

Exceptional service in the national interest



Space Based Solar Power

Charles M. Carter (6133)

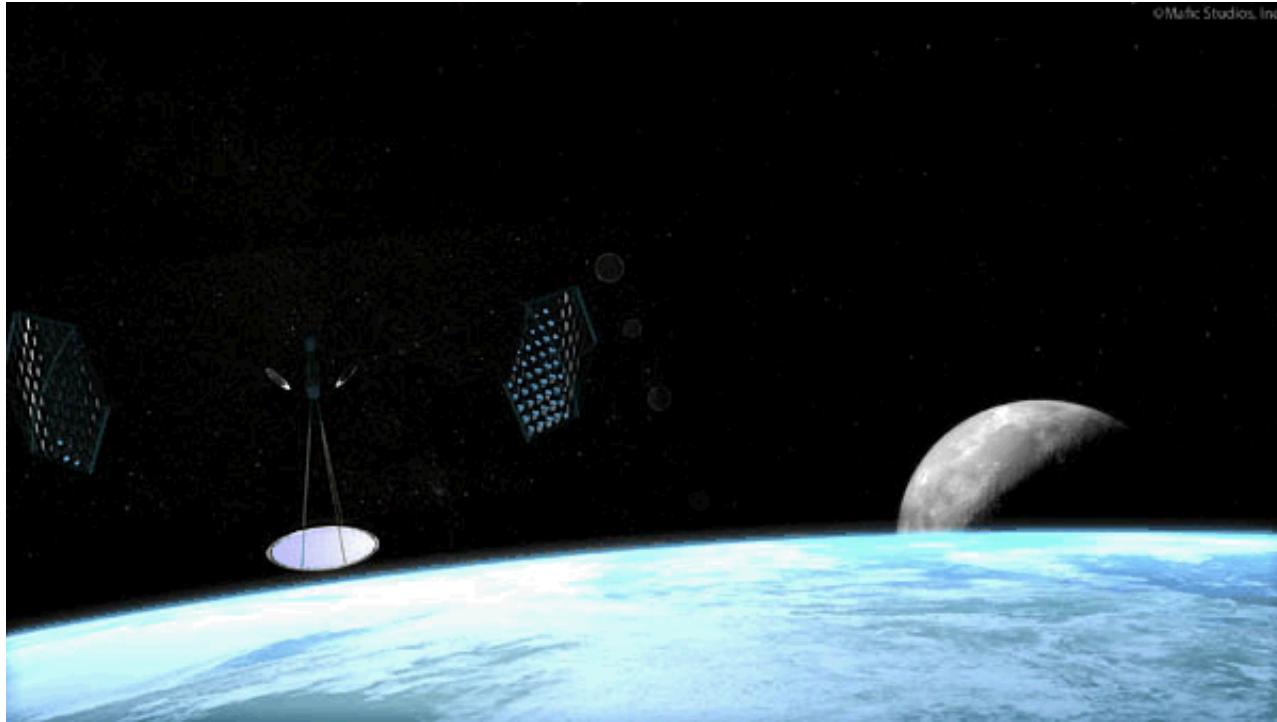
Cory M. Hensley (6133)

Stephen J. Verzi (6132)

