

A satellite is visible in the upper left corner, emitting a bright, focused beam of light that extends diagonally across the frame towards the right. The background is a deep blue space, with the curved horizon of the Earth visible on the right side, showing a thin layer of white clouds and a blue atmosphere. The overall scene suggests a high-tech, space-based application of solar energy.

SPACE-BASED SOLAR FARMING

Space Engineering Seminar

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Outline

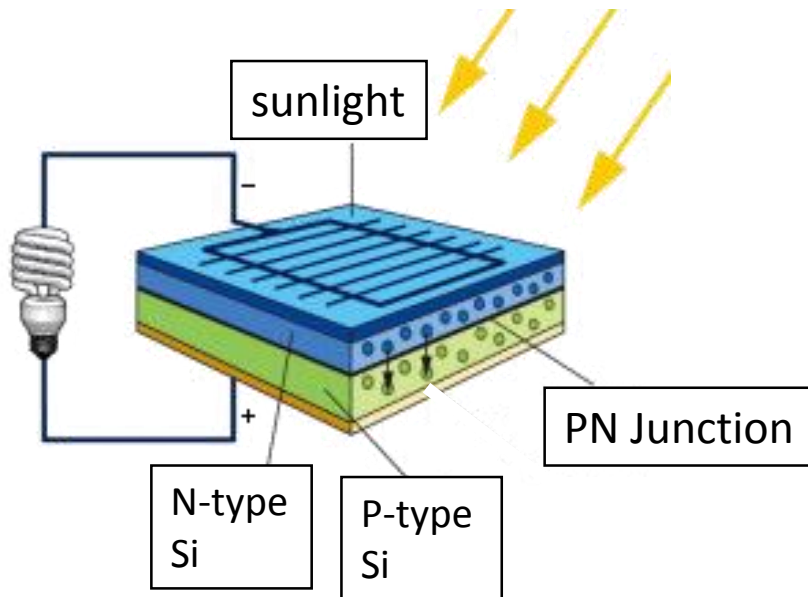
- Solar Energy
 - The disadvantage of Solar Energy
- Space Based Solar Generation
- Why Space Based Solar Power?
 - How It Works
 - Rectenna
- Pros and Cons
- Issue and Challenge
- Research Related to Space Based Power Satellite / System
- Conclusion
- Source



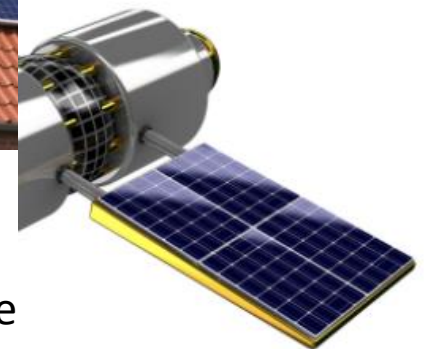
Solar Energy

What is solar power?

Convert energy from sunlight into electricity. It's a renewable energy, which already applied in so many areas, including in terrestrial and space field



From house..



