Aerogel
Space Exploration Applications

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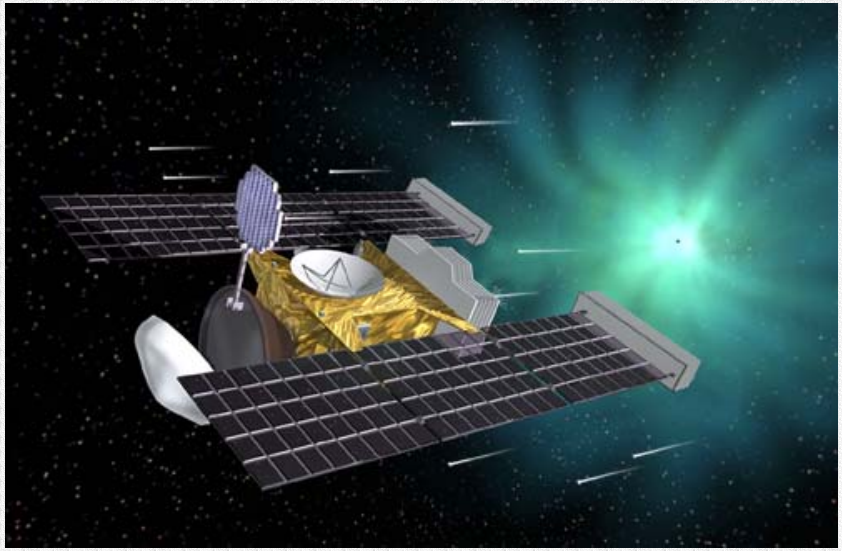
Applications	Missions
Hypervelocity Particle Capture	Stardust SCIM
Thermal Insulation	2003 Mars Rovers Thermoelectric Devices
Liquid Containment	STEP Mission

Stardust Mission

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



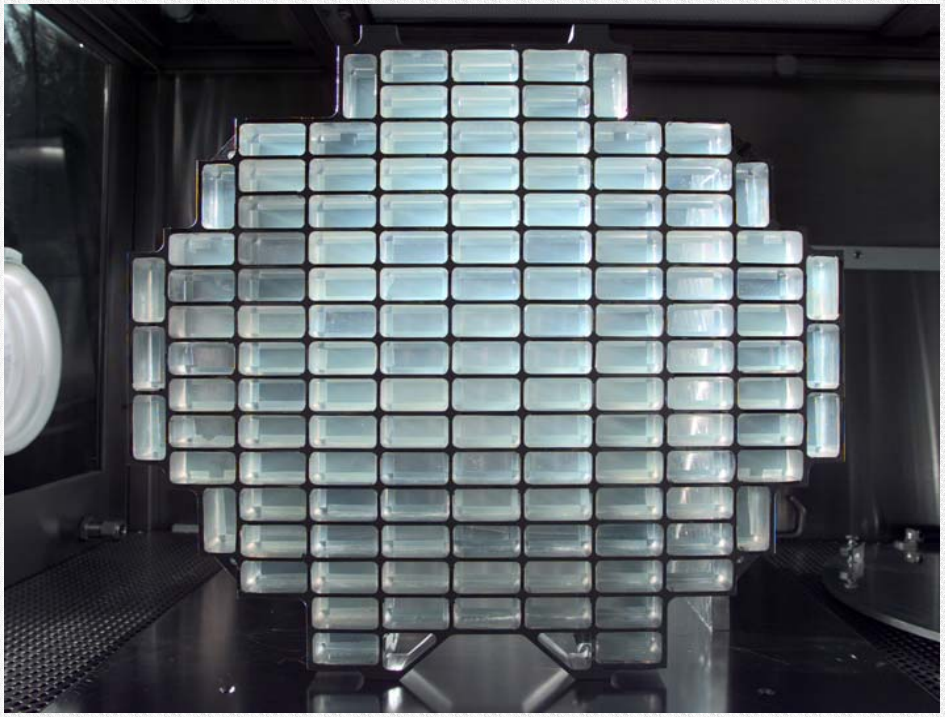
- Launch 01/99
- Interstellar Collection A 10/99 - 03/00
- Interstellar Collection B 05/02 - 10/02
- Wild2 Encounter 01/04
- Return to Earth 01/06

Stardust Aerogel Collection Grid

- Capture 1000 15μm Comet Particles in Aerogel at 6 km/sec
- Capture Interstellar Grains in Aerogel
- Two Collection Grids
  - 1040 cm^2 each grid
  - 2 cm X 4 cm each block
- Silica Aerogel
- Gradient Density

