Overview of Ablation Activities at NASA Johnson Space Center in FY2016

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Oct. 6, 2016

Introduction

- Intent of these charts are to provide an overview of the ablator activities occurring at NASA JSC:
  - Ablator materials being investigated for several programs
  - Ablation analysis tasks
  - Thermal testing to validate ablation models

NASA JSC TPS Responsibilities

- TPS System Management
  - Define high-level TPS design guidelines/standards
  - Oversee contractor led TPS design and verification
  - Sign Certificate of Flight Readiness
- Ablation Model Development and Validation
  - Develop specific ablation models
  - Plan and direct arc-jet tests to validate ablation models
    - Arc-jet tests are conducted at NASA Ames and AEDC
  - Deliver ablation models to contractors for use in TPS system design

Commercial Crew Program TPS Overview

- The Boeing Company (CST-100)
  - Boeing Lightweight Ablator (BLA), Base Heatshield
  - Advanced Flexible Reusable Surface Insulator (AFRSI), Backshell
- SpaceX (Crew Dragon)
  - Phenolic Impregnated Carbon Ablator (PICA-3), Base Heatshield
  - SpaceX Proprietary Ablative Material (SPAM-Lite), Backshell

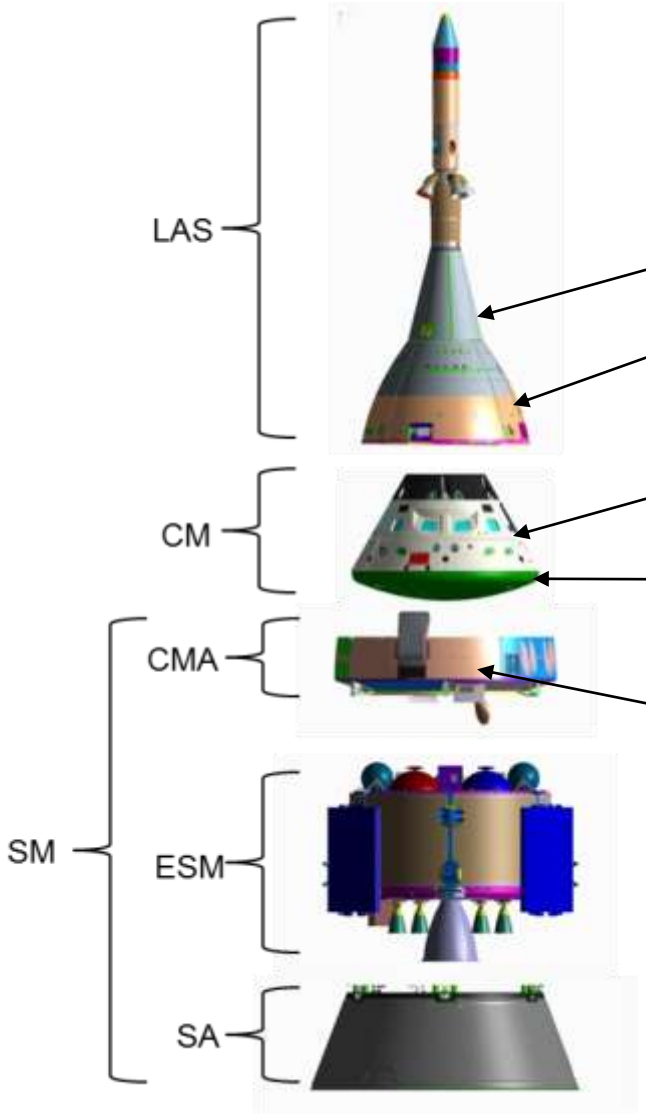
Commercial Crew Program TPS Ablation Activities

- Ablative Thermal Model Development
  - SPAM
  - FM5504
  - BLA No. 18
- Arc Jet
  - SPAM-Lite
  - BLA No. 18/20
    - Wedge
    - Stagnation
  - BRI-18

Commercial Crew Program TPS Ablation Activities, Cont.