To satellite

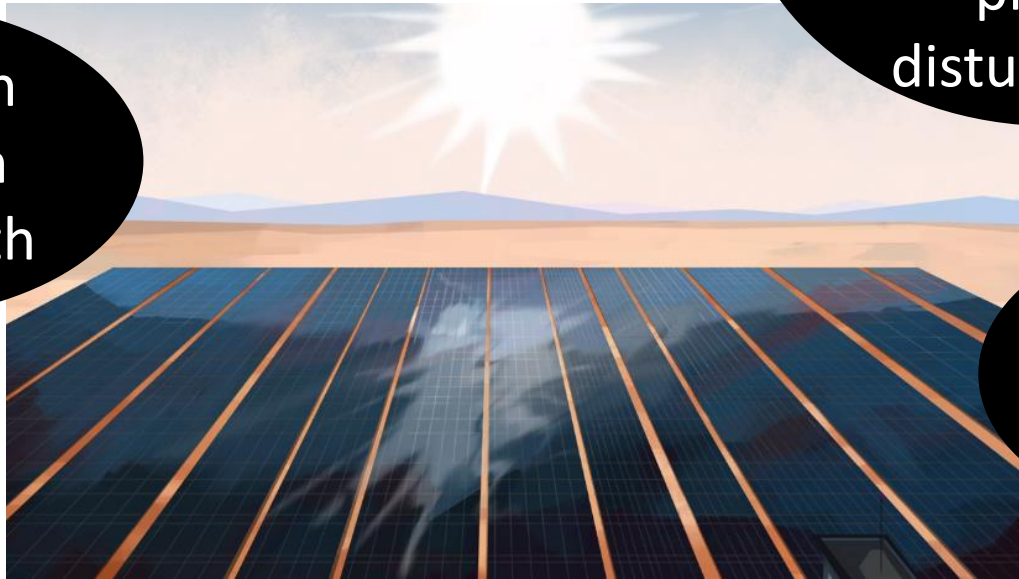


The Disadvantages of Solar Energy?

Depend on
the weather
& Climate

Natural
phenomena
(ex.: clouds,
dust, animal &
plants
disturbance)

Depend on
the region
on the earth



Cannot
collect solar
energy at
night

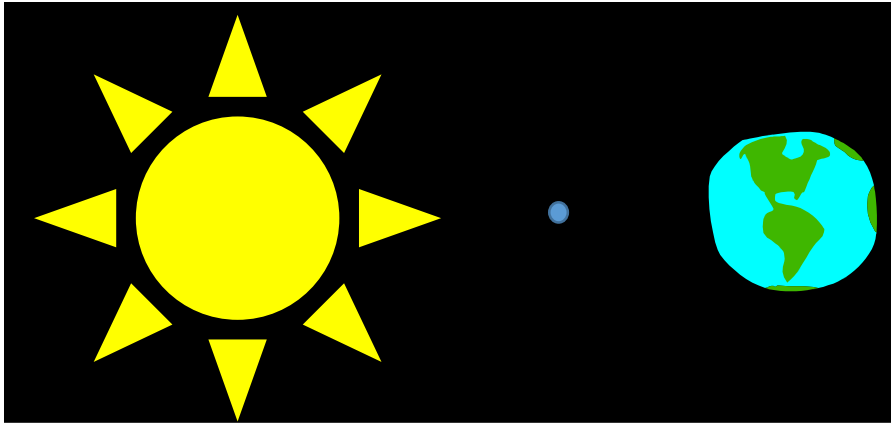
How if we farm the solar energy from space?



Space-Based Solar Generation

- Based on simple idea to collect solar energy in space and send it back to earth
- In 1941, Science fiction writer Isaac Asimov published the short story “Reason”. In that story, the space station transmits energy collected from the sun to several planets using microwave beams
- So many researchers are inspired by this Sci-Fi concept

Why Space-Based Solar Power?

