear plants but their clear advantage is that fish farms and agricultural crops can be grown and greenhouses situated on SunSat sites, the power they generate will be non-polluting and there will be no toxic waste to dispose of.

Just as the teleports and antenna farms of satellite communication are connected into the broadband fiber optic networks distributing signals terrestrially, SunSat antenna farms will be connected into the terrestrial grid that distributes electrical power. While ComSats are networked with data centers for the storage and retrieval of information, the SunSats will be networked into power distribution centers that insure balanced energy flow from the multiple electricity sources within regions served.

Launch Segment: SunSats will employ the same private, commercial and government rockets used to lift communication satellite structures from earth to space. Some plans involve assembling solar satellites and their antennas from components lifted by medium power rockets into a low earth (LEO) orbit, possibly using the International Space Station as a staging area, later transferring them into their final position, preferably in a geosynchronous orbit (GEO) at 36,000 Km above earth. Other plans include inserting the solar spacecraft and their large arrays into GEO orbit directly using the more powerful thrusters.

Launch Segment © NASA

Launching satellites safely and economically into space is among the greatest challenges of the satellite industry. Both the communications and solar power industries will be the beneficiaries of the ongoing private/public collaborative efforts to regularize space transport, making it a viable business enterprise in the way that aerospace is today. To avoid the high costs of launching men and material into space, some visionaries see space-based infrastructures being built from materials found in space, with robotic manufacturing and assembly managed from earth via virtual communications and control.

Challenge Points

As with communication satellites, solar power satellites must be lifted from earth and delivered into designated orbits, where they will be expected to provide service to designated regions. No matter the orbit, such satellites must have gone through a nation-by-nation approval process to decide upon a particular location that will ultimately involve the International Telecommunications Union, an agency of the United Nations. Since the most promising orbital locations for SunSats appear to be in geosynchronous (GEO) earth orbit - the sweet spot for communication satellites located some 36,000 Km above earth - the ComSat industry must be in on these discussions from day one.

The solar power satellite industry can expect some push back on such matters as orbital slots and frequency assignments. World satellite communication is strictly regulated in terms of orbital registration and position, frequency allocations and levels of power transmission. Minimizing interference with electromagnetic spectrum assignments of other space users and with those on the ground is the principal reason for such controls. Consumer safety is also a consideration. It can be expected that solar power satellites, as they are arriving late to market, will face intense competition for prime orbital slots and frequencies that are by their nature scarce. Although incumbent players in space will be conducting operations and businesses that may not be in direct competition with the new SunSats, they can be expected to resist sharing any positions and any spectrum, just to protect their territory.

All the more reason why the building of SunSat/ComSat partnerships is a matter of priority. In January 2008, the Space Solar Power Institute of Atlanta GA, approached the U.S. House Committee on Science and Technology with a proposal to form "a congressionally chartered public/private corporation" patterned after the highly successful model provided by the COMSAT Act of 1962. The purpose of the Sun Satellite Corporation would be "to build commercial power satellites to collect and transmit energy to electric power grids under contract to wholesale (utility) customers on earth," a strategy that would improve America's energy security. News about this initiative hasn't yet made headlines, but since such an approach is exactly the one most likely to be taken by such other spacefaring nations as Canada, China, India and Japan - our collaborator/competitors in the race to space for energy - this idea is not going away.

It is now clear that the more significant barriers to realizing a new satellite business based on energy from space are not technological barriers. Technical features of solar power satellite systems do require further development, including improvements in easier/cheaper access to space, efficiencies and capacities of solar cells, wireless power transmission and receiver networks, energy conversion, storage and distribution. Space visionaries have always looked to governments to get their ambitious projects off the ground. In the case of building SunSat infrastructures, governments can help with R&D funding, assist with demonstration projects and agree to be the anchor tenant purchasing the first products produced, but the commercial sector must be involved, and involved early, for long run implementation and management.

Progress made in raising capital for SunSat businesses will inevitably be tied to progress made in commercialization of space overall, and the development of plausible business plans related to alternative energy markets in particular. The fact that the U.S. demand for electricity is expected to increase by as much as 40 percent in the next two decades, and assumptions that lesser developed nations will wish to grow even faster, should be enough to get private enterprise paying attention.

Significance

The world is facing a perfect storm in which an energy crisis and an environmental crisis are occurring simultaneously. Earth's population continues to grow. Oil, gas and coal, the principal energy basis for the steadily improving standards of living among the more developed societies - and coveted by lesser developed societies - are contaminating earth's atmosphere as they are mined, processed and consumed. Those non-renewable fossil fuels are rapidly being used up. Within the next human generation, fossil fuels - plus all known alternative energy sources on earth - are predicted to fall far short of what will be needed.

Several government commissions, think tanks, energy companies and utilities in more than one country investigating space-based solar power have concluded that SunSats are the world's most promising long-term solution. The argument is that the solar energy available in space is several billion times greater than any amount we could ever use on earth. The sun's energy is always available and it is inexhaustible. Unlike the fossil fuels of earth, space solar power does not emit greenhouse gases. Moving to solar can reduce competition for the limited supplies of earth-based energy, which is predicted to be the basis for future wars.

It is encouraging to see that Japan has already made a financial commitment to go to space as one of its alternative energy solutions. In September 2009, a research group representing 16 companies, including Mitsubishi Electric and Mitsubishi Heavy Industries, announced a two trillion yen ($21 billion) effort to build and launch a 1 GW solar station into GEO orbit that will be in operation by 2030. The satellite will be fitted with four square kilometers of solar panels. In 2015, a smaller demonstration satellite fitted with wireless power transmission equipment will be used to test power beaming to earth.

Final Thoughts

Figuring out how to generate energy in space and make it available on-demand anywhere on earth will be an undertaking unparalleled in human history. Its significance, in the long run, will be far greater than placing a man on the moon or building a human habitat on mars, because ready access to energy on earth (and elsewhere) is key to all exploration of the universe. Because SunSats can tap the one energy supply that cannot be depleted, any corporation or country that is in the space energy business will have a perpetual competitive advantage.

In practical terms, building international businesses around solar energy from space may be the only way we can keep alive our individual and collective dreams for a better life. Having abundant, safe, non-polluting energy could represent a tipping point for human productivity and creativity, that one essential ingredient enabling us to not just to survive but to live up to our potential as a human race. If indeed solar energy could make that difference, let us hope that it will happen, as there are no other sustainable solutions currently up for consideration that have the potential to meet our expectations.

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