National Aeronautics and Space Administration

Orion Flight Test-1
Thermal Protection System Instrumentation

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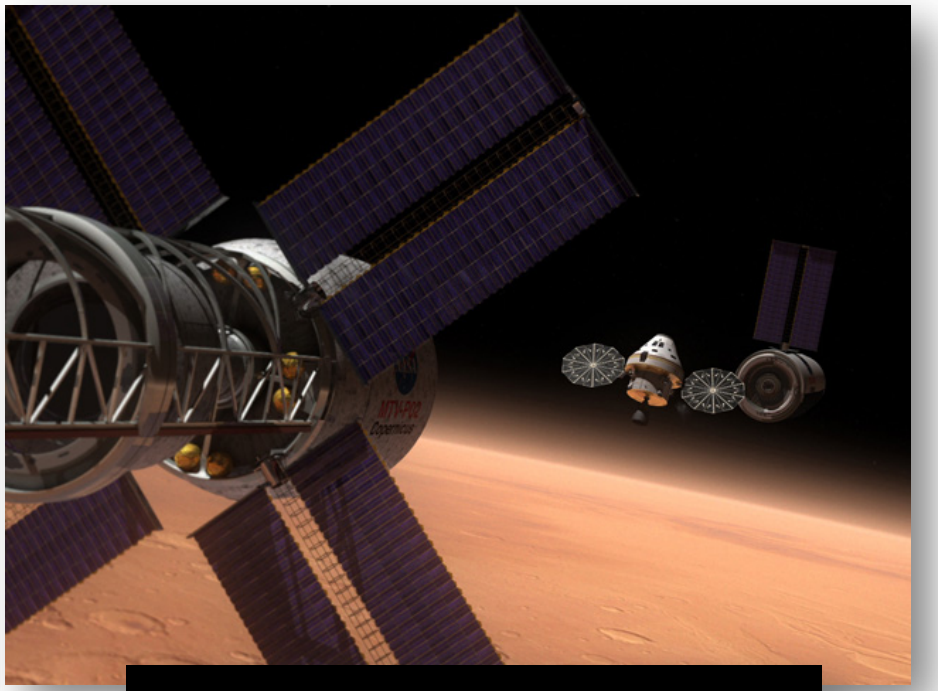
Since Last We Talked…

- Constellation Program has been cancelled
- Orion transitioning to the Multi-Purpose Crew Vehicle (MPCV)
  - Spacecraft to serve as the primary crew vehicle for missions beyond LEO
- Revised near-term focus on incremental spacecraft development with greater emphasis on orbital flight testing.
  - Targeting initial flight test to validate critical systems capability in 2013-2014 timeframe

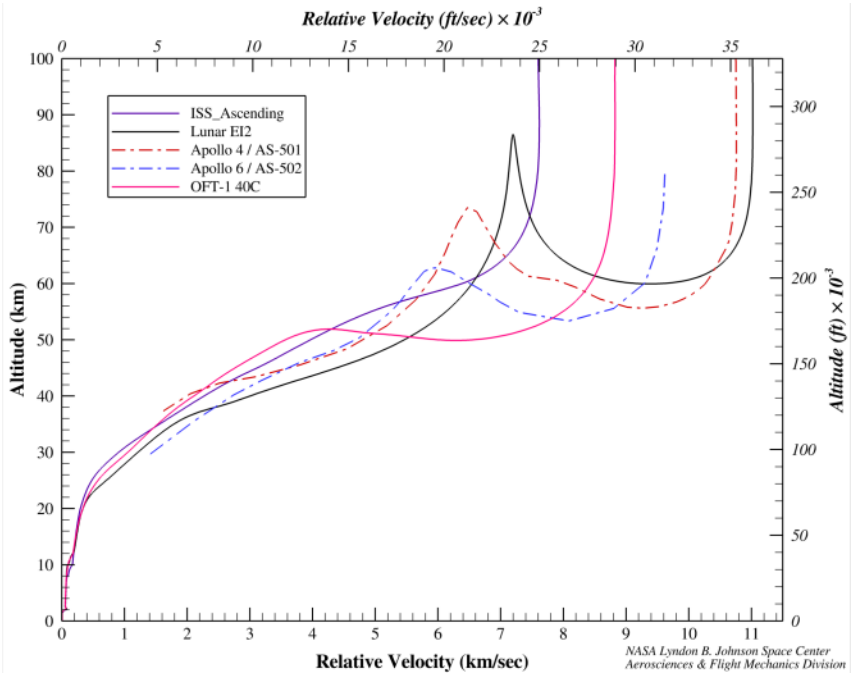


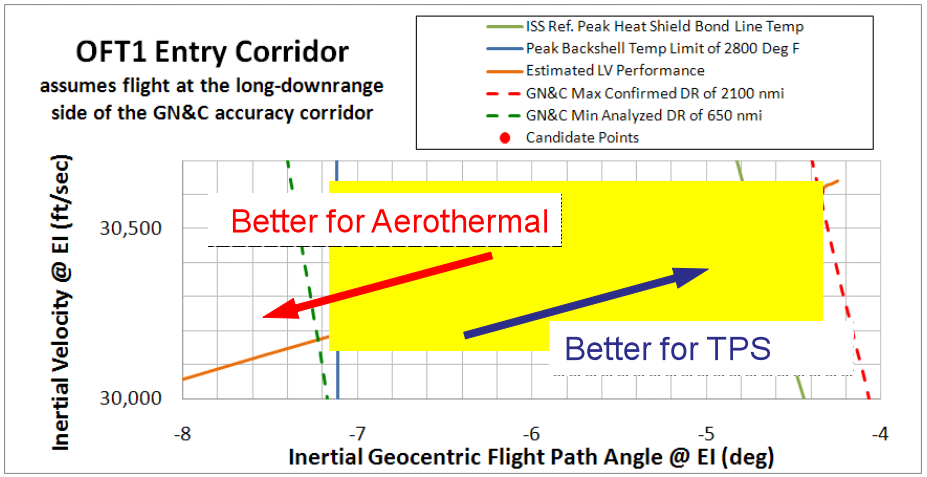
Orion Flight Test #1 (OFT-1) Objectives:

- Demonstration of *Critical Events* for a crewed Orion mission
- Validate Orion *Environments*
- Demonstrate *System/Subsystem Performance* in integrated configurations and Orion 'Beyond-LEO' flight environments

OFT-1 Entry Flight Design

- A “high energy” trajectory is preferred for OFT-1 in order to optimize aerothermal benefits in demonstrating Beyond-LEO capability
  - Steep flight path angle
  - Max entry interface velocity for expected launch vehicle & booster performance
  - Heat load, and thus TPS bondline, is not maximized
    - Efforts to adjust GN&C performance in order to target TPS bondline temperatures consistent with an ISS mission
- High energy entry trajectory achieved with a 2 rev, high apogee orbit





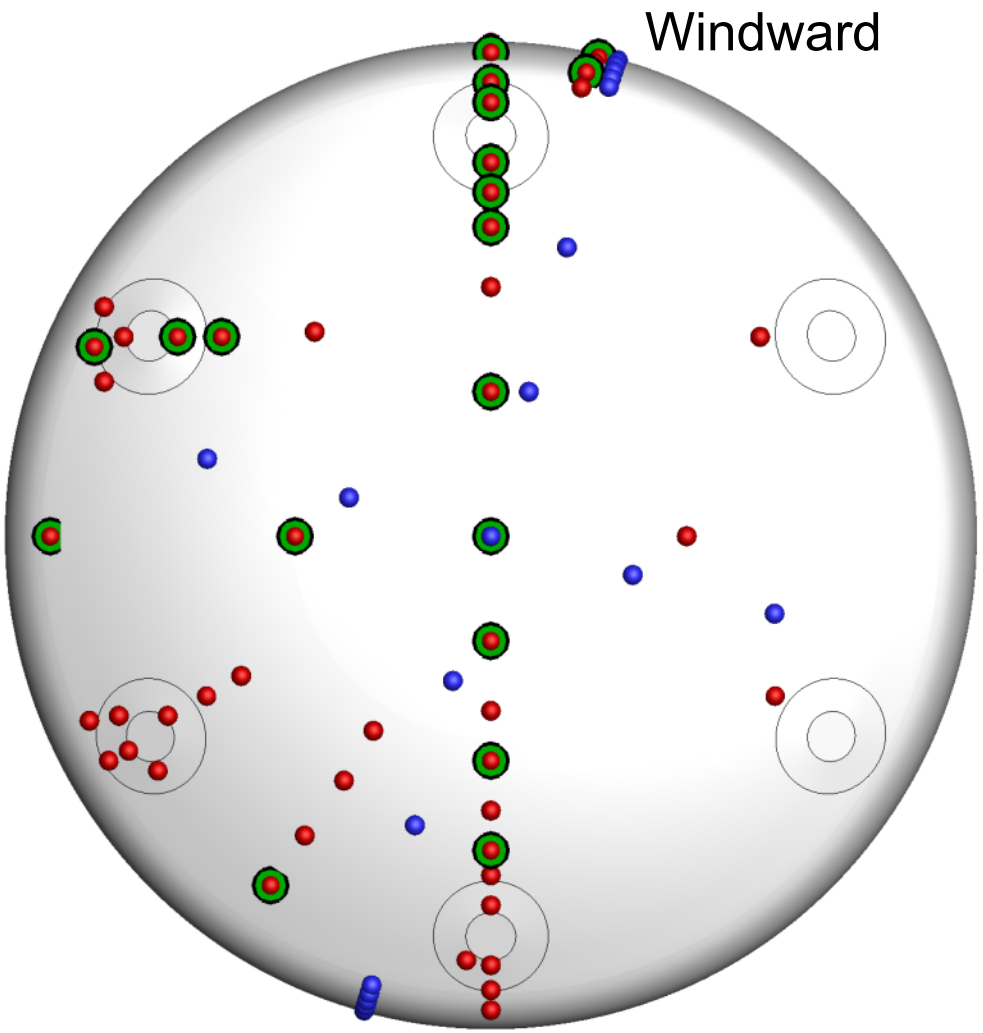
OFT1 TPS and Aeroscience FTOs

Flight Test Objectives (all primary)
OFT1.086 Determine CM TPS thermo-structural performance during re-entry environments. (Primary) *Rationale: Integrated TPS performance is un-testable on the ground due to the size of the system and the complexity of combined thermal and mechanical loads. The TPS is a DFMR subsystem relying on analytical verification for entry performance.*
OFT1.087 Determine CM TPS thermo-structural performance during launch, ascent, and on-orbit environments. *(Primary)*
OFT1.041 Obtain data on TPS response due to CM RCS plume heating augmentation during re-entry. *(Primary)*
OFT1.091 Determine heatshield and backshell aerothermodynamic environment during re-entry. *Rationale: Flight test data supports validation of transition, laminar and turbulent modeling of baseline OML for both equilibrium flow and non-equilibrium flow.*
OFT1.092 Determine catalytic overshoot environments. *(Primary)*
OFT1.093 Determine RCS jet impingement aerothermodynamic environment during entry. *(Primary)*
OFT1.095 Determine cavity aerothermodynamic environment during reentry.
OFT1.101 Determine characteristics of MMOD cavity heating environment during entry. *(Primary)* *Rationale: Flight test data on a known intrusion into the thermal protection system supports validation of the cavity heating model which is the primary driver on tile thickness.*
OFT1.099 Determine the aerodynamic environment of the vehicle during all phases of nominal entry/descent. (Primary) *Rationale: Aerodynamic data is a critical element of the vehicle entry and descent flight environment.*
OFT1.026 Determine RCS jet effects on aerodynamics of CM during entry/descent. *(Primary)*

