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Solar Electric Propulsion Mission Architectures

Thomas W. Kerslake
Glenn Research Center, Cleveland, Ohio

June 2003

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National Aeronautics and
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Glenn Research Center

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Solar Electric Propulsion Mission Architectures

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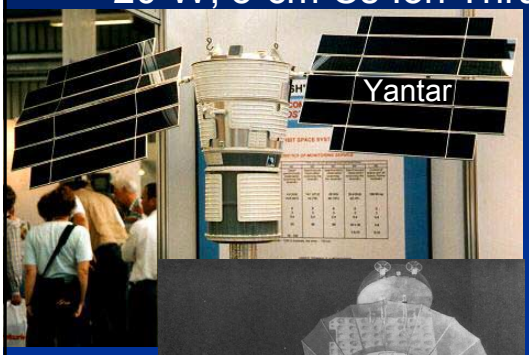
Abstract

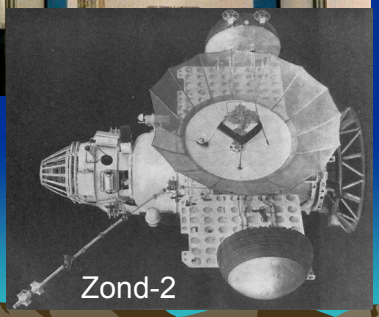
This presentation reviews Solar Electric Propulsion (SEP) Mission Architectures with a slant towards power system technologies and challenges. The low-mass, high-performance attributes of SEP systems have attracted spacecraft designers and mission planners alike and have led to a myriad of proposed Earth orbiting and planetary exploration missions. These SEP missions are discussed—from the earliest missions in the 1960's, to first demonstrate electric thrusters, to the multi-megawatt missions envisioned many decades hence. The technical challenges and benefits of applying high-voltage arrays, thin film and low-intensity, low-temperature (LILT) photovoltaics, gossamer structure solar arrays, thruster articulating systems and microsat systems to SEP spacecraft power system designs are addressed. The overarching conclusion from this review is that SEP systems enhance, and many times enable, a wide class of space missions.

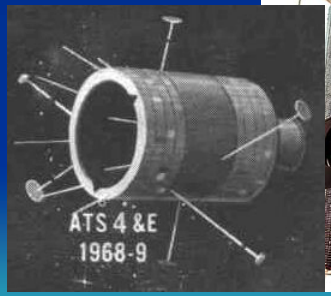
- SEP attractive for missions
  - High Isp, mass savings
- SEP Mission Review
  - Past- Present – Future
    - Robotic
    - Human
  - Technologies, Challenges & Benefits
    - Power Systems
    - Structures

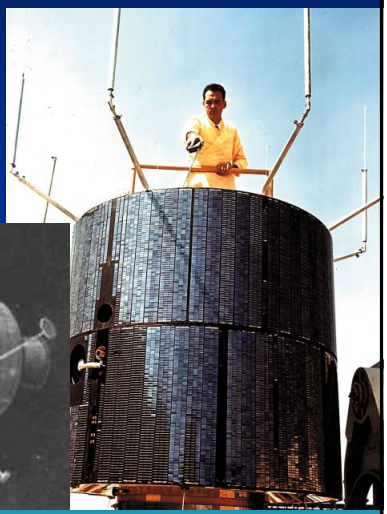
Introduction

- First Russian SEP Missions in 1964
  - Yantar-1 / Ion thruster, Zond-2 / 6 PPTs (Mars Flyby)
- First US SEP Mission 1968: ATS-4
  - 20-W, 5-cm Cs Ion Thrusters, 300-W PVA







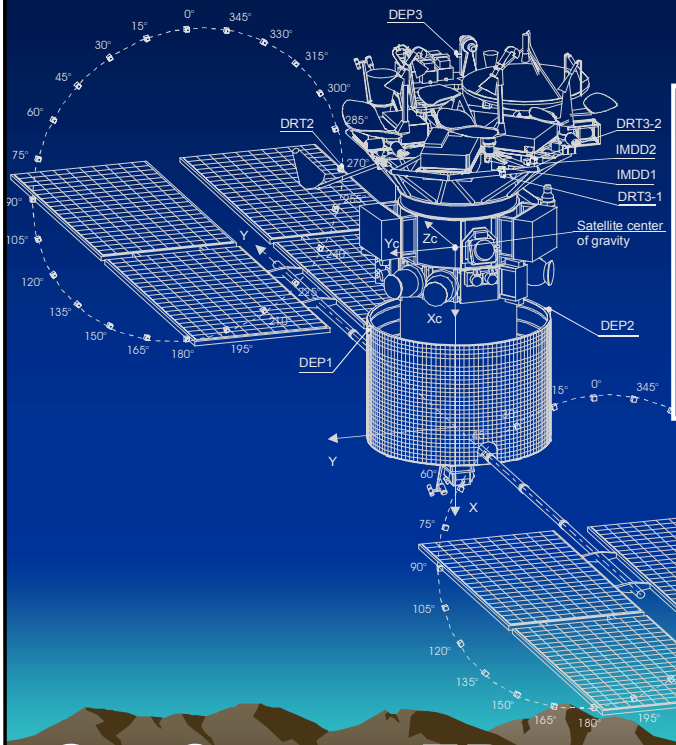


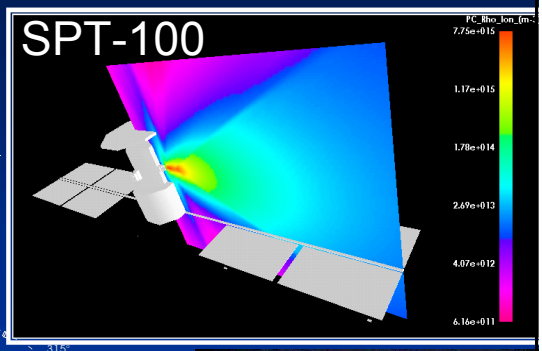
In The Beginning…

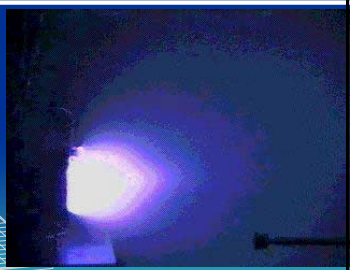
- Primary EP
- Reduced cell count, concentrator PV