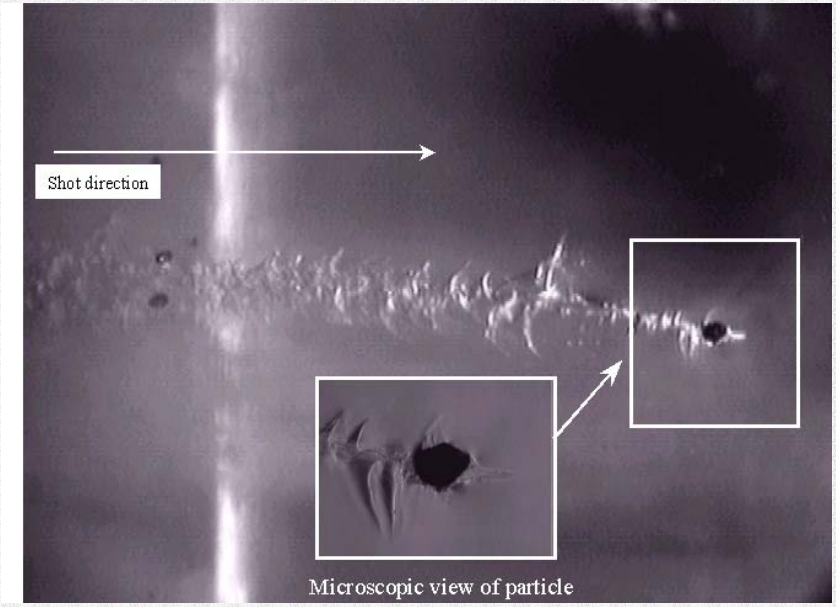
  Comet 10 - 50 mg/cc

  Interstellar 10 - 20 mg/cc



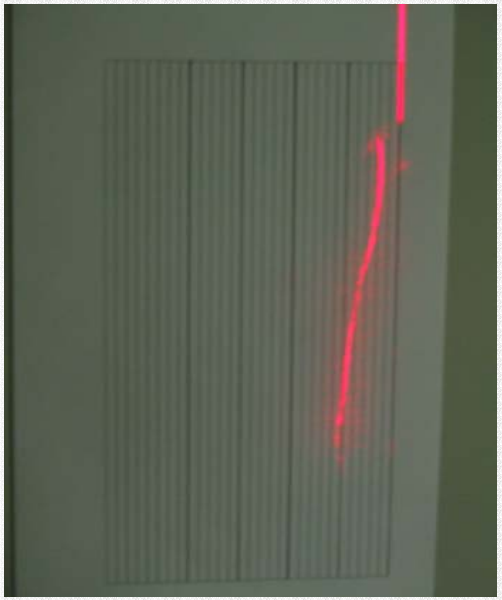
Particle Capture in Aerogel

- Particles are much larger than aerogel network elements
  - Network nm
  - Particles μm
- Kinetic energy gradually converted to thermal and mechanical energy, so particle slows
- Particles remain largely intact



Gradient Density Aerogel

- Produced by gradually diluting sol precursor
  - Two step method
- Density measured by change in refractive index
  - Gladstone Method
- Other properties correlated to density
  - Thermal, acoustic, dielectric, optical



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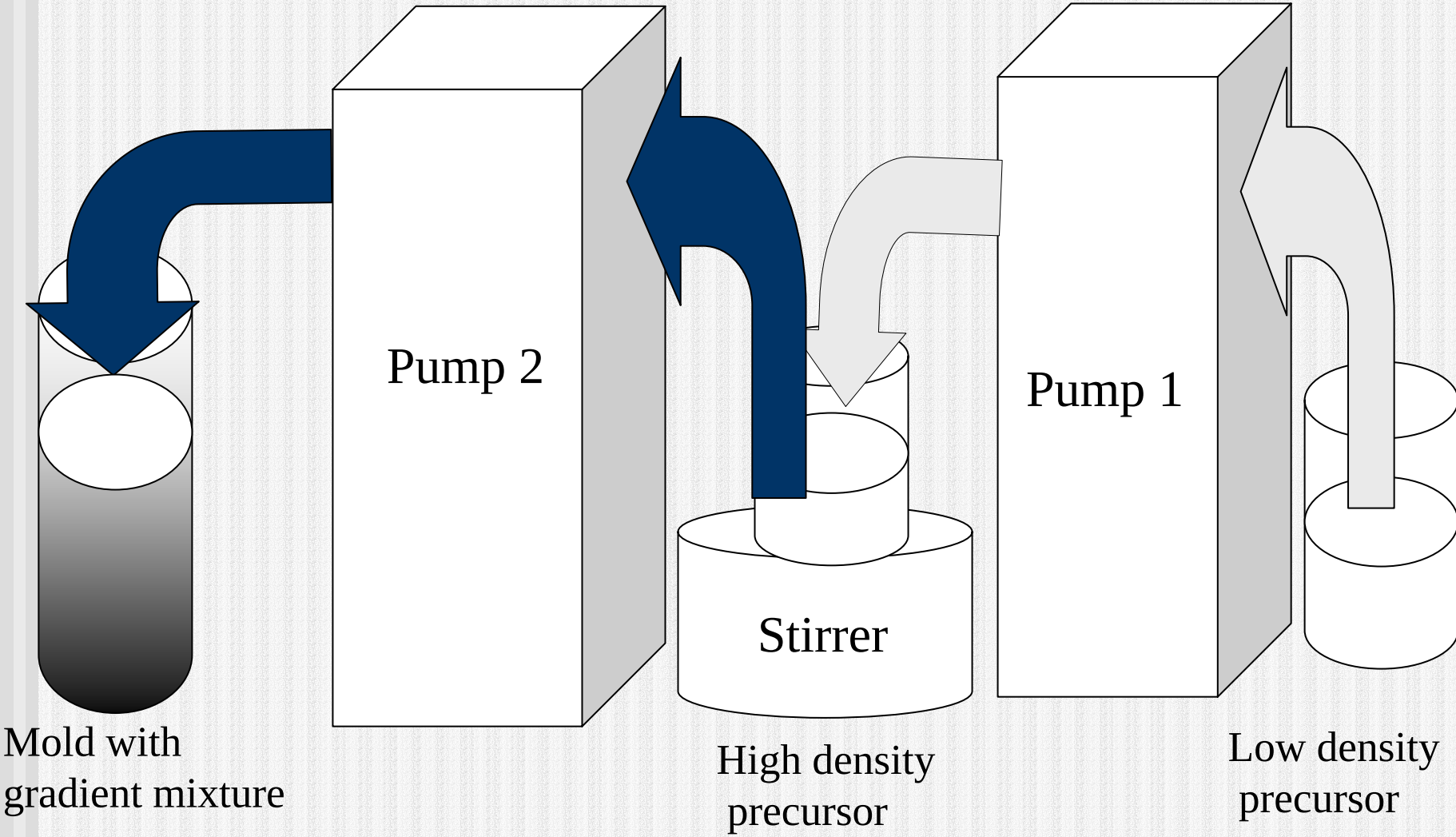
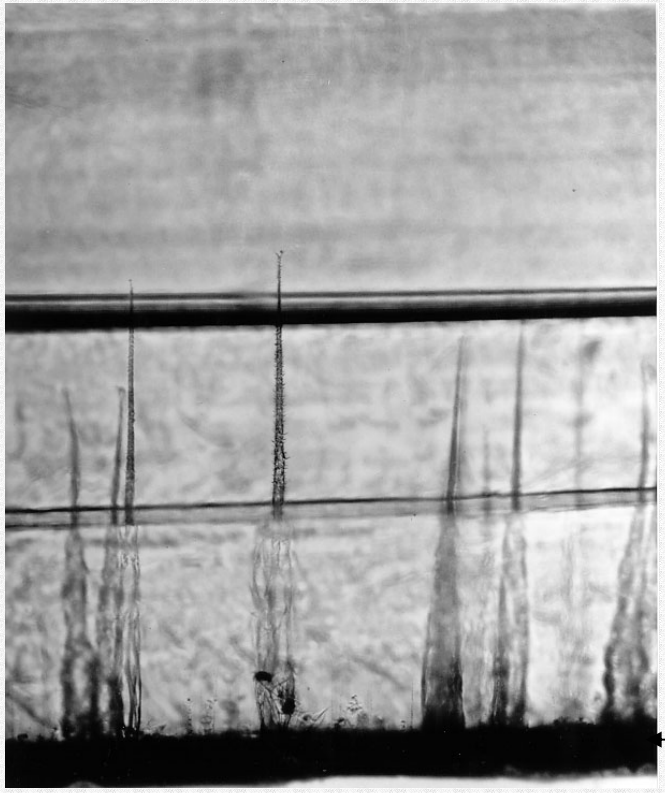
Gradient Density Aerogel Production



