# Gigawatt Space And Terrestrial Manufacturing

# Two Sides of the Same Solar Energy Coin

## *Ultra-lightweight CFRP Boom SBSP Solar Arrays*

## *Zero Consumer Cost Rooftop Solar Modules*

*ISDC 2008 Washington DC*

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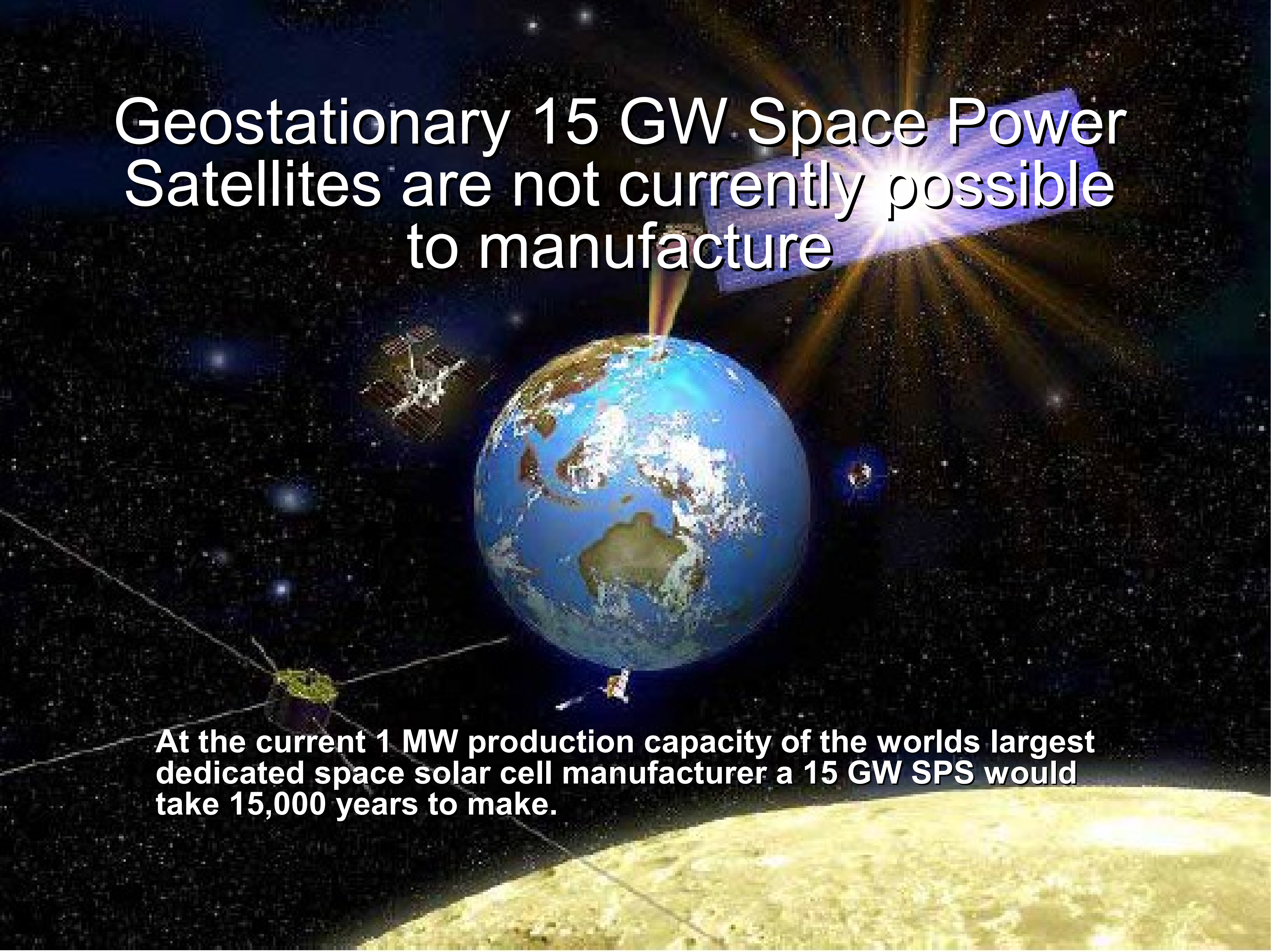
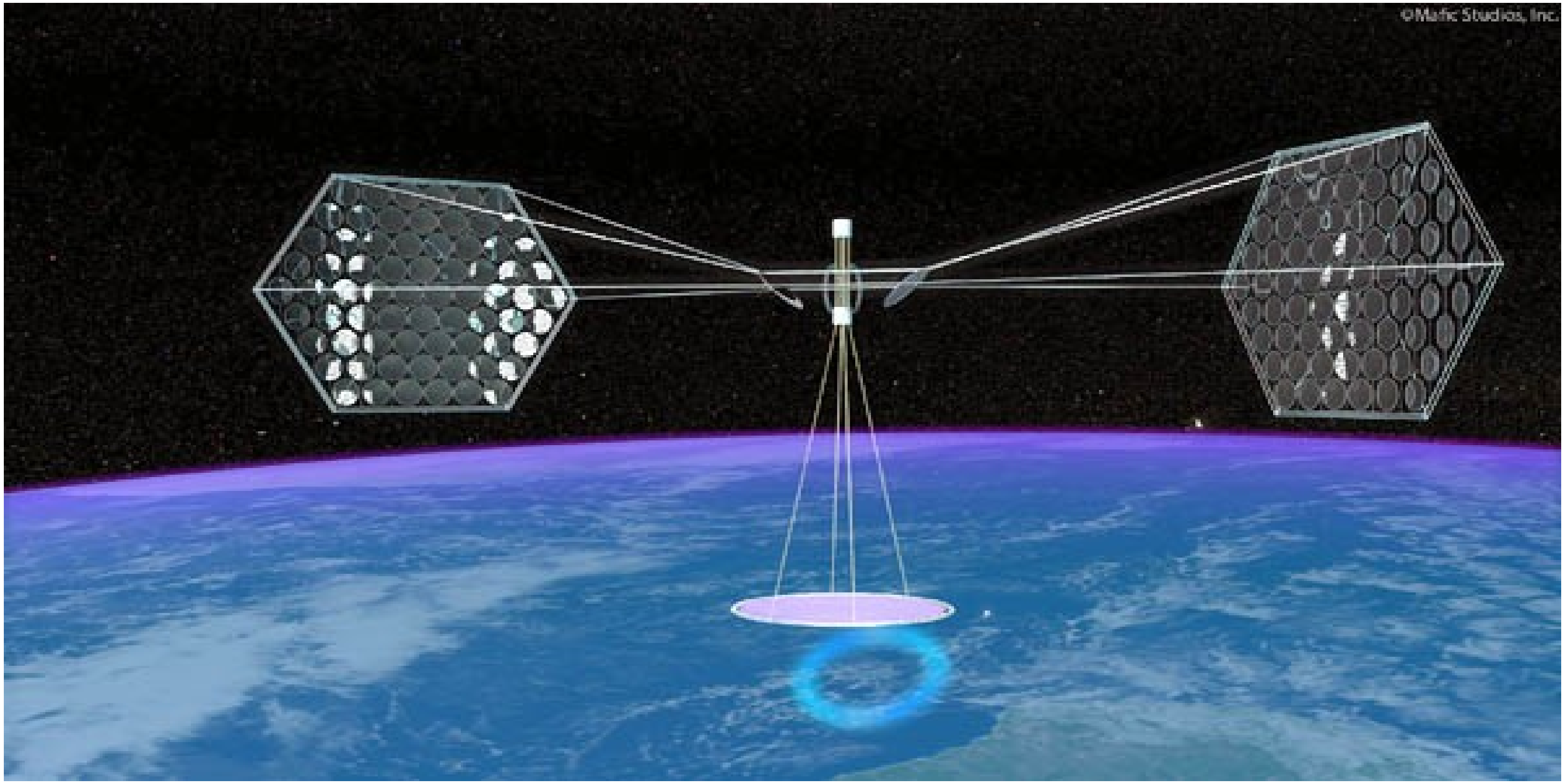
# Geostationary 15 GW Space Power Satellites are not currently possible to manufacture



**At the current 1 MW production capacity of the worlds largest dedicated space solar cell manufacturer a 15 GW SPS would take 15,000 years to make.**

# No Business Case to Support Concentrator SPS




**Theoretical power density at 54% efficiency is 733 Watts/m2**
**Mass add-ons total 4 kg per m2* = 183 Watts per kilogram power density**
**10 suns concentration still equals only 1,830 Watt/kg power density**

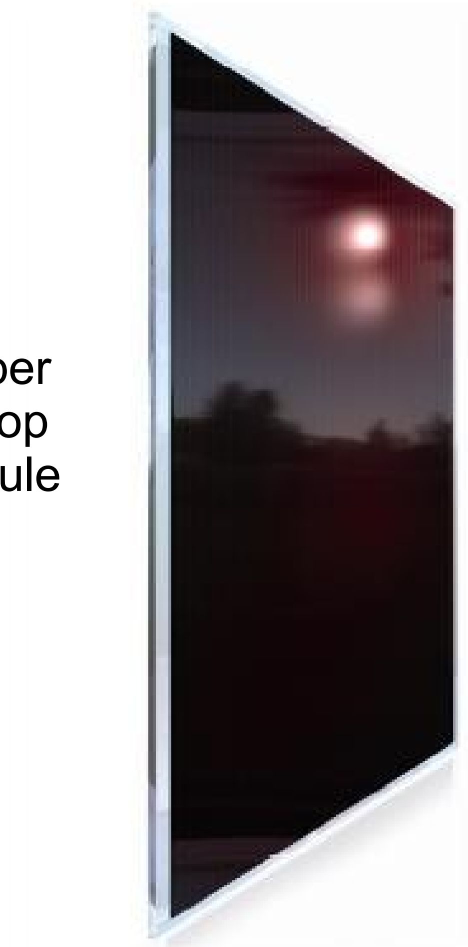
*Boeing SpectroLab Website- http://www.spectrolab.com/DataSheets/Panel/panels.pdf

