30 April 2024

Lunar Space-Based Solar Power

Innovation

Space-based solar power on the moon can replace the traditional solar cells used in lunar exploration. Past lunar spacecraft missions had to hibernate and go to sleep to survive the lunar night (two Earth weeks), but many did not wake up because of the freezing temperature on the moon. For example: the Intuitive Machine's Odysseus Moon Lander and the Indian Space Research Organization's Chandrayaan 3 Moon Lander. Generating energy using space-based solar power consists of collecting solar energy in space and transmitting the energy back to the moon to power the lunar exploration spacecraft. The idea of space-based solar power was first introduced in a short story by the scientific writer Isaac Asimov in 1941. This research will explore space-based solar power, with the moon being the target to support future lunar exploration.

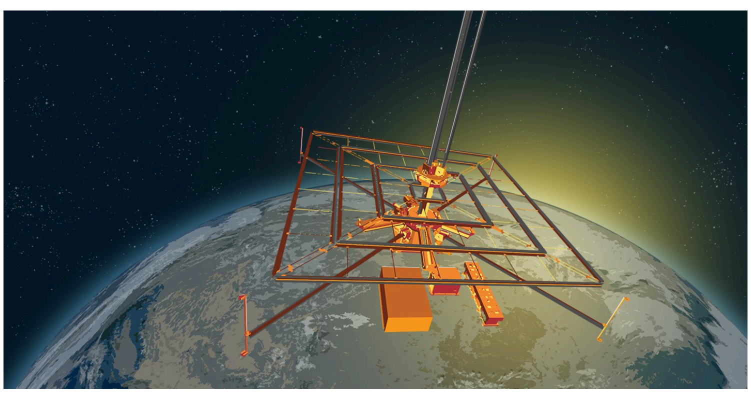

Figure 1: Caltech's Space Solar Power Project

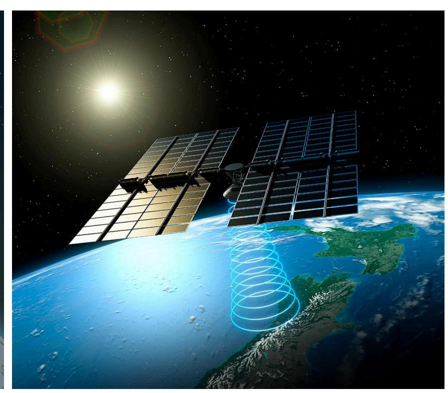

Figure 2: Space-Based Solar Power

Materials

A satellite that orbits the moon in geostationary orbit and is also equipped with solar panels that are three kilometres across to convert solar energy to microwave energy is the first crucial step in space-based solar power. The efficiency of harnessing solar energy on the moon can be similar to that on Earth depending on the location, but solar power in space can harness solar energy at all times because there are no seasons, night and day, or atmospheric absorption in space. As a result, space-based solar power can generate eight times more energy than the power produced by terrestrial solar energy. Gallium arsenide solar arrays are the most promising thin-film photovoltaic cells due to their benefits, which make for a better space exploration electrical system compared to conventional silicon solar cells. The lightweight and flexibility of gallium arsenide solar cells support the deployment of the satellite (JWST unfolding) in space and lower the cost of rocket launches by minimizing the amount of fuel used. Gallium arsenide solar cells can convert a higher amount of sunlight into electricity, maximizing the energy being produced. The major disadvantage to making gallium arsenide cells is that the initial cost of construction is one thousand times more expensive than silicon cells, but gallium arsenide cells have a longer life span due to their resistance to varying temperatures and radiation damage. As of right now, no technology can bring 80,000 tons of satellites into lunar synchronous orbit. However, the advantages outweigh the disadvantages, as also said by the team of the Space Solar Power Project from the California Institute of Technology that 'Gallium arsenide cells consistently performed well overall.' The satellite should also be equipped with a one-kilometre-long microwave antenna transmitter that beams 2.45 GHz of energy to the receivers on the surface of the moon. Microwave energy is the best choice for transmission of electromagnetic energy because microwaves can easily pass through the thin atmosphere of the moon and safely beam the energy to the receiver without damaging any spacecraft while also being cost-effective during production. A rectenna farm that is between 3 to 10 kilometres across will harness the energy beamed from the satellite. A rectenna, or rectifying antenna, has a rectifying circuit integrated into the antenna. The antenna in the rectenna system receives the microwave energy that is beamed, and the rectifier circuit converts electromagnetic energy (microwave in this case) into direct current. The antenna should be made out of conductive materials to be able to conduct electricity. The conductive materials should be malleable for good mechanical durability to ensure the antennas cannot deform or be broken under harsh conditions. Conductive materials that are malleable will allow the antenna to last longer because deformation can not happen even under harsh conditions on the moon. The flexibility of the material will also allow scientists to minimize the size of antennas while preserving the same efficiency.