Stardust Aerogel Requirements

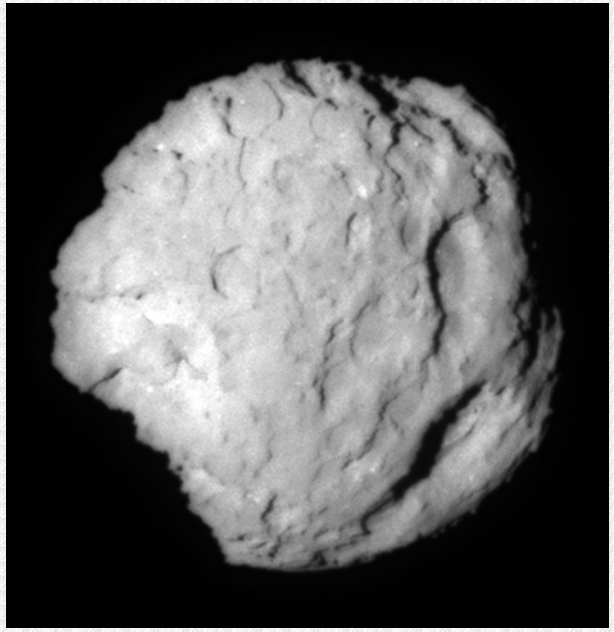
- Intact Capture
- Size/shape
  - Molds/Processing
- Flaws
  - Processing
- Purity
  - Inorganics
    - Distill reagents, Quartz molds
  - Organics
    - Thermal post-processing
- Launch/Landing Survival



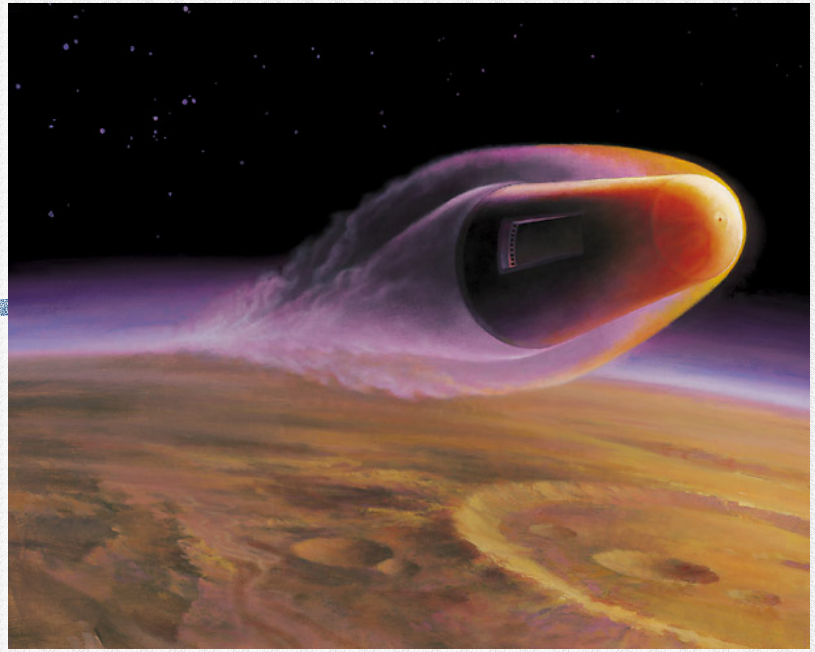
Aerogel Testing/Qualification

- Impact/Capture Testing
  - Ground - Light Gas Gun
  - Space - Shuttle/MIR
- Inspection
  - Size/Shape/Flaws
- Chemical Testing
  - Inorganics
  - Organics
- Launch Vibration Tests
- Landing Pyro Shock Tests