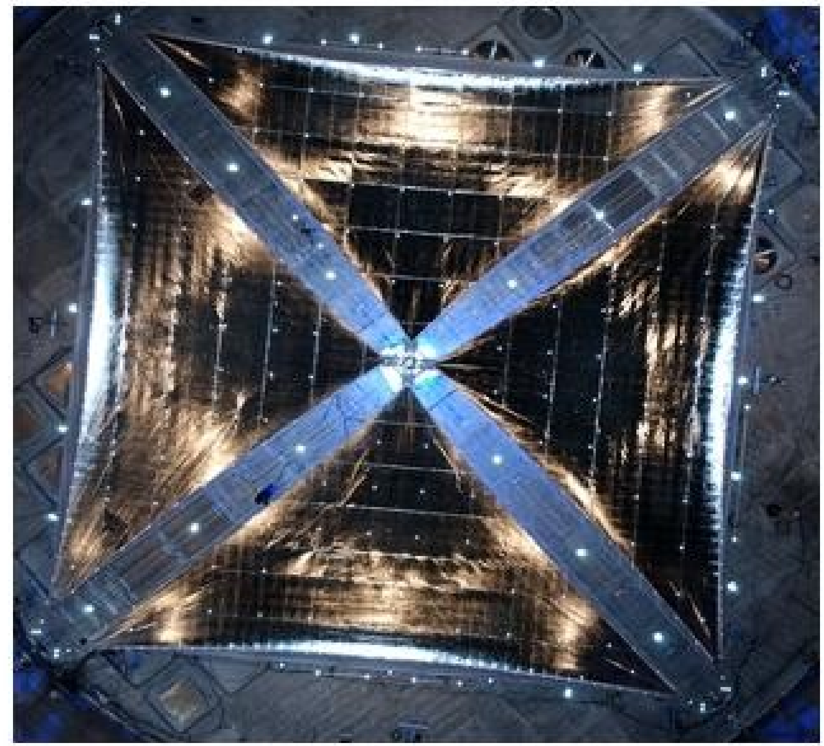
**29 % Efficient Triple Junction cells are too expensive for roof solar modules at cost of $1,000 per Watt.**
**A single 10 kw roof top at current cost for space solar cells would $10,000,000 US.**

**No synergy in rooftop modules and rigid space cell manufacturing.**

# Compatible Dual Use Manufacturing for Space Applications Arrays and Rooftop Modules

70 cents per Watt rooftop solar module





50 kW to 8 MW Ultra-lightweight Solar Arrays

Gigawatt Scale Dual Use Manufacturing

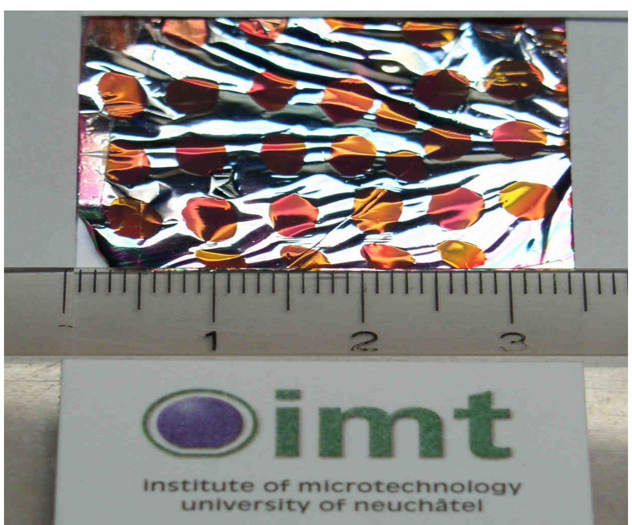
Rooftop modules at 70 cents a Watt in the box ready to ship
GW production scales for Space-Based Solar Power Applications

Current results of 5,880 Watts per kilogram at 7-9 micron polymer.
16,800 Watts kilogram for 2 micron thickness polymer at 168 Watt/m2 AMO Standard 1357 W/m2 @ +90°C, 12.4% efficient, a-Si:H cells.

# Power density over 10,000 Watts per kg for European Sail Tower SPS Concept

## a-Si:H cells on 2 micron NASA CP1 or M-SRS CORIN Polyimide

M-SRS Technologies CORIN is UV, radiation and ATOX resistance stable for long term LEO assembly of SBSP




Amorphous Silicon TF cell size compared to TJ or silicon rigid cells (a-Si in orange)

Zero welded interconnections for a-SI:H cell monolithic cell interconnection – no arcing 1,000V

428 Welded connects for rigid cell- - arc at 100V to300V

## TRIPLE JUNCTION CELL SPACE SOLAR ARRAY

| | | |
|---|---|---|
| Cerium Oxide coating | 3 Mil | (76.2 micron) |
| Coverslide | 5.5 Mil | (139.7 micron) |
| Adhesive | 2 Mil | (50.8 micron) |
| Triple Junction Cell | 8 Mil | (203.2 micron) |
| Interconnect-cell Adhesive | 4 Mil | (101.6 micron) |
| FM dielectric | 10 Mil | (254 micron) |
| Adhesive | 2 Mil | (50.8 micron) |
| Coverslide | 5.5 Mil | (139.7 micron) |
| Graphite-epoxy face sheet | 10 Mil | (254 micron) |
| Epoxy-scrim clothe | 2 Mil | (50.8 micron) |
| Al Honeycomb | 750 Mil | (19,050 micron) |
| Epoxy | 2 Mil | (50.8 micron) |
| Graphite-epoxy face sheet | 10 Mil | (254 micron) |
| White paint | 2 Mil | (50.8 micron) |

Total (deployed array thickness) = 2.02 centimeter = 816 Mil (20,726.4 micron)

## CP1/a-Si:H SPACE SOLAR ARRAY

| | | |
|---|---|---|
| CP1 polyimide | 0.4 Mil | (9.95 micron) |
| a-Si:H Cell | 0.012 Mil | (0.30 micron) |
| CP1 polyimide | 0.4 Mil | (9.95 micron) |
| Pyralux copper laminate rip-stop integrated bus wiring | 1.97 Mil | (50 micron) |

Subtotal (cell thickness alone) = 0.812 Mil (20.2 micron)

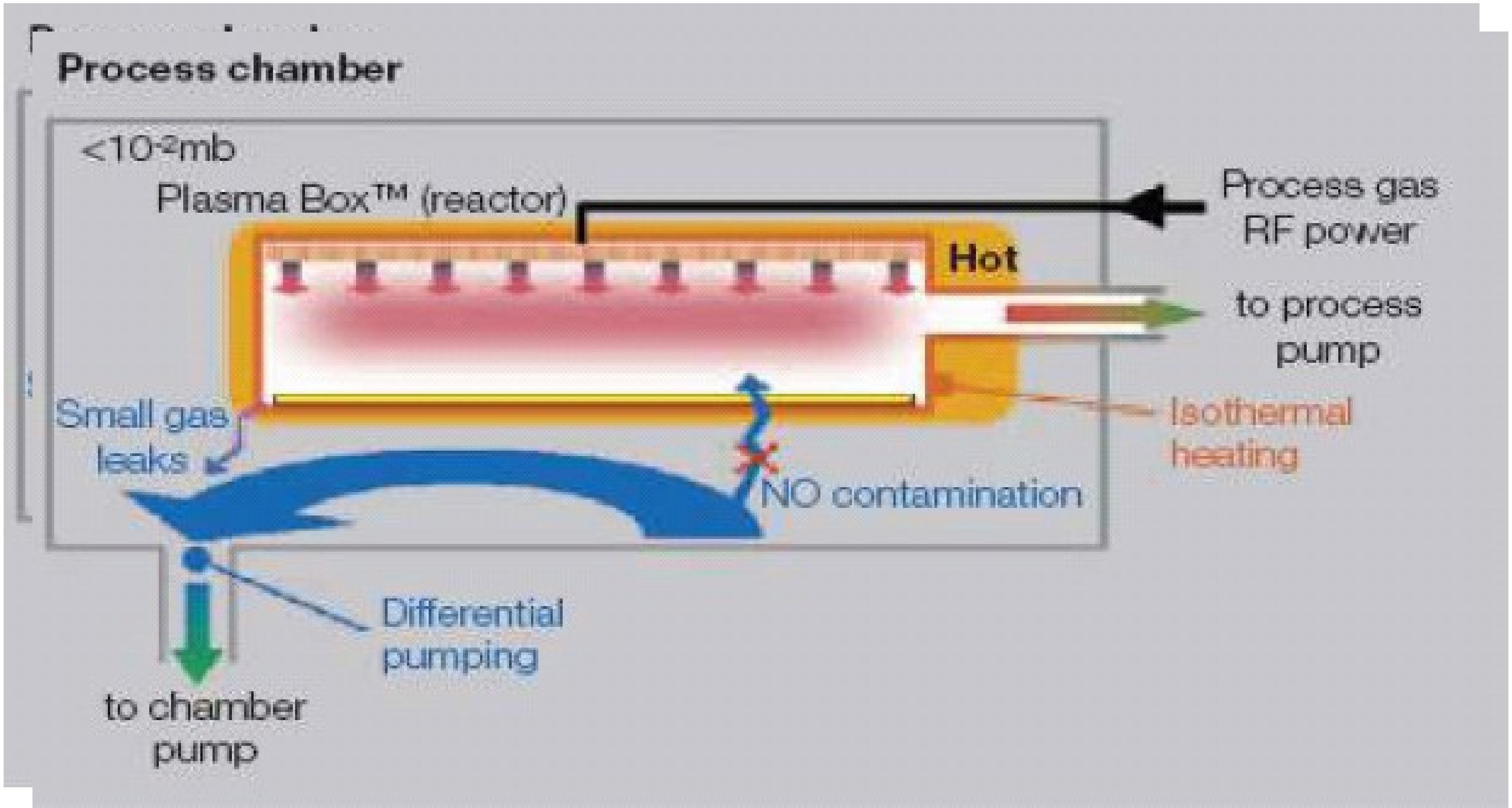
Total (deployed array thickness) = 2.78 Mil (70.62 micron) at Ripstop

No Honeycomb Panels, glass cover slide, or cushion blankets as Mass Add-ons required by TJ cells for space launch.

