Space Solar Power, now called:
Energy From Space & our Future…

World's Presentation Slides

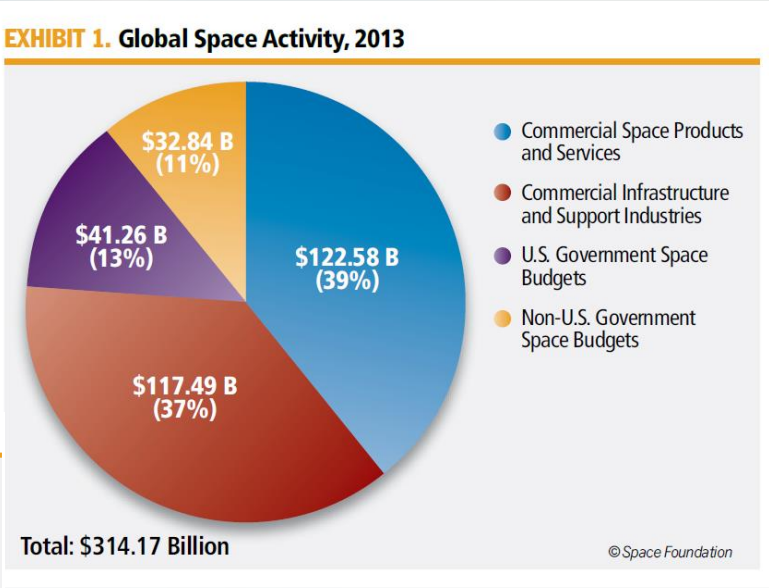
2015 Dr. Dave's twin sister died he cancelled his Presentation, gone to his ethnic homeland, UK

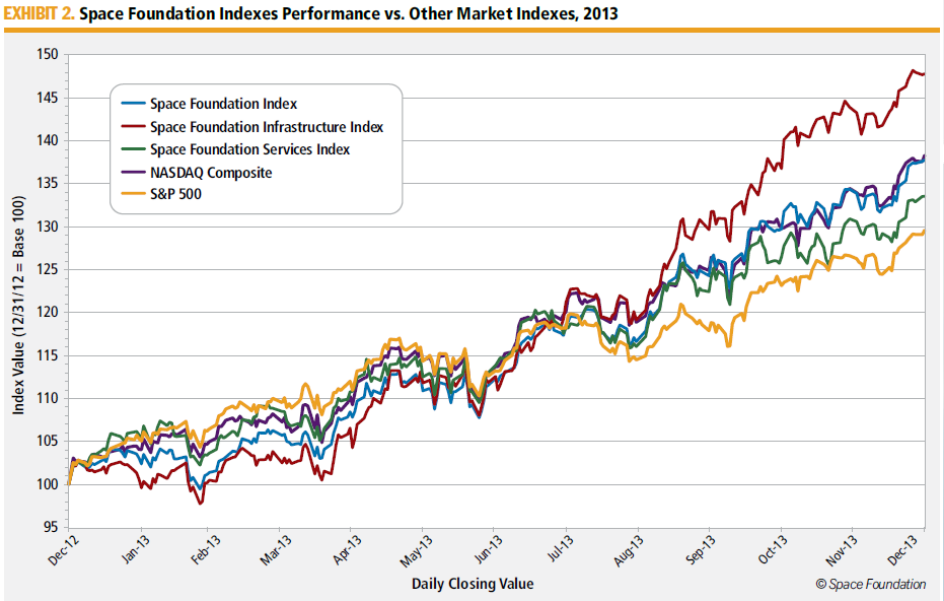
This Program Leads to World Peace!

Please linkedin to me, so I may keep you up to date & maybe help someday. Use: shawnboike@aol.com, my email is: spboike@gmail.com or spboike@solutioncell.net Ph:562-343-5660

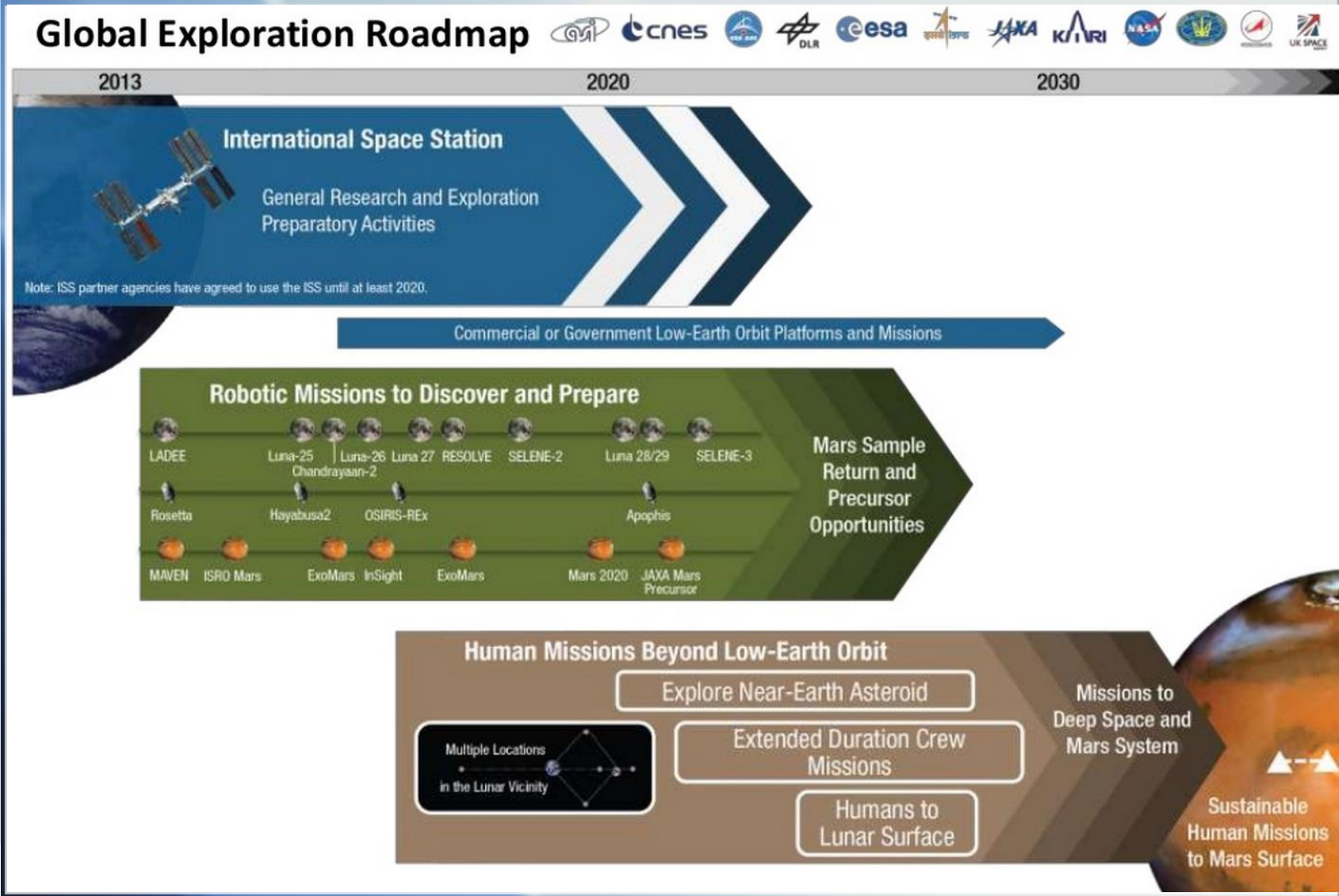
Space, Energy & Engineering the Future!

- **Goal: The Future!: How to:**
  - ***Make Space Valuable & to All Forever…***
  - ***Marketplace Value:***
  - ***Increasing 75%/yr.***
    Recent year is >$530B

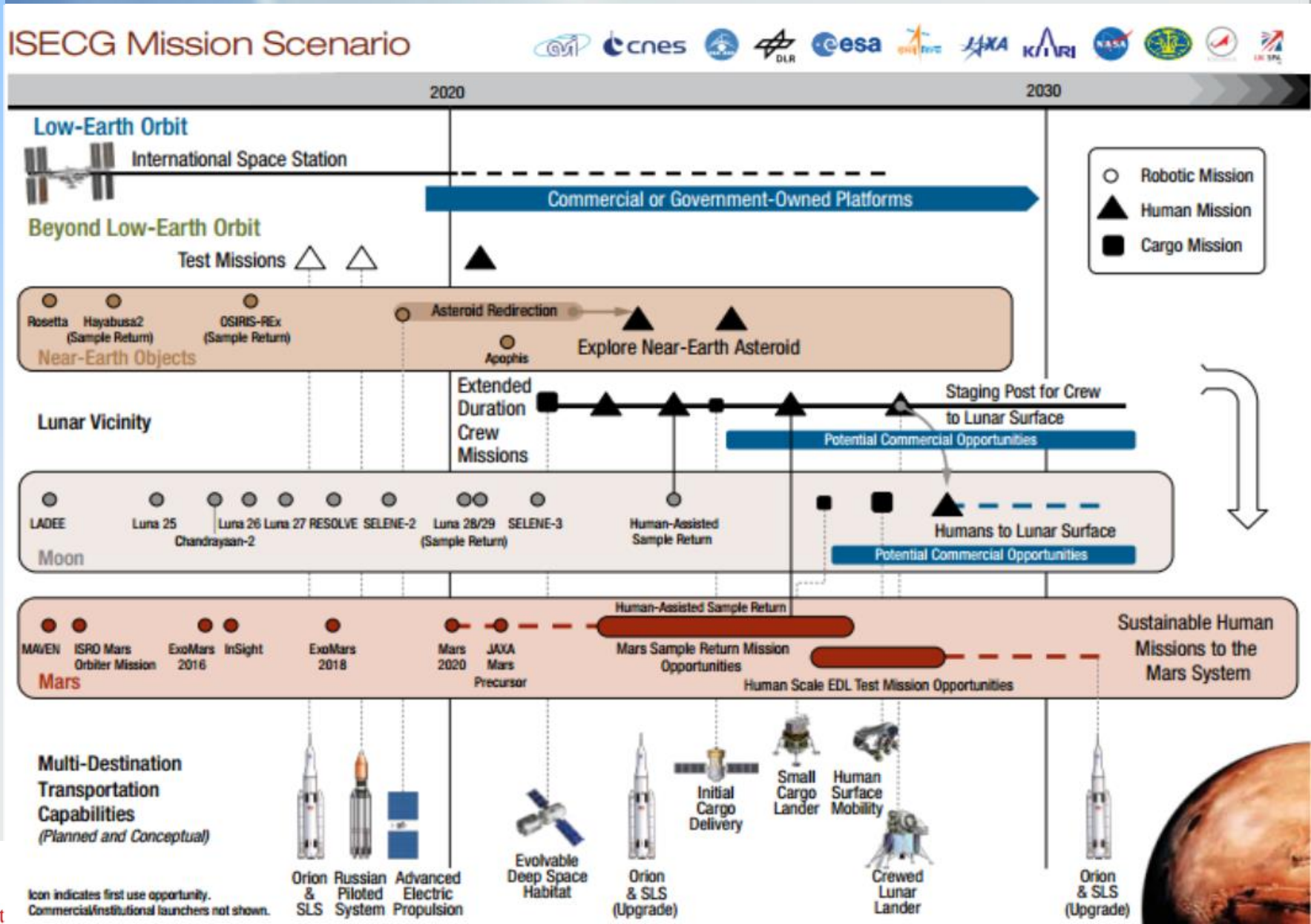




Space Exploration map

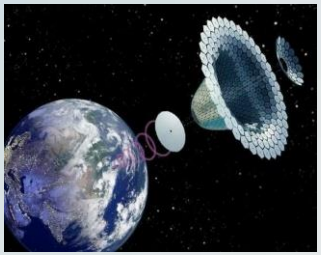


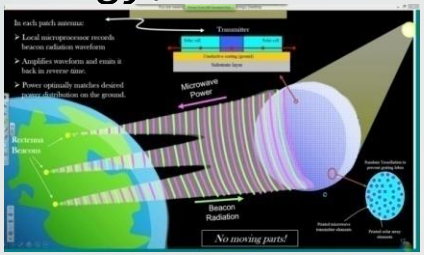
Space Plans- 25 Years



What are **Space Energy** Programs ?

- **<u>Many</u> Space Energy** Producing **Satellites**
  - *Beaming Energy & Communications down to Earth's Collectors*
  - *Various types of Satellites >10% Energy, no 1 fits all, or all purposes…*





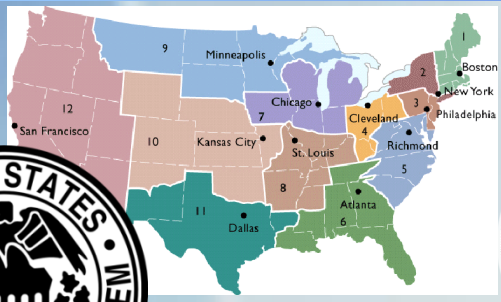
- A **few Maintenance & Tow Spaceships**
  - ***Keeping them*** *in proper* ***Orbit*** *&* *Upgraded* ***Functionality…***
- **Captured Space Debris**; junk (yard) gathering.
- **New Space Station** for: Research, Materials, grinding, sorting & 3D Printing for Repair & Mfg.
- **Control Centers** with Predictability & Simulation
  - ***Projected*** *on a large* ***Science On A Sphere, 3D capable***
  - ***Transparency*** *& Viewing Available to All* ***(****within reason)*

Where Do We Start?

- **Investors Start on the Satellite #1 Concern**
  - ***Develop Systems & Build Prototypes 1st in gets rich 1st.***
- **Perform all Studies listed** in this presentation…
- **"Grow the Teams" & get Public, Business & Government "awareness & funding"…**
- **Design & Simulation** the **Satellites**
  - *Hyland's* ***Powerstar*** *& Mankin's* ***Alpha 1***
- **Have Universities get re-educated on this Subject & away from old, outdated courses.**
- ***Make this a Worldwide incentivized Program$***
  - ***17 Trillion/Year Industry getting much bigger***

Funding & Teams

Private & Foreign Investors $$B



http://www.energybackedmoney.com/chapter1.html

Since we left the Gold Std. Currently Oil is tied to US Dollar

"The Federal Reserve sets the nation's monetary policy to promote the objectives of maximum employment, stable prices, and moderate long-term interest rates."[5] - The Federal Reserve

http://www.energy.gov/maps/space-based-solar-power

http://www.energy.gov/maps

Goal & Objectives

- **The Goal:** ***Develop the Best Energy from Space System to help save us, our planet & produce the Most Value & Best Bang for the Buck! Aid in World Peace…***
- **Objectives:**

1. **Build the Right Team** for Funding, Development and Implementation (No Big Companies that Swallow Time & Money too much with little value to show for it, *my old employers use to be Great*-eg, Lockheed, Boeing, etc.).
2. **Build the Right Systems for the Right Purposes;** Not 1 System is a Cure All, it depends on Purpose & Priority.
3. **Perform** Professional Systematic Networked Approach to Develop what is the Right System Choice(s) Hybrid System Achieving Goal & Priorities in the Efficient means without Waste or Loss.
4. **Use Simulation** in all Aspects for Engineering Answers & run multiple models.
5. **Perform** "Real Hyperlinked Logical Decision Making" **Formal Trade Studies** for Results (Data & No Egos).

Reason 1, Save US All…

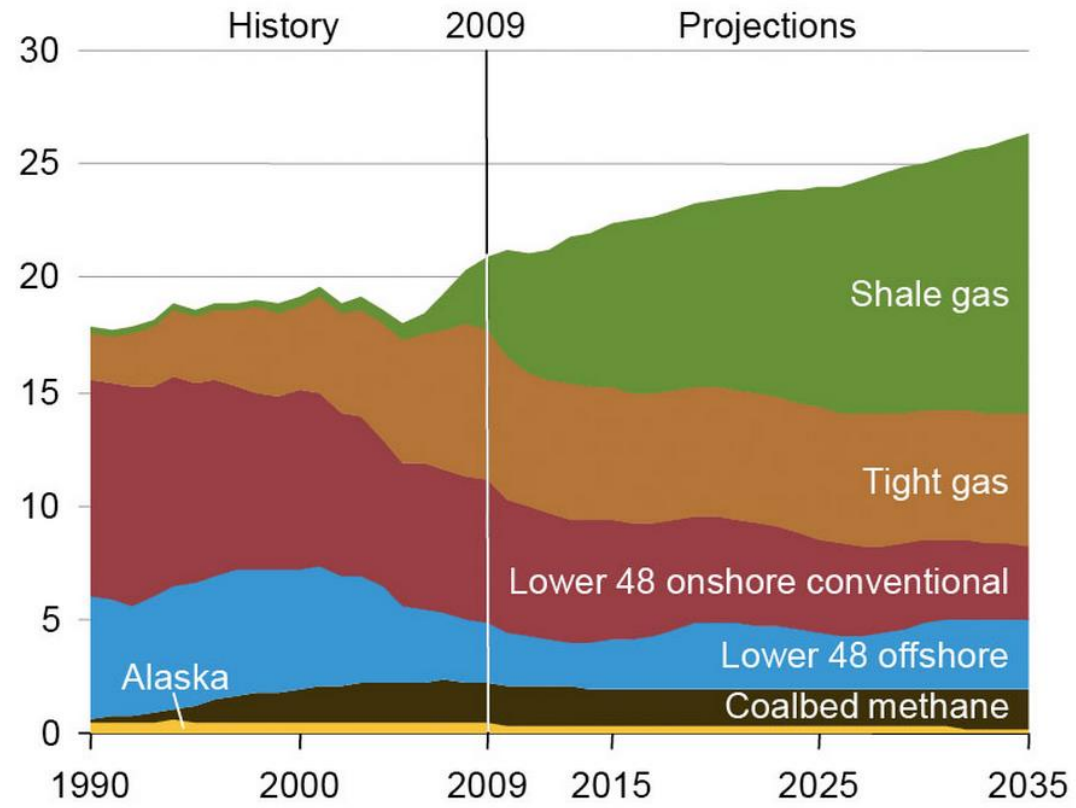
- **Weather/Climate Change & Ice Melt:**
  - **http://www.whitehouse.gov/climate-change**
  - May 19, 2014, **RELEASE 14-141**
    Hidden Greenland Canyons Mean More Sea Level Rise

    http://www.nasa.gov/press/2014/may/hidden-greenland-canyons-mean-more-sea-level-rise/#.U3rXWBBdV8F
  - **Ice loss from Greenland has accelerated during the last few decades**. However, older ice sheet models predicted the speedup would be temporary because **the glaciers would soon melt back onto higher ground and stabilize**. The models projected that Greenland's contribution to global **sea level rise would therefore be limited.**

- **2012 Surface Melt of Greenland Ice Sheet Driven by Combined Effects of Rising Temperatures and Ash from Forest Fires**
  - http://www.nsf.gov/news/news_summ.jsp?cntn_id=131422&WT.mc_id=USNSF_51&WT.mc_ev=click
  - If, as expected, Arctic temperatures and the frequency of forest fires increase with climate change, the researchers' results suggest that large-scale melt events on the Greenland ice sheet may begin to occur almost annually by the end of century. These events are likely to alter the surface mass-balance of the ice sheet, leaving the surface susceptible to further melting. The **Greenland ice sheet is the second largest ice body in the world after the Antarctic ice sheet.**

