1. HEEET Background/ NF Proposal Team Interaction

- **HEEET** is a game changing core-technology that is being designed with:
  - Broad mission applicability and long-term sustainability
  - Substantial engagement with TPS community
  - HEEET goal is to develop a woven TPS technology to TRL 6 by the end of Fiscal year 2017
  - HEEET leverages a mature weaving technology that has evolved from a well-established textile industry
  - Dual-layer design allows some tailor-ability of TPS for mass efficiency across a wide range of entry environments

2. Architecture and Engineering Testing Unit (ETU) Manufacturing Plan

- HEEET project has prioritized a dual layer TPS architecture for maturation - A layer-to-layer weave is utilized, which mechanically interlocks the different layers together in the thru-the-thickness direction
  - High density all carbon surface layer developed to manage reentry
  - Lower density layer is a blended yarn to manage heat load
  - Woven architecture is then infused with an ablative resin

3. Thermo / Arcjet Test Plan

- The HEEET thermal / aerothermal test campaign spans four facilities and at least twelve test conditions
  - Test ranges:
    - Heat Flux W/m²
    - Pressure atm
    - Shear (Pa)

4. 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

5. TPS Sizing for Saturn

- **Saturation point analysis**
  - 200 kg, 1-meter diameter, 45-deg sphericone entry vehicle with a nose radius of 25 cm
  - Inertial entry velocities of 36 and 38 km/s
  - Entry flight path angles of -8, -12, -16, -20 and -24 deg
  - Equatorial entry in the eastern direction

6. Recent Accomplishments

1. Manufacturing
   - 1) FMJ under contract for Forming/Infusion for MDU
   - 2) FMJ completed machining study on Nosecap Pathfinder
2. Seams
   - 1) Completed seam arcjet testing @ >5000 W/m² and 5 atm
   - 2) Completed shakedown test on LMHEE 4pt Bend testing
   - 3) Maturing Seam/Tile integration approach
3. MDU/ETU: composite carrier structure is in fabrication
4. HEEET Independent Reviews (Revisions: AP, Goddard & JPL)
   - 1) ETU system requirements review (Sep 2014)
   - 2) Design review (February 2015)
   - 3) Thermal test plan review (June 2015)
   - 4) Structural test plan review (February 2016)

7. 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/an 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
  - Baseline use of Softened HEEET (SH) as a gap filler in the seam design
  - Seam approach has demonstrated excellent performance in the arcjet at >5000 W/m² and 5 atm
    - Requires thin adhesive bond line between accretion sites and gap filler
  - Project is currently on target to mature HEEET to TRL 6 in support of next New Frontiers

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**HEEET Project Schedule**

**Recent New Frontiers**

- Community Announcement of Opportunities states:
  - NASA is also considering providing an increase to the PMMC core for investigations utilizing the Heat Shield for Extreme Environment Technology (HEEET), a woven Thermal Protection System

**Interaction with NF-4 Proposal Teams**

- Provide in-depth briefing on HEEET technology development
  - Particular focus on core-technology TPS integration and analysis required for specific mission design
  - Conduct a Workshop targeted towards NF-4 Proposal teams planning to provide an ablation HEEET
  - HEEET Team anticipates participation in critical reviews to assess HEEET infusion and gap
  - HEEET Team anticipates reviewing proposal implementation approach of HEEET and to provide a credibility assessment report
  - HEEET Team participates is limited to HEEET technology, and not to EDL in general

**Proposal Team Responsibilities**

- Entry interface, geometries and testing conditions have to trace back to the mission requirements, loads and environments to the extent possible within ground facilities
  - Entry structural loads (pressure and deceleration loads)
  - Thermal environments (hot soak and cold soak)
  - Shock loads
  - Launch loads

**Guidance on HEEET specific implementation tasks (> TRL 6)**

- Risk/Challenge related to implementation of HEEET for specific proposal
  - Review/Review cost, schedule and technical aspects of HEEET implementation and provide a written report
  - Engineering Science instrumentation
  - Proposal writing related to HEEET

**Aero thermal constraints, TPS thickness constraints, TPS Sizing**

- Constraints on trajectory based on manufacturing implementation
  - HEEET surface roughness estimates to be used by proposal teams to constrain roughness heating augmentation
  - Test plans will perform limited testing for design transition
  - Guidance on margins policy for HEEET

**Center Structure Guideline**

- Seam load limit, Radius of curvature, Interface with payload, etc
  - Guidance on estimating implementation cost and schedules
  - HEEET Team will provide cost estimates based on the estimated design, and guidance on generating a HEEET implementation schedule

**Guidance on HEEET specific implementation tools (> TRL 4)**

- Review of HEEET/ETU/MDU forming/infusion strategies

**HEEET implementation credibility review**

- Review/Recall cost, schedule and technical aspects of HEEET implementation and provide a written report

**Engineering Science instrumentation**

- Proposal writing related to ground based instrumentation
  - This is outside the scope of HEEET development