**296 Times Less Payload Volume Than Coventional Ridged Triple-junction Solar Cell Arrays.**

**Still more dramatic payload savings are possible with 2 micron thickness CP1 or CORIN superstrates.**

# CP1/a-Si:H Solar Cell Deposition Process

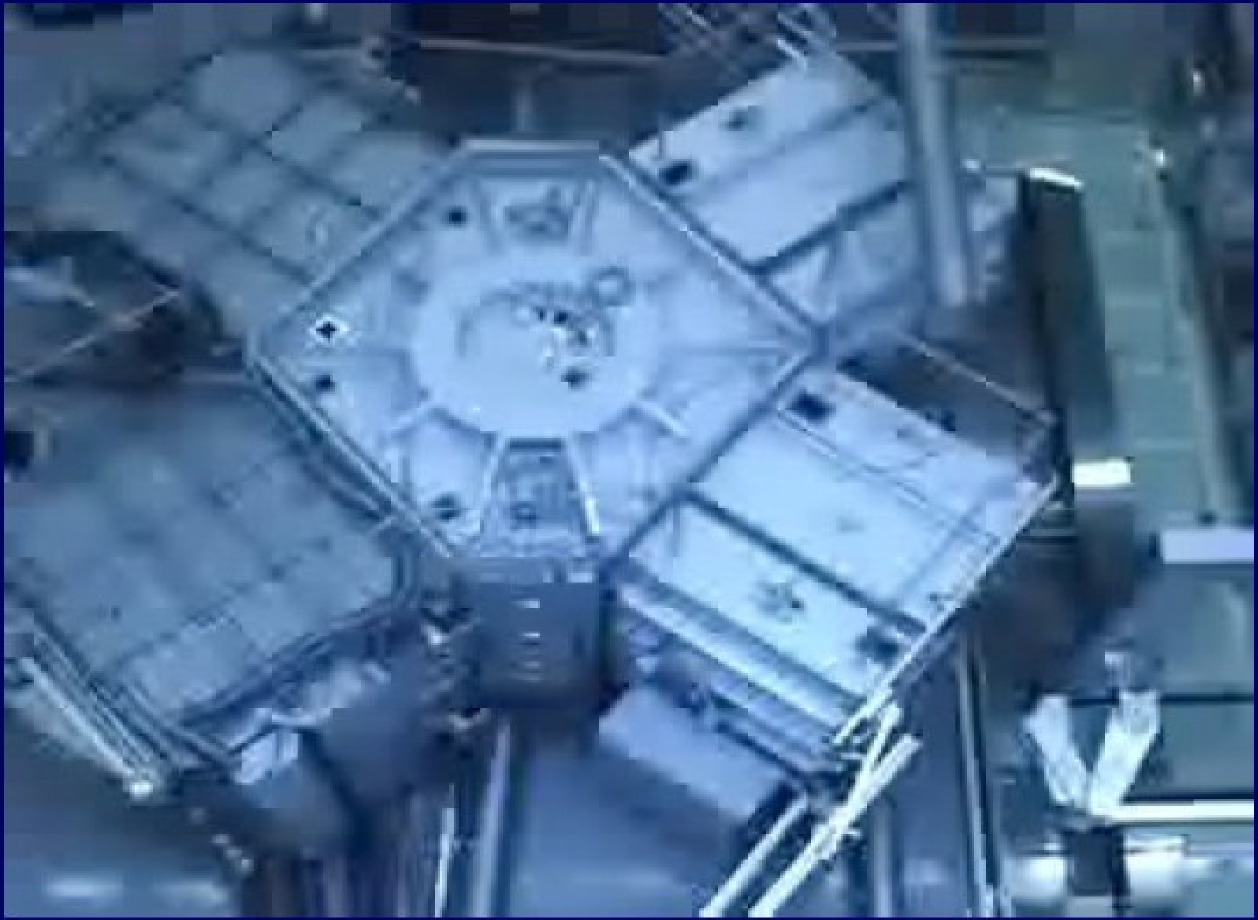



CP1/a-Si Thin Film Solar Cells are deposited by plasma-enhanced chemical vapor deposition (PECVD). The PECVD system has been shown to be very efficient for low temperature deposition of solar cells onto thin film CP1 polyimide substrates.

CP1/a-Si:H Solar Film has been optimized for large scale production on a fully automated solar cell line that is used to manufacture standard terrestrial solar cells.


Totally modular system for large scale manufacturing of CP1/a-Si solar cells

# GW Scale Synergistic Space and Terrestrial TFSC Manufacturing



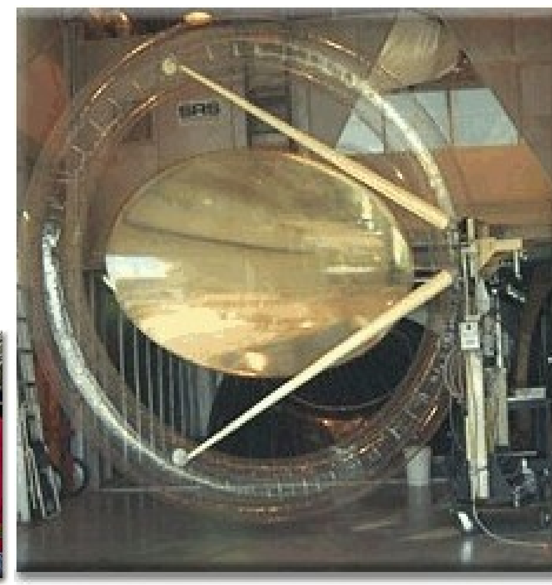
- Zero Consumer Cost Rooftop Solar Modules subsidized by

- Gigawatt Capacity Low Cost ATOX Resistant, 2 micron thickness Space Applications a-Si:H TFSC made on the Same Factory Line.

# SRS Technologies CP1 and CP2 Polyimides

***Developed by NASA and Produced under License to SRS Technologies***

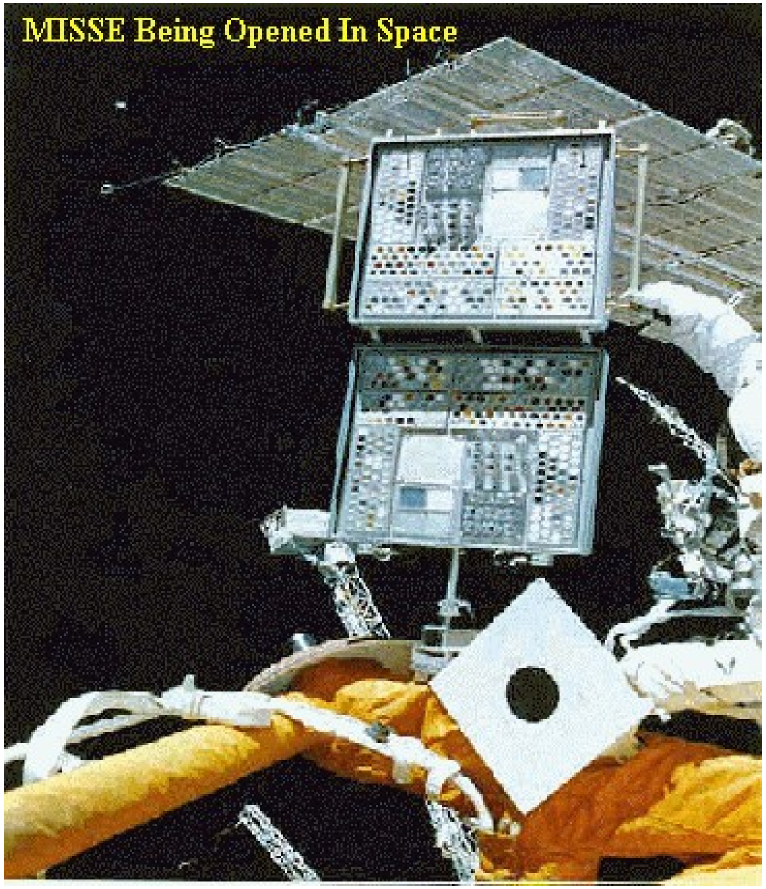
**LaRC™-CP1** and **LaRC™-CP2** polyimides are revolutionary.



CP1 is a high performance material with a wide variety of uses in space structures, thermal insulation, electrical insulators, industrial tapes and advanced composites.  provides superior physical and electrical properties over a wide temperature range and in a number of harsh environments.

# Space Tested on ISS

Competing polyimide materials have less UV resistance and are not as transparent as CP1 and CP2. CP1 and CP2 are superior for long-duration, space-based applications where transparency is needed for functionality. CP1 has been tested and is rated for a 10 year life in GEO. CP1 is the superior solar array component used a a supersubstrate for CP1/a-Si:H Thin Film Solar Cells.