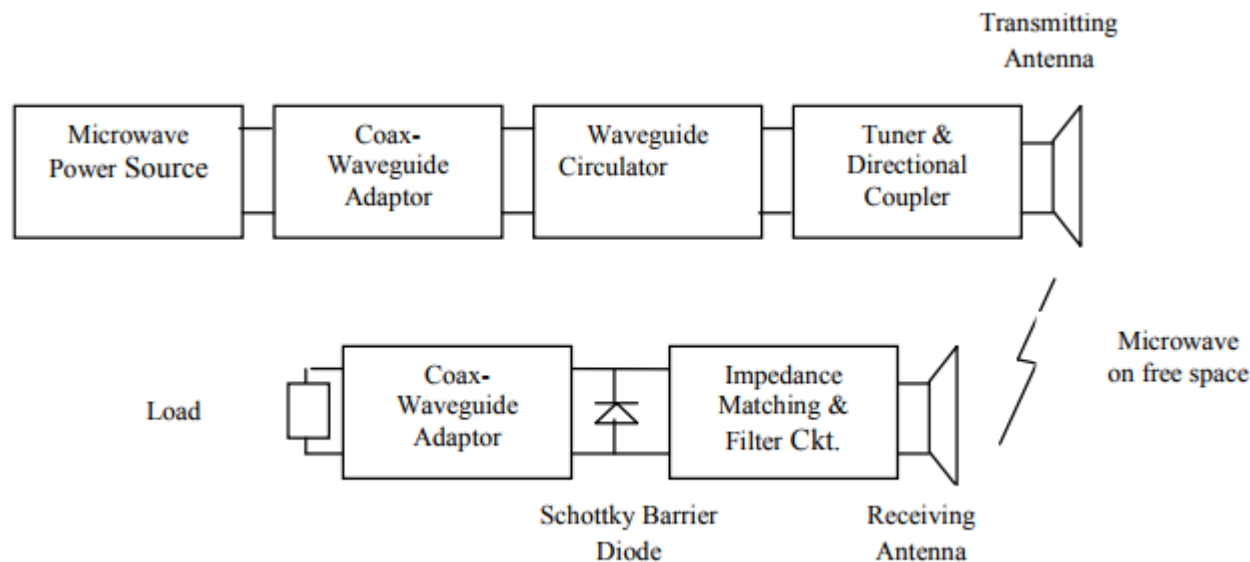


- In space, the sun is always shining → no atmospheric effect, no night time
- We can 'farm' solar energy from the space nearly 24 hours a day
- The solar light intensity is much higher than earth → no reflection from atmosphere



How It Works

- Space elements: Reflector, solar array, transmitter and antenna
- Earth elements: rectenna, and converter from radio wave to electricity
- There are two concepts to send the electricity to the earth: by microwave transmitting satellite and by laser transmitting satellite



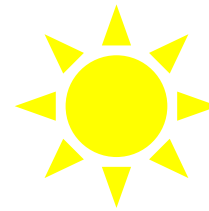


How It Works

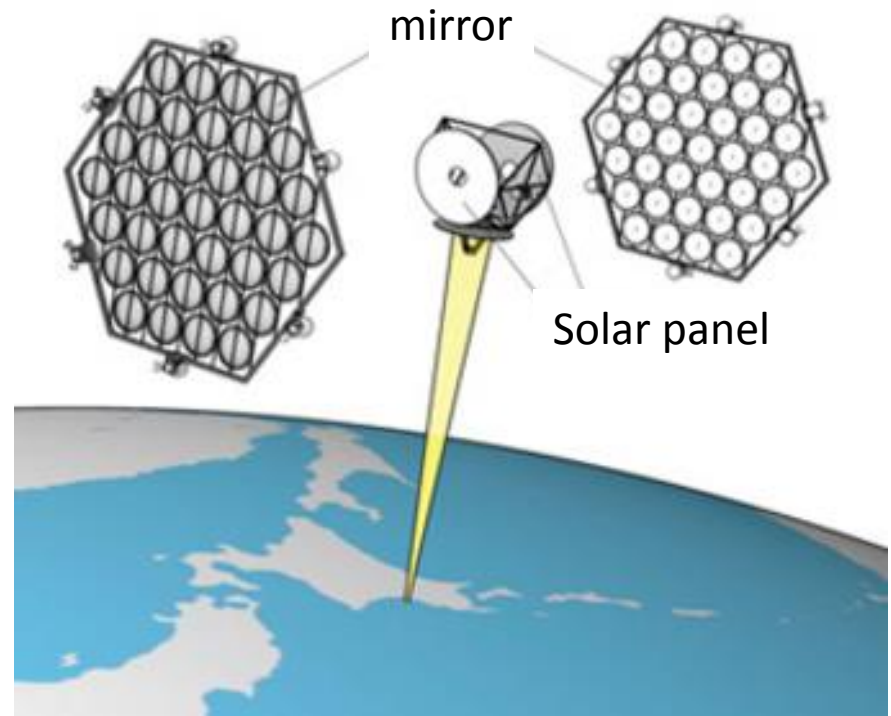
Mirror like solar reflectors concentrate the sun's photons into the solar panel modules

