

# *Sustainable Energy for many Tomorrows*

**ECE 6390**

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**Georgia Institute of Technology**  
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Darel Preble

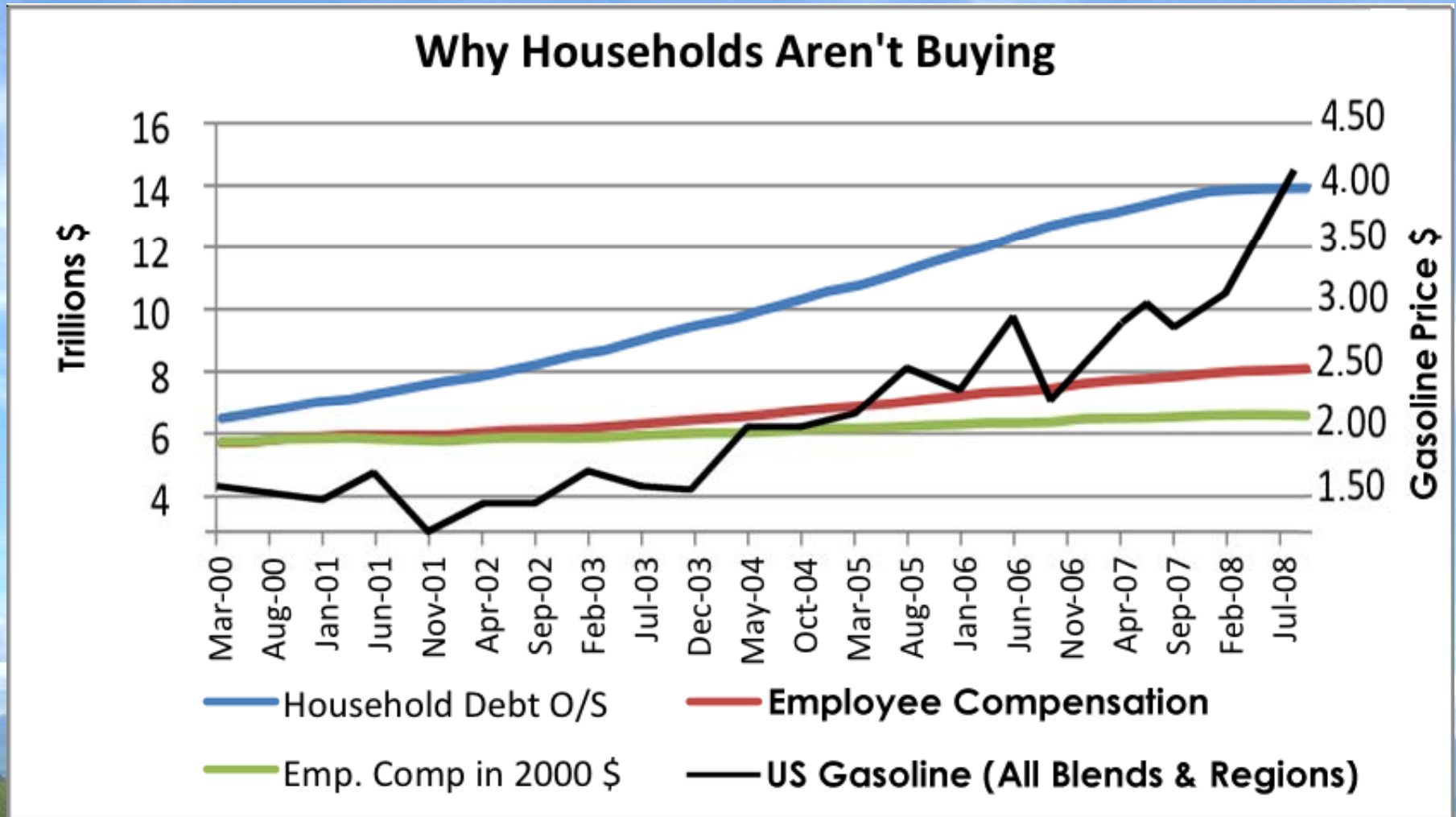
Space Solar Power Institute

[www.solarsat.org](http://www.solarsat.org)

Space Solar Power Workshop

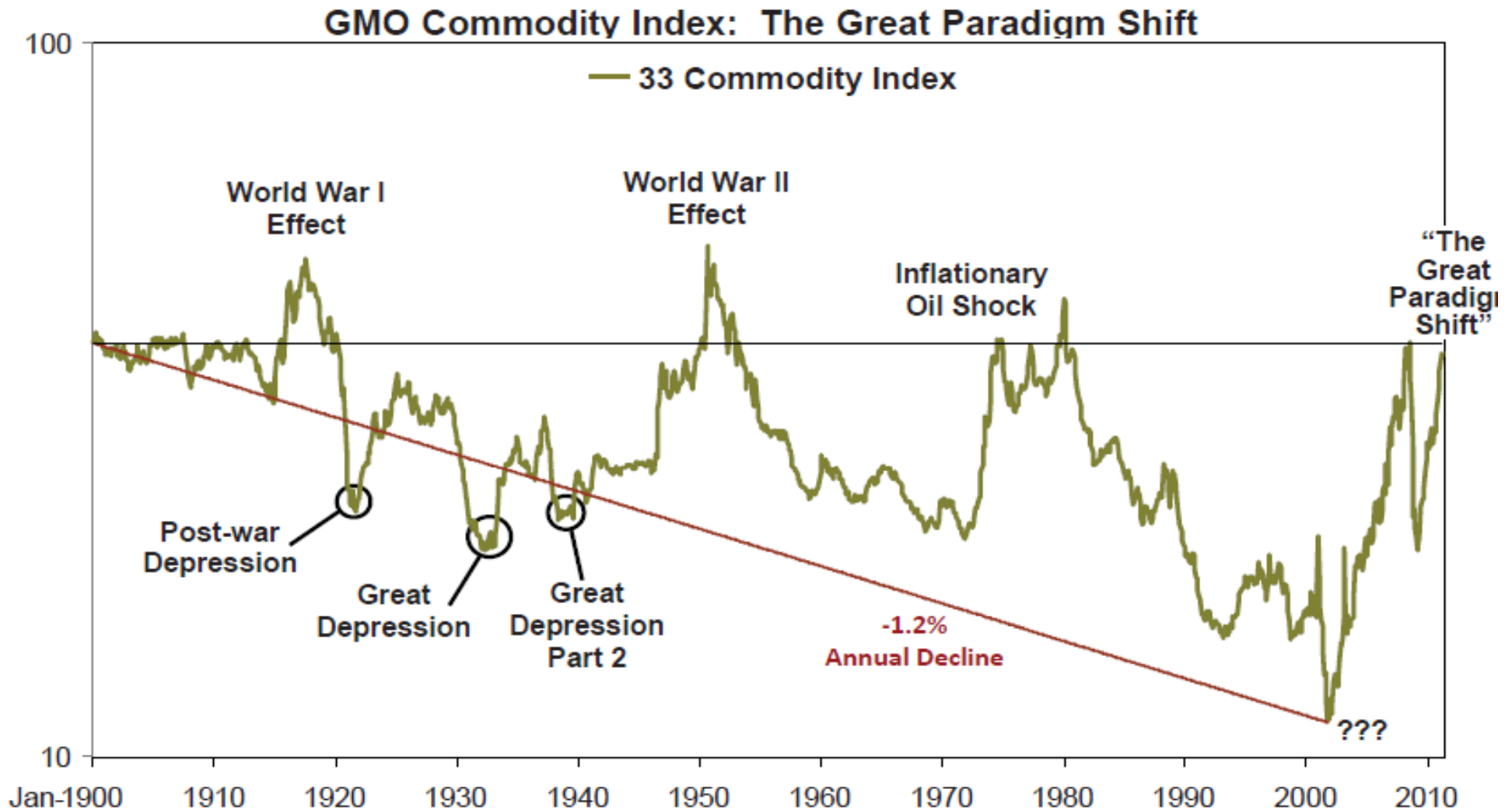
[www.sspi.gatech.edu](http://www.sspi.gatech.edu)

Overextended on debt, people are squeezed by rising costs and declining real wages.



- The shocking oil prices of July 2008 were caused by strong demand confronting stagnating world oil production.[1] (We need energy and commodities to create economic value (exergy). Global oil production has been flat since 2005, although prices have soared.
- The prices of all important commodities except oil declined for 100 years until 2002, by an average of 70%. From 2002 until now, this entire decline was erased by a bigger price surge than occurred during World War II.
- Most commodities are now so far away from their former downward trend that that old trend has very probably finally changed – a Paradigm Shift – the most important economic event since the Industrial Revolution.[2]

# Commodity and energy prices will restrict the global & US economies:



Note: The GMO commodity index is an index comprised of the following 33 commodities, equally weighted at initiation: aluminum, coal, coconut oil, coffee, copper, corn, cotton, diammonium phosphate, flaxseed, gold, iron ore, jute, lard, lead, natural gas, nickel, oil, palladium, palm oil, pepper, platinum, plywood, rubber, silver, sorghum, soybeans, sugar, tin, tobacco, uranium, wheat, wool, zinc.

Source: GMO As of 2/28/1

## *Global Food Supply*

USDA forecasts near record corn harvest levels, but surging global demand portends supplies going to a 16-year low next year. USDA's August crop report forecasts dramatically less grain and soybeans than expected this year. Damaging heat and dryness took a toll on corn and soybean fields, while excessive rains hampered spring wheat plantings. These portend continued high prices for bread, meat, milk, eggs and other staples. Consumers can expect continued tight food supplies and historically high prices during the year ahead.

## *Global Food Prices*

World food prices are near a record as growing demand from China and India outpaces harvests hurt by flood and drought. Rising prices have put 44 million people into poverty in the past year, helping fuel conflict and unrest in the Middle East and North Africa and spurred central banks from Brasilia to Beijing to increase interest rates.

# Peak Oil

Charlie Maxwell, “**dean of world oil analysts**” foresees a “peak” in conventional oil production in 2012 or 2013. He sees a peak in the production of all liquids - including condensates, tar sands oil and biodiesel in 2015.

Private UK studies, such as "The Oil Crunch" report also projects a global oil peak production around 2012 or 2013.

## *Booming U.S. coal exports surging to 100 million tons/yr thanks to Asia*

While the U.S. is slated to close 35 gigawatts of coal-fired power plants next decade, 249 gigawatts of coal-fired power plants are under construction worldwide.