Stardust Wild2 Encounter



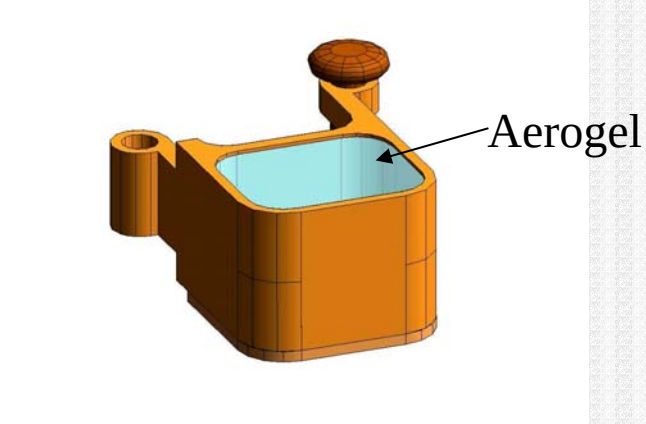
SCIM Project

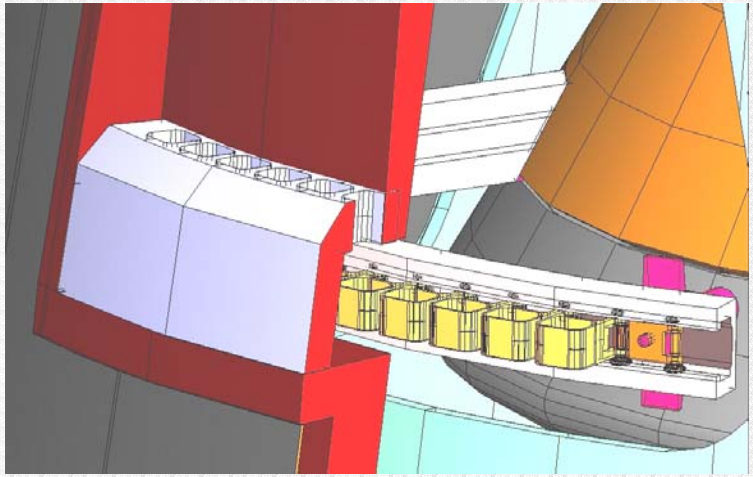


- Sample Collection for the Investigation of Mars
- Mars Atmospheric Dust Collection
- Mars Atmosphere Collection
- Low Cost/Low Risk
- Global Sample
- 2003 Mars Scout Proposal

SCIM DuCE Aerogel

- Martian dust collection
- Passive collector
- Particles in free molecular flow
- CFD modeling of aerogel heating
- Aerogel retracted into return capsule after collection
- Aerogel/sample heating for planetary protection

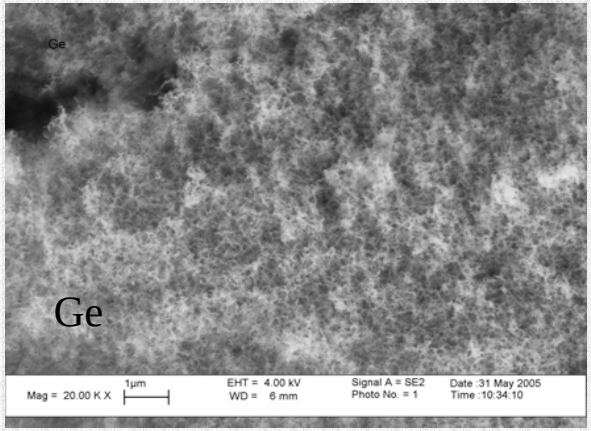


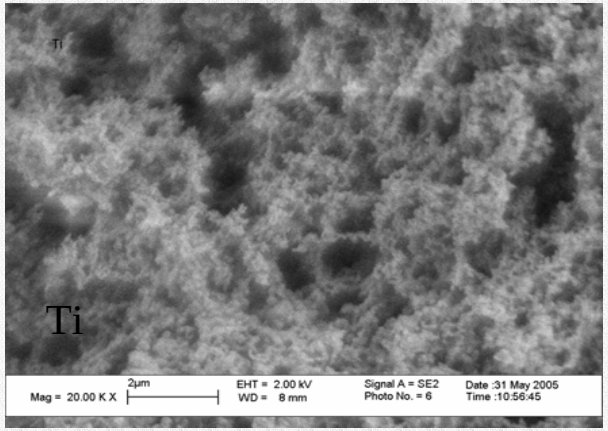


Images courtesy of Lockheed Martin

Non-Silicate Aerogel

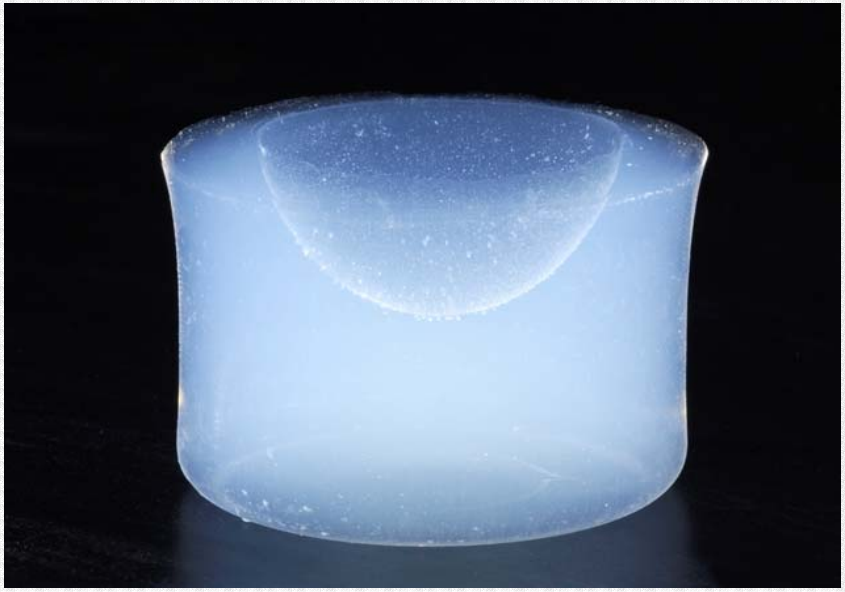
- Solar system is silicate rich
- Use non-silicate aerogel to complement silica aerogel
- C, Al, Ti, Ge, Zr, Nb, Hf
- Non-silica aerogel networks are suitable for efficient hypervelocity capture