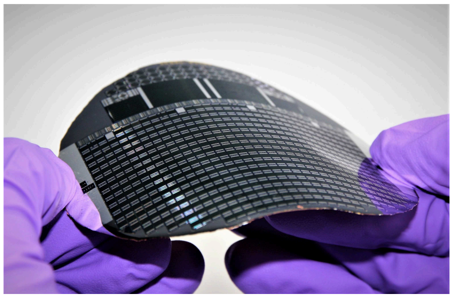

Figure 3: Gallium Arsenide Cells

Figure 4: Microwave Antenna Transmitter

Figure 5: Electrical Grids

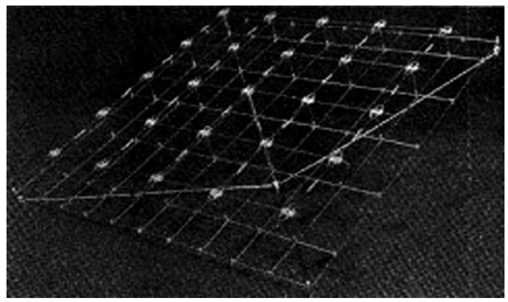

Figure 6: Recetennas Receiver

Material For Prototype:

- cardboard boxes
- A pair of scissors
- A piece of clay
- Markers
- A stick (to support the satellite)
- A glue

Procedure to Make Model

A satellite with three kilometres of solar panels and one kilometre of microwave antenna transmitter is sent to lunar synchronous orbit, around the same altitude as geostationary orbit on Earth. The solar panels collect energy from the sun for the microwave antenna transmitter to convert to microwave and transmit the energy to the receiving rectennas on the lunar surface. Once the rectennas receive microwave energy, the microwave will be converted into DC electricity by the rectifying circuit in the rectenna system and sent through an electrical grid so the generated electricity can be transported to power the rovers on the moon. Another way is for the rectennas to send energy via wireless power transmission. For wireless power transmission, the rectenna receives the microwave beams, converts the beams to DC electricity, and converts them back to microwave energy to beam to the receiving antenna on the lunar rover. The antenna on the rover is too small to receive and convert the microwave beams into electricity, so energy has to go through the rectenna farm before reaching the lunar rover. The goal is to store the excess energy produced by the rectennas since the solar panels constantly receive 2 gigawatts of power, which is enough to power more than a million houses on Earth.