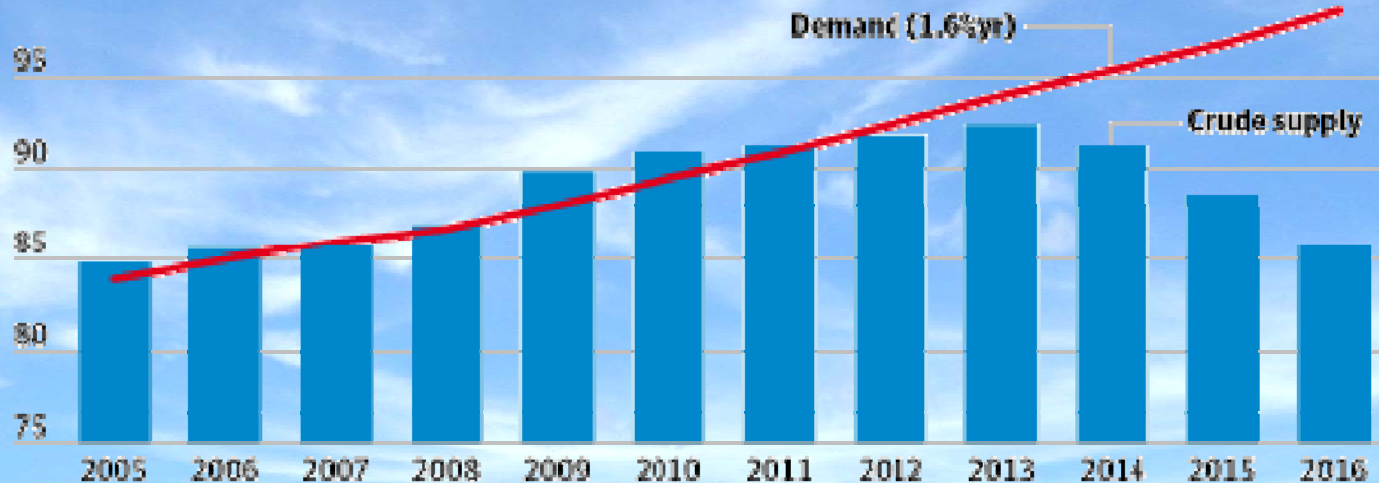
<http://www.reuters.com/article/2011/05/12/businesspro-us-coal-usa-idUSTRE74B2FH20110512>



# Peaking Fossil Fuels

## Supply and demand

Global oil supply versus projected demand in a best-case analysis



SOURCE: PEAK OIL CONSULTING

**IEA World Energy Outlook projects the global petroleum decline rate at 6.7% !**

<http://www.guardian.co.uk/business/2008/dec/15/oil-peak-energy-ia>

# Conservation ... nice, but not enough

- Carpooling
- *New* LED and compact fluorescent lighting
- Energy efficient appliances
- Cooking with Microwave ovens, inductive heating, etc., over conventional ovens
- Adding insulation to walls and ceiling, Double glaze windows; Bermed houses
- Decoupled energy rate structures
- Jevon's paradox

# Job One

Electrify our transportation system

Hybrid/Plug-in Electric cars & trucks

Light rail & subways

Electric trains - with

Super batteries – e.g. Cui's nanowire battery

Super capacitors – e.g. EEstor

# ELECTRIC CARS



**ARE YOU READY?** *Highway Speed Electrics are Here! Zero Gallons per Mile!*

## WELCOME TO THE FUTURE

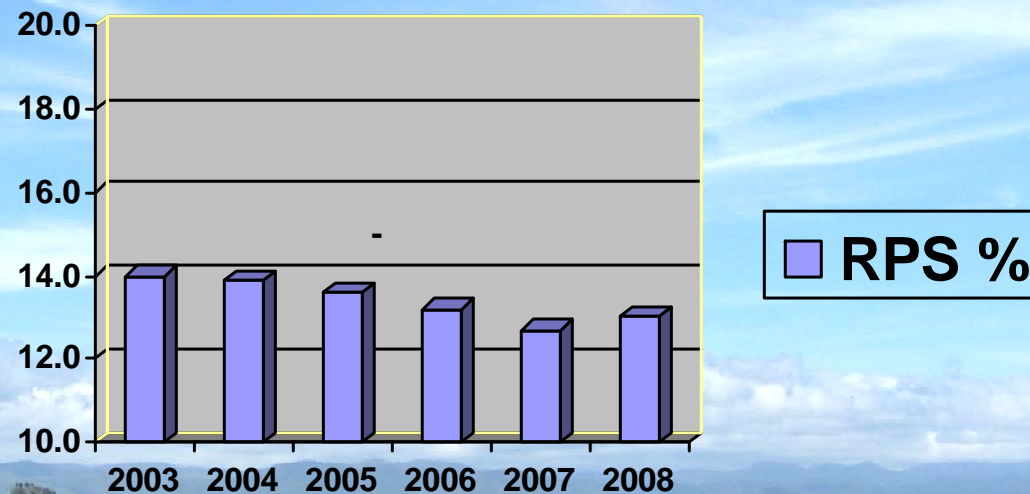
**FORD, GM, CHRYSLER, TESLA, TOYOTA, BMW, MERCEDES, HONDA and MORE!**

*There are Two Types of Auto Makers, Those Who are Developing Electric Cars and Those who will be EXTINCT*

America's energy security and global environment are at risk.

*The U.S. is doing NOTHING on the massive energy scale required.*

Most states, led by California's aggressive and failing Renewable Portfolio Standard (RPS), have legislated a renewable energy transformation. California's RPS was initiated in 2002. **Their goal is 20% RPS by 2010... and 33% by 2020.** Developing countries would crush these gains that Gov. Schwarzenegger has ordered and the utilities cannot deliver.



Since 2006 California PUC has mandated “feed-in tariffs” intended to encourage renewable power. Toby Couture, E3 Analytics, found that only 14 MW have been installed in the 500 MW program. California’s peak power is about 63,000 MW.

Feed-in tariffs are the latest fashion to encourage Renewable Power Standards.

## Energy Storage Technologies Capital Cost Estimates (EPRI Estimate, February 2009)

Storage Type (See footnotes)	\$/kW	\$/kWh	Hours <sup>4</sup>	Total Capital, \$/kW
<b>Compressed Air Energy Storage</b> Large ( 100-300 MW Underground storage))	590-730	1-2	10	600-750
Small (10 - 20 MW Above ground storage)	700-800	200-250	3	1300-1550
<b>Pumped Hydro</b> Conventional ( 1000 MW )	1300	80	10	2100
<b>Battery ( 10 MW )</b>				
Lead Acid, commercial	420-660	330-480	4	1740-2580
Sodium Sulfur (projected)	450-550	350-400	4	1850-2150
Flow Battery (projected)	425-1300	280-450	4	1545-3100
Lithium ion (small cell)	700 - 1250	450 - 650	4	2300 - 3650
Lithium ion (large cell, projected)	350 - 500	400 - 600	4	1950 - 2900
<b>Flywheel ( 10 MW )</b>	3360-3920	1340-1570	0.25	3695-4313
<b>Superconducting Magnetic Storage</b> commercial	200-250	650,000-860,000	1 sec	380-489
<b>Supercapacitors</b> (Projected)	250 - 350	20,000 - 30,000	10 sec	300 - 450

1. In this table, Total Capital Cost = \$/kW + (Number of Hours x \$/kWh)
2. All figures are rough order -of -magnitude estimates and are subject to changes
3. Total capital costs include power conditioning system and all equipment necessary to supply power to the grid. Not included are battery replacement costs, site permitting, interest during construction and substation costs.
4. These costs are for the hours shown  $\pm 25\%$
5. Cost may vary depending on the price of commodity materials and location of project





- IF CAES were truly a cost effective method for time shifting energy generation, it would have been widely adopted in the US.
- It has not been. There is still just one CAES plant in the US.
- True utility bulk power storage is not planned anywhere – peak shaving frequency regulation, etc., but not bulk power storage.

# 33% RPS by 2020 ?

How? CAES (Compressed Air Energy Storage) A natural gas plant “in disguise”, burning natural gas with the decompressed air stream.

## 1 MW CAES Plant

8,200,000 BTU  
(2403 kWh) plus  
4,600,000 BTU  
(natural gas)

12,800,000 BTU

27% Efficient

## 1 MW Fossil Plant

10,000,000 BTU

10,000,000 BTU

34% Efficient

## But what are our power alternatives?

	Clean?	Safe ?	Reliable?	Baseload?
Fossil Fuel	No	Yes	Imminent Peaks	Yes
Nuclear	No	Yes	Cost, Water, Proliferation	Yes
Wind Power	Yes	Yes	No, intermittent; 8.7% Cap. Factor*	No
Geothermal	Yes	Yes	No, Limited availability	Yes
Ground Solar	Yes	Yes	No, intermittent	No
Hydro	Yes	Yes	No; drought; complex scheduling	
Bio-fuels	Yes	Yes	Very limited quantities & competes with food production. Poor EROEI	
SSP	Yes	Yes	Yes	Yes

## *Can roof top solar (or wind) run our grid?*

A PV panel at GSO will collect about 9.6 times as much power per square meter per year as an average location in the continental US and require less maintenance. To store the sun or wind, to make it 24/7 like the grid, how long do we need to store it?

To store power to compensate for just one day, suppose we have a 1 MW ground PV or wind power unit that over some length of time (FAR more than 24 hours) stores 24 MWH into our CAES. When it has been thus loaded, we can then get about 6.48 MWH generated by the CAES when we want it, since a CAES is about 27% efficient.

## *Can roof top solar (or wind) run our grid?(cont.)*

Suppose it takes 4 days of sun to get 24 MWh. We need 14.8 of avg. sunny days to store our 24 MWh to cover a sunless 24 hour day. That is for just one 24 hour day.

*(Note - CAES uses natural gas to make most efficient use of the cold compressed air to generate the power, but PV or wind cannot provide gas so it still depends on a fossil fuel.)*

Approximately 50% of space solar's PV output will get to the grid, so that 9.6 factor is reduced to 4.8 ;

Attempting to make terrestrial PV or wind “dispatchable“ using the best available storage technology, we have shown by comparison that SSP provides **71 times** ( $= 14.8 \times 4.8$ ) **more dispatchable baseload energy.**

Existing state of the art can return 42% of SSP power for injection into the electric grid.