Original Baseline Heatshield (HS) Developmental Flight Instrumentation (DFI)

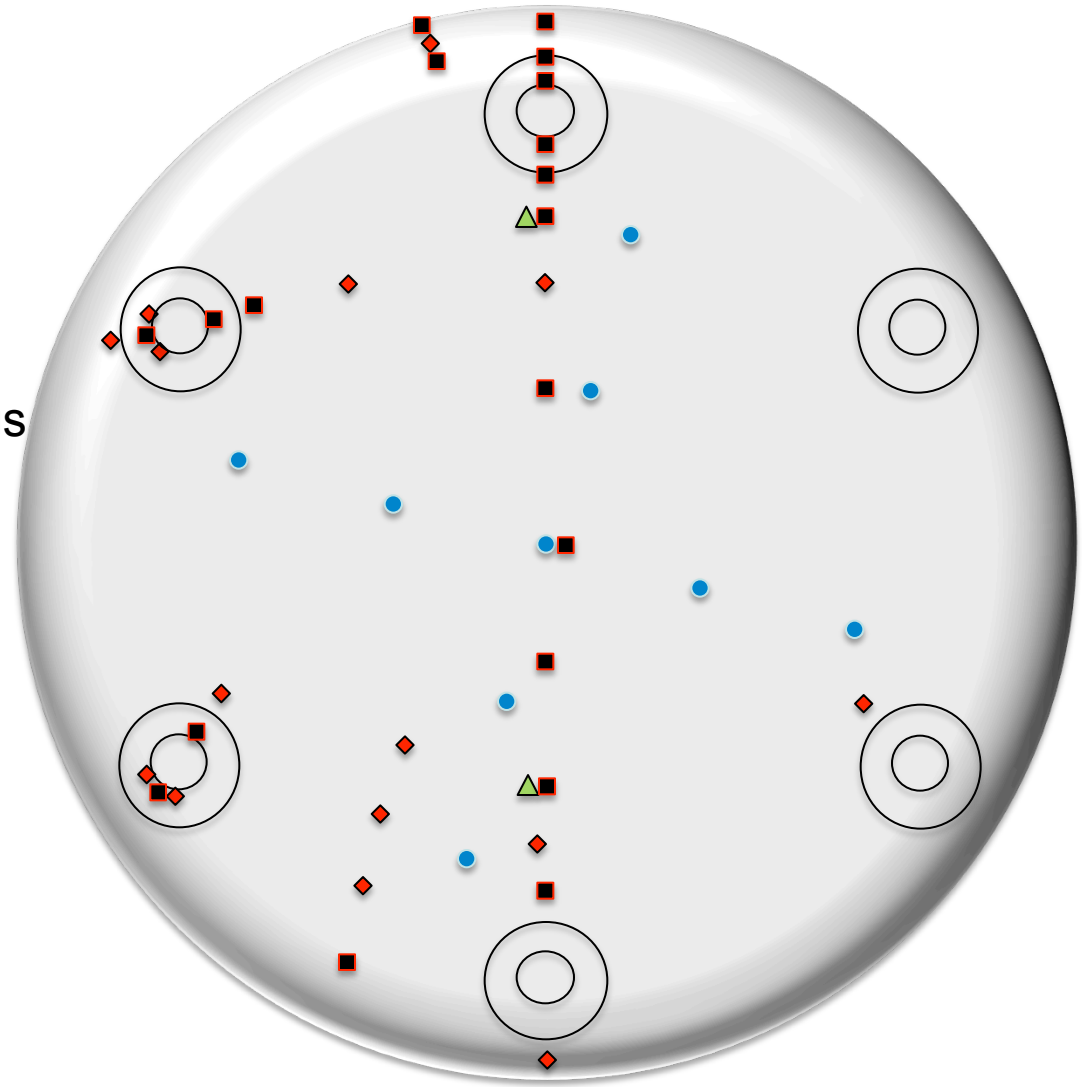
- As defined by Master Measurement List (MML)
- 31 Surface Thermocouple Plugs (Aerothermal)
- 25 Heatshield Pressure Ports (Aerodynamics)
- 19 Heatshield Thermal Plugs (TPS)
- ~~75 sensors total~~

- Total number reduced, based on consideration of:
  - Relative benefit
  - Integration Schedule
  - Integration Difficulty
  - Cost