The transmitter module in the middle convert electricity into radio frequency in microwave band

Antenna on the bottom side, beams the radio waves to earth



Altitude ~ 36,000 Km



Space segment

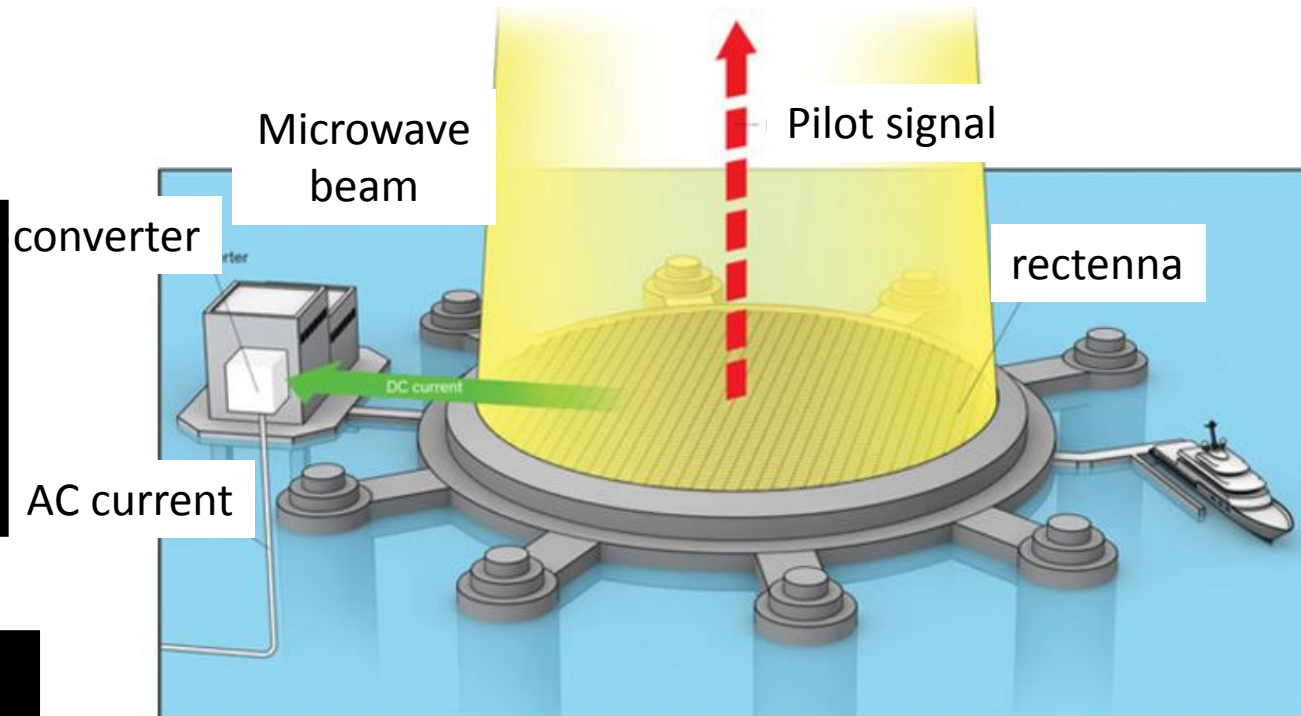


How It Works

Pilot signal will be sent from the earth to the satellite

Satellite received pilot signal, calculate the necessary phase for its microwaves and adjust accordingly