### Photovoltaic/microwave end-to-end system efficiencies

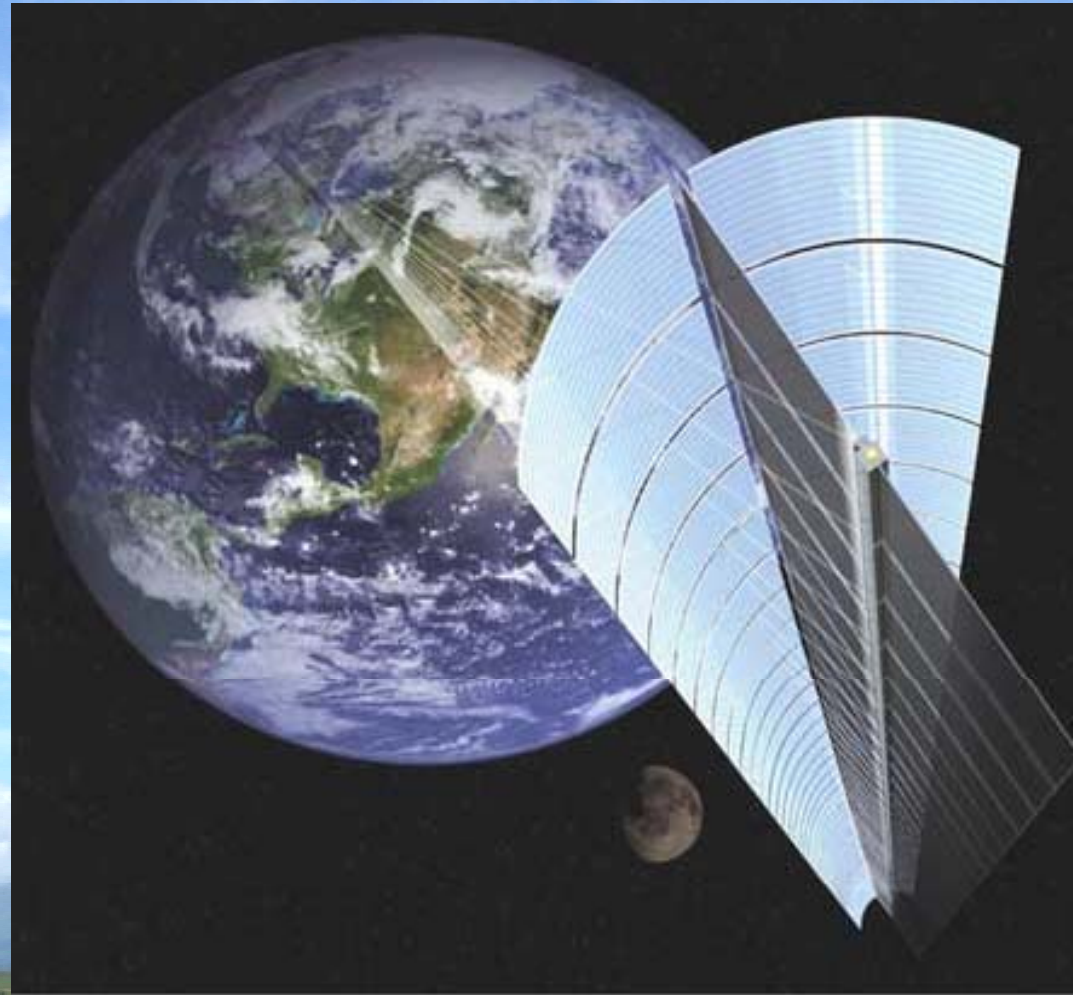
Segment	Efficiency	Reference	Notes
Power management and distribution losses from PV	99%	None	Estimate
DC-to-RF conversion	60%	Phase-controlled magnetron at Kyoto U.	Up to 85% w/out phase control
Antenna/phase scan losses	90%	Mailloux Phased Array Handbook	10 deg scan angle
Atmospheric attenuation	98%	"Total Attenuation from 5km to the ground", Bruce Wallace, MMW Concepts LLC	Assumed ~ 0.1 dB attenuation
RF collection area efficiency	90%	For 1.0km transmit antenna diameter, 4.8km rectenna receiver area, GEO orbit	Depends on aperture sizes.
RF to DC conversion by rectenna	90%	W.C. Brown 1980	@ 5.8 GHz
Power management and distribution losses	99%	None	Estimate
<b>TOTAL</b>	<b>42%</b>		

2008-09-30



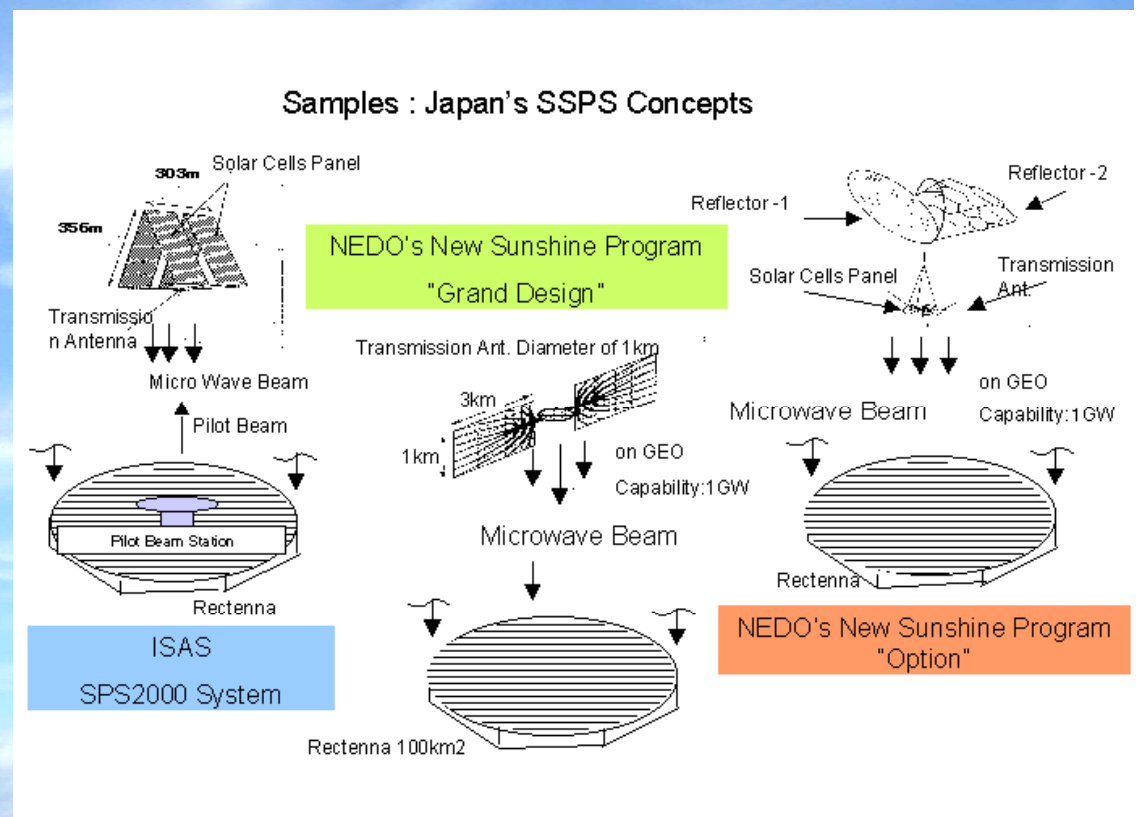
# Mitsubishi, IHI to Join \$21 Bln Space Solar Project

Japan's USEF consortium is developing a 1-gigawatt solar station by 2025. It would produce electricity at eight yen (nine cents) per kilowatt-hour, six times cheaper than its current cost in Japan.



# Land of the Rising Sun Power! Japan Plans to Build a Solar Station in Space by 2030

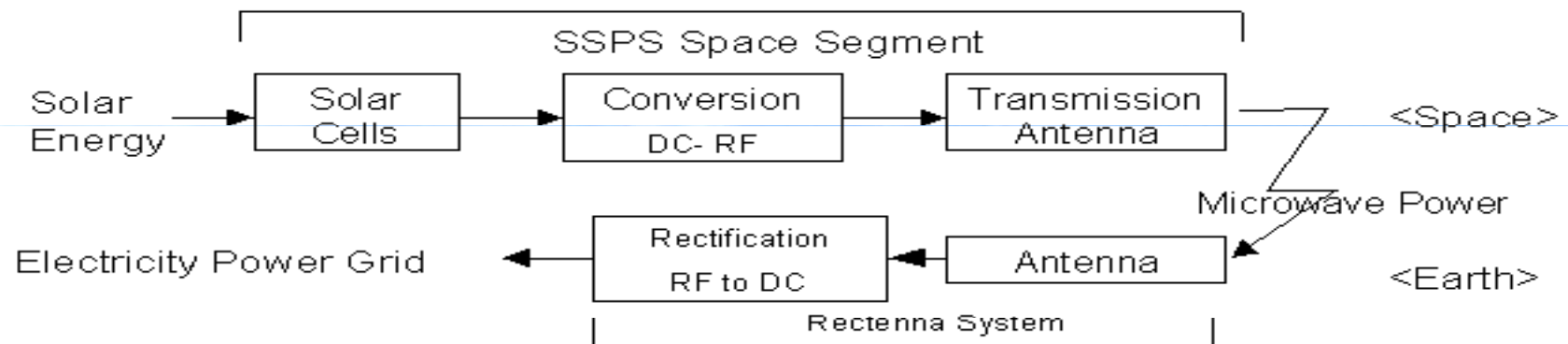
The Institute for Unmanned Space Experiment Free Flyer (USEF) of 18 major Japanese companies hope to launch a small satellite in 2015 to test microwave power beaming through the ionosphere. ...





# *Land of the Rising Sun Power! Japan Plans to Build a Solar Station in Space by 2030 (2)*

## Space Solar Power System : Scheme and Application



### ☆Sustainable Power Source:

Space Solar Power System could supply indefinitely a sustainable electricity power using the solar energy in space, whether it is fine or not, day or night on the Earth.