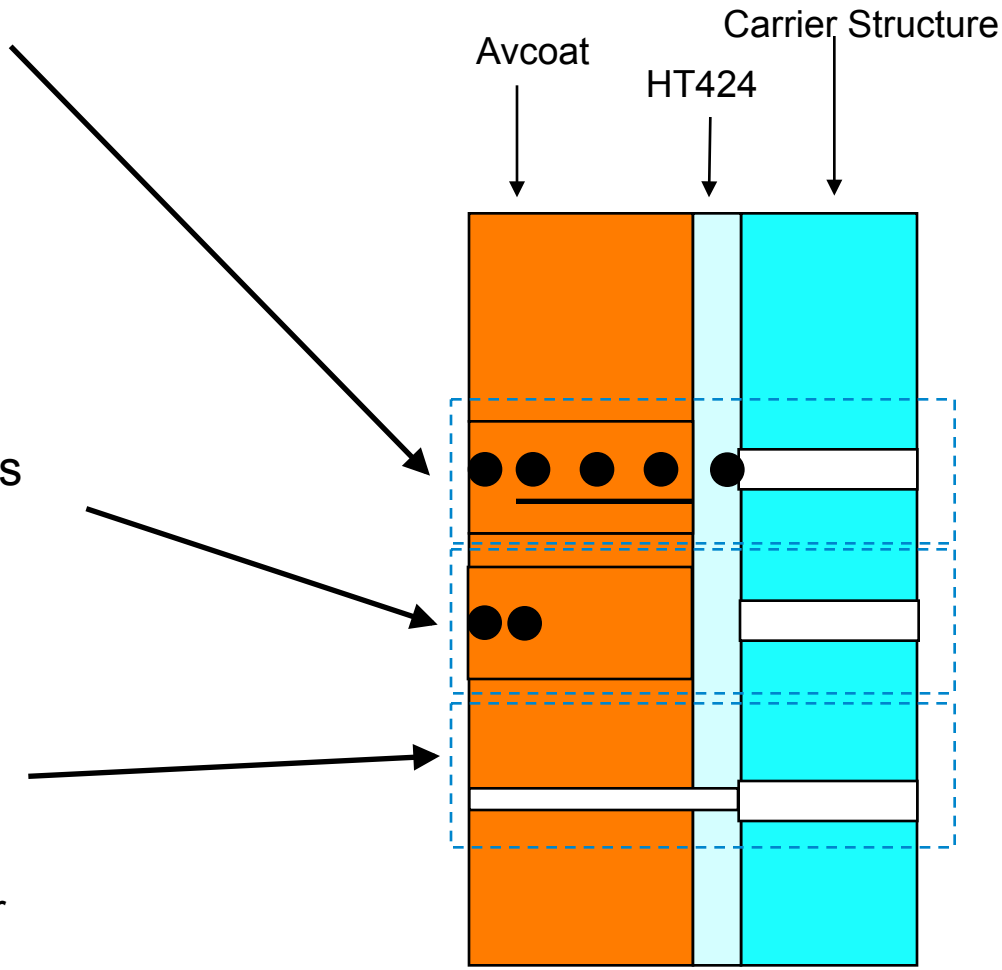
Updated Heatshield Instrumentation

- 19 Heatshield Thermal Plugs
  - ■ Symbol
    1 surface TC
    3 in-depth TCs,
    1 bondline TC
    Isotherm follower
- 15 Heatshield Aerothermal Plugs
  - ◆ Symbol
    1 surface TC, 1 embedded
- 9 Heatshield Pressure Ports
  - ● Symbol
    9 FADS - Pressure port and transducer
- 2 Radiometers
  - △ Symbol



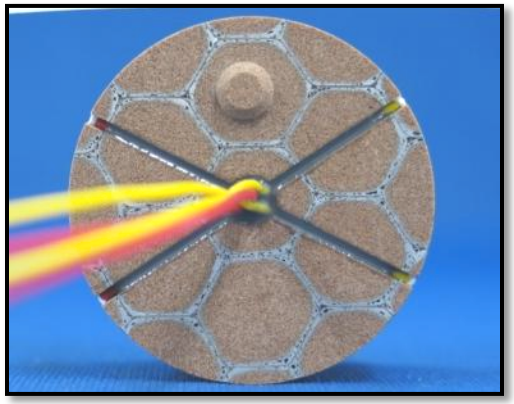
Heatshield DFI Sensor Types

- Heatshield Thermal Plugs
  - 1 near-surface TC
  - 3 in-depth TCs,
  - 1 bondline TC
  - HEAT sensor
- Surface Thermocouple Plugs
  - 1 near-surface TC
  - 1 in-depth TC
- Heatshield Pressure Ports
  - Not a plug
  - Pressure port and transducer

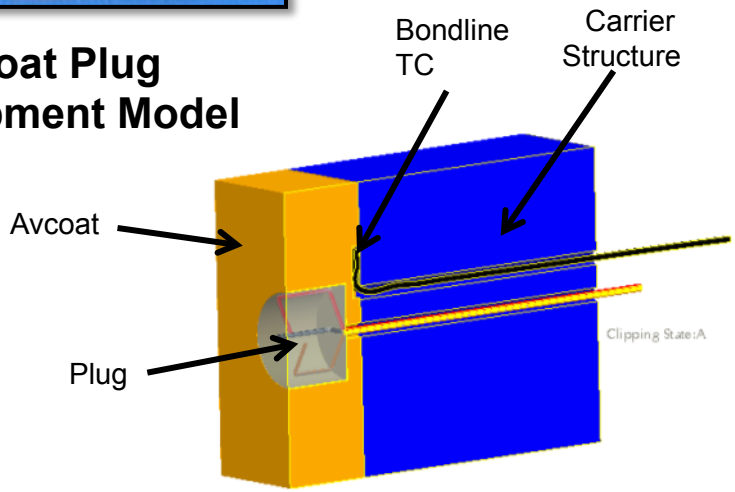


Thermal Plug Concept

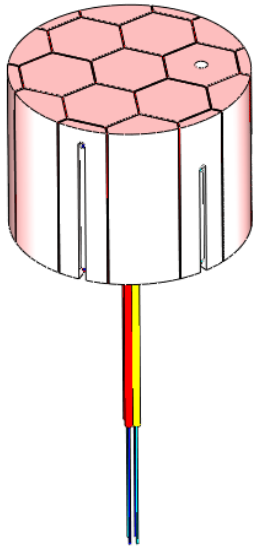
- Plug design derived from MSL Entry, Descent & Landing Instrumentation (MEDLI) Project
- Adapted for integration in Avcoat ablator