DS-1: 1998

- Express-A #2/3: Induced plasma at PVA in GEO - 2000

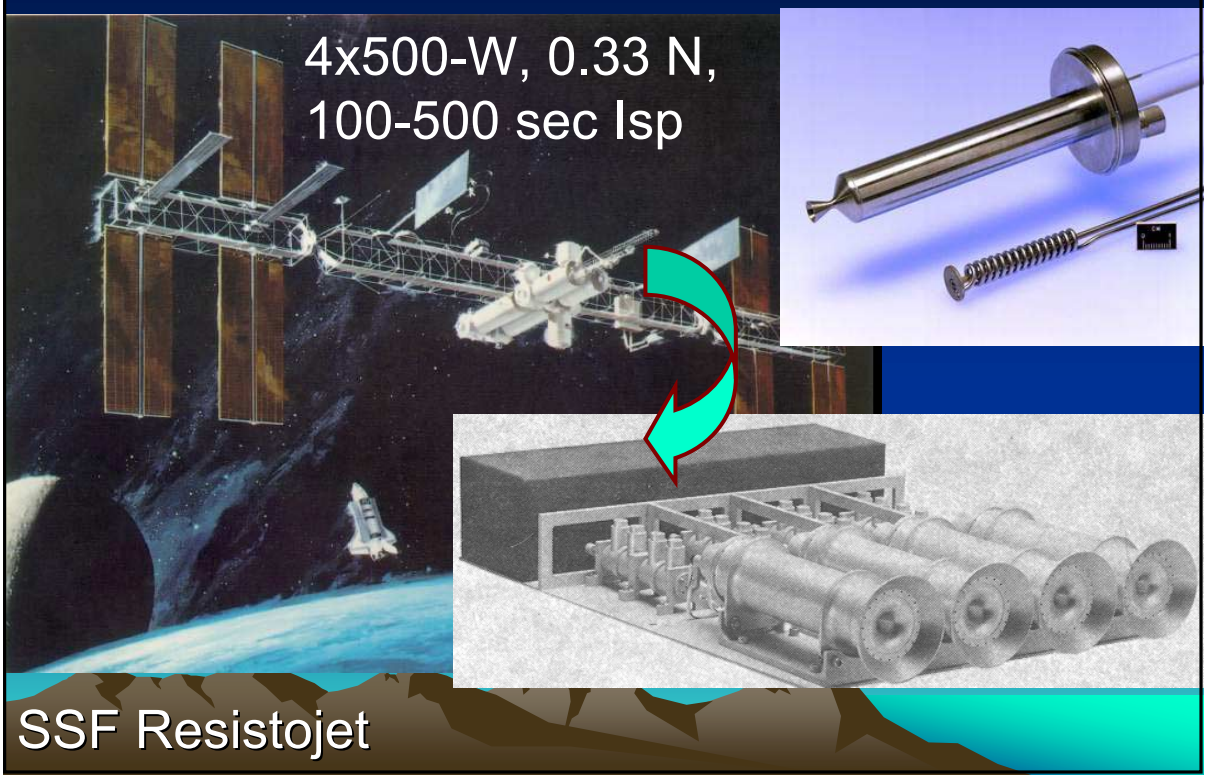






GeoComsat EP

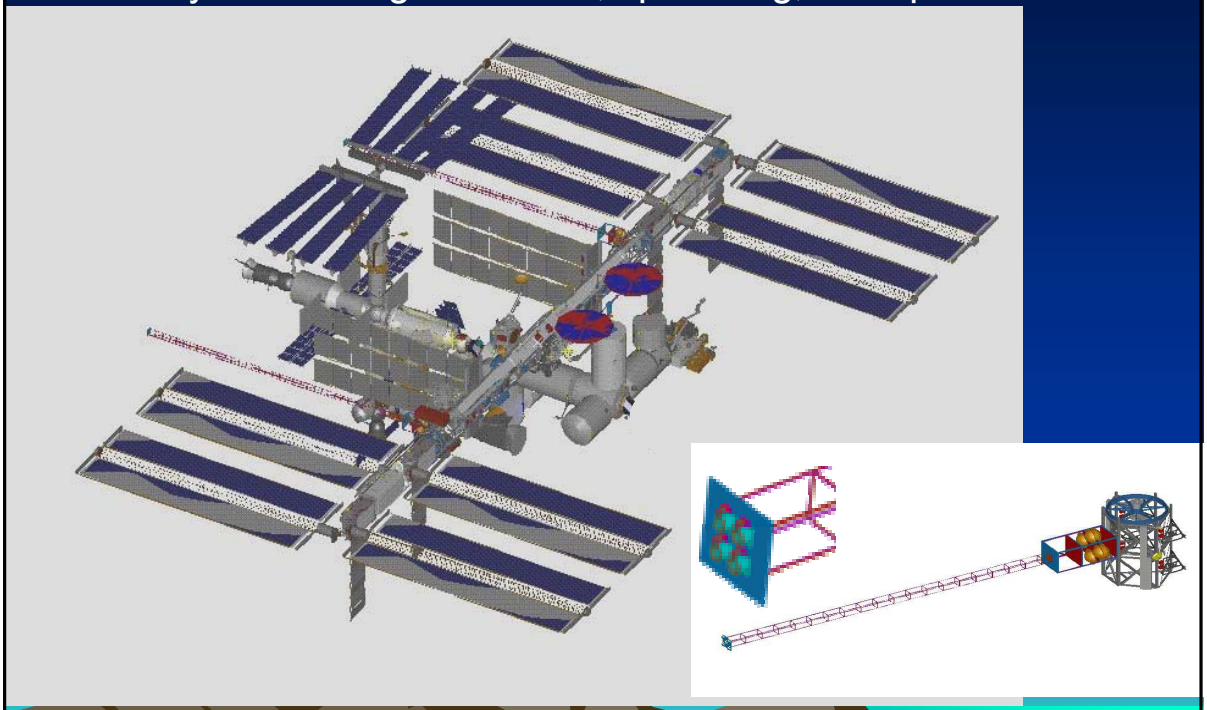
➢ Waste Gas Management, Reboost



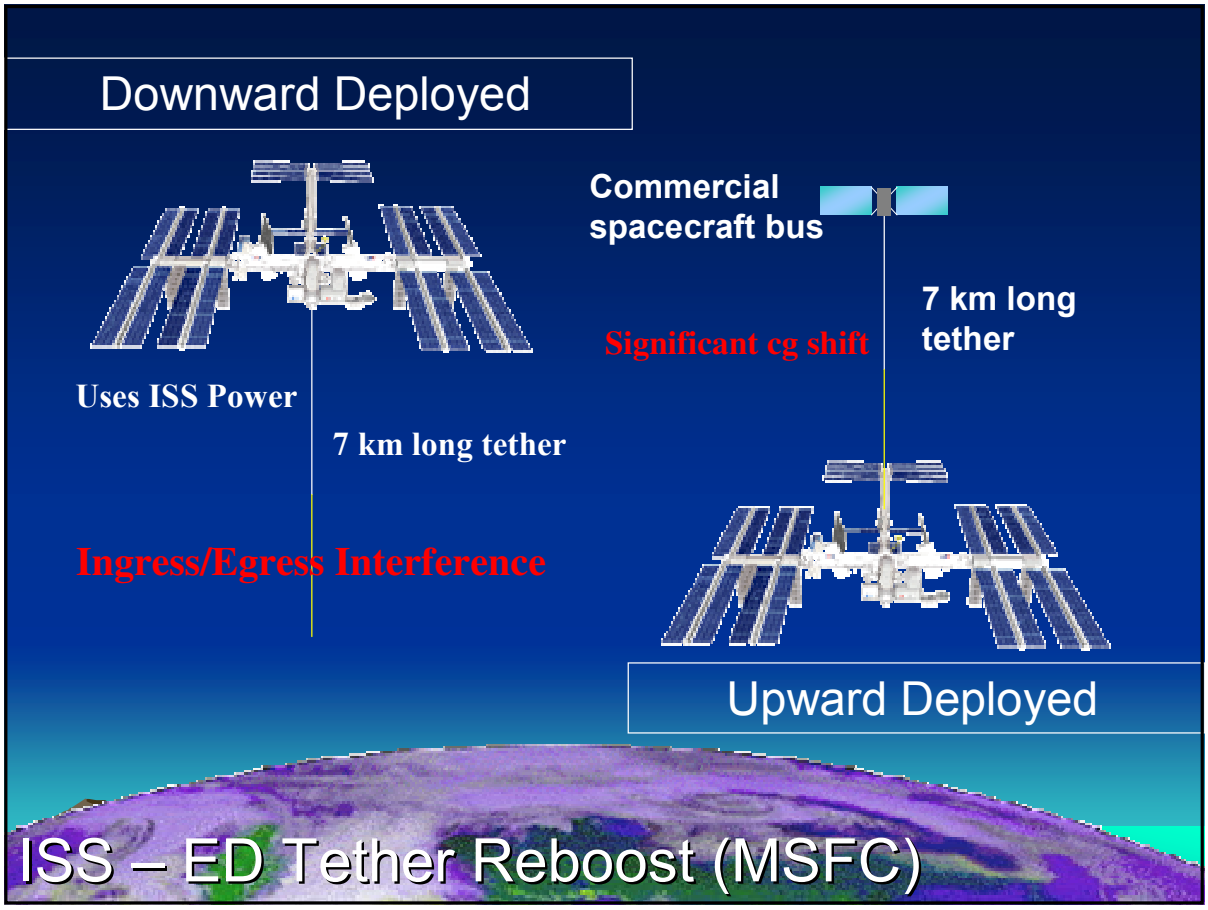
SSF Resistojet

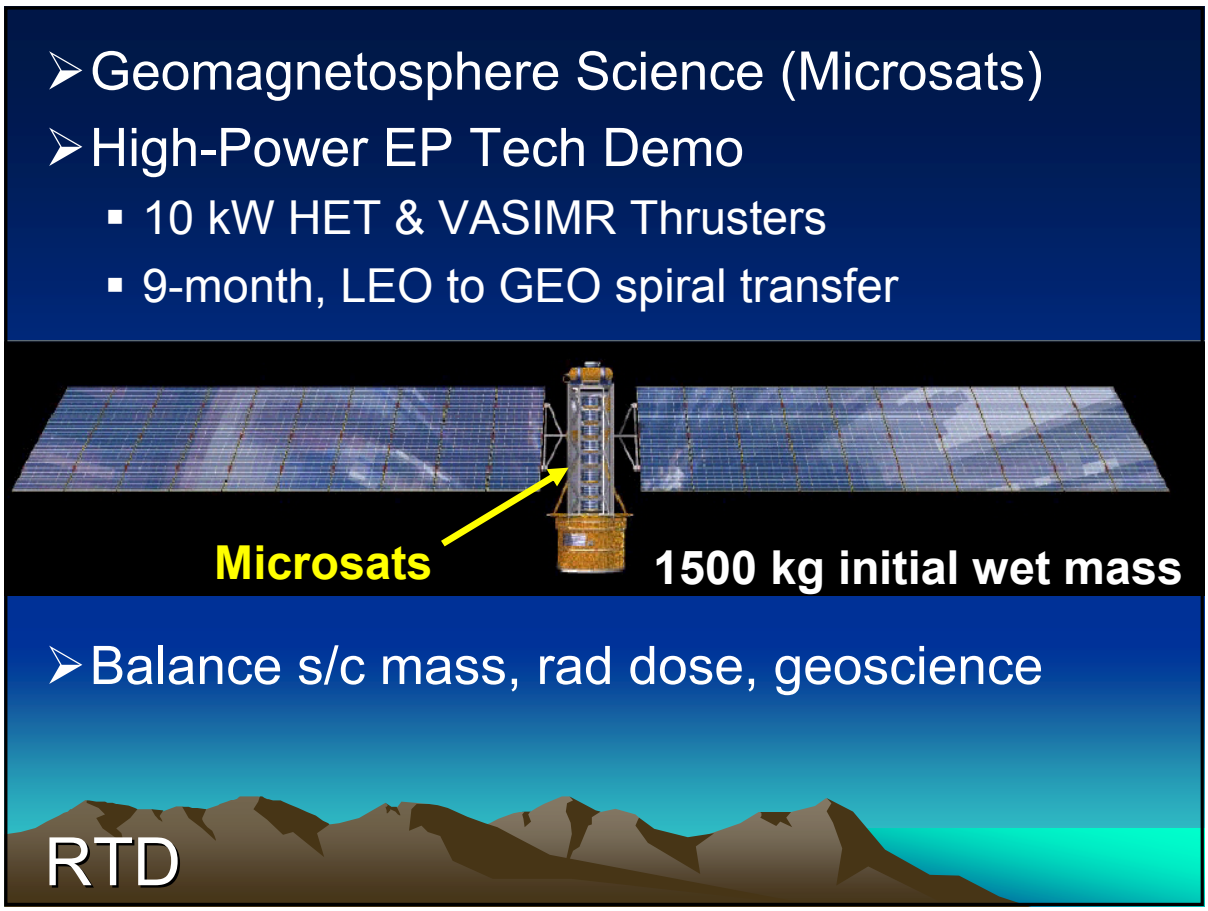
➢ Options: 10-kW HET (shown), 5-kW Arcjet

- Array shadowing/clearance, sputtering, PPU placement



ISS – 2001 EP Reboost Study