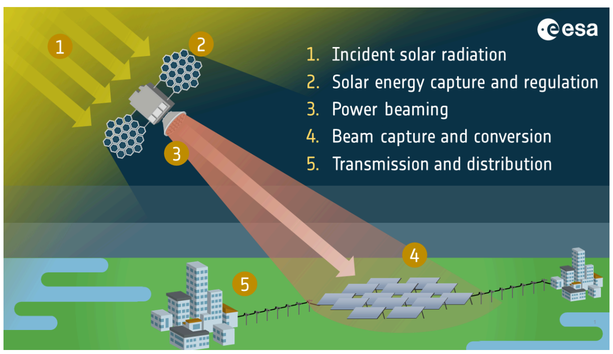

Figure 7: ESA's Stages of Space-Based Solar Power

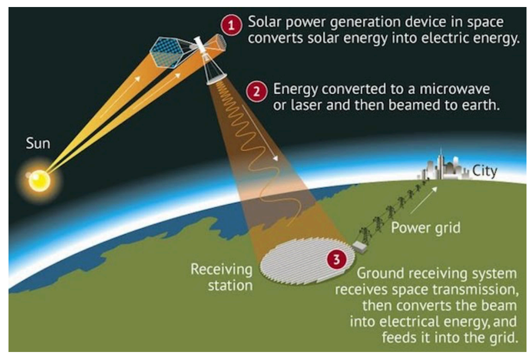

Figure 8: PAGEPOWER How it might work

Discussion

Space-based solar power offers benefits that solar panels on the moon would never be able to achieve. Space is the best space to harvest energy since there is no atmosphere in space, and solar energy can be harvested for an uninterrupted amount of time. The California Institute of Technology (Caltech) put the Space Solar Power Demonstrater (SSPD-1) in space in January 2023, which was a part of the Space Solar Power Project. The experiment successfully demonstrated wireless power beaming in space. The team has put the new cost-effective and lightweight deployable structure into space and tested 32 different solar panels' efficiency. The first problem that the team ran into was a snagged wire in the structure during the deployment of the Deployable on-Orbit ultraLight Composite Experiment and later, part of the structure was jammed under the deployment mechanism. Although the problem was successfully solved, this shows how the deployment process is hard for a 1.8 by 1.8-meter satellite, let alone the official one that is one kilometre long.

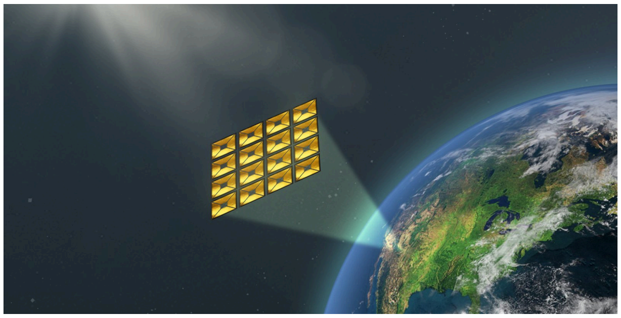

Figure 9: Beaming Clean Energy From Space

The United Kingdom has been supporting the idea of space-based solar power (distribution to Earth) by commissioning the Fraser Nash Consultancy to do a study and funding 4.3 million pounds to universities and companies to develop a model. The study found a promising production of energy (10GW) that reaches a quarter of the UK's energy demand by 2050 and can also achieve net zero by the same year. According to the study, the technology is achievable within the next 18 years but requires a 16.3 billion pound development program. This could create a multi-billion-pound industry and act as a GDP multiplier by exporting energy elsewhere and creating 143,000 jobs across the country.

Figure 10: UK Space-based solar power

China is another one of the many countries alongside Canada, the U.S., Japan, South Korea, Europe, and Australia that are researching space-based solar power. China's goal is to put a gigawatt-level space solar power station system in orbit by 2040 and a 10,000-ton space power plant in orbit by 2050. The Boeing X-37B Orbital Test Vehicle (OTV) is a top-secret robotic spacecraft mission carrying the solar energy experiment designed by the Naval Research Lab. In the U.S., the Air Force Research Laboratory, Naval Research Laboratory, and Northrup Grumman are planning to launch the most important experiment of the Space Solar Power

Incremental Demonstrations and Research Project (SSPIDR), which is the Arachne, in early 2025.

Figure 11: Space Solar Power Incremental Demonstrations and Research Project (SSPIDR)

NASA has stated that space-based solar power can become feasible within the next two decades, but the challenges space-based solar power may face are many including the costs, the challenges of putting a satellite in geostationary orbit, the mass of the satellite, and more. In the future, this technology can also be used for future Artemis missions when humans begin settling on the lunar surface. The energy from the lunar space-based solar power can mine ice deposits on the moon to make propellant or power houses on the moon. Space-based solar power has long-term benefits and aligns with the goals of future human exploration.

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