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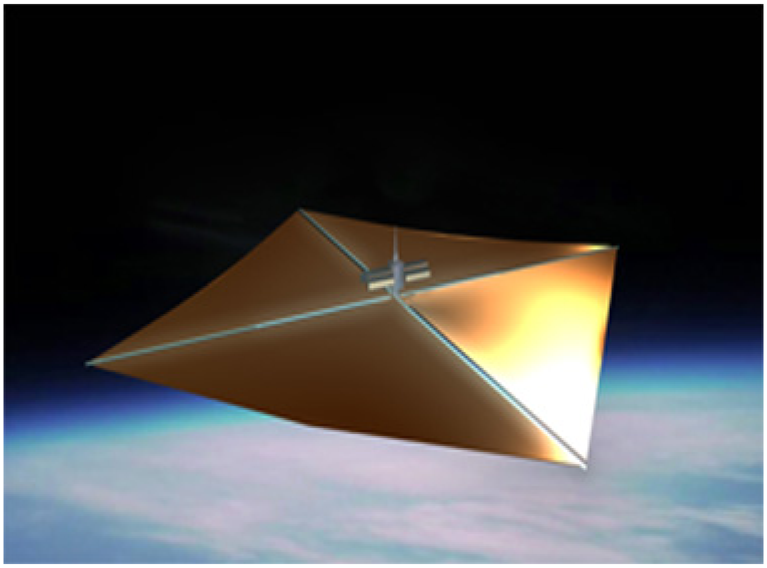

Solar Sails

Towards An Early Profitable PowerSat

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ABSTRACT

Successful development of space solar power would provide vast quantities of clean electrical energy for the next few billion years. Such a prize is worth considerable effort and risk. However, the technical difficulties and the huge scale of proposed systems, requiring enormous up front costs and long development times, have prevented SSP from making much progress.

If a way could be found to field a small SSP system profitably, even if limited to niche markets, operational progress could be made with relatively small investments over short time scales. This visualization explores the concept of a "thin-film heliogyro" – a solar sail - as a lower cost approach to producing energy in space and transmitting it to earth as an infrared (IR) power beam.

Solar Sails: Towards An Early Profitable PowerSat from Space Communication Journal on Vimeo.

TECHNICAL BRIEF

A SunSat (Powersat) will need four major systems:

1. a system for solar power collection;
2. a system for power beam generation;
3. a system to direct the beam to Earth;
4. a receiver on the ground to convert the power beam into electricity.

Solar Power Collection

The powersat design under consideration requires the use of solar sails that serve several important purposes. Their main use would be to collect solar power in space so that it can be transferred to Earth. They would also help maintain the stability of the solar power satellite in space orbit. Importantly, these solar sails will allow the powersat to require only one launch and there would be no need to assemble it in space.

Power Beam Generation

This powersat design makes use of fiber lasers. Fiber lasers will assist in the efficient transfer of energy in space from the collection arrays to the main infrared transmission antenna, which will beam it to Earth. Fiber lasers will also provide support for the solar sails.

Beam Direction

This powersat design requires the use of infrared power beaming. An infrared antenna will be delivering energy towards earth 24 hrs/day. Since there are narrow transmission windows in the atmosphere around 1− 2 μ, this type of powersat will be limited to a wavelength between the two.

Ground Receiver

Most powersat designs use microwave antennas to transfer their power to Earth. The use of microwave-type antennas requires a minimum size of at lease one kilometer, and a corresponding kilometer-size receiving station. With this new solar sail design, using an infrared antenna operating within the 1 μ frequency, the minimum receiver size would only need to be 32 m.

Other Information

The main difference with this design compared to the design of other powersats is how small and lightweight it is. This lighter weight design allows for a cheaper and more efficient delivery of the powersat vehicle into space orbit. These solar sail satellites can be completely constructed on Earth. The solar sails can be wrapped for launch. When delivered into space, the sail unfurls itself.

BUSINESS PLAN

By Clinton Riddell and Mark Grady are students of the Ohio University College of Business

In developing a financial model for the space-based solar power satellite developed by Al Globus and his team, the following technical assumptions were under consideration:

1. Thin-film Heliogyro power (solar sails) have been tested by the Japanese Ikaros satellite. Only 14 m of this technology was used for the sails and it produced about 500w for the satellite;
2. The sail material is extremely low mass per unit of collection area, about 45g/m2;
3. With the use of infrared antennas, there would need to be a minimum of a 32 m receiver on the ground. Since the land needed for such a receiver is small, the cost of land has been disregarded in this calculation;
4. The satellite will have an expected lifespan of 15-20 years;
5. The entire satellite will only require a onetime launch, by a Falcon 9 rocket. Self-assembly in space will eliminate the need for additional launches;
6. Each satellite will produce 6.2MW of power;
7. Launch provider SpaceX expects to reduce its launch prices by a factor of 3.6 for orders of 1,000 launches; 1000 launches would generate 6.2GW of power;
8. The Solar Sail design requires an energy transmitter with a diameter of 5m.
9. The 5m infrared antenna will transmit in frequencies between 1− 2 μ;

Al Globus' paper acknowledges that it is too early to make a reasonable estimate of the cost of the satellite's construction, along with receiver construction and operations. The Ohio University SunSat design team was therefore unable to create a complete business plan with this lack of information. However, for potential customers interested in this technology, the following three high-end applications are worth consideration.

Potential Customers

1. A recent DOD report suggests that the U.S. military is willing to pay at least $1/kwh for power beamed to forward bases in Asia. Trucks transporting diesel fuel can be ambushed, power beams cannot. Football-field sized receivers could fit on the larger bases. Five 6.2 MW systems at this price could provide up to $54 million per year revenue per SunSat, enough to pay for a Falcon Heavy launch in less than four months.

2. For commercial customers, the highest priced electricity the researchers could find world-wide was $0.29/kwh for industrial users in Italy in 2008. This payback rate could

provide up to $15 million per year for each of five SunSats. The energy production time required to pay for a Falcon Heavy launch would be one year.

3. There are many remote locations that depend on diesel generation for electricity. The highest priced diesel fuel by country appears to be Malawi, at $1.67/liter. Assuming 0.25 liters/kwh, this is $0.42/kwh, meaning the target SunSat could provide up to $22 million per year per satellite, requiring eight months to pay for a Falcon Heavy launch.

4. There may be places smaller than whole countries that pay even higher rates for fuel. For example, diesel fuel in Antarctica costs $3.17/liter or more. This works out to to be as much as $0.79/kwh. Unfortunately, orbital constraints make space-based solar power in Antarctica impractical. Recent increases in oil prices are not included in these figures. These increases and likely increases in future crude oil prices will, of course, improve financial viability of space based solar power.

Since the real cost of the solar sail satellite, its ground station and operations are unknown, the payback times can be expected to be quite a bit longer. Still, satellite construction and launch are already not that many orders of magnitude from feasibility. Furthermore, as increased numbers of satellites are built, manufacturing costs can be expected drop dramatically, and so will launch costs.

Students with Advisor Al Globus at the International Space Development Conference in Huntsville AL in May 2011

REFERENCES

1. Globus, A. (2010) Towards an Early Profitable PowerSat. San Jose State University, October 2010. Note: this article contains an additional bibliography.