- Ablation Analysis
  - SpaceX 3D MMOD Flight Experiments
  - SpaceX 3D Quick Disconnect
  - Boeing 2D Base Heatshield Shoulder
  - SpaceX Red Dragon TPS Margin of Safety
- Post-Flight Inspection of Multiple Heatshields (Cargo Dragon)

Orion (MPCV) TPS Overview



Launch Abort System (LAS)
- VAMAC
- Cork

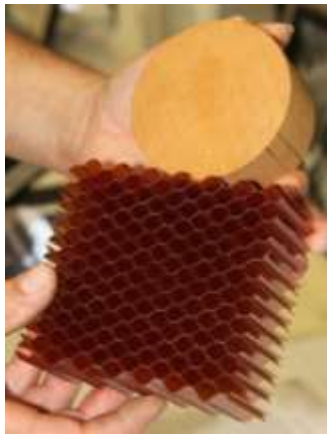
Command Module (CM)
- AETB-8 tile (backshell)
- Carbon-Phenolic (backshell closeouts)
- FRSI (Flexible Reusable Surface Insulation) (docking hatch)
- Molded Avcoat™ (heat shield blocks)
- RTV-560-5PMB (heat shield gaps)
- 3DMAT (heat shield compression pads)

CM Adaptor (CMA)
- Cork

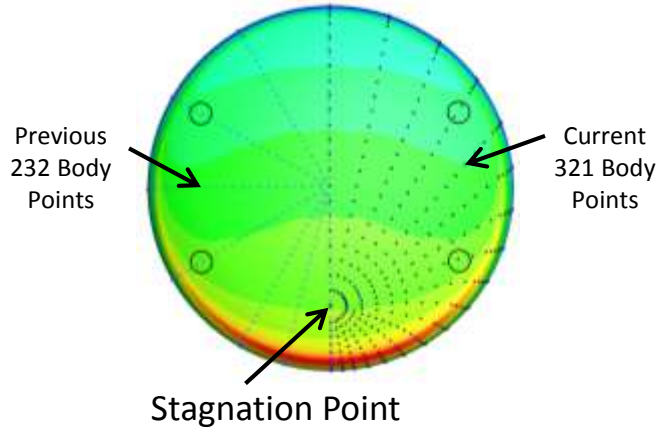
Orion (MPCV) TPS Ablation Analysis Activities

- Major Heatshield architecture change going from EFT-1 to EM-1
- Switch from monolithic honeycomb Avcoat to molded Blocks of solid Avcoat.
- The bonded block approach now requires a gap filler material so an RTV derivative was selected
- A new CHAR code ablation model was developed for Molded Avcoat and the RTV Gap Filler
- Due to the presence of two material, there is a concern regarding differential recession resulting in augmented heating to the creation of gaps and fences.
- A process to 'size' the Orion heat shield molded Avcoat thickness distribution developed
  - 1D analyses at body points along streamlines
    - Allows for downstream heating changes due to material response
  - Delivered to Lockheed Martin for EM-1 heat shield design

EFT-1 Avcoat

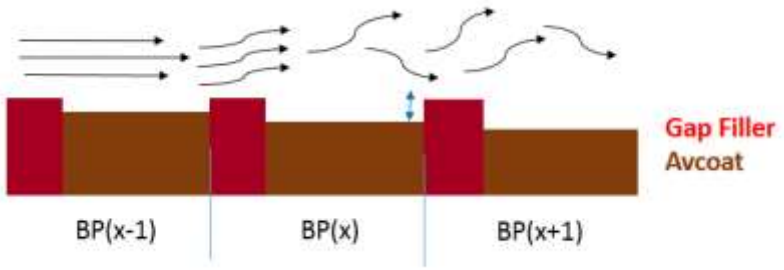


EM-1 Avcoat Blocks



Orion (MPCV) TPS HS Sizing Scripting

- Generate RTV-5PMB CHAR Input Files
  - Thickness based on previous body point sizing
  - Boundary Conditions
- Perform 1D RTV Ablation Analysis
- Compare RTV recession to previous body point's Avcoat recession
- Determine gapping/fencing heating factors

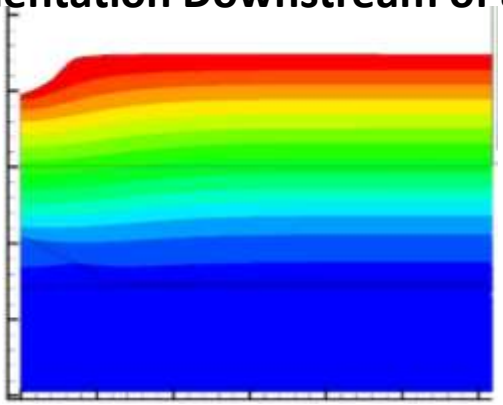


- **Generate Avcoat CHAR Sizing Input Files**
  - Initial thickness based on previous body point sizing
  - Augmented Heating Boundary Conditions
- **Perform 1D Avcoat Ablation Sizing Analysis**