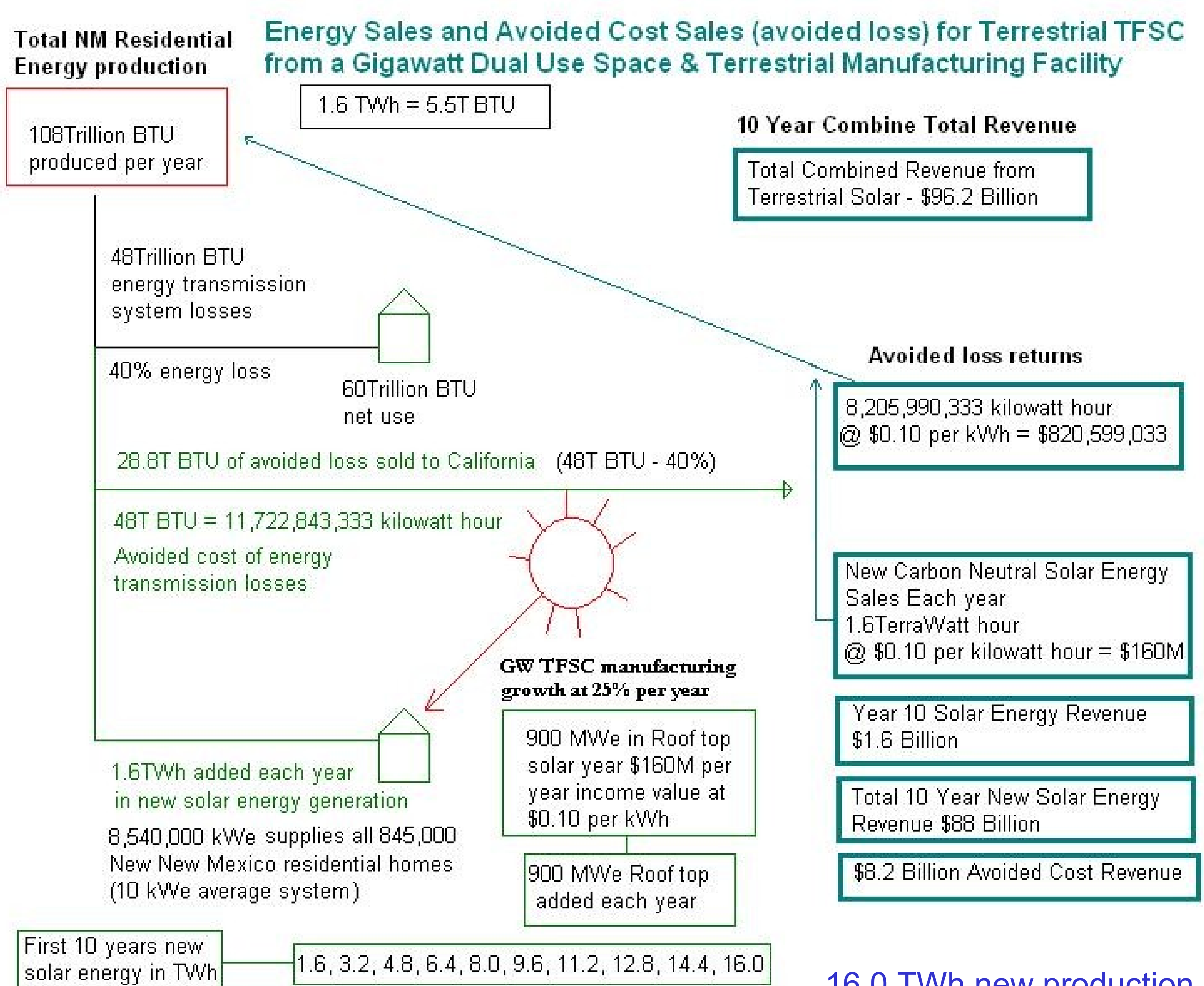



For applications requiring transparency, other polyimides absorb too much solar energy. Materials that do have similar transparency to CP1 and CP2 degrade more rapidly in the harsh environment of space.

**CP1 and CP2 Compared to Typical Polyimides**

| | CP1 and CP2 | Typical Polyimide |
|---|---|---|
| Transparency (0.5 mil film at 500 nm) | 95% | 35% |
| Transparency After UV Radiation (300esh) 0.5 mil film at 500 nm) | 82 - 86% | 35% |
| Dielectric Constant at 1 MHz (Relative Humidity 30% / 100%) | 2.77 / 2.80 | 3.38 / 3.85 |
| Solubility | Soluble | Insoluble |

# 900 MW per Year of Added Terrestrial and 100 MW of Space Solar 10 Years




16.0 TWh new production by year 10

# Space-Based Solar Power: Realizing the Vision

Major technology transitions, as example transition from wood burning to coal to internal combustion fossil fuels or sail, wind and water power to steam power, have historically required "local" economic feasibility to be realized, that is – technology transition, yields and Return on Investments, has been within a few years to a decade, with revenues drawn within some relatively predictable setting. The decision to make the transition must be rational at the local level and it must make sense for the individual local decision makers.

# Key to locally rational decisions that bring about the Distributed Energy Solar Economy and Space-Based Solar Power are four fold:

1.) The the technologies to be developed must have applications that are nearer term and multi-faceted.

2.) Interim systems must provide value to the decision-makers/investors within both government and industry that also provide income for sustained market expansion and sustained growth of manufacturing capacities.

3.) Space-Based Solar Power pilot projects must be affordable, have value and retire risks while providing legitimate Energy and Wireless Power Transmission services.

4.) Space-Based Solar Power must maintain current energy production gains while expanding manufacturing for Space-Based Solar Power to provide Sustainable Carbon Neutral Energy Generation at Terrawatt levels.

## *Welsom Offer of Worldwide Strategic Alliance*

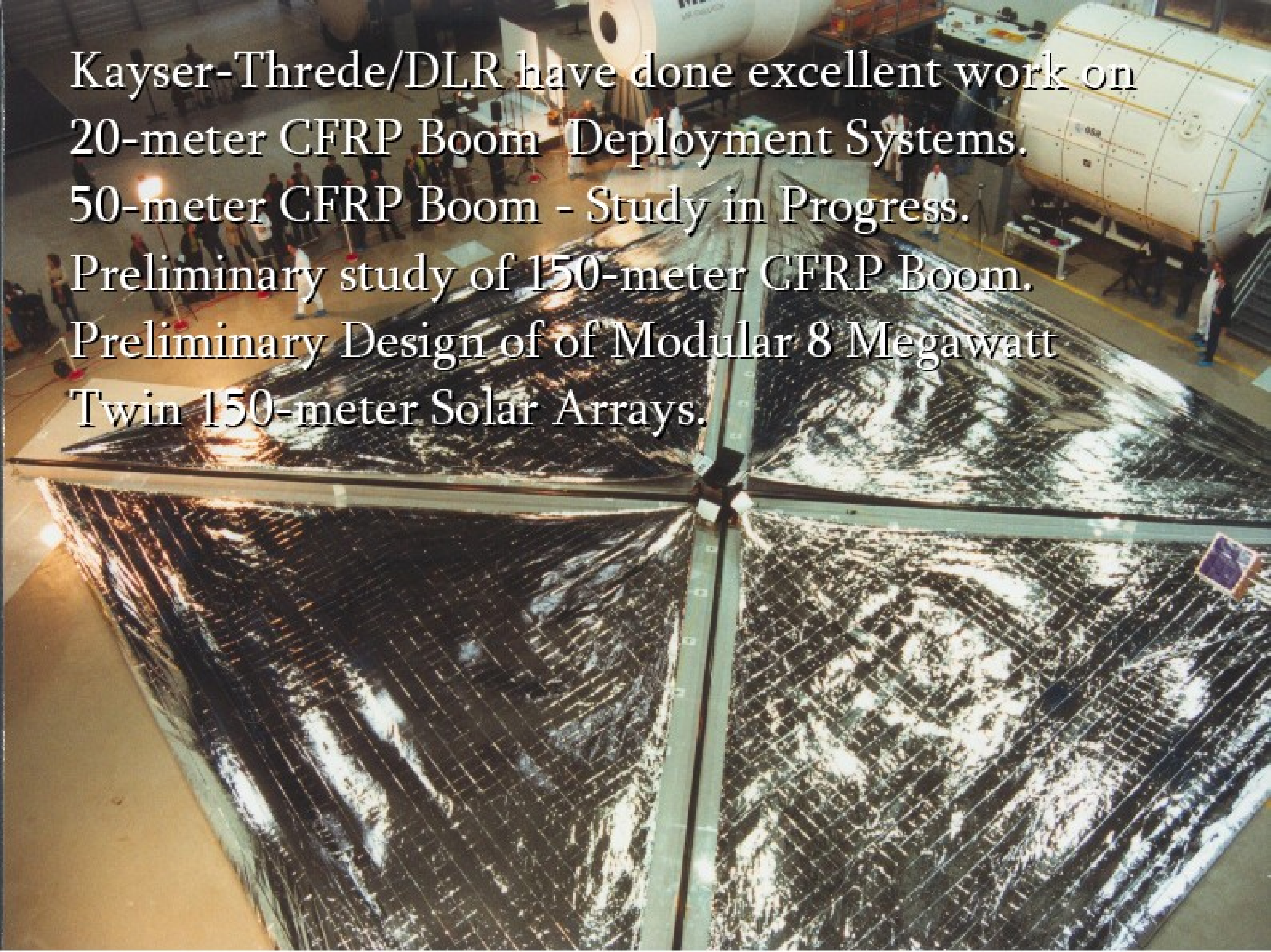
New Mexico Strategic Alliance with European firms, National Technical Agencies, ESA and DLR for utilization of GW TFSC Production.

Alliance to JPL, Sandia National Labs, NREL, AFRL, NSSO Pentagon and Welsom Space Power Consortium..

Alliance to Grand Bassin, JAXA and Japan rectenna technologies, JPL and JAXA for beam safety.

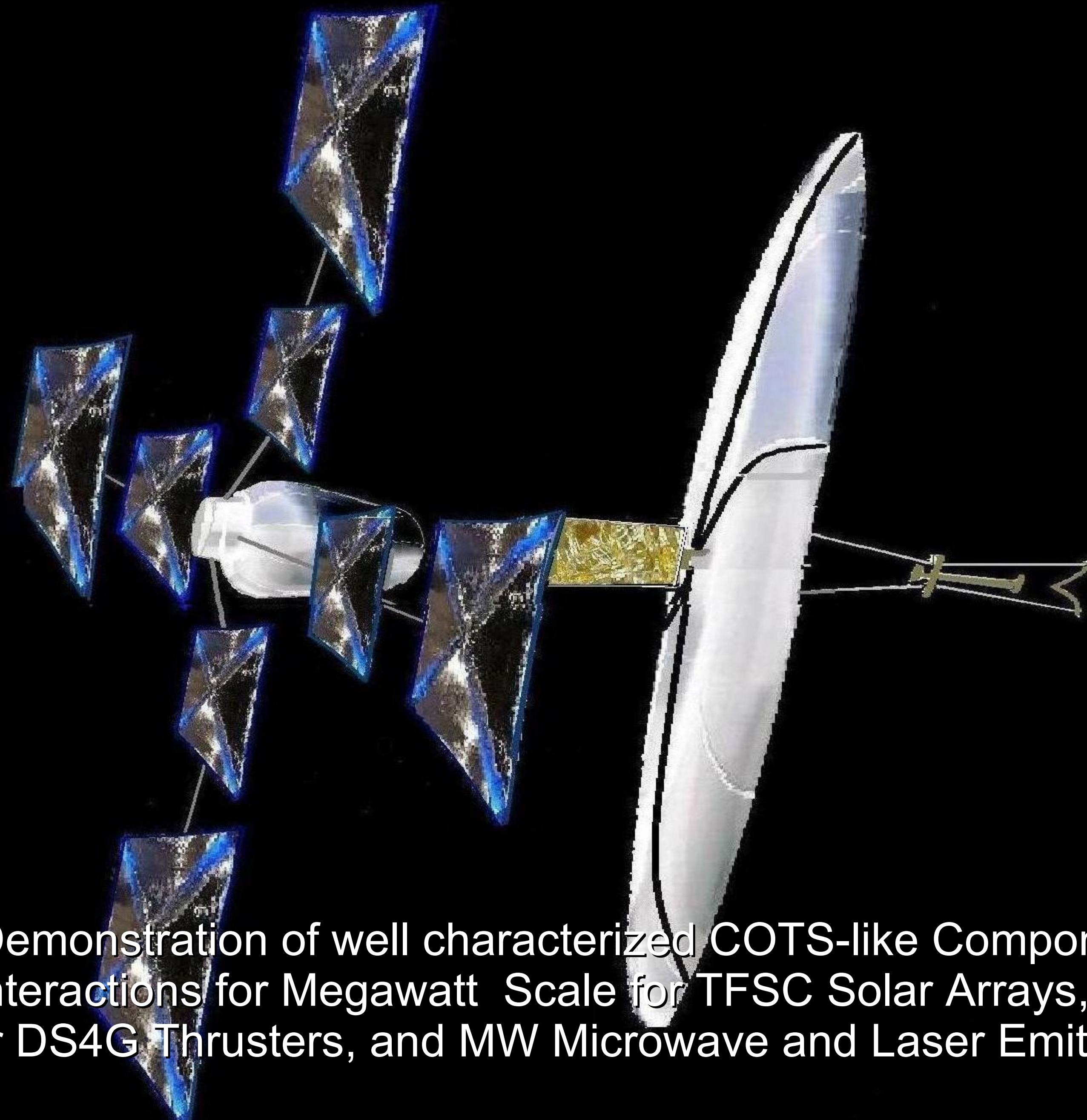
EU Planning for SPS, Combined Space and Terrestrial Solar and Hydrogen Energy Storage. Additional Commercial Hydrogen Production.