Our Polluting Energy

- ***Our addiction is the "Real Culprit"***



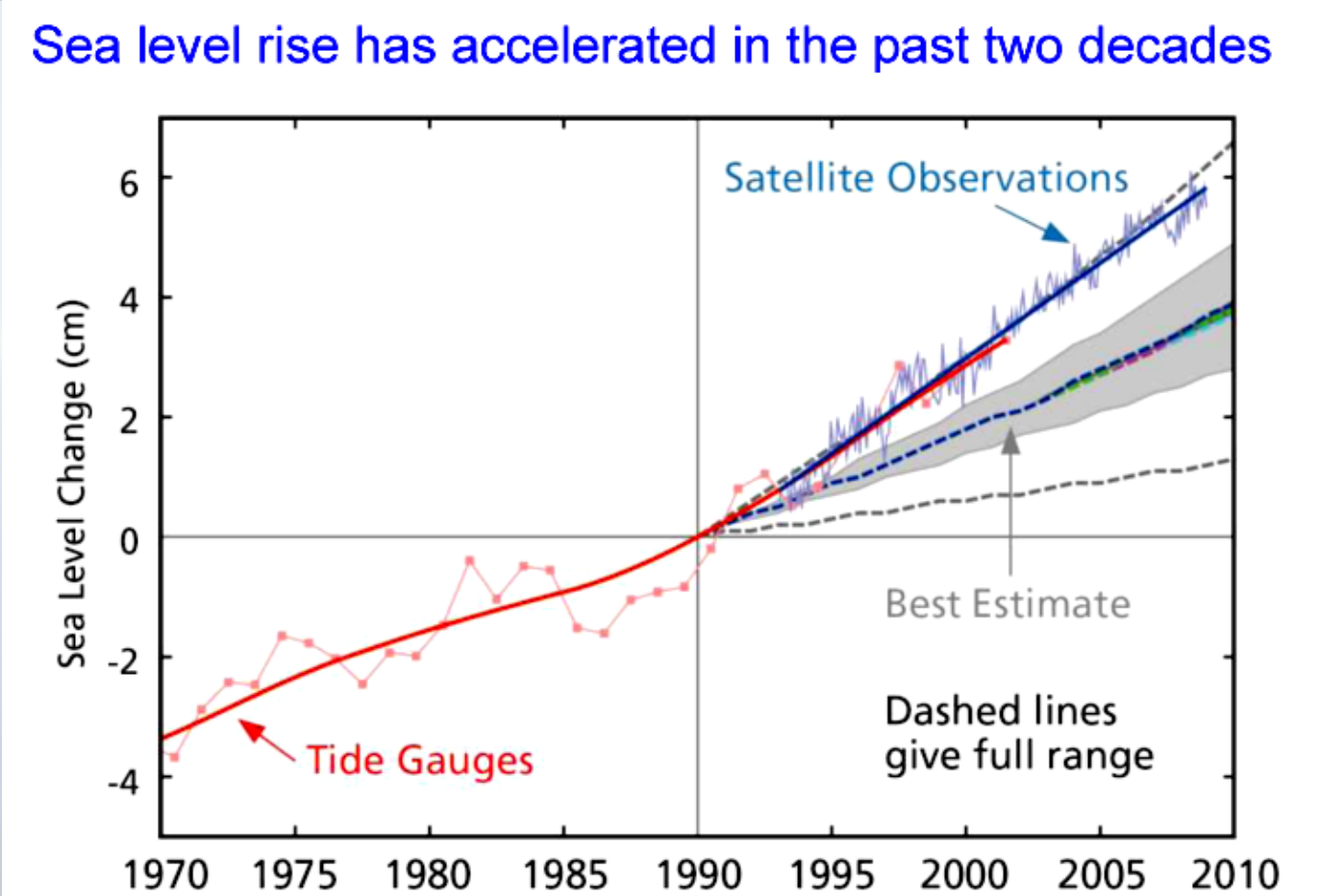
Trillions of cubic feet per year, U.S. natural gas production, 1990-2035. EIA, *Annual Energy Outlook 2011*, U.S. Energy Information Administration, U.S. Department of Energy, Washington, DC, April 26, 2011, p. 3

Reason 2, Earth's Water Crisis

- **Water in the Future:**
  http://growingblue.com/water-in-2050/#?1#?1#WebrootPlugIn#?1#?1#PhreshPhish#?1#?1#agtpwd
- A Must See Documentary; ***The Future Of Water***
- **Floods** will increase
- **Droughts & Fires** will **increase**
- **Tornadoes & Hurricanes** will increase
- **Famines & pestilence** will follow
- **We Can Save US All…**
  - Desalination powered from Space
  - Taming & Controlling Weather

Sea Level Rise / Ice Melt

- ***The Real Truth from our Addiction***



Reason 3, Supply World's Energy

- **World consumes >132 Terra-watts hours per year.**
- **Develop Energy From Space for >100%** (2X=Best)
  - Do Not go after transportation nor anti-oil, just provide the grids.
- This can back the **Federal Reserve** Value for Centuries.
- Provide Crisis Energy ASAP (2-3 days) <1 week for Floods, Fires, Hurricanes, WARS…
- Provide Worldwide **Communications** along with **Energy**.
- **Better than Nukes>**

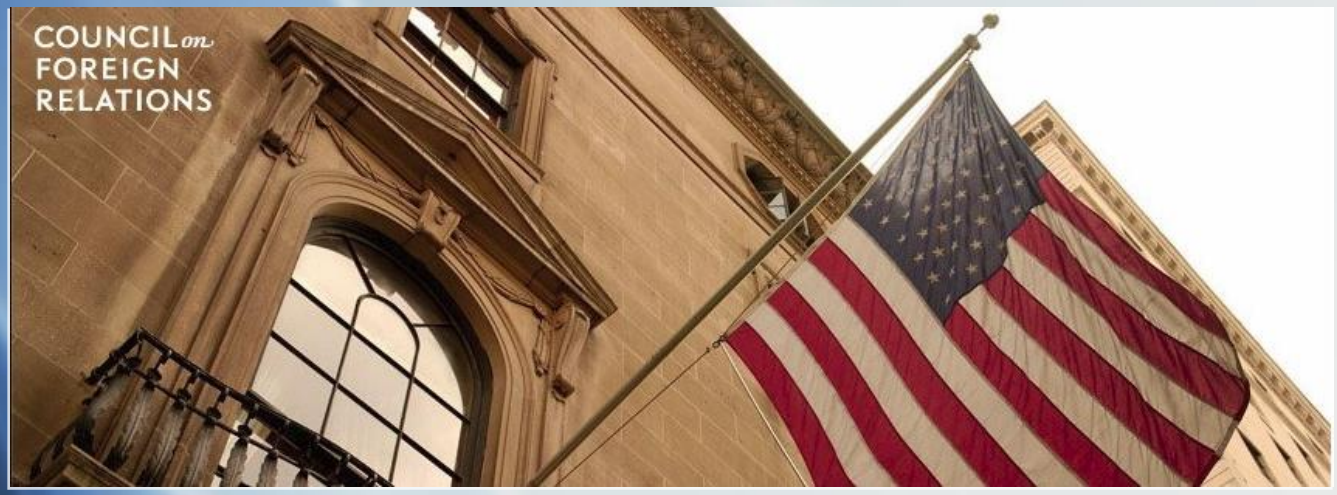
Table 2: Nuclear reactors under construction (as of January 2014)

Unit(s)	Province	Gross capacity (MWe)	Reactor model	Project control	Construction start (m/y)	Operation expected (y or m/y)
Changjiang 1&2	Hainan	2x 650	CNP-600	CNNC & Huaneng	4/10, 11/10	2015, 2015
Fangchenggang 1&2	Guangxi	2x 1080	CPR-1000	CGN	7/10, 12/10	2015, 2016
Fangjiashan* 1&2	Zhejiang	2x 1080	CPR-1000	CNNC	12/08, 7/09	12/13, 10/14
Fuqing 1-4	Fujian	4x 1080	CPR-1000	CNNC	11/08, 6/09, 12/10, 11/12	11/13, 9/14, 7/15, 5/16
Haiyang 1&2	Shandong	2x 1250	AP1000	CPI	9/09, 6/10	12/14, 3/16
Hongyanhe 3&4	Liaoning	2x 1080	CPR-1000	CGN, with CPI	3/09, 8/09	2014, 2015
Ningde 3&4	Fujian	2x 1080	CPR-1000	CGN, with Datang	1/10, 9/10	2014, 2015
Sanmen 1&2	Zhejiang	2x 1250	AP1000	CNNC	4/09, 12/09	12/14, 9/15
Shandong Shidaowan	Shandong	210	HTR-PM	Huaneng	12/12	2017
Taishan 1&2	Guangdong	2x 1750	EPR	CGN	11/09, 4/10	2014, 2015
Tianwan units 3&4	Jiangsu	2x 1060	VVER-1000	CNNC	12/12, 9/13	2018, 2018
Yangjiang 2-4	Guangdong	3x 1080	CPR-1000	CGN	6/09, 11/10, 11/12	2014, 2015, 2017
Yangjiang 5&6	Guangdong	2x 1087	ACPR1000	CGN	9/13, 12/13	2017, 2018
Total (28)		approx. 30,500				

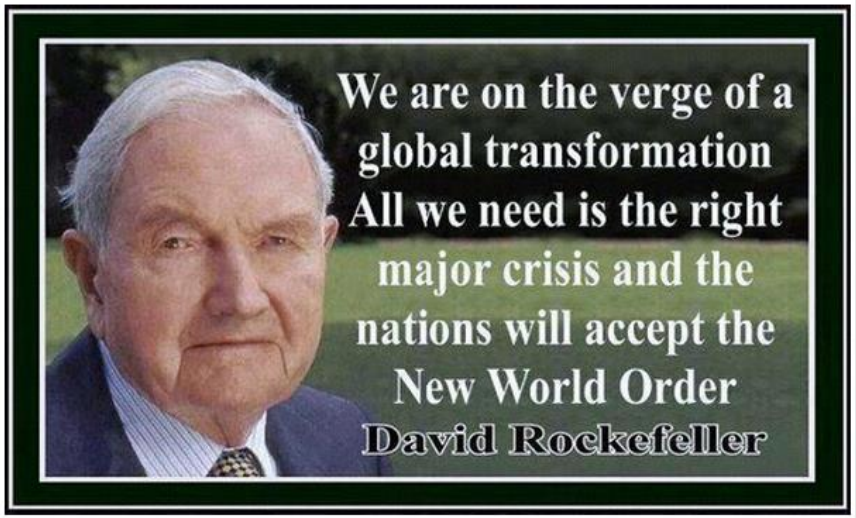
Source: International Atomic Energy Agency

** Fangjiashan is very near to Qinshan 1 and is sometimes referred to as an extension of Qinshan 1, or a new phase of Qinshan*

The Ultimate Goal



YES,
A World without oil dependency…



Analysis of Alternative Energy Sources

Commercial Baseload SBSP must be able to compete with Land Based (Terrestrial) Solar Power, Wind Power, Biofuels, Fossil Fuels, Nuclear Fission and with future sources of energy which have not yet been developed.

This chart compares a number of sources of power with SBSP in terms of their safety, reliability, ability to provide baseload power and whether they qualify as clean and green.

Source	Clean	Safe	Reliable	Base-load
Fossil Fuel	No	Yes	Decades remaining	Yes
Nuclear	No	Yes	Fuel Limited	Yes
Wind Power	Yes	Yes	Intermittent	No
Ground Solar	Yes	Yes	Intermittent	No
Hydro	Yes	Yes	Drought; Complex Scheduling	
Bio-fuels	Yes	Yes	Limited Qty – Competes w/Food	
Space Solar	**Yes**	**Yes**	**Yes**	**Yes**

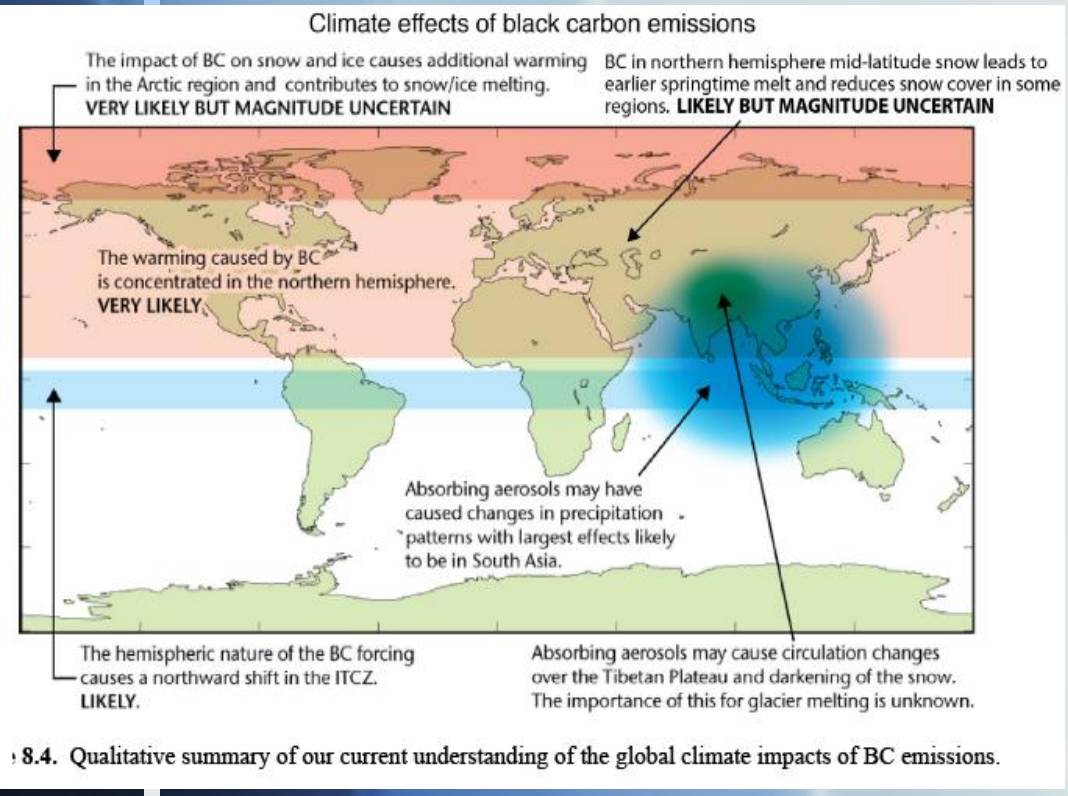
Other speculative energy sources which may come into importance in the future could include fusion. Fusion would be the most comparable to SBSP as it also offers access to, for all immediate purposes, an unlimited supply of energy.

The interest of the public and of investors in alternative energies and fuels is rising rapidly.

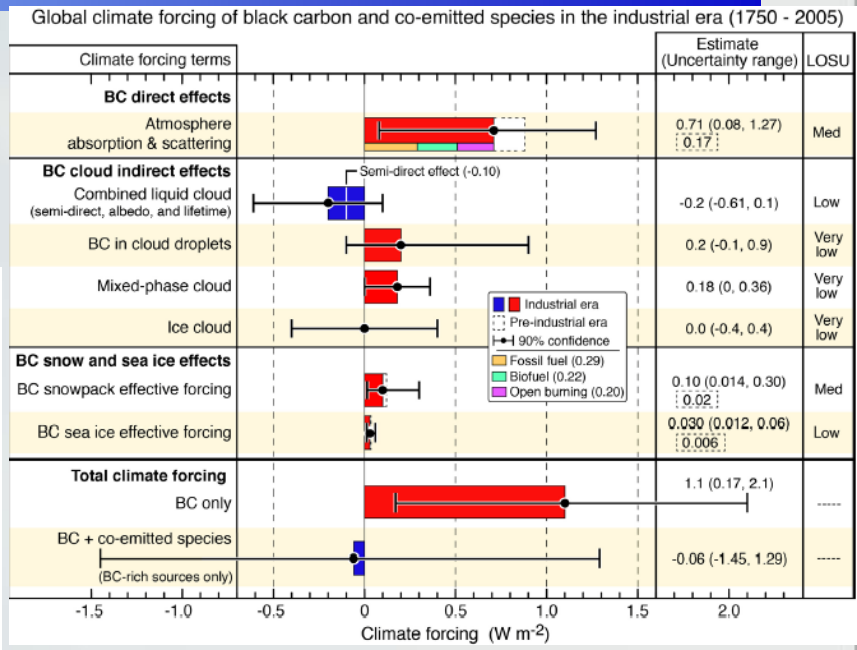
When to Transition to Commercial Sector

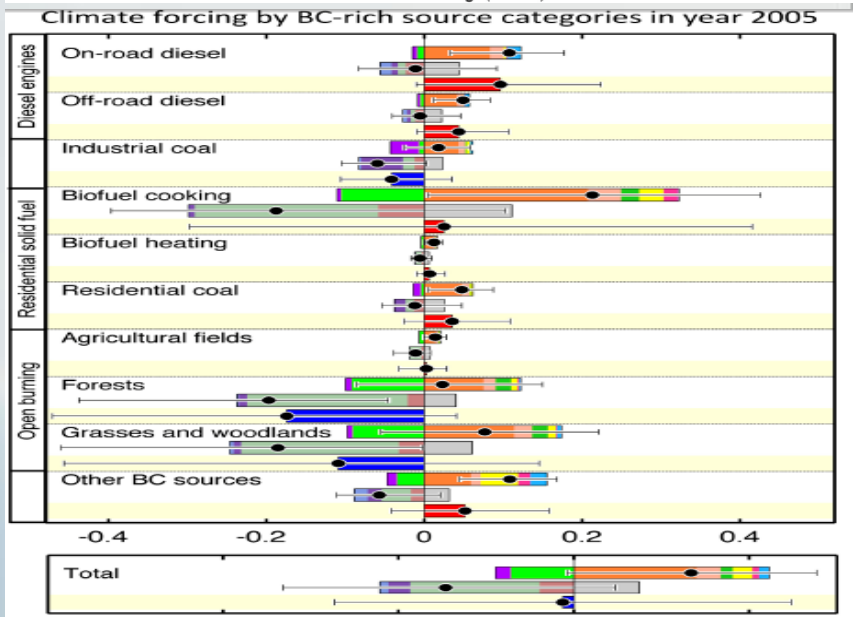
CO2 & Climate

- **Our Atmosphere:**



8.4. Qualitative summary of our current understanding of the global climate impacts of BC emissions.

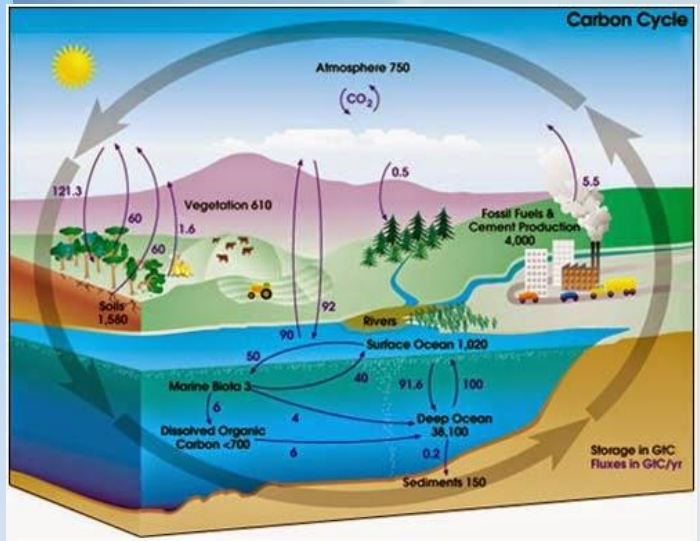


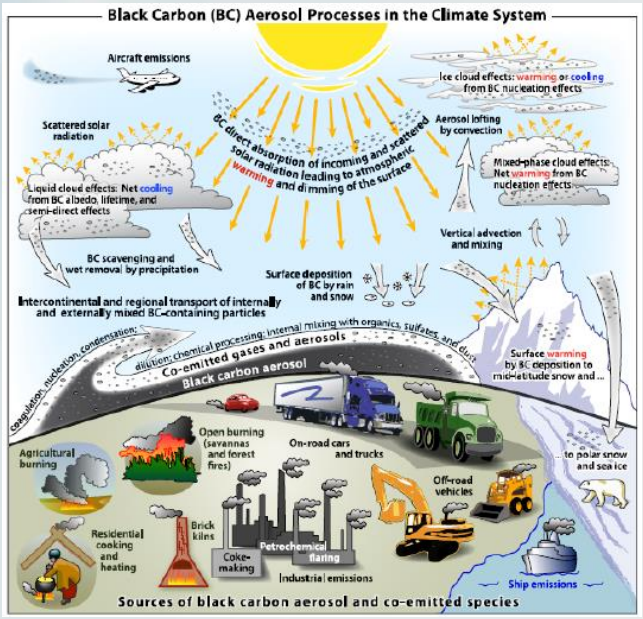


CO2 on Earth

REF Data

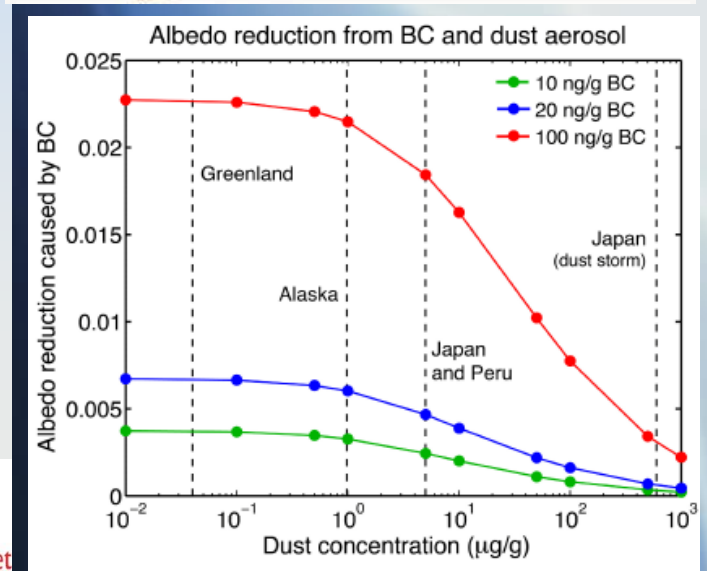
- CO2 effects…

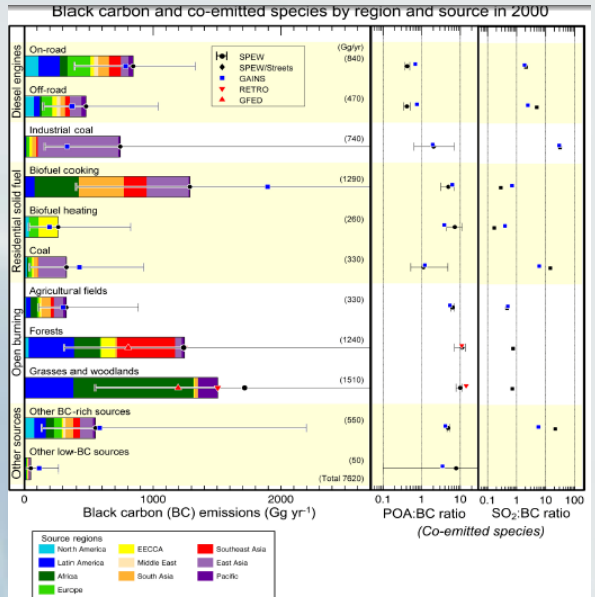


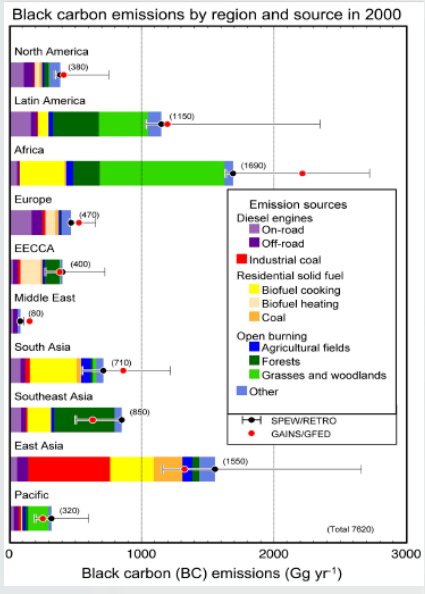


combustion in the year 2000 (Gg yr^{-1}) [a]

