Solar Power from Space, ThermoPhotoVoltaic (TPV) Cells & IR Power Beaming

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Summary: Sun & Life

Photosynthesis Solar Energy

$CO_2 + H_2O > CH_2O + O_2$ Carbohydrate Plant Life

Food

$CH_2O + O_2 > CO_2 + H_2O$ Energy for Animal Life

Stored Solar Energy

$CH_4 + O_2 > CO_2 + H_2O$ Human Civilization

What's Next? Solar Power from Space

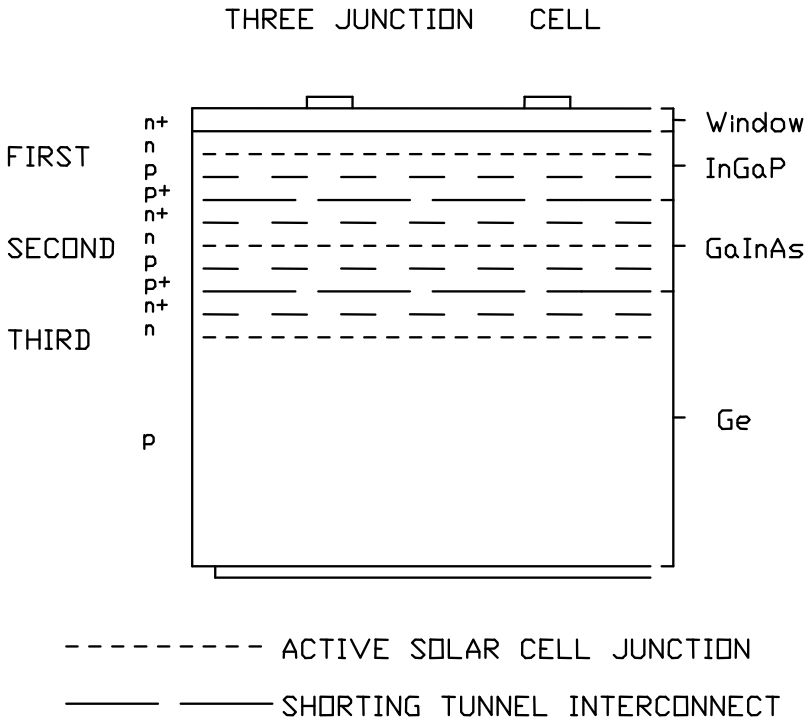
Outline & Timeline

40% Triple Junction Solar Cell –
HRL 1978
GaAs/GaSb 37% Solar Cell –
Boeing 1989
PASP GaSb IR Cell CPV Space Flight -
NASA 1994
TPV GaSb IR Cell & Applications –
JX Crystals Inc 2001
40% PV Cells, SPS, and Mirrors in Space –
L. Fraas 2012
IR Power Beaming & GaSb CPV for Affordable
MW SPS in Geo – L. Fraas 2018
Space Mirrors and Municipal Street Lighting –
L. Fraas 2019

Monolithic Triple Junction InGaP/GaInAs/Ge CPV Cell

First Described in 1978 by L. M. Fraas & R.C. Knechtli
13th IEEE Photovoltaic Specialist Conference

Predicted 40% Efficiency at 300 Suns AM1.5



From Figure 1c on p. 890

From p. 888
(at 300 suns AM1.5)