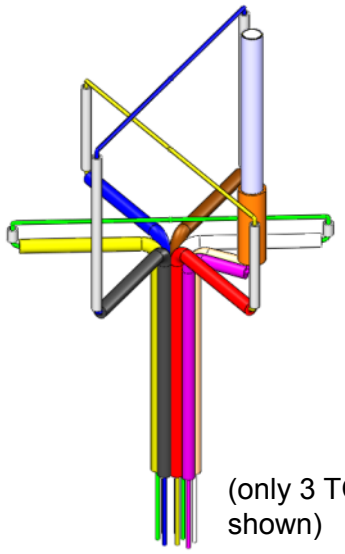


Avcoat Plug Development Model



Final Orion HS DFI Plug Design:





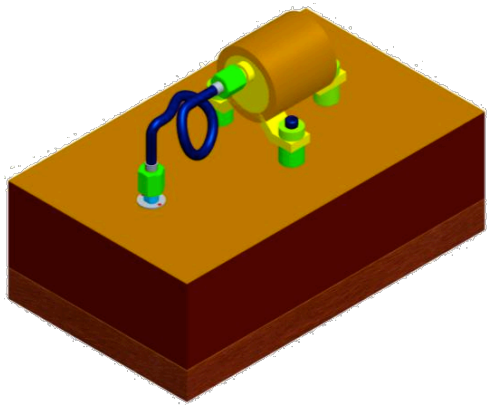
(only 3 TCs shown)

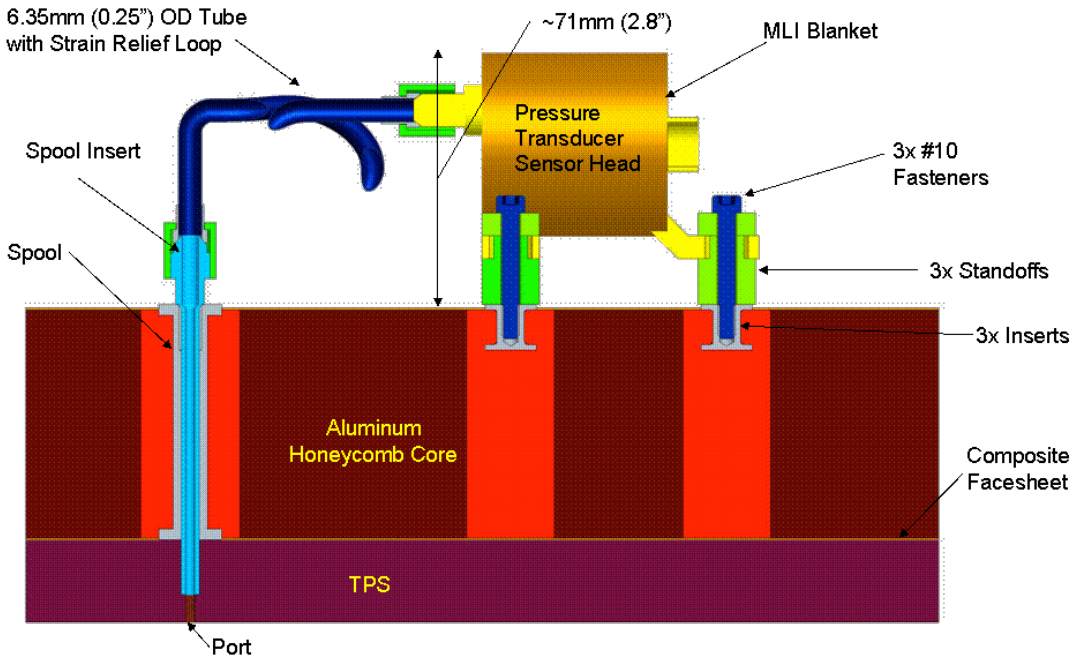
Thermal Plug:
- 4 in-depth TCs
- TCs at the required depth
- Compatible adhesive
- Hollow aErothermal Ablation and Temperature (HEAT) sensor

Aerothermal Plug
- 2 in-depth TC's

Pressure Port and Transducer Concept

- Leverage experience from past programs
- Utilize commercial off-the-shelf components, where applicable
- Confirm design compatible with Avcoat ablator

