Reentry Thermal Protection Systems

NASA Roadmap Feedback

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Lockheed Martin Space Exploration Division Experience

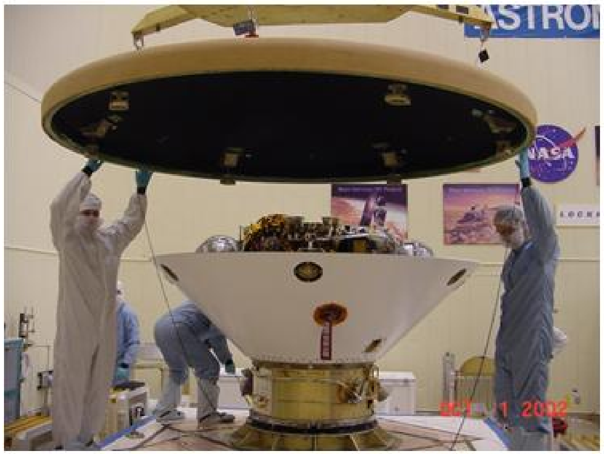
- Re-Entry Related Flight Programs
  - Small unmanned missions, Modest $ value
- Mars Entry
  - Viking
  - Mars Pathfinder (Aeroshell)
  - Mars 2001 / Phoenix
  - Mars Exploration Rover (Aeroshell)
  - Mars Science Laboratory (Aeroshell)
- Earth Entry
  - Stardust Sample Return Capsule
  - Genesis Sample Return Capsule
- Jupiter / Venus Entry (former GE Reentry Systems)
  - Pioneer Venus Probes (Aeroshell + Parachutes)
  - Galileo Probe (Aeroshell + Parachutes)
- Aerobraking
  - Magellan
  - Mars Global Surveyor
  - Mars Odyssey
  - Mars Reconnaissance Orbiter

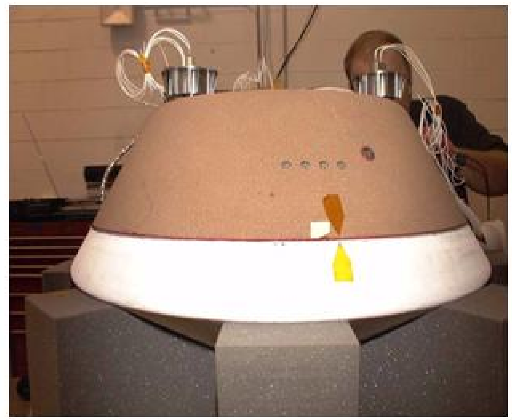
Phoenix Mars Lander

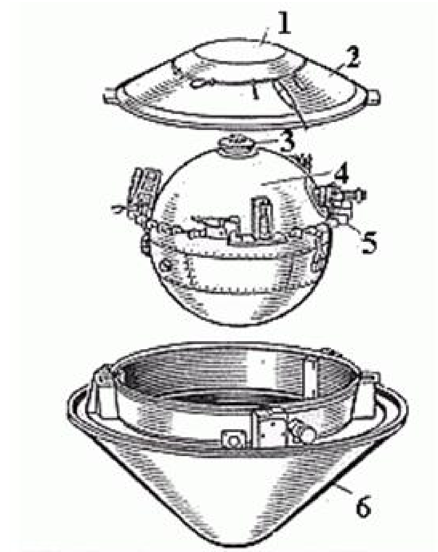
Stardust Probe

Galileo Probe

Aeroshell TPS Types – Flight Program Experience







<u>Low-Energy</u>	**<u>High-Energy</u>**	**<u>Very-High-Energy</u>**
SLA-561V	**PICA**	**Carbon-Phenolic**
SLA-565S	**Carbon-Carbon**	
10-400 W/cm2	**400-1500 W/cm2**	**50,000 W/cm2 +**
Monolithic	**Monolithic / Tiled**	**Monolithic**

<u>Affordability paradigm fits with LM small probe experience</u>

Affordability – Comparison of Two Large TPS Systems - MSL

Comparable Size TPS Compare: PICA & SLA for MSL (>3X cost)

PICA (Heatshield)

Tiled Application

1) Design Tile Layout
2) Manufacture Billets
3) Precision Machining
4) Tile Dry-Fit
5) Tile Application
6) Gap-Fill

SLA-561V (Backshell)

Monolithic Application

1) Prep Flexcore
2) Bond Flexcore
3) Pack Material
4) Surface Finish

While more capable, PICA is more expensive to incorporate on large-scale due to tiling

Challenge: Produce a TPS with PICA-Like Performance but SLA-Like Affordability

Monolithic High Heat Rate Ablator - MonA

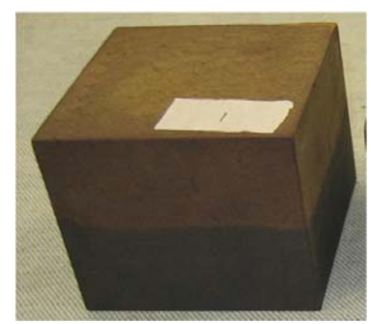
- **Carbon Phenolic, Slurry-based TPS developed under LM IR&D Project D-90d in 1995**
- **Leverage off Cost-Effective SLA-561V Production Process (TPS in Honeycomb)**
- **Unique Formulations for Ablator and Gap Filler Applications**
- **Low Density (~0.29 g/cc) Material for Primary Heatshield**
- **Graded MonA Optimizes TPS Performance with Depth (dual-attribute cured material)**
  - **Top Level – Robust Ablator (standard MonA)**
  - **Bottom Level – Low-Density Insulator**
- **MonA Selected by NASA Ames for TDP Program**
  - **TRL Improvement Technology Program**
  - **Material Has Passed Phase 1 Gate**