Need for Alternative Energy Sources

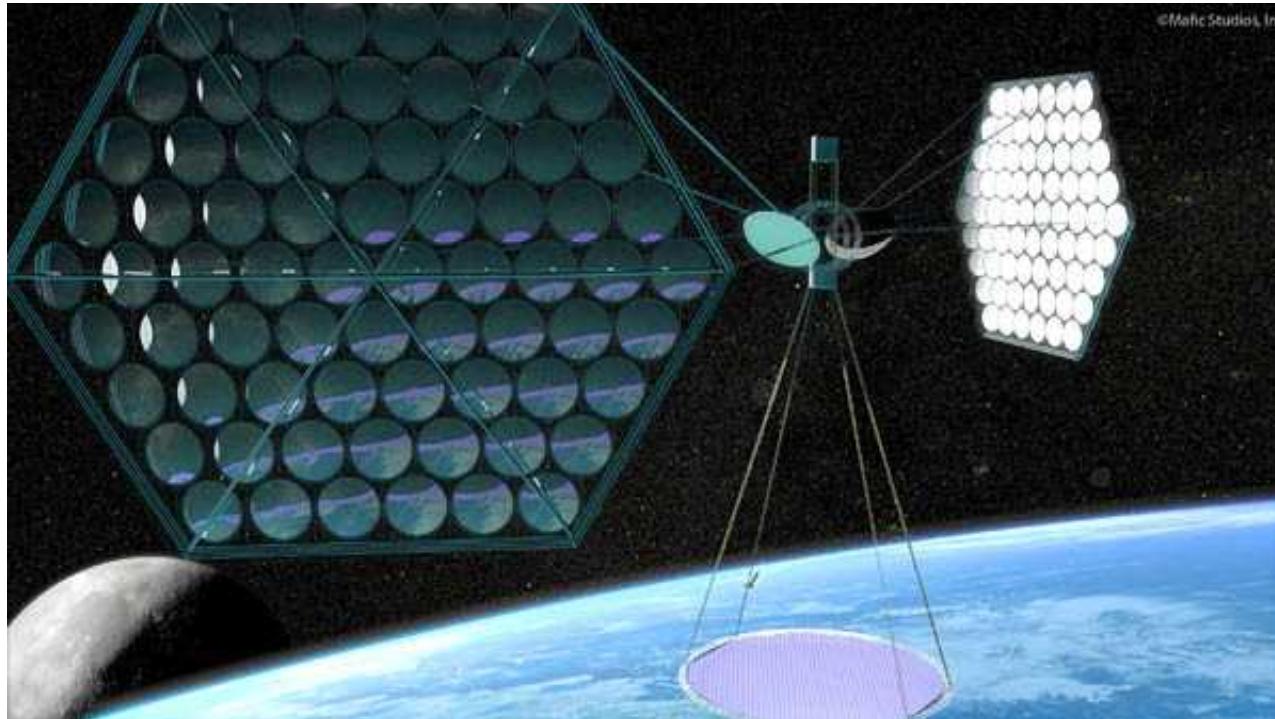
- Global demand for energy is increasing
- Concern regarding the long-term accumulation in Earth's atmosphere of fossil fuel derived greenhouse gases
- Fossil fuels are limited resources

Space Based Solar Power (SBSP)



- In the late 1960s, Dr. Peter Glaser of Arthur D. Little invented a fundamentally new approach to global energy: the Solar Power Satellite.

