HEATSHIELD FOR EXTREME ENTRY ENVIRONMENTS TECHNOLOGY (HEEET)

Ethiraj Venkatapathy
TPS Materials Project Manager
&
Donald T. Ellerby
HEEET Element Manager
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Washington, DC
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Goal: Mission infusion into Discovery 2014 and New Frontier-4

An integrated 3-D Woven, dual-layer, multi-material, resin infused architecture

- Capable of withstanding extreme entry environments
  - Fills the TPS Gap - Peak heat flux $>> 1500$ W/cm²; Peak pressure $>> 1.0$ atm.
  - Example missions: Venus, Saturn and High Speed Sample Return

- Single step, uniform resin infusion (PICA like)

Segmented heatshield configuration
Venus Entry at 10.8 km/s
Areal Mass Comparison

- Aeroshell - 3.5m dia., 45° sphere cone, 2,000 kg total mass
- Areal mass of HEEET is ~ 50% of Carbon Phenolic (CP) for a broad range of entry trajectories
  - Efficiency of HEEET allows for trade between TPS mass vs lower entry g’load.
- Performance combined with robustness makes HEEET an exceptional choice
Design Space & HEEET Arc-jet Test History

HEEET Materials Test History to Date =

- Saturn High Lat. Steep (-19°) Entry
- Saturn Equatorial, Shallow (-8°) Entry
- Pioneer Venus Large Probe (-32.4°)
- Venus VITaL Steep (-22°) Entry
- Venus VITaL Shallow (-15°) Entry

**Stag. point total heat flux, kW/cm²**

**Stag. point pressure, bar**

- IHF 6” Nozzle 2” Flat Face
- IHF 3” Nozzle 1” Flat Face
- AEDC (Wedge)

AEDC H3 2” Flat Face March 2014

POC: Ethiraj.Venkatapathy-1@nasa.gov
HEEET Thermal Testing

Testing to date has not induced thermal failure modes in acreage material.

~1600 W/cm², 1.3 bar
Post-Test

~1800 W/cm², 14 bar
Pre-Test

~4000 W/cm², 5 bar
Post-Test
The project team has extracted generic, high-level, heat shield requirements from MSL, Orion and Stardust experience

- Requirements addressed both functional requirements and sustainability (manufacturability, operability, etc.)

Requirements presented and reviewed at HEEET workshop (June 2013)

General TPS requirements have been flowed down to HEEET specific requirements for technology development

Verification strategies/approach for each requirement have been identified

Development tasks are traceable to verification

TRL can be assessed against requirement verification status
Current TRL for HEEET is 3+

<table>
<thead>
<tr>
<th>TRL Level</th>
<th>Hardware description</th>
<th>Level 1 Requirements</th>
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<tbody>
<tr>
<td>3</td>
<td>Analytical studies place the technology in an appropriate context and laboratory demonstrations, modeling and simulation validate analytical prediction.</td>
<td>Function Thermally: Mission studies indicate feasible thicknesses and good TPS mass fractions. Function Structurally: Strength requirements established from analysis of mission-relevant loads. Coupon testing of candidate seams indicate adequate strength achievable. Be Operable: Analogy with other TPS systems involving carbon and phenolic: benign dust, out-gassing, etc. Be Manufacturable: Trade studies on candidate manufacturing approaches. Interface with Vehicle: Concepts for penetrations and closeouts are established. Be Certifiable: Integrated inspection and repair study is in work. Traceability from ground test to flight similar to previous TPS.</td>
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<td>A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments.</td>
<td>Tests of acreage material and candidate seam concepts over a range of arc-jet environments. Weaving, cutting, bonding, infusion and seam production demonstrated at subscale. Flaw detection in weave, infusion and seams demonstrated at subscale.</td>
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### Key Milestones

<table>
<thead>
<tr>
<th></th>
<th>FY14 Q1</th>
<th>FY14 Q2</th>
<th>FY14 Q3</th>
<th>FY14 Q4</th>
<th>FY15 Q1</th>
<th>FY15 Q2</th>
<th>FY15 Q3</th>
<th>FY15 Q4</th>
<th>FY16 Q1</th>
<th>FY16 Q2</th>
<th>FY16 Q3</th>
<th>FY16 Q4</th>
<th>FY17 Q1</th>
<th>FY17 Q2</th>
<th>FY17 Q3</th>
<th>FY17 Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DIS-13</strong></td>
<td>Draft AO</td>
<td>AO</td>
<td>Step 1.</td>
<td>Phase A (Start)</td>
<td>Phase A (end)</td>
<td>Phase B</td>
<td>PDR</td>
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<td><strong>Mission Infusion</strong></td>
<td>Mission Infusion Workshop</td>
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<td>HEEET Workshop</td>
<td>HEEET Workshop II (Phase A)</td>
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<td>HEEET Tech. Readiness Review</td>
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<td><strong>Heatshield Design</strong></td>
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<td>DAC-1 Design Review</td>
<td>DAC-2 Design Review</td>
<td>DAC-3 Design Review</td>
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<td><strong>WTPS Seam Development / Test</strong></td>
<td>Seam Design Review</td>
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<td>Seam Design(s) Selected</td>
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<td><strong>Engineering Test Unit (ETU)</strong></td>
<td>ETU-DR-1</td>
<td>ETU-DR-2</td>
<td>ETU-MRR</td>
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<td>ETU Build Complete</td>
<td>ETU TRR</td>
<td>ETU Testing Complete</td>
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- HEEET Maturation is aligned with the Discovery 2014 Mission Selection and Proposal Phases
- HEEET project milestones, deliverables and workshops focuses on proposals and study report development
HEEET Challenges

- **Weaving scale-up (in place ~ Feb. 2015):**
  - Critical to maturing manufacturing processes: molding, seams, resin infusion
    - Current capability: ~1” thickness x 6” width
    - Expanded capability: ~3” thickness x 24” width

- **Seam Design (down-selected by early 4th Q FY'15):**
  - Single piece heat shield is not feasible. A segmented heat shield is required
  - Goal is an aerothermally monolithic solution
    - Seam thermal performance the same as acreage TPS

- **Infusion Scale**
  - Infusion size currently ~1.2 m due to industrial vessel limitation
    - Once demo’ed at 1.2m scale further scale up is not considered a significant challenge but will need to be demonstrated
  - Scale-up is not currently planned beyond 1.2m size
    - Resin Infusion may or may not limit the size of the heat shield
  - On-going trades may lead to heat shield integration approaches not requiring the infusion to be scaled-up
Planned AO Library Content and Support for HEEET Mission infusion

- Announcement of Opportunity (AO) Library planned contents:
  - Questionnaire to be filled out by proposal team planning to use HEEET
  - Documented requirements and requirements verification plan
  - HEEET exit criteria for TRL 6
  - Mission studies report for Venus, Saturn and High-Speed Sample Return missions
  - Arc Jet test summary report
  - Preliminary material property database
  - Conference papers and publications

- HEEET team plans to support proposal teams in Step 1 and Step 2 proposal phases by engaging with them directly
  - Will perform limited sizing studies
  - Consultation on integration approaches
  - Guidance on mission design that take into account TPS manufacturing and integration, testing and verification for flight.
POC for HEEET

Ethiraj Venkatapathy
NASA Ames Research Center
(Primary interface with proposal teams)

ethiraj.venkatapathy@nasa.gov
650-248-1596 (Cell) primary
650-604-4282 (office)