Progress Towards Providing
Heat-shield for Extreme Entry Environment Technology (HEEET)
for Venus and Other New Frontiers Missions

Ethiraj Venkatapathy
TPSM Project Manager

Don Ellerby
HEEET Project Lead

Peter Gage
HEEET Lead System Engineer

Presented at the VEXAG-15
Applied Physics Laboratory
Laurel, Maryland
November 15, 2017
Heatshield for Extreme Entry Environment Technology
Manufacturing and Integrated System

- 3-D, integrally woven, dual layer that is robust, mass efficient and capable of withstanding extreme entry environment
- Heat-shield system requires tiled approach with seams.
HEEET Manufacturing Development: 24” Weaving

➢ Weaving: BRM
  ◆ 24” loom set-up complete
  ◆ BRM hosted event demonstrating 24” loom
    ▪ Attendees included STMD AA and ARC Center Director
  ◆ Currently weaving
HEEET ETU Manufacturing: Acreage and Seam Tiles Fabrication

- **ETU Tile/Gap Filler Manufacturing: FMI**
  - 22 acreage tiles completed:
    - Forming/infusion
    - Machining
    - IML surface densification (ARC)
  - 30+ Gap Fillers completed: FMI/ARC
    - Tech transfer of Gap Filler manufacturing to FMI completed

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- **Fiber Manufacturing** (Raw Materials)
- **Carbon Fiber** (Recession Layer)
- **Stretch Break / Carding Blending**
- **Blended Yarn** (Insulation Layer)
  - Weaving
  - Cutting
  - Forming
  - Tile Infusion
  - Gap Filler Infusion
  - Gap Filler Softening Process
  - Machining
  - HEEET TPS Assembly & Integration

- **Radial Gap Fillers**

- **Nose Cap**
- **Inner Tile**
- **Outer Tile**
ETU: Acreage Tile Install Completed

Acreage Tiles on Carrier
Before Vac Bag/Cure

Vac Bag Prior to Cure

After Cure

Good OML Match Between Tiles
No steps in tile to tile height
ETU: Radial ESH Install Completed

Routing Radial Channels

Laser Scan Inspection

Radial Routing Completed

After Cure
Critical Features
Thermal Testing at AEDC

- IHF 3” Nozzle
- HEEET Acreage Testing
- IHF 3” Nozzle 1” IsoQ
- HEEET Seam/Adhesive Testing
- IHF 6” Nozzle 2” Flat Face

- LHMEI
- AEDC H3
- AEDC (Wedge)
### HEEET Development Schedule

#### KEY MILESTONES (New Frontiers)

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
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<tr>
<td>NF Proposal Submission</td>
<td>4/28</td>
</tr>
<tr>
<td>Phase A Concept Study Initiated</td>
<td>12/29</td>
</tr>
<tr>
<td>Project Complete</td>
<td>9/28</td>
</tr>
<tr>
<td>Phase A Concept Study Reports Due</td>
<td>12/31</td>
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#### Design Data Book

- May 2017: NF Proposal Submission
- Aug 2017: Phase A Concept Study Initiated
- Nov 2017: Phase A Concept Study Reports Due

#### 24" Weave Task

- Build 4pt Bends Rnd 1: 2017-01-01
- Test Group 1: 2017-03-01
- LHMEI Rd 1 Post Analysis: 2017-05-01

#### 4-Point Bends

- Test Group 2: 2017-04-01
- Build 4pt Bends Rnd 2: 2017-05-01
- Test Reg 4pt Bends Rd 1: 2017-06-01
- LHMEI Rd 2 Post Analysis: 2017-07-01

#### ETU Build/Test

- ETU ESH (FMI): 2017-08-01
- ETU Build: 2017-09-01
- ETU Build Complete: 2017-10-01
- ETU Test: 2017-11-01
- Post-ETU Test Analysis: 2017-12-01

#### AEDC Test Run 1

- Material Deliveries
- Panel Processing
- ESH Processing
- Test Article Int.
- First Test Run @AEDC
- AEDC Test Run 1 Analysis

#### AEDC Test Run 2

- Material Deliveries
- Panel Processing
- ESH Processing
- Test Article Integration
- Second Test Run @AEDC
- AEDC Test Run 2 Analysis

#### IHF (ARC)

- Material Deliveries
- Panel Processing
- ESH Processing
- Test Article Integration
- IHF Test Run @ARC
- IHF Test Run Analysis
The AO states that the risk of developing 3D woven TPS on time will not impact proposal evaluation (Table 4. Infusion strategies of NASA-developed technologies). However, it is unclear what risk NASA is shouldering to ensure readiness of HEEET. What is NASA’s scope of TPS (thermal protection system) in this context and is there a specific TRL that applies? Please clarify that NASA will carry the risk through development of a mission representative engineering model or prototype heat shield tested in a relevant environment (to TRL 6) as implied in the Technology Workshop material?