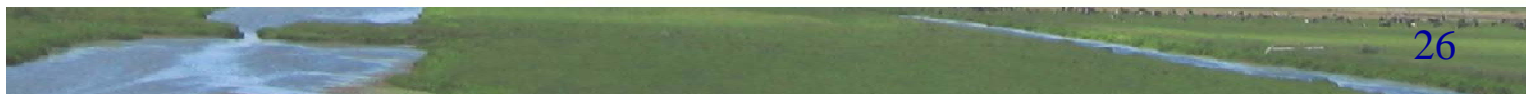
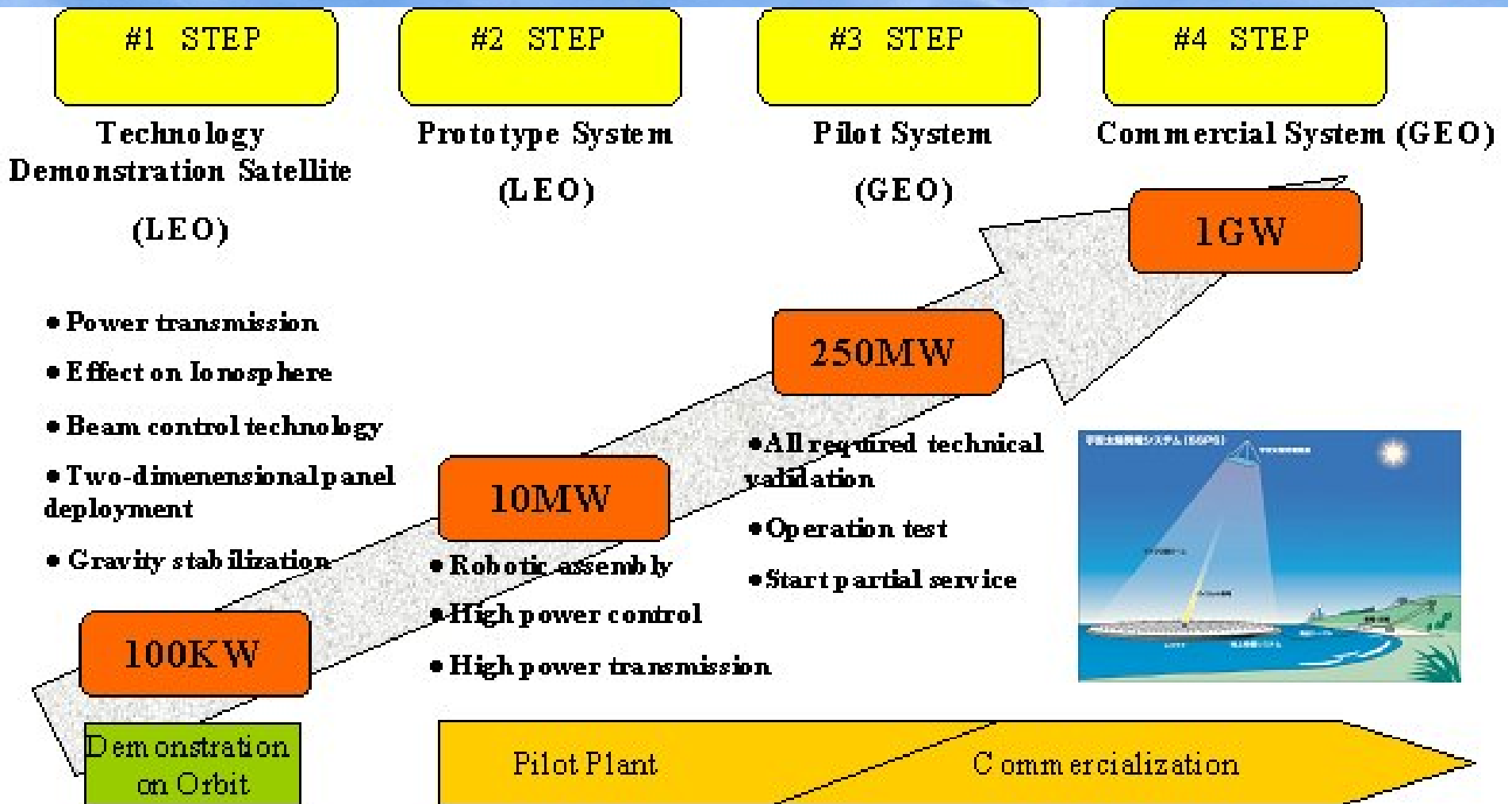
### ☆Sizable Power Supply and a Pillar to Energy Mixture Structure:

SSPS could become a large-scaled power source and realize power mixture structure with existing power sources, providing the electric power as much as 1GW.

### ☆Least Emission of Greenhouse Gases:

SSPS does neither depend on fossil fuel nor emit greenhouse gases on operation.

# Land of the Rising Sun Power! Japan Plans to Build a Solar Station in Space by 2030 (3)



# Report for Obama Questions Fracking Regulations Effectiveness

“In sharp contrast with gas industry portrayals, a draft report released August 11, 2011 by a federal panel on shale gas drilling explicitly acknowledges that current regulations may be insufficient to protect the environment and public health.

- <http://www.propublica.org/article/report-for-obama-questions-effectiveness-of-gas-drilling-regulations>

# *Fracing Overstates Nat Gas Reserves*

## *Shale Gas—Abundance or Mirage?*

*“Shale gas plays in the United States are commercial failures and shareholders in public exploration and production (E&P) companies are the losers.”*

# Fracking Overstates Nat Gas Reserves



## INVESTOR RELATIONS

### Rig Counts

Area	Last Count	Count	Change from Prior Count	Date of Prior Count	Change from Last Year	Date of Last Year's Count
U.S.	14 Aug 09	968	+2	7 Aug 09	-1022	15 Aug 08
Canada	14 Aug 09	170	-25	7 Aug 09	-256	15 Aug 08
International	July 2009	974	+7	June 09	-118	July 08

[www.theoil Drum.com/node/5676#more](http://www.theoil Drum.com/node/5676#more)

[www.aspousa.org/index.php/2009/08/lessons-from-the-barnett-shale-suggest-caution-in-other-shale-plays](http://www.aspousa.org/index.php/2009/08/lessons-from-the-barnett-shale-suggest-caution-in-other-shale-plays)

[http://investor.shareholder.com/bhi/rig\\_counts/rc\\_index.cfm](http://investor.shareholder.com/bhi/rig_counts/rc_index.cfm)

# Loss of wind causes Texas power grid emergency

Feb 27, 2008 - A drop in wind generation triggered an electric emergency that caused the Texas grid operator to cut service to some large customers. ERCOT said the grid's frequency dropped suddenly when wind production fell from more than 1,700 megawatts, before the event, to 300 MW when the emergency was declared.

<http://www.reuters.com/article/domesticNews/idUSN2749522920080228?feedType=RSS&rpc=22>

# Solar panels a 'loser,' professor says

Installing them amounts to 'THROWING MONEY AWAY'

Feb. 21, 2008 - Installing solar panels on homes is an economic "loser" with the costs far outweighing the financial benefit, said a respected University of California-Berkeley business professor. Using photovoltaic panels to generate electricity is not competitive with fossil fuels and costs more than other renewable fuels, said Severin Borenstein, who also directs the UC Energy Institute. A typical PV system costs between \$86,000 and \$91,000 to install, while the value of its power **over its lifetime** ranges from \$19,000 to \$51,000. Even using favorable criteria, the cost would still be 80 percent more than the value of the electricity produced.

<http://www.bizjournals.com/eastbay/stories/2008/02/18/daily43.html>

"We are in the beginning stages of major changes to agricultural markets caused by rapidly expanding production of bio-fuels."

– Credit Suisse Group, in "Corn Is Booming as Ethanol Heats Up",  
<http://online.wsj.com/article/SB116260858542413472.html>

To reach Bush's 20 percent ethanol goal, corn production must grow to 167 percent of its 2005 levels, *and every kernel must go into ethanol*. Corn is the major feed/ingredient for chickens, pigs, cattle; milk, cheese, eggs, hamburger, Coke, Pepsi, Jack Daniels, etc., ...

(By weight, a McDonald's hamburger is 52% corn.)

