1. HEET Background/ NF Proposal Team Interaction

- **HEET** is a game changing core-technology that is being designed with:
  - Broad mission applicability and long term sustainability
  - Substantial engagement with TPS community
  - HEET goal is to develop a woven TPS technology to TRL 6
  - By the end of fiscal year 2021
  - HEET leverages a mature weaving technology that has evolved from a well-established textile industry
  - Dual-layer design allows some tailoring ability of TPS for mass efficiency across a wide range of entry environments

Interaction with NF-4 Proposal Teams

- **HEET** provides in-depth briefing on HEET technology development
  - Focus on current status/TPS integration and analysis required for specific mission design
  - Conduct a Workshop targeted towards NF-4 Proposal teams planning to provide an overview of HEET
  - HEET Team anticipates participation in critical reviews to assess HEET infusion and gap
  - HEET Team anticipates reviewing proposal implementation approach of HEET to and provide a credibility assessment report
  - HEET Team participation is limited to HEET technology, and not to EDL in general

**HEET Project Schedule**

- **HEET** 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 recession
  - Lower density layer is a blended yarn to manage heat load
  - Woven architecture is then infused with an ablative resin

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

- HEET Project Schedule

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- **ETU** geometries, interfaces 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

3. Thermal /Arcjet Test Plan

- **HEET** thermal / aerothermal test campaign spans four facilities and at least twelve test conditions

**Test objectives**

- Test acreage and seams to guide HEET architecture down-select and requirements verification
- Demonstrate applicability of chosen design under high heat flux, pressure and shear for relevant Venus and/or Saturn mission conditions (look for failure modes)
- Develop a thermal response model for future proposals to use for TPS sizing and analysis

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  - Shock loads
  - Launch loads

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
- **Component Test Objectives**
  - Verify 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 HEET design for the given thickness under all mission loading events except acoustic environments and entry

5. TPS Sizing for Saturn

- **Stagnation point analysis**
  - 200 kg, 1-meter diameter, 45-deg spherocone 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

- **Areal mass of the 2-layer HEET TPS** is ~5% of the mass of fully dense carbon phenolic
  - Analysis holds true for a broad range of atmospheric entry vehicles
- **Sizing results** are for zero margin utilizing preliminary thermal response model

6. Recent Accomplishments

1) **Manufacturing**
   - 1) FMI under contract for Forming/Infiltration for MDU
   - 2) FMI completed machining study on Noscap Pathfinder
2) **Seams**
   - 1) Completed seam arcjet testing @ ~3000 W/cm² and 5 atm
   - 2) Completed shakedown test on LMMEl 4pt bending test
   - 3) Maturing Seam/Tile integration approach
3) **MDU/ETU**: composite carrier structure is in fabrication
4) **HEET Independent Reviews**
   - Reviewers: AIP, Goddard & JPL
5) **ETU** system requirements review (Sep 2014)
6) **Design review** (February 2015)
7) **Thermal test plan review (June 2015)**
8) **Structural test plan review (February 2016)**

7. Summary

- **Woven TPS** is a game-changing approach to design, 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
  - Baseline used of Softened HEET (SH) as a gap filler in the seam design
  - Seam approach has demonstrated excellent performance in the test at -500 W/cm² and 5 atm
  - Requires thin adhesive bond line between acreage sites and gap filler
  - Project is currently on target to mature HEET to TRL 6 in support of next New Frontiers