Source	Inventory SPEW	Inventory GAINS
Diesel engines		
On-road diesel engines	840	780
Off-road diesel engines	480	370
Total diesel	1320	1150
Industrial coal		
All coal in industry	740	340
Total industrial coal	740	340
Residential solid fuel		
Wood, cooking regions	1000	1580
Other biofuel, cooking regions [b]	290	310
All biofuel, heating regions [b]	260	200
Coal, cooking and heating	330	420
Total residential solid fuel	1880	2510
Other sources		
Non-coal industry, including biofuel	170	30
On-road gasoline engines	110	80
Residential, including diesel generation	100	170
Aviation	20	1 [c]
Shipping	100	40 [d]
Flaring	- [e]	260
All other BC-rich sources	70	20
Power plants [e]	20	20
Other low-BC sources [f]	- [e]	60
Total other sources	590	690
Grand total	4510	4690



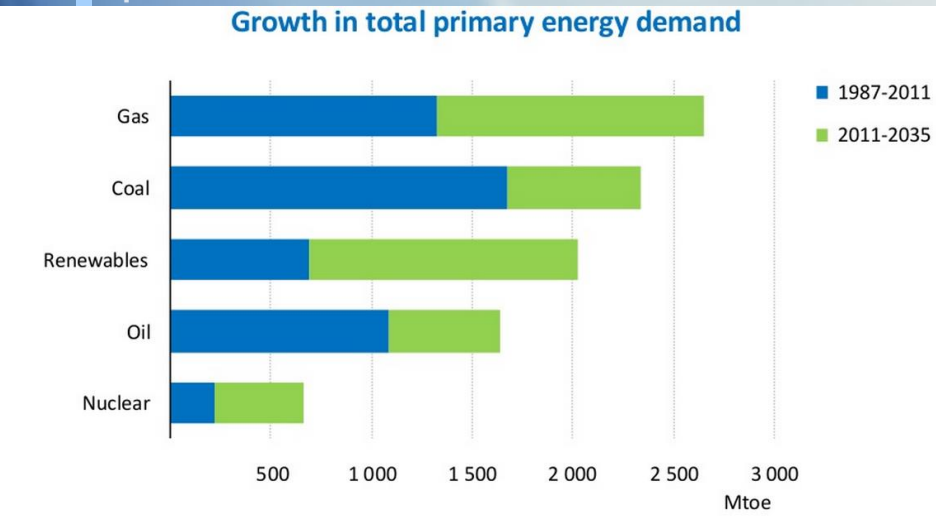


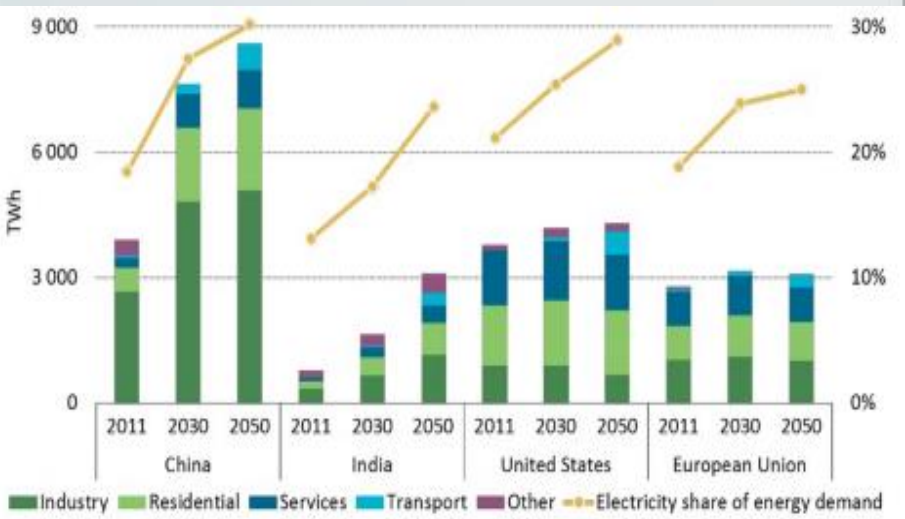


Energy Costs & Forecasts

- **Energy Sales is:**

$17.225 Trillion/Year





25 years ago the share of fossil fuels in the global mix was 82%; it is the same today & the strong rise of renewables in the future only reduces this to around 75% in 2035

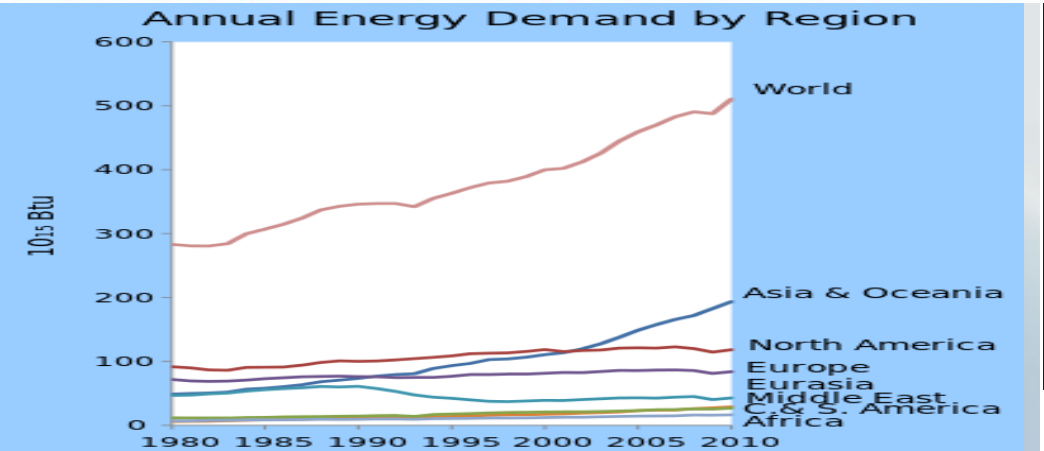


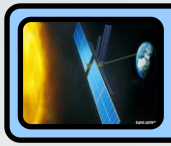
Table 2-1 Current Day (2012) and Forecast Energy/Environment Factors[3]

		2012	2030-40	2060-70	2090-2100
Global Population	High	~7 billion	~9 billion	~11.5+ billion	~12.5+ billion
	Medium	~7 billion	~8.5 billion	~9+ billion	~8.5+ billion
	Low	~7 billion	~7.5 billion	~7+ billion	~5.5+ billion
Current / Projected Global Annual Energy Consumption[4]		~120,000 Billion kWh	~220,000 Billion kWh	~400,000 Billion kWh	~480,000 Billion kWh
Low Renewable Energy Case	Renewable Energy: Low Share Case[5,6]	~10%	~10%	~10%	~10%

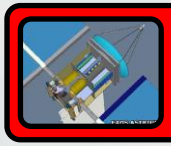
R & D Studies Required

- Each **System** Requires many **Detailed Studies**

1. **Best Solar Satellites**
   - Modular, Expandable, Controllable, etc.
2. **Optimal Beam/Energy Transmission**
   - Laser vs. EB vs. EM microwave…
3. **Selectable Ground Base Collection & Energy Storage System**
4. **Performance Database & Software**
5. **A Full Development & Integration Plan**
6. **The Satellites to be planned & retrofitted with Beam Control; Earth's Weather Control System**
7. **Self Focusing Satellite to Transmit (Tracker) Beams to Transport(s)**
8. **Desalination System**

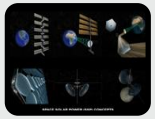


Solar Energy Satellite(s)



Beam Transmit System

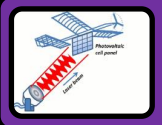
Ground Collector System



Full Turnkey System Integration

Added Purpose

Weather Control System



Tracker Beam-Planets Exploration

Desalination System

R & D Studies (concern)

- 1) if you are interested in this idea, then you should take a look at the Mira-solar (or Mirasolar) design developed by Dr Fraas [inventor of the triple junction solar cell], here are some web links:
  http://nextbigfuture.com/2012/03/mirrors-in-space-for-low-cost.html
  http://jxcrystals.com/solarPV/MiraSolar_Satellite_Concept.pdf

  2) In **LEO** it is not possible to get global coverage from a SSO, because you can only see a small part of the Earth from the altitude of ~1000 kilometres. You can only supply power to the thin strip of the Earth which is near the day/night terminator

  3) for a multi-satellite constellation in **LEO outside of SSO**, to achieve global coverage you need to have thousands of Earth ground stations on day one. For **GEO** you only need one ground station.

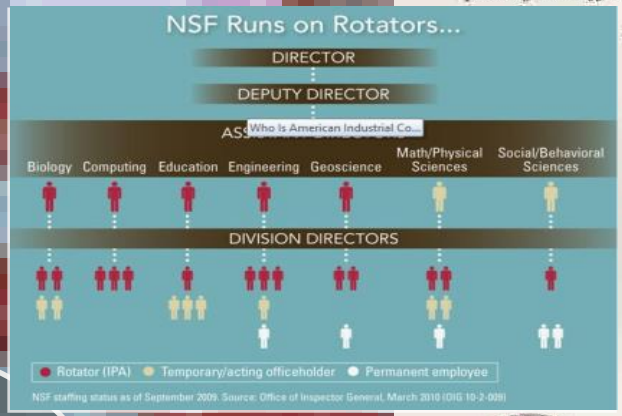
  4) the changing line of sight distance and polarization makes the ground stations and the spacecraft much more expensive than for a **GEO** architecture, i.e. with active steering and adjustable gains.
- ***Thank You Charles Radley for in depth research & concerns…***

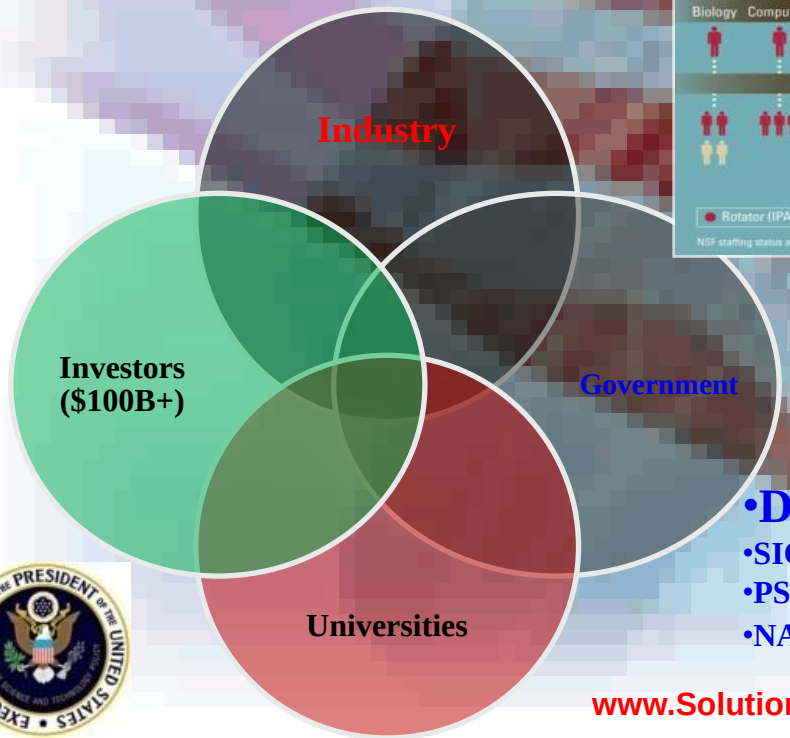
Who Is American Industrial Co.

We are Modeled from DOD's Industrial Modernization Incentive Program (IMIP) recreated through NSF

We are a Consortium:

Taking R & D out of the Labs and into Production for the Good & Right of Man Kind and Products Improvement





*"The Industrial Modernization Incentives Program (IMIP) is a major DoD initiative. . . It is an important part of our efforts to promote manufacturing and productivity improvements in the acquisition environment."**

Caspar Weinberger
Secretary of Defense

McDonnell Douglas Corporation (MDC) welcomes its Department of Defense (DoD) and other customers to the DoD/MDC Industrial Modernization Incentives Program (IMIP).

This brochure provides an overview of present MDC involvement in this important program with an account of the current program goals, approaches, and accomplishments within the individual MDC component companies.

*Annual Report to the Congress FY 1988 (Washington, D.C.: U.S. Government Printing Office, 1987) p. 141.

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- **SIC Code 8748-0203**
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- **NAIC: 333999 (Mfg Misc)MS Partner**

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Replace with New very Useful Space Solar Power Systems

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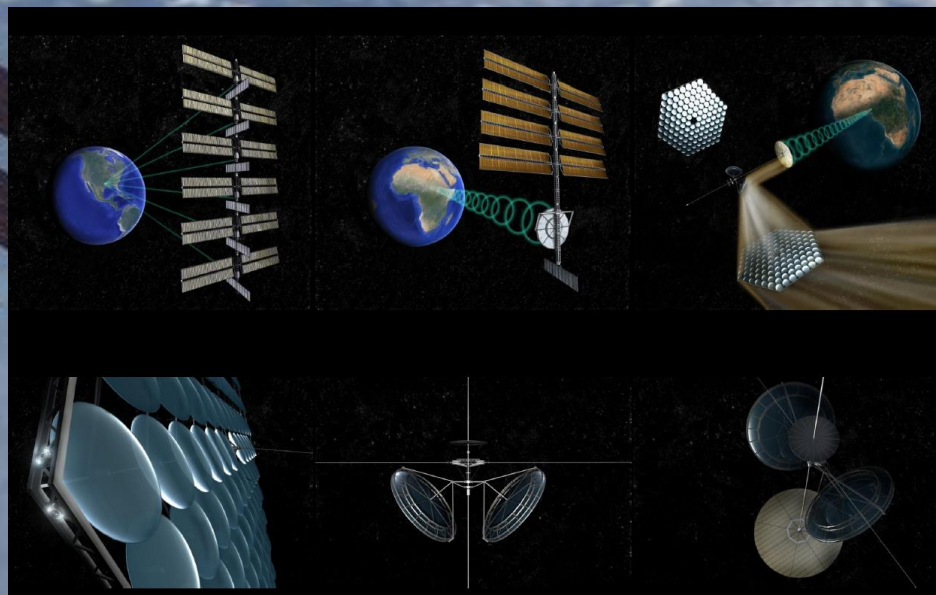
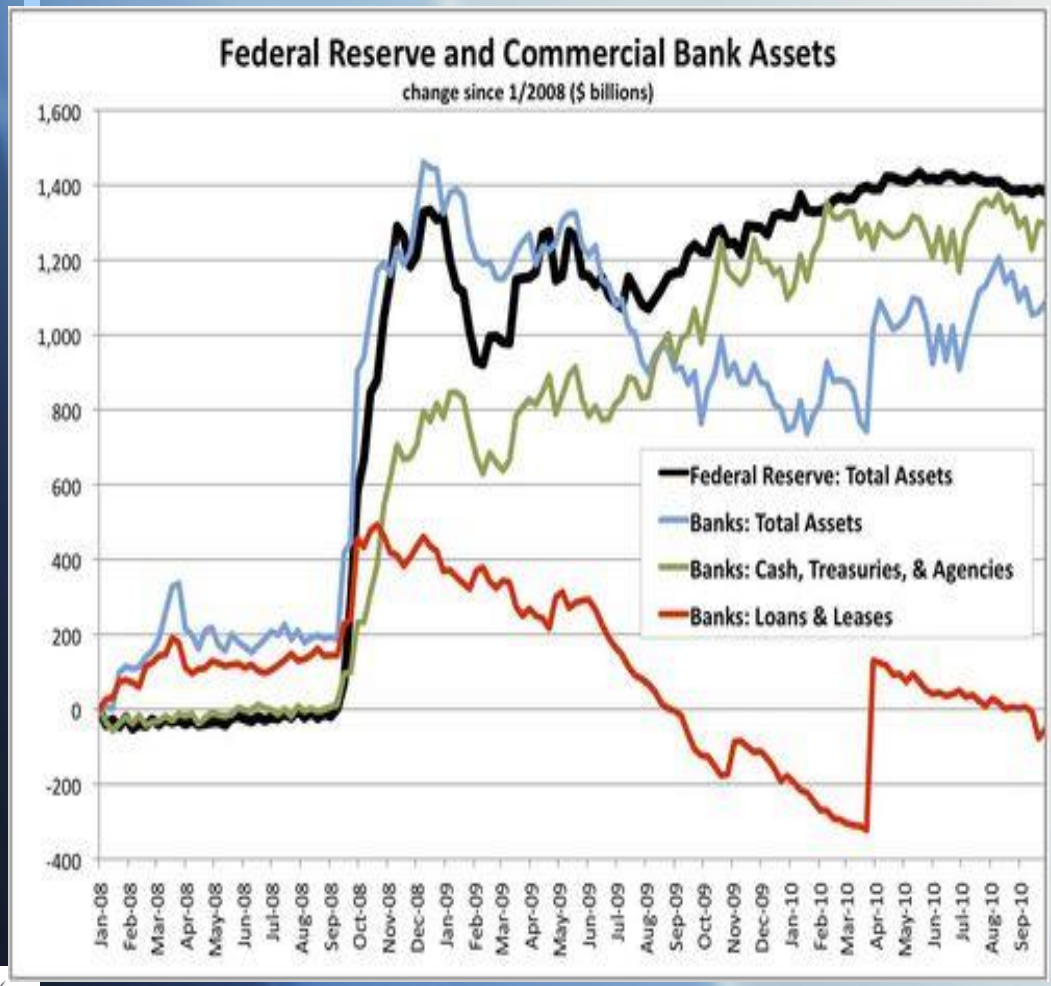


SPACE SOLAR POWER (SSP) CONCEPTS

Fed Reserve & Banks

- Funding NSF-ref only:
  http://www.youtube.com/watch?v=jN2o_0m1Jk8&feature=colike

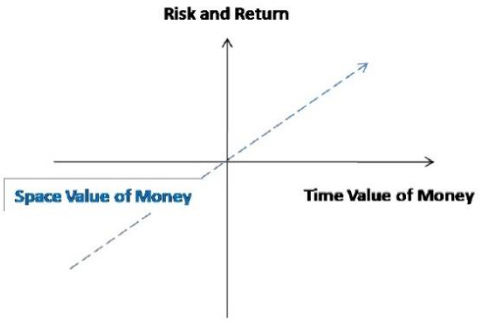
REF Data



expected cash flows. This process is the process of assessing the current monetary value of future expected cash flows by discounting them to the present using the return of an alternative investment with the same level of risk.