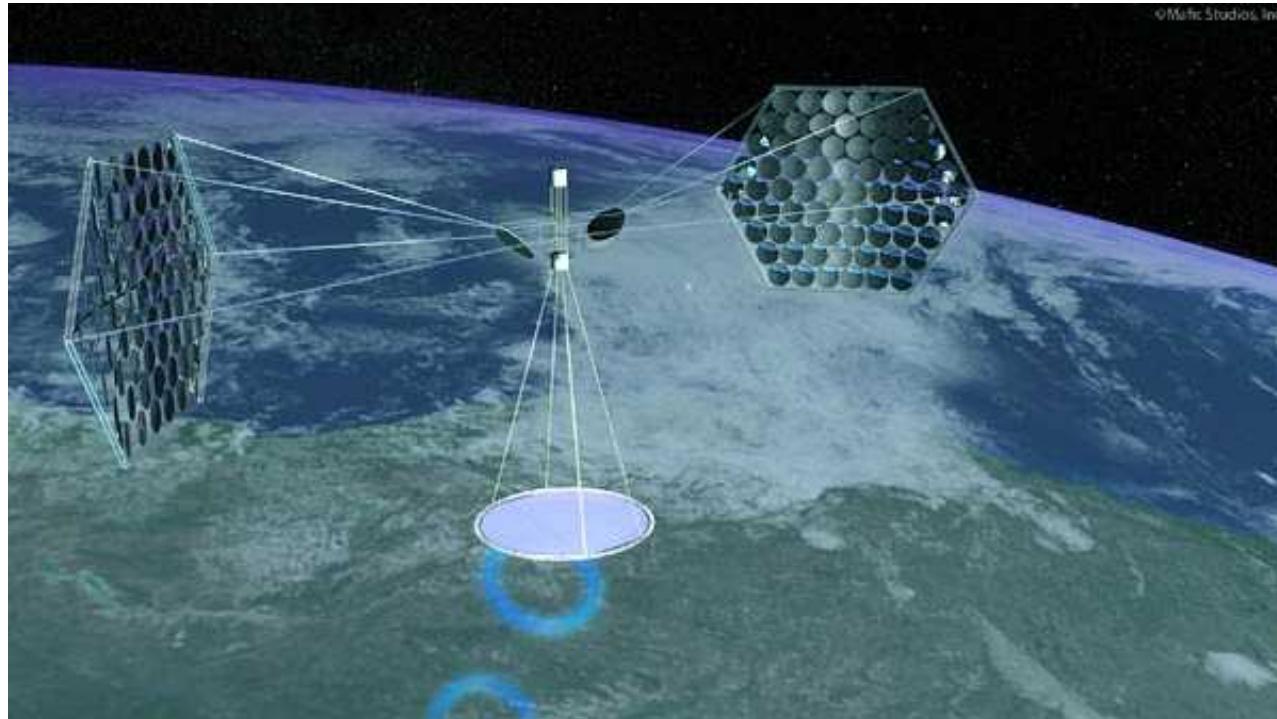
SBSP Concept



© Mafic Studios (permission obtained via email)

- A large platform, positioned in space in a high Earth orbit continuously collects and converts solar energy into electricity.
 - Sunlight is almost five and a half times as strong in space than it is on the surface of the earth

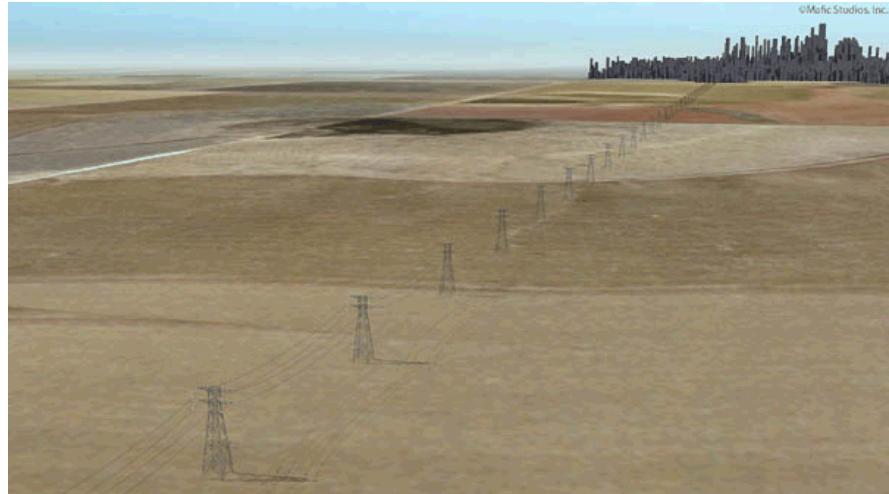
SBSP Concept



© Mafic Studios (permission obtained via email)

- This power is then used to drive a wireless power transmission (WPT) system that transmits the solar energy to receivers on Earth.

SBSP Concept



© Mafic Studios (permission obtained via email)

- This architecture includes large-scale ground based rectifying antennas (“rectennas”) as receivers for the transmitted power

Recent Technology Studies

- International Academy of Astronautics (2011)
 - “There are no fundamental technical barriers that would prevent the realization of large scale SPS platforms in the coming decades.”
- “Space Based Solar Power: Industry and Technology Assessment” (2011)
 - “We determined that large capital and R&D are required for SBSP to occur”... “Without disruptive technology or large government investment, SBSP will not be feasible as a mainstream source of energy until at least 2040”

Sandia Energy Surety Metrics



- Safety
 - Supply energy safely to end user
- Security
 - Protection of energy supply infrastructure
- Reliability
 - Can provide needed energy when and where needed
- Sustainability
 - Can be maintained for long durations
- Cost Effectiveness
 - Provided at affordable cost