PICA

MonA

Preliminary Tests Show Equivalent Performance

Arcjet Test Specimens



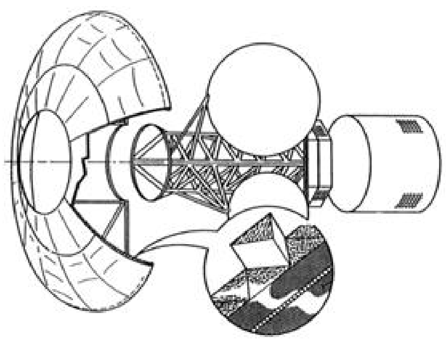
MonA Graded Specimen

Deployable Aeroshell Technology

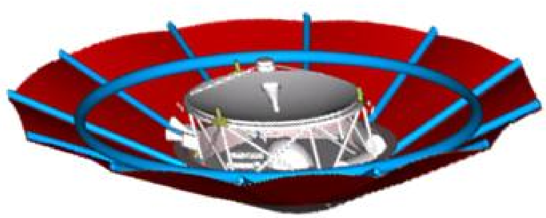
- **LM has investigated variety of deployable aeroshells under NASA / DARPA Studies**
  - **Inflatable Flexible – In-Space AID NRA, Rapideye DARPA, Aeromorphing Supersonic Decelerator**
  - **Deployable Flexible – AOTV Phase A Study (1984)**
  - **Deployable Rigid – Manned Mars Systems Study, Mars 2001 Lander**

- **Main Issue is Flexible TPS Robust to In-Flight Heating & Flutter**
  - **IR&D testing of flex TPS to 120 W/cm2**
  - **Mixed Success to Date**
  - **No Flutter Testing Yet**

- **Intermediate Option**
  - **Deployable rigid panels**
  - **Not as efficient as deployable flexible but available sooner**



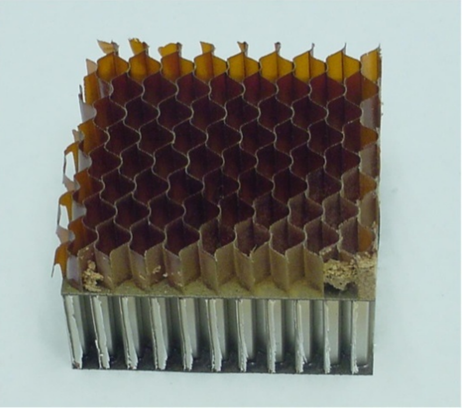
OTV 1980's



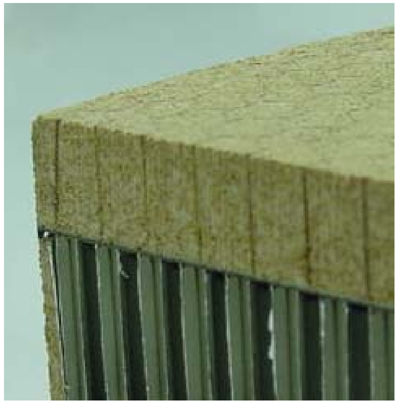
AID NRA 2000's

"Old" TPS Technology

- While Developing New Technology, Don't Lose the Old
  - Cost & Schedule may require proven system
- SLA-561V used on many successful entry missions
  - Viking, Mars Pathfinder, Phoenix, MER, Stardust (BS), MSL (BS)
  - Monolithic material with continuous application
    - Ablator packed into pre-bonded flexcore
    - Regional pack using 1-2 ft sq areas
  - Originally developed in early 1970's
  - Successful stagnation tests from 10 to 400+ W/cm2
- MSL Experience
  - Originally slated for heatshield
  - High shear test anomalies forced switch to PICA
  - Used on MSL Backshell (thruster plume interaction heating)
- Overall
  - Although old, the material is very efficient (thermally & cost)
  - Flight certified & space qualified for use on heatshields
  - IRAD tests of minor mod to increase shear capability



Flexcore Pre-Bonded to Struct



SLA Heatshield Cross-Section (TPS+Struct)

Wrap-up

- **LM-SES has produced multiple flight aeroshells for NASA**
  - **Unmanned probe missions using multiple TPS materials**
  - **Flight certification a driving issue**
  - **Production costs & schedule are key considerations**

- **Investment in TPS**
  - **Resurrection of Carbon-Phenolic for Venus & Giant Planets**
  - **Advanced TPS development funding for LBIR**
  - **Small funding for maintenance of existing TPS**
    - **Ingredient obsolescence**
    - **Resolution of flight program issues (ex: MSL SLA)**
  - **Dependent on NASA Program Support to Offset Arcjet Costs**

- **Keep industry involved (In-Space NRA example)**
  - **Insights into Affordability (Certification, Production, Cost Impacts)**