Republic of Palau, United Nations, and Global Coral Reef Alliance partnership in Space to Ground (Ocean) WPT Demonstration Safety Testing, Reef Fisheries Restoration, BioRock Building Materials, Vertically Integrated Accretion Hydrogen production; and Sustainable Industry and Energy for Emerging Island States.



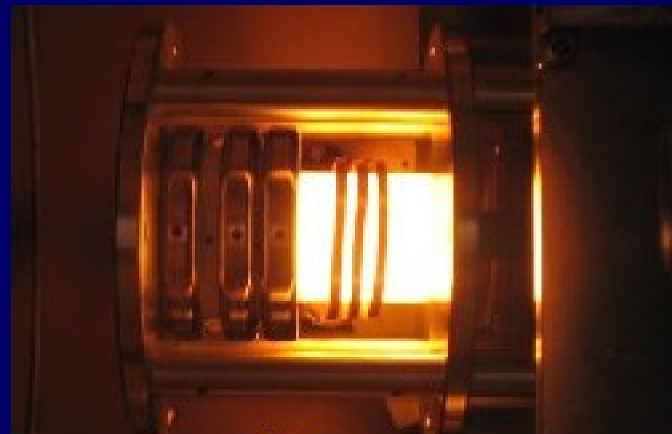
Kayser-Threde/DLR have done excellent work on 20-meter CFRP Boom  Deployment Systems.
50-meter CFRP Boom - Study in Progress.
Preliminary study of 150-meter CFRP Boom.
Preliminary Design of of Modular 8 Megawatt Twin 150-meter Solar Arrays.

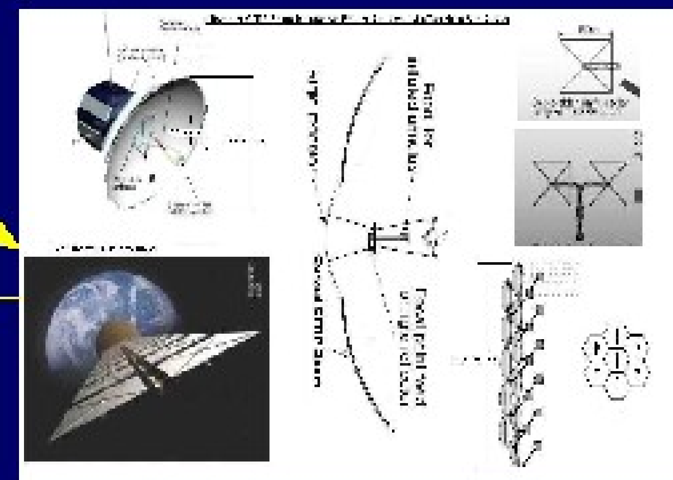
# Demonstration of  Space-Base Solar Power



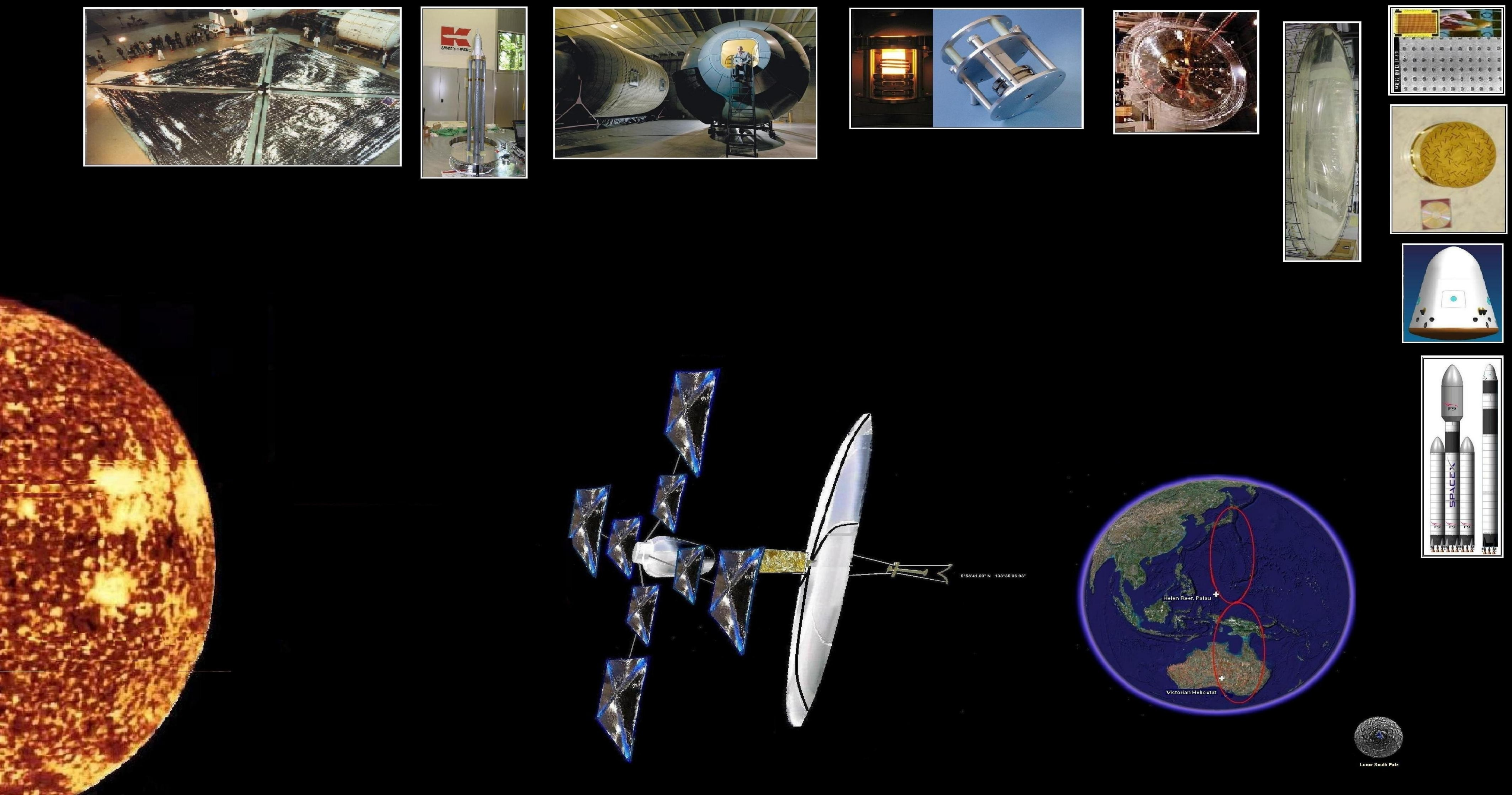
In Space Demonstration of well characterized COTS-like Components:
Systems Interactions for Megawatt  Scale for TFSC Solar Arrays,
MW Power DS4G Thrusters, and MW Microwave and Laser Emitters

The Demonstrator should be useful to assembly of the Sail Tower SPS
and to Provide Lease Income from other Space Enterprise for 40 years.





Systems interactions and Space Qualification of MW Arrays, MW Thrusters, MW Emitters and Manned Capable Space Habitat




## All COTS-like Components Ready for Space Launch by 2012

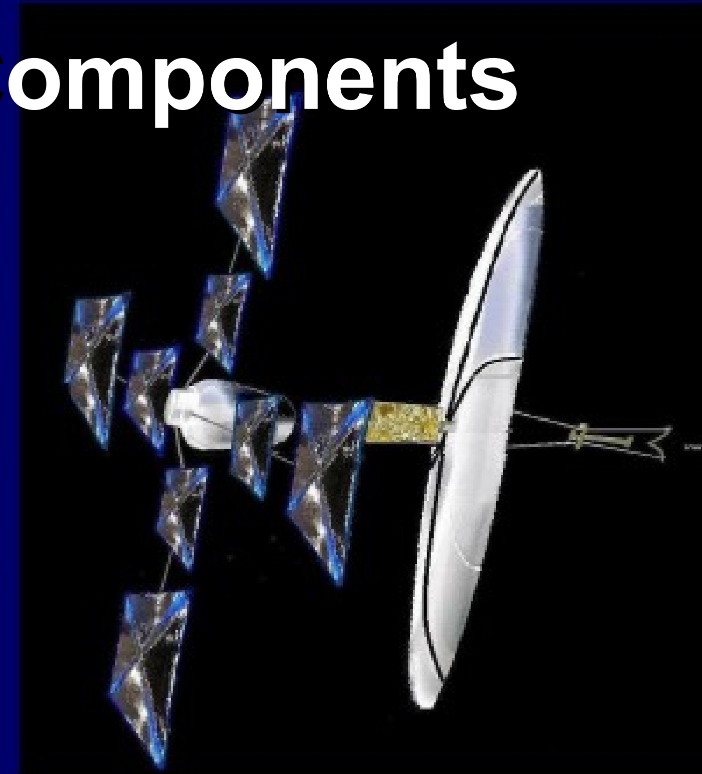
Reed-Willenberg SPS

**Multi-national COTS-like 1.2 MW Space Solar Array for
Early Commercial Demonstration of Space-Based Solar Power**

Welsom Space Power "The Race is On!"