Downward Deployed
Commercial spacecraft bus
7 km long tether
Significant cg shift
Uses ISS Power
7 km long tether
Ingress/Egress Interference
Upward Deployed
ISS – ED Tether Reboost (MSFC)

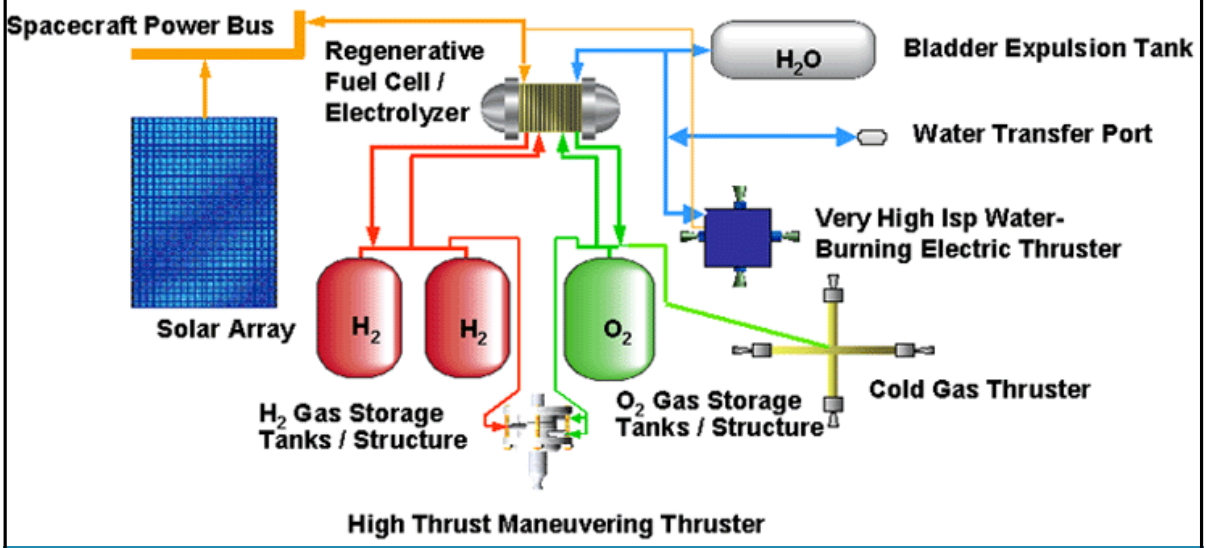

➢Geomagnetosphere Science (Microsats)
➢High-Power EP Tech Demo
▪ 10 kW HET & VASIMR Thrusters
▪ 9-month, LEO to GEO spiral transfer
Microsats
1500 kg initial wet mass
➢Balance s/c mass, rad dose, geoscience
RTD

