Overview of Heat Shield for Extreme Entry Environment Technology (HEEET) Project

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Don Ellerby
Presenter

Dave Driver, Matt Gasch, Milad Mahzari, Frank Milos, Owen Nishioka, Keith Peterson, Mairead Stackpoole, Raj Venkatapathy, Zion Young
NASA Ames Research Center

Peter J. Gage
Neerim Corp
Moffett Field, CA

Tane Boghozian, Jose Chavez-Garcia, Greg Gonzales, Grant Palmer, Dinesh Prabhu, Joseph Williams
Analytical Mechanics Associates, Inc.
NASA Ames Research Center

Cole Kazemba
Science and Technology Corp.
NASA Ames Research Center

Alex Murphy
Millennium Engineering and Integration Co.
NASA Ames Research Center

Mike Fowler
NASA Johnson Space Center

Charles Kellermann
Jacobs Technology, Inc.
NASA Johnson Space Center

Sarah Langston, Carl Poteet, Scott Splinter
NASA Langley Research Center
Goal: Mature HEEET system to support NASA Science Mission Directorate robotic entry missions (TRL 6)
- Utilizes a novel material based on 3D weaving
- Target missions include Venus Lander and Saturn Probes
- Capable of withstanding extreme entry environments:
  - Peak Heat-Fluxes >5000 W/cm²; Peak Pressures >5 atm
- Scalable system from small probes (~1m scale) to large probes (~3m scale)
- Develop Integrated system, including seams
  - Culminates in testing 1m Engineering Test Unit (ETU)
    - Integrated system on flight relevant carrier structure
    - Proves out manufacturing and integration approaches
    - Used to validate structural models

Project is co-funded by NASA Space Technology (STMD) and Science Mission Directorates (SMD)
SMD offered HEEET as NASA-developed New Technology

- Discovery-2014, NF-4 (2016) and ESA M-5
  - AO guaranteed NASA will deliver HEEET at TRL 6, if mission selected.
    - Commitment to close gap between current status and TRL 6
- HEEET was enabling for several proposals
  - Four NF-4 proposals and one ESA M-5 proposal (HERA Saturn Probe mission).
  - All these proposed designs relied on HEEET performance
    - HEEET enables the high heat loads experienced by trajectories with peak entry decelerations loads of < 50 g’s
      - Permits sensitive instrumentation and ground-based dynamic verification of instrument robustness
    - Heatshield mass reduced by at least 40% relative to Carbon Phenolic
      - Additional mass available for payload
  - None of these missions were not selected by the New Frontiers program for further evaluation
- HEEET development will be completed in mid FY19 benefiting
  - Future small spacecraft missions to Venus,
  - Discovery, New Frontiers AOs, and
  - Flagship missions to Saturn, Uranus and Neptune
A primary project objective was to technology transfer as much of the manufacturing to industry to put in place the supply chain to support missions.

Success in tech transfer is demonstrated through build of the Engineering Test Unit.
The HEEET project has baselined a gap filler between tiles to perform two primary functions:

- Provide structural relief for all load cases by increasing compliance in the joint
- Provide an aerothermally robust joint, with adhesive widths $<0.010”$ and recession performance in family with acreage material

Seam:

- Gap Filler
  - Compliant version of acreage material
- Thin Adhesive (0.010 in)

Close Out Plugs

- Series of close out plugs are used at some gap filler to gap filler intersections
Seam Aerothermal and Structural Tests Critical for TRL Advancement

- T-Junction Radial to Circumferential
- Radial Downstream
- Radial Upstream
- Circumferential to Circumferential Closeout Plug

Recent AEDC Test Matrix

LaRC 4-pt Bend Flexure Testing

LHMEC 4pt Bend Testing

IHF 3” Nozzle

FLOW
Arcjet environments from Venus, Saturn and Earth entry concept studies

- AEDC wedge allows testing at mission relevant Hot Wall turbulent shears of ~4000 Pa
MDU and ETU Carrier Structure Proof tests to served as precursor to ETU testing and Static Mechanical testing

ETU tests planned for NASA Langley Research Center

MDU Carrier Structure Proof Test
ETU Carrier Structure Proof Test
Pre-Integration

Integrate TPS on Carrier Structure

Static Mechanical Test

Point Load Test

Thermal-Vacuum

Point Load Test

ETU with Rigid Plate Closeout (Inverted)

LARC 6x6 Thermal-Vacuum Chamber
HEEET Project Status

- **ETU testing to be completed in August 2018**
  - ETU instrumentation to be completed early June 2018
    - 80 strain gages and 24 thermocouples
  - ETU testing starts mid-June 2018

- **Two remaining arcjet test series planned in FY18/FY19**
  - Arnold Engineering Development Center (AEDC)
    - Combined heat flux, pressure and high shear environments
    - Completed 1st round of testing on 5/18/2018, 2nd round planned for FY19
  - NASA Ames Interaction Heating Facility (IHF) 3” Nozzle (June 2018)
    - High heat flux and pressure

- **4pt Bend Testing at NASA Langley (December 2018)**
- **4pt Bend Testing at LHMEL (October 2018)**
- **Pyroshock testing (July 2018)**
- **Final documentation in Design Data Book (March 2019)**
Backup
Element, subcomponent, component and subsystem level testing are being performed to verify the structural adequacy of the ETU

- ETU design assumes a 1m Saturn Probe mission
- Analytical work will be used to evaluate vehicles > 1-meter diameter (Venus)

Element Level Testing:

- Recession and Insulating Layers
- -175F – RT – 350+F
- Warp, Fill, Thru The Thickness (TTT)
- Tension, Compression and Shear

Sub-Component Level Testing:

- Seam Tension Testing
- TTT Tension Test: TPS Bonded to Carrier
- 4pt Bend Testing (28 tests)
  - Acreage, seams
  - -175F – RT – 350+F
- LHMEEL 4pt Bend Testing (17 tests)
  - Seam structural performance during entry phase

Pyroshock test will be performed at the coupon level

ETU Testing
Flexural testing in the LHMEL facility provides analytical model validation and capability demonstration at elevated temperatures.

Round 1 testing completed FY17

Round 2 testing in Oct 2018
  • 17 test articles
Comprehensive set of arcjet testing is performed to:

- Establish system capability: ~5000 W/cm² and 5 atm
- Test for failure modes within the system
  - Adhesive bond between Gap Filler and Acreage Tiles is weak link
- Provide data needed to develop and verify material response models and margin policies
  - Utilized to design TPS thicknesses
- 6 test campaigns completed, 2 more planned