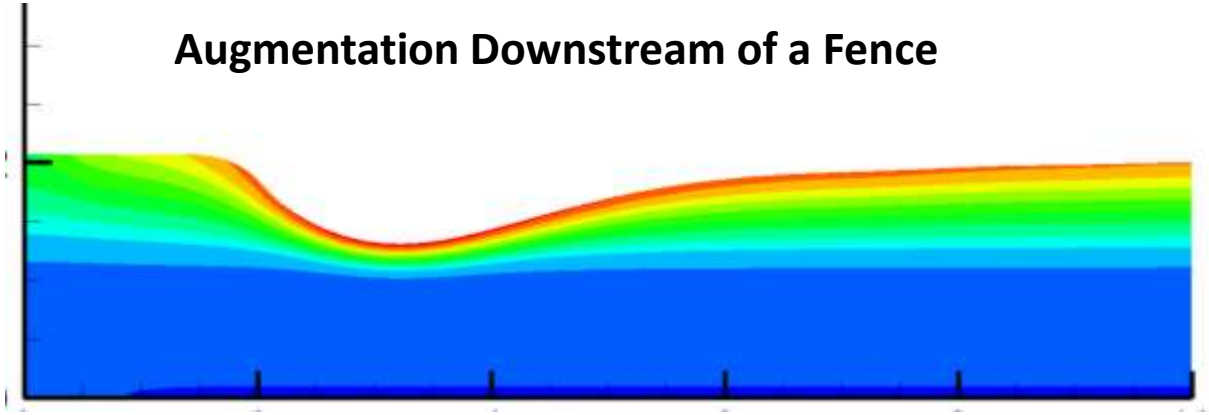
Orion (MPCV) TPS Multidimensional CHAR Analysis

- Continued development of multidimensional ablation modeling capabilities

Augmentation Downstream of a Gap



Augmentation Downstream of a Fence

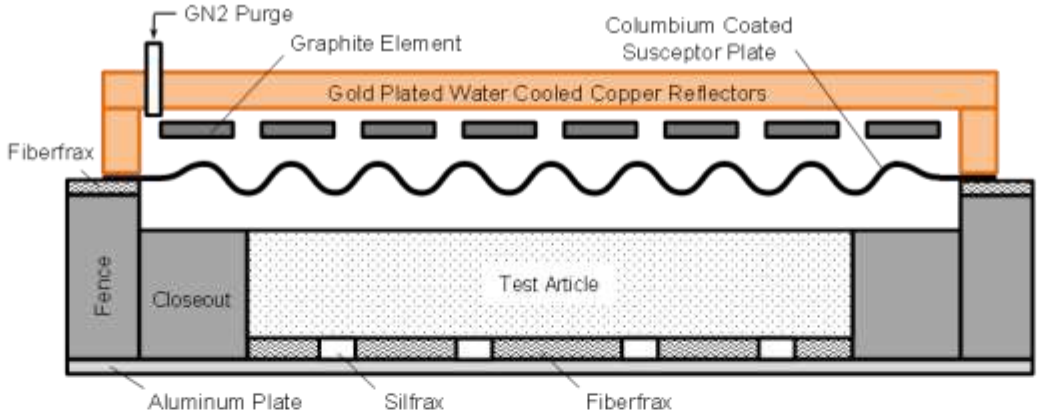


Thermal Testing
Arc-jet

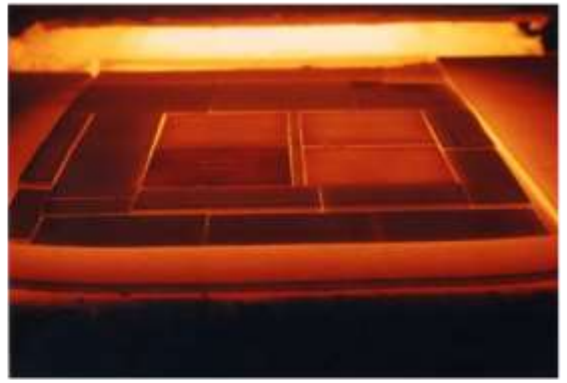
- Test Facilities and Model Size
  - NASA Ames Research Center
    - Stagnation models – 4” to 8” diameter
    - Wedge models – 20 to 30 AoA
      - 4”x5” to 6”x6”
  - AEDC – Arnold Engineering Development Center
    - Wedge models – 4”x5”
- Typical Measurements
  - Indepth temperatures – thermocouple plugs
  - Surface recession
  - Surface Temperature – pyrometers
- MPCV Driving Flow Field Diagnostics in NASA Arc-jets
  - LIF (laser induced flouresence)
  - Heat flux and pressure probe sweeps
  - CFD of models in flow field
- Future Capabilities at Ames – LEAF (Lunar Environments Arcjet Facility)
  - Laser radiant heating of wedge and panel test articles in IHF
  - New nozzles in IHF
    - 9” dia. for larger wedges
    - Semi-elliptical nozzle for panel test articles

