Overview of Heatshield for Extreme Entry Environment Technology (HEEET) Project

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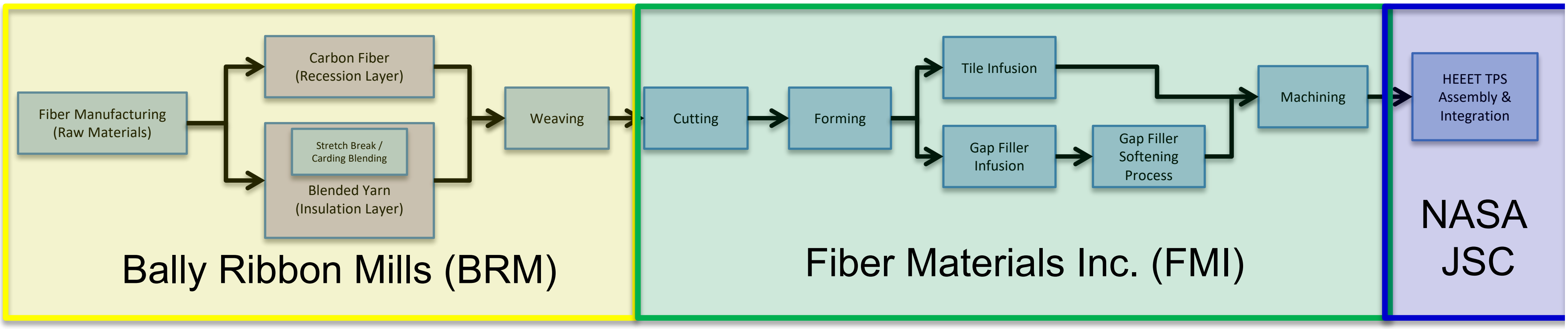
Heatshield for Extreme Entry Environment Technology (HEEET) Project

- **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/cm^2; 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)**

HEEET Mission Infusion

- **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

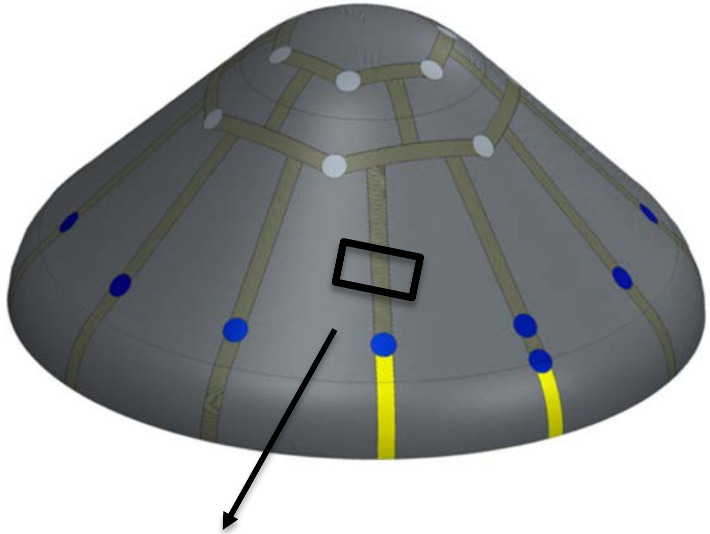
HEEET Manufacturing

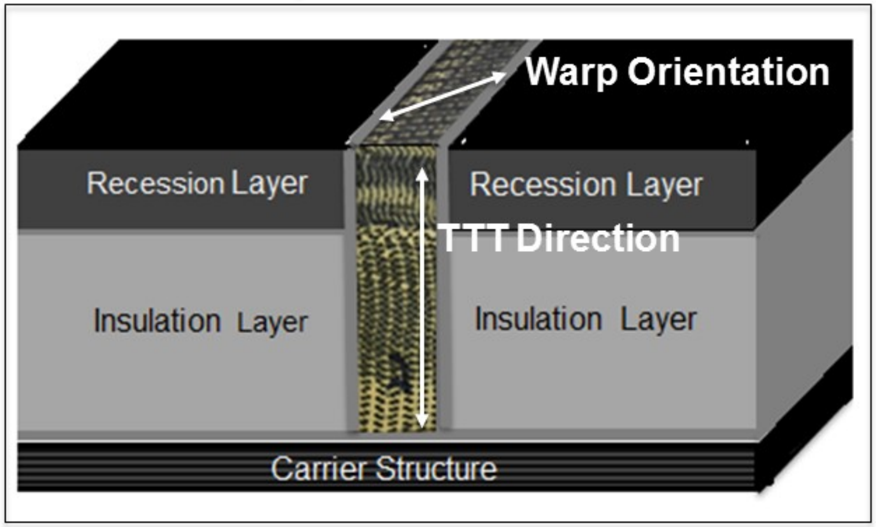


- A primary project objective was to technology transfer as much of the manufacturing to industry to put in place the supply chain to support missions
- Success in tech transfer is demonstrated through build of the Engineering Test Unit

