NEW MILLENNIUM PROGRAM

NMP

Back-up Quad Charts

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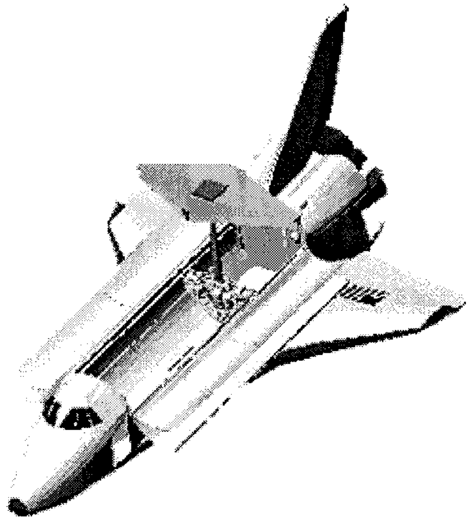
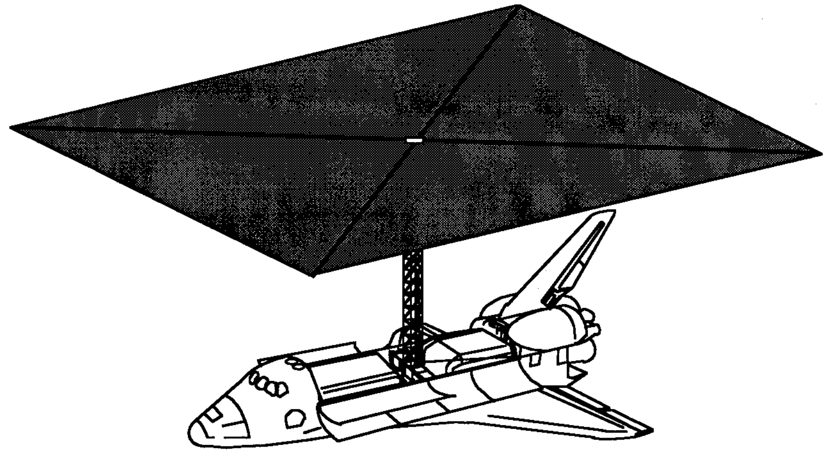
Membrane Deployment Experiments





ISIS Flight Experiment

- 1/4-scale model of NGST sunshield
- Shuttle attached payload (2001 launch)
- Sunshield dimensions: 8.2 m x 3.6 m
- 4 Kapton membrane layers (20 g/m^2)
- Inflatable rigidizable support structure (400 g/m)

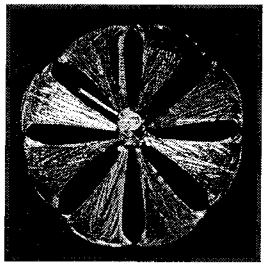
NMP Solar Sail Deployment Experiment

- Prototype solar sail
- Shuttle attached payload (2003 launch)
- Sail dimensions: 40 m x 40 m
- Advanced sail membrane: 10 g/m^2
- Ultra-lightweight sail booms: < 100 g/m

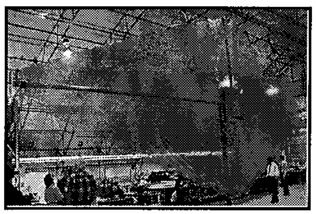
NMP Solar Sail Experiment will demonstrate deployment of a gossamer structure 5x larger than the ISIS sunshield, and have 1/2 the mass.

Solar Sail Materials

Critical properties for solar sail materials are low areal density (< 1 g/m^2), and long lifetime (> 10 years). Candidate materials are:

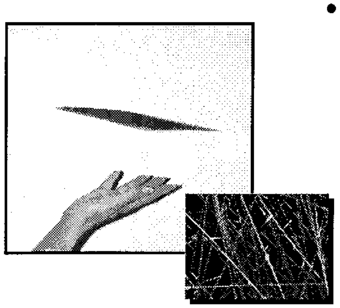


- Mylar
  - Flown on Russian Znamya sail in 1993 (areal density ~20 g/m^2)
  - Astral Technology Unlimited has fabricated 0.9-micron thick Mylar film (areal density ~2 g/m^2)
  - Poor resistance to UV radiation. Cannot be used for long-duration sail missions.



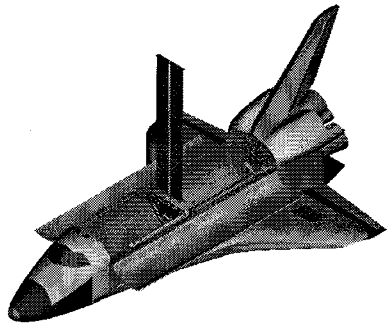
- Kapton
  - Space-durable material; Good resistance to UV and particle radiation.
  - ISIS flight experiment will use Kapton membranes for sunshield.
  - Thinnest material commercially available is 8 microns thick (areal density ~10 g/m^2)

- CP-1
  - Space-durable material; High resistance to UV radiation.
  - SRS Technologies has fabricated 2.5-micron thick CP-1 film (areal density ~5 g/m^2)
  - Flown on Hughes HS-702 geosynchronous communications satellite



- Carbon Microtruss Fabric
  - Areal density ~1 g/m^2
  - 1400 K temperature tolerance
  - Small pieces have been fabricated by Energy Science Laboratories, Inc.
  - Being used in proof-of-concept experiments to demonstrate microwave and laser propelled sails.