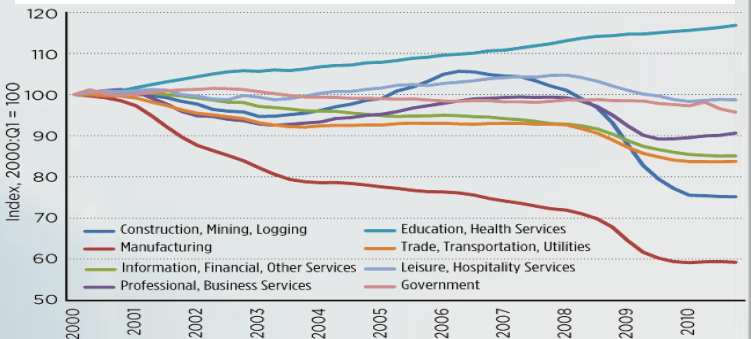
Chart-2: Examples of Time Value of Money and Risk and Return Equations

Source: Author



$$PV = \frac{FV}{(1+i)^n} \qquad PV = \sum_{t=0}^{n} \frac{FV_t}{(1+i)^t}$$

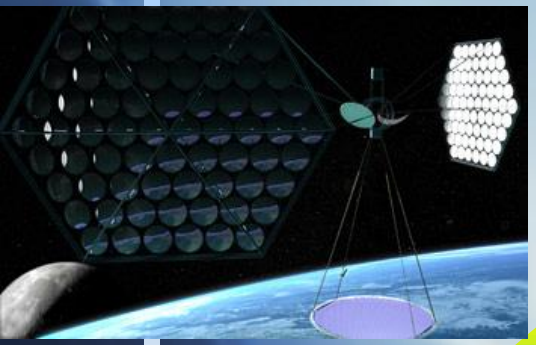
$$\mathrm{E}(R_i) = R_f + \beta_i(\mathrm{E}(R_m) - R_f)$$



Program Schedule Milestones

IAA Report 2011: http://iaaweb.org/iaa/Studies/sg311_finalreport_solarpower.pdf
Aviation Week: http://billionyearplan.blogspot.com/2011/11/excellent-coverage-of-sbsp-from.html

Mankins-Study: http://www.scribd.com/doc/216866353/The-Case-for-Space-Solar-power-Mankins-2014



2015
Phase 1
R&D

2017
Feasibility
Review

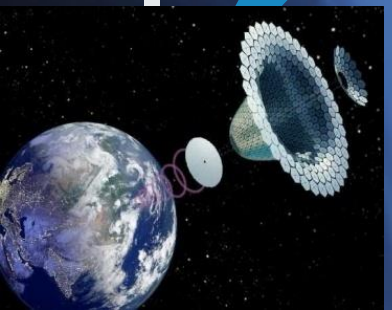
2020
Phase 2
Predesigned
Transition

2024
Phase 3
1st Rev.
System
LRIP

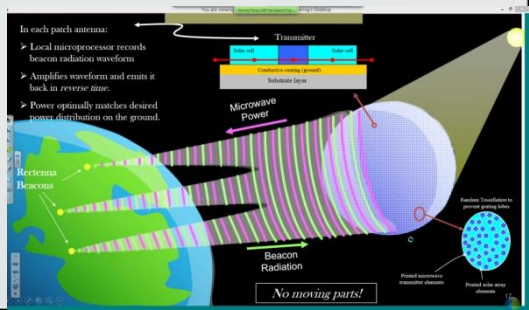
2028
Phase 4
Full Scale
Development

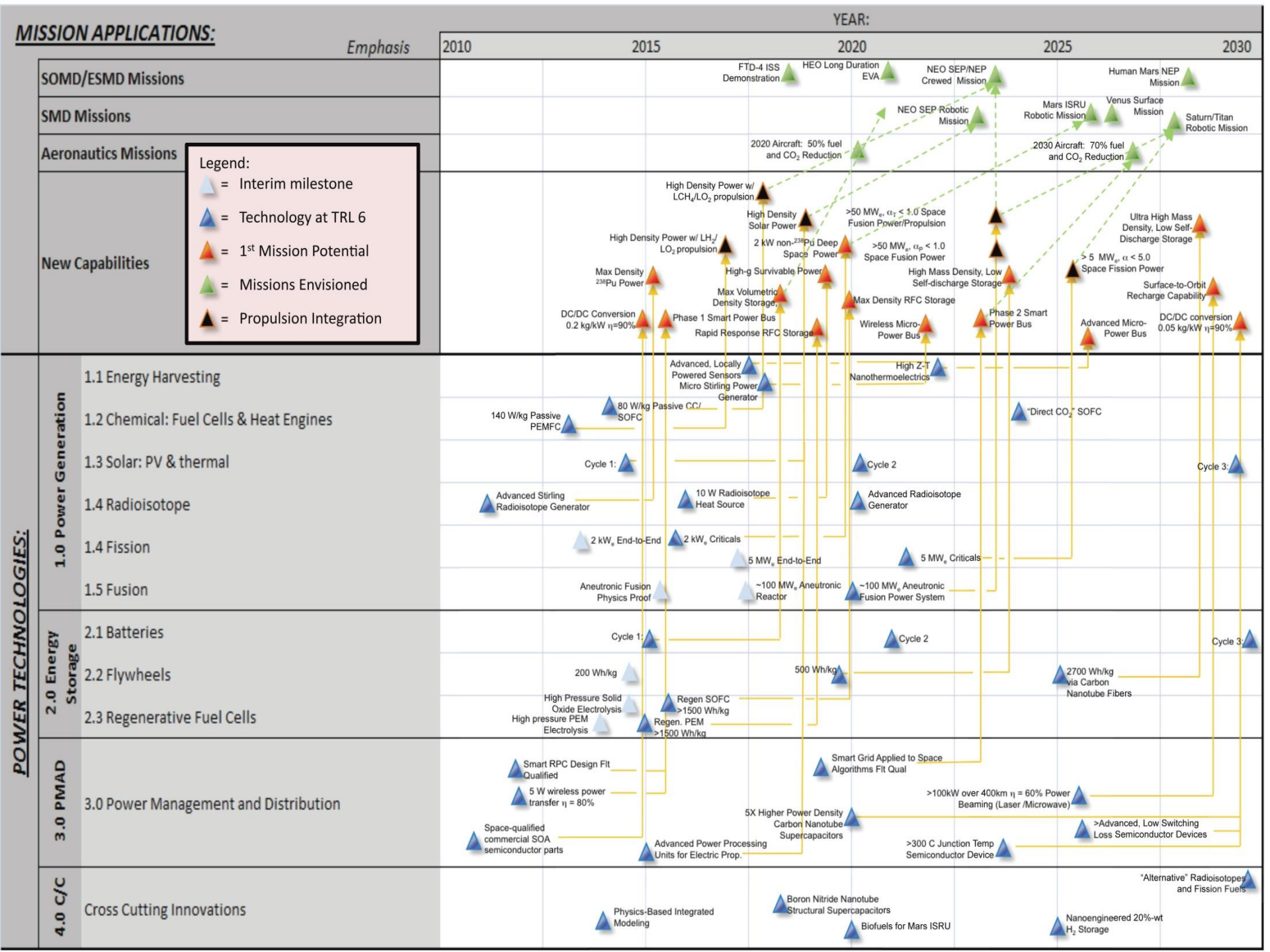
Space Solar Power

Limitless clean energy from space

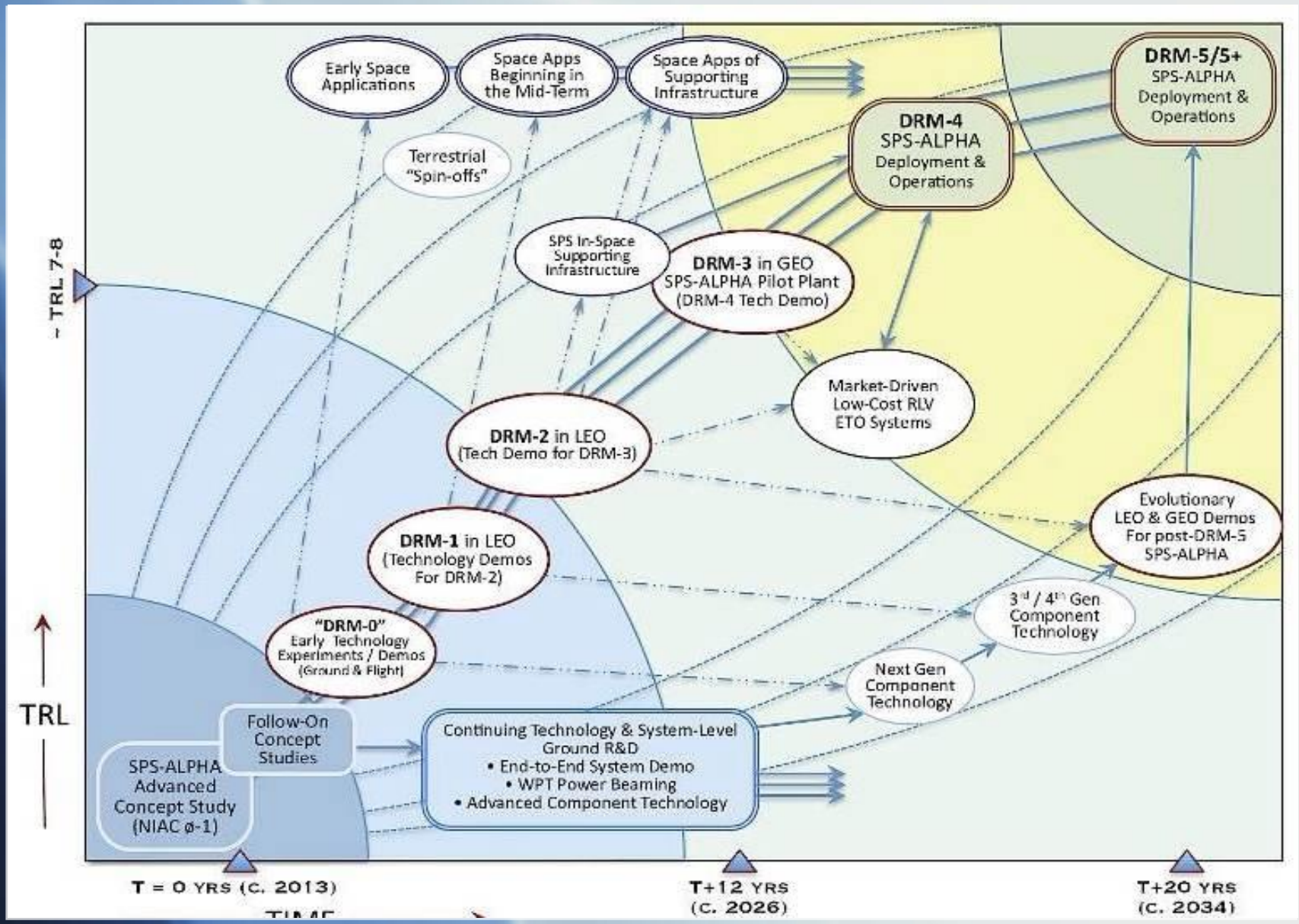


- Space Solar Power Library
- October 2007 SBSP Report
- Links - Websites
- Links - Articles (updated regularly)
- Videos

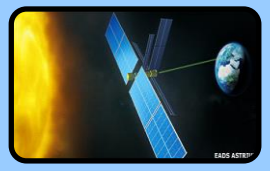



MISSION APPLICATIONS:
Emphasis
YEAR:
2010
2015
2020
2025
2030
SOMD/ESMD Missions
SMD Missions
Aeronautics Missions
New Capabilities
Legend:
= Interim milestone
= Technology at TRL 6
= 1st Mission Potential
= Missions Envisioned
= Propulsion Integration
FTD-4 ISS Demonstration
HEO Long Duration EVA
NEO SEP/NEP Crewed Mission
Human Mars NEP Mission
NEO SEP Robotic Mission
Mars ISRU Robotic Mission
Venus Surface Mission
Saturn/Titan Robotic Mission
2020 Aircraft: 50% fuel and CO2 Reduction
2030 Aircraft: 70% fuel and CO2 Reduction
High Density Power w/ LCH4/LO2 propulsion
High Density Solar Power
>50 MWe, αT < 1.0 Space Fusion Power/Propulsion
Ultra High Mass Density, Low Self-Discharge Storage
High Density Power w/ LH2/LO2 propulsion
2 kW non-238Pu Deep Space Power
>50 MWe, αP < 1.0 Space Fusion Power
> 5 MWe, α < 5.0 Space Fission Power
Max Density 238Pu Power
High-g Survivable Power
High Mass Density, Low Self-discharge Storage
Surface-to-Orbit Recharge Capability
Max Volumetric Density Storage
Max Density RFC Storage
DC/DC Conversion 0.2 kg/kW η=90%
Phase 1 Smart Power Bus
Rapid Response RFC Storage
Wireless Micro-Power Bus
Phase 2 Smart Power Bus
Advanced Micro-Power Bus
DC/DC conversion 0.05 kg/kW η=90%
POWER TECHNOLOGIES:
1.0 Power Generation
1.1 Energy Harvesting
1.2 Chemical: Fuel Cells & Heat Engines
1.3 Solar: PV & thermal
1.4 Radioisotope
1.4 Fission
1.5 Fusion
Advanced, Locally Powered Sensors
Micro Stirling Power Generator
High Z-T Nanothermoelectrics
80 W/kg Passive CC/ SOFC
140 W/kg Passive PEMFC
"Direct CO2" SOFC
Cycle 1:
Cycle 2
Cycle 3:
Advanced Stirling Radioisotope Generator
10 W Radioisotope Heat Source
Advanced Radioisotope Generator
2 kWe End-to-End
2 kWe Criticals
5 MWe End-to-End
5 MWe Criticals
Aneutronic Fusion Physics Proof
~100 MWe Aneutronic Reactor
~100 MWe Aneutronic Fusion Power System
2.0 Energy Storage
2.1 Batteries
2.2 Flywheels
2.3 Regenerative Fuel Cells
Cycle 1:
Cycle 2
Cycle 3:
200 Wh/kg
500 Wh/kg
2700 Wh/kg via Carbon Nanotube Fibers
High Pressure Solid Oxide Electrolysis
Regen SOFC >1500 Wh/kg
High pressure PEM Electrolysis
Regen. PEM >1500 Wh/kg
3.0 PMAD
3.0 Power Management and Distribution
Smart RPC Design Flt Qualified
Smart Grid Applied to Space Algorithms Flt Qual
5 W wireless power transfer η = 80%
>100kW over 400km η = 60% Power Beaming (Laser /Microwave)
5X Higher Power Density Carbon Nanotube Supercapacitors
>Advanced, Low Switching Loss Semiconductor Devices
Space-qualified commercial SOA semiconductor parts
Advanced Power Processing Units for Electric Prop.
>300 C Junction Temp Semiconductor Device
4.0 C/C
Cross Cutting Innovations
"Alternative" Radioisotopes and Fission Fuels
Boron Nitride Nanotube Structural Supercapacitors
Physics-Based Integrated Modeling
Biofuels for Mars ISRU
Nanoengineered 20%-wt H2 Storage

Evolution Roadmap-Very Smart!



Solar/Energy Absorption

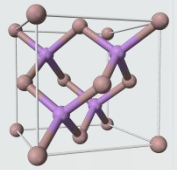


Solar Energy Satellite(s)

Studies:

1. Best Solar Photovoltaic - Absorption/Conversion
2. Modular, Expandable, Commonizing
3. Controllable & Shape Changing/Morphing
4. Best Earth Orbit positions, & how many - where?
   - Alpha (Mankins) – uses Mirrors
   - Power Star, along with other Types?
   - Which Type (Morphing Mirrored) SolutionCell Design optimization?

Best PhotoVoltaic Conversion



REF Data

Alta Devices reports NREL verification of 23.5% efficiency for counter-intuitive solar panel ***http://energy.gov/eere/sunshot/sunshot-initiative**

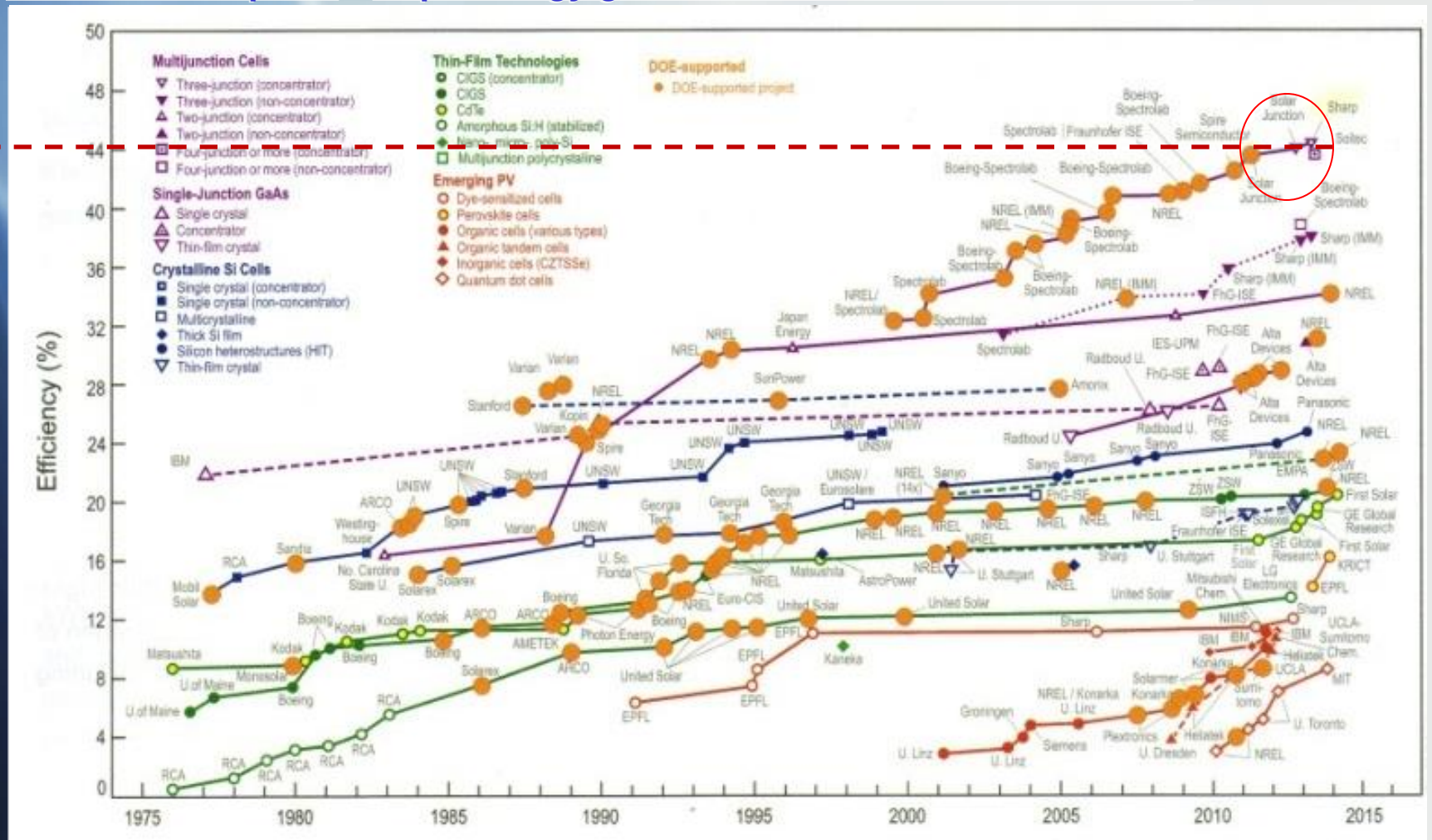
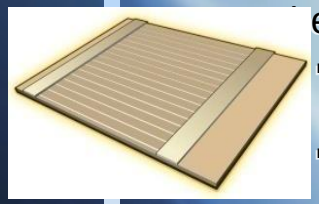