The received microwave beam is then converted back into electricity

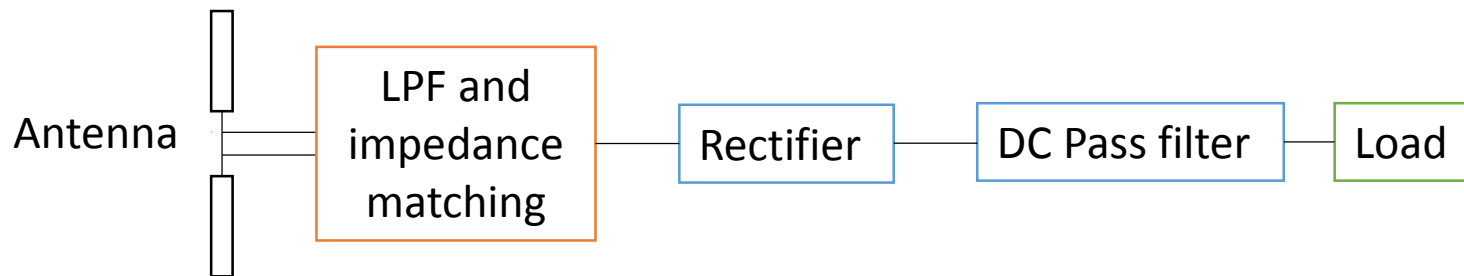


earth segment



Rectenna?

- It is rectifying antenna – antenna which collect the radio waves and convert it into electricity
- The concept of rectenna:

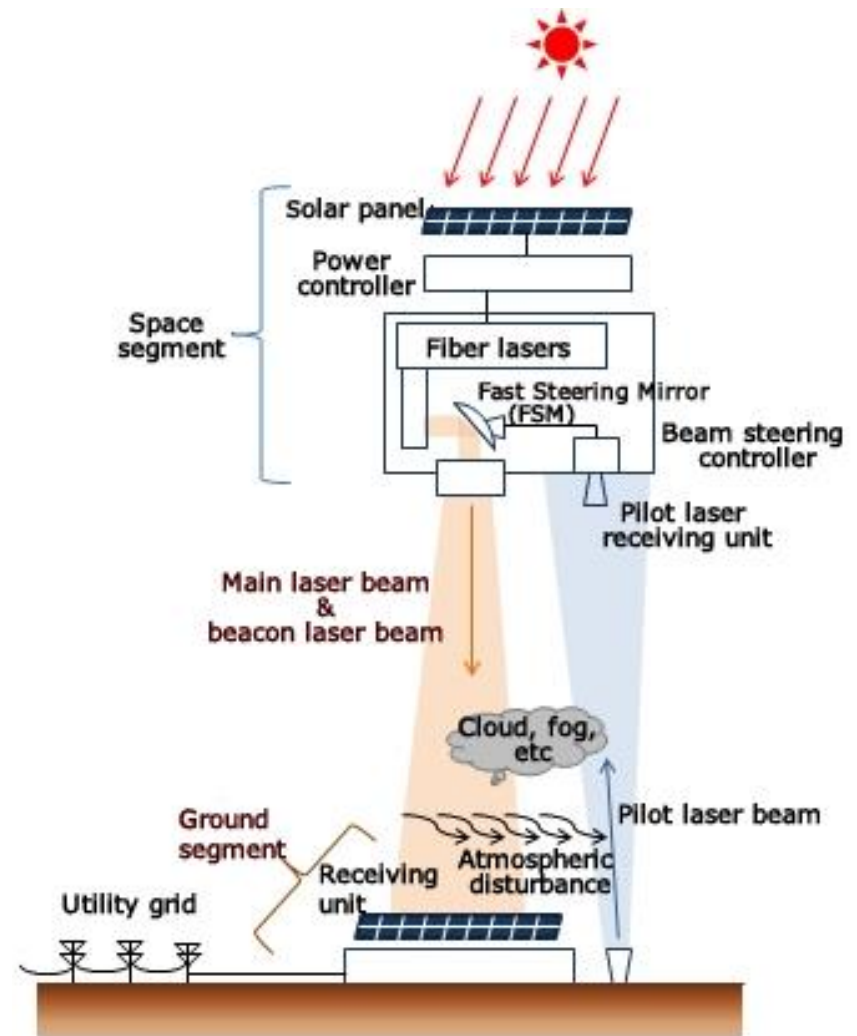


- For the concept of Space-based solar power, microwave power transfer is used. frequency 2.45 GHz or 5.8 GHz of ISM band