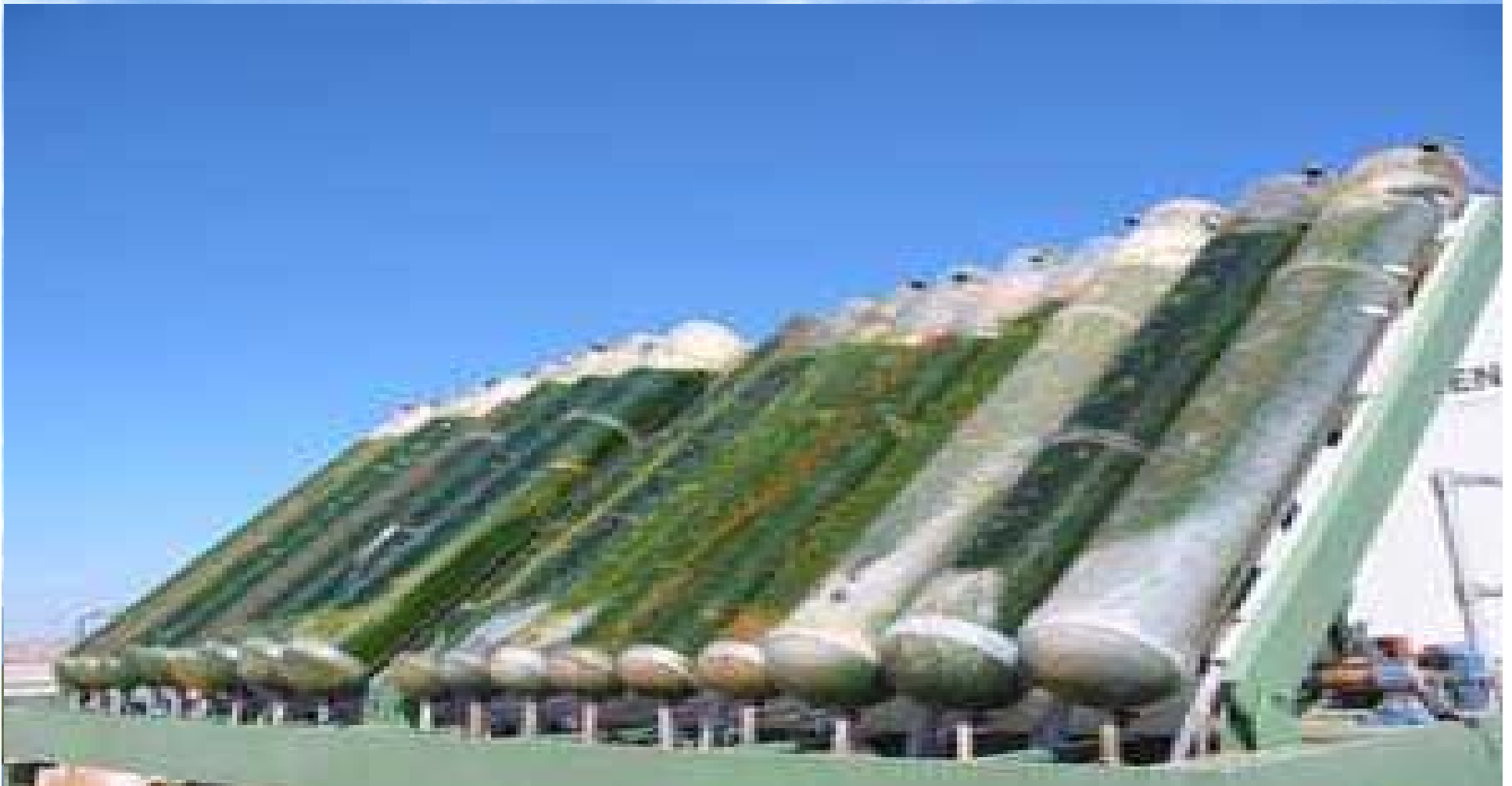


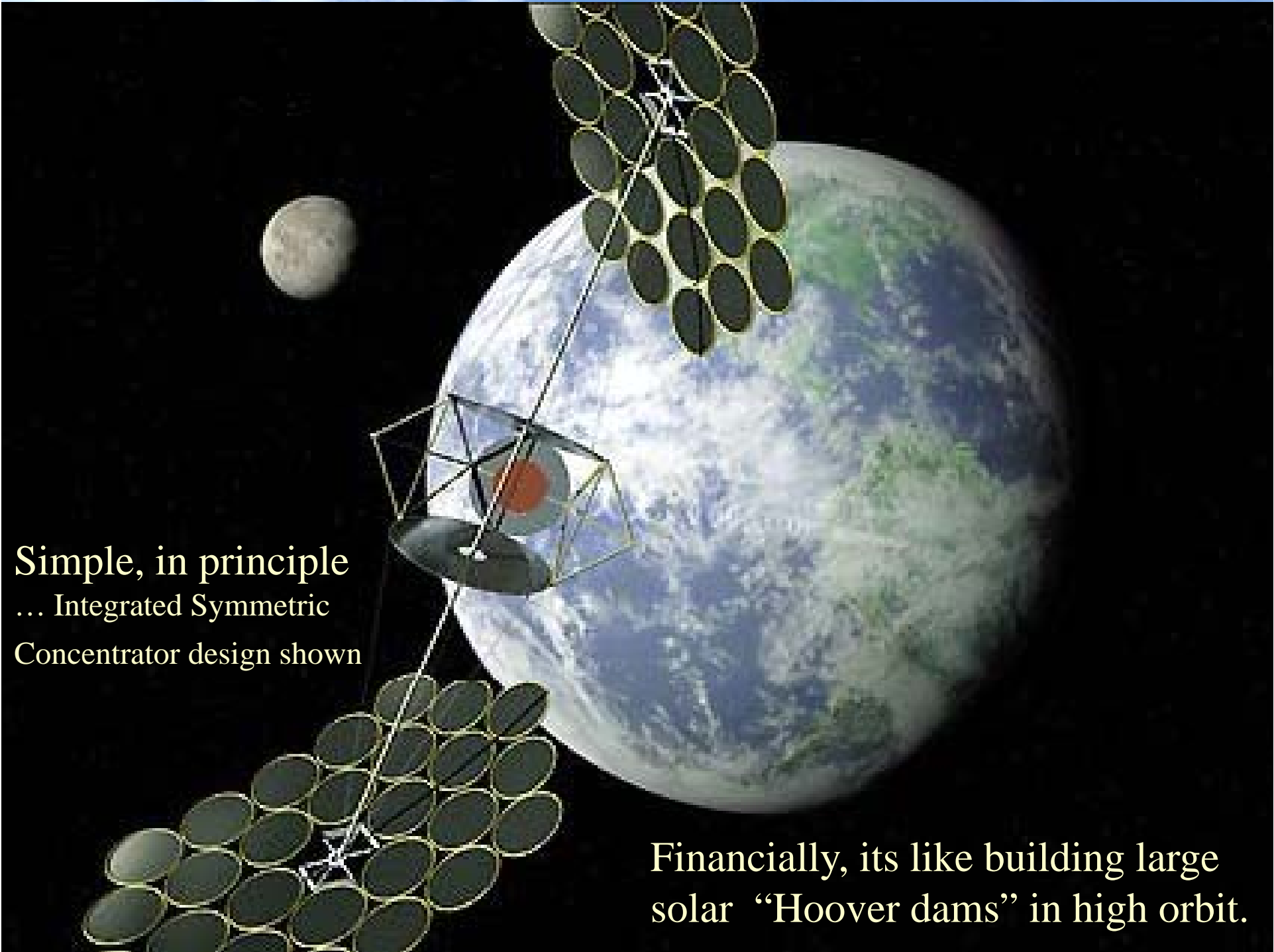
# BioFuels

For biodiesel production, you want a high lipid fraction. All evidence to date shows that the high lipid contents desired, can only be achieved in physiological stress, notably nitrogen starvation.

**GreenFuel** uses flue gases - which are rich in CO<sub>2</sub>. Nitrogen starvation is, however, out of the question, since flue gases are also rich in NO<sub>x</sub>. Krasnov has shown that **GreenFuel's** method will not be economically feasible. **“Fundamental thermodynamic constraints make it impossible for the approach to be commercially viable for fuel prices below \$800/bbl, even with flawless technological implementation.”**

**Algae frontrunner GreenFuel Technologies closes doors**  
*May 13, 2009 -- Harvard-MIT algae company winds down after spending \$70 million since 2001*





Simple, in principle  
... Integrated Symmetric  
Concentrator design shown

Financially, its like building large  
solar “Hoover dams” in high orbit.

# Advantages of Space Solar Power

1. SSP is “**baseload**” available 99% of the year from GeoSynchronous Orbit. Baseload nuclear or coal plants, are actually available only 90% of the year. It ignores clouds, night, wind and dirt. Windmills or ground solar are intermittent, providing power for 25-30% of a day typically.
2. SPS requires no fuel – zero pollution – and has no operations personnel – it is an antenna with farms underneath. (rectenna is the proper term). SSP is the *cleanest* source of virtually unlimited *baseload* energy.

# Advantages of Space Solar Power

3. SSP takes advantage of our historic investment in aerospace and other technical expertise to increase STEM jobs. SSP technology is near-term-available with multiple attractive approaches and would create millions of inspiring and important jobs.
4. SSP would revitalize America by taking advantage of a multitude of space-development-related technologies that are vitally relevant to our current problems, including

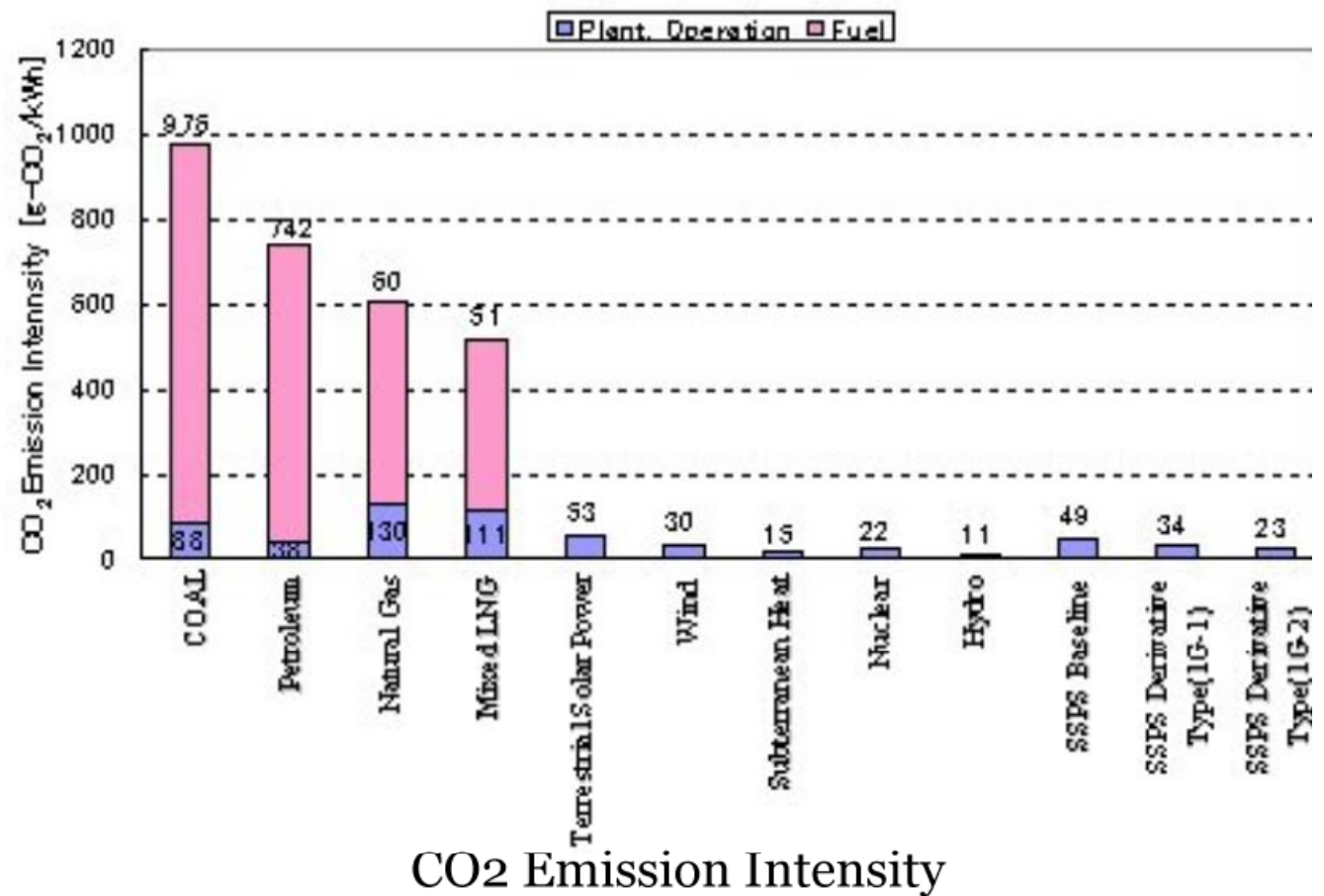
space transportation      telerobotics      space communications  
wireless power transfer      photovoltaics      aerospace and other engineering  
environmental science      control systems      space environmental weather  
clean energy competition

# Advantages of Space Solar Power

5. Unlike oil, gas, ethanol, bio-fuel, and coal, SSP emits no CO<sub>2</sub>. It is an antenna (or rectenna)! Rising CO<sub>2</sub> drives climate change, compounding our massive and growing environmental problems:
  - ✓ Slowly declining global nutrition, since most plants, such as rice and wheat, are critically dependent on CO<sub>2</sub> levels.
  - ✓ CO<sub>2</sub> linked weather changes from drought to hurricanes that we are barely beginning to understand.

# SSP emits no CO<sub>2</sub> - it is a rectenna

Rising CO<sub>2</sub> drives climate change; slowly declining global nutrition, since most plants, such as rice and wheat, are critically dependent on CO<sub>2</sub> levels and weather changes from drought to hurricanes.



Source: JAXA - [www.usef.or.jp/english/f3\\_project/frame\\_3.htm](http://www.usef.or.jp/english/f3_project/frame_3.htm)

# Advantages of Space Solar Power

Drought & Competition for Water - Today's average coal-fired power plant withdraws 25,000 gallons of river water to provide an average household with 1,000 kilowatt-hours a month; 31,000 gallons if nuclear-fired. Output water must be carefully monitored, especially in summer, to avoid fish kills from dangerously higher water temperatures. Newer "closed loop" power systems that rely on cooling towers use less water, but "consume" much more - over 70 percent of the water withdrawn.