- PPTs, photography, microscopy
  - 1000's sorties, precision control

ISS Inspector - PowerSphere

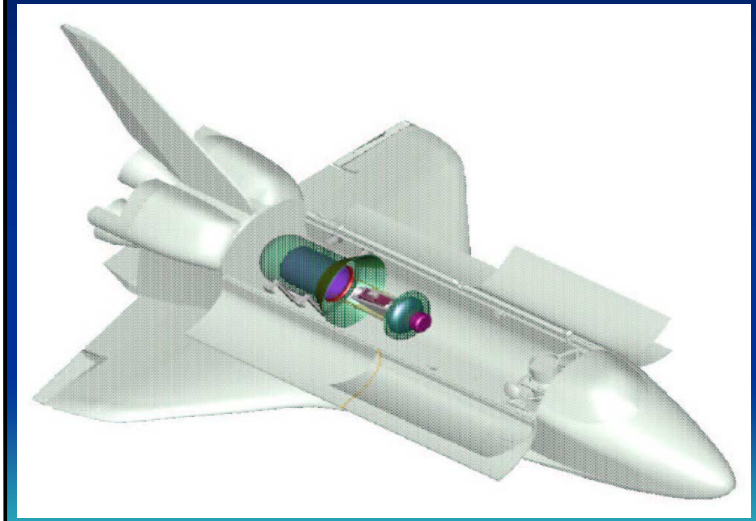
Aerospace/
AFRL

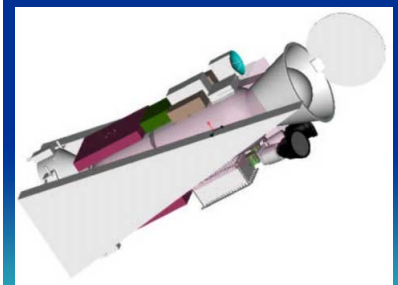
- Unitized PEM EL/FC, H2/O2 Prop
- Non-hazardous, low pressure fuel



Water Electrolysis Thruster – "WET"

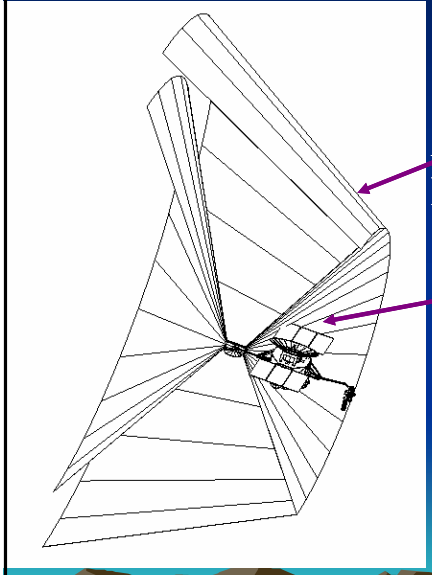
- Shuttle launched/retrieved
- 10 kW Xe Ion Thrusters, Xe resistojet ACS
- 20 kg canister returned LMO->LEO

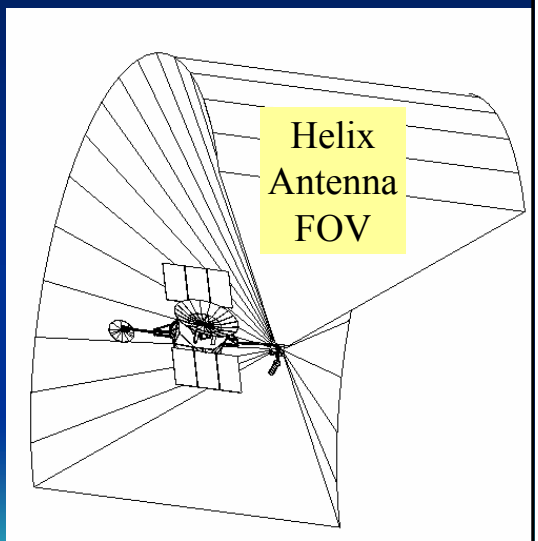




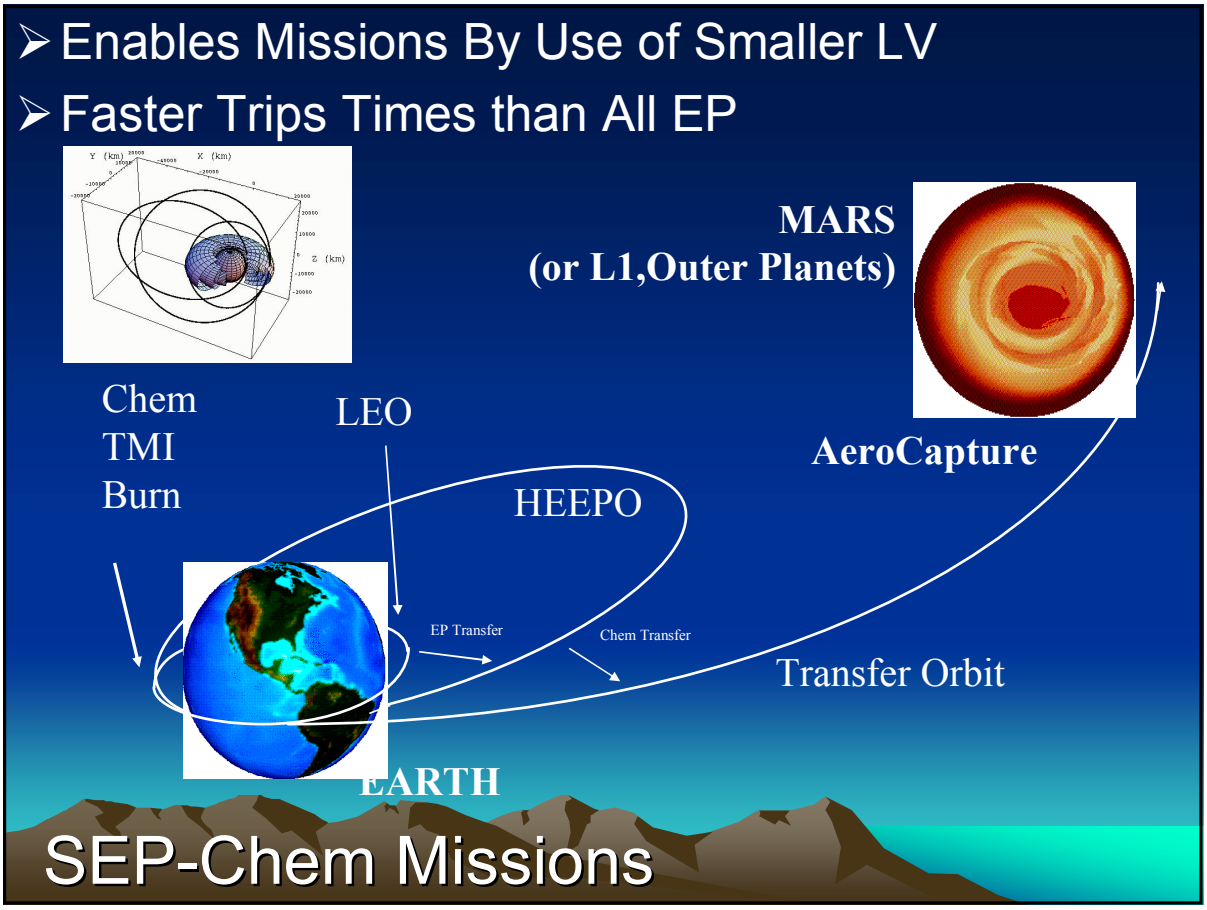
Mars Sample Return (JSC)