How It Works: Laser Method

- Example: JAXA research
- Laser beam must be pointed with an accuracy of $1 \mu\text{rad}$ (5.7×10^{-5} deg) for LEO satellite \rightarrow to limit the divergence to several cm
- For GEO orbit, accuracy become $0.1 \mu\text{rad}$ (5.7×10^{-6} deg)





Pros and Cons

	Pros	Cons
Laser	<ul style="list-style-type: none">- Single launch per laser transmitting satellite would be low cost- Small diameter of low beam, simpler and cheaper to implement on the ground	<ul style="list-style-type: none">- Trouble beaming power through heavy clouds and rain- Several safety concerns with lasers in space, such as blinding and weaponization
Microwave	<ul style="list-style-type: none">- Steady, uninterrupted transmission of power through rain, clouds, and other atmospheric condition- Much safer to transmit power	<ul style="list-style-type: none">- Production cost in tens of billions of dollars range- Need several KM terrestrial receiver- Impossible to repair because such long distance



Issue and Challenge

- Cost – very high cost to construct the system (some says roughly \$12 billion)
- Biological impact – concerns of people that it might harm the body. But studies in this field has proved that the microwave radiation level would never be higher than the microwave oven. Though it is slightly higher than the emission created by cellphones
- For some research center, instead of biological concerns, it focuses on the technological development. At least need to demonstrate well six different disciplines: wireless power transmission, space transportation, construction of large structures in orbit, satellite attitude and orbit control, power generation, and power management. JAXA, which is the most concern about this development, focusing on wireless power transmission research



Research Related to Space Based Power Satellite / System

Nikola Tesla first convinced people with the idea of wireless power transmission. He demonstrated the illumination of vacuum bulbs without using wires. He even built Tesla tower (wardenclyffe tower) which firstly intended to send wireless power in wide applications



<http://www.teslasciencecenter.org>



Research Related to Space Based Power Satellite / System

- JAXA research about Space based solar power with ground testing
- Test using laser, with 500 m horizontal distance
- To achieve accuracy of $1 \mu\text{rad}$