- "Energy Risk – Sinking Water and Rising Tensions", December 7, 2007, by [Ken Silverstein, EnergyBiz Insider, Editor-in-Chief,](http://www.riskcenter.com/story.php?id=15710)

It takes 9,100 liters of water to make one liter of biodiesel fuel. – "Report Warns of Rising Water Demand", November 23, 2009, by Robert P. Walzer <http://greeninc.nytimes.com/2009/11/23/report-warns-of-rising-water-demand/>



# Advantages of Space Solar Power

7. SSP would reduce competition for other scarce resources besides water. E.g. Thin film PV uses much less energy to make, as it is 1% as thick as crystalline silicon - regular PV, while yielding 9.6 times as much daily energy in GSO.

# Advantages of Space Solar Power

8. Liquid fuels can be made from SSP power, water and air, such as anhydrous ammonia which is moved in the same pipelines as gasoline. It is 111 octane, with the same energy (MJ/kg) as methanol. We have been making liquid ammonia for 50 years for farming. It fueled the X-15 rocket plane! For further background visit the ammonia (NH<sub>3</sub>) fuel association:  
[http://www.nh3fuelassociation.org/index.php?option=com\\_content&id=15&Itemid=74](http://www.nh3fuelassociation.org/index.php?option=com_content&id=15&Itemid=74)

# Advantages of Space Solar Power

9. Valuable farm land, forest and wetlands is not wasted. Ground solar takes 100 times as much land usage to provide the same power as *baseload SSP!!*

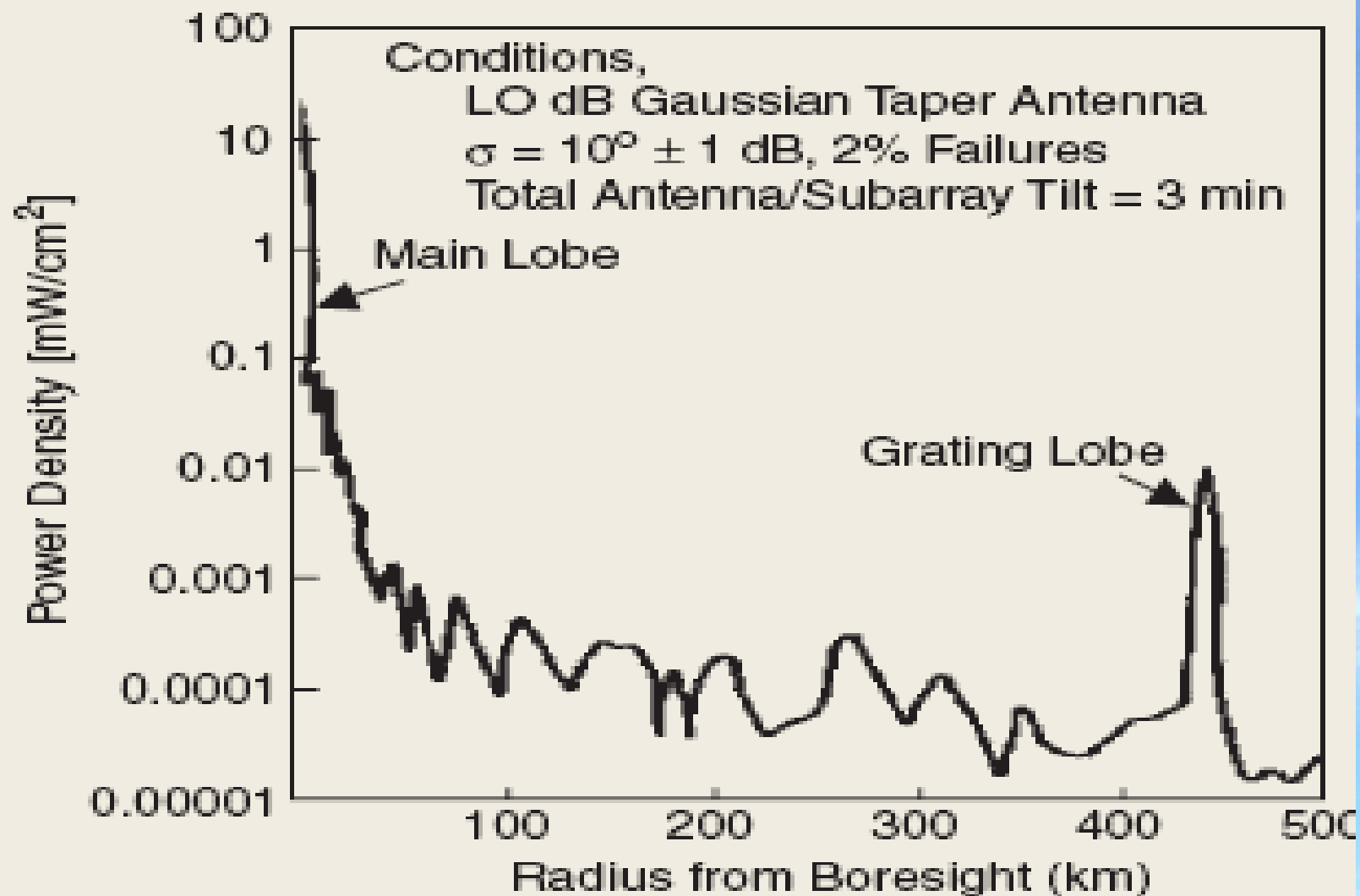


Terrestrial Solar Farm



Illustration of SBSP Rectenna

*Credit: MAFIC Studios*



Predicted ground-level microwave power density for a full-power GEO SPS as a function of distance from the rectenna.

Credit: J. M. Osepchuk, IEEE Microwave, "How Safe Are Microwaves and Solar Power from Space", *IEEE Microwave magazine*, vol. 3, issue 4. page 58-64, Dec. 2002.

# Advantages of Space Solar Power

10. Unlike bio-ethanol or bio-diesel, SSP does not compete for increasingly valuable natural-gas-derived fertilizer. Corn can continue to be a major export instead of a fuel to burn, while raising the prices of other foods from milk and eggs to cheese, hamburgers and Jack Daniels.
11. Unlike nuclear power plants, SSP will not produce hazardous waste, invite nuclear weapons proliferate, or provide targets for terrorists.

# Advantages of Space Solar Power

12. Unlike coal and nuclear fuels, SSP does not require environmentally problematic mining operations.
13. SSP can provide true energy independence for the nations that develop it, reducing hostile competition for limited Earth-based energy resources and dependence on unstable foreign oil providers.

# Advantages of Space Solar Power

14. SSP can be easily exported anywhere in the world. Contracting local utilities can provide it's energy to local needs from household appliances in rural India to desalination of sea water in Australia.

Only local utilities can provide the massive customer load SSP naturally delivers with currently available technology. They would build and own the rectenna, which would be part of their transmission grid, partners with their SSP company - Sunsat Corp.

# Advantages of Space Solar Power

15. Low cost launch - Only SSP can provide a market large enough to develop the low-cost space transportation system required to enable an SSP business case. This low-cost space transport will open the solar system to Earth's economic reach and even settlement, but only Sunsat Corp. can and must incentivize the low cost orbital space transportation market it requires to close its business case.



# Advantages of Space Solar Power

16. Sunsat Corp should have no financial stake in lunar settlement, but may enable it by being a major customer for products manufactured on the Moon. It is twenty-two times more energy efficient to bring products from the Moon than Earth. Asteroid miners are already building business cases for cis-lunar mining based on lower launch costs.

Asteroid protection becomes more vital to not only protect Earth, but also a large assortment of jumbo satellites. For more information see <http://www.b612foundation.org>

# Google LUNAR X PRIZE

PRIZE DETAILS

THE TEAMS

EDUCATION

MEDIA

STAFF BLOG

ABOUT

## PRIZE DETAILS HOME



The Google Lunar X PRIZE is igniting a new era of lunar exploration by offering the largest international incentive prize of all time. A total of \$30 million in prizes are available to the first privately funded teams to safely land a robot on the surface of the Moon, have that robot travel 500 meters over the lunar surface, and send video, images and data back to the Earth. Teams must be at least 90% privately funded, though commercially reasonable sales to government customers are allowed without limit.

Team registration for the competition closed on December 31, 2010. There are currently **26 teams** located around the world who are fundraising, mission planning, and building robots in a new race to the Moon -- what we like to call, "Moon 2.0". The teams have until the end of 2015 to get to the Moon, meet the

prize objectives, and win the prize purses.

# Advantages of Space Solar Power

17. Eventually Sunsat Corp could provide much of its own fuel, through electromagnetic launch which even now could be developed as a first stage. See [www.ga.com/atg/EMS/emals.php](http://www.ga.com/atg/EMS/emals.php)

# So How do we build SSP?

No company(s) or agency(s), however, is prepared to assume the immense financial risk of initiating construction of an SSPS.

There are simply too many engineering, financial, regulatory and managerial risks for any group we have been able to identify to undertake SSP today.

But this road has been well traveled by America before ...

There is a tried and true vehicle, that could initiate SSP construction today.

A private Congressionally chartered corporation has all the requisite advantages. Comsat Corp., chartered in 1962, opened space for communication satellites - when we knew little about space, rockets or space communications. Communications satellites are now a \$100+ Billion industry per year. The “Sunsat Act” would accomplish the same task, creating a space solar power industry of much greater size.



## Trans-Continental Railroad

“Cape Horn at The Head of The Great American Canon”,

- *Frank Leslie's Illustrated Newspaper*, April 27, 1878

Congress chartered Comsat Corp. in 1962 to build communications satellites. Comsat Corp. opened space to the diverse \$100+ Billion per year communications satellite business of today. Congress should charter a new corporation, Sunsat Corp. to build *power* satellites. Draft legislation for Sunsat, very much like Comsat, would have all the requisite advantages. We recommend that congress charter Sunsat Corp.

The electric power industry is the most capital intensive business in the world. This is why utilities are generally regulated monopolies – because ownership of major power plants is really a public trust. Sunsat also needs to be organized the same way.

This legislation would provide a launch “subsidy” to **new** private or public/ private businesses, such as SunSat Corp, which are contracting for space transportation. This subsidy would be in the form of stock transfers and loan guarantees.

Sunsat Corp. would require thousands of flights per year. Prices would quickly fall below current levels once subsidies established such a market volume.



## The Path of Space Solar Power

Global Solar Market to reach \$75.2 Billion and 227 GW (peak installed output) by 2016

"Development of remote regions, the substitution of nuclear reactors with renewable sources and technological innovations such as **space solar power generation** are the main market opportunities responsible for compounded annual growth rate of 30.3 percent in annual solar power installations in the next five years," a briefing on the report provided to **pv magazine** said. ...