Tokyo-Sydney-Melbourne QGSO Orbital Analema
Helen Reef, Palau - Microwave WPT Testing Station
Victorian Power Station 154 MW Heliostat - Laser + PV WPT Nighttime Testing

# Scalable COTS-like Components



*Existing Qualification and Teaming Agreements save time and money in MW Scale SBSP Demonstrator.*

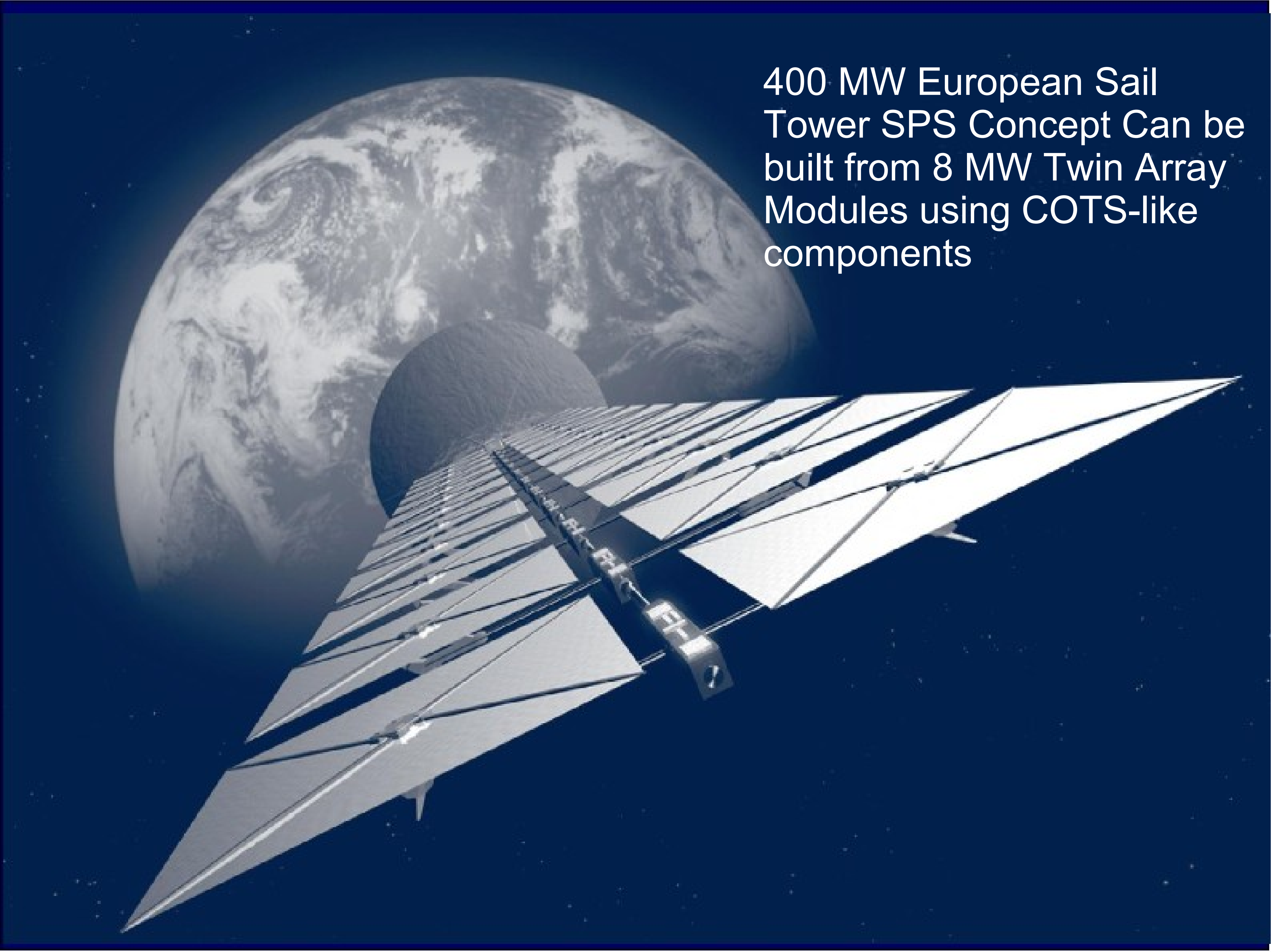
*Upscaling from :*

*1. 20-meter CFRP Boom to*

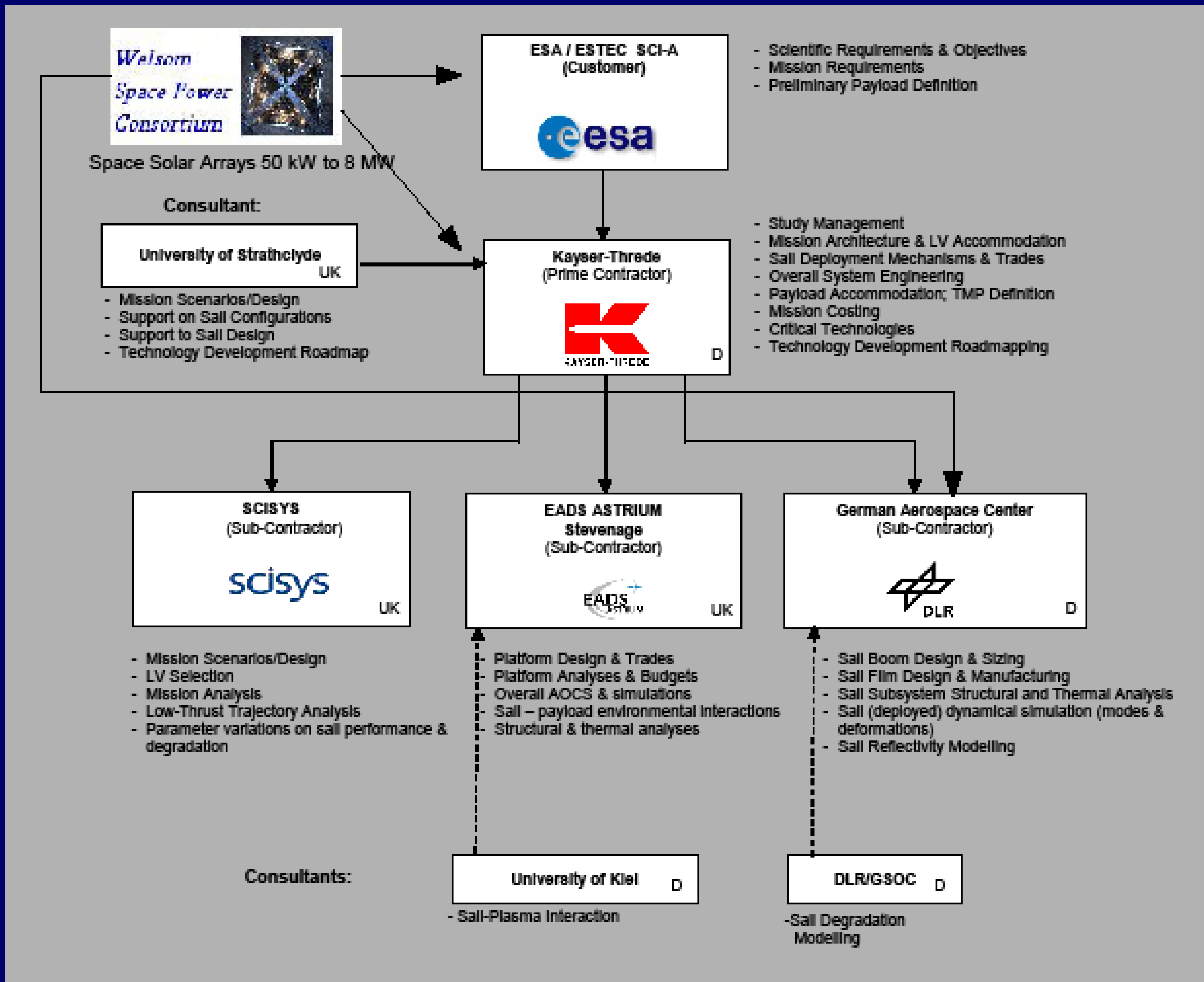
*2. 50-meter arrays to*

*3. 1.2 MW, with four (4) each of 20-m and 50-m sub-arrays*

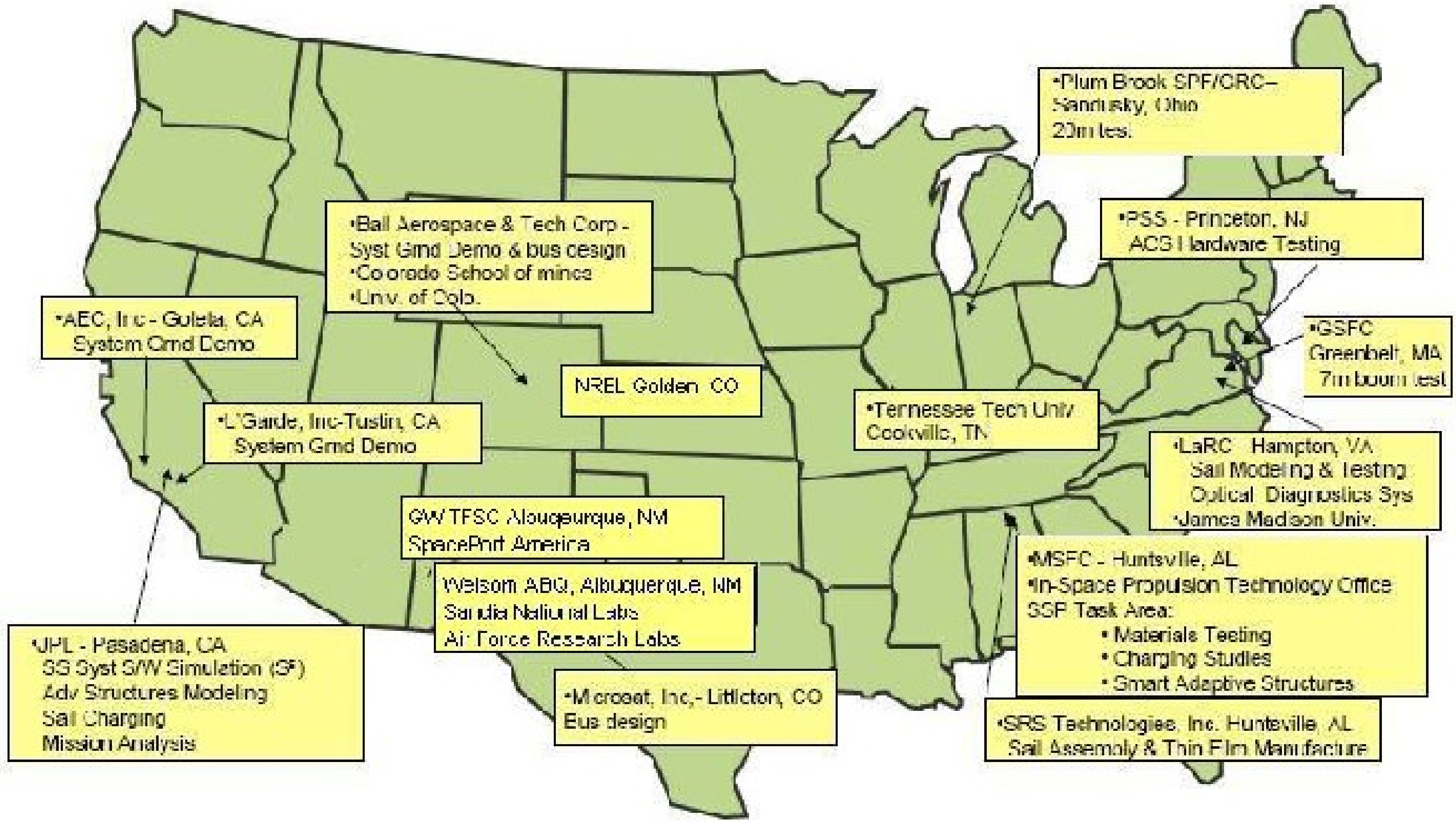
*4. Twin 150-meter 8 MW Modules*


400 MW European Sail Tower SPS Concept Can be built from 8 MW Twin Array Modules using COTS-like components

# European Geo-sail Team for 20-meter,50-meter and Twin150-meter CFRP Boom Arrays



# US 20-meter Solar Sail Team and Welsom Team



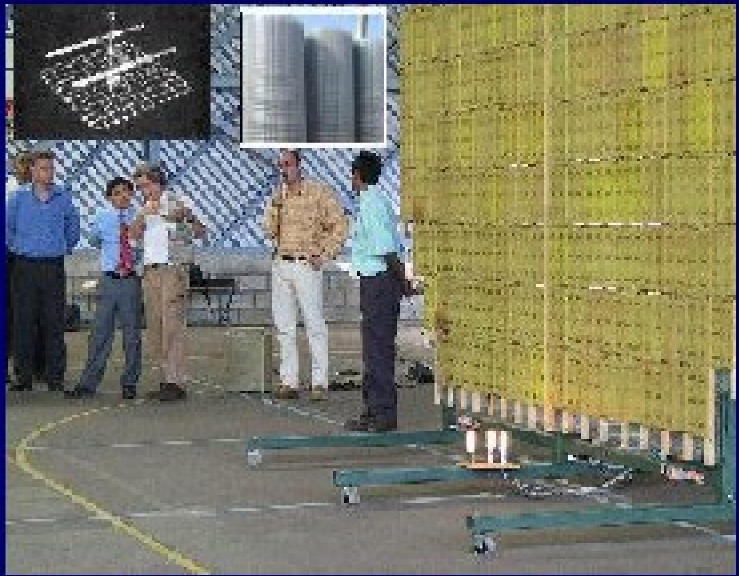
SBSP WPT (Wireless Power Transmission) Demonstration

Commercial Microwave Demonstrations Commercial:

1. Microwave for Low Energy Ambient Field Hand Held End User Device Recharge.
2. Large Grid Connected Rectenna


