# Thermal Testing of the Heatshield for Extreme Entry Environment Technology (HEEET) TPS


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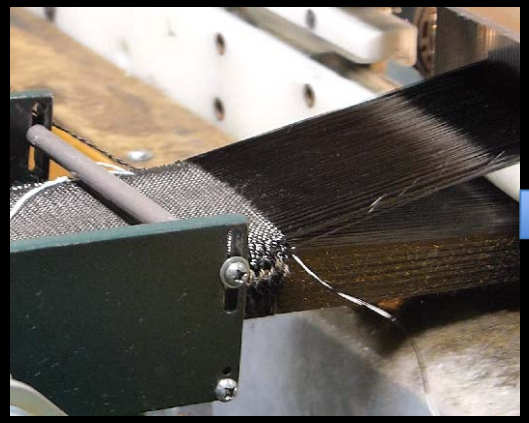
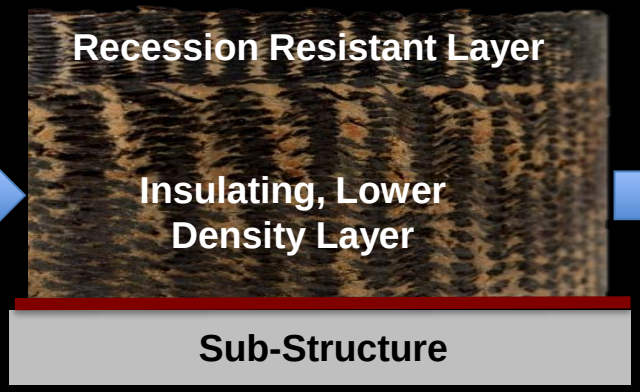
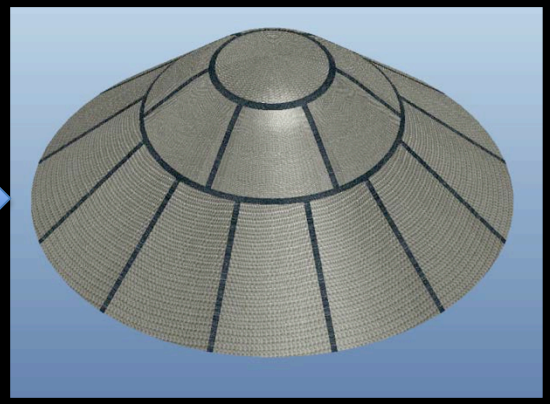
# Heatshield for Extreme Entry Environment Technology (A product of 3-D Woven TPS Effort)