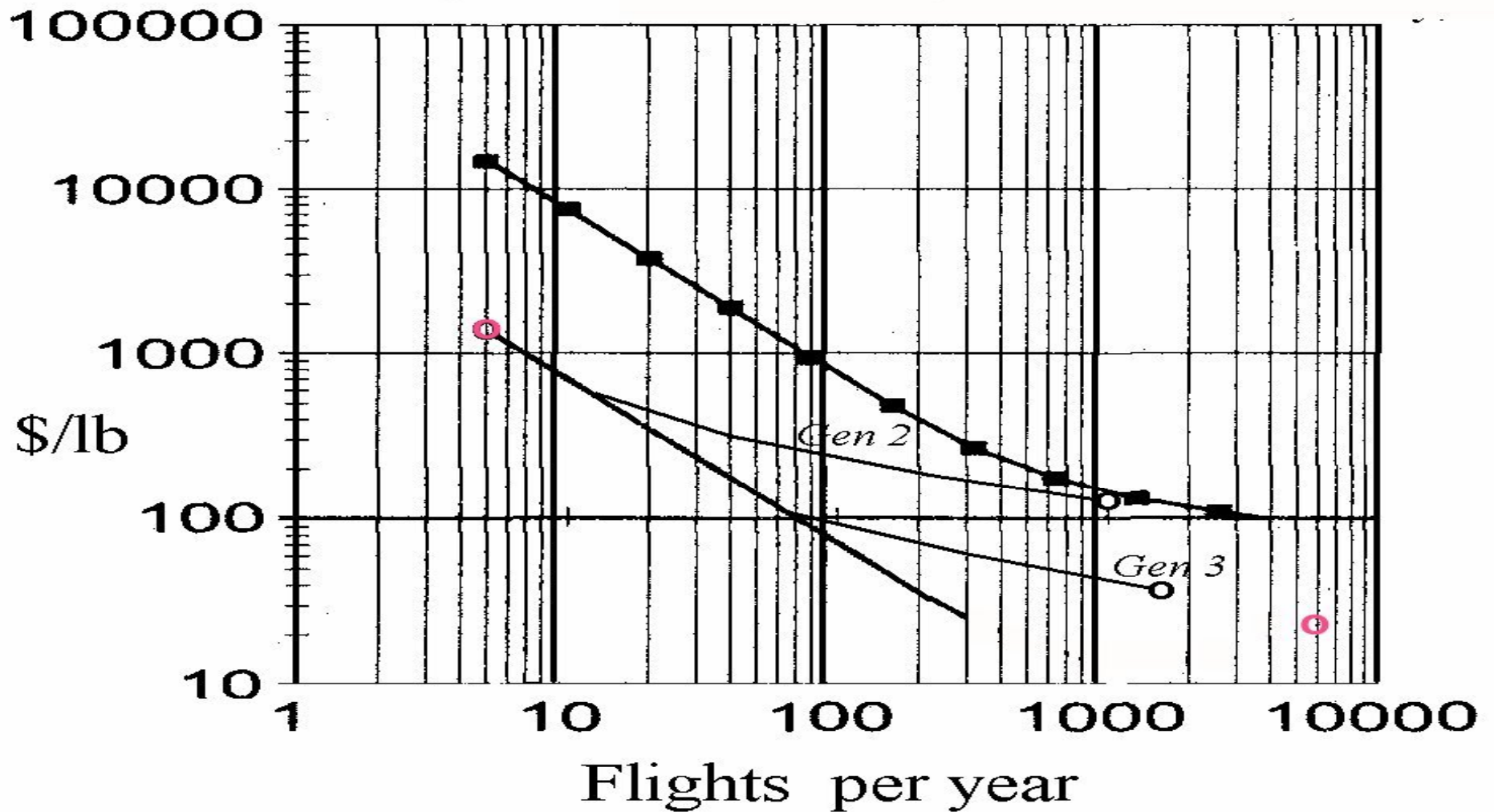
"CSP technologies are expected to grow at a faster rate than photovoltaics due to new markets like China, India, Brazil, Canada, Germany, and France opening up, as they look to exploit the newest technologies. ...

# Prices drop as flight rate increases

Red dots are Elon Musk, SpaceX, \$1300/lb and Roger Angel's \$20/lb (Sandia electromagnetic launch)

## More Flights, Lower Cost

○ Cheap Rides? Falcon9, Dnepr, Kistler, ISRO Avatar, .?



FAA's 2008 & 2009 Commercial Space Transportation Forecasts show a declining launch market – no improvement in launch costs – necessary for SSP. SSP must incentivize the orbital market fleet it needs to close the business case. SSP is the only market capable of doing this. The FAA shows it won't happen with business as usual assumptions, we need the Sunsat Act.

Table 1. Commercial Space Transportation Satellite and Launch Forecasts

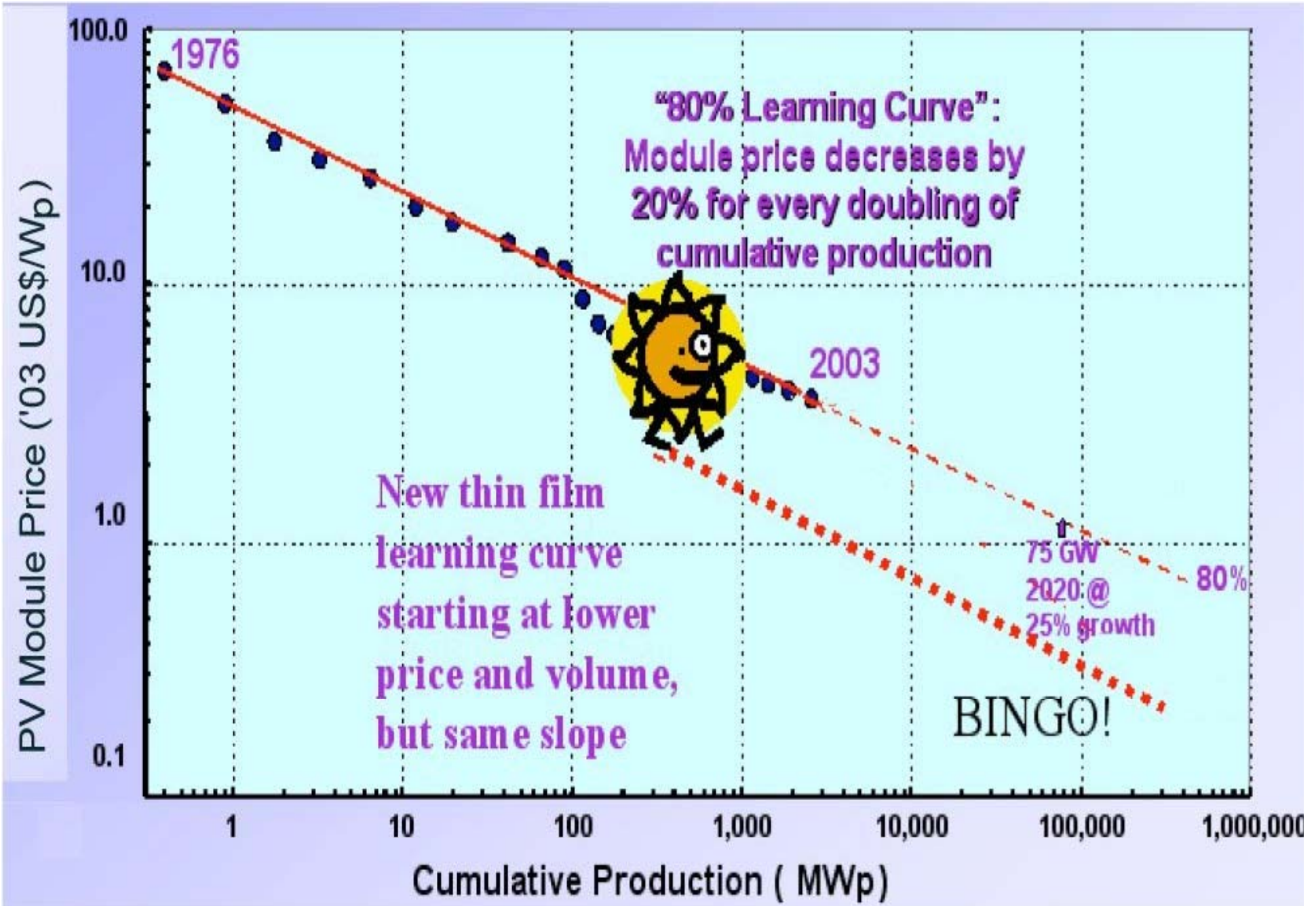
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total	Average
<b>Satellites</b>												
GSO Forecast (COMSTAC)	27	27	23	22	21	21	20	19	19	19	218	21.8
NGSO Forecast (FAA)	24	27	37	29	25	9	38	41	36	10	276	27.6
<b>Total Satellites</b>	<b>51</b>	<b>54</b>	<b>60</b>	<b>51</b>	<b>46</b>	<b>30</b>	<b>58</b>	<b>60</b>	<b>55</b>	<b>29</b>	<b>494</b>	<b>49.4</b>
<b>Launch Demand</b>												
GSO Medium-to-Heavy	22	23	18	16	15	15	14	13	13	13	162	16.2
NGSO Medium-to-Heavy	5	10	6	6	10	4	13	12	11	4	81	8.1
NGSO Small	6	2	5	5	2	2	2	2	2	3	31	3.1
<b>Total Launches</b>	<b>33</b>	<b>35</b>	<b>29</b>	<b>27</b>	<b>27</b>	<b>21</b>	<b>29</b>	<b>27</b>	<b>26</b>	<b>20</b>	<b>274</b>	<b>27.4</b>

# *Space assets must be defended!*

- A dead Russian satellite collided with an Iridium satellite on Feb 10 shocked world satellite community. The crash was not predicted by the U.S. military or private trackers, underscoring the vulnerability of U.S. satellites.
- The Air Force tracks more than 20,000 objects in space, but the actual number of objects is much greater.
- "Our goal is to do conjunction assessment for all 1,300 active satellites ... by the end of the year and provide that information to users," Gen. Chilton told reporters. About 500 of those satellites are not maneuverable.
- We must have an active defense against meteorites and other Near Earth Objects!

- Washington, Nov 3, 2009, by Andrea Shalal-Esa; editing by Alan Elsner and Chris Wilson © Thomson Reuters 2009. All rights reserved.

[www.reuters.com/article/rbssTechMediaTelecomNews/idUSN0351968920091103](http://www.reuters.com/article/rbssTechMediaTelecomNews/idUSN0351968920091103)



Source: Ken Zweibel, NREL

- Continuing - since space transportation is expensive we want to find high performance photovoltaic cells.
- PV efficiency alone is not the right goal we want to increase the power output for the same weight carried to orbit.
- Space qualified thin-film solar cells in the fabline today can provide 16,800 Watts/Kg. These are adequate specifications to begin SSP design and/or construction *now*.