- NASA is committed to delivering the HEEET TPS system at TRL 6, meaning that mission-representative prototype hardware will be built and tested in relevant environments in a timely manner.
  - TRL 6 for HEEET can be achieved with meaningful assemblies involving full-scale components, without requiring construction of a complete heatshield at scale for the selected mission.
- For any proposal selected for a Phase A study, HEEET project personnel will be available to work with the proposal team on a TRL gap analysis between the generic ETU hardware built by the HEEET development project and the specific design for the mission.
- Where necessary, NASA will build, test and demonstrate HEEET elements at fully relevant scale to close any identified TRL gaps in a timely manner.
HEEET Component and System TRL Assessment

- **High heat flux arc jet tests** (9/2016)
- **Integration tests complete** (2/2017)
- **ETU Build Complete** (2/2018)
- **Integration/Manufacturing Processes Validated by Testing** (7/2018)
- **Design Data Book Complete** (9/2018)
- **ETU Testing Complete** (7/2018)
- **Integration/Manufacturing Processes Updated with ETU Lessons Learned** (3/2018)
- **4pt Bend/LHMEI Testing (Features) Complete** (7/2018)
- **ESH Gap Filler Feature Arcjet Testing** (6/2018)
- **Thermal response model update** (5/2017)
- **ETU Testing Complete** (7/2018)
- **LHMEI 4pt Bend Testing (Features) Complete** (7/2018)
- **HREEET Structural Performance**
  - **LHMEI 4pt Bend Shakedown Tests** (12/2015)
  - **4pt Bend Testing Complete** (10/2017)
  - **4pt Bend/LHMEI Testing (Features) Complete** (7/2018)
  - **LHMEI 4pt Bend Testing (Basic Seam) Complete** (11/2017)
- **HEEET Manufacturing**
  - **Nose + tile ring integration demo** (12/2015)
  - **Draft mfg processes – 1st ring and nose** (8/2016)
- **HEEET Structural Performance**
  - **LHMEI 4pt Bend Shakedown Tests** (12/2015)
  - **4pt Bend Testing Complete** (10/2017)
  - **4pt Bend/LHMEI Testing (Features) Complete** (7/2018)
- **HEEET Acreage/Seam Thermal Performance**
  - **AEDC Shear/High P arcjet tests** (9/2016)
  - **Integration tests complete** (2/2017)
  - **Thermal response model update** (5/2017)
  - **Thermal response model update** (5/2017)
- **HEEET Design Databook**
  - **Thermal response model update** (5/2017)
  - **Thermal response model update** (5/2017)
- **HEEET Areal Mass**
  - **Thermal response model update** (5/2017)
  - **Thermal response model update** (5/2017)
Concluding Remarks

- HEEET Development is progressing well
  - Integration of 1m diameter engineering test unit is nearing completion
  - New Loom set-up is complete and weaving at 24” width
  - Significant testing will take place between Jan – July
    - Full scale Testing of ETU
      - Static Load testing,
      - Thermal-vac testing
      - Point-Load testing
    - AEDC arc jet testing for features
    - LHEML testing

- NF-4 Phase A proposals
  - HEEET Team plans to support the teams that have baselined HEEET

- Goal is to complete testing and analysis and deliver HEEET by FY’18 at TRL
HEEET Team

**NASA ARC:**
- Don Ellerby - Lead
- Dave Driver
- Jay Feldman
- Matt Gasch
- Milad Mahzari
- Alberto Makino
- Frank Milos
- Owen Nishioka
- Keith Peterson
- Mairead Stackpoole
- Raj Venkatapathy
- Mike Wilder
- Zion Young
- **Neerim Corp:**
  - Peter Gage (Lead SE)
- **AMA, Inc. (@ ARC):**
  - Tane Boghozian
  - Jose Chavez Garcia
  - Greg Gonzales
  - Grant Palmer
  - Dinesh Prabhu
  - Joseph Williams
- **Science and Technology Corp (@ ARC)**
  - Cole Kazemba
  - Steve White

**NASA LaRC:**
- Max Blesser
- Eric Burke
- Sarah Langston
- Carl Poteet
- Louis Simmons
- Scott Splinter
- **AMA, Inc. (@ LaRC)**
  - Will Johnston (@ LaRC)
  - Stewart Walker (@ LaRC)

**NASA JSC:**
- Mike Fowler
- **Jacobs Technology Inc. (@JSC)**
  - Charles Kellermann

**NASA ARC, AEDC, LaRC and LHMEL test facilities and their crew**

**Vendors:**
- Bally Ribbon Mills (BRM), PA
- Fiber Materials Inc. (FMI), Maine