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Space solar power

Let the sun shine in

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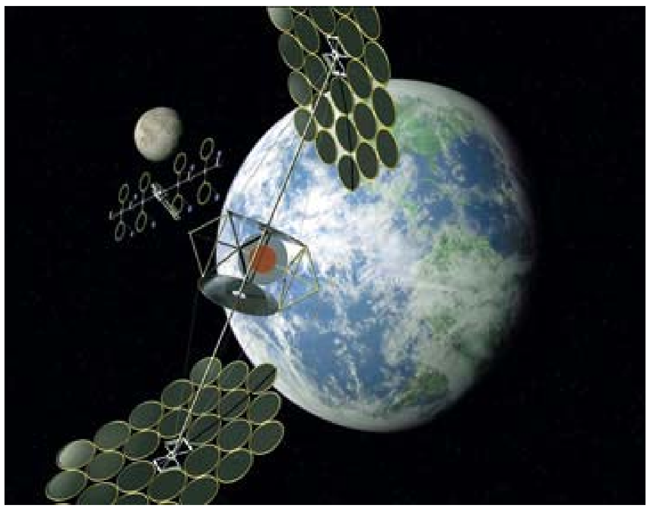
Energy: Satellites that beam solar power to earth have often appeared in science fiction. Will they ever become reality?



“REASON”, a short story written by Isaac Asimov that was published in 1941, is set on a space station which collects solar energy from the sun and sends it, via microwave beams, to earth and other planets. The robots that control the beams are under the command of a more advanced model called Cutie, which turns out to have developed its own religion, and ignores the wishes of two astronauts who visit the station. As a solar storm approaches, the humans worry that Cutie will be unable to control the beam sending power to earth, causing it to fall on cities and incinerate them. But in the event, the robot’s religious yearning to keep the power flowing means that no harm is done. The moral: actions matter more than beliefs.

Today it is not just robots in science-fiction tales who are believers in the wonders of space solar power (SSP); the idea also has a small but growing number of human adherents. The basic idea is simple. Light from the sun is the most abundant and cleanest source of energy available in the solar system. Around the clock, 1.3 gigawatts of energy pour through every square kilometre of space around the earth. This energy could be captured by vast arrays of photovoltaic cells mounted on a satellite in orbit around the planet. These solar cells would be illuminated at all times of day, whatever the weather or the season, overcoming one of the main drawbacks of solar power on the earth’s surface. And with no atmosphere in the way to absorb or scatter the incoming sunlight, solar panels in space would produce over five times as much energy as those on the ground. (Some proposals for SSP involve large arrays of mirrors or lenses to concentrate the light onto a smaller array of panels.)

The logical place to put the satellite would be in a geostationary orbit, 35,800 kilometres above the earth’s equator, so that it completes one circuit of the planet per day, and thus appears (from the ground) to hover in a fixed place in the sky, like the communications satellites used to broadcast television signals. The solar-power satellite would send the collected energy down to earth in the form of a microwave beam, which would be picked up on the ground by a huge array of antennae, spread over several square kilometres in open country. The power density of the beam at the receiver would be little greater than what leaks out from a domestic microwave oven, so there would be no danger of incinerating entire cities. Microwave communications links are already used in the telecoms industry without doing any harm to wildlife.

The concept of beaming gigawatts of solar power down from space was first put on a sound scientific footing by Peter Glaser of Arthur D. Little, a consultancy, in 1968. He built on the research of William Brown of Raytheon, an American defence firm, who pioneered the transmission of electric power by microwave beams. Since the oil shocks of the early 1970s, the idea has been dusted off and re-evaluated every ten years or so by America's Department of Energy, its space agency, NASA, and big aerospace companies such as Lockheed Martin and Boeing.

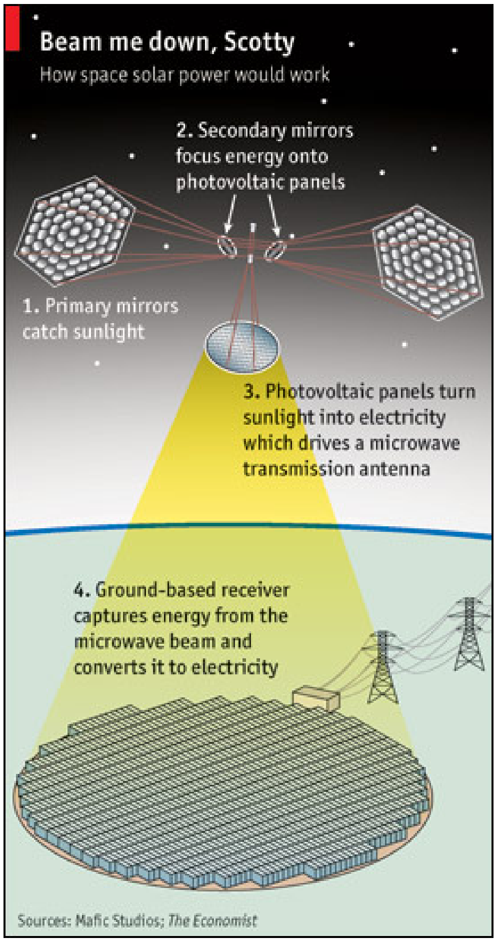
These studies usually conclude that there is no technical barrier to implementing SSP. For example, a study published in 1981 by the Department of Energy, NASA, the Environmental Protection Agency and the Department of Commerce found "no show-stoppers" or "insurmountable obstacles" to the idea. But further development work has always fallen between the cracks of different agencies. "The trouble is that the Department of Energy doesn't do space, and NASA does space, not energy," says Colonel M.V. ("Coyote") Smith of the National Security Space Office (NSSO), a Pentagon think-tank, who recently conducted another study of SSP.