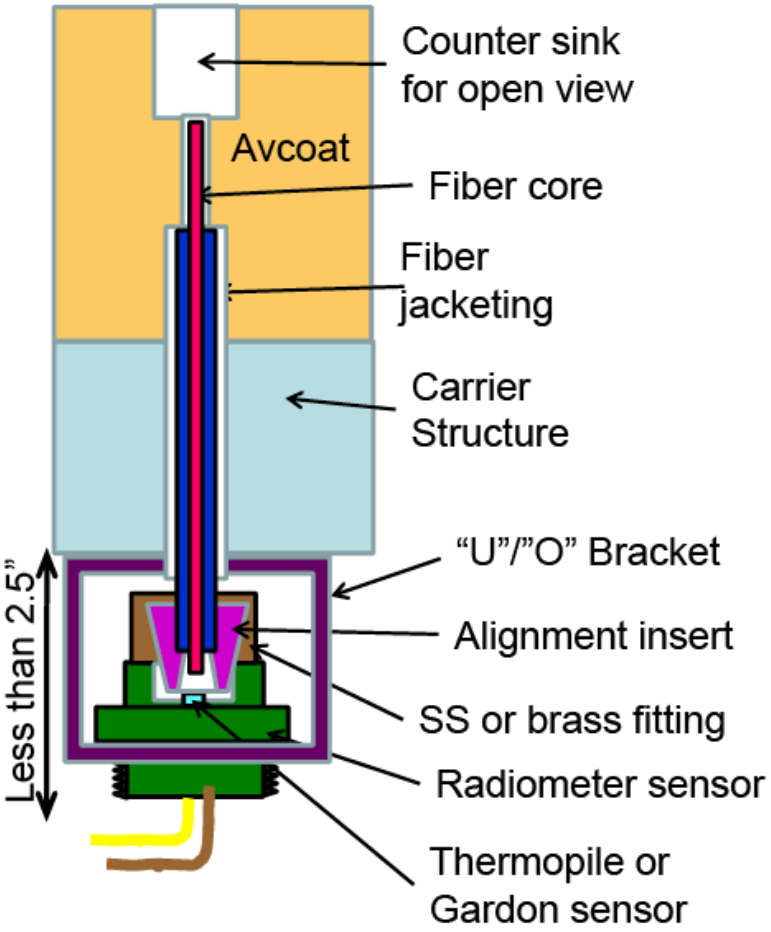




Avcoat Arcjet Model With Various Size Simulated Pressure Ports

Radiometer Design

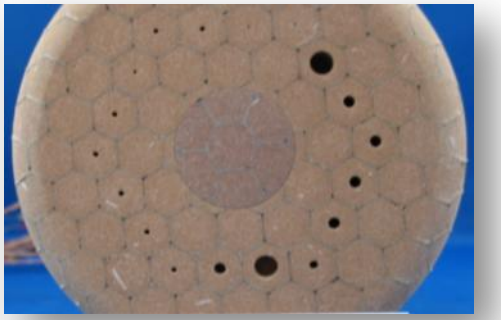
Radiometer Design Concept



Objective: Measure radiative component of incident heat flux

- OFT-1 reentry heating is primarily convective, but radiative heating is significant
- For NEO missions, heating from shock layer radiation dominates both heat rate and heat load
- Radiative heating uncertainty/margin is larger than convective heating uncertainty/margin, and will have a large mass impact on a heatshield sized for a NEO mission

Prior Development Model



Recent Avcoat Arcjet Model

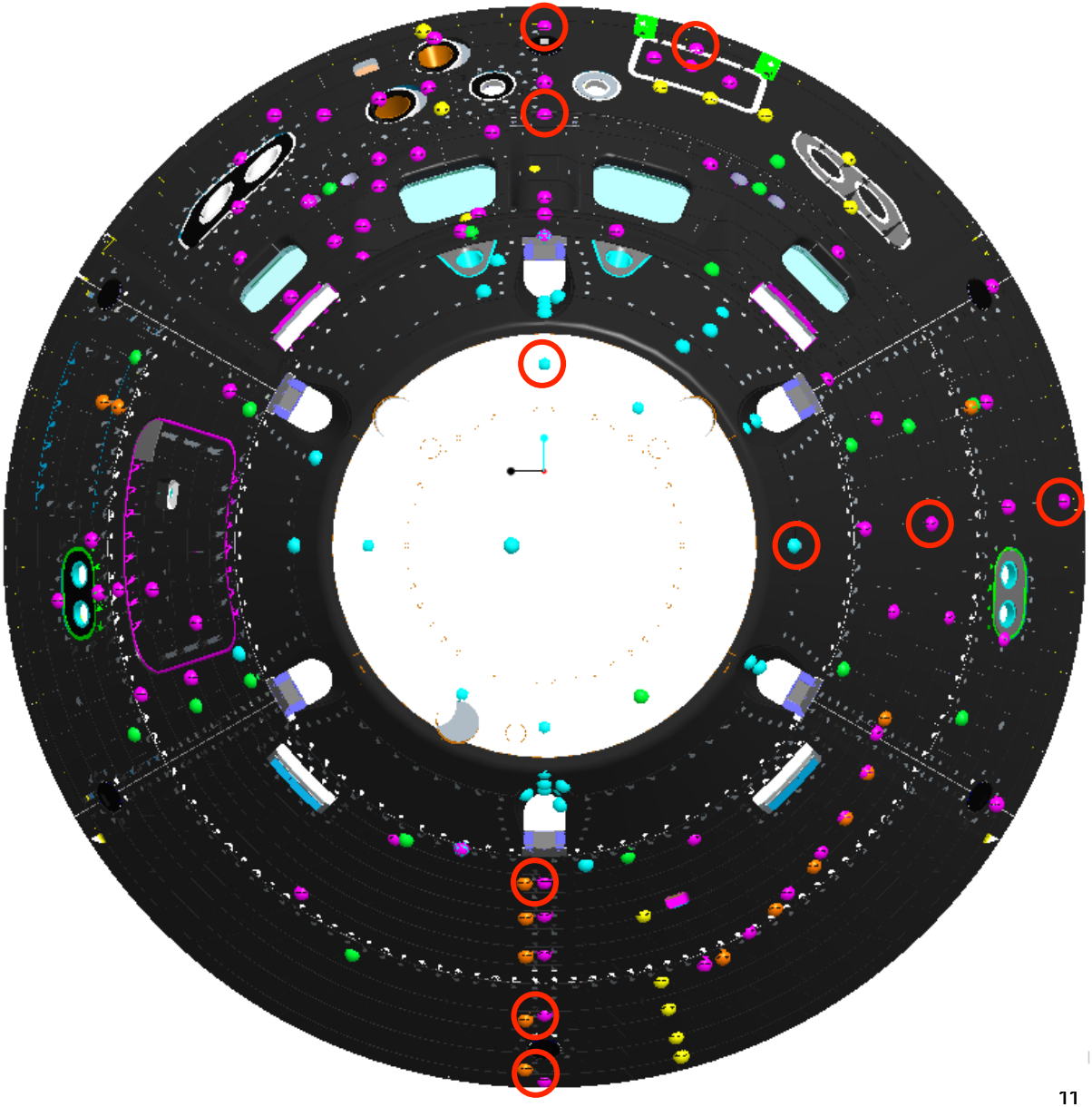
Backshell DFI Sensor Locations

- Pressure Sensors (33 total)