SCIM ACE Aerogel

- Particle collector for atmospheric collector
  - Particles embed in aerogel; gasses flow past aerogel into collector tanks
  - Planetary protection measure

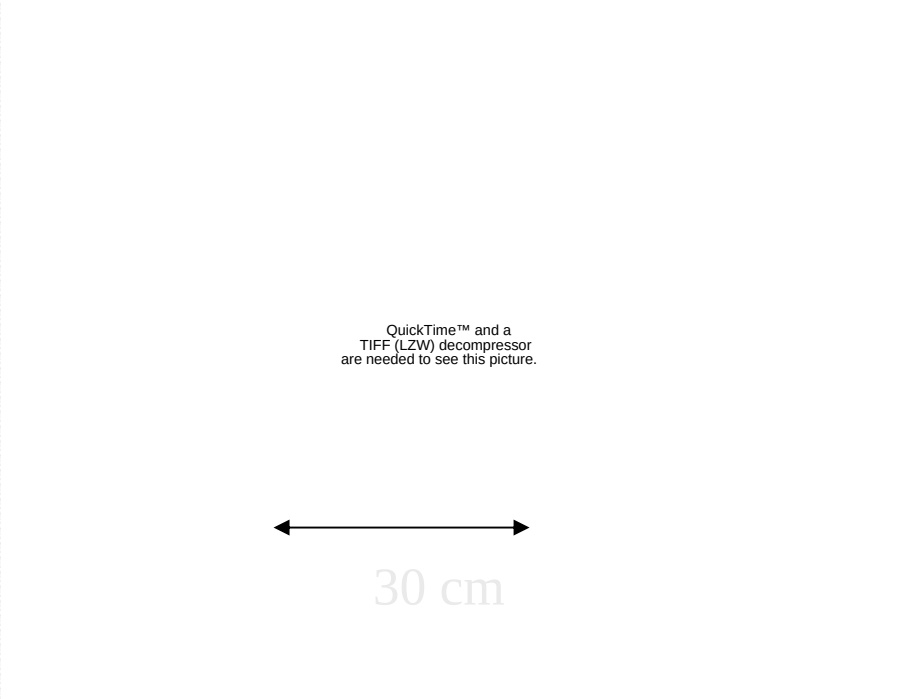


2003 Mars Exploration Rover

- Launch 05 - 06/03
- Landing 01/04
- Exploration 02/04 -
- Termination ?

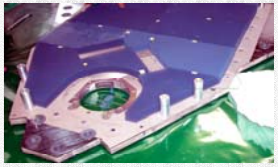
Aerogel Panels for 2003 MER

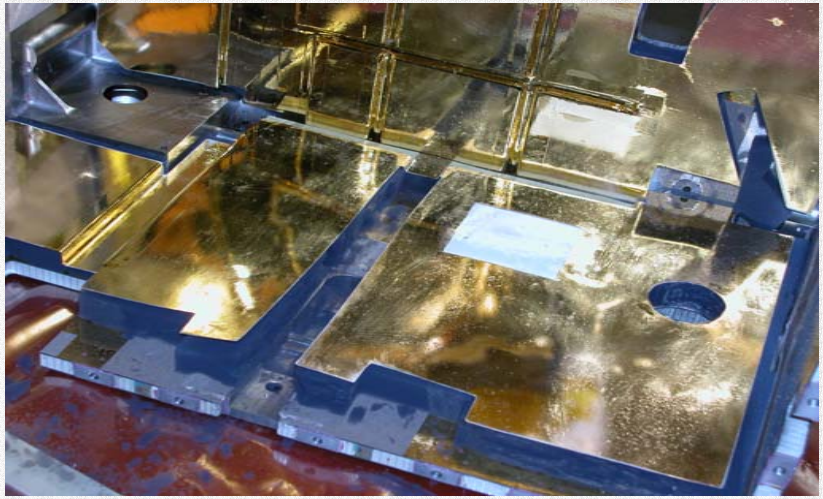
- Density = 20 mg/cc
- Opaque
  - Graphite content 0.4%
  - Prevent irradiative heat transfer
- Thickness = 2.5 cm
- Two-step process
- Sol Processing Important
  - Reflux for many hours