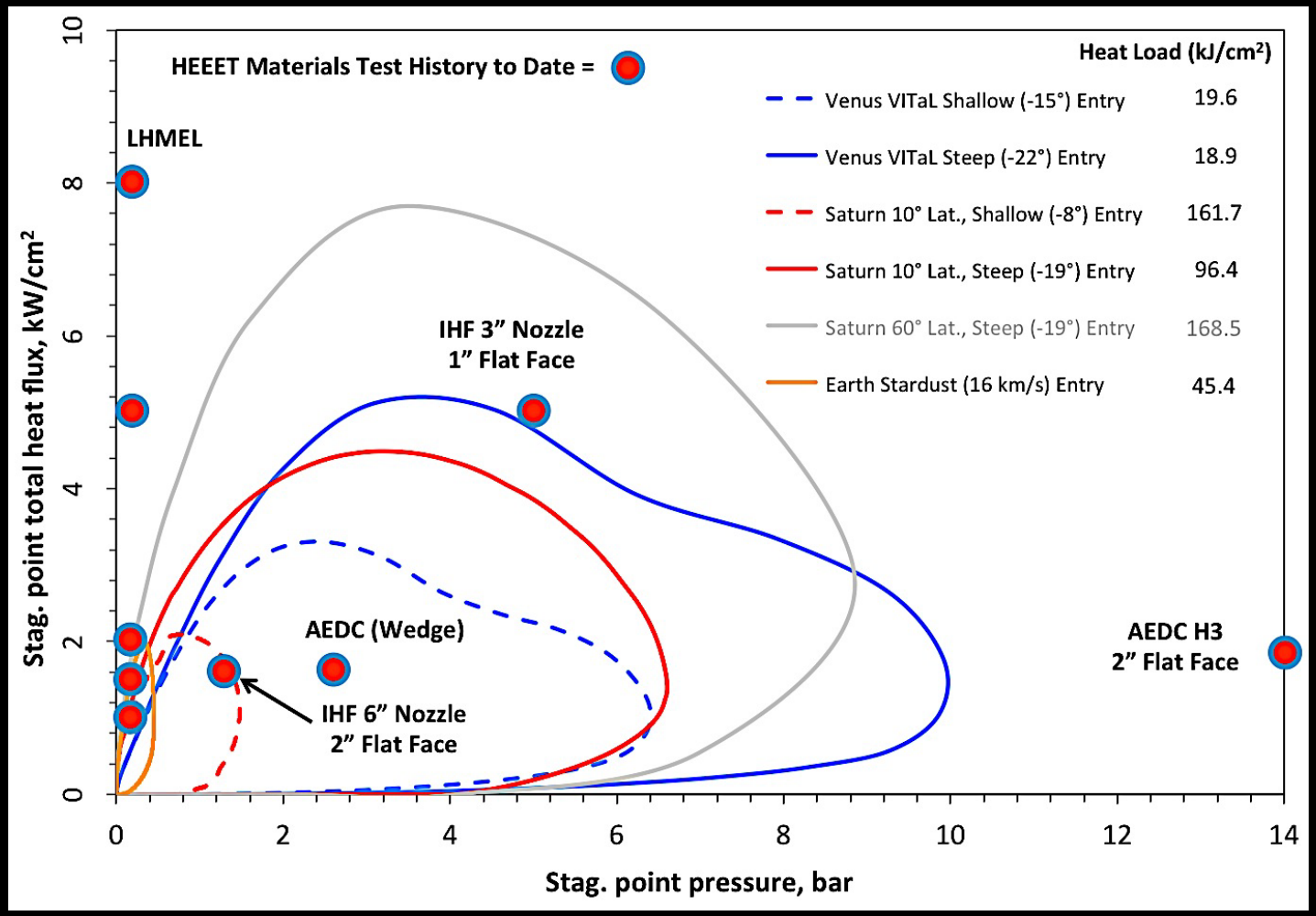
- HEEET development is targeted towards:
  - In-situ Venus, Saturn Probe or higher speed Sample Return missions
    - Entry environment are extreme
  - HEEET is currently being designed to be efficient and robust.
- HEEET is in the second year of the four year development
- HEEET is funded by Space Technology and Science Mission Directorates
  - STMD is committed to delivery of HEEET at TRL 6
  - SMD is committed to mission infusion
  - HEEET is offered as GFE and incentivized for Discovery 2014





# Ground Testing Capabilities vs Mission Needs




Material behavior depends on shear and gas-composition in addition to heat-flux and pressure .
For missions of interest Peak shear can range from (1500 pa – 4000 pa) & (CO2, AIR, H2/HE)
IHF and AEDC Testing is in Air. Testing at LHEML is purely Laser heating.