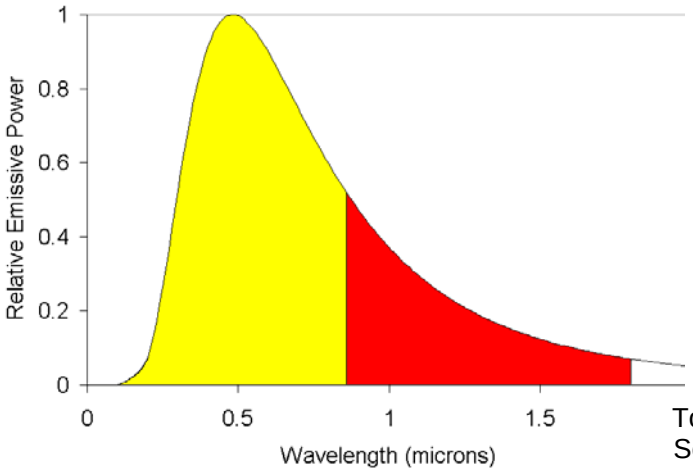
$$\eta = \frac{13.3\ \text{mA/cm}^2 \times \text{Vop}}{84\ \text{mW / cm}^2}$$

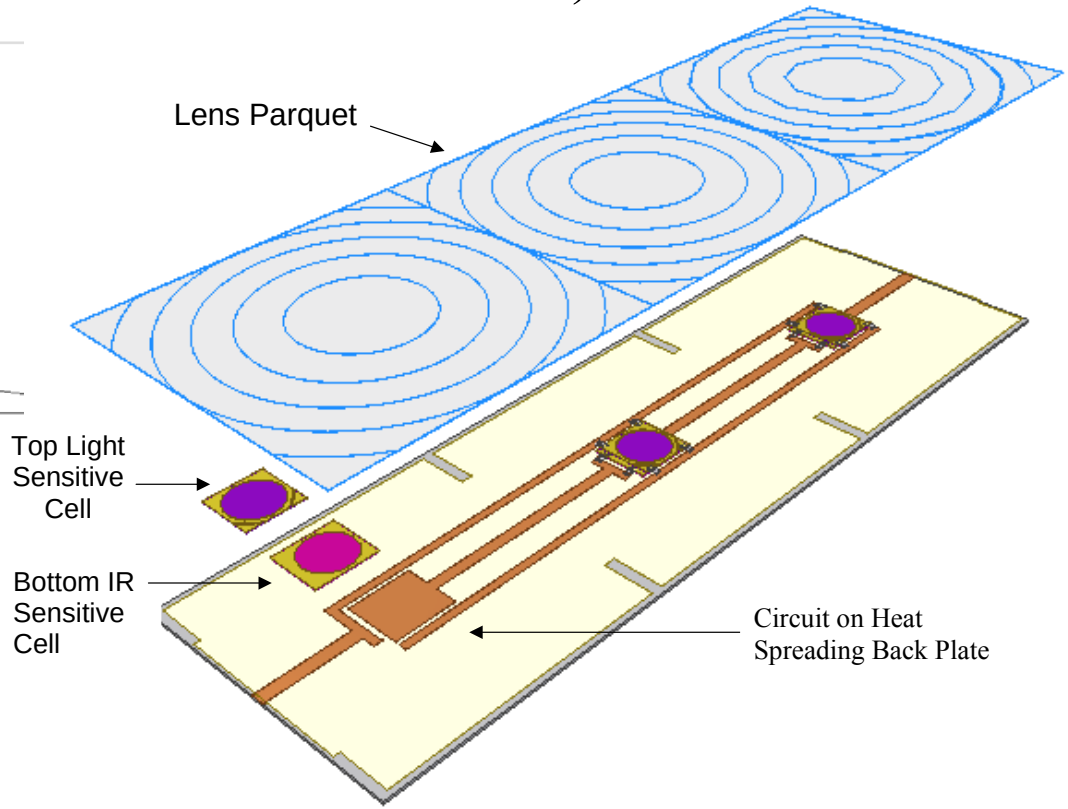
Vop = 2.55 V

Efficiency = 40%

CRYSTALS
Intelligent Alternative Energy

35% Efficient
Stacked Tandem Multicolor Solar Cell
(Uses New Infrared Sensitive Cell)