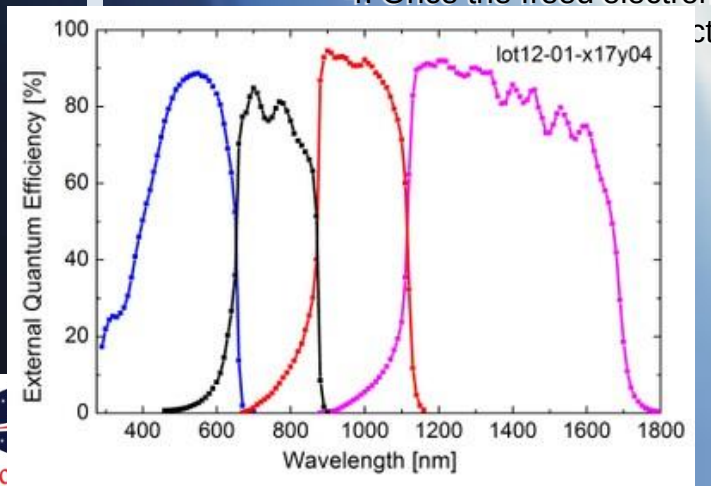
Figure 2. Record solar cell efficiencies of different technologies over the past several decades. Over one-half (orange dots) were funded by the PV subprogram its precedessors. (Chart courtesy of NREL)

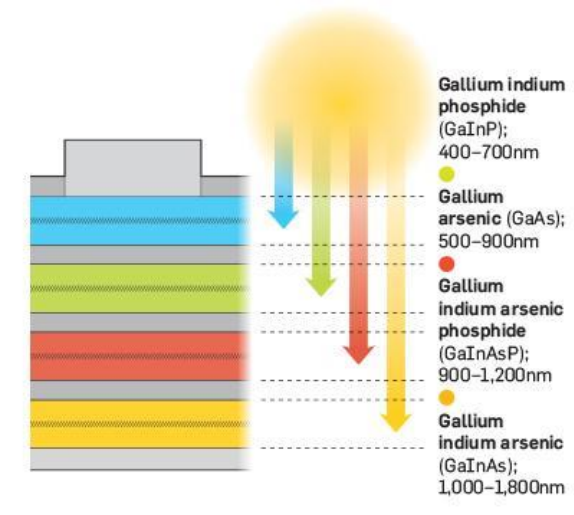
Best Solar Cells

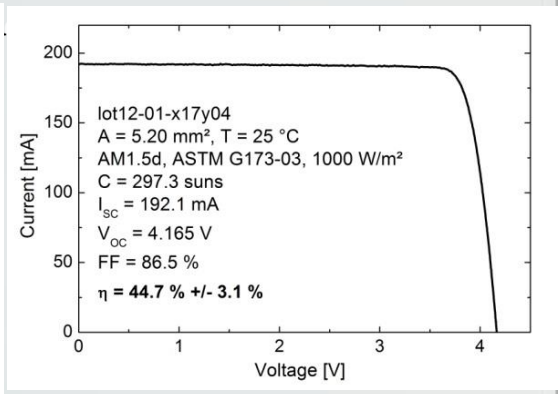
- Most Efficient Solar Cells:
  - Solar cells typically convert not more than 20 percent of incoming energy into electricity, in part because they capture only certain wavelengths of light. Researchers at Germany's Fraunhofer Institute for Solar Energy Systems have developed a solar cell that **converts 44.7 percent—a new record**. It consists of a lens that concentrates sunlight onto four stacked subcells, each designed to absorb a distinct portion of the spectrum. The team estimates it will take them another two to three years to scale up e 5.2-millimeter prototype for use in solar-power plants.



    - 1. Sunlight passes through a multifaceted lens known as a Fresnel. The lens focuses direct sunlight, delivering the power equivalent of 297 suns to the solar cell below.
    - 2. The first subcell, made from gallium indium phosphide, captures photons from the shortest wavelengths of light. The subcells beneath it contain elements capable of capturing progressively longer wavelengths.
    - 3. Each subcell consists of several semiconductor layers, which create an electric field. As photons enter, they excite electrons, freeing them from the subcell.
    - 4. Once the freed electron

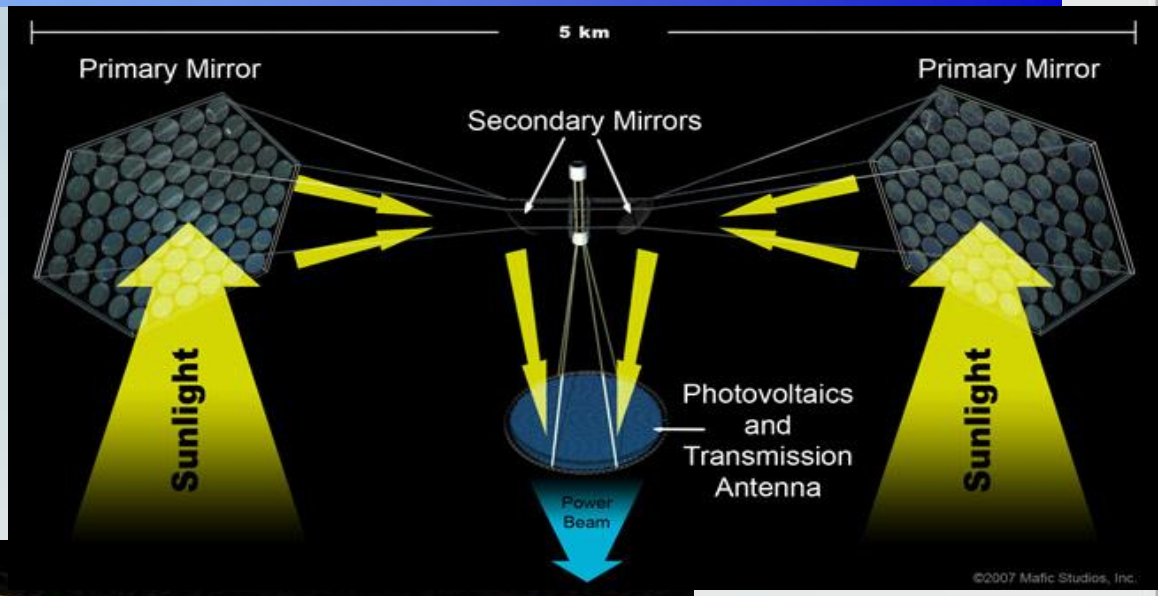


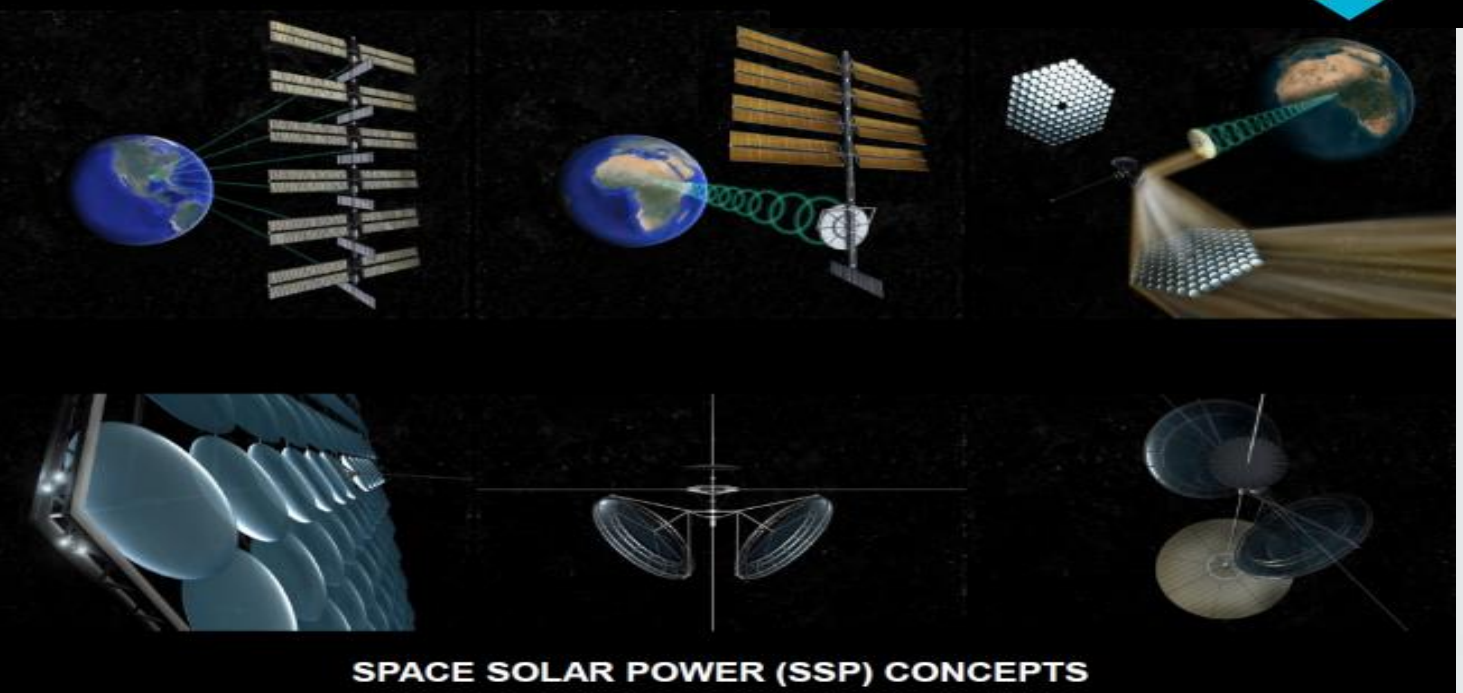




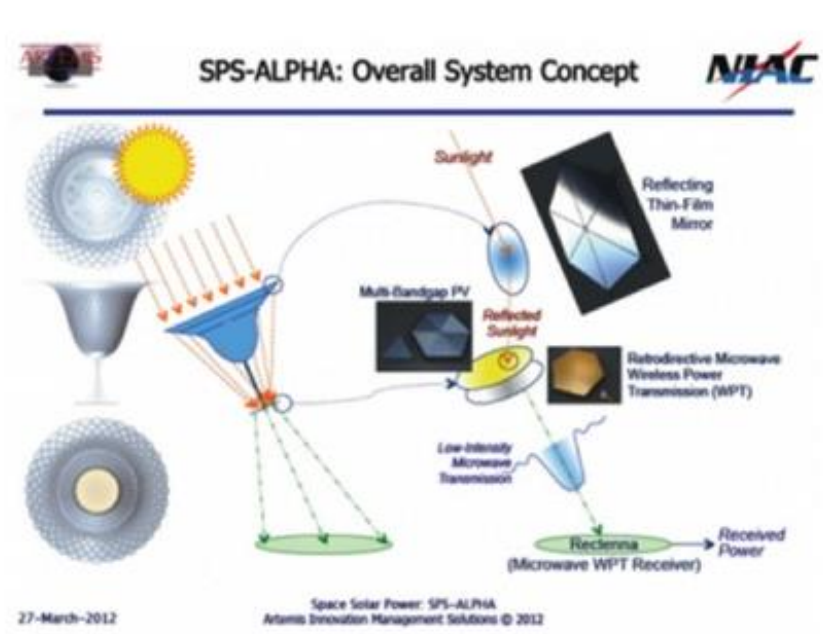
SSP Technique

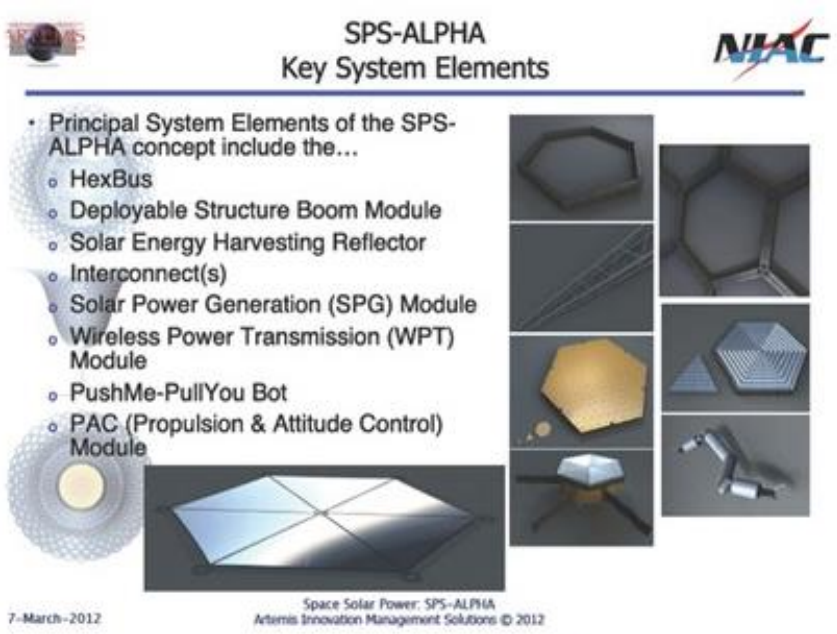
- old SSP techniques:





New Alpha System Concept





Illustrations, above and below, of the SPS-ALPHA concept. (credit: Artemis Innovation Management Solutions)

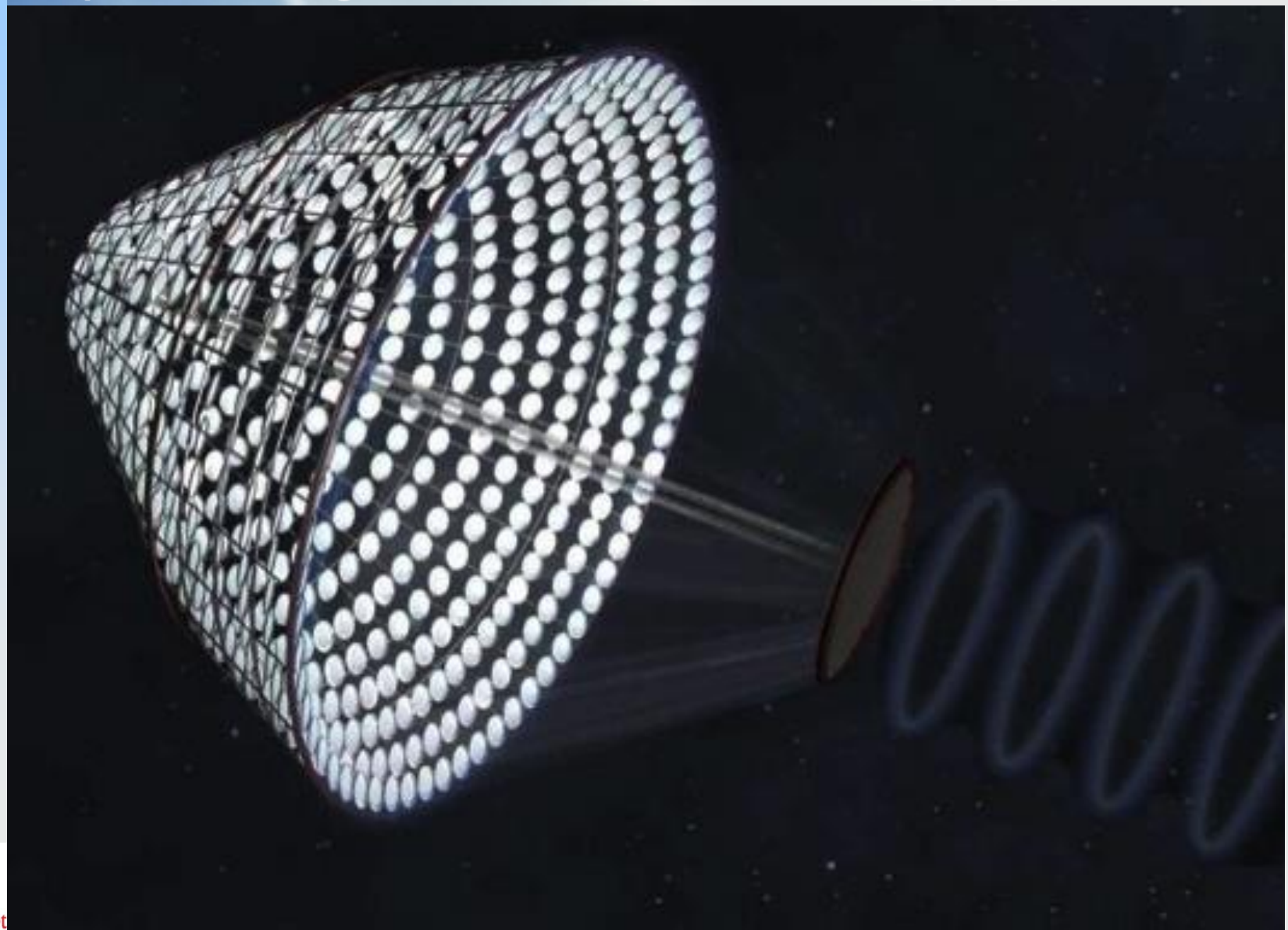
Table 7-16 SPS-ALPHA System Analysis Selected Preliminary Results

Table 7-16 SPS-ALPHA System Analysis Selected Preliminary Results

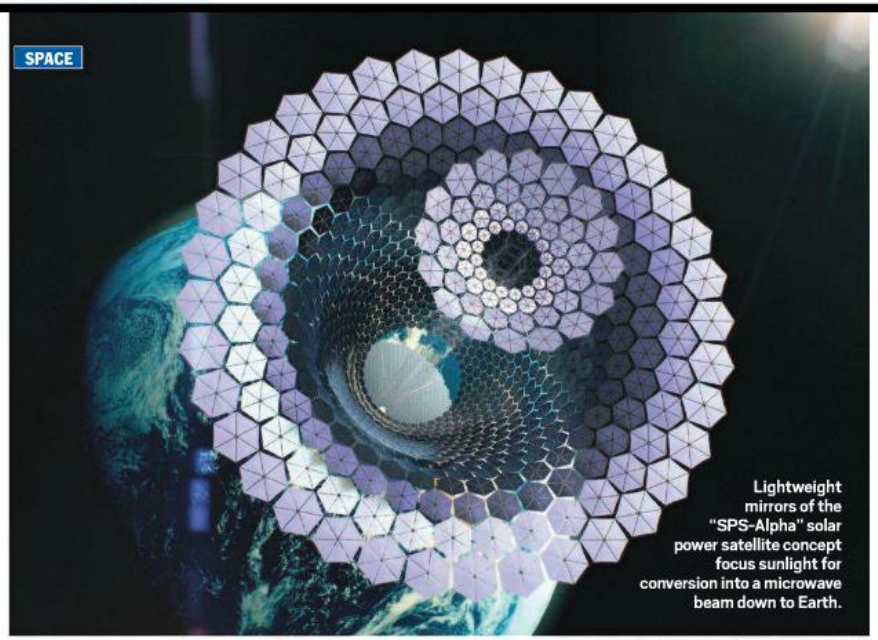
Parameters	DRM 3 / Case 1 (SPS-ALPHA Pilot Plant, with Minimal Tech Advances)	DRM 4 / Case_1 (First Full-size SPS, with Minimal Tech Advances)	DRM 5 / Case_4B (Recurring SPS, with Aggressive Tech Advances)
Power Delivered to Earth	18 MW	500 MW	2,000 MW
WPT Transmission Freq.	2.45 GHz	2.45 GHz	2.45 GHz
Solar Power Gen. Efficiency	25% BOL	48% BOL	60% BOL
WPT Efficiency	70% (DC-to-RF)	70% (DC-to-RF)	80% (DC-to-RF)
ETO Cost ($/kg)	$1,500/kg	$500/kg	$500/kg
Cost to First Power (estimated at Earth)	~$ 4.5 B (~$250 per Watt)	~$ 12.2 B (~$24 per Watt)	~$ 31 B (~$16 per Watt)
Lifetime	10 years	Indefinite; > 30 years (with Maintenance and Spares)	Indefinite; > > 30 years (with Maintenance and Spares)
Levelized Cost of Electricity (LCOE; $/kW-hour)	~ $3.26 per kW-hr	~ 15¢ per kW-hr	~ 9¢ per kW-hr

SPS-ALPHA: The First Practical Solar Power Satellite via Arbitrarily Large PHased Array

http://www.nasa.gov/offices/oct/stp/niac/mankins_sps_alpha.html#



SPS-ALPHA: Smart "Reduce Sticker Shock w/Added Uses…"



Lightweight mirrors of the "SPS-Alpha" solar power satellite concept focus sunlight for conversion into a microwave beam down to Earth.