# Arcjet/Thermal Test Objectives

## Arcjet Testing:

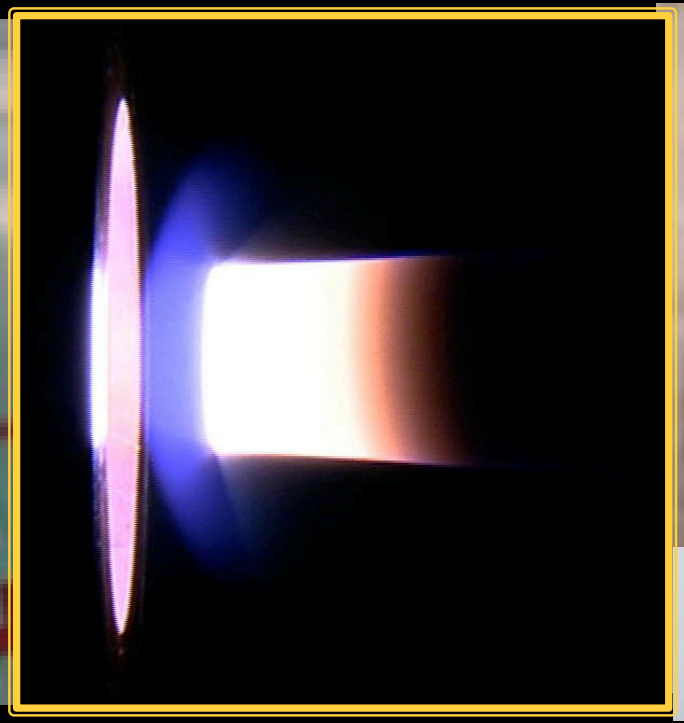
- **Demonstrate design is robust under high heat flux, pressure and shear for relevant Venus, Saturn or Sample return missions**
- **Obtain data for thermal response model - flight hardware design and sizing**
- **Test campaign spans four facilities and twelve test conditions.**
  - LHEML, IHF, AEDC and AHF and 12 different conditions

| Facility | Nozzle | Sample Size | Sample Shape | CW Heat Flux ($W/cm^2$) | Stag Pres (atm) | Shear (Pa) | Enthalpy (MJ/kg) | Test Gas |
|---|---|---|---|---|---|---|---|---|
| AHF | 12-inch | 4-inch | IsoQ & Flat Face | 100<br>250 | 0.1<br>0.3 | 0<br>0 | 21<br>26 | N2<br>N2 |
| IHF | 3-inch | 1-inch | Flat Face | 5000 | 5.0 | 0 | 28 | Air |
| IHF | 13-inch | 4-inch | IsoQ & Flat Face | 400<br>800 | 0.3<br>0.3 | 0<br>0 | 17<br>29 | Air |
| IHF | 6-inch | 2-inch | Flat Face | 1850 | 1.3 | 0 | 25 | Air |
| LHMEL | L2 | 1 x 1-inch<br>1 x 1-inch<br>2 x 2-inch<br>2 x 2-inch | Flat Face | 8000<br>5000<br>2000<br>1000 | 0<br>0<br>0<br>0 | 0<br>0<br>0<br>0 | 100 (kW) | Air |
| AEDC | H3 | 4 x 5-inch | Wedge | 1650 | 2.6 | 4000 | 7 | Air |
| AEDC | H3 | 2-inch | Flat Face | 2000 | 14.0 | 0 | 7 | Air |

# IHF 3-inch Nozzle Stagnation
## ~5000 W/cm$^2$, 5 atm, Dwell 5 sec.

- Model edge condition was more severe
  - ~6000 W/cm$^2$ and ~7000 Pa shear
- High shear exposed insulating layer at edges
- No unusual ablation

Pre-Test

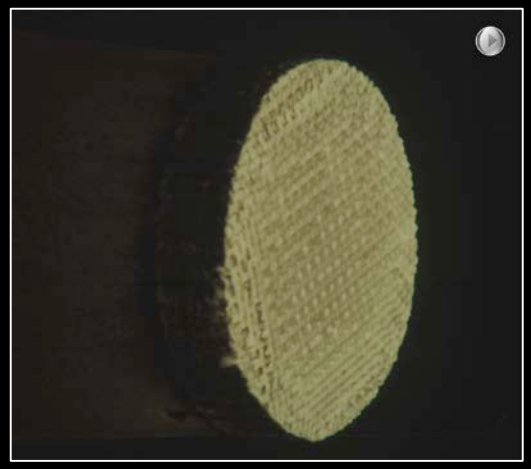


Post-Test

# AEDC Stagnation – Dwell 2.2 sec.
# Stag. Heat-Flux ~1850 W/cm$^2$ @ 14 atm

Pre-Test

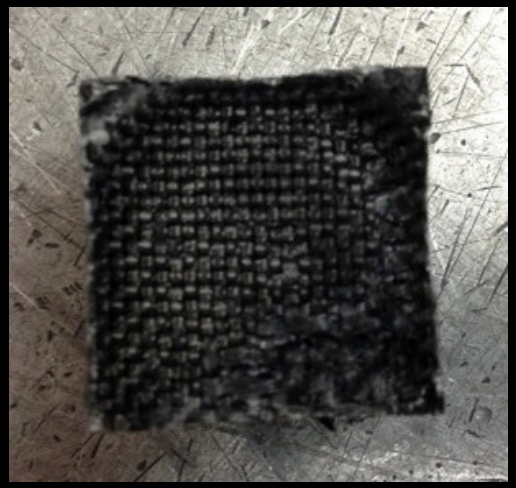
Post-Test

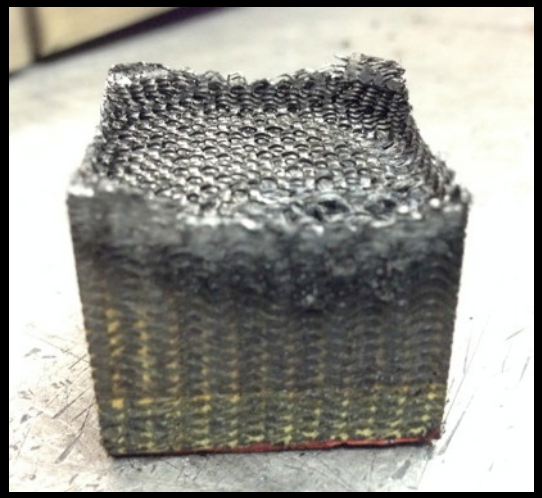


The recession was uniform. Post test picture captures some tows (frayed and charred fibers visible). This most likely happened when exiting the flow when there was significant shear forces on the model. Video of the model in the flow does not show any tows sticking up or frayed.