Thermal Testing
JSC Radiant Heat Facility

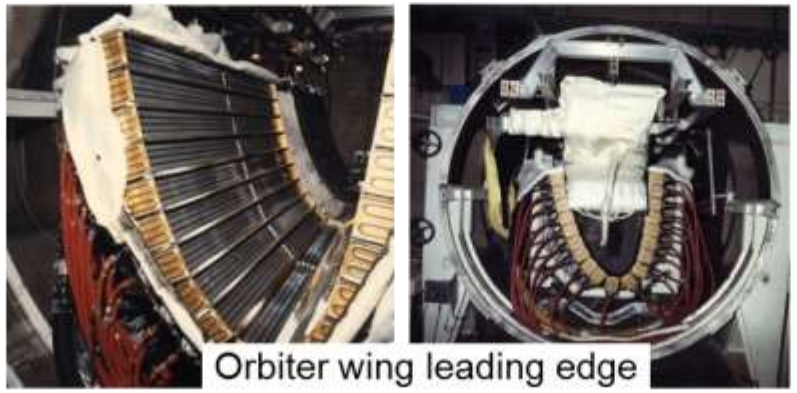
R1 Chamber
36” x 48+” Test Articles



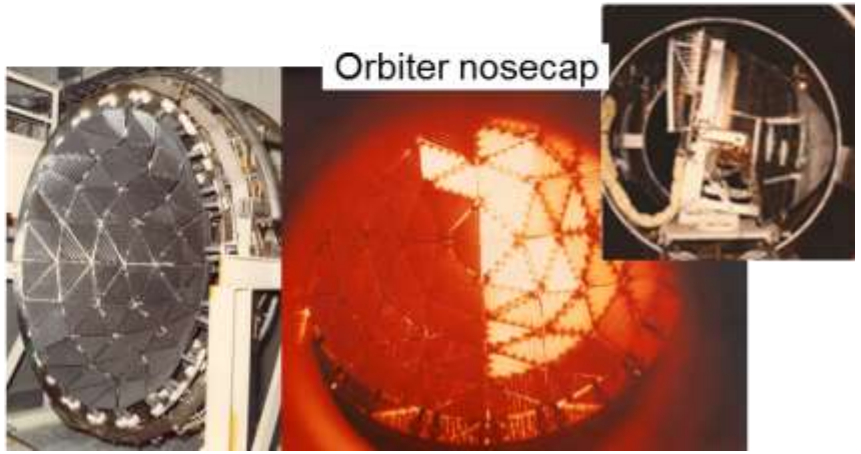
Typical Radiant Test Setup
(not to scale)



R2 Chamber
30” x 30” Test Articles



Orbiter wing leading edge



Recently Modified to Test Ablators

Thermal Testing
ICP Torch

50kWatt Inductively Coupled Plasma Torch
At The University of Texas at Austin

Torch to be used for screening materials and understanding basic ablator behavior.