JOHN MANKINS/ARTEMIS INNOVATION MANAGEMENT SOLUTIONS

Waiting Market

Reusable-launch work is changing the space solar power game

Frank Morring, Jr. Kobe, Japan

Preparations for launch of a SpaceX Falcon 9 rigged to flight test a nascent flyback capability in its first stage drew close attention from solar power satellite (SPS) advocates meeting here, who know that low-cost reusable launch is one key to realizing their dream of providing abundant electric energy from space.

While they are taking different approaches to developing SPS, the small but international group of participants at the SPS 2014 conference here agreed that their goal continues to be an end to the increasingly dangerous struggle to meet the energy needs of a growing world population. They see space solar power as an alternative to the environmental fallout from extracting and burning fossil fuel, and the military cost of securing supplies in unstable regions.

Like California-based SpaceX, the Japan Aerospace Exploration Agency (JAXA) is conducting research into reusable launch as a way to cut the cost of space launch drastically. Japan is the only nation that has made beaming solar power collected in space back to Earth a goal of its space policy, and JAXA engineers calculate reusable launch is one way to reduce the up-front investment needed to put gigawatt-class power stations in geostationary orbit.

"We need a reusable launch system," says Susumu Sasaki of Tokyo City University, a professor emeritus at JAXA who has studied the relationship between launch costs and the cost of power delivered from space.

Using a 2003 JAXA reference model with a 1-gigawatt station weighing 10,000 tons, Sasaki says power would cost a prohibitive $1.12/kwh at a launch cost to low Earth orbit (LEO) of $10,000 per kilogram. That is in the ballpark of what space launch costs today. Cut that to $1,000 a kilogram—in the ballpark for a reusable launch vehicle (RLV)—and electricity from space drops to 18 cents/kwh.

The SpaceX RLV work, which includes prototype landing legs on the current Falcon 9 taking cargo to the International Space Station (see photo on page 25) and using the rocket's engines to control the first stage's return to a splashdown in the Atlantic, is but one development in the fast-changing worldwide spaceflight endeavor that holds promise for space solar power.

Sasaki also cites the need for an orbital transfer vehicle (OTV) to move SPS hardware from LEO to the geostationary Earth orbit (GEO) where space power systems would operate, a development that meshes nicely with NASA's efforts to develop a high-power solar electric propulsion system for deep-space exploration (*AW&ST* March 31, p. 26).

Such a system would shuttle "like a Ferris wheel," in Sasaki's analogy between LEO and GEO, delivering 50 tons a year in the JAXA model with a four-month round trip. Overall, the JAXA approach—which already has a prototype robotic assembly device aggregating simulated power-converter units into larger structures on the ground at Tsukuba Space Center near Tokyo—would require 15 RLVs and more than 200 OTVs to build a power station in GEO, according to Sasaki.

John Mankins, a former NASA chief technologist who has worked with Kobe University professor Nobuyuki Kaya for decades on SPS, has devised a modular approach that would take a small SPS prototype into LEO, increase its capability and then upgrade it to megawatt-class stations in GEO. Parts of the "SPS-Alpha" concept (see illustration on page 24), outlined in great detail in a new book by Mankins entitled *The Case for Space Solar Power*, match up well with the modular "satlet" self-assembly concept the U.S. Defense Advanced Research Projects Agency (Darpa) is pursuing to lower the cost of military satellites (*AW&ST* Jan. 20, p. 24).

To help fund development of the mass-produced components that would self-assemble in LEO and later GEO to increase capability, Mankins proposes a commercial approach that would sell electricity from the beginning. Users of the early systems in LEO could attach their payloads to the system in place of the power transmitters that are the ultimate goal, enabling much more powerful—hence capable—systems than exist today.

"You have costs, but you also begin to have revenues, because these systems are directly applicable to GEO communications satellites," says Mankins, who co-chaired the SSP 2014 conference with Kaya. "They are directly applicable to all manner of LEO communications satellites, Earth-observing satellites and so on."

Unlike Japan, which is working toward an SPS orbital test, and China, the U.S. has no government program supporting SPS development. But last year the Naval Research Laboratory (NRL) thermal vacuum ran a small program to test a lightweight prototype device melding a photovoltaic cell and a flat radiofrequency transmitter in a "sandwich" assembly that lends itself to the evolving space power station architectures and the mass production that would be needed to hold down the cost.

Paul Jaffe, the NRL engineer who put together the demonstration, says that aside from being the first test of SPS technology in space-like conditions, it also gives a data point for forecasting the economics of space-based power.

"It gives you kind of a rough estimate of what the cost is going to be, and it really just considers four factors," Jaffe says. "We've talked a lot during this conference about how the cost of launch figures very prominently into whether SPS is likely to be economically feasible; the cost of the satellite [is important] as well [as the satellite service life]. This watts per unit kilogram is critical and probably the most difficult to quantify, which is one reason why the research we did with the module development is helpful in establishing this empirical basis."

SPACEX

SpaceX has installed landing legs on the Falcon 9 as it works toward reusability, which would make space solar power more feasible.

Last fall Ge Changchun, a Chinese academician who conducts SPS research at the University of Science and Technology in Beijing, told the International Astronautical Congress that China's work in the area was underfunded because of the focus on human spaceflight. Since then, the government has paid more attention, he said here. Other attendees say the annual expenditure on the research in China has reached an estimated $30 million, which exceeds that of Japan.

Ge gave a detailed technical presentation on the Chinese SPS program, including his own focus on materials for the enormous but lightweight spacecraft that would be needed to collect solar energy in GEO. Although China is pursuing both laser and microwave power transmission options, there appears to be a growing consensus that microwaves in the 2.45 GHz or 5.8 GHz regions are the preferred wavelengths to pursue because of their all-weather capability, less-rigorous pointing requirements and other factors.

At those microwave wavelengths, conference participants agreed, there is not a safety risk in beaming huge amounts of power down from GEO-based power satellites. Birds could fly through the beams without injury and the huge rectennas set up to receive the microwaves and convert them into electricity would allow enough sunlight to pass through to the ground to support some kinds of agriculture in the proper climate zones.

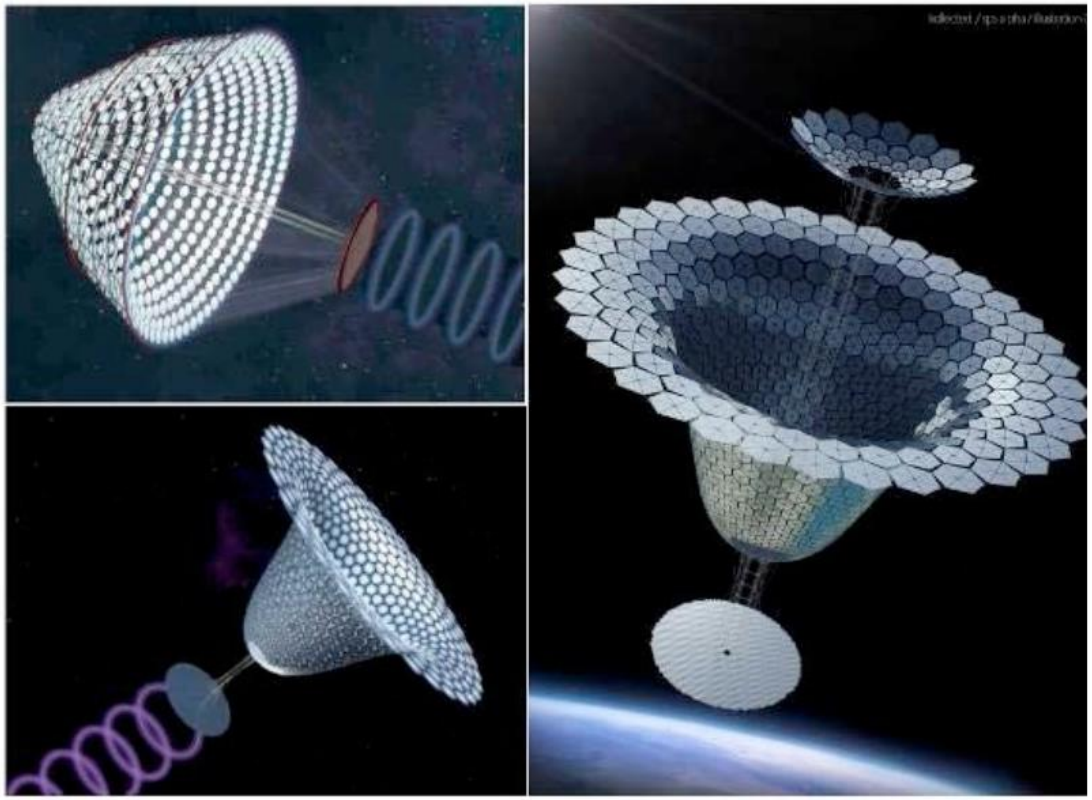
But the preferred frequencies are already used for scientific research, and the International Telecommunications Union would need to allocate spectrum for SPS. Conference participants noted that the ITU has raised questions about SPS spectrum requirements that need to be addressed in time for the organization's World Radiocommunication Conference in November.

There was also an appreciation that development of SPS should be incremental, both for technical reasons and to avoid "sticker shock" by those who hold the public and private purse strings. Additionally, other uses need to be found for the technology to broaden support for its development, as Mankins suggests.

Isabelle Dicaire, a physicist with the European Space Agency, outlined studies that show both microwaves and lasers from space could literally weaken dangerous hurricanes and other tropical cyclones by heating the water in them with microwave radiation to change the thermal dynamics or by using lasers to seed rainfall in a storm's outer walls to weaken the strength of its rapidly rotating eye. Given the $100 billion cost of Hurricane Katrina in Louisiana, she said, the cost of a system that could mitigate cyclones and provide a space-based power source might be more acceptable.

John Mankin's Alpha Concept

Figure 5-2a High-Level Illustration of Alternative Versions of SPS-ALPHA



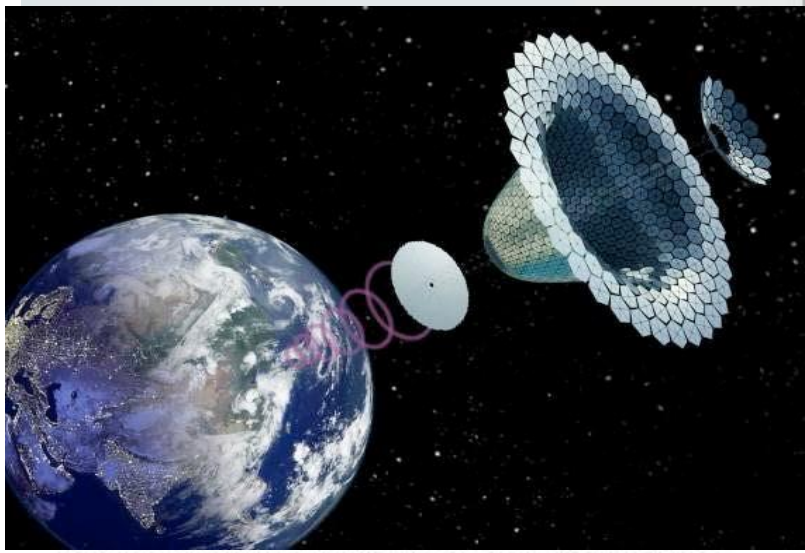
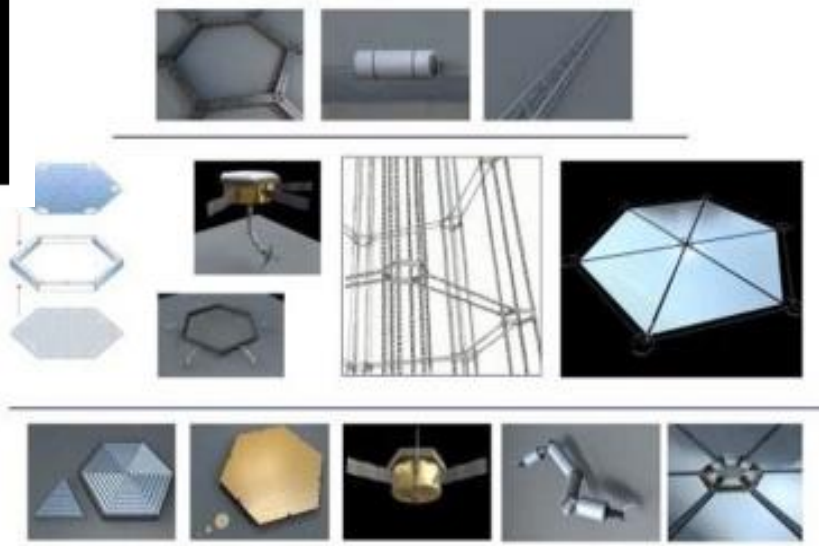


Figure 5-12 SPS-ALPHA Modules-to-Assemblies Illustration



Distributed Aperture Power Collection System

Distributed aperture phased array in GEO

Adaptive Beam Forming

(Multiple, narrow beams transmit nearly all power collected)

Small, local power reception stations

- **Multiple smaller satellites, not a few gigantic spacecraft. Improved robustness.**
- **Much smaller rectennas, serving local areas. Reduced ground-based power transport, reduced ground footprint**
- **Reduced initial investment to obtain an operational system.**

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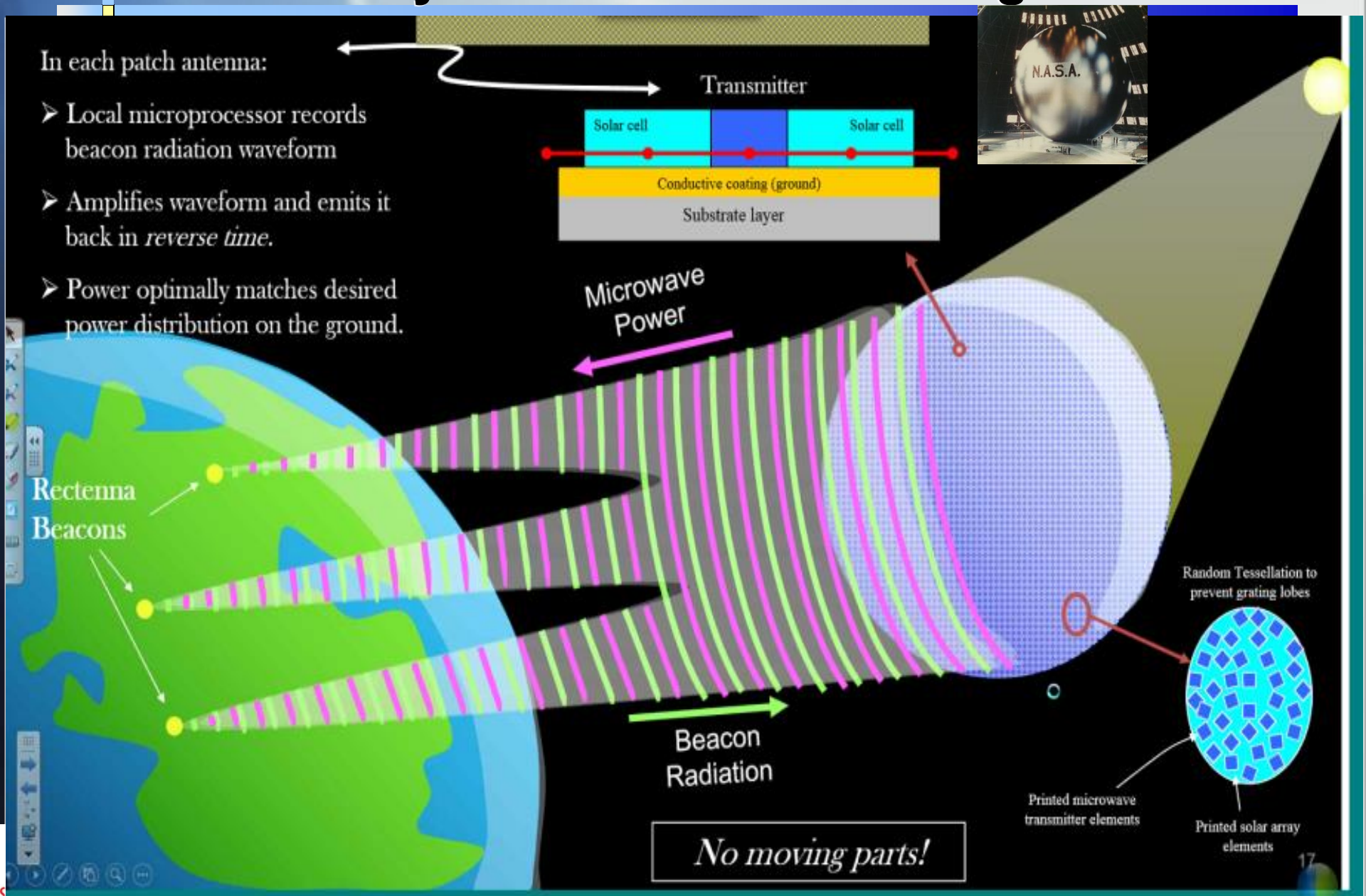
Email: dhiland@tamu.edu

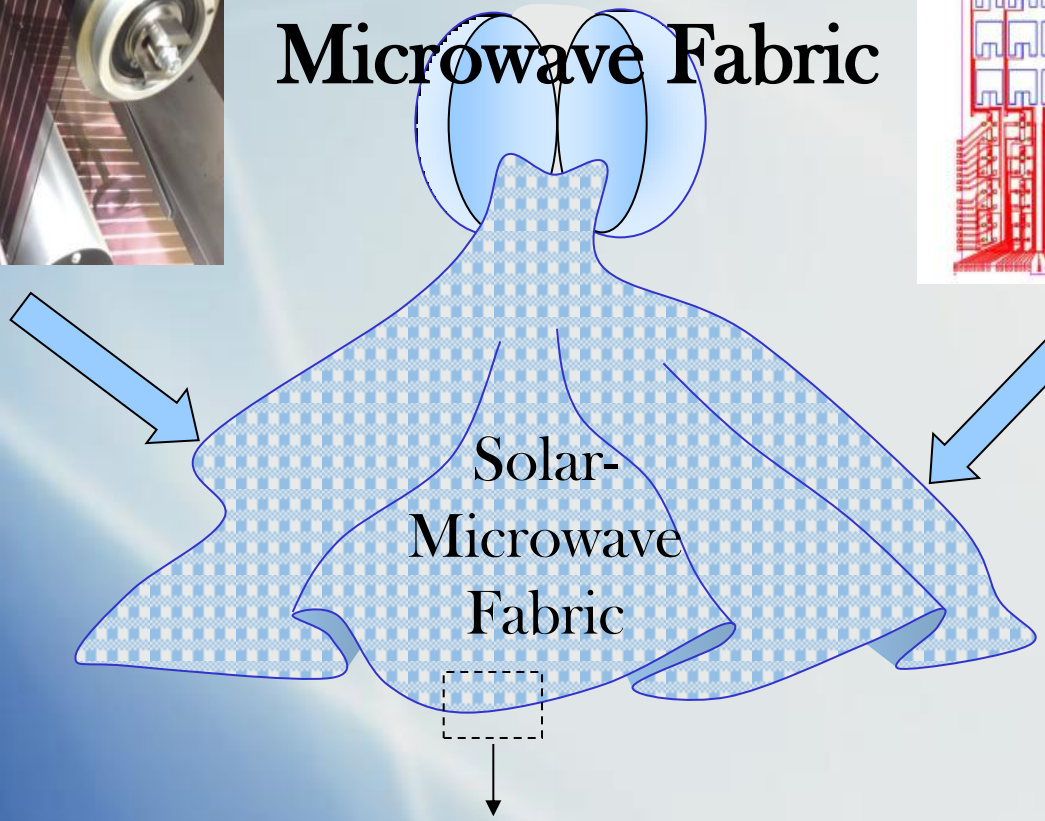
The Second Practical Solar Power Satellite
Hyland's Powerstar Design



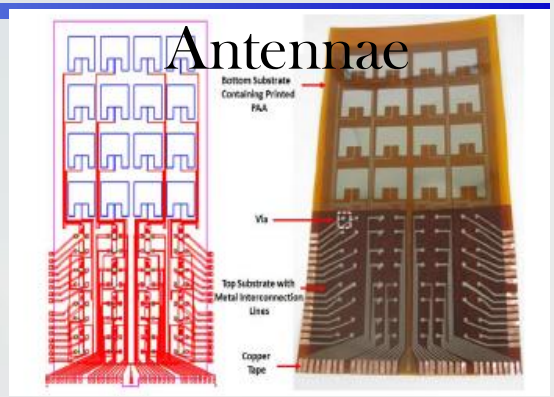
Designed for Mass Production & Low Cost

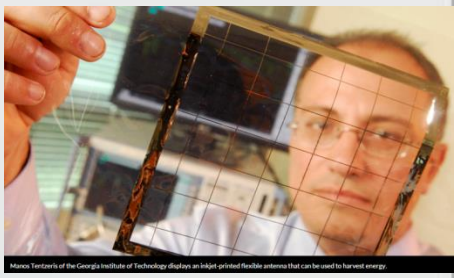
Printed Solar Arrays

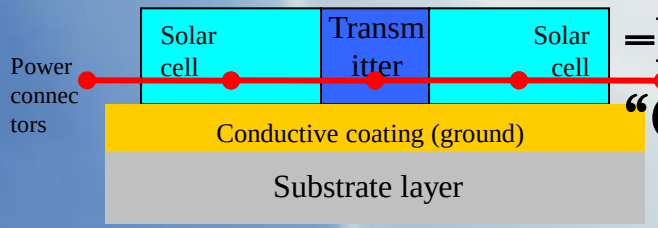
The New Solar Microwave Fabric



Printed Patch Antennae





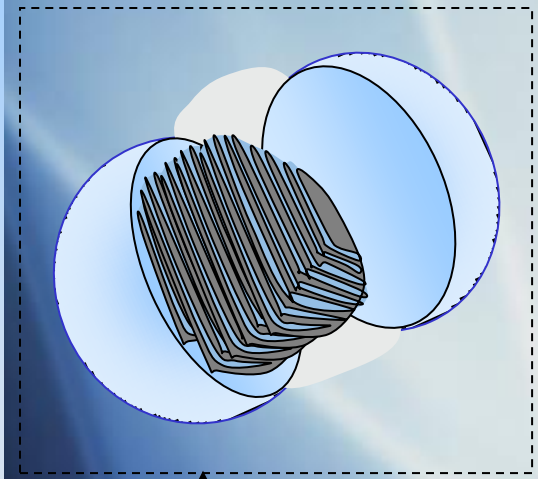


=New "Collectenna"

Shima Seiki-Fabric Mfg.