Assessment Ratings

Rating	Description
	Overall assessment for proposed solution is as good or better than other energy production solutions
	Proposed technology is on track to be a viable energy production solution but some concerns remain
	Significant challenges remain before the technology can be considered a viable solution

Safety

- Positive attributes
 - Will not produce hazardous waste, which needs to be stored and guarded for hundreds of years.
 - Does not require environmentally problematic mining operations.
- Concerns
 - Microwave energy affecting life on earth
 - Physical barriers on ground will limit access
 - Energy dispersed to very low level (approx. 1/10 of acceptable)
 - Global warming due to influx of microwave energy
 - Shown to be negligible (0.003 °C at 6E+06 MW)

Overall Rating

Security

- Positive attributes
 - Majority of system assets are extremely remote
 - Does not provide easy targets for terrorists
 - Eliminates dependence on foreign oil
 - Potential capacity is great enough to serve as a base source
- Concerns
 - Potential weaponization of technology
 - May require treaty modification or agreement

Overall Rating

Reliability

- Positive attributes
 - Available 24 hours a day, 7 days a week
 - Solar power hitting the Earth every second is more than all human kind has used since the dawn of the industrial era
 - It works regardless of cloud cover, daylight, or wind speed
 - Can be exported to virtually any place in the world
 - Simpler than International Space Station
 - Many identical parts
- Concerns
 - Wireless Power Transmission
 - Atmospheric losses
 - WPT has been demonstrated, but at much lower power levels than needed for SPS
 - 2008: NASA executive and physicist John Mankins captured solar energy from a mountain top in Maui and beamed it 92 miles to the main island of Hawaii.
 - Ability to focus a high power beam

Overall Rating

Sustainability

- Positive attributes
 - Low amount of maintenance for space assets
 - No exposure to rain, hail, dust
 - Does not compete for or depend upon increasingly scarce fresh water resources.
 - Does not compete for increasingly valuable farm land or depend on natural-gas-derived fertilizer
- Concerns
 - Large scale in-orbit construction
 - Requires robotic assembly
 - Space debris
 - Inaccessibility for corrective maintenance

Overall Rating

Cost Effectiveness

- Positive attributes
 - Economy of scale
 - High capacity potential will offset initial capital investment
 - Does not compete for or depend upon increasingly scarce fresh water resources
 - Reduces cost of maintaining worldwide oil access
 - Economic stimulation
- Concerns
 - Research and development cost
 - Cost of launching space assets
 - Roughly \$2K/kg now
 - Needs launch costs to be significantly less
 - Cost of building large receiver rectenna