Space solar power is an idea far ahead of its time, but the necessary technology already exists.

Although there may not be any technical difficulty with the idea, the economics are another matter. The main obstacle to SSP is the huge cost of launching the satellites into space. Conventional electricity in America costs between four cents per kilowatt hour (kWh) for hydro-electric power (the cheapest kind) and ten cents for coal-fired generation. Even under the most optimistic scenario, SSP would produce electricity at a cost of around 50 cents per kWh with existing technology. It sounds hopeless. Yet recent developments mean that advocates of SSP are more optimistic than ever before.

Bridging the gap

These developments were not so much technological as geopolitical. The NSSO's recent evaluation of SSP, published in 2007, took a more favourable view of the idea than any previous assessment. Colonel Smith admits that he was sceptical about the idea at first. But he concluded that the Department of Defence was "a potential anchor-tenant customer of space-based solar power", because SSP could provide a much cheaper alternative to existing energy supplies.



The armed forces are America's single greatest consumer of oil. The Department of Defence delivers 1.6m gallons (7.3m litres) of fuel a day—accounting for 70% by weight of all supplies delivered—to its forces in Iraq alone, at a delivered cost per gallon of $5-20. It also spends over $1 per kWh on electric power (ten times the domestic civilian price) in battle zones, because electricity must often be provided using generators that run on fossil fuels.

If some of this fuel could be replaced by power beamed down from space, it could cut costs and reduce the need for complex and vulnerable supply lines, the NSSO report argues. It could be used to power electric vehicles, along with radar stations and other pieces of equipment that currently rely on electrical power from generators. (The study dismisses the notion that the Pentagon might be interested in SSP as a means of beaming death rays down on enemies: it points out that the beam is nowhere near powerful enough to present a plausible alternative to conventional missiles and other weapons.)

Getting SSP off the ground will require the involvement of the private sector, the study observes, but private firms are unlikely to act without a demonstration project to confirm the viability of the scheme. The NSSO estimates that this would cost $8 billion-10 billion, and suggests that it could be funded by a consortium involving America and its allies—such as Canada, Japan, the European Union or Australia, all of which have shown interest in SSP in the past. In the meantime, NASA is evaluating the possibility of an experiment involving the International Space Station.

SSP was one of the original projects in Japan's "New Sunshine Plan" for renewable-energy development after the first oil shock of the 1970s. India is interested because it has a huge problem building a grid that serves the more remote parts of the subcontinent and suffers chronic blackouts. Canada thinks solar power could be used to process the filthy tar-sands deposits of Alberta. Shell, an oil company, has developed a process for refining the dirty tar underground, so that all that comes out is relatively clean oil. But the process needs lots of energy, and the government has ruled out the use of nuclear power.

The optimistic NSSO report was followed in May 2008 by a milestone for SSP, with the transmission of a microwave beam, of the kind that would be used to transmit energy to Earth, between two Hawaiian islands 148 kilometres apart. The distance was chosen because it is equivalent to the thickness of the atmosphere that a microwave beam from space must penetrate. The experiment was carried out by American and Japanese researchers in only four months, and for less than $1m, under the direction of John Mankins of Managed Energy Technologies, a firm he founded after a long career developing space systems at NASA. The experiment was sponsored by Discovery Communications, a TV company, for a documentary.

Announcing his results, Mr Mankins said that what was needed next was a two-year engineering study of a full SSP system, covering everything from the launch vehicles to the ground receivers. Such a study has not been carried out since the 1980s, and technology has since changed radically. With that done, at a cost of about $100m, the next step would be to develop the necessary architecture to make SSP economically viable, and to test it in low-Earth orbit. Mr Mankins thinks this could be done by 2015, at a cost of less than $1 billion. After that, a full pilot system could be deployed in geostationary orbit, at a cost of $10 billion, and commercial operation could begin by 2025.