MER Aerogel Thermal Insulation

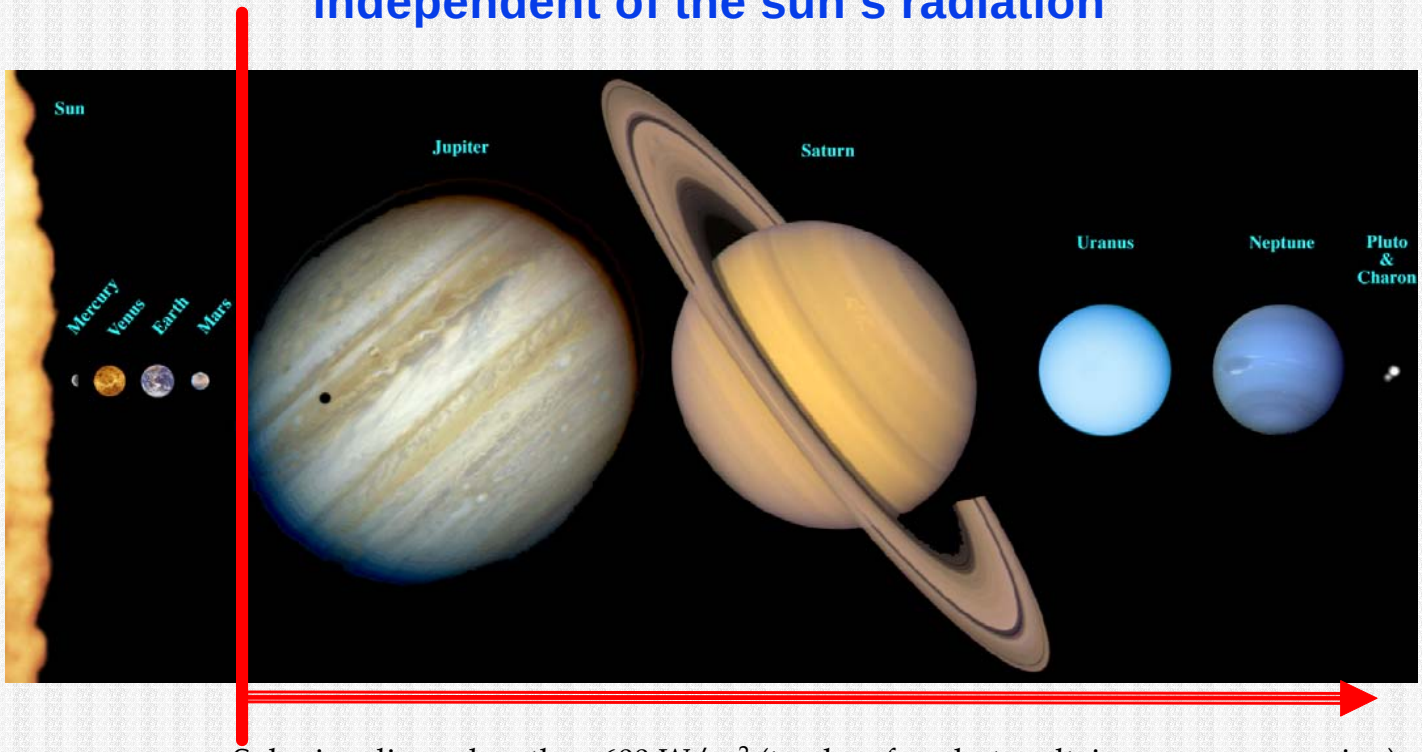
- Individual shapes cut from larger panels
- Sandwiched structure
  - WEB walls
  - Fiberglass/Kapton
  - λ = 0.012 W/mK
    - 10 Torr CO_2 at 0 C





Aerogel Use in Thermoelectric Devices

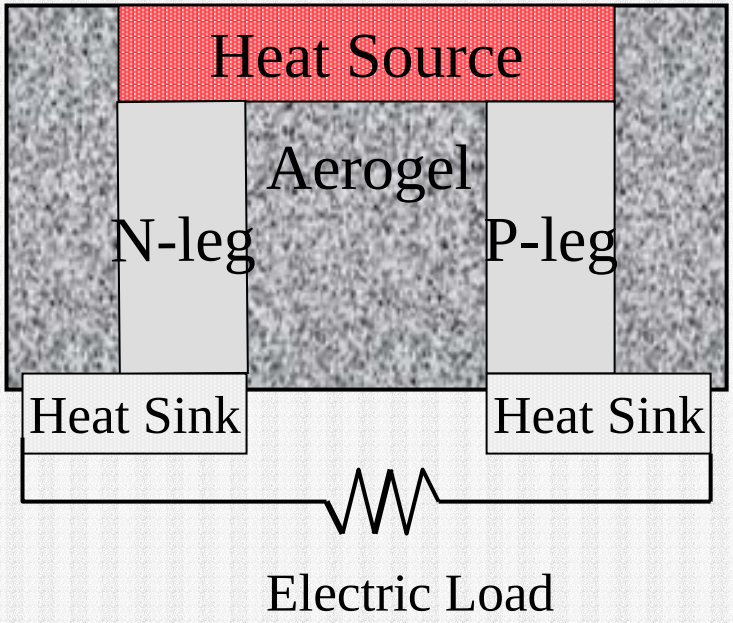
Thermoelectric Generators provide reliable power independent of the sun's radiation



Solar irradiance less than 600 W/m^2 (too low for photovoltaic energy conversion)

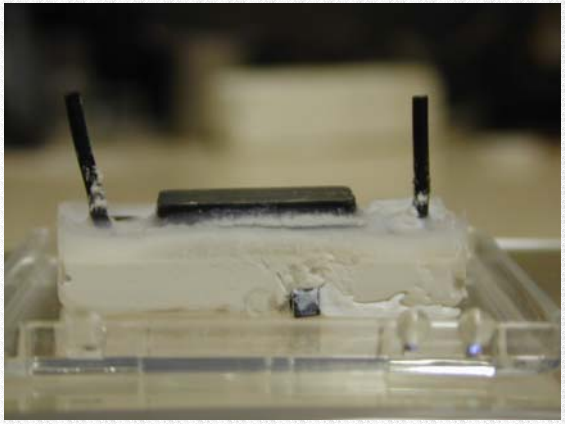
Thermal Insulation for Thermoelectrics

- Thermal energy from radioisotope converted to electrical energy
- Thermal insulation
  - Directs heat through legs
- Use of aerogel simplifies construction
- Aerogel inhibits alloy component sublimation