Commercial Laser WPT

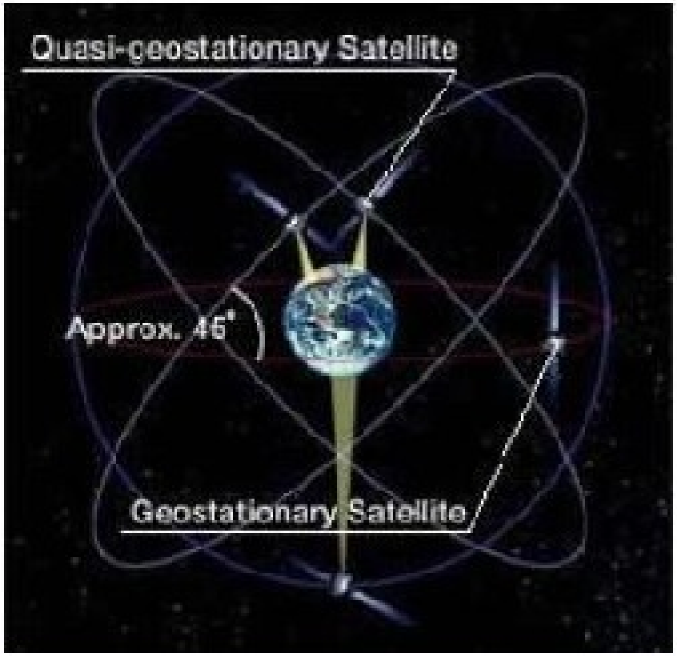
1. Laser + PV (Photovoltaics)
2. Laser + Thermal Energy Receiver

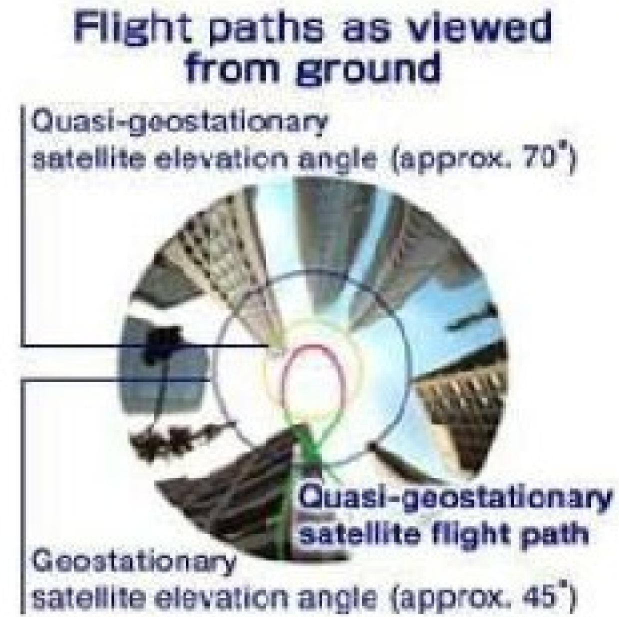


All WPT Demonstrations recurrent as:

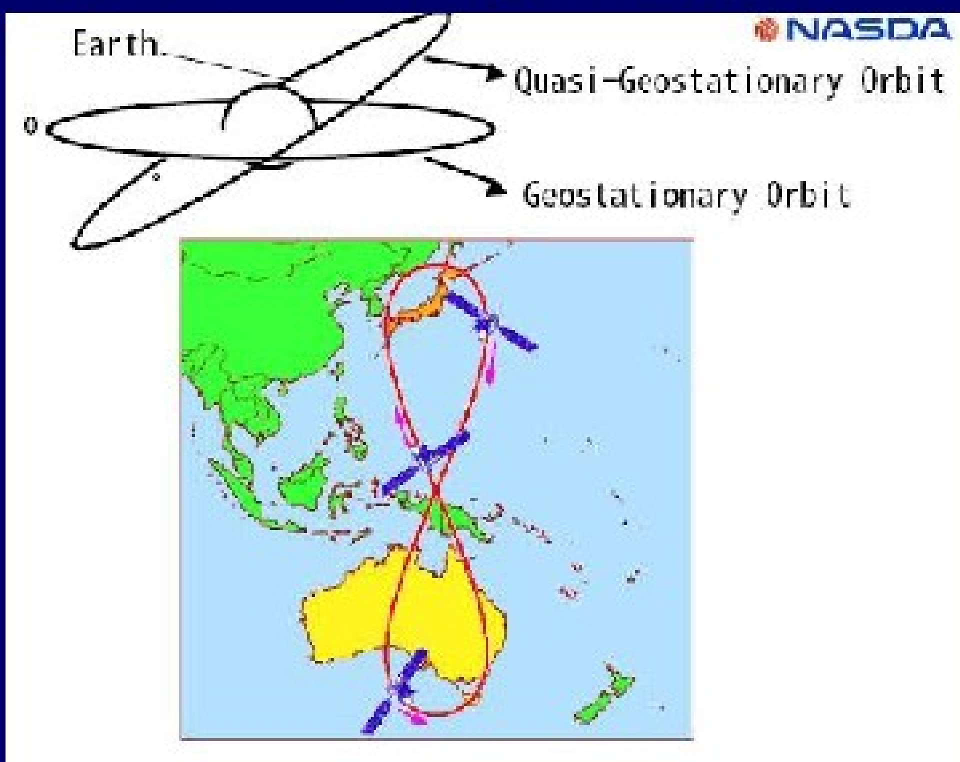
1. Space to Space
2. Space to Near-Space

3 Space to Ground (Ocean)




# QGSO – Longer ellipse = Longer Overhead Dwell




Possible Selenocentric "QGSO" Type Lunar Orbits for WPI SBSP

## $1Trillion Yearly Market for End User WPT Rechargeable Devices

Power Cast and others are proving there is a substantial market share available to WPT End User Products as Premium Products.

The current yearly market for Cell Phones in set at $174 B USD

The President of Ford Motor Company has stated Ford will manufacture 1,000,000 Hybrid Autos in 2008. He also sets market penetration of this $1T USD yearly market at 30% by 2012.

SBSP WPT Rechargeable End User Devices like WPT Rechargeable Cell Phones and WPT Rechargeable Hybrid Autos that need no plug-in Recharge or Fuel in Metropolitan Beam Down Areas would seem due a very large share of these markets.