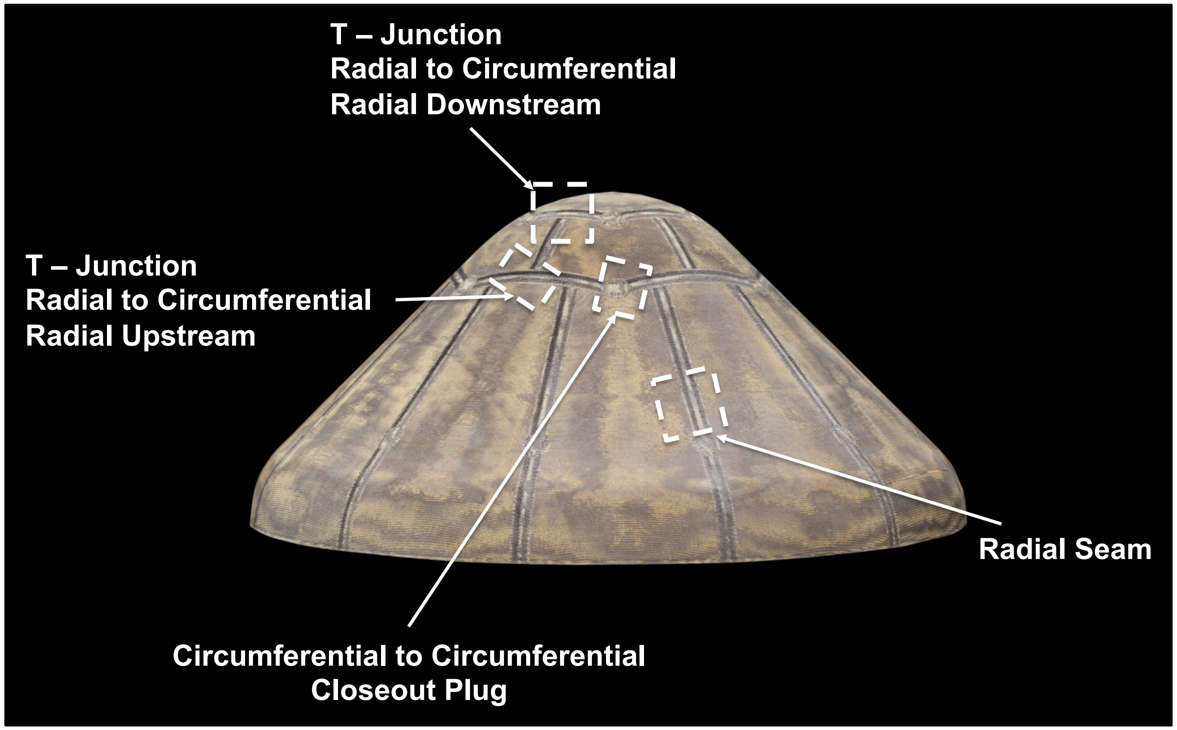
Seams in the HEEET Architecture

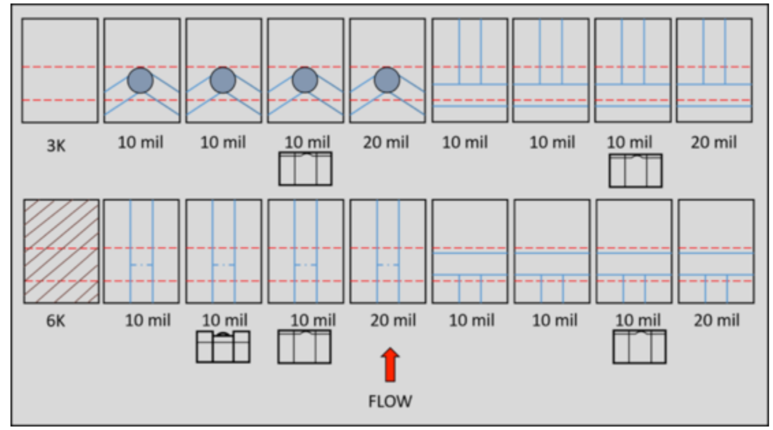
- **The HEEET project has baselined a gap filler between tiles to perform two primary functions:**
  - Provide structural relief for all load cases by increasing compliance in the joint
  - Provide an aerothermally robust joint, with adhesive widths <0.010” and recession performance in family with acreage 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