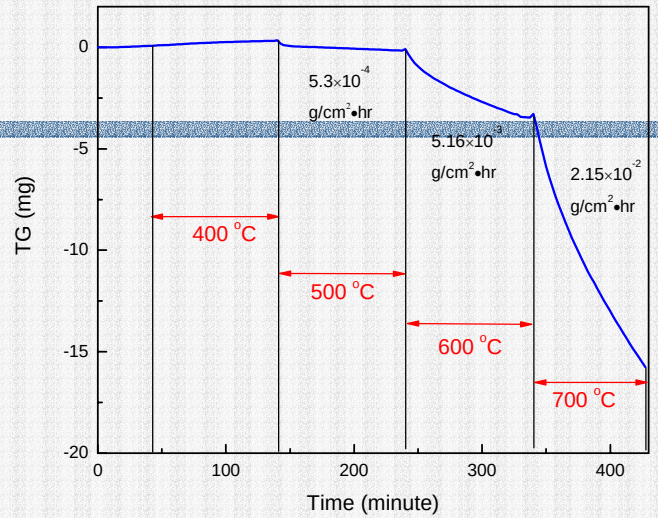
Thermoelectric Modules in Aerogel

- Aerogel can be cast in place throughout module
- Cast as exterior thermal insulation
- Oxide powder added to reduce shrinkage
- Must prevent any cracking to ensure complete encapsulation

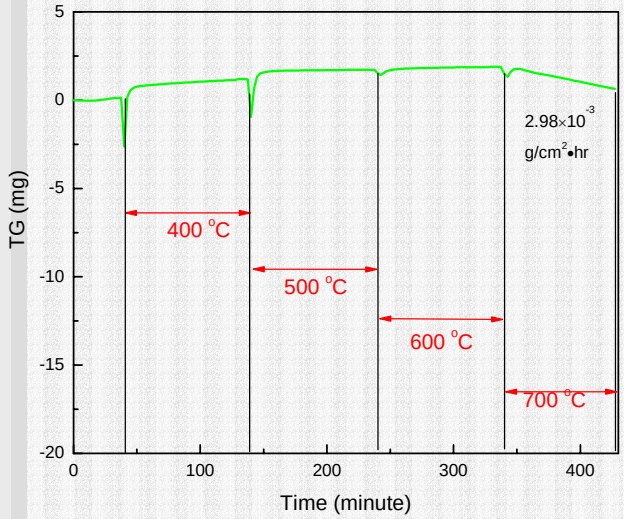


Sublimation Suppression

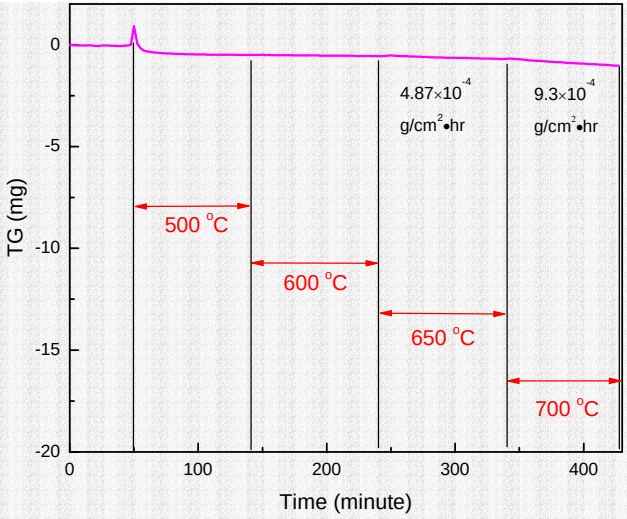
Uncoated



Low Density Aerogel (50 mg/cm^3)



Higher Density Aerogel (100 mg/cm^3)



STEP Mission

- Satellite Test of the Equivalence Principle
- Test equivalence of Inertial Mass and Gravitational Mass
- Increase precision by orders of magnitude

Aerogel Tidal Flow Control

- Accelerometer sensors require liquid helium temperatures
- Liquid helium tidal flow disturbs sensors
- Prevent tides by containing liquid helium with aerogel network