WPT Recharge form SBSP low energy level ambient microwave fields could provide valuable revenue to Bridge the Chasm from MWSBSP WPT beaming to cost parity energy production from Space-Based Solar Power WPT at +5GW Grid Connected Systems.

End User Device Rectennas/ WPT Microwave Receiver Systems likely for Palau Beam Down Demonstration are being developed by Hitachi, Z. Popovic, H. Visser, HRL-Raytheon, Mitsubishi, Power Cast and SESCRC/Welsom and a Evanescent Wave Coupling WPT by A. Karalis.

# SESCRC/Welsom WPT Beam Down Site Proposals

Microwave Safety Testing
Helen Reef, Tobi Island,
Republic of Palau
We seek to demonstrate unequivocal safety for WPT with Coral Reef Ecosystems Marine Microorganisms

**Laser + PV Testing, Victorian Heliostat Concentrating Photovoltaics Power Station**
We seek to demonstrate peak load augmentation and night time Laser +PV

Tokyo/Sydney-Melbourne QSGO Beam Down Path
Incorporates Helen Reef and Victorian Power Station


Highly Elliptical Quasi-Geostationary Orbit

SESCRC/Welsom 2008 Commercial Development for Commercial WPT Utilization:

**1 WPT/Solar PV CF Hyperblimp UAV Sensor Airships.**

WPT CF Hyperblimps are designed as relatively small fast, highly maneuverable UAV airships for low altitude and HAP at 22 km altitude deployment.

Deployments of maximum 14 days continuous 24/7 continuous operation, operational 50 km distance from base.

Designed with Maximum payloads of 15 kg for MISAR/MiniSAR sensor packages with optical imaging recognition/tracking to be used in Munich Traffic Monitoring and Civilian Security in cooperation with DLR Oberpfaffenhofen Telemetry and Oversight with connection to DLR Traffic Tower Systems.

JPL Pasadena has offered that JPL commercial units will design and build both microwave emitter arrays and Hull Integrated Thin Film/ Mesh CF rectennas for Hyperblimp on payment by SESCRC/Hyperblimp.

These WPT send/receive arrays would also be used for Space to Near-space WPT Hyperblimp Commercial Demonstrations

SESCRC is an Associate Member of the European Union HAPCOS 297 Cost Action

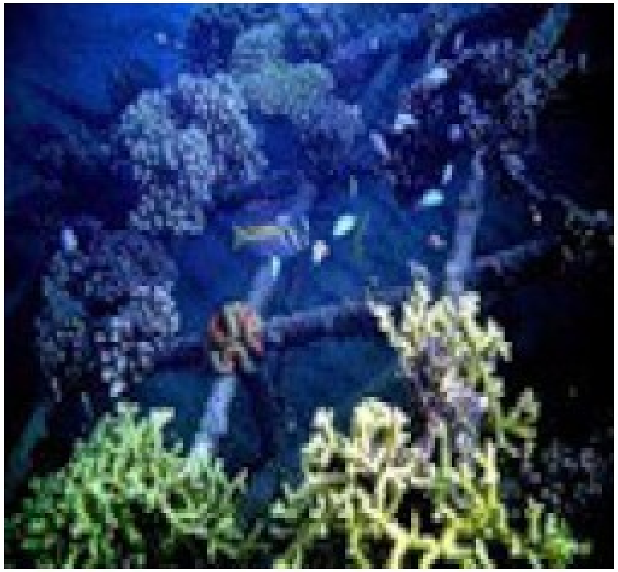
The mass required for On Board Power Storage and Active Mitigation of Thermal Cycling are game killers for nighttime operation of Long Endurance L-T-A, HAA or HAPs.

Especially in the Space to Near-space segment, WPT enables Active Mitigation Nighttime Thermal Cycling for 22 km Long, Endurance HAA and for WPT/Solar PV Power/ Propulsion

CF_Hyperblimp_Prototype11_Utah_Optical_Systems_Testing _Jan14,2008

**2. Commercial Development of BioRock Seawater Accretion Building Materials, byproduct Hydrogen Energy Storage**

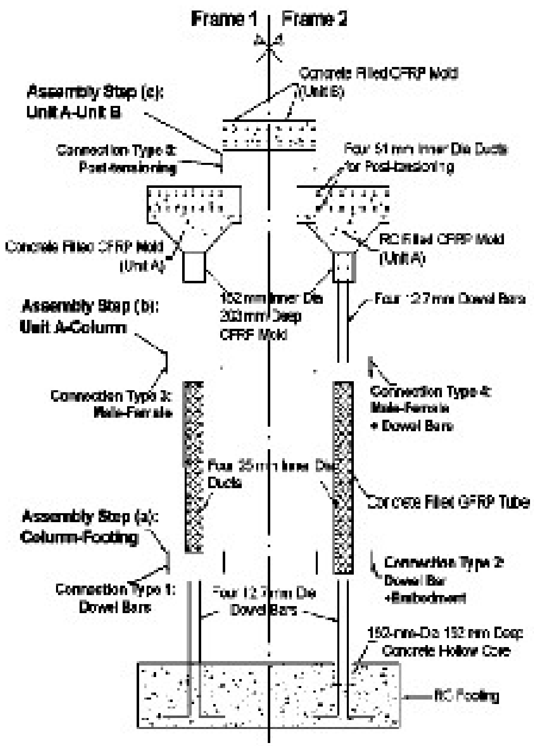
Global Coral Reef Alliance BioRock is used in Coral Reef and Fisheries Restoration which is on going Helen Reef (Hotsarihie), Republic of Palau. Reef and Fisheries Restoration provides higher Fisheries output and substantially increased Fisheries Licensing Revenues.

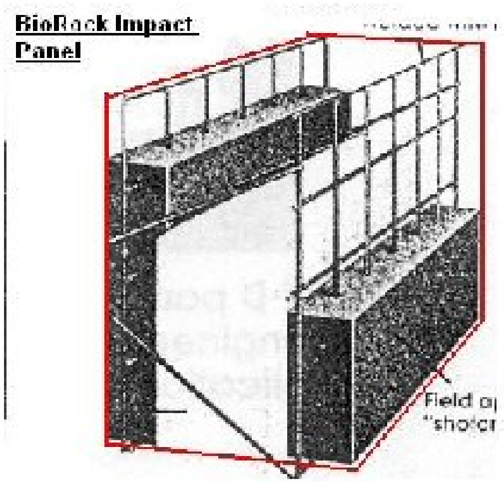


**While less than 70% efficient as DC to Hydrogen energy, Direct Hydrogen Production is the normal goal of both Electrolysis of Thermal Solar (SOT).**
There is no cost offset for this energy conversion/ energy storage inefficiency.

BioRock process can be used to make low cost building materials by Seawater Accretion that are 7 to 10 times stronger and 10 times less costly to pre-cast than concrete.

Hydrogen is also evolved as a Byproduct of BioRock Electro-accretion Process at up to 60% Efficiency. Sales of BioRock Building Materials offset the 40% energy loss by 400%.or more.




**PVC** mold ar**ound impact** panel **stops** accretion as sea **water can not enter** the **completely full mold. Panel attachments can be likewise** protected **from** accretion and used **to assemble finish**ed structures.

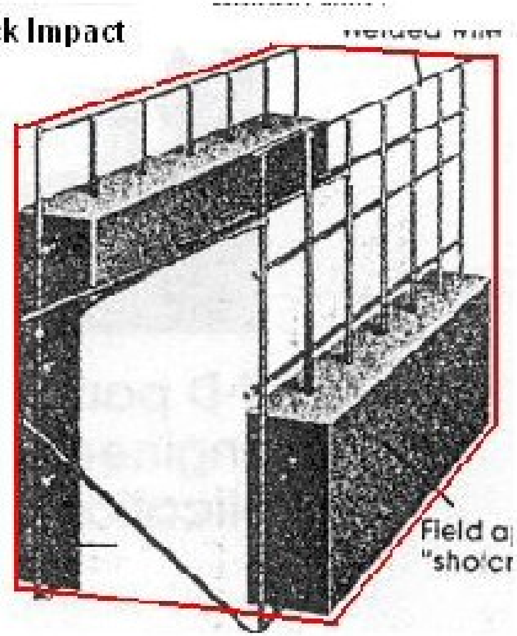
**All evolved** gases may be **collected for later** separation into CO2, O2, H2 and Cl2 **components.**

As BioRock Accretion Process sequesters 1 molecule of $CO_2$ as $CaCO_3$ by increasing seawater pH and also releases1 molecule of into the atmosphere with hydrogen and oxygen gases evolved where all gases are captured in BioRock Building Materials Process.

Capture of $CO_2$ and conversion to Supercritical $CO_2$ allows this to be used as a Solvent to extract valuable Commodity Bio-polymers like alginate, gums, fertilizers, natural pesticide and anti-erosion coatings as value-added products.

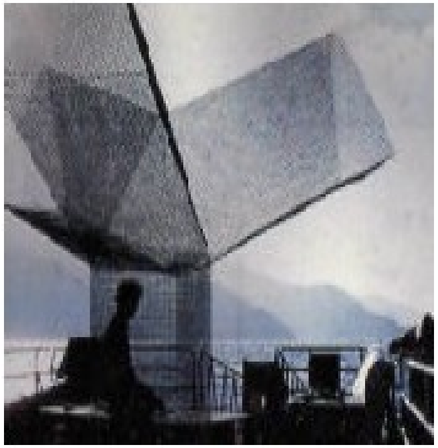
Supercritical $CO_2$ processing of alginate is also used to form Cross-linked Alginate aerogels that provide core insulation for Pre-cast BioRock Impact Panel Modular Building Materials made in standard builder sized.

**BioRock Impact Panel**




PVC mold around impact panel stops accretion as sea water can not enter the completely full mold. Panel attachments can be likewise protected from accretion and used to assemble finished structures.

All evolved gases may be collected for later separation into $CO_2$, $O_2$, $H_2$ and $Cl_2$ components.



BEFORE

AFTER

# Supercritical CO2 can be used then converted to neutral slurry for trench sequestration

BioRock Products could be shipped by WPT power sea cargo to Japan and Australia on the Tokyo – Sydney-Melbourne Beam Down Path

Spent Supercritical CO2 could be sequestered as liquid CO2 in Deep Ocean Trenches that begin conveniently adjacent  to Helen Reef, Republic of Palau.