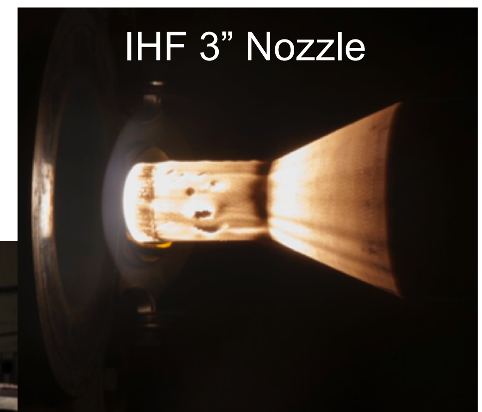


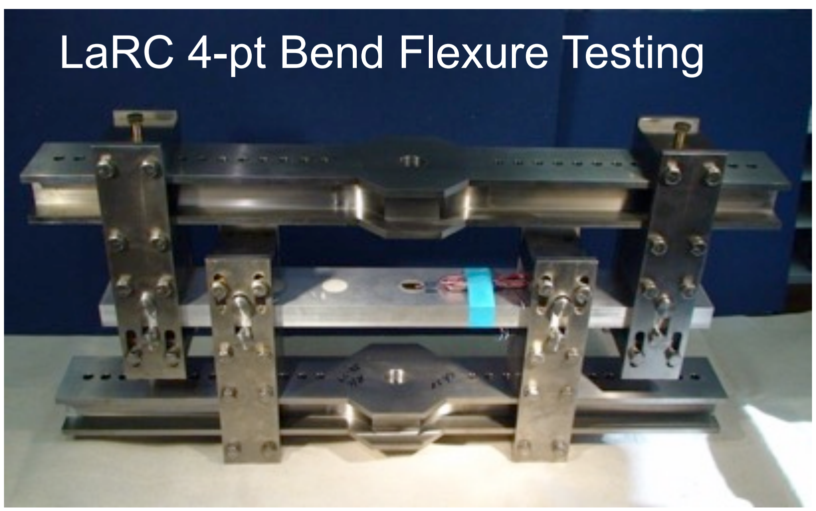
Seam Aerothermal and Structural Tests Critical for TRL Advancement