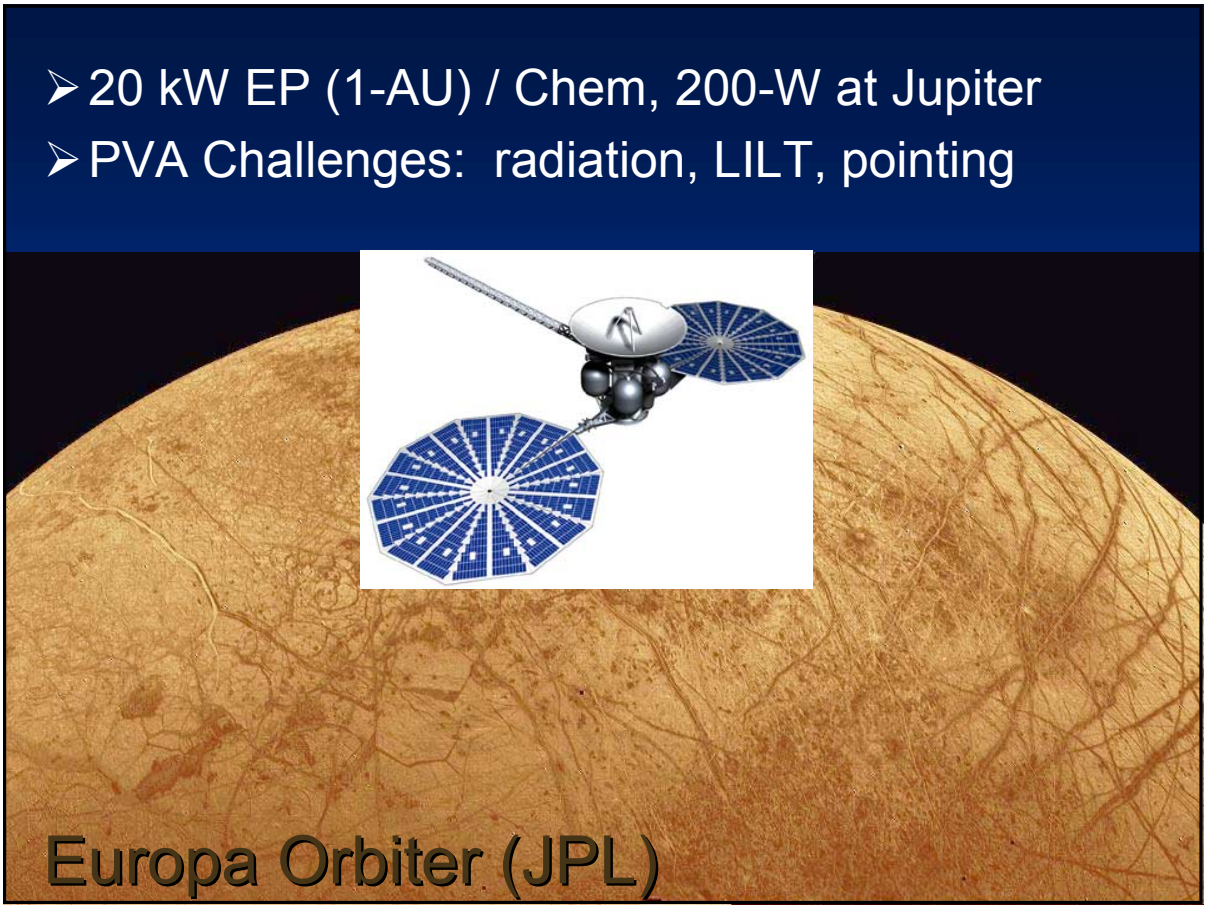
- 6-12 kW Ion/Hall EP plus Chem Prop.
- Enabled launch on Delta 7925
- Enabled Mars Orbit Maneuvering – KOZ Issue



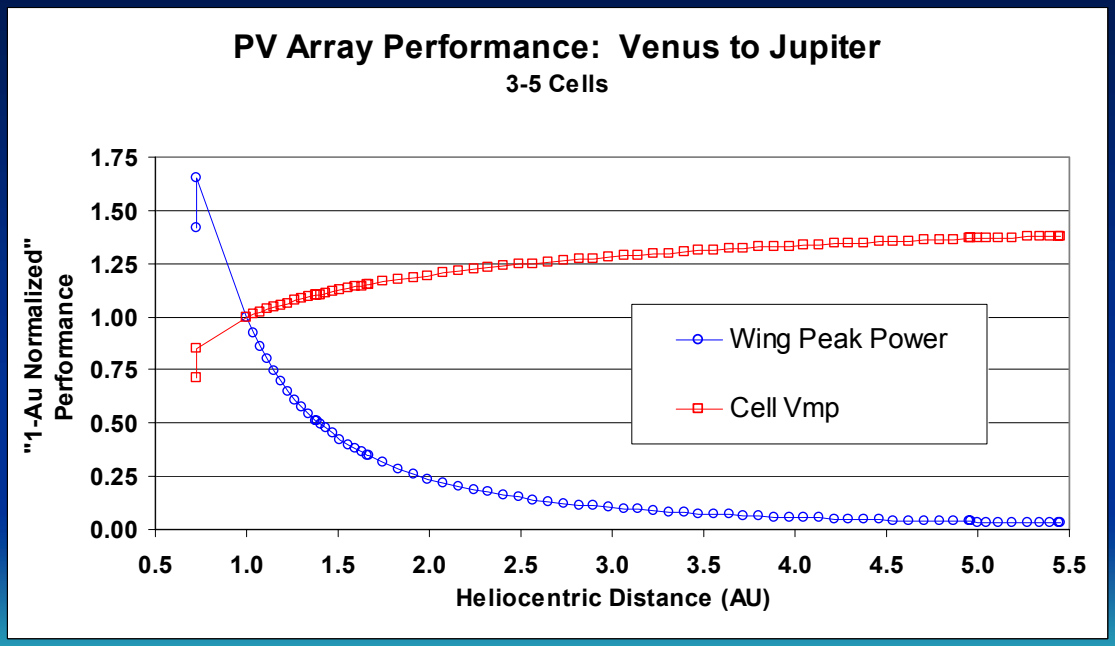


Mars ComSat (GSFC)