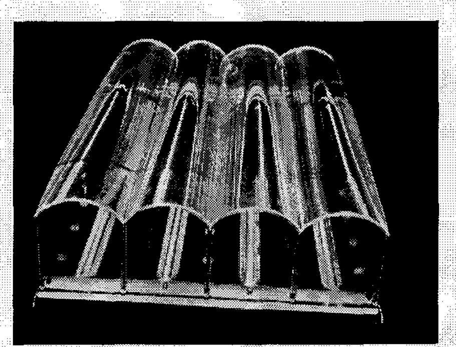
Lightweight Solar Array Technology



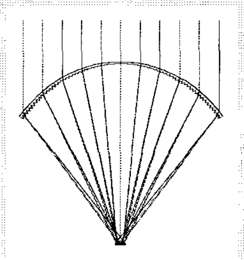
Advanced technologies will enable 3x increase in specific power

- Thin-film Fresnel lens concentrators
- High efficiency (~25%) multijunction PV cells
- Lightweight inflatable support structure

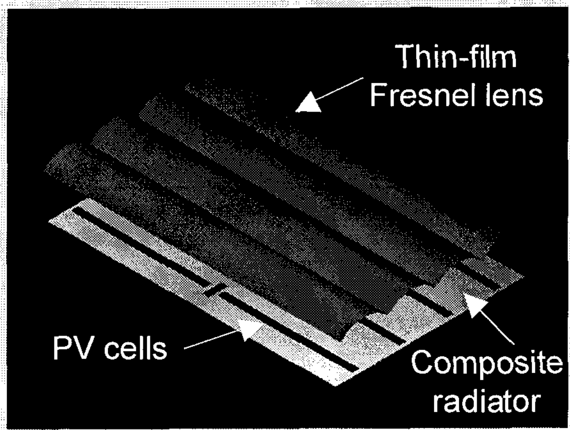
Entech Stretched Lens Array



- Specific power = 378 W/kg
- Developed under Space Solar Power Program

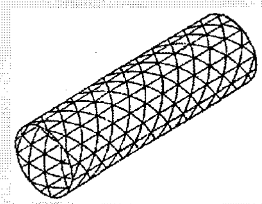


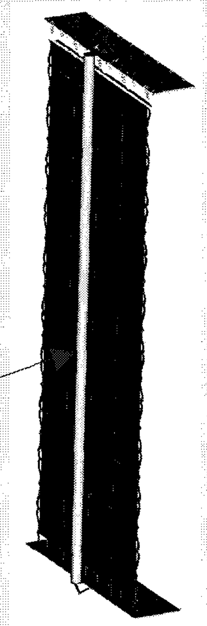
Fresnel lens concentrates sunlight 8.5x



Inflatable Support Structure

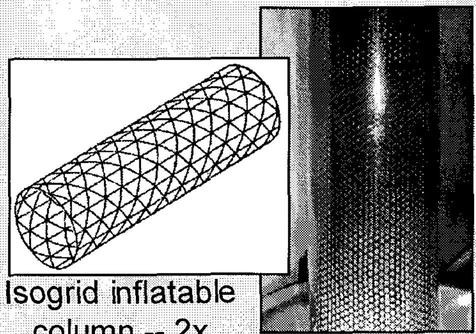
- ILC Dover is developing isogrid column for inflatable solar arrays
- 2-3x lighter than mechanically deployable booms



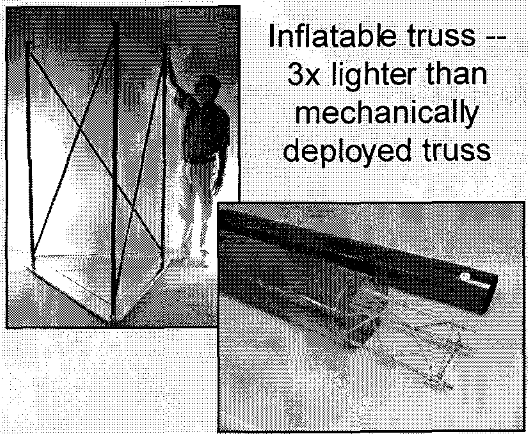


NMP Deployable and Inflatable Boom Experiment

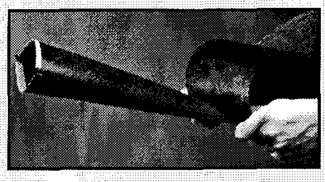
Validate new structural concepts



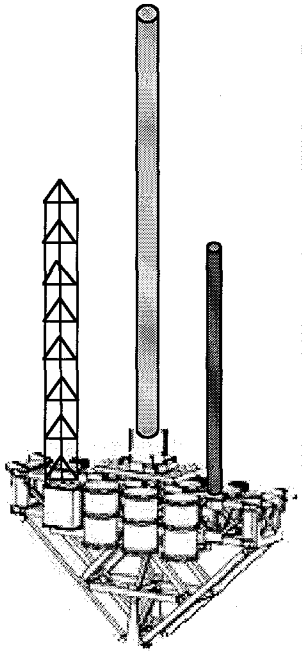
Isogrid inflatable column -- 2x lighter than simple tube



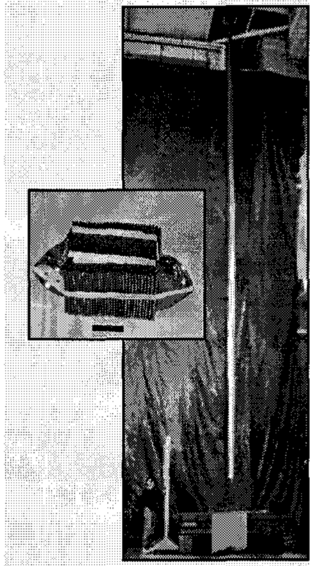
Inflatable truss -- 3x lighter than mechanically deployed truss



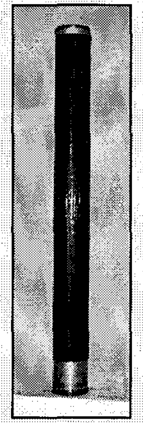
Strain-energy deployed boom -- requires no inflation system