Torch Status

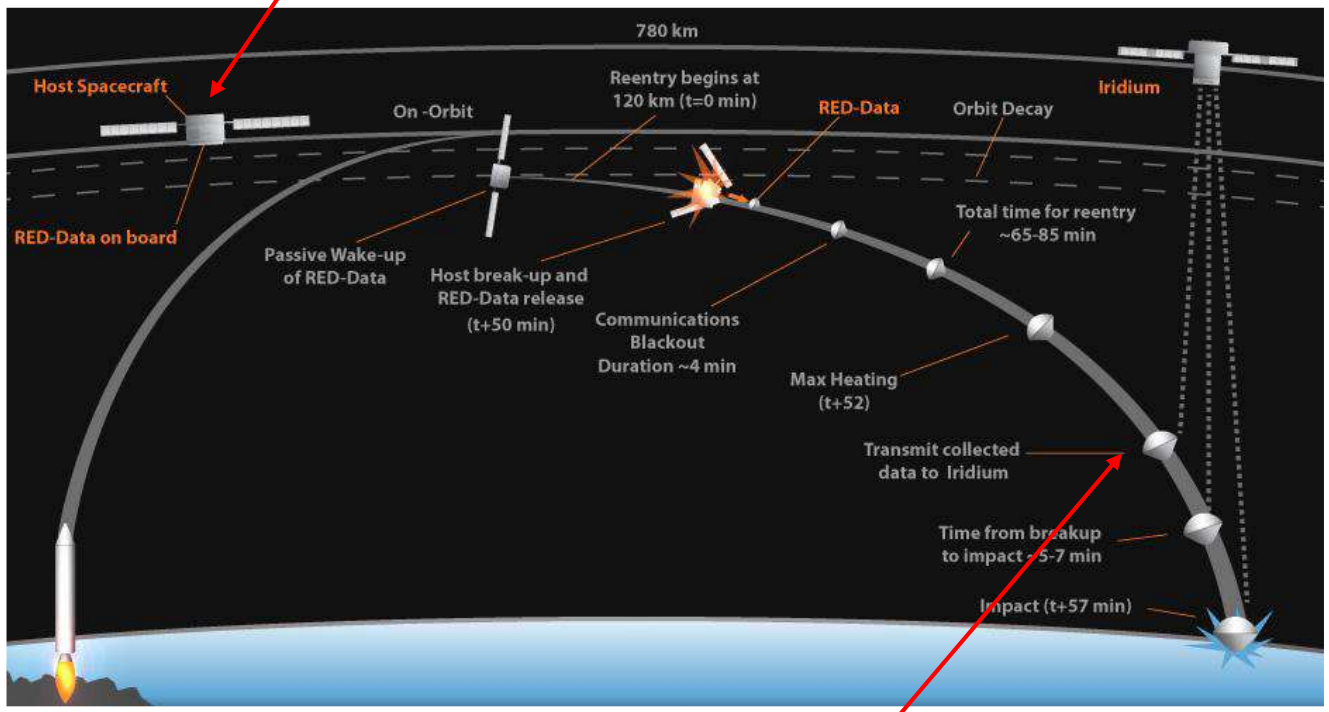
- Flow characterization – Fall 2016
- Teflon and graphite model testing – Fall 2016
- Initial Avcoat™ model testing – Winter 2016
- AIAA Paper – Jan. 2017

Space Act Agreement (SAA) between Univ. of Texas and NASA JSC Engineering

Flight Testing Ablators

Three Capsules to be Flown

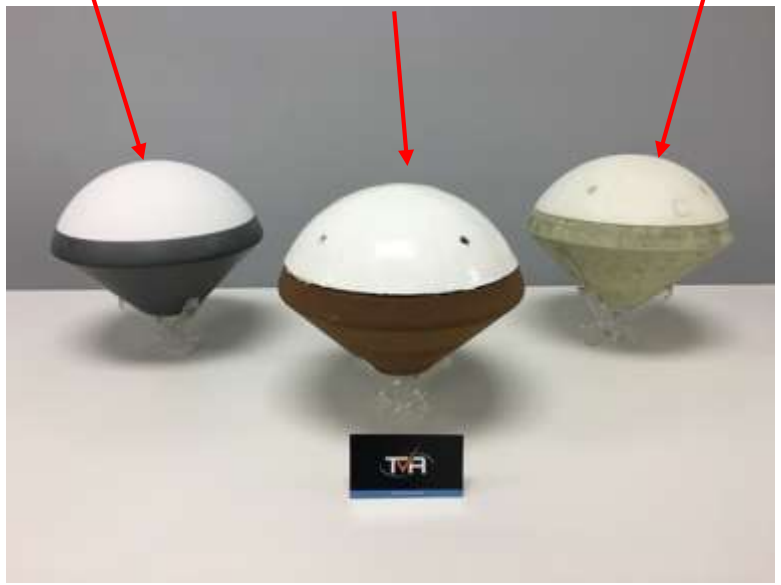
Cygnus OA-7
ISS Resupply Mission



Shuttle Tile

Conformal PICA

Molded Avcoat™



Instrumented TPS Provided by NASA JSC and Ames

Thermocouple data
transmitted to ground

NASA JSC Awarded Phase 3 SBIR Contract to Terminal Velocity Aerospace (Atlanta, GA)
Flight Expected Jan. 2017

Concluding Remarks

- NASA JSC is involved in all aspects of TPS selection, design, analysis, test and certification for NASA space vehicles.
- Emphasis is on design and integration of TPS and the certification of TPS for Human Spaceflight vehicles.
- Ablation models of many materials have been developed and provided as support to Orion and Commercial Crew partners.

- JSC TPS personnel are always on the look-out for
  - Improved physics-based ablation models
  - Low cost, better characterized TPS ground test facilities
  - New light-weight, robust and low cost TPS materials
  - Inexpensive flight test opportunities