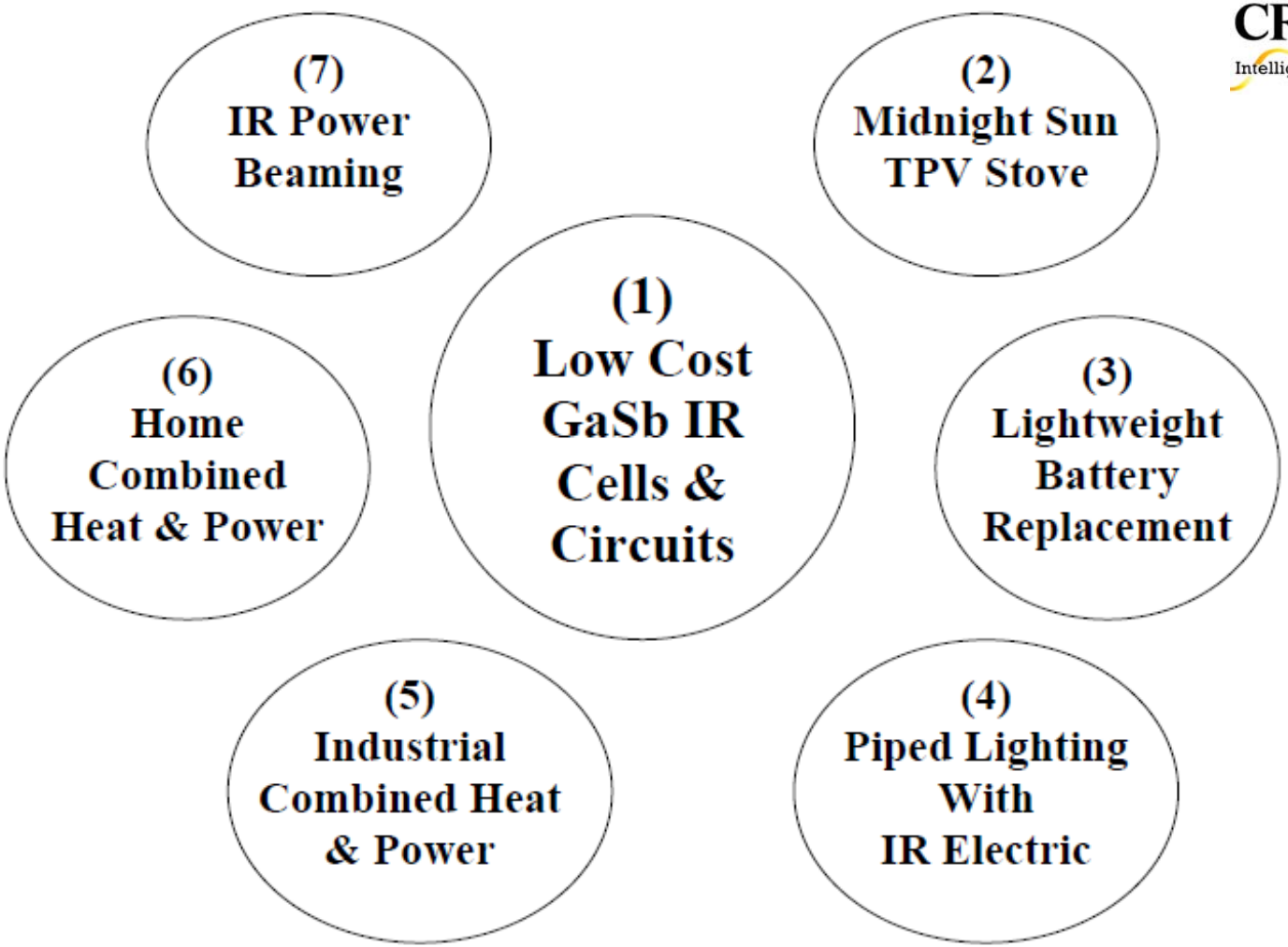


JX Crystals Team Achieved World Record Solar Cell Efficiency of 32% for Space and 35% for Terrestrial in 1989.