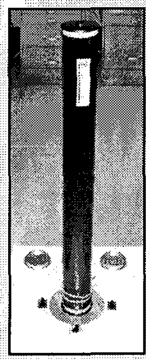
Validate new rigidizable materials



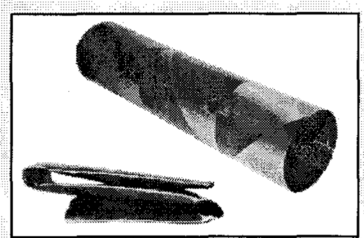
20 m aluminum laminate boom -- rigidized by over-pressurization to yield Al foil



Thermoset composites -- rigidized by heating



Thermoplastic composites -- rigidized by radiative cooling

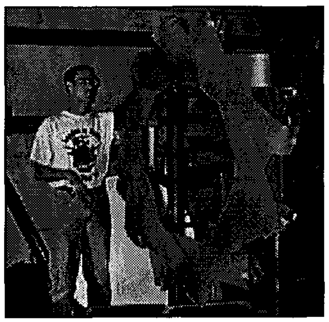


Elastic memory composites -- shape recovery by heating

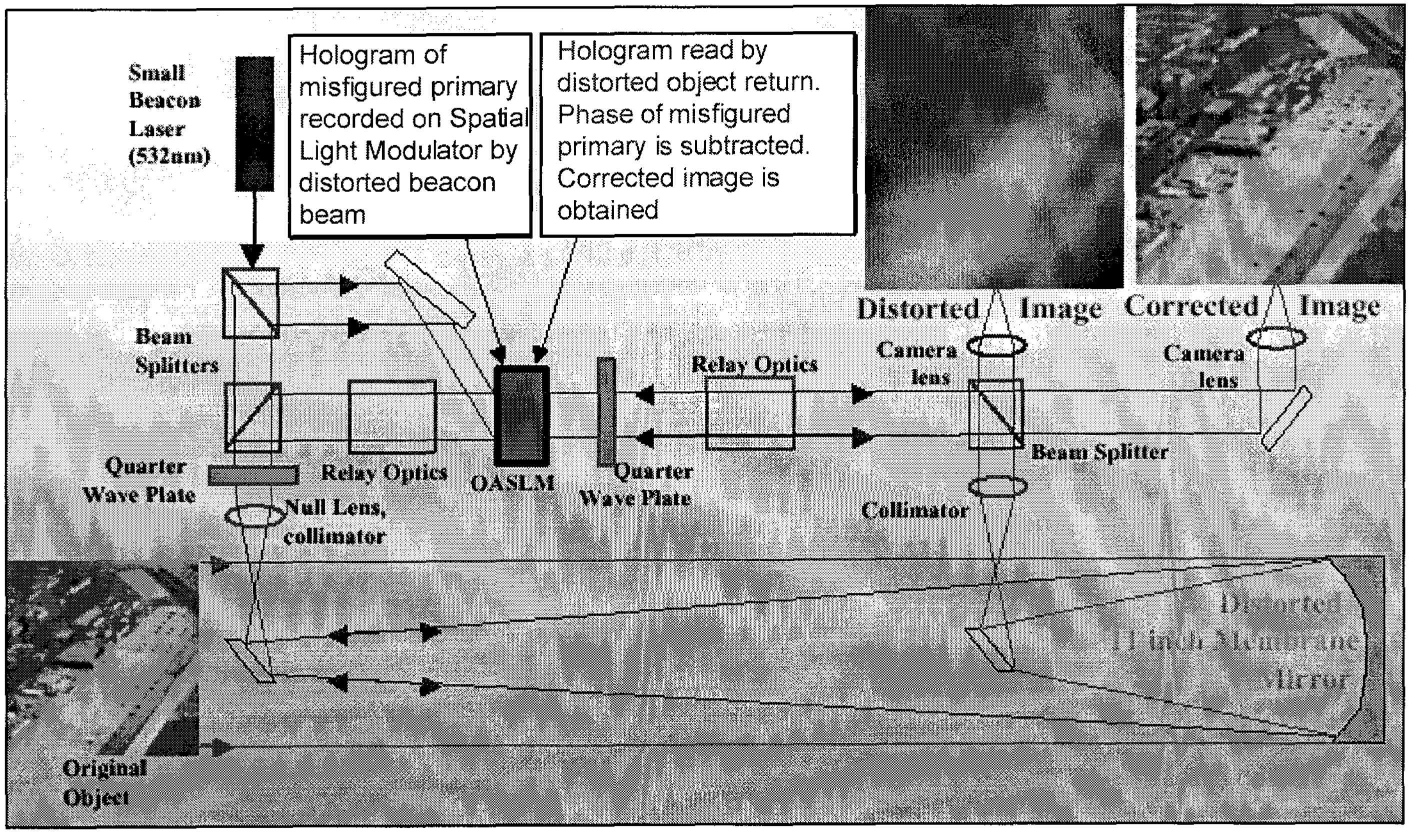
Membrane Optics Technology

- Membrane optics are under development by Air Force Research Laboratory, University of Arizona, and JPL.
- Goal is to achieve areal density < 1 kg/m^2 to enable very large telescopes.
- Membrane optics will require adaptive systems to correct wavefront errors resulting from surface distortions.
- NMP flight experiment will characterize surface distortions caused by space environment.