There is no doubt that SSP has become far more practical since engineers began evaluating it in any detail. Since 1977 the efficiency of solar cells has increased from around 10% to over 40%, and that of solid-state amplifiers from 20% to over 80%. New lightweight composite materials have been developed. Most striking of all have been the advances in computing and robotics, as demonstrated by the presence of several semi-autonomous rovers on the surface of Mars. An SSP system need not be constructed by astronauts working in an orbiting factory, as was originally assumed, but could be a self-assembling system made up of lots of small parts.

Enter the space entrepreneurs

But there is one area where there has been much less progress, and it remains SSP's Achilles heel: the cost of access to space. For its first half-century, since the launch of *Sputnik* in 1957, space has been largely the province of governments, for which prestige and strategic clout (military rockets) often matter more than cost. But the growth of communications and other services delivered by satellite has spawned a commercial space industry around the world.

A high-flying construction project

George Nield of the Office of Commercial Space Transportation at the Federal Aviation Administration (FAA) points out that the commercial space business, including its suppliers, accounted for over $139 billion in economic activity in 2006—up from $61 billion in 1999. (This covers everything from making launch vehicles and spacecraft to satellite-navigation systems for cars and boats.)

As the industry develops, interest is growing in making cheaper launch vehicles, not least for space tourism, starting with sub-orbital projects. According to the FAA there are about 18 companies involved in developing low-cost launchers. Most (such as Blue Origin, a company founded by Jeff Bezos, an internet tycoon, who is building a spacecraft at a ranch in Texas) are keeping a low profile for the moment. The notable exceptions are Virgin Galactic, founded by Sir Richard Branson, a British entrepreneur intent on taking his aged parents for a holiday in space before too long, and SpaceX, founded by Elon Musk, another internet millionaire.

SpaceX's *Falcon 1* rocket successfully reached orbit at the fourth attempt in September 2008, becoming the first privately funded, liquid-fuelled rocket to do so. The company is developing a much larger rocket, *Falcon 9*, which will be able to carry payloads of up to 12 tonnes into orbit (compared with a few hundred kilograms for *Falcon 1*). SpaceX is one of two companies chosen by NASA to develop crew and cargo resupply systems for the space station. It has also been contracted to launch satellites for a number of government and commercial clients.

Mr Musk thinks his non-bureaucratic, low-cost approach could reduce the cost of launching payloads into low-earth orbit from around $6,000-10,000 per kilogram today to around $3,000 with *Falcon 9*, and eventually (by reusing more of each launcher) to around $1,000. Mr Musk has his eye on manned missions to Mars, among other things, but much lower launch costs would also have the side-effect of making SSP more viable. The NSSO estimates that a launch cost of $440 per kilogram, for example, would reduce the cost per kWh to between eight and ten cents.

One company with a specific plan for SSP is Space Island Group, based in California. Its novel scheme involves using the technology that has already been developed by NASA for the space shuttle to build orbiting space-stations out of the empty fuel tanks that are usually discarded when the shuttle reaches orbit. Space Island's plan is to launch several of these tanks, convert them into living quarters and rent them out. Gene Meyers, the boss of Space Island, says it has identified 200 companies and 300 university research groups which would be interested in renting facilities at its proposed rates; there would also be opportunities for space tourism. The resulting revenues, the company says, would cover the cost of launching the components for a large SSP system, piggybacked onto each fuel tank. It sounds rather far-fetched—but the same was true of Mr Musk's plans just five years ago, before he had launched a single rocket. That is an indication of how quickly things can change in the commercial space industry.

When Mitsubishi Electric started looking at solar power in Japan it, too, was thinking along the lines of launching giant structures and assembling them in space. After a while it balked at the difficulty and cost of that route, and in recent years it has been concentrating on the idea of launching squadrons of small satellites orbiting in formation. Mitsubishi Electric has continued to invest in SSP research, and Japan's space agency, JAXA, is also taking the idea seriously, with talk of a working system in orbit by 2030.

If today's gloomy economic conditions make SSP seem even more outlandish, it is worth remembering that America's commercial-aviation industry was born in the midst of the Depression. The 1930s witnessed the formation of aerospace companies such as Grumman and Hughes, the launch of airlines such as American and United and the birth of the Douglas DC-3—the workhorse of the pre-jet age, which is still going in some corners of the world.

Space solar power is still an idea far ahead of its time. But the necessary technology already exists and is gradually falling in cost. The commercialisation of space—and, in particular, the enthusiasm building around space tourism—could be the trend that brings down launch costs and brings SSP within reach. It will take entrepreneurs as well as engineers to kick-start the public-private process needed to tap the energy of the great fusion reactor in the sky. Lots of people believe it can be done. But as Cutie the robot demonstrated, what you believe matters less than what you actually do.