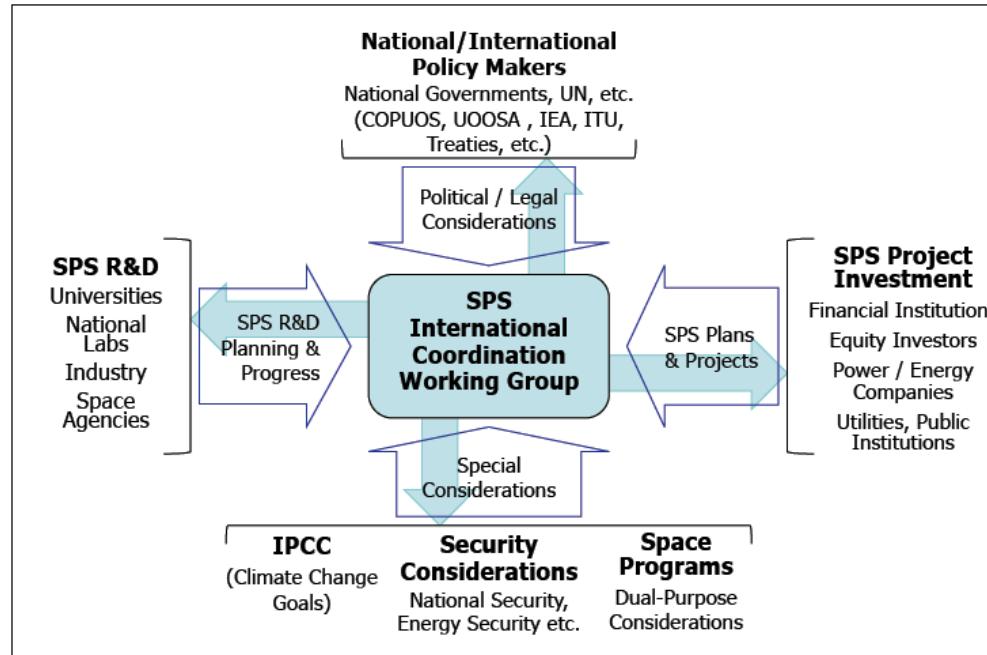
Overall Rating

Sandia Metrics Summary

Metric	Rating
Safety	<div style="width: 100%; background-color: #6aa84f; height: 100px;"></div>
Security	<div style="width: 100%; background-color: #6aa84f; height: 100px;"></div>
Reliability	<div style="width: 100%; background-color: #6aa84f; height: 100px;"></div>
Sustainability	<div style="width: 100%; background-color: #ffcc00; height: 100px;"></div>
Cost	<div style="width: 100%; background-color: #ff0000; height: 100px;"></div>

The Path Forward

- Space solar power will require involvement of numerous government, industry, and educational institutions



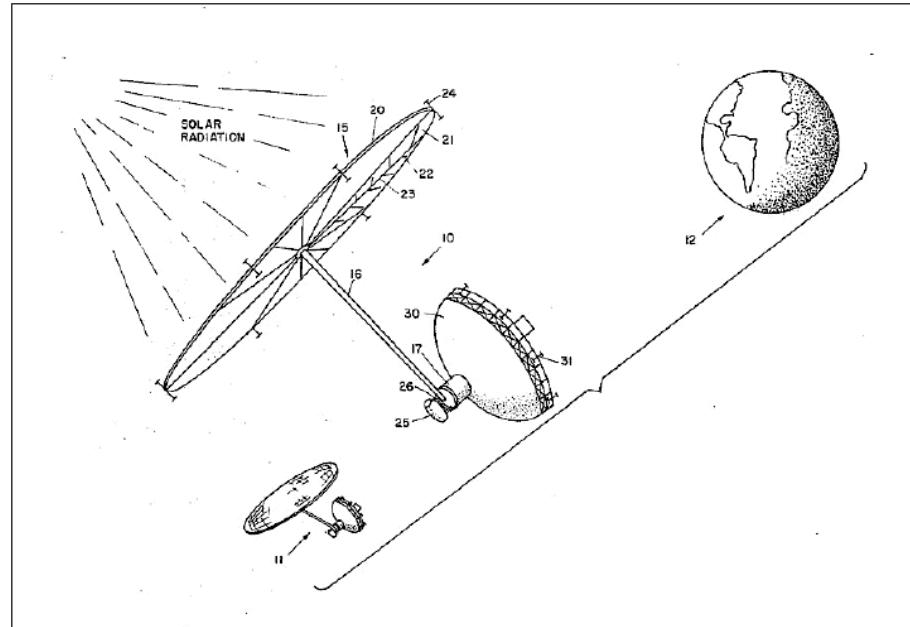
- Potential for military application for initial development
 - System offers targeted delivery to remote locations
 - Current estimate for military Forward Operating Base (FOB) power - \$36.90 kW/hr

Conclusions

- Very significant engineering undertaking
 - Similar to Apollo space program
- Will require significant government investment
- Great potential
 - Could provide a high percentage of world energy needs
- Role for Sandia
 - Solar Panel Technology
 - Weight of solar panels reduced to lower launch costs
 - Reliability/Survivability of solar panels within a space environment
 - Cost of manufacturing solar panels
 - Reliability – System of Systems expertise
 - Complex Systems
 - Interaction of technology into current power grids
 - Complex systems modeling and simulation

Space Based Solar Power (SBSP)

Illustration of the SPS concept from the 1973 patent awarded to Dr. Peter Glaser



Credit: US Patent and Trademark Office; Patent No. 5019768

Questions?