AFRL 30-inch diameter Membrane Mirror



University of Arizona 1-m diameter Membrane Mirror

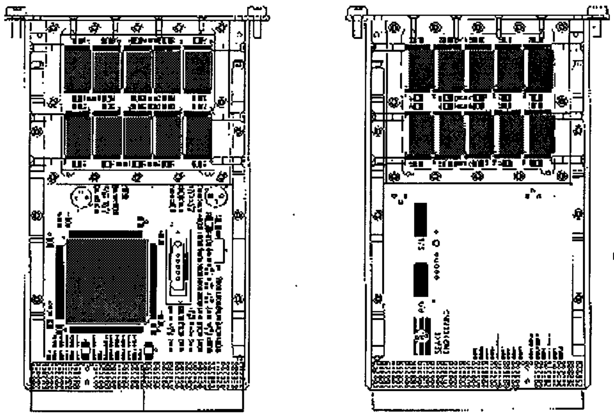


Adaptive Optical System for AFRL Membrane Mirror

Non-Volatile Memory: Path to 8 Gbit/Watt

Typical Architecture (All devices on)

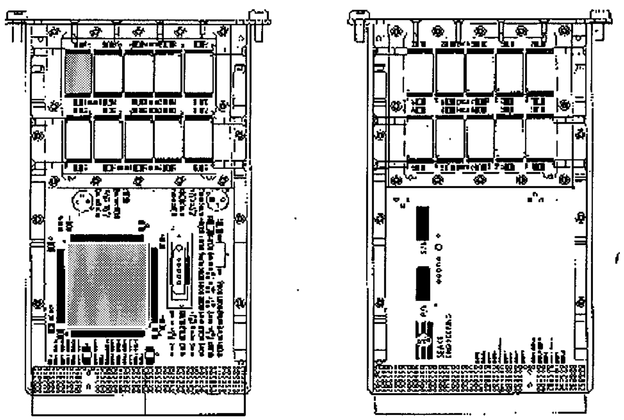
Side 1 Side 2



Current 2 Gbit Implementation

- 20, 128 Mb flash memory devices
- 1939 Mb/W per active memory device
- 1 Gbit Data (8 devices) & 256 Mb EDAC (2 devices) per side
- Conventional PWBs
- Total Power = 2W @ 3.3V → 1 Gbit/W

Ultra Low Power Architecture (Power strobing with single device data & EDAC implementation)



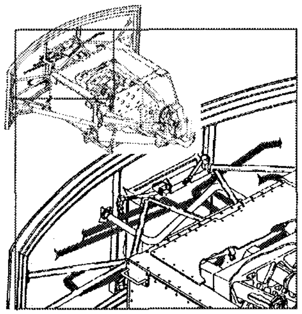
Ultra low-power 8 Gbit Implementation

- 40, 256 Mb flash memory devices in 2-device stacks
- 3878 Mb/W per active memory device
- 4 Gbit Data (8, 2-device stacks) & 1 Gbit EDAC (2, 2-device stacks) per side
- Ultra low-power memory controller ASIC (@ 1.8 V)
- MicroVia PWBs
- Total power ~ 0.9 W → >8 Gbit/W

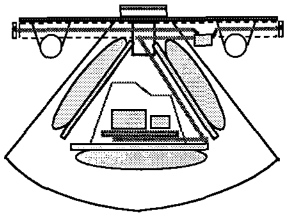
ADVANCED HEAT TRANSPORT TECHNOLOGIES FOR MINIATURE ENERGY-SAVING THERMAL CONTROL SUBSYSTEM

HEAT TRANSPORT LOOP TECHNOLOGIES

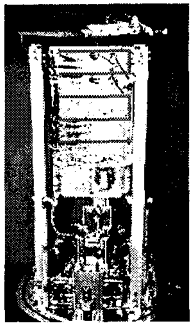
1992 —— 1996 —— 1997 —— 2002 —— 2003 ——



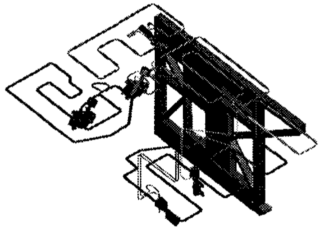
Heat Pipe (2 Phase)
Hubble Wide Field /
Planetary Camera 2



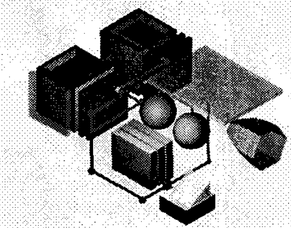
Pumped Single
Phase Loop
Mars Pathfinder



Capillary (2 Phase)
Pumped Loop
STS-85



Loop Heat Pipe
(2 Phase)
EOS TES



NMP

HEAT REJECTION APPLICATIONS

- Transport loops used when hot components can not be located near radiator.
- Technologies have evolved through a series of successful flight applications

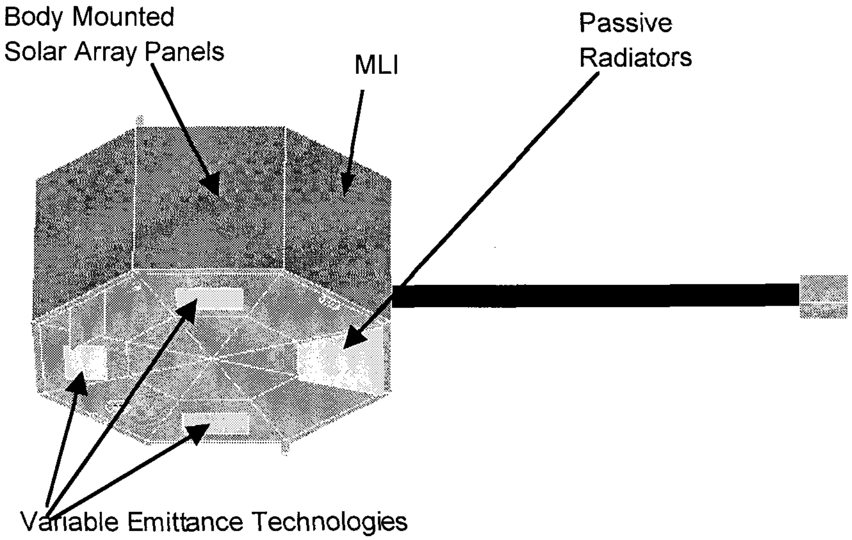
MINIATURE ENERGY SAVING CONTROL SUBSYSTEM