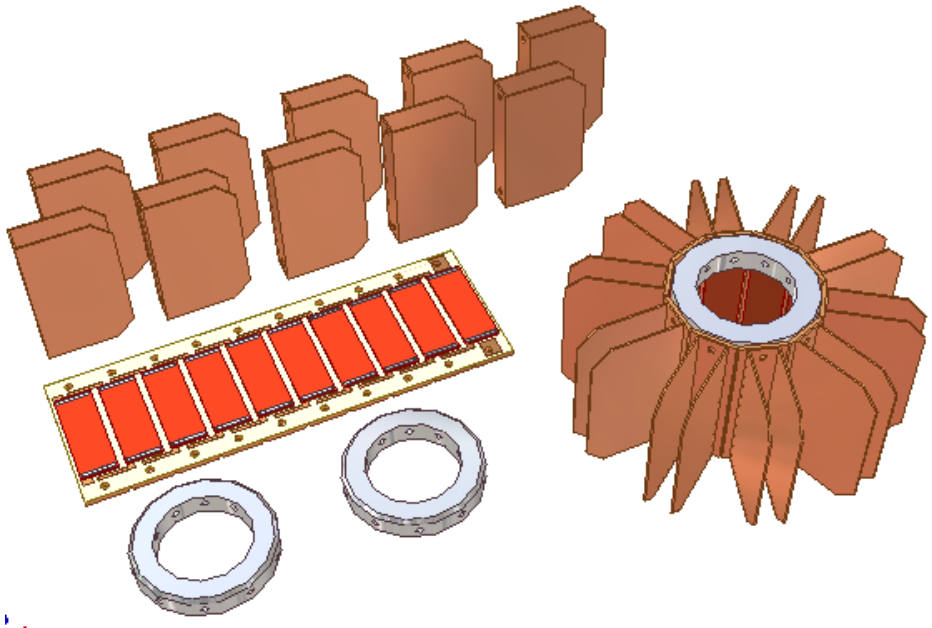
Photo of the CPV array using GaSb IR cells in the PASP+ Mini Dome Concentrator NASA flight experiment in 1994

Photo courtesy of NASA

JXC GaSb IR Cell Core Technology leads to Multiple Applications



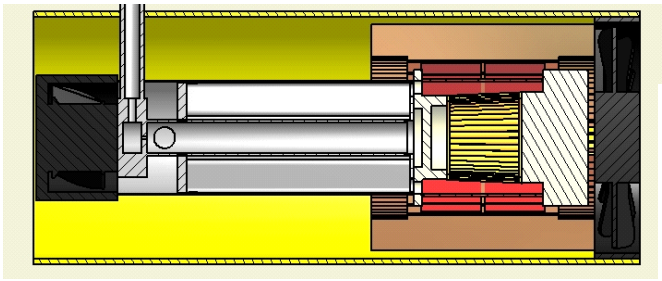
JX Crystals TPV Demonstrator



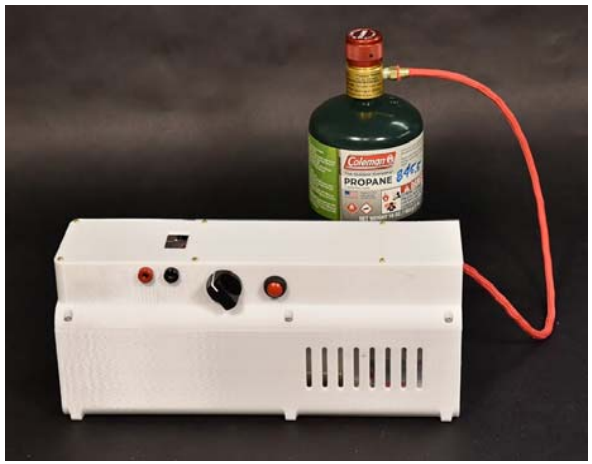
TPV Circuit rolls up into cylinder with fins added for cooling