Temperature Sensors

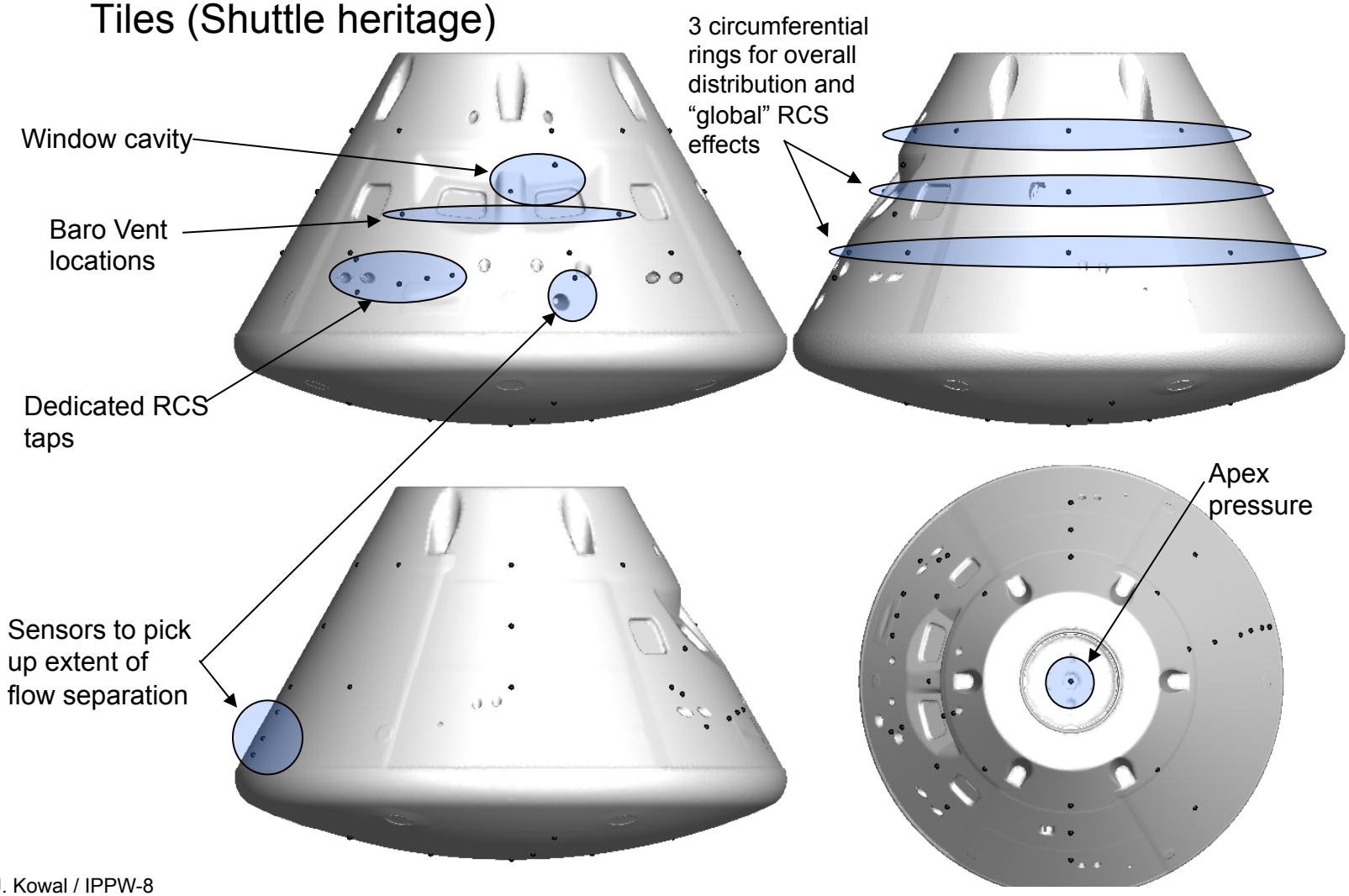
- 115 surface tc's
  - Backshell
  - FBC
- 10 Plugs (4 in-depth tc's)
  - Circled in Red

- Proposed relocations of temperature sensors



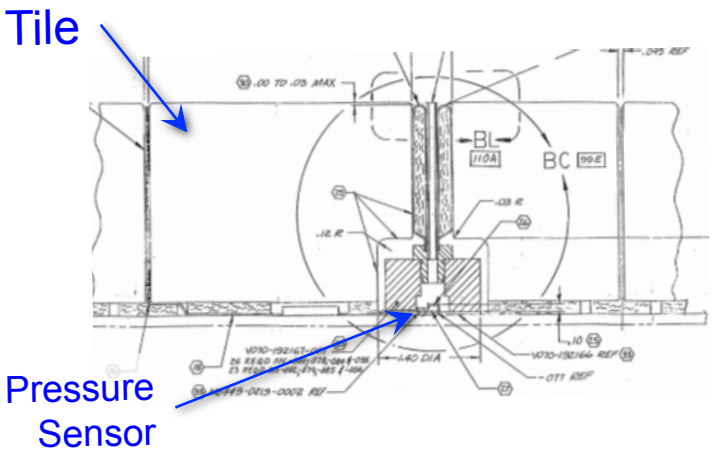
Backshell Pressure Sensor Locations

- 33 Pressure Sensors Total
  - Sensors embedded in ceramic TPS Tiles (Shuttle heritage)