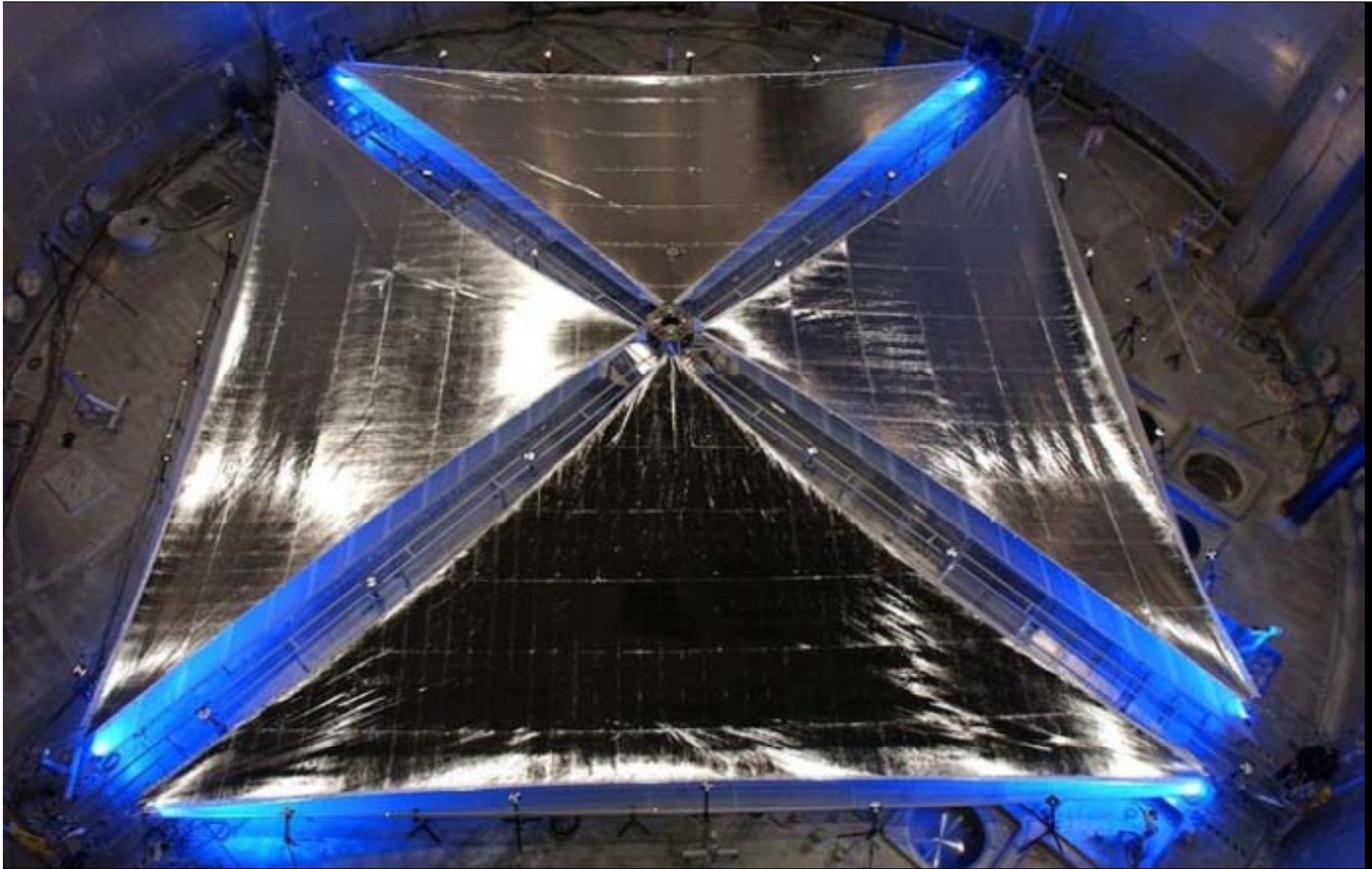
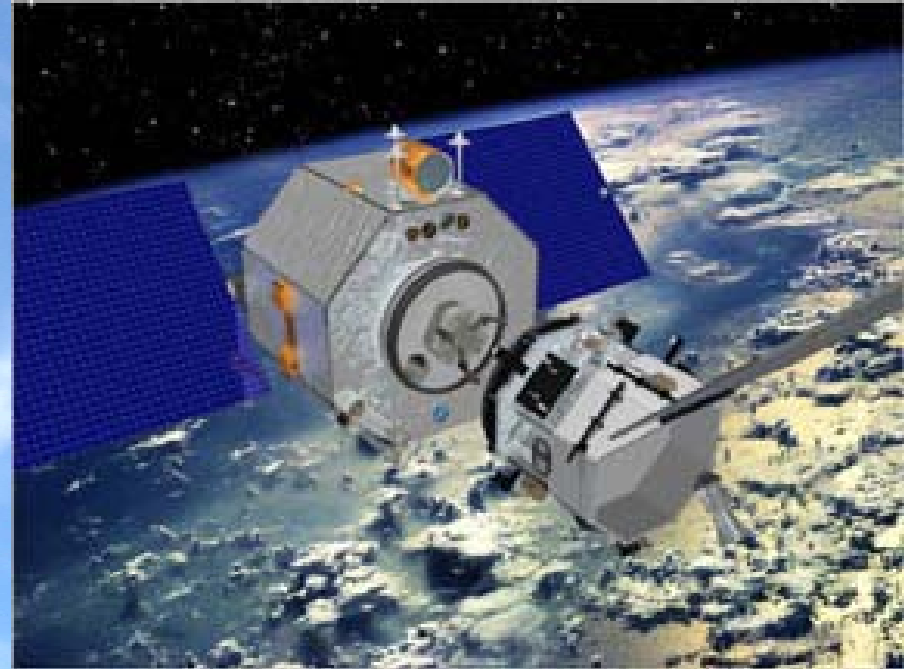


Photo courtesy NASA, and ManTech-SRS  
Technologies

## ASTRO Captures NextSat

On July 23, 2007, for the first time ever, a satellite autonomously rendezvoused with and captured another orbiting satellite, pioneering future robotic work in space. ASTRO (Autonomous Space Transport Robotic

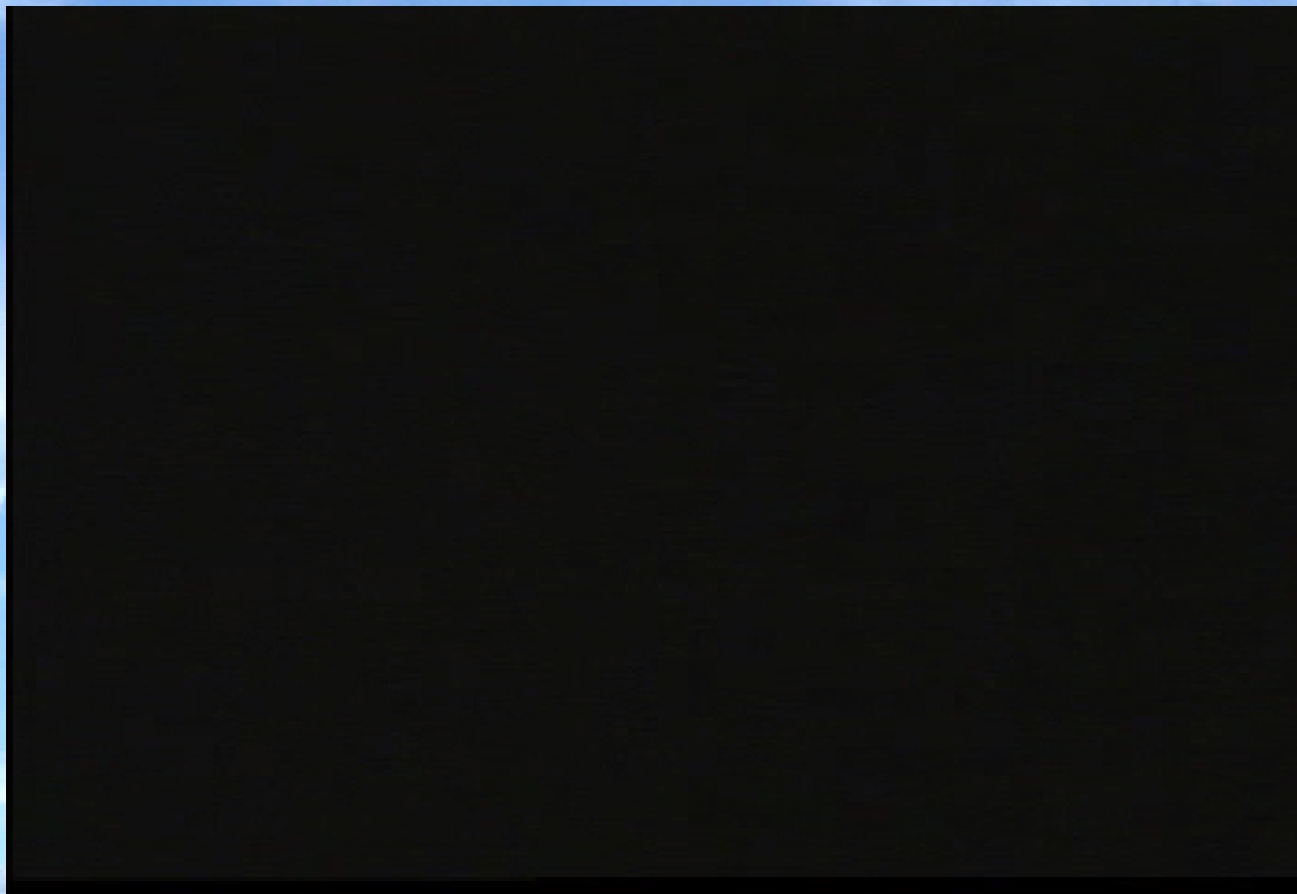


Operations), part of Boeing's Orbital Express system, successfully demonstrated advanced on-orbit satellite refueling and reconfiguration capabilities with NextSat. ASTRO, the robotic, on-orbit spacecraft mechanic, successfully captured NextSat. Orbital Express is a DARPA program which has validated on-orbit satellite servicing technologies.



# SkyWorker

an autonomous robot to build multi-kilometer size space structures



Credit – Red Whitaker, CMU Robotics,  
<http://www.frc.ri.cmu.edu/projects/skyworker/temp/skyworker2.mpg>

Choosing to charter an SSP corporation would be “a small step for man, a giant leap for mankind.”

Space Solar Power Institute

[www.solarsat.org](http://www.solarsat.org)

Draft Sunsat Act legislation and much  
more available at the  
Space Solar Power Workshop

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