Oil Lamp with TPV cylinder operates radio

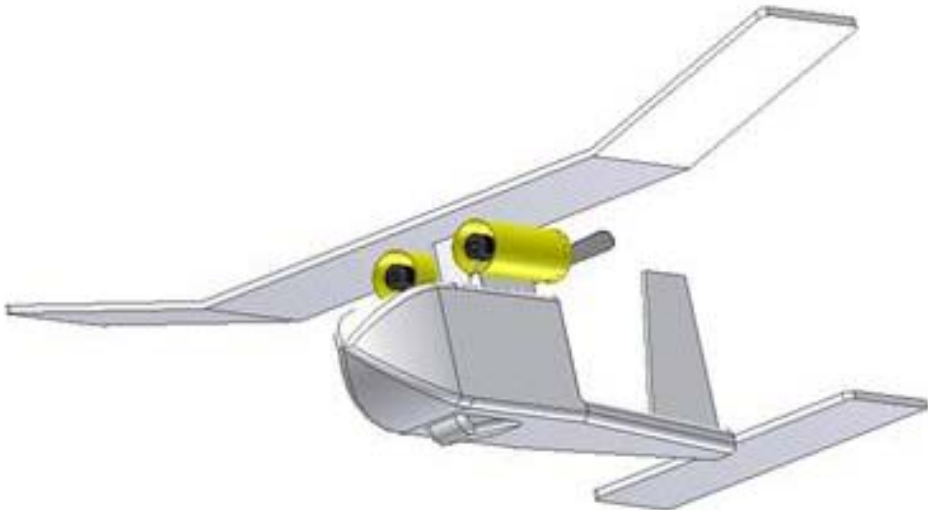
(3) Light Weight Battery Replacement
20 W or 50 W TPV Cylindrical Generator



(a) TPV Cylinder design



(b)
22 cm long 20 W TPV cylinder with 9 cm diameter Propane fuel canister



(c)
Two Quiet 50 W TPV Cylinders Could Power Unmanned Aerial Vehicle

IR Solar Power Beaming System in GEO

Advantage – MW & multi million $, not GW and not multi billion$$

A 70 m diameter mirror collects 5 MW of solar energy and concentrates it onto the 12 sq m solar cell array which in turn powers a diode laser pumped laser generating a 1 MW IR beam.

The 1 MW 1.5 micron eye safe beam then illuminates a 40 m diameter ground receiver site with a beam intensity of 800 W / sq m or approximately 1 sun equivalent.

40% efficient GaSb IR cells in CPV modules on the ground then convert the beam energy Into DC electricity. **Viable National Security Niche Power Market**

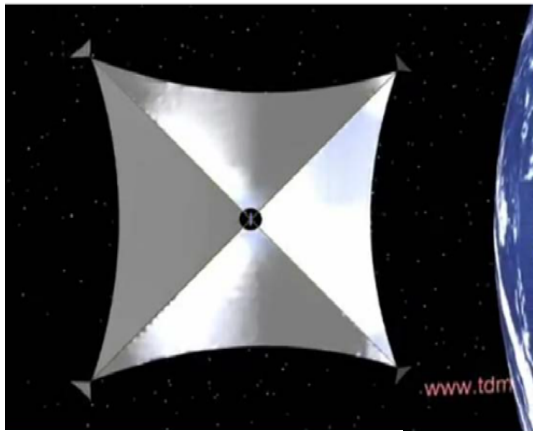
Photo courtesy of NASA

SPS Space Mirrors – 2012 – **2 yr payback but multi billions $$**

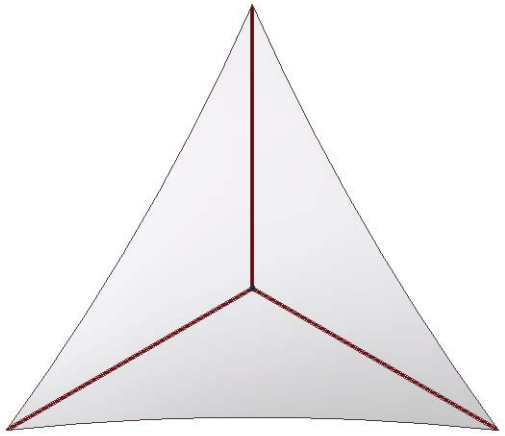
Revolutionary Concept:

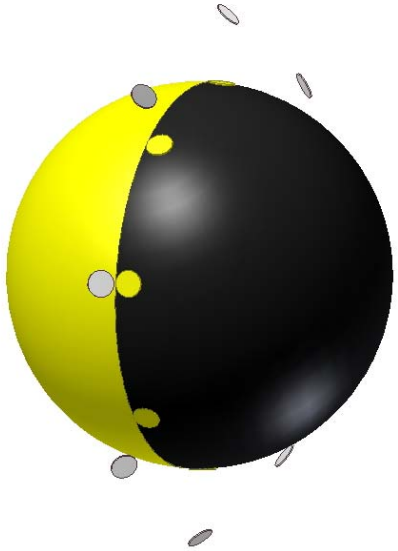
Lightweight mirrors
in a Dawn-Dusk Orbit
beam sunlight to
earth PV stations
providing solar
electricity in evening
& winter for
14 hours per day
increasing
solar power station
capacity factor
to 60% & reducing
Solar electricity cost tc
Under 6 cents / kWh.

NASA L'Garde Sunjammer

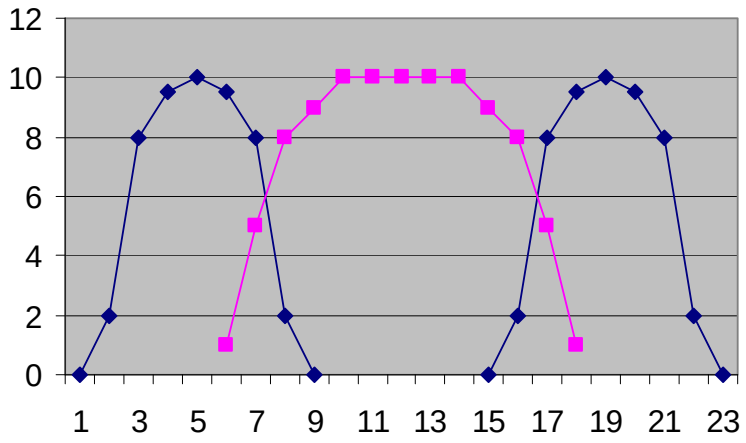


Space Mirror

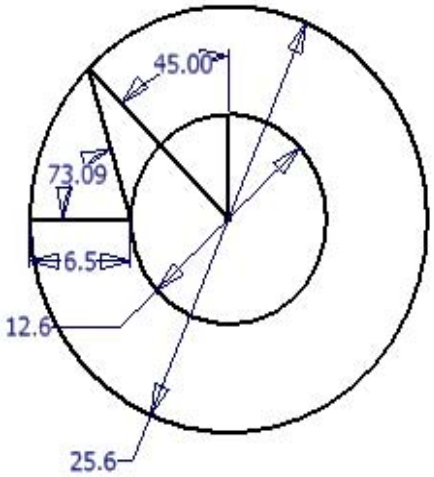




Space Mirrors Normal Sunlight



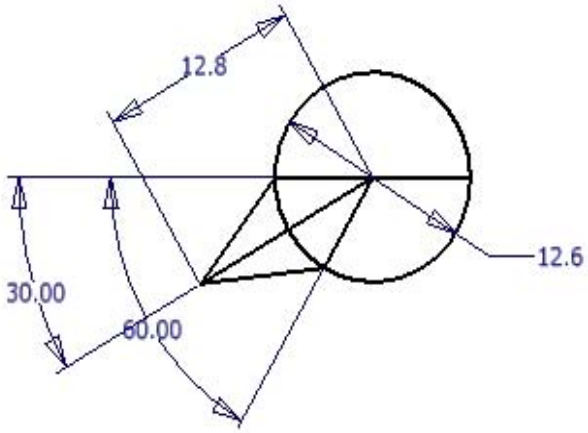
Space Mirror Orbit for Municipal Street Lighting