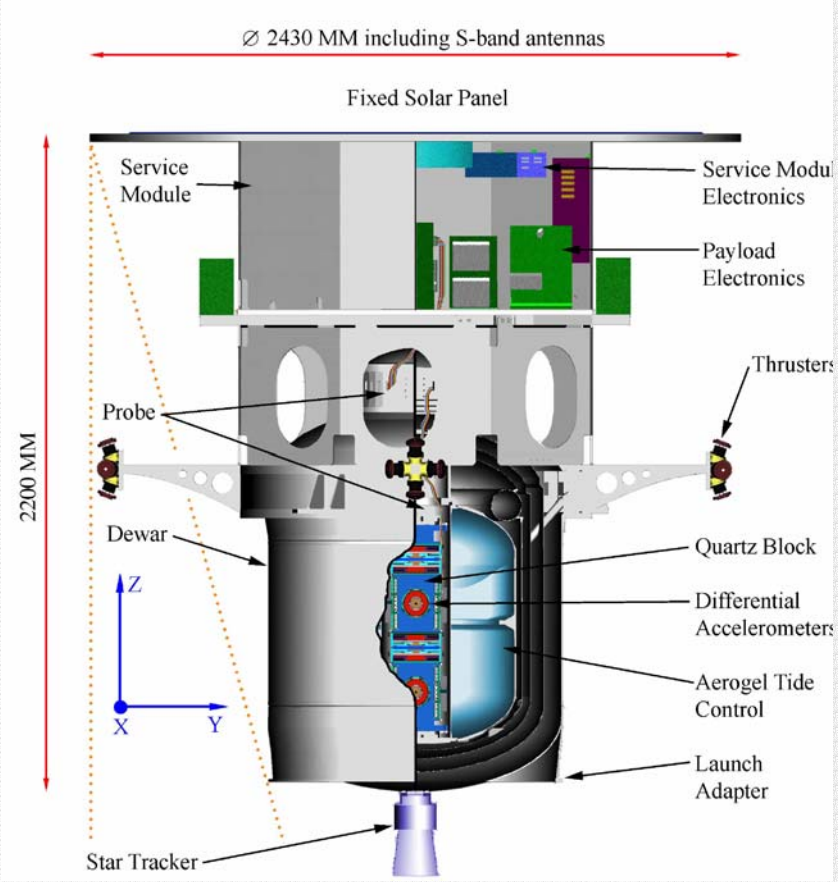
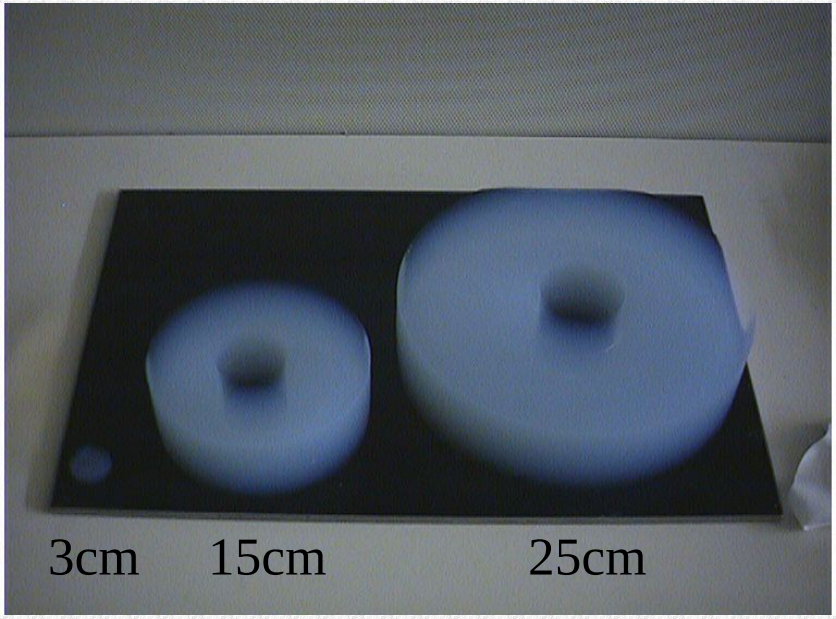
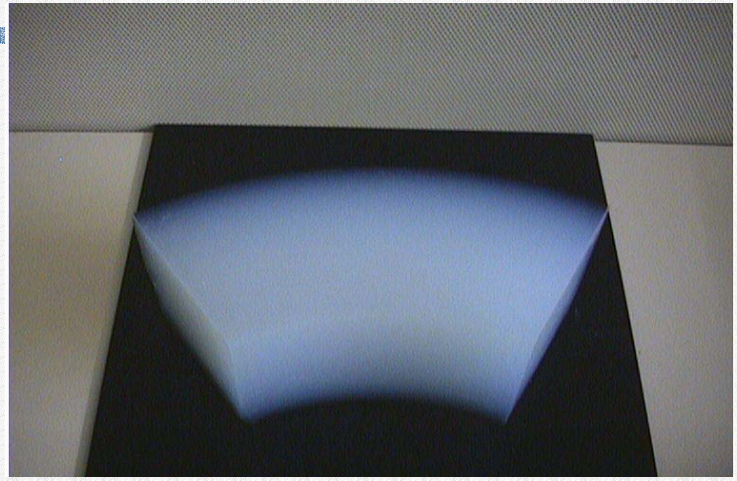
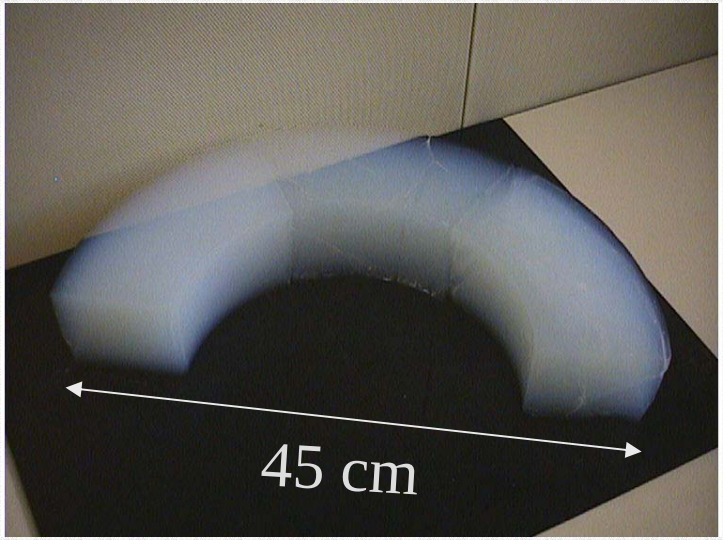


Image courtesy of STEP - Stanford University

STEP Aerogel

- Aerogel tested with torsion balance while immersed in liquid helium
- Annular cylinder to mimic shape of Dewar
- Dewar filled with silica aerogel
- Aerogel filled with liquid helium



Aerogel Assembly

- Rounded Trapezoids
  - 2 liter volume
  - 60 degree angle
- Annular cylinders to fill Dewar
- Assembled to build larger structures
- Blocks banded to place under compression
- Tested 50 and 100 mg/cc aerogel