Enables Missions By Use of Smaller LV
Faster Trips Times than All EP
MARS
(or L1,Outer Planets)
Chem
TMI
Burn
LEO
HEEPO
AeroCapture
EP Transfer
Chem Transfer
Transfer Orbit
EARTH
SEP-Chem Missions


20 kW EP (1-AU) / Chem, 200-W at Jupiter
PVA Challenges: radiation, LILT, pointing
Europa Orbiter (JPL)

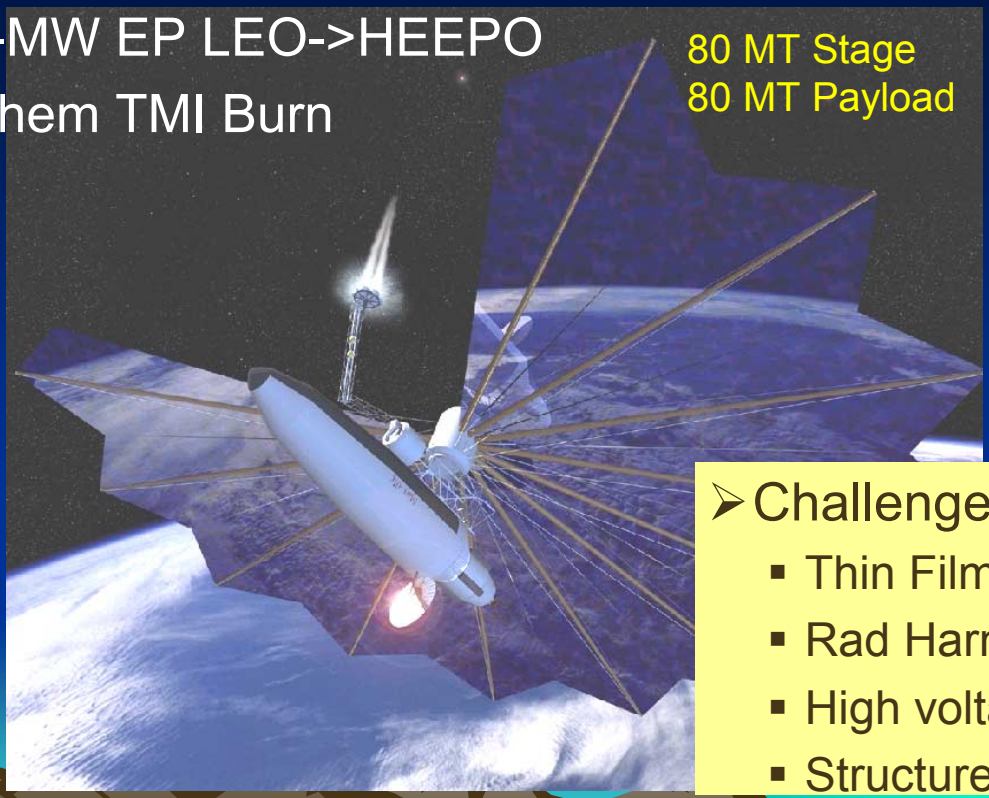
➢HES, Multijunction Solar Cells



LILT Tolerant PV & Power Electronics

➢1-MW EP LEO->HEEPO

➢Chem TMI Burn



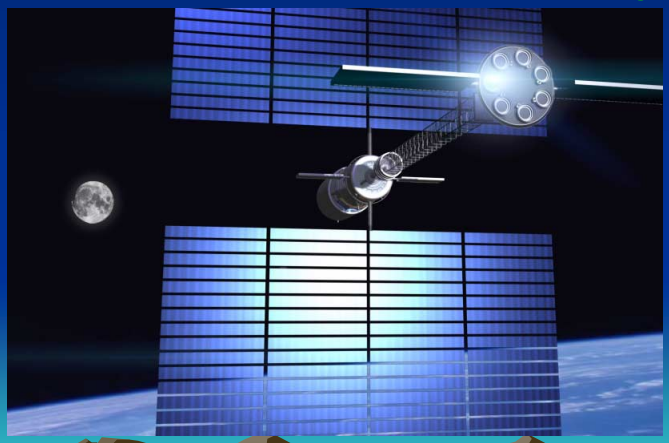
➢Challenges:

- Thin Film PV
- Rad Harness
- High voltage
- Structures

Human Mars – 2020's

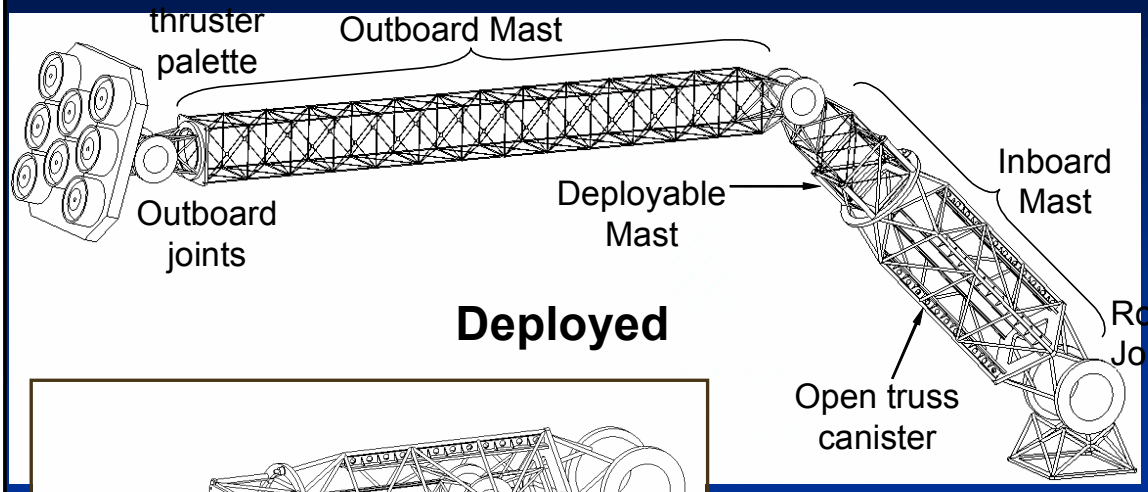
➢400 kW Ion EP : LEO to L1

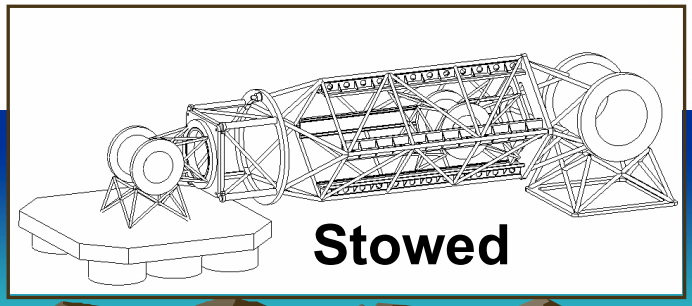
30 MT Stage
30 MT Payload



Human Gateway-HPM-OASIS LaRC/RASC

➢AEC-Able Design : SRTM Heritage



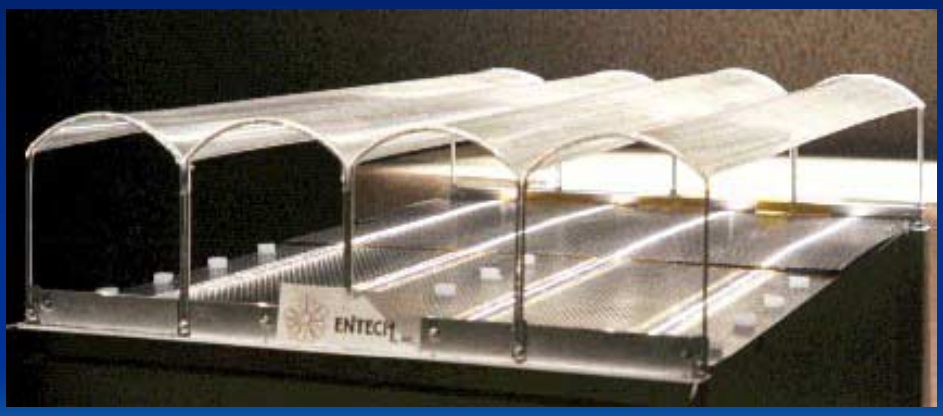


SEP Positioning Arm

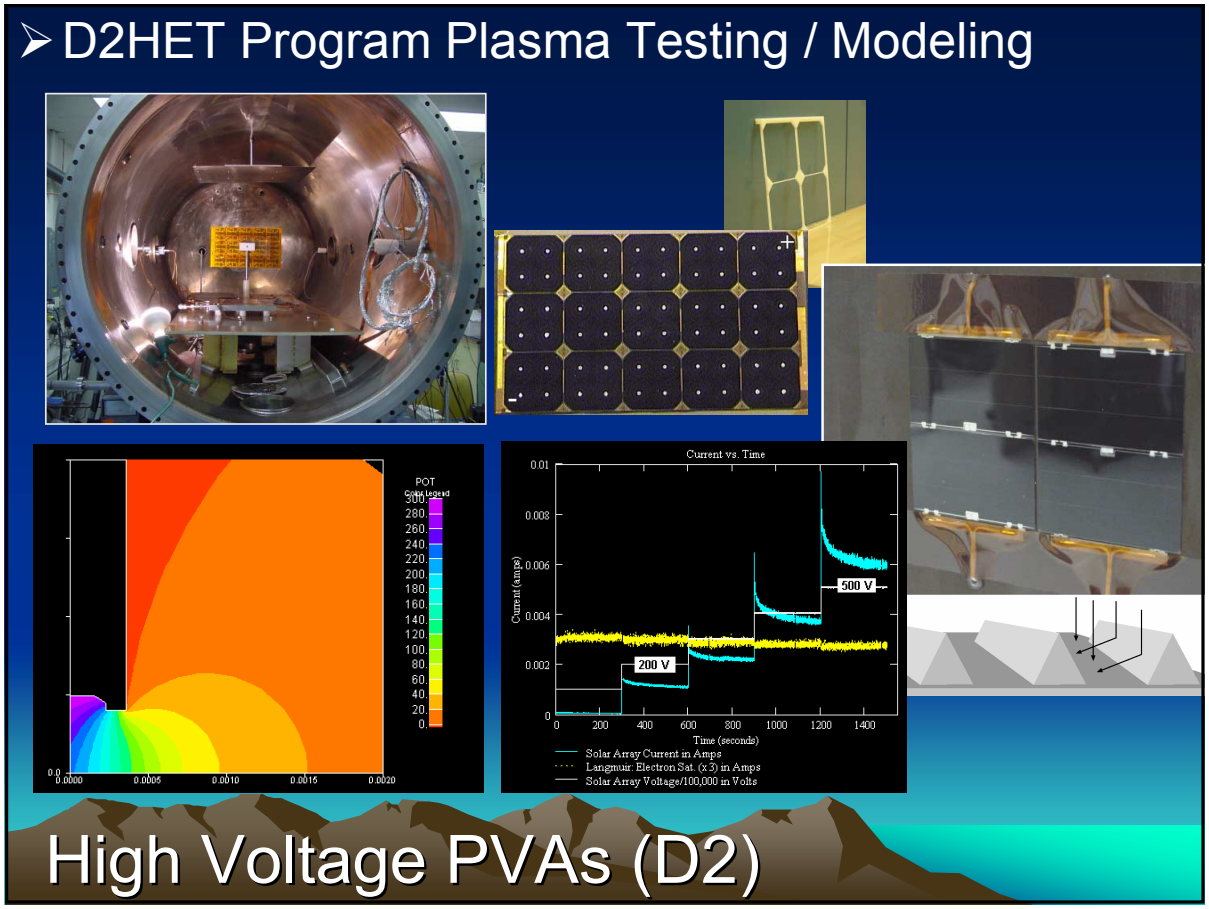
- High efficiency (15-20%)
- Low mass substrates (0.1-0.2 kg/m2)
- Encapsulated for High Voltage Operations
- Low cost