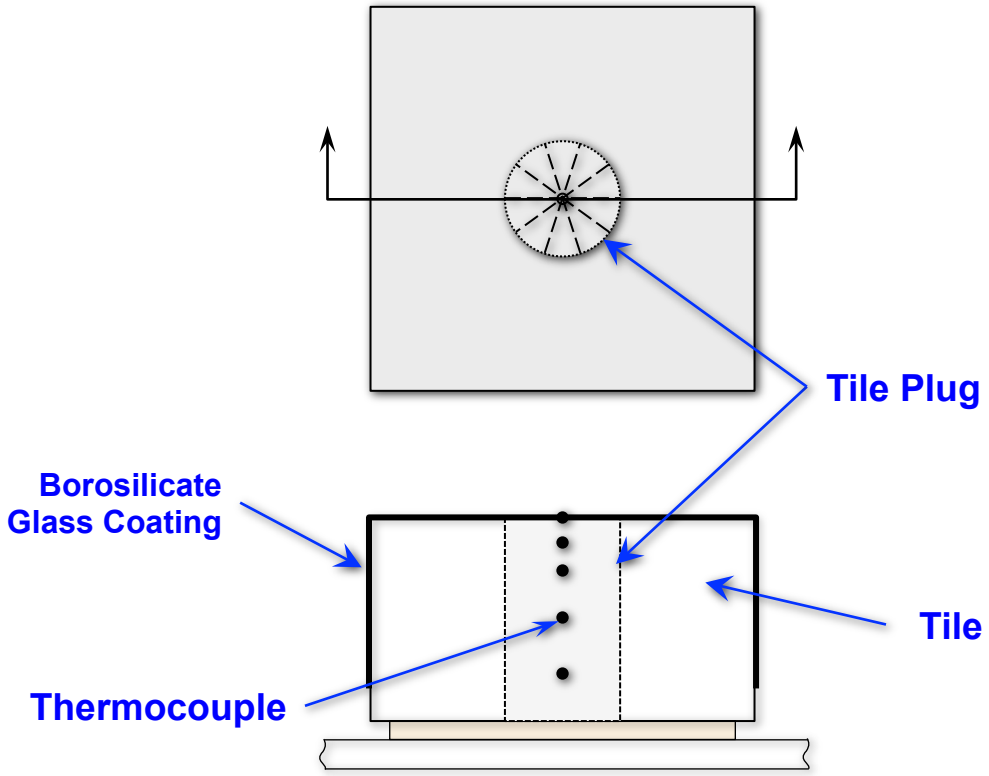


Backshell Instrumentation

- Backshell instrumentation based on Shuttle design heritage

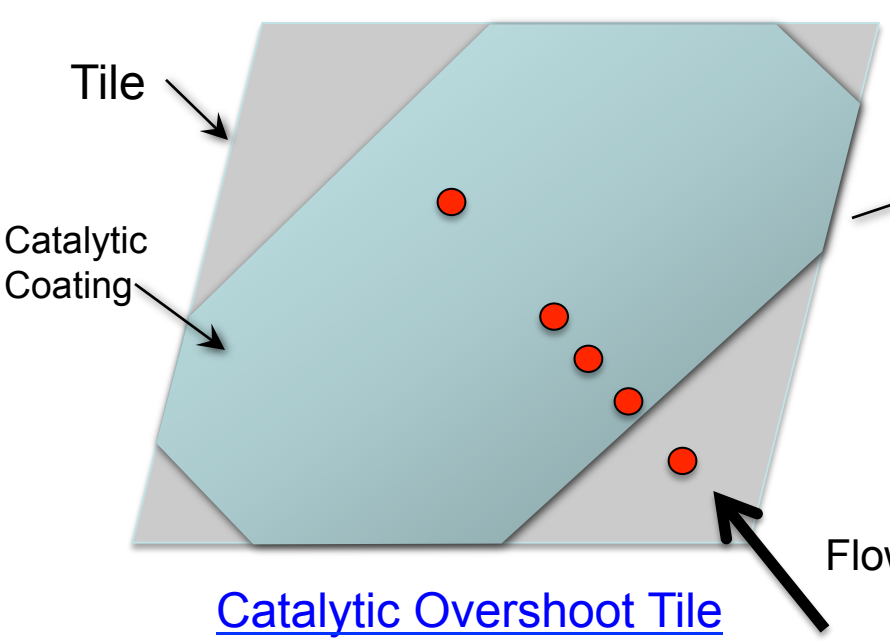


Space Shuttle Tile Pressure Port Design

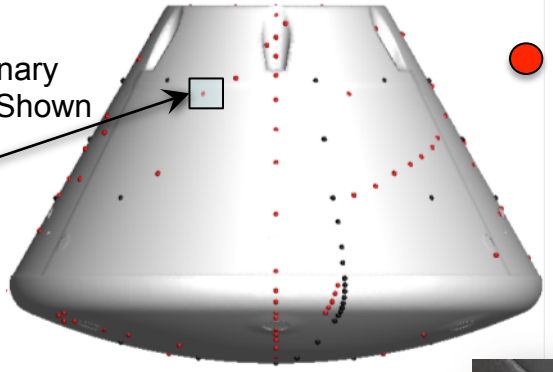


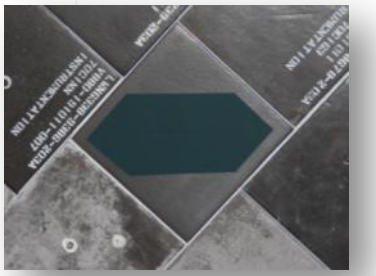
Space Shuttle Tile Thermocouple Installation (surface and in-depth tc's)

Catalytic Overshoot Experiment



Catalytic Overshoot Tile