- Transport loops used to transport heat from hot to cold components
- Evolution has reached the stage where advanced loops can be integrated into the thermal control subsystem that provides S/C power and mass savings of ~15%

ADVANCED VARIABLE EMITTANCE TECHNOLOGIES

NMP

ST-5 VALIDATION



ST-5 Technology Objectives:

- Develop highly innovative thermal control coatings which can repeatedly change their properties in response to an external signal
- To validate the technologies as part of the spacecraft thermal control system

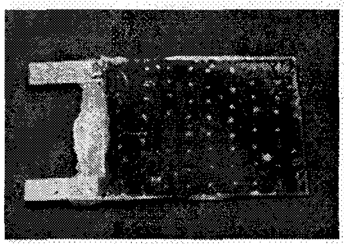
ST-5 Variable Emittance Technologies:

- MEMs Louvers: Micromachined devices which are similar in function and design to conventional mechanical louvers.
- Electrochromic Devices: Emittance modulation is achieved by applying a bias voltage (~1v) to a conducting polymer material.
- Electrophoretic Devices: Movement of suspended particles (i.e., very small flakes) through a highly absorptive fluid under the application of a small electrical field overlap and form a highly reflective surface.

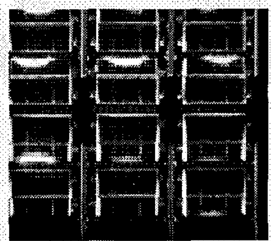
MINIATURE ENERGY SAVING THERMAL CONTROL SUBSYSTEM

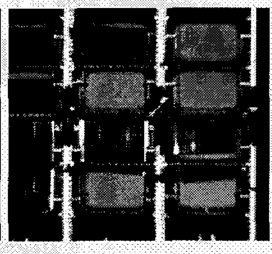
Example Technologies:

Electrochromic Device



MEMs Louvers Closed





MEMs Louvers Open

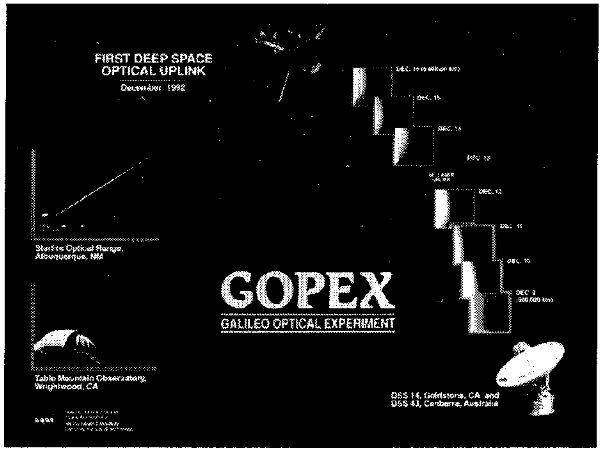
NMP Technology Objectives:

- Validate subsystem thermal control and energy saving over wide range of operating scenarios including rapid changes in environmental sink temperature e.g. due to s/c maneuvers.
- Determine effect of transient variable emittance characteristics on thermal control subsystem performance capabilities.

NMP Variable Emittance Technologies

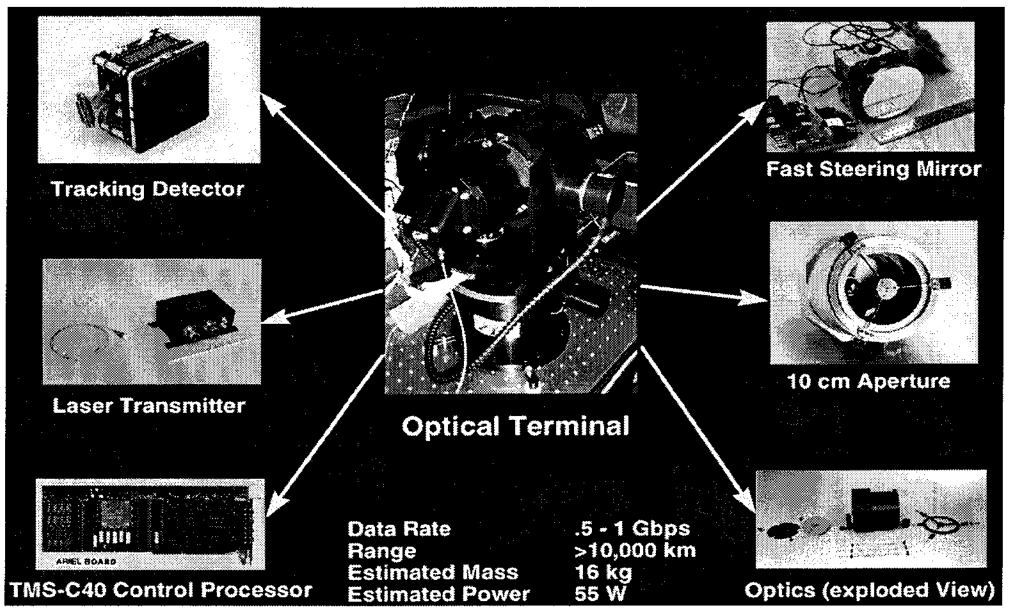
- Solicitation will seek technologies that will perform well as part of the integrated control subsystem.