Thin-Film Photovoltaics

- Thin Film PV
- Entech SLA



Radiation Hardness


D2HET Program Plasma Testing / Modeling
POT
Color Legend
300.
280.
260.
240.
220.
200.
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160.
140.
120.
100.
80.
60.
40.
20.
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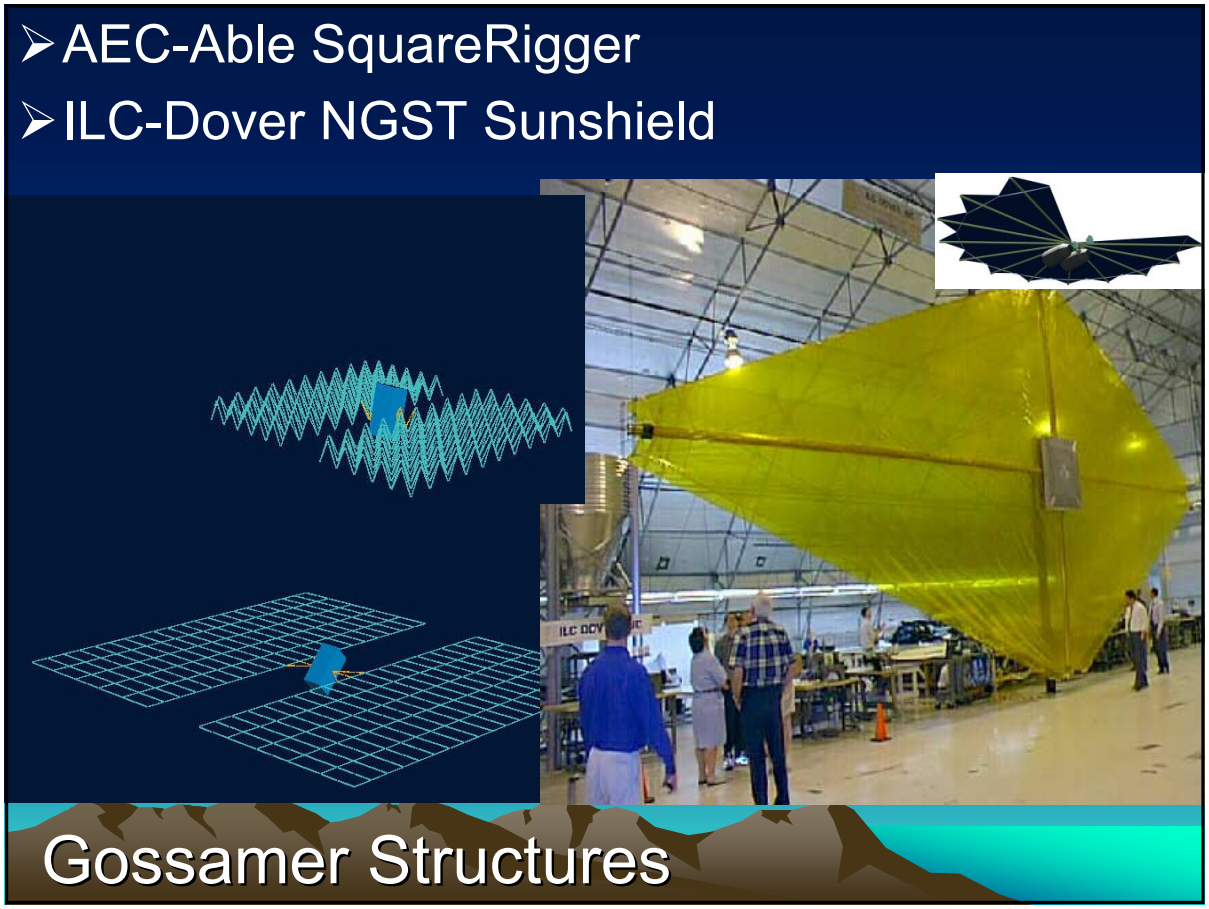
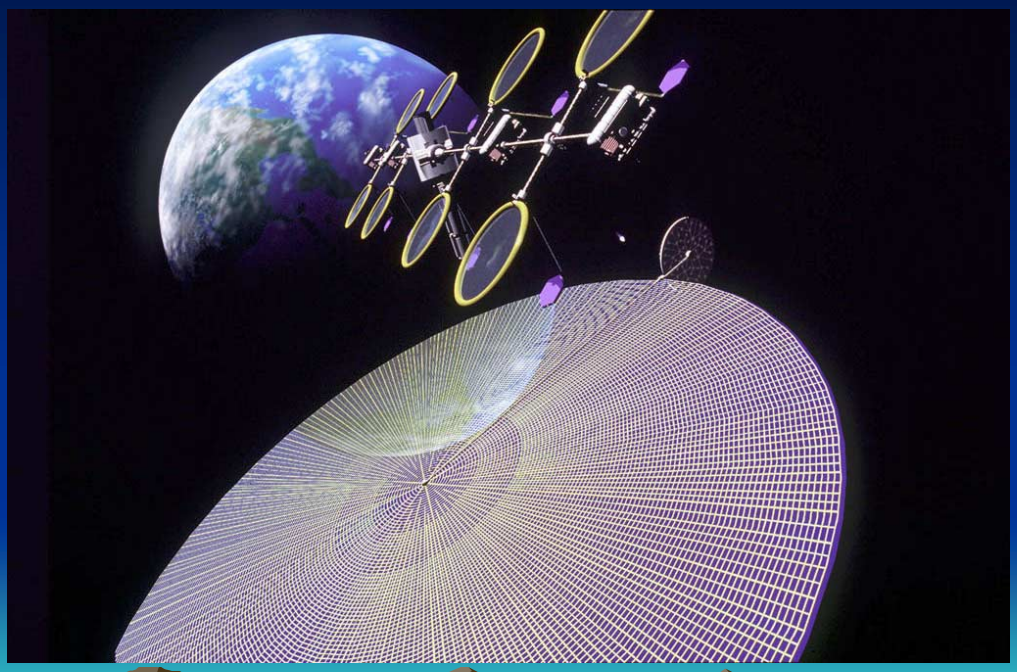
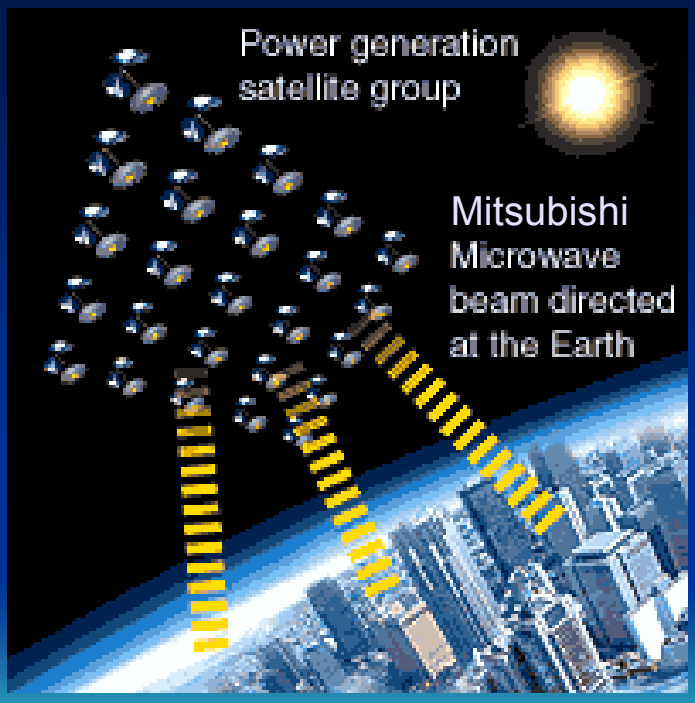
0.0
0.0000
0.0005
0.0010
0.0015
0.0020
Current vs. Time
0.01
0.008
0.006
0.004
0.002
0
Current (amps)
500 V
200 V
0
200
400
600
800
1000
1200
1400
Time (seconds)
Solar Array Current in Amps
Langmuir Electron Sat. (x 3) in Amps
Solar Array Voltage/100,000 in Volts
High Voltage PVAs (D2)


AEC-Able SquareRigger
ILC-Dover NGST Sunshield
Gossamer Structures

➢ 200 kW HET per node; 20 MT LEO->GEO, ACS

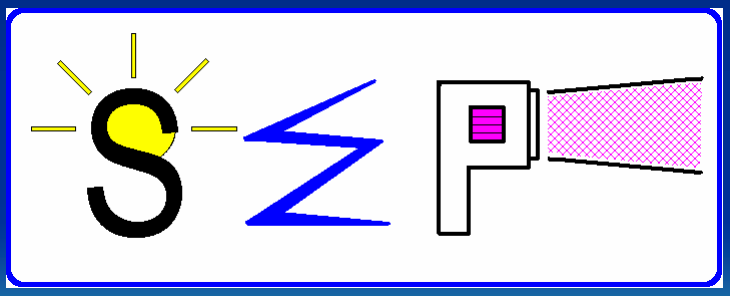


The Future? Space Solar Power



Or The Future? “SolarBird”

- SEP systems enhance,
  and many times enable,
  a wide class of space missions



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