Powerstar Deployment

- PowerStar Concept Deployment:

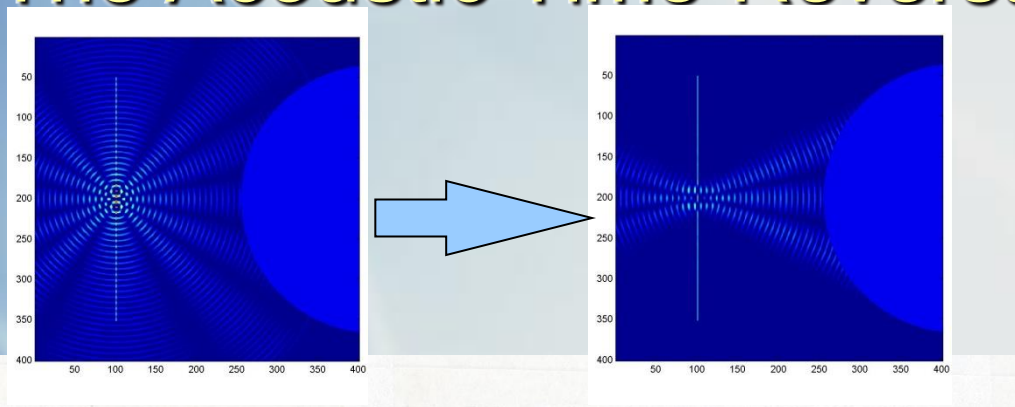


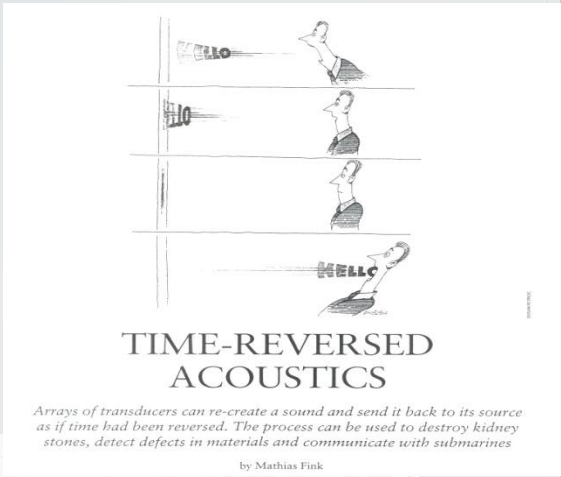
Negligible final angular velocity

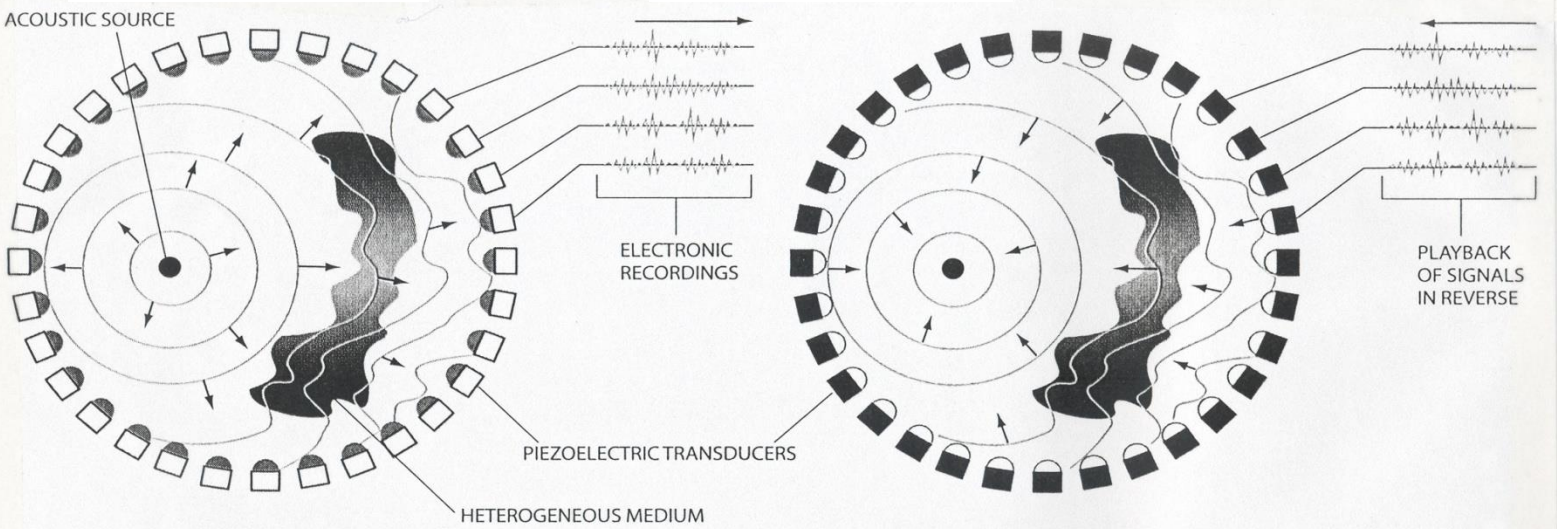
Packaging and

Power Delivery Technique

- The Acoustic Time-Reversal





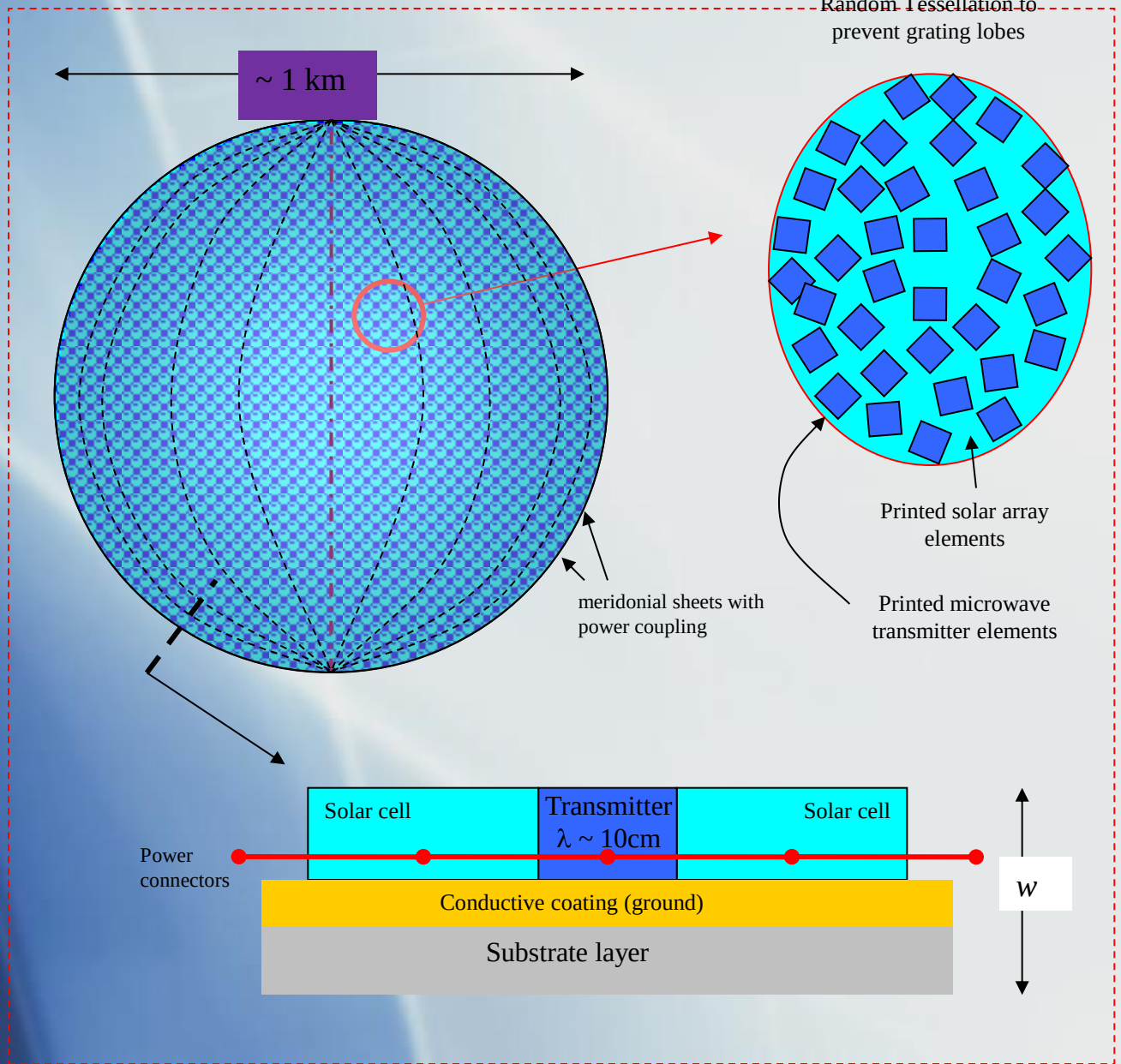


ACOUSTIC TIME-REVERSAL MIRROR operates in two steps. In the first step (*left*) a source emits sound waves (*orange*) that propagate out, perhaps being distorted by inhomogeneities in the medium. Each transducer in the mirror array detects the sound arriving at its location and feeds the signal to a computer.

In the second step (*right*), each transducer plays back its sound signal in reverse in synchrony with the other transducers. The original wave is re-created, but traveling backward, retracing its passage back through the medium, untangling its distortions and refocusing on the original source point.

REF Data

Summary Sketch of the Concept



Use of Future Materials

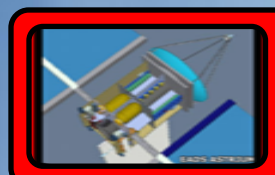
- 1. **Aerogel**

Aerogel *protecting crayons from a blowtorch.*

This tiny block of transparent aerogel is supporting a brick weighing 2.5 kg. The aerogel's density is 3 mg/cm^3.

Aerogel holds 15 entries in the *Guinness Book of Records*, more than any other material. Sometimes called "frozen smoke", aerogel is made by the supercritical drying of liquid gels of alumina, chromia, tin oxide, or carbon. It's 99.8% empty space, which makes it look semi-transparent. Aerogel is a fantastic insulator — if you had a shield of aerogel, you could easily defend yourself from a flamethrower. It stops cold, it stops heat. You could build a warm dome on the Moon. Aerogels have unbelievable surface area in their internal fractal structures — cubes of aerogel just an inch on a side may have an internal surface area equivalent to a football field. Despite its low density, aerogel has been looked into as a component of military armor because of its insulating properties.

Energy Beam Transmission

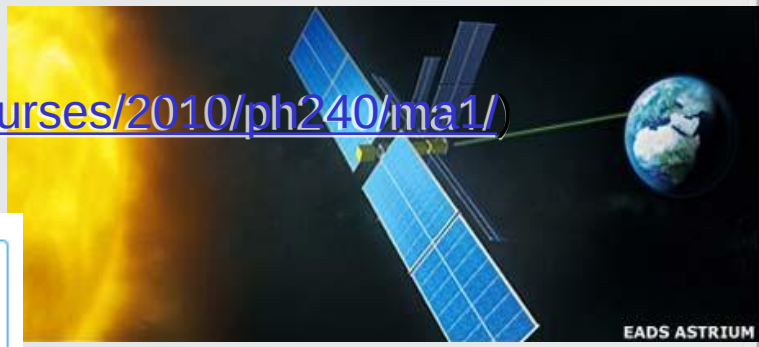


Beam Transmission Science

Optimal Beam/Energy Transmission

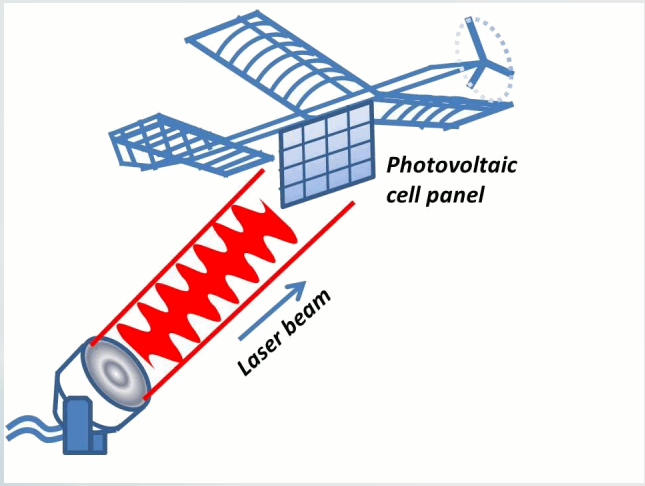
Detailed Studies:

1. **Optimal Beam/Energy Transmission**
    1. **Laser** (http://large.stanford.edu/courses/2010/ph240/ma1/)
    2. **E**lectron **B**eam
    3. **EM** (microwave)
2. **Expandable**
3. **Controllable & Morphing**
4. **Usage:**
    1. Weather C.S.
    2. Orbit Transport Energy
    3. Death Ray



Key Topics

- Laser beam effects
- Laser beams
- Beam plasma instabilities
- Energy transfer
- Hohlraum
- Laser impact
- Polarization
- Stimulated scattering



Microwave / Antenna

•The largest such array yet built and will serve as a test bed for a concept known as "Massive MIMO."

MIMO, or "multiple-input, multiple-output," is a wireless networking technique aimed at transferring data more efficiently by having several antennas work together to exploit a natural phenomenon that occurs when signals are reflected en route to a receiver. The phenomenon, known as multipath, can cause interference, but MIMO alters the timing of data transmissions in order to increase throughput using the reflected signals.

• The Hyland's Power Star incorporates the Antenna

•Other Options

Ground Collection System

Ground Collector System

Studies:

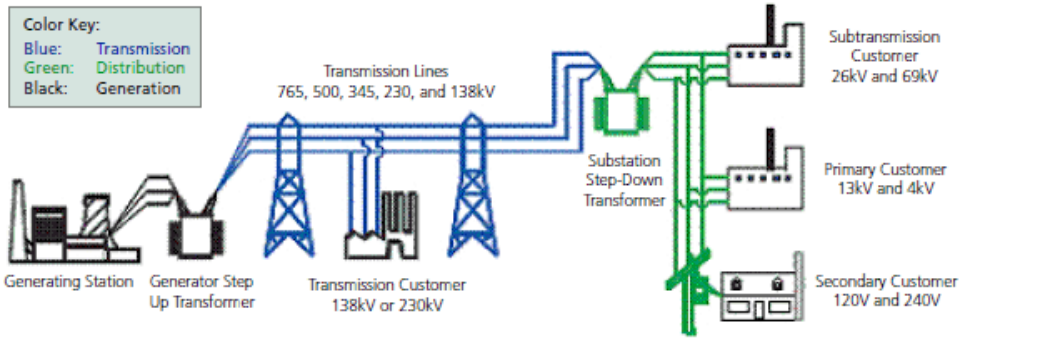
1. Sizing per consumed kWh/population
2. Storage Systems Types (Existing, piggyback or new)
3. Modular & Expandable increased consumption & Population
4. Spread & Placement
5. Safety Improvements & Improved techniques over existing grid.
    1. Safety First, Not another Governor Moon beam microwave of ducks.
    2. Less Susceptible to Nuclear or EMP (Hardening Requires a 60 DB shrouding/insulation)
    3. Near Grid Systems & Prevent Beam stray

Receiver Concepts

- **Requirements:**
  - Orbital conditions for Direct & Safe Delivery & Timing
  - How Many Collectors of which Type?
  - Building Over **Existing Grid Stations**, while **EMP Protection**

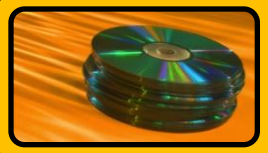
Figure 5-2b Alternative Ground Receiver Placement for SPS-ALPHA Wireless Power

Figure I. Electricity Generation, Transmission, and Distribution



Source: Graphic courtesy of North American Electric Reliability Corporation (NERC)

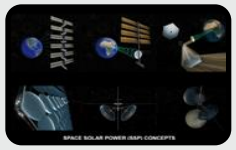
Software & Dbase Required



Database & Software Development

- Requirements:
  - Orbital conditions for direct Delivery & Timing
    - How Many Satellites Required of which Type?
  - Earth Conditions Locations for Allies being fed
  - Weather Conditions & Effects
  - Schedule Deliveries & Grids
  - Every Sub System to be developed
  - Simulation of optional cause & effect prior to deployment or actions (Similar to FCS program w/Northrop Grumman). To be done on NOAA - SOS

Turnkey Integration Required



Full Turnkey System Integration

- **Requirements:**
  - **Space Delivery** vs. Requirements
    - Design & Build
    - How Many Satellites Required
  - **Suppliers** to Design & Build
    - Boeing, Lockheed, Northrop, Honeywell, Raytheon, BAE, B/E, etc…
  - **Schedule** Deliveries & **Grids**
  - Every **Sub System** to be developed

Weather Taming & Control

Weather Control System

- **What Value could this Have, No Tornadoes, Floods, Droughts – Devastation ?** ($10 Billion Katrina)
- **Requirements**:
  - **Mirror Morphing** System Requirements
    - **How Many** Satellites Required
    - Optimal Orbital **Positions**
    - Design Options & Simulation on techniques
  - **Suppliers to Design & Build**
    - Boeing, Lockheed, Northrop, Honeywell, Raytheon, BAE, B/E,
  - **Schedule** Deliveries & **Grids**
  - Every **Sub System** to be developed

*Must see "**Earth From Space-Nova**": http://youtu.be/38peWm76l-U*
Earth in 1,000 years: http://youtu.be/V5YdsYJR5Qw (30:10 map)

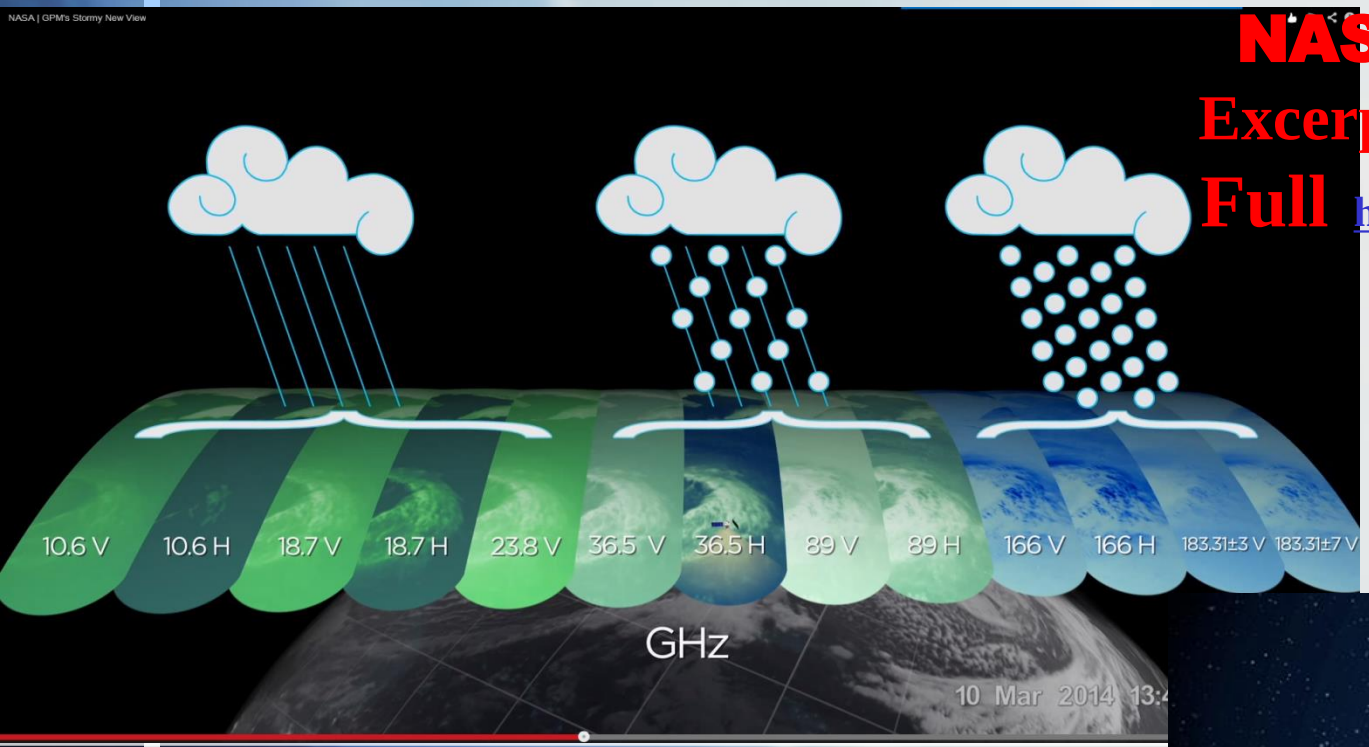
American Ind Co & SolutionCell
www.solutioncell.net

Understanding Weather 1st

NASA-JAXA Global Rain and Snowfall Satellite

http://www.nasa.gov/press/2014/march/first-images-available-from-nasa-jaxa-global-rain-and-snowfall-satellite/#.U01yRxBdV8E

http://climate.nasa.gov/nasa_role



NASA | Dynamic Earth

Excerpt: http://youtu.be/6hD52H7rQak

Full **http://youtu.be/ujBi9Ba8hqs**

The agency's research encompasses solar activity, sea level rise, the temperature of the atmosphere and the oceans, the state of the ozone layer, air pollution, and changes in sea ice and land ice. NASA scientists regularly appear in the mainstream press as climate experts. So how did the space agency end up taking such a big role in climate science?

