Heatshield for Extreme Entry Environment Technology (HEEET) – Enabling Missions Beyond Heritage Carbon Phenolic

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1: Heritage Carbon Phenolic – Sustainability Challenges

- NASA's future robotic missions utilizing an entry system into Venus and the outer planets, results in extremely high entry conditions that exceed the capabilities of the art to low to mid density ablators such as ACA and AVCOAT.
- In the past mission planners had to use a fully dense carbon phenolic heat shield similar to what was flown on Pioneer Venus and Galileo.
- Carbon phenolic is a robust TPS material however its high density & relatively high thermal conductivity constrain mission planners to steep entries, high heat fluxes & pressures and short entry durations.
- The high entry conditions pose challenges for certification in existing ground based test facilities.
- Longer-term sustainability of CP continues to pose challenges especially with the chopped molded nose cap.

NASA has decided to invest in new technology development rather than invest in reviving carbon phenolic.

2: HEEET – 3D Woven TPS for Extreme Entry Environments

HEEET – co-funded by NASA's Space Technology Mission Directorate and Science Mission Directorate to mature and scale-up a game changing Woven TPS technology for insertion into future NASA robotic missions.

- HEEET leverages a mature weaving technology that has evolved from a well-established textile industry.
- HEEET has down selected a single Woven TPS architecture for maturation.
  - Architecture consists of a high density all carbon surface layer designed to manage recession and a lower density insulating layer composed of a blended yarn to manage heat load.
  - This HEEET architecture is infused with phenolic
  - A layer to layer weave is utilized in HEEET which mechanically interlocks the different layers together and minimizes TTI thermal conductivity.
  - Dual layer design allows some tailor-ability of TPS for mass efficiency across a wide range of environments.

HEEET project goal is to mature the heat-shield system that is efficient for NASA missions based on woven TPS technology to TRL 6 by the end of FY 2018.

3: HEEET Mission Infusion

NASA's Science Mission Directorate encouraged the adoption of HEEET technology by the community for mission infusion into the New Frontiers - 4 proposals

- HEEET is an incentivized new technology for New Frontiers - 4
- Multiple mission proposals (NASA's NF-4) have availed themselves of this opportunity
- HEEET development is targeted to meet the NASA NF-4 mission requirements

From NNH16ZDA008J Announcement of Opportunity NF 4 Table 4. Infusion strategies of NASA-developed technologies.

6: Structural Testing

- Element, subcomponent, component and subsystem level testing are being performed to verify the structural adequacy of the ETU
  - Analytical work will be used to evaluate vehicles > 1-meter diameter
- Component Test Objectives:
  - Verify seam structural performance on a large scale with anticipated ETU representative stress levels
  - Verify entry stresses in seams under relevant thermal environments
- Subsystem Testing: ETU testing will verify the performance of the HEEET design for the given thickness under all mission loading events except acoustic environments and entry

7: Recent Accomplishments

1. Manufacturing
   - Weaving scaled up to 25-in width @ 2-in thickness
   - Successfully formed & infused all tiles to support ETU build
   - ETU tile machining in process

2. Seams
   - Completed seam arcing test @ AEDC facility (downselected integration approach used for coupon fabrication)
   - Completed LHMEI 4pt Bend testing
   - Matured Seam/Tile integration approach

3. ETU: composite carrier structures fabricated

4. HEEET Independent Reviews (Reviewers: APL, Goddard, JPL, JSC, KSC, LaRC and UC Boulder)
   - ETU system requirements review (Sep 2014)
   - Design review (February 2015)
   - Thermal test plan review (June 2015)
   - Structural test plan review (February 2016)
   - Manufacturing and Integration review (March 2016)
   - Failure modes and margins review (Oct 2016)
   - ETU Manufacturing, Schedule and Future Work Review (Feb 2017)

8: Summary

- Woven TPS is a game-changing approach to designing, manufacturing, and integrating a TPS for extreme entry environments by tailoring the material (layer thicknesses) for a specific mission
- A comprehensive set of requirements have been developed which is guiding testing/analysis required for verification
- Given constraints on weaving technology a heat shield manufactured from the 3D Woven Material will be assembled from a series of panels, which results in seams between the panels
- Seam design needs to meet both structural and aerothermal requirements
- Down-selected use of Expanding Softened HEEET (ESH) as a gap filler in the seam design
- Seam approach has demonstrated excellent performance in the arcer t > (5000 W/cm² heat flux and 5 atmospheres of stagnation pressure)
- Project is currently on target to mature HEEET to TRL 6 in support of next New Frontiers for which it is incentivized

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