Wideband Optical Communications Past and Current Activities



Ground to Galileo S/C up to 6 million km (JPL)

Uplink and Downlink to a Japanese S/C (JPL & NASDA)



Optical Communications Demonstrator (OCD)
A Unique Simple Architecture Lasercomm Brassboard Terminal Built By JPL

Wideband Optical Communications Past and Current Activities

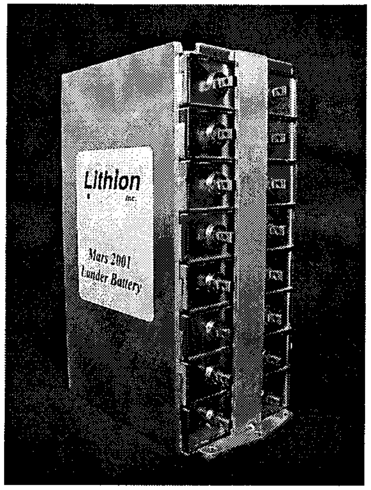
Europe and Japan:
Very Active programs for LEO, GEO & LEO-to-GEO

NASA:
No terminal flown in space yet.

DoD:
- BMDO - STRVII S/C - Launched in May (5/00)
  Contractor: a small company, AstroTerra (in San Diego)
  JPL tested the flight terminal. BMDO asked JPL to manage and participate in experiments with S/C.
  Current Capabilities: 2000 km Slant Range, 1 Gbps, Commercial hardware.
  Desired Capabilities: >10,000 km range, 1-10 Gbps, Space qualified hardware.

Industry & Other Agencies:
No flight terminals yet.

Secondary Batteries for Deep Space Missions
Lithium-Ion Back-up Charts



- ***Flight Validation Rationale*:**
  - Space Environment:
    - The effects of microgravity on the distribution of electrolyte and possible two phase fluid effects on electrode wetting and surface tension within the lithium-ion cells must be evaluated via flight tests to demonstrate adequate cycle life performance.
    - There is a higher rate of crystallinity of polymeric membranes in a space environment than on the ground and this may adversely impact the mobility of lithium ions through the Solid Electrolyte Interface (SEI). The loss of the SEI would lead to increased dendrite growth that in turn may lead to lower energy efficiency and possible short circuits within a cell.
    - The microgravity environment coupled with the charge/discharge electrochemical reactions of the Li-Ion cells must be evaluated for potential impact to the polymer structure, molecular mobility, and component morphological changes especially under thermal cycling.
    - The impact of high radiation levels has not as yet been assessed on the polymeric materials.
    - The synergistic effects of the thermal, radiation, and microgravity environments need to be determined via flight experience.
  - Implementation Shift:
    - Lithium-Ion batteries have not been used as the primary energy storage system for orbiting spacecraft.
    - The integration of the Lithium-Ion battery with a passive thermal control system needs to demonstrate adequate cycle life performance.

- ***Flight Test Scenario:***

  •Determine the effect of the space-flight environment on the operational performance characteristics of the battery through BITE to monitor temperature, voltage, and current to thoroughly map the electrodes within the battery to ascertain non-uniformity of performance and to compare with ground-based tests. The use of ampere-hour and watt-hour meters allow calculation of efficiencies of the electrical power system.

Secondary Batteries for Deep Space Missions
NiMH Back-up Charts

•*Jump from State-of-the Art (SOA)*:

A new design concept using low cost bipolar wafer cells for compact nickel-metal hydride batteries yields high specific energy and energy density. The bipolar configuration provides twice the specific energy and at 1/10 the volume of the state-of-the-art IPV nickel-hydrogen battery. The bipolar nickel-metal hydride battery concept approaches the battery from the system level and is projected to cost 1/5 as much as a comparable nickel-hydrogen battery.

•*Flight Validation Rationale*:

• Space Environment:

•The effects of microgravity on the distribution of electrolyte and component morphological changes within the wafer cells must be evaluated via flight tests to demonstrate long term cycle life. The addition of electrolyte to each individual wafer cell and subsequent sealing operation provides the proper quantity of electrolyte for the battery and significantly reduces the possibility of shunt currents with a common electrolyte manifold design. During long term charge/discharge cycling, pore size changes in the electrodes impact the wetted surface areas of the electrode which lead to a gradual increase of the impedance of the battery and ultimately a reduction in delivered ampere-hours.

•The bipolar battery employs a gas filled bladder to provide uniform compression over the planar surface of the electrode stack to provide excellent electrical conductivity between adjacent cells. Long-term pressure cycling needs to be addressed.

•The impact of high radiation levels has not as yet been assessed on the polymeric materials. Although the polymeric materials are suitable for the space environment, and the packaging enclosure provides some degree of shielding, the long term integrity of the seals needs to be addressed.

•Synergistic effects of thermal, radiation, and microgravity need to be assessed.

•Implementation Shift:

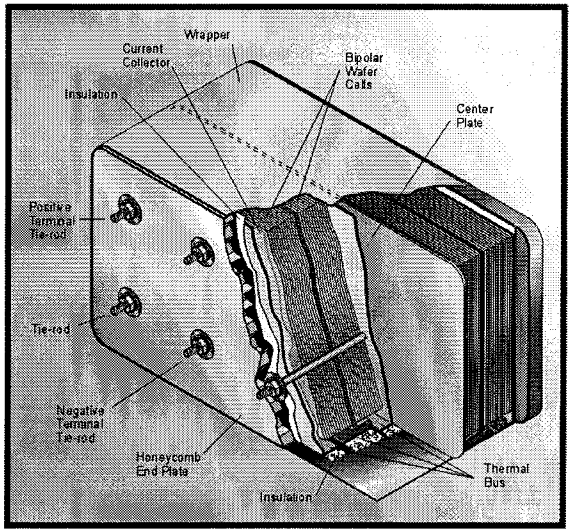
•The bipolar packaging concept has never been flown.

•Nickel-metal hydride batteries have not been used as the primary energy storage element for orbiting spacecraft.