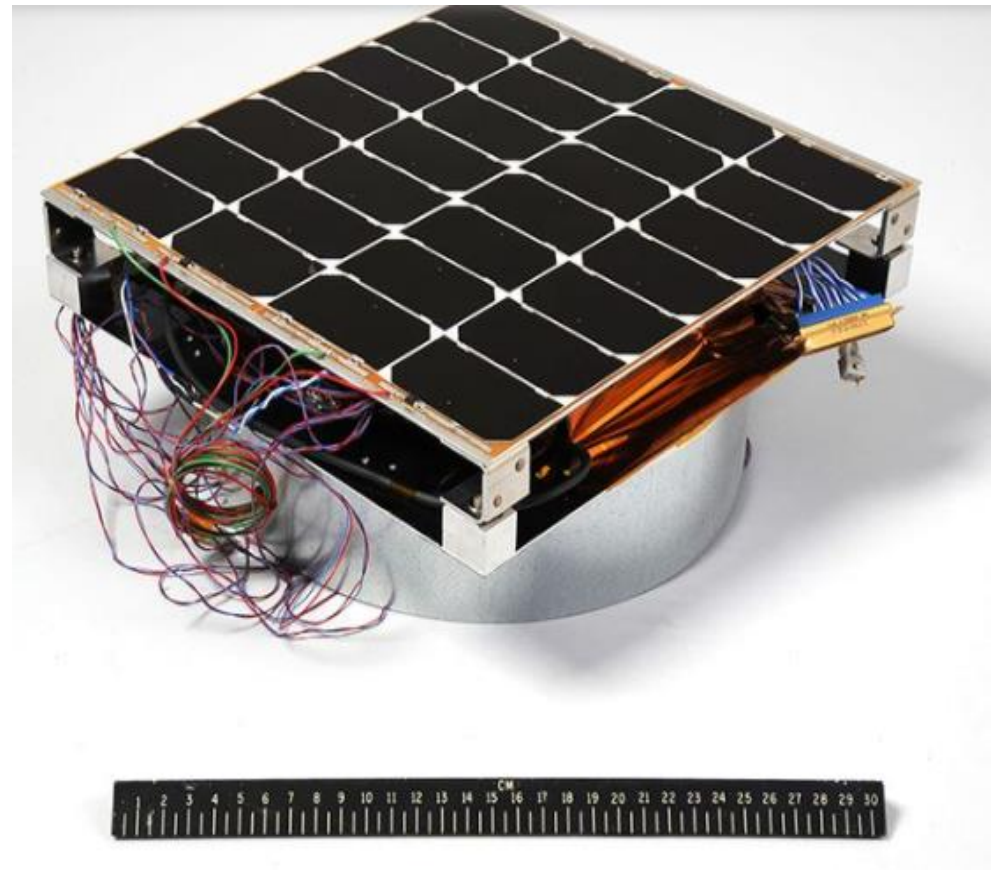




Research Related to Space Based Power Satellite / System

Naval Research Laboratory from Washington D.C., worked on two prototypes of collection module. The modules consists of solar collector, power converter, and RF emitter, and put together into a foot square tile 2 inches thick. Current model can generate 6 watts per Kg module.