SolutionCell.net

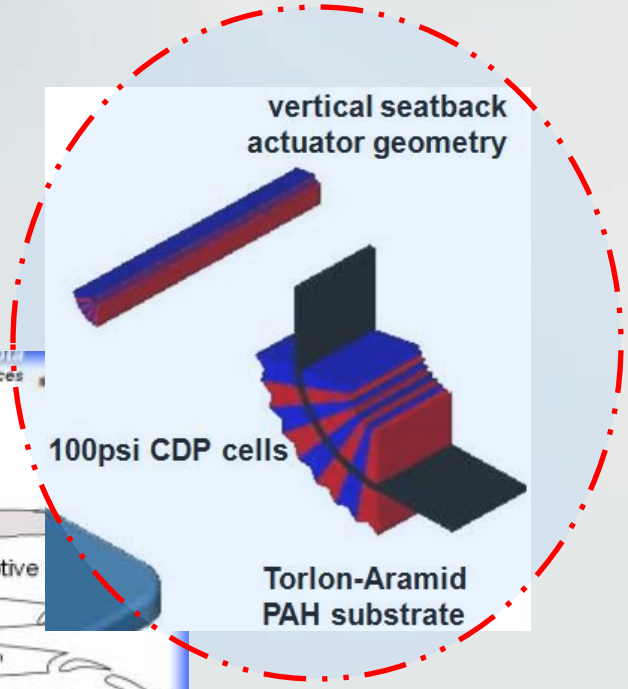
Weather/Clouds Opened by Heat

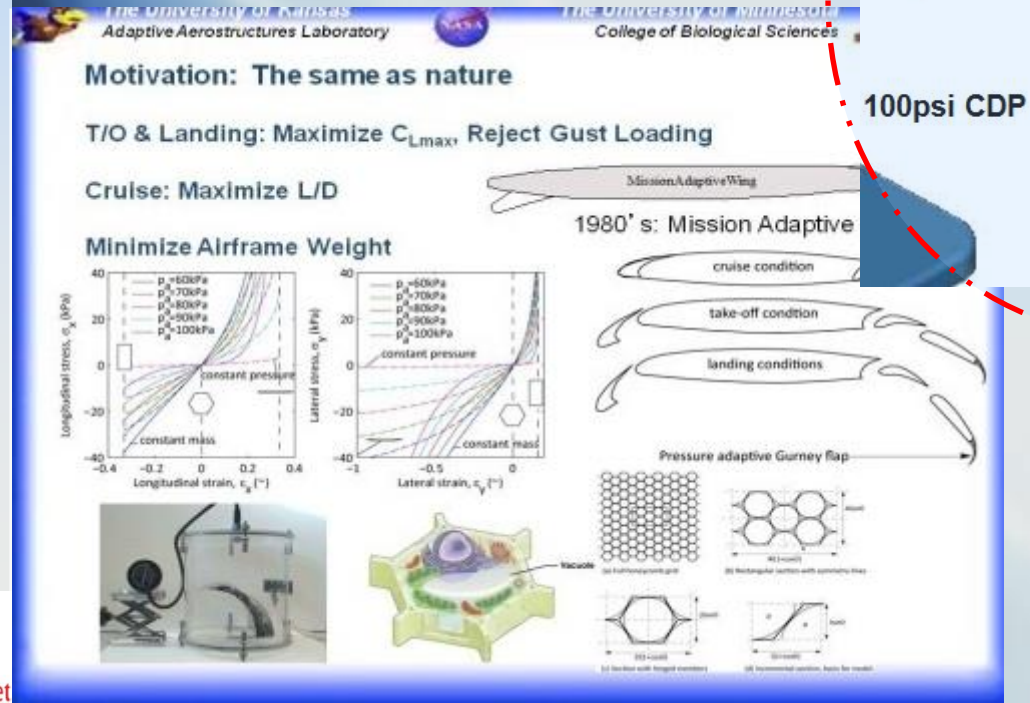
Global Crop Production Increases Threefold Over The Past 50 Years http://bit.ly/14mN5MZ

REF Data

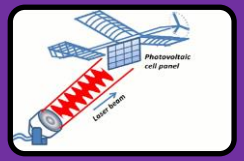
SolutionCell for Mirror Morphing

- Optimize SolutionCell for Structural Mirror Morphing.
- Strength & Speed: (solutioncell.net)

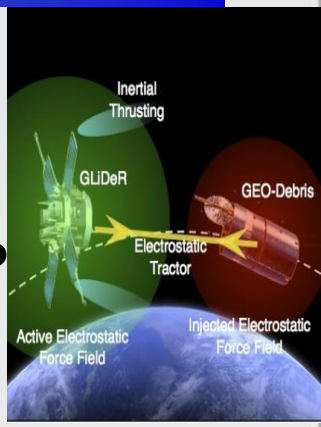




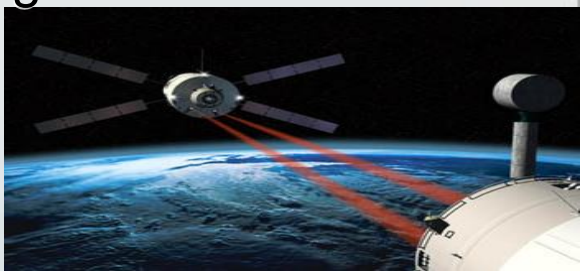
Tracker Beams – Outer Planetary Exploration



Tracker Beam-Planets Exploration



- **What Value could it be, well into the Future?**
- **Requirements:**
  - Controllable / Morphing Mirrors or Antennas-Accuracy
    - How Many Satellites Required
- Design & Build
  - Requirements to Be Driven by Transport to Mars or ARM.
  - Our Beam sends Ultra Power to Outer Orbital Transport (More than million times that of the Sun for Boeing's Solar Electro Magnetic Propulsion)
  - Schedule Deliveries & Techniques
  - Every Sub System to be developed

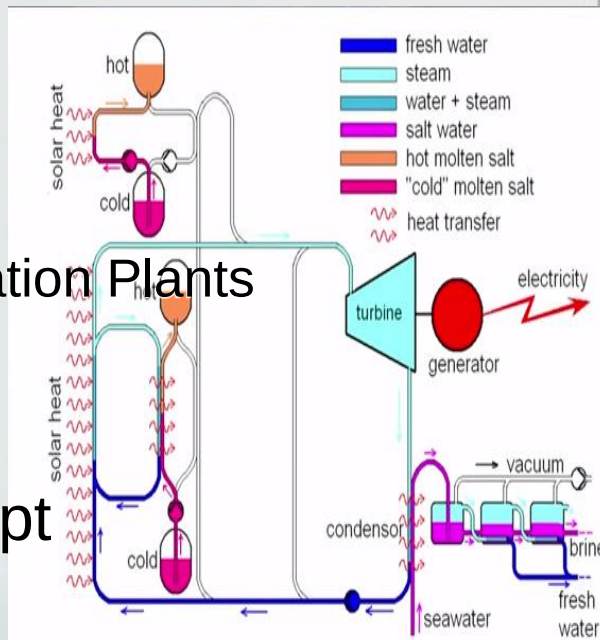


Desalination Systems

Desalination System

- **What Value could it be, well into the Future?**
- **Requirements:**
  - Controllable / Morphing Mirrors or Antennas-Accuracy (How Many Satellites Required)
- **Design & Build**
  - Requirements to Be Driven by Transport to Mars or ARM.
  - Our Beam sends Ultra Power to Desalination Plants
  - Schedule Deliveries & Techniques
  - Every Sub System to be developed
- SunSats=Energy From Space Concept

http://youtu.be/UcSmLX3TzIQ

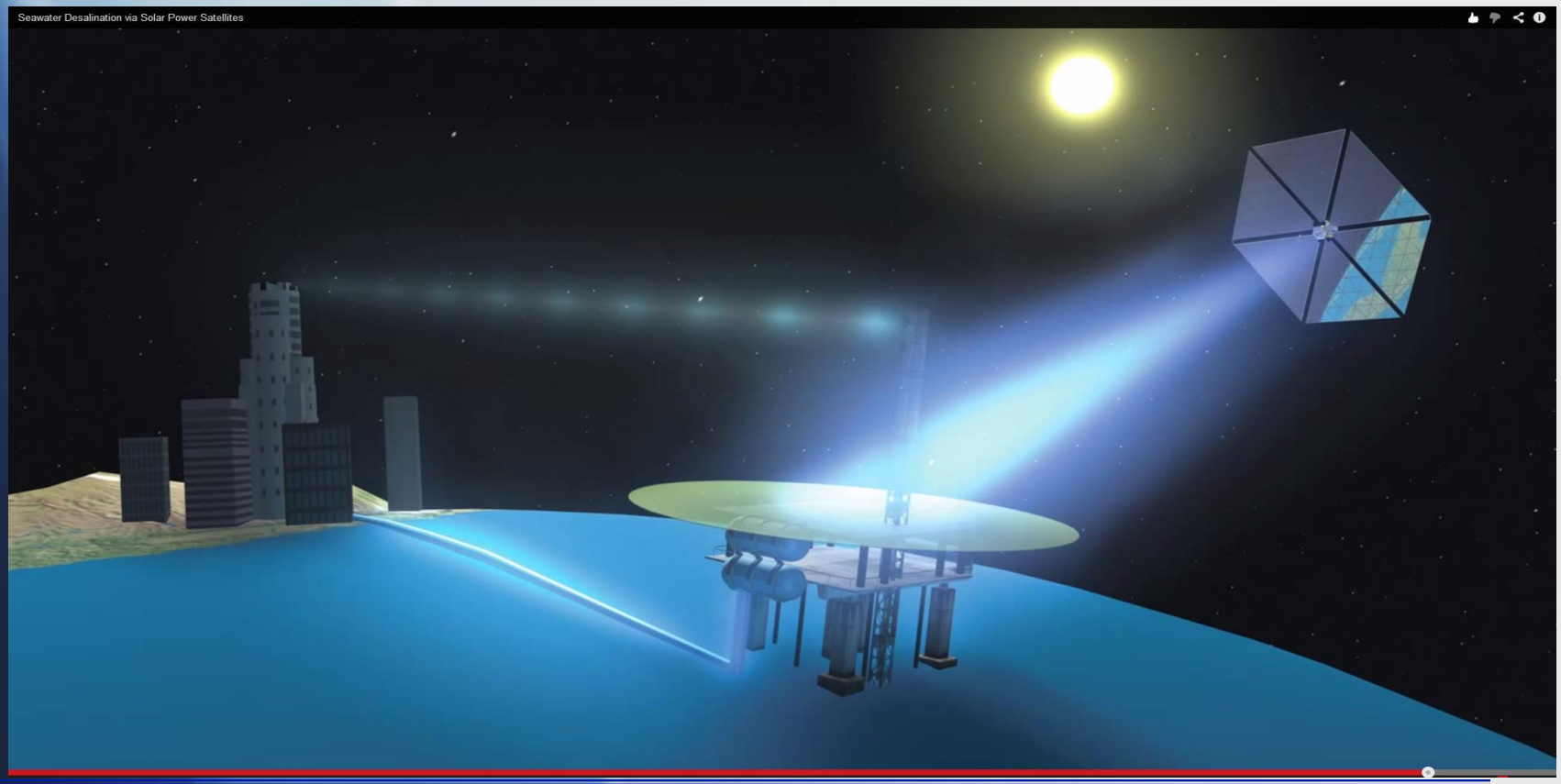


Desalination Systems Overview

- SunSats=Energy From Space Concept

http://youtu.be/UcSmLX3TzIQ, http://sunsat.gridlab.ohio.edu/

- Concept Lead by Space Environment Technologies Space Weather Division & Ohio State University



Desalination Systems Team

REF Data

Seawater Desalination via Solar Power Satellites

A visualization based on "Vision for Producing Fresh Water Using Space Power" by Kent Tobiska published in the Online Journal of Space Communication, Fall 2009.

Presented at the International Space Development Conference, May 27, 2010.

THE SPONSORS

The SunSat Competition is an initiative of:

The Online Journal of Space Communication

In partnership with:

The Society of Satellite Professionals International

The National Space Society

The Ohio University GRID Lab

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Faculty:
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Don Flournoy
Steve Mokris

OHIO UNIVERSITY
Scripps College of Communication

Game Research and Immersive Design Lab

Engineering the Future!

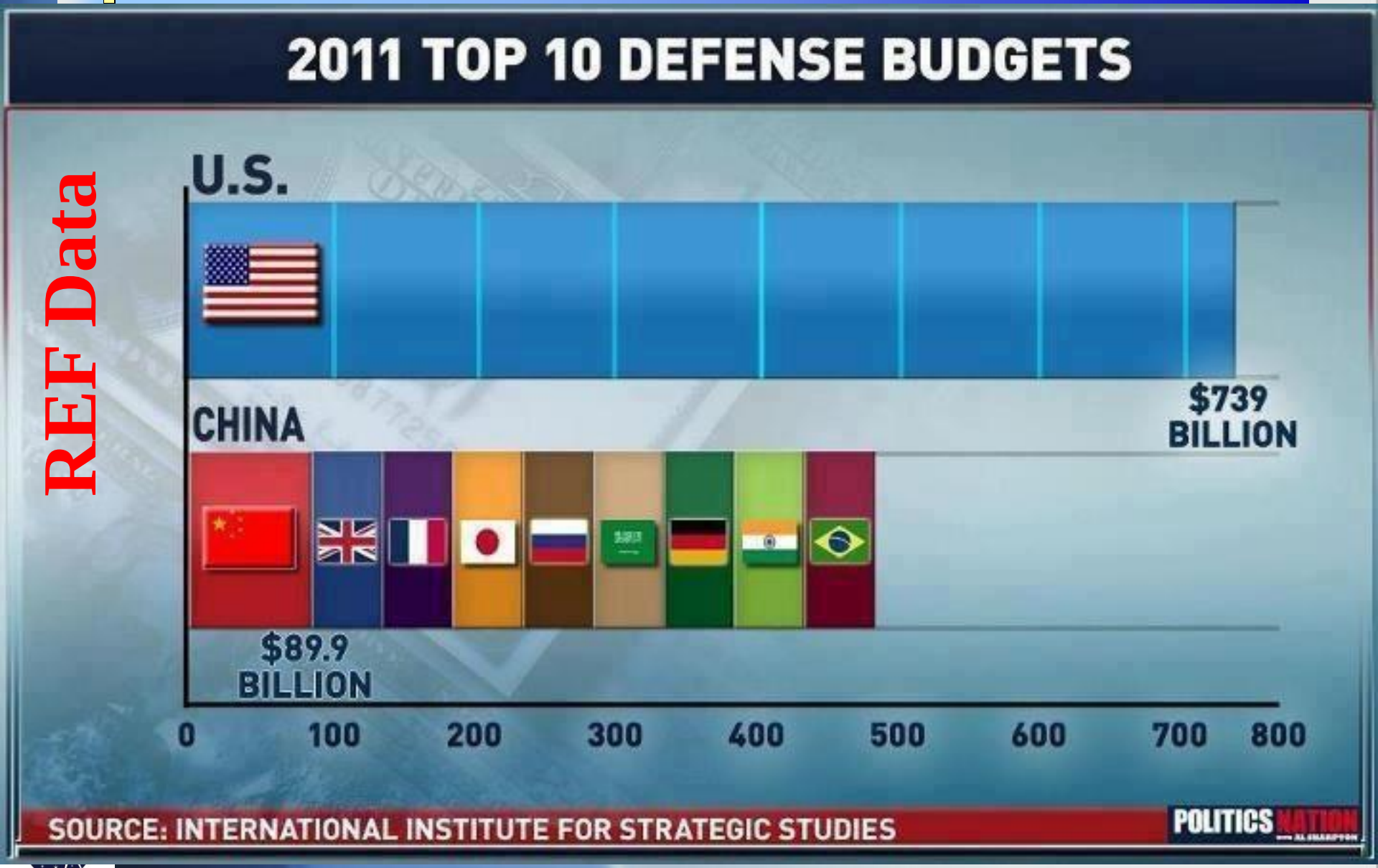
1) **Design & Development**
   - Concept, Design
   - Planning, Development Advancements
2) **Manufacturing & Logistics Support**
   - Manufacturing (MRP) Advancements
     - **3D Printing Futures (Multi Layered Mfg)**
   - Logistics Improvements (MRO, R&R, Support)
3) **STEM Realities (both sides)**
   - Where the Skills are needed; Countries
   - What skills are needed…
   - What Government & HR Recruiters say vs. What Company Jobs Outlook say (AW spring & summer)

D) The World: Yours & Our Future…

- Initial Futuristic means for US All via Microsoft's & Aerospace's Video
- Overcoming Global Warming & Sea Rise
- Overcoming Population Growth & Feeding US All.
- Overcoming Disease, Genetic Disorders & Aging Issues.
- Overcoming Political, Religious, Race/Ethnic Indifferences…
  - Conclusion 1.75 Billion years left of Earth, not so much for us during heat up activity. (Show things from Through the Wormhole)…

FYI – Who runs the World & Where's the Bucks

REF Data



Next> Stuff to do

REF Data

- **Send another update** to: **White House & Science & Technology, Fed Reserve, Senate, Congress, NSF, NASA, USAF, DARPA , MDA & World…**
- **Send SSP+ Data & new Book** to “the 3rd Floor” Chris Edwards & Hollywood Pictures Mike Peyser.
- By year 2030 over 2 Billion cars will be on Earth.
- Over **9.8 Trillion people on Earth by 2050**
- Write Integration Plan to upgrade grids & provide new grids
- Address arguments that **oil and gas industries will not be hurt.**
  - **It Makes Great Investment Sense to Oil Industries & Countries for the Future>**