• The integration of the bipolar battery with a passive thermal control system needs to demonstrate adequate cycle life performance.

• *Flight Test Scenario:*

•Determine the effect of the space-flight environment on the operational performance characteristics of the battery through built-in temperature, voltage, and pressure sensors to thoroughly map the electrodes within the battery to ascertain non-uniformity of performance and to compare with ground-based tests. The use of ampere-hour and watt-hour determeters to allow calculation of efficiencies from the electrical power system.



Onboard Processing to Reduce Downlink & Mission Operation Staff

Technology Description

Spacecraft has the smarts to:

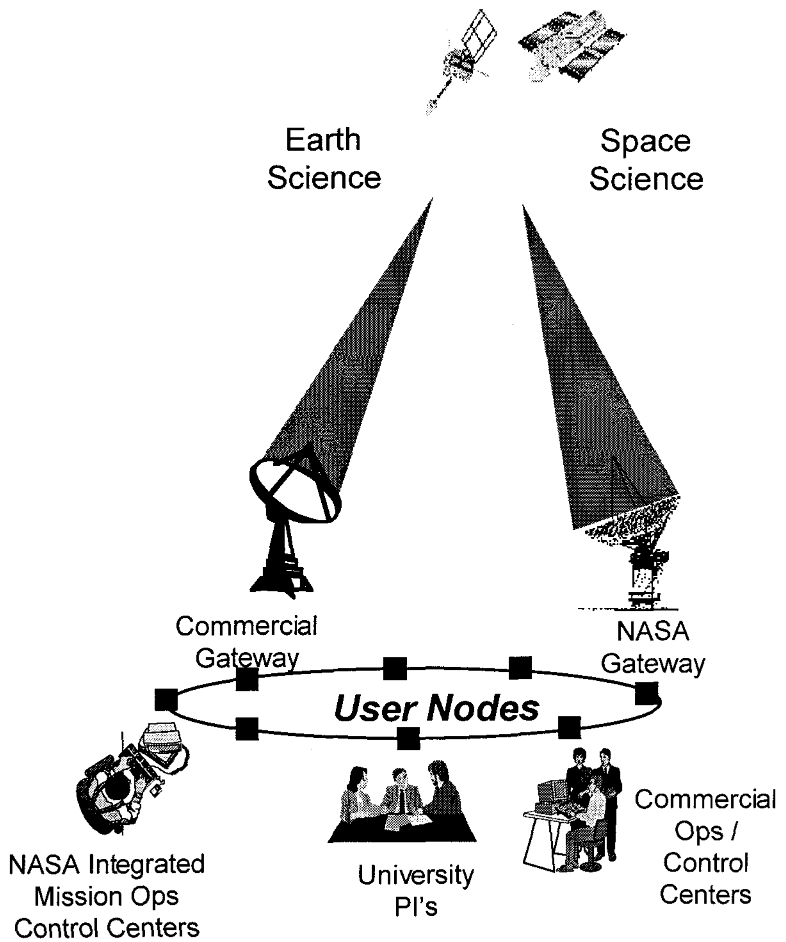
- Reason on sensor data to close-loop
- Retarget to repeat observation or path re-plan to avoid hazard
- Accommodate uncertainties with autonomous optimization of resource needs

State-of-the-Art Capabilities

- Engineers analyze and reason on the ground

Technology Validation Rationale

- Overcome the inherent fear of not being in control of the S/C at all times



Model-Based Fault Protection for Complex Systems

Technology Description:

Spacecraft has smarts to:

- Express desired behavior
- Reason on behavior models of s/c functionality
- Provide best combination of capability to continue mission

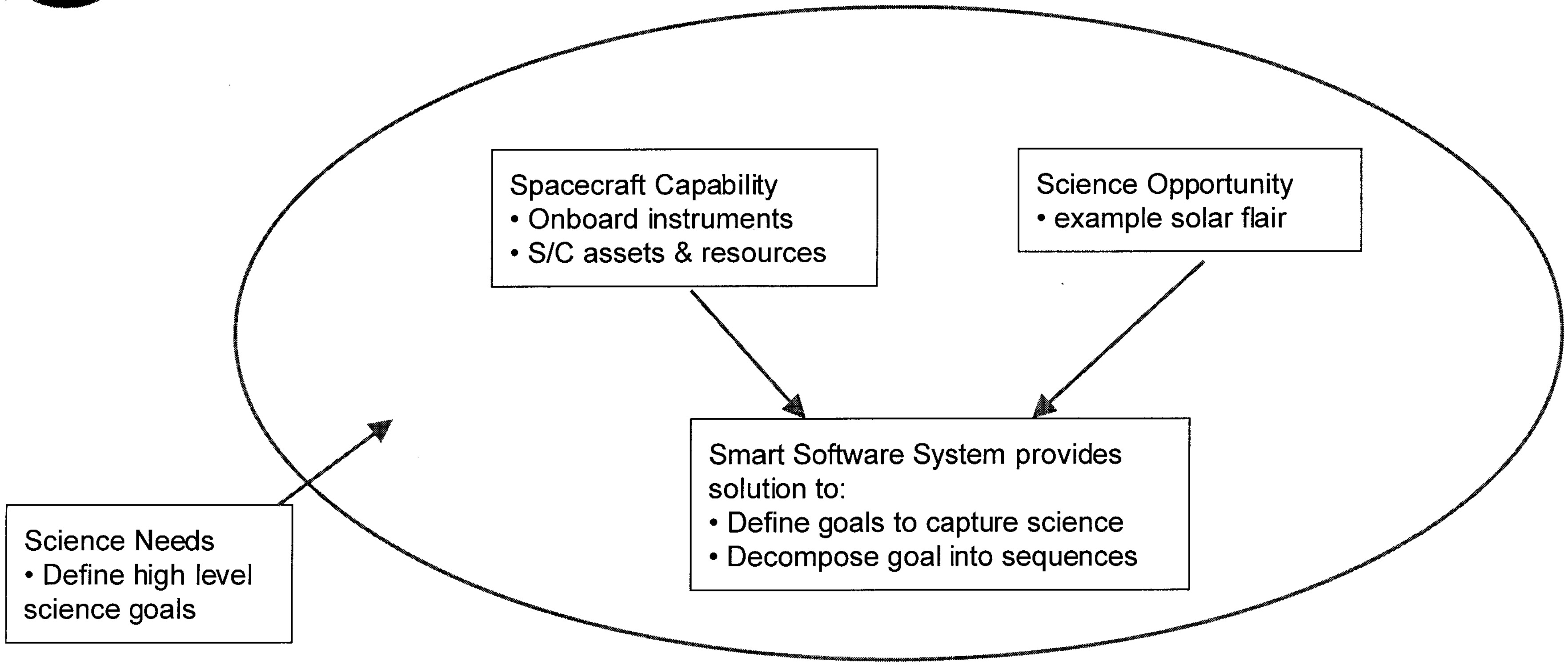
State-of-the-art Capabilities are:

- RA limited to simple behavior models
    - No science encounter behavior models
    - No formation reconfiguration behavior models

Technology Validation Rationale:

- to overcome the inherent fear of not being in control of s/c at all times

Autonomous Goal-based Mission Commanding & Execution

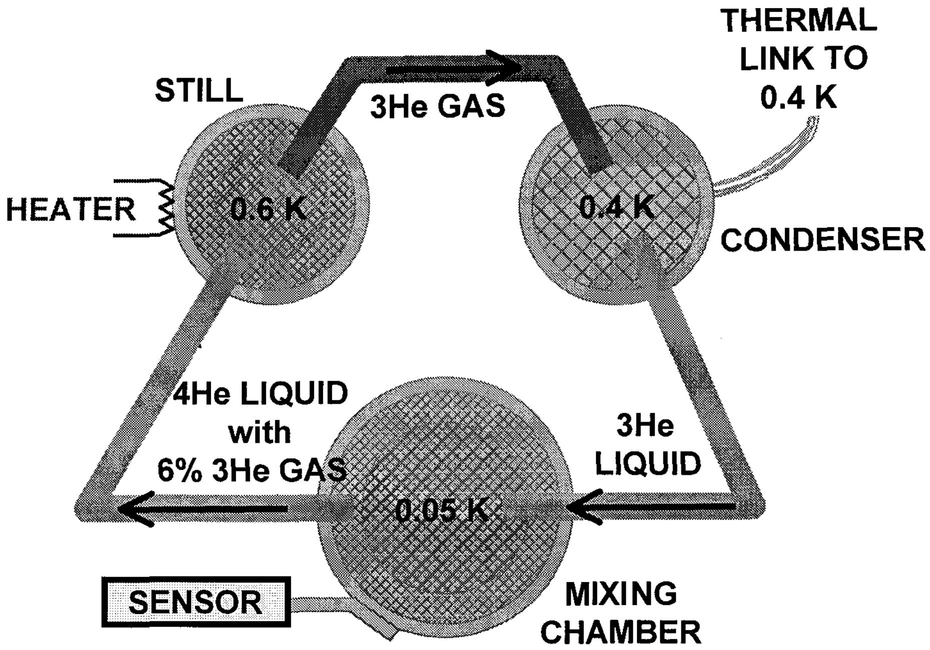


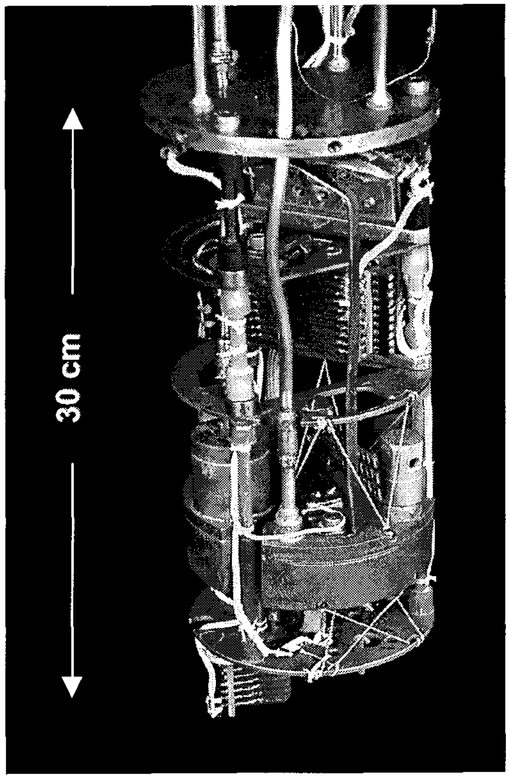
State-of-the-art Capabilities are:

- Remote Agent developed sequences for simple s/c cruise tasks
  - No complex sequence generation for science observation such as encounter.

- XTE ground-based utilized Control Center Software for s/c monitoring, to alert ops team for intervention and place data on web. No decision making or sequence generation.

Dilution Cryocooler





- OPERATION:
  - In MIXING CHAMBER, evaporative cooling occurs where Liquid ^{3}He 'evaporates' into a background of liquid ^{4}He which can produce cooling down to 0.002 K.
  - In STILL, ^{3}He is distilled from ^{4}He.
  - In CONDENSER, ^{3}He gas is recondensed and returned to Mixing Chamber.
    - ^{4}He does not circulate.
    - Gravity or other acceleration pull liquids from their correct chamber.
    - Surface tension forces in porous materials in mixing chamber hold liquids in place.
- NOTE: Operation in microgravity could be very different from operation on ground. In fact it should work better in microgravity because hydrostatic pressures are zero.