Already tested in space environment condition inside laboratory

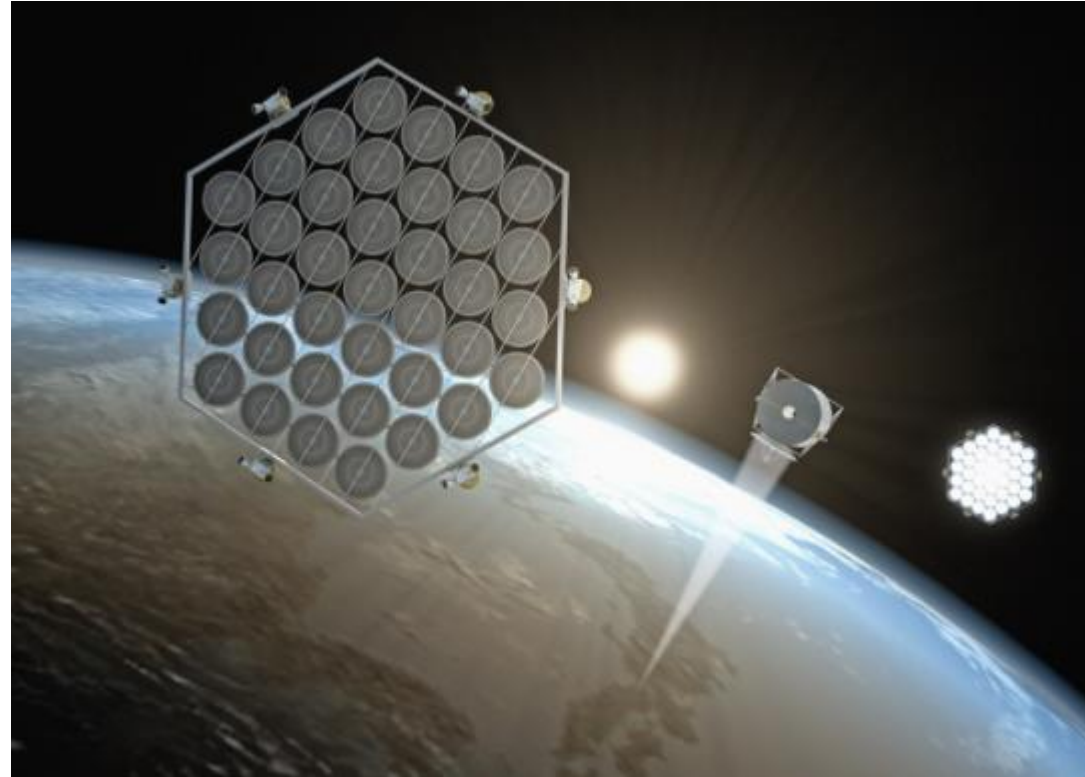




Research Related to Space Based Power Satellite / System



JAXA Proposed the research which leads to the development in 2030 of 1 GW commercial system produce by the solar power satellite. One of the proposed method is using the mirror to concentrate the light

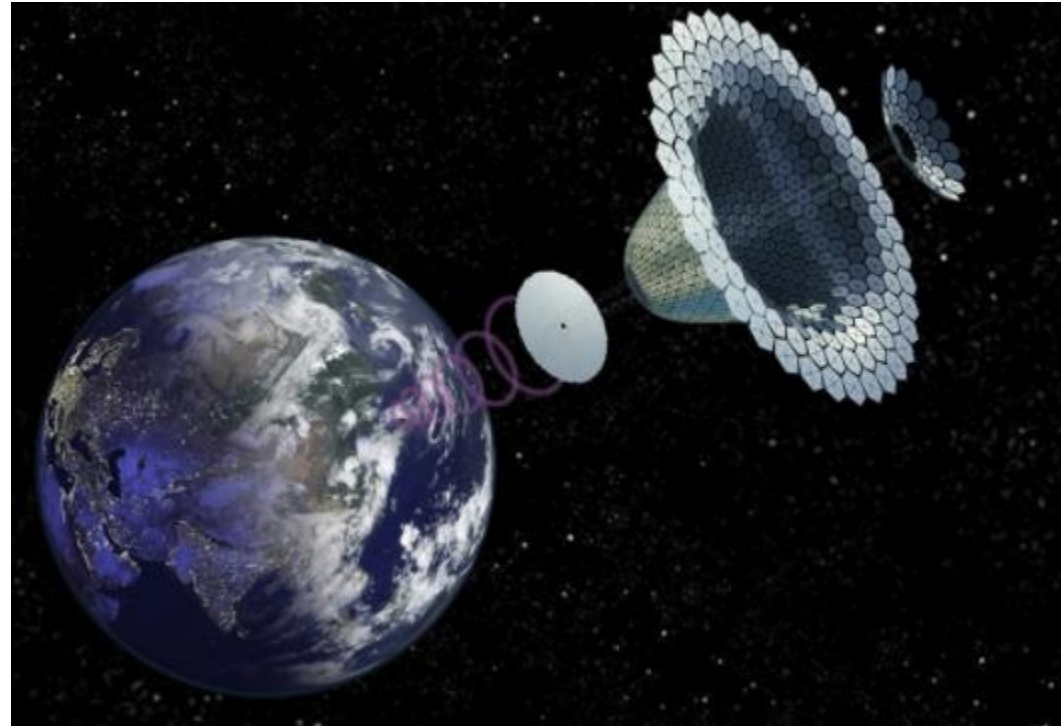




Research Related to Space Based Power Satellite / System



SPS (Solar Power Satellite) - Alpha, proposed by NASA. Instead using plate-like mirror, it will use a cone of mirrors to redirect sunlight into photovoltaic panels. The energy is then converted to microwaves and beamed down to earth





Conclusion

- Space-based solar power generation is not just a sci-fi. With the current research, it may lead to the commercialized solar power from space
- Many research focusing on using microwave beam instead of laser, mainly because of efficiency and safety issues
- Researches related to the Space-based solar power are still on going process



Source

- Shanmuganatham T. , Mohamed S., '*Wireless Power Transmission – A Next Generation Power Transmission System*', International Journal of Computer Application
- Zhang J., Huang Y., '*Rectennas for Wireless Energy Harvesting*', University of Liverpool
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