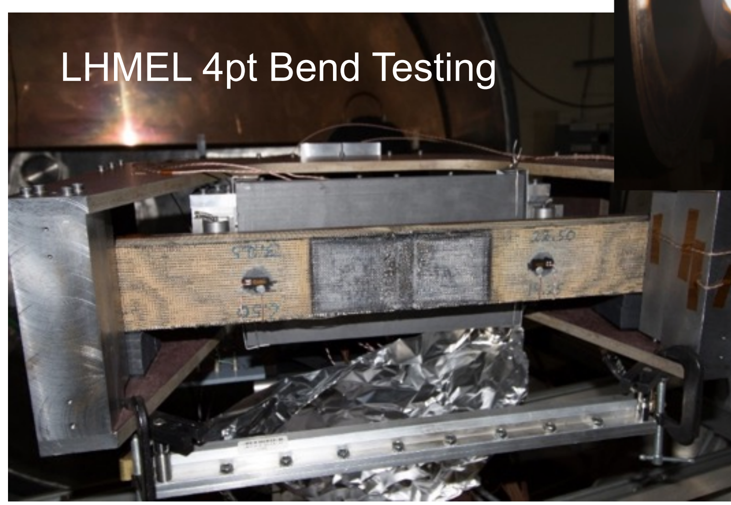




Recent AEDC Test Matrix

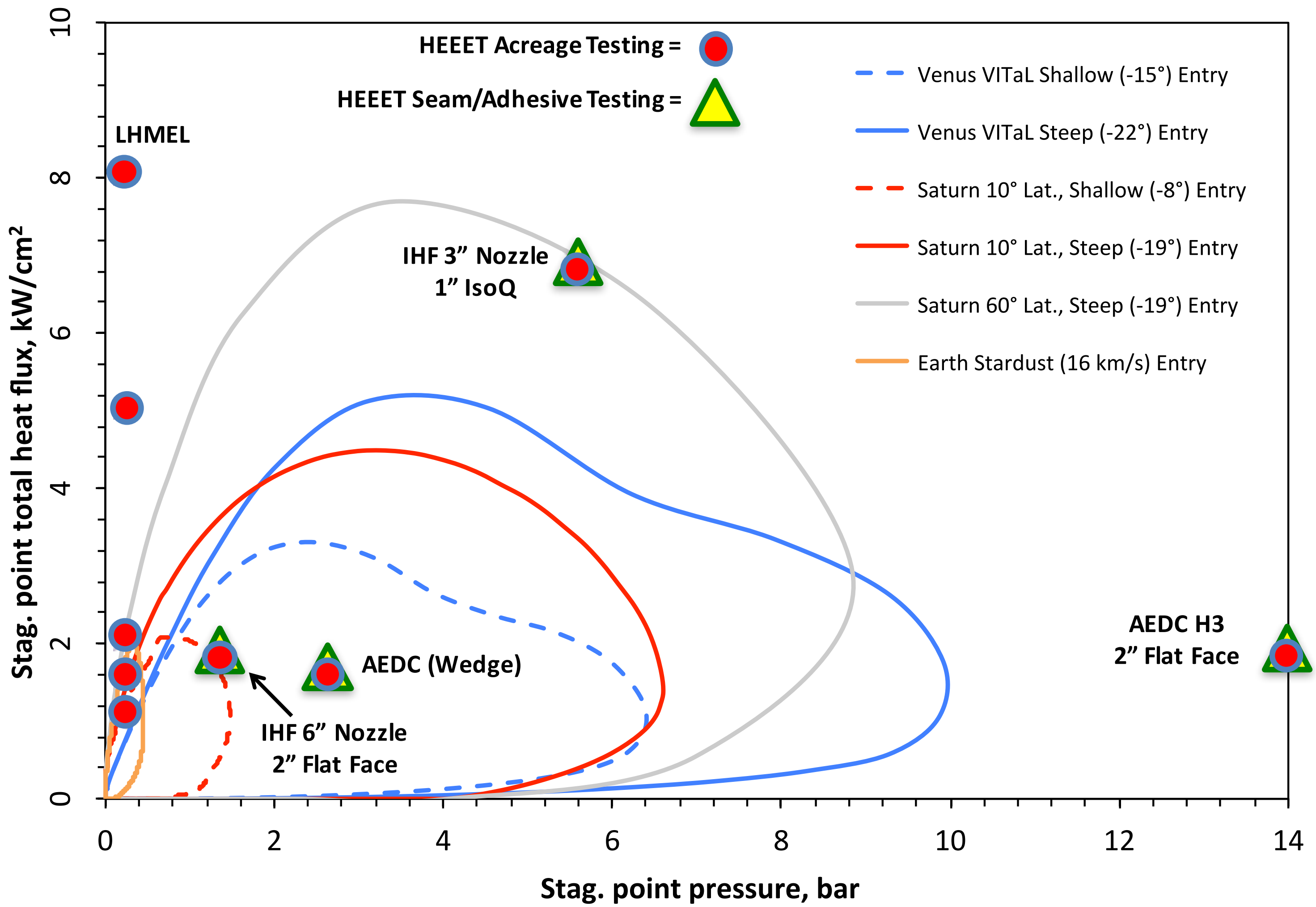






HEEET Aerothermal Testing

➢ **Arcjet environments from Venus, Saturn and Earth entry concept studies**



◆ **AEDC wedge allows testing at mission relevant Hot Wall turbulent shears of ~4000 Pa**

Engineering Test Unit Testing Overview

- **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

NDE (CT)

⇩

Static Mechanical Test

⇩

Point Load Test

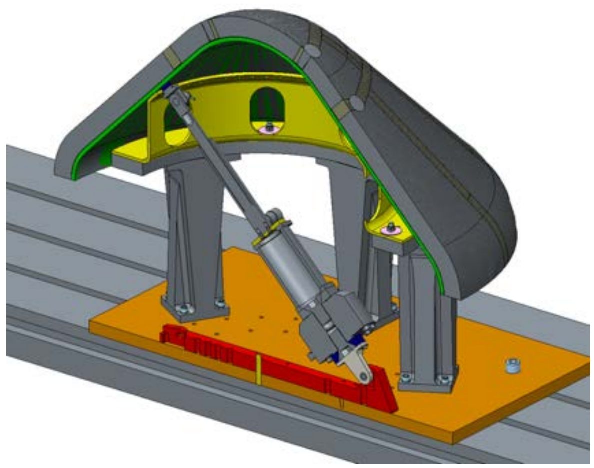
⇩

Thermal-Vacuum

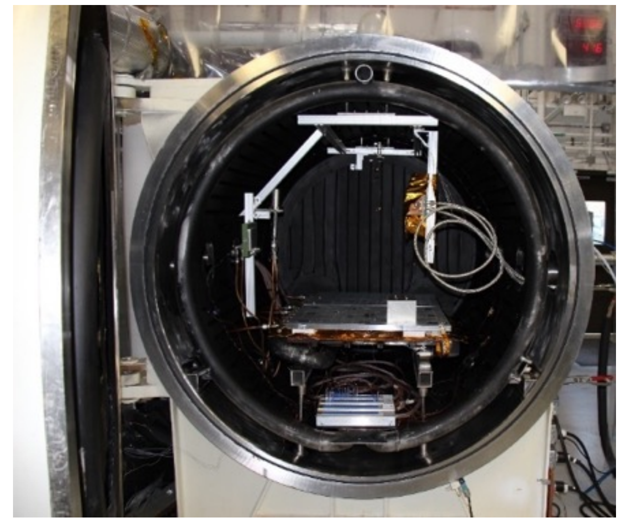
⇩

Point Load Test

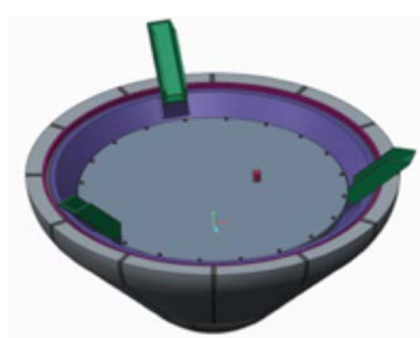
NDE (CT)



Point Load Test Setup



LARC 6x6 Thermal-Vacuum Chamber



ETU with Rigid Plate Closeout (Inverted)

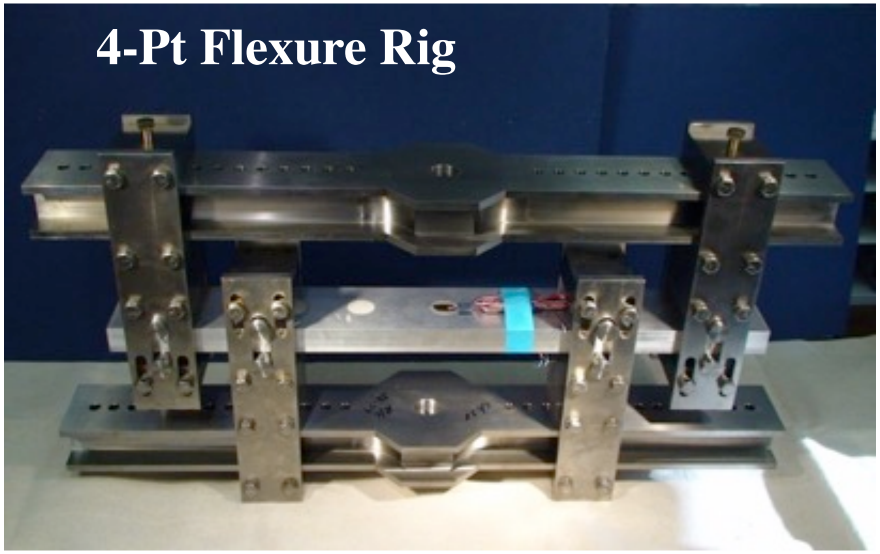
HEEET Project Status

- **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

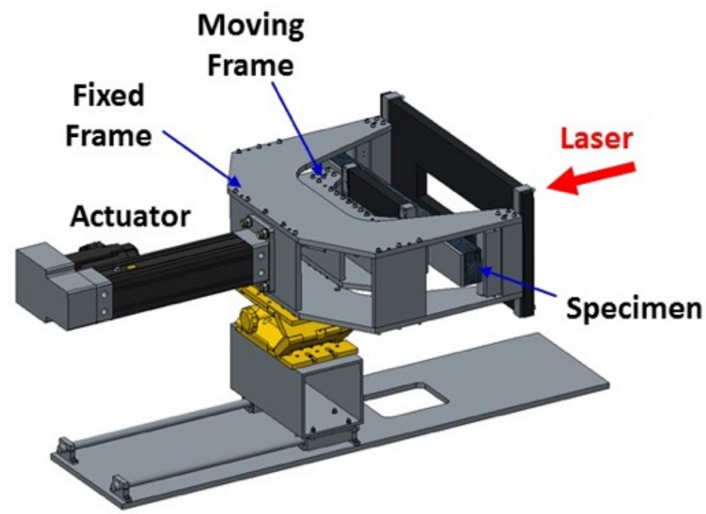
Structural Testing

- **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
  - LHMEL 4pt Bend Testing (17 tests)
    - Seam structural performance during entry phase
  - Pyroshock test will be performed at the coupon level
- **ETU Testing**

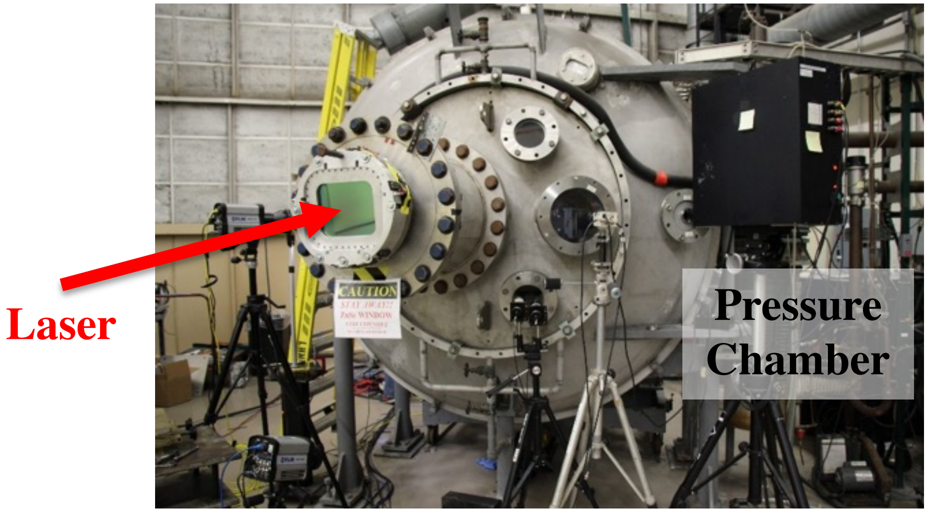


LHMEL Testing Overview

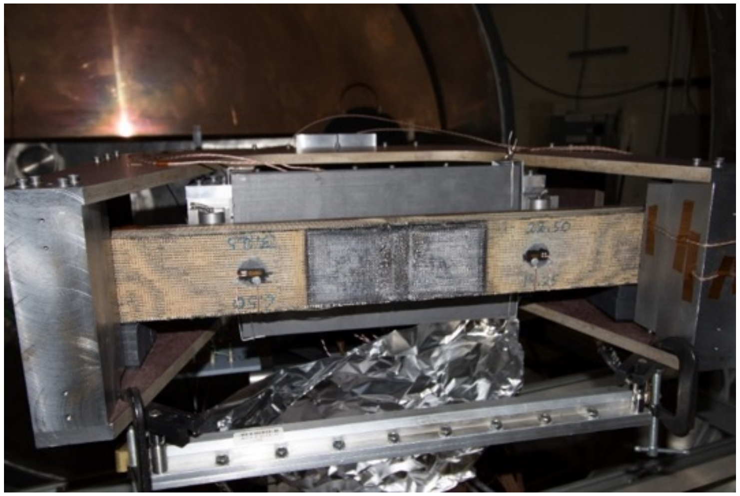
- Flexural testing in the LHMEL facility provides analytical model validation and capability demonstration at elevated temperatures.
- Round 1 testing completed FY17
- Round 2 testing in Oct 2018
  - 17 test articles



Load Application Apparatus



LHMEL II Facility



Thick Structural Specimen Post-Test

HEEET Aerothermal Testing

- **Comprehensive set of arcjet testing is performed to:**
  - Establish system capability: ~5000 W/cm^2 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