4 mirror satellites in 4 hour polar orbit;
Each Mirror flies over municipal site in evening for 1 hour providing street lighting with full moon intensity.

Orbit altitude: 6,540 km
Orbit radius: 12,800 km

First diagram is a view from the night time side of the earth. The mirror satellite comes into view from the ground site from the N horizon at an angle of 73 degrees off overhead and it travels to overhead 30 minutes later and then goes out of view in the south at an angle of 73 degrees one hour later. Imagine 4 mirror satellites in orbit spaced by 90 degrees. A second mirror satellite could then come into view in the north.

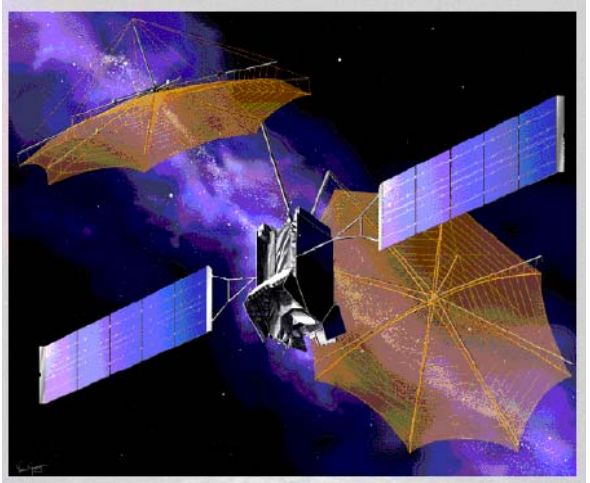


Second diagram is a view looking from the north pole. The terminator is the horizontal line. The satellite orbit is tilted 30 degrees toward the night side of the terminator. The mirror satellites can see an angle relative to the center of the earth of 60 degrees corresponding to a 4 hour period in the evening.

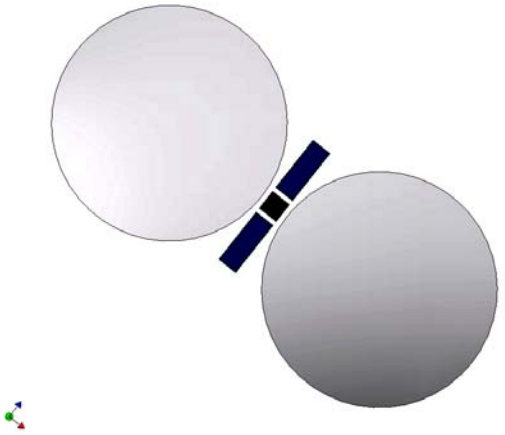
Mirror Design & Economics

Target Site Diameter = 57 km
Full Moon Intensity = 0.6 mW per sq m
Power on target site = 1.53 MW
Mirror diameter = 38 m
2 ground sites targets per orbit
6 revolutions in 24 hour
12 ground sites for 12 hours per day
$0.05 per kWh
$0.36 million per year per mirror
weight of a space mirror = 1 MT
$1,500 per kg for launch cost
1.5 million $ per mirror
Payback time per mirror = 4.2 years
Cost for 4 mirrors = 6 million $
Does not include R&D

Space Power Satellites can be economical



Municipal mirror satellite is Plausible by analogy with reflecting antennas on space communication satellites. Harris offers a 22 m diameter reflecting satellite antenna.



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