# LHMEL Post-Test: 8000 W/cm$^2$, 5 sec.

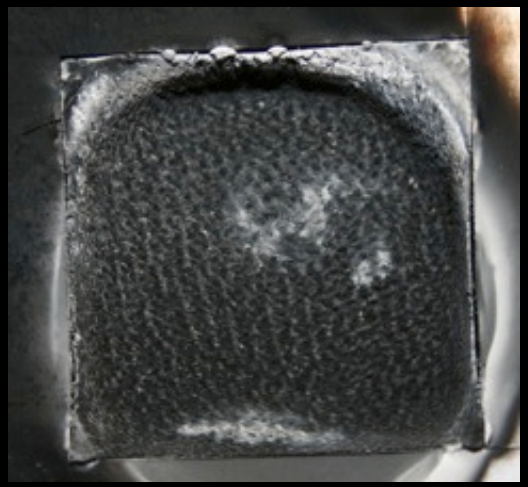
HEEET Acreage

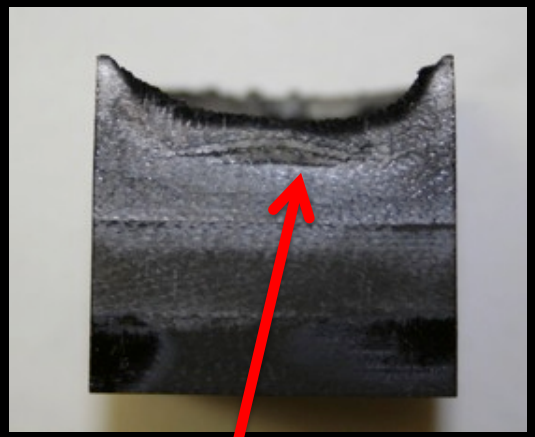




No surface spallation, delamination or cracks

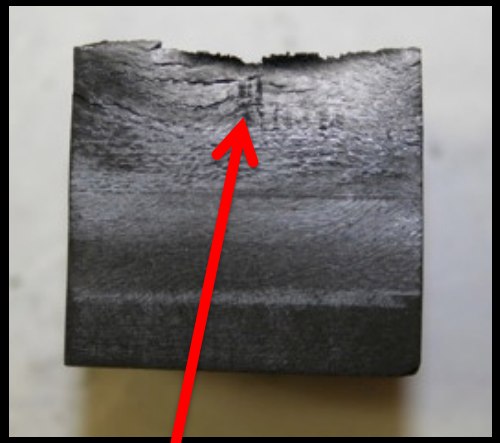
Tape Wrap CP





Ply lift and sub-surface cracking

Chop Molded CP

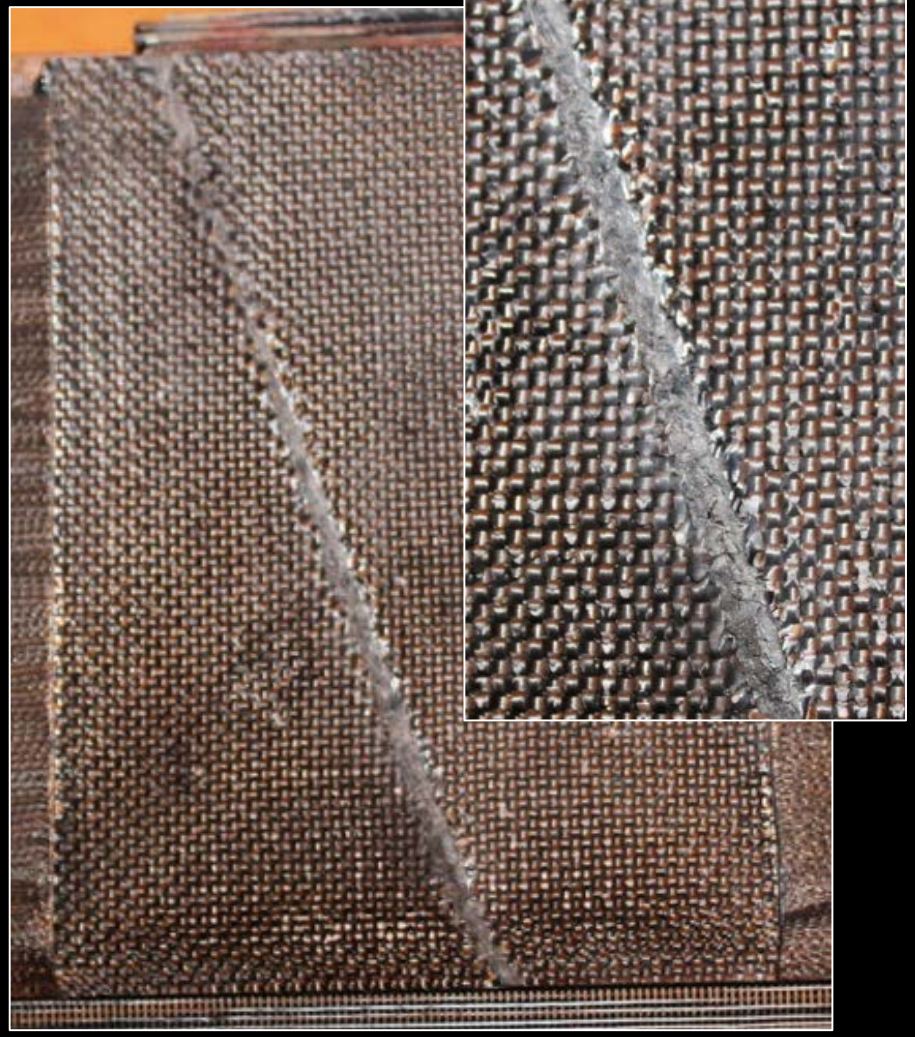


Ply lift and sub-surface cracking

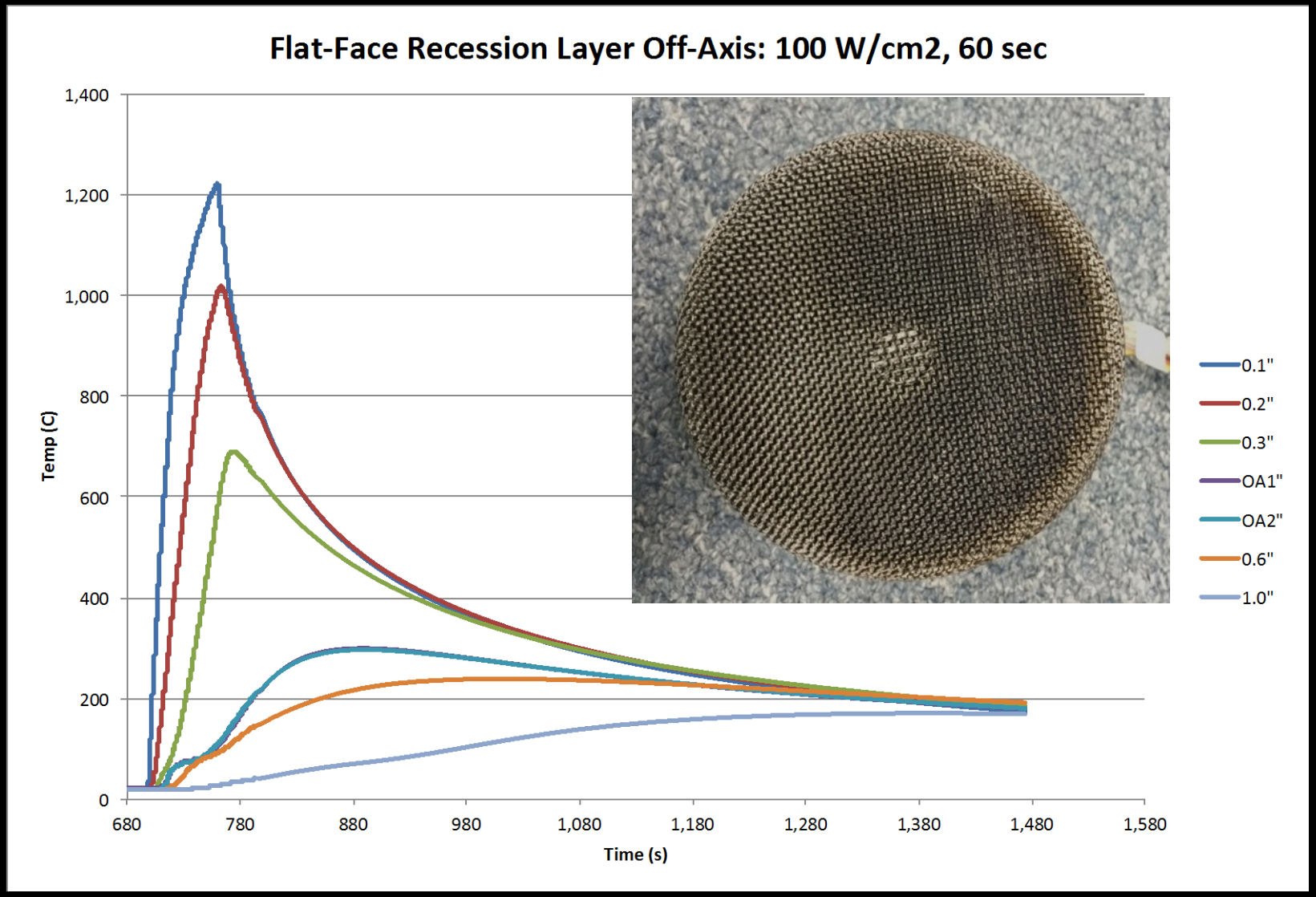
# AEDC Wedge Shear – Dwell 6 sec.
# ~1650 W/cm$^2$, 2.5atm, 4000 Pa Shear

Pre-Test

Post-Test



# AHF Thermal Response (100-250 W/cm$^2$, Nitrogen)
# Post-Test Off-Axis Thermal Response



# Future Arcjet Testing - Seams

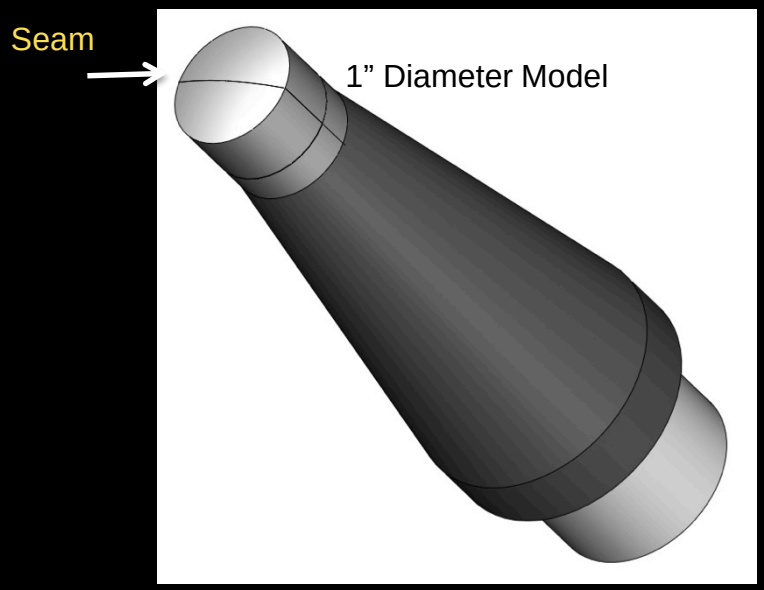
- **HEEET testing in Shear and High Heat Flux/Pressure**
  - Obtain recession data and verify aerothermal performance of seam at high heating/pressure and mission relevant shear

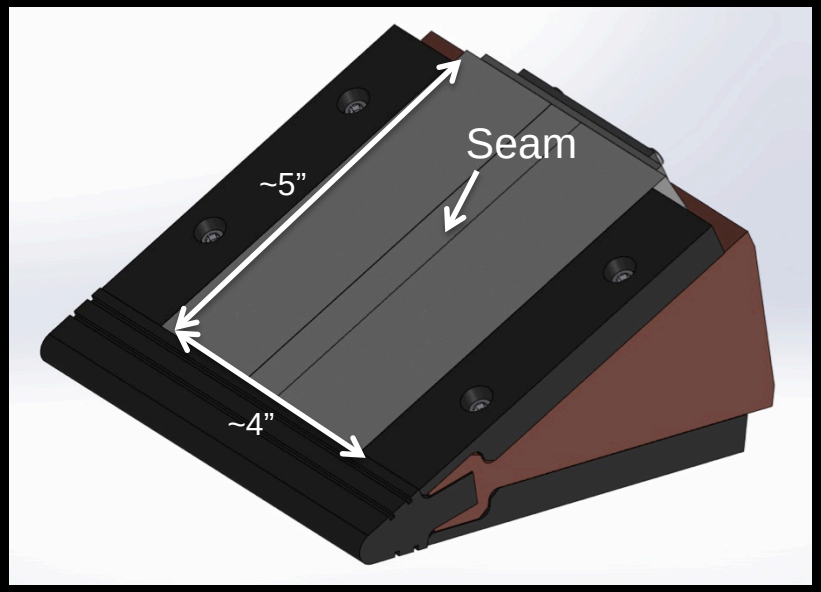
**IHF 3” Nozzle – September 2015**

| CW Heat Flux (est. CFD) ($W/cm^2$) |
|---|
| |

**AEDC Shear – January 2016**

| CW Heat Flux Wedge Flank ($W/cm^2$) |
|---|
| |



# Concluding Remarks

- Maximized the ground test capabilities and test design to in achieving test conditions of relevance
- Test results show HEEET acreage material is robust
  - No catastrophic behavior, even with the insulating layer exposed
  - Seam testing is planned and results will establish robustness of the seam
- Mission designers need to take into account limitations due to ground testing capabilities
- Project on target to mature HEEET to TRL 6 by FY17

# Acknowledgements


- Support and commitment of STMD, SMD-PSD and Game Changing Development Program Leadership
- Bally Ribbon Mills, our partner in this effort, has shown extraordinary commitment and willingness to explore the myriad of possibilities
  - Met our requirements in a timely and cost effective manner
  - We thank them for their commitment to be a great partner in our effort to enable future planetary exploration
- Staff at AEDC, LHMEL and NASA Arcjets for their support