

# Conformal Ablative Thermal Protection Systems (CA-TPS) for Venus and Saturn Backshells

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## 1: Background

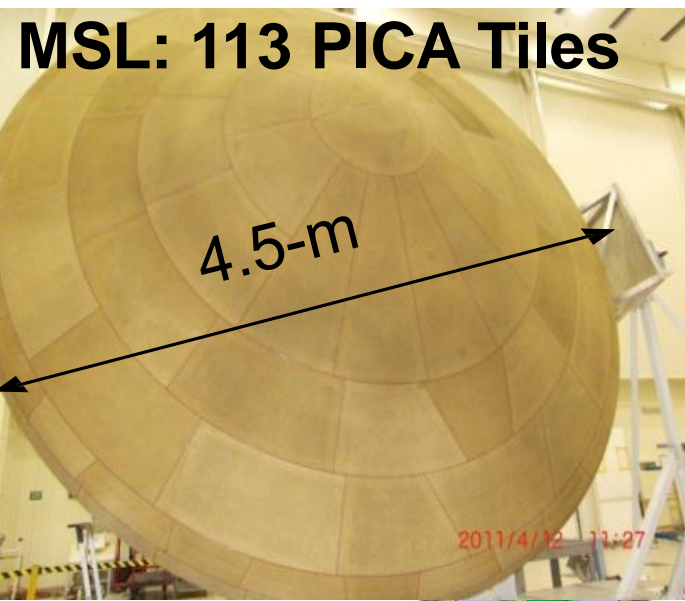
### CA-TPS: The Problem – The Solution

#### The Problem

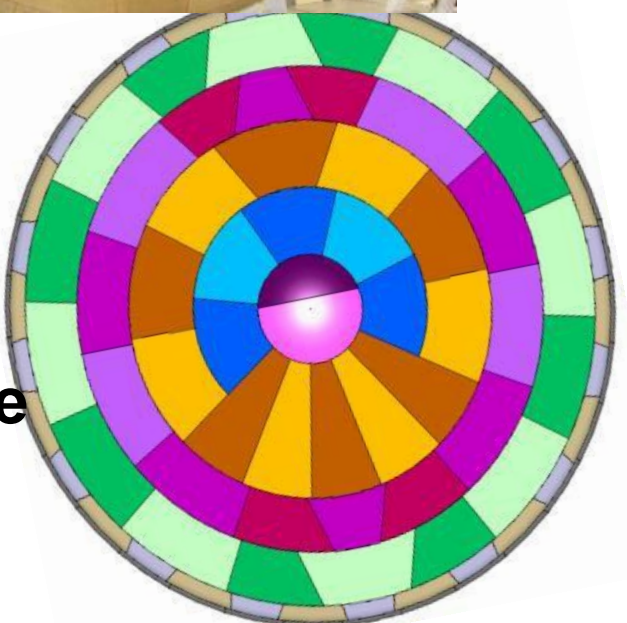
- NASA requires TPS ablator advances (TA14.3.1) to significantly lower the areal mass of TPS concepts, demonstrate high entry environment capability, demonstrate high reliability, demonstrate improved manufacturing consistency and lower cost
  - Current SOA materials require complicated installation techniques and/or high touch labor costs

#### SOA

- Limited number of certified TPS materials available
- PICA tile on rigid heatshields is limited by small size billet manufacturing and low strain-to-failure resulting in high tile count and gaps with filler designs
- Honeycombed concepts (AVCOAT) require extensive touch-labor, large curing ovens, and complicated NDE



MSL: 27 different tile drawings



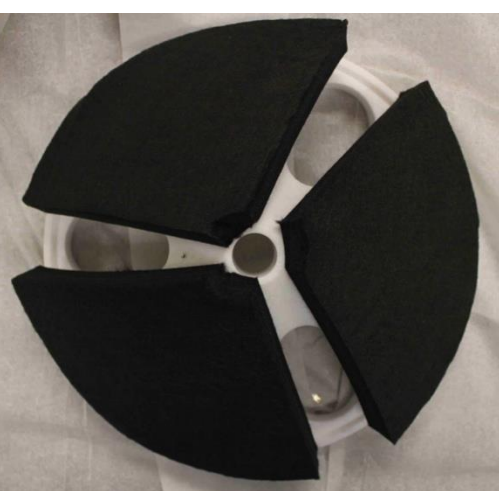
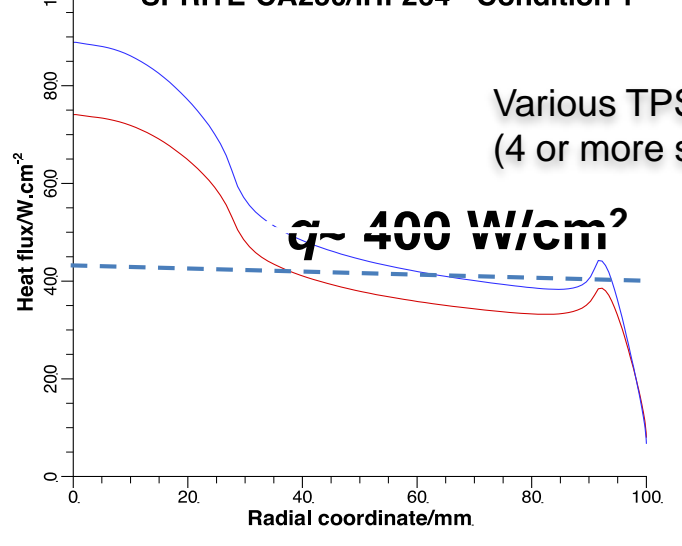
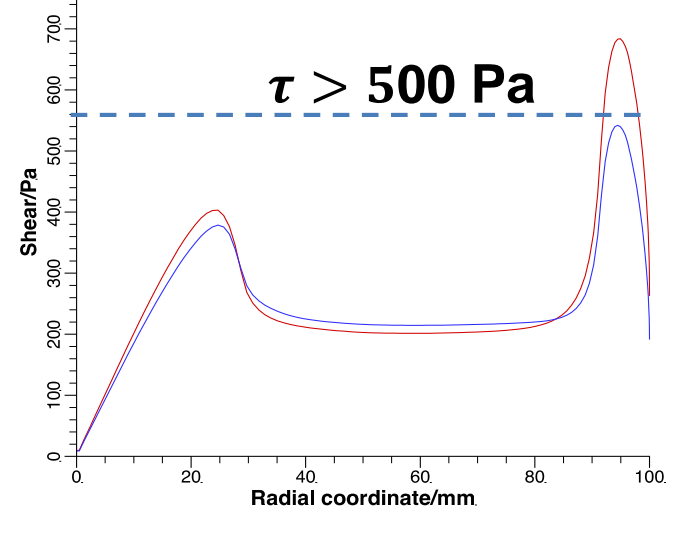
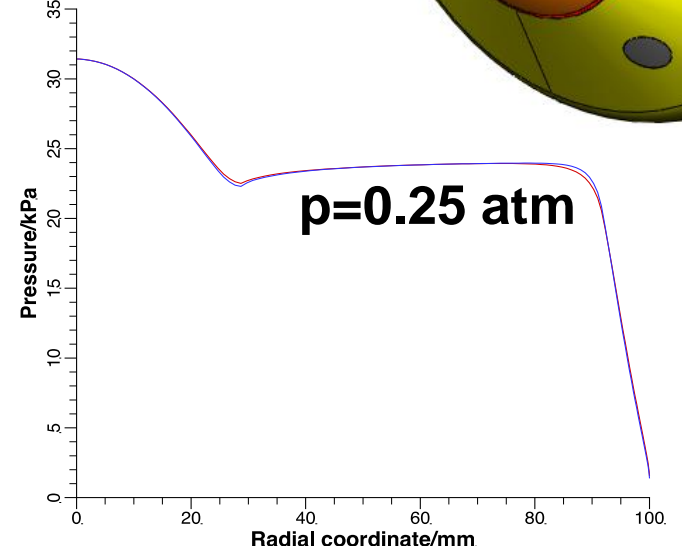
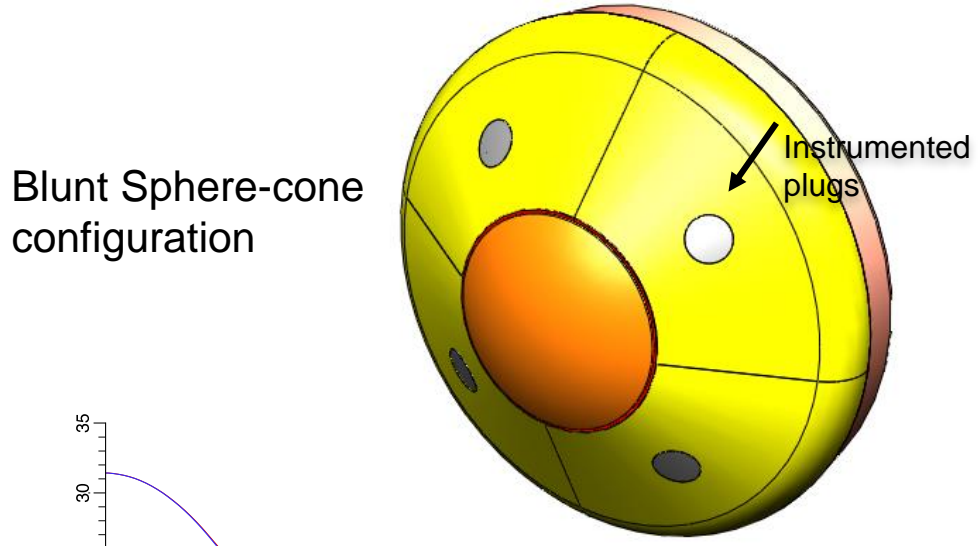
#### The Solution

- Develop a high strain-to-failure TPS capable to ~250 W/cm<sup>2</sup> to allow for easier application and reliable thermal protection
  - Successfully tested at ~400 W/cm<sup>2</sup> in shear
  - Successfully tested at 1850 W/cm<sup>2</sup>, 1.5 atm in stagnation
- Utilizing flexible reinforcement, parts can be molded and then infused, resulting in a near-net shaped composite with higher strain-to-failure and lower thermal conductivity than SOA materials made on a rigid reinforcement and machined to shape
  - New material can be made in larger sizes, directly bonded to a wide selection of aeroshells without the need for strain isolation pads or gap fillers (reduced installation costs)

## 3: C-PICA Accomplishments

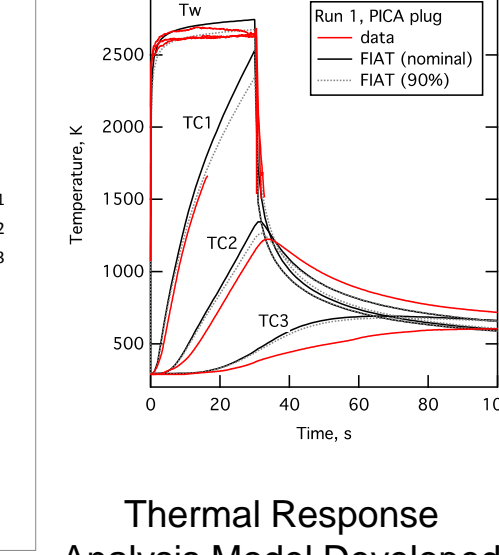
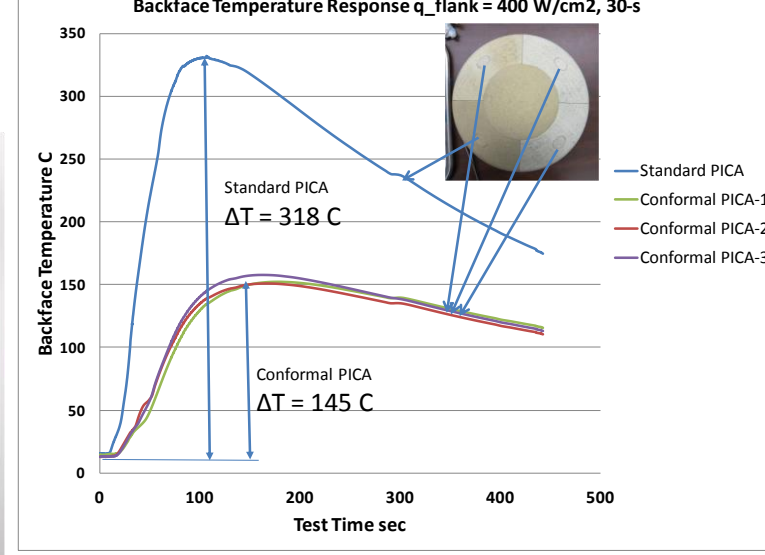
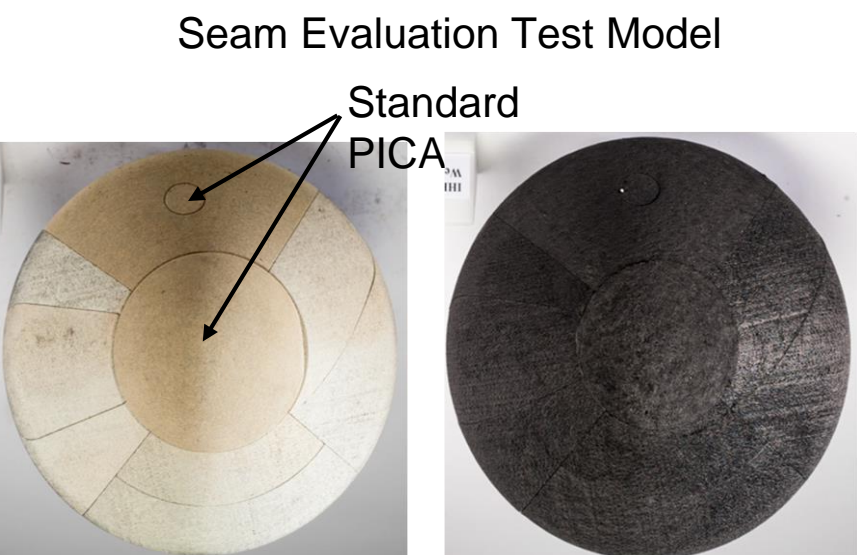
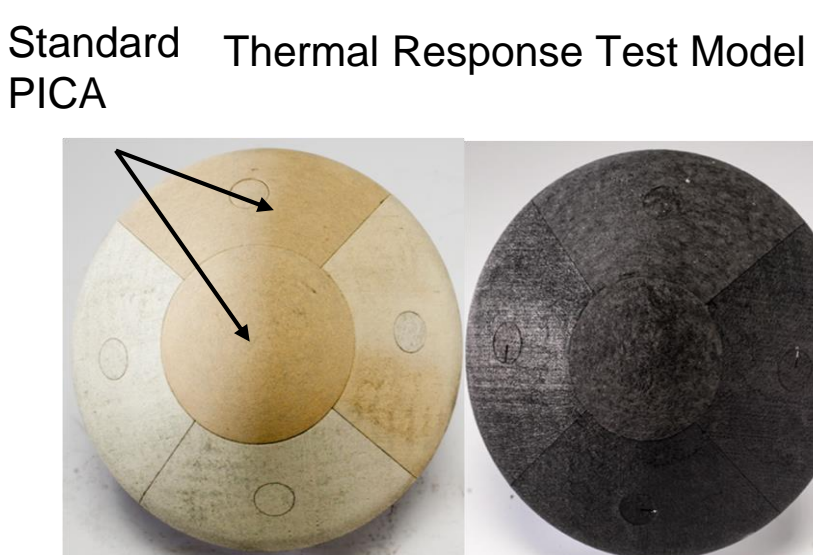
New TPS Shear Testing Approach

- Heritage shear test configurations (cooled-copper wedges) result in non-representative pressure gradients and often dissimilar flow fields
- New blunt sphere-cone (small probe) design results in flight-like gradients and similar flow fields
- Objectives of the test:
  - Demonstrate moldability of conformable ablators on a curved structure at MSL-type and COTS LEO conditions or beyond
  - Demonstrate advanced instrumentation of conformable ablators and measure in-situ temperature data for the development of a material response model
  - Gather recession and back-face temperature data on conformable ablators in a representative heating, pressure and shear environment for verification and validation of materials requirements.
  - Investigate different seam designs
  - Compare materials on a single arc jet model



### C-PICA has similar recession and much lower thermal penetration than PICA

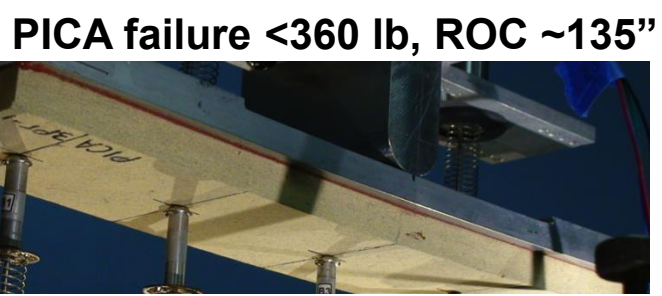
Flank heating ~400 W/cm<sup>2</sup>, 30 s, Shear ~200 Pa on flank, ~500 Pa at shoulder



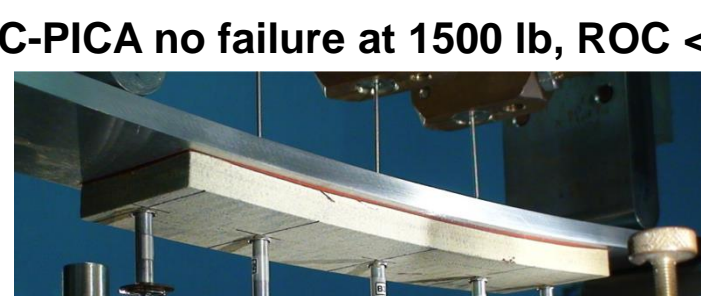
All seams were well behaved, even 90° butt joints between test segments

### C-PICA has much better performance in flexure testing than PICA

3-point bend tests

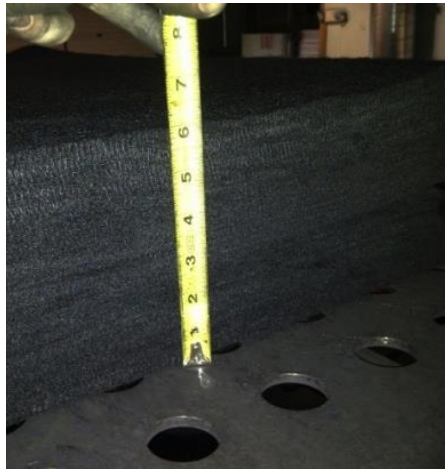


4-point bend tests

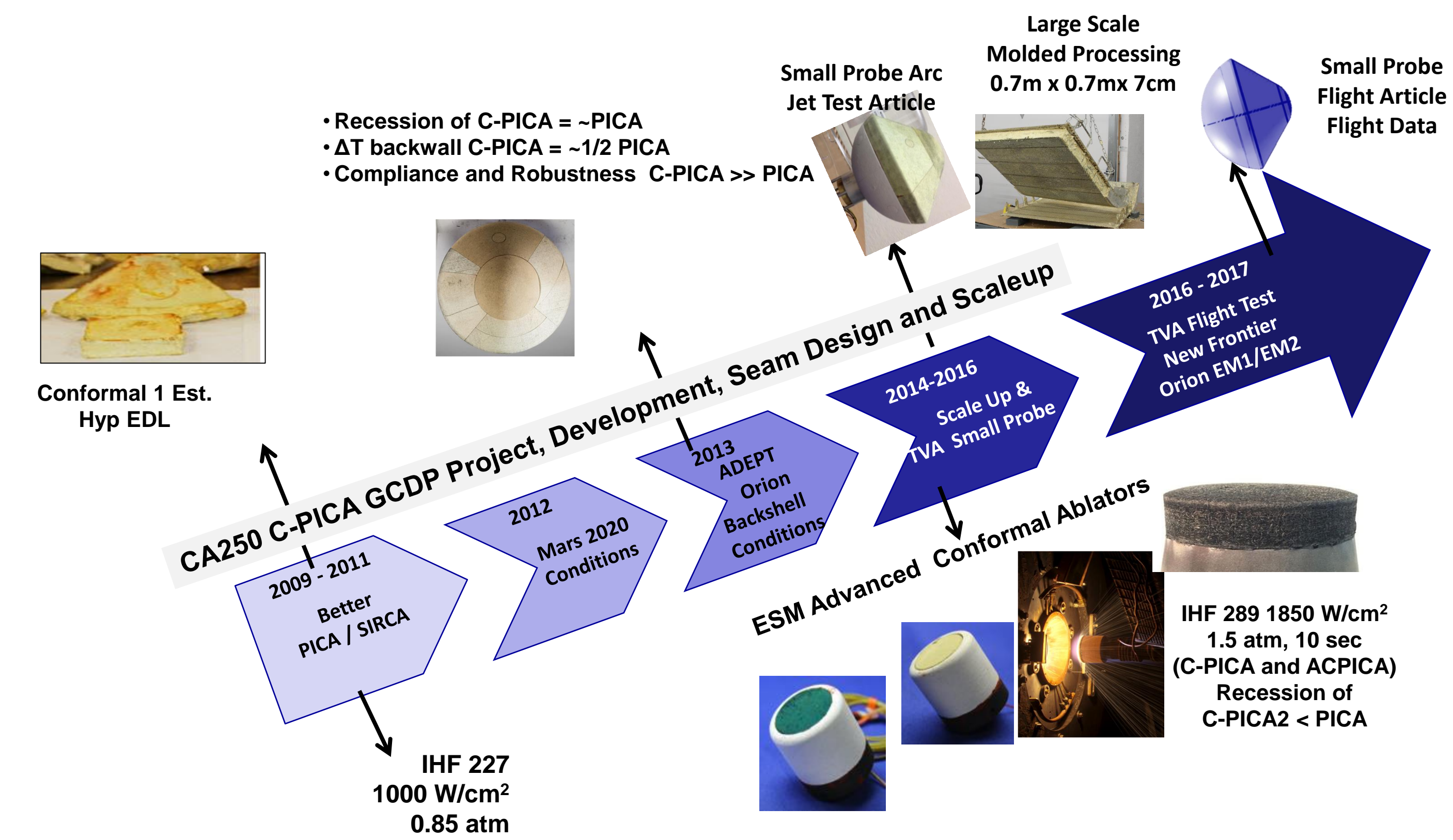


### Felt Scale-up successful for thick C-PICA – 4" Rayon Felt yields ~3" Carbon Felt

- State of the art for carbon felt ~1.0-in thick, density 0.8-1.0 g/cm<sup>3</sup> resulting in ~0.5" finished part
- Desire for thicker and higher density felt led to working with a felt vendor to make 4" rayon-based white goods, which would carbonize to ~3"

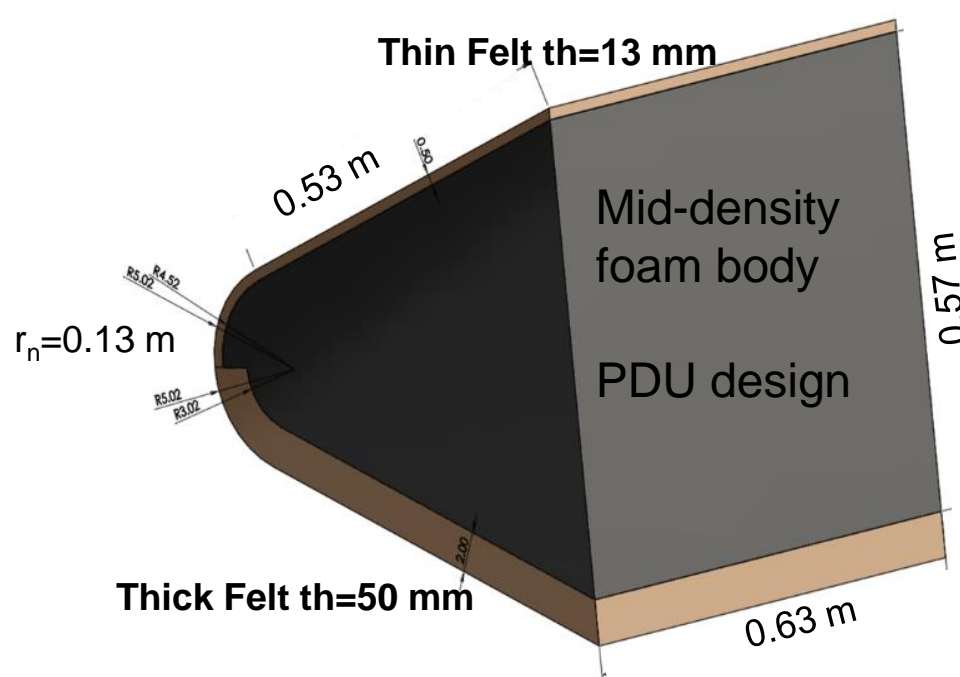
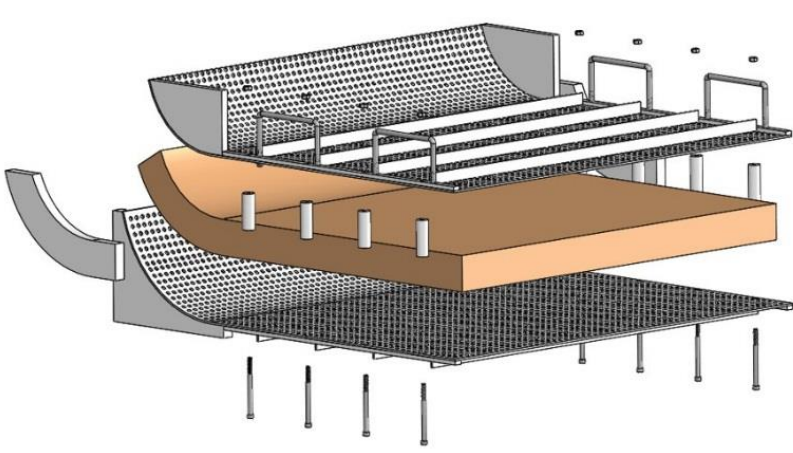


## 2: Conformal Ablator TPS Development



## 4: Demonstration of Scale-Up of C-PICA

- Part scale up – Design and build a prototype demonstration unit (PDU)
  - Objective is to demonstrate scale up of impregnation for different felt thicknesses, handling, machining and assembly of large parts
  - Metallic molds designed and fabricated
  - First large, thick felt part produced for evaluation
  - Changes recommended and second part underway



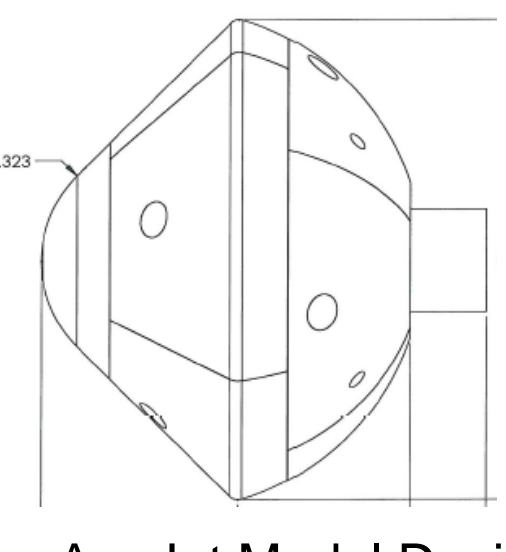
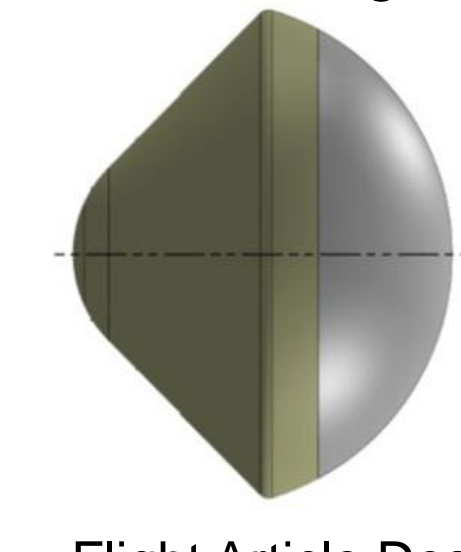
## 5: Conformal Ablator Mission Infusion – Small Probe Development with Terminal Velocity Aerospace

- Small probe vehicle designed for break-up evaluation
- TVA responsible for entire design
  - Ames responsible for TPS selection, sizing, manufacturing, instrumentation and installation for initial arc jet models and test flight vehicles
- Ames hardware
  - Backshell TPS bonded to carrier structure
    - RF transparent Silica/silicone (C-SIRCA)
    - In-depth instrumentation included
  - Heatshield TPS bonded to carrier structure
    - C-PICA
    - In-depth instrumentation included
- Remaining hardware is TVA's responsibility
- Designed for heating at ~400 W/cm<sup>2</sup> on the nose, 200 W/cm<sup>2</sup> on the flank, 20 W/cm<sup>2</sup> on backshell
  - Heatshield thickness ~0.9" (using thick felt)
  - Backshell thickness ~0.35"
- Flight manifest: from Station in late FY16



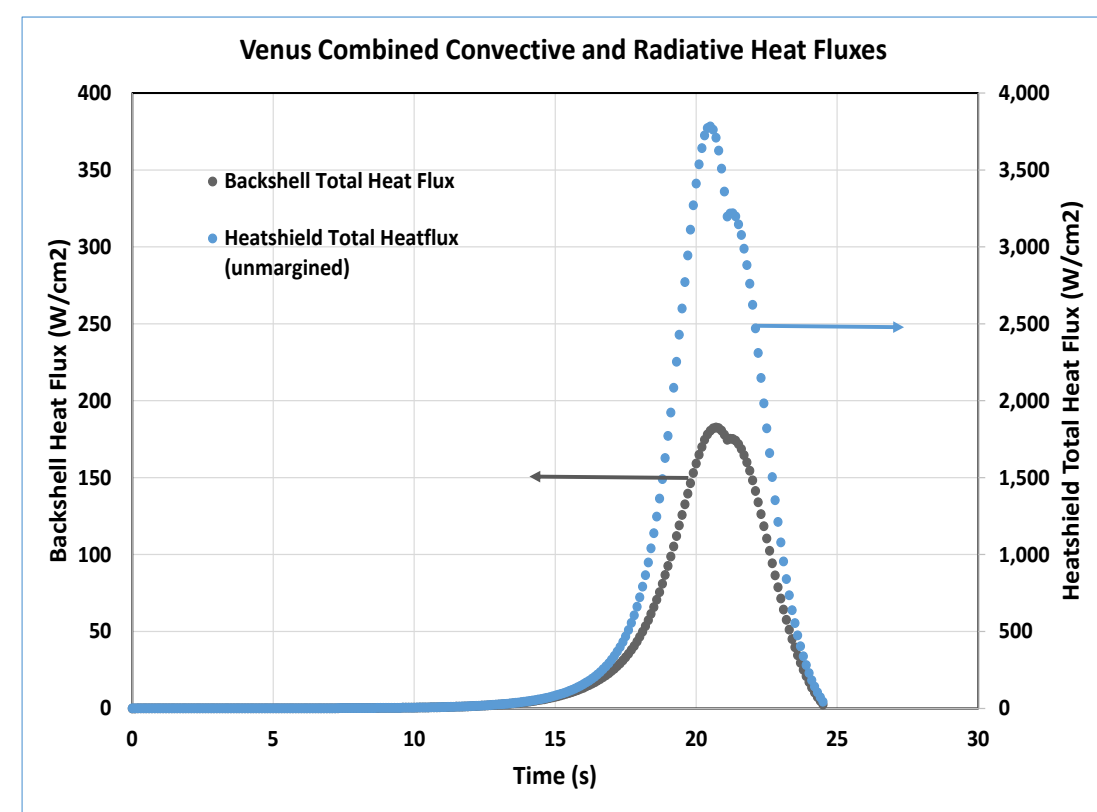
#### Progress to date:

- Vehicle and arc jet test article configuration iterations completed
  - Trajectory analyses performed, environments defined, TPS sizing completed
- TPS parts designed for arc jet and flight
- TPS processing molds designed and manufactured
- Segments for arc jet test articles processed, machined, instrumented, assembled and tested
- Processing specs completed
- Processing of flight materials underway

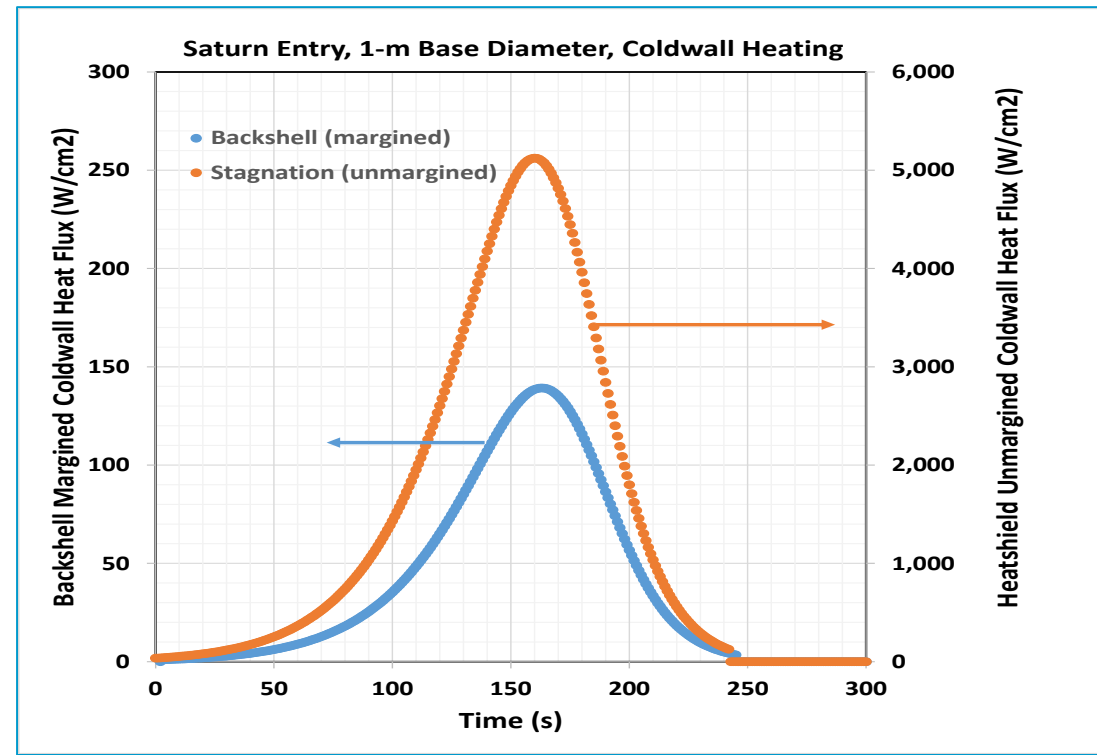


## 6: C-PICA for New Frontiers Backshell Applications

- Why C-PICA for Venus backshells?
  - Heating too high for SLA-561V without melting
  - Lower conductivity than PICA results in >30% mass savings over PICA on backshell TPS
  - Higher strain-to-failure than PICA results in fewer tiles, lower cost to install



- Why C-PICA for Saturn backshells?
  - Heating too high for SLA-561V without melting
  - Lower conductivity than PICA results in >40% mass savings over PICA on backshell TPS
  - Higher strain-to-failure than PICA results in fewer tiles, lower cost to install



- Current development is material focused. For NF, our current plans are to complete TRL 5 to 6 in FY'17/FY'18
- TRL 5 to 6 will be minimal
  - MDU with curved panels, structural testing, moderate amount of testing for thermo-structural properties and tailored arc jet testing for qualification
  - Large curved panel molding and resin infusion, machining and integration to achieve desired gap width tolerance.
  - Can be accomplished in 1-2 years.

## 8: Acknowledgements

- This work is funded by NASA's Game Changing Development Program under the Space Technology Mission Directorate
- Arc jet specimen design, manufacturing, instrumentation and assembly performed by the NASA Ames TSM Branch
- Arc jet testing performed by the NASA Ames TSF Branch
- Thick rayon felt manufactured by American Felt and Filter Company (AFFCO) and carbonized by Fiber Materials Inc (FMI)
- Scaled panel processed by the Ablatives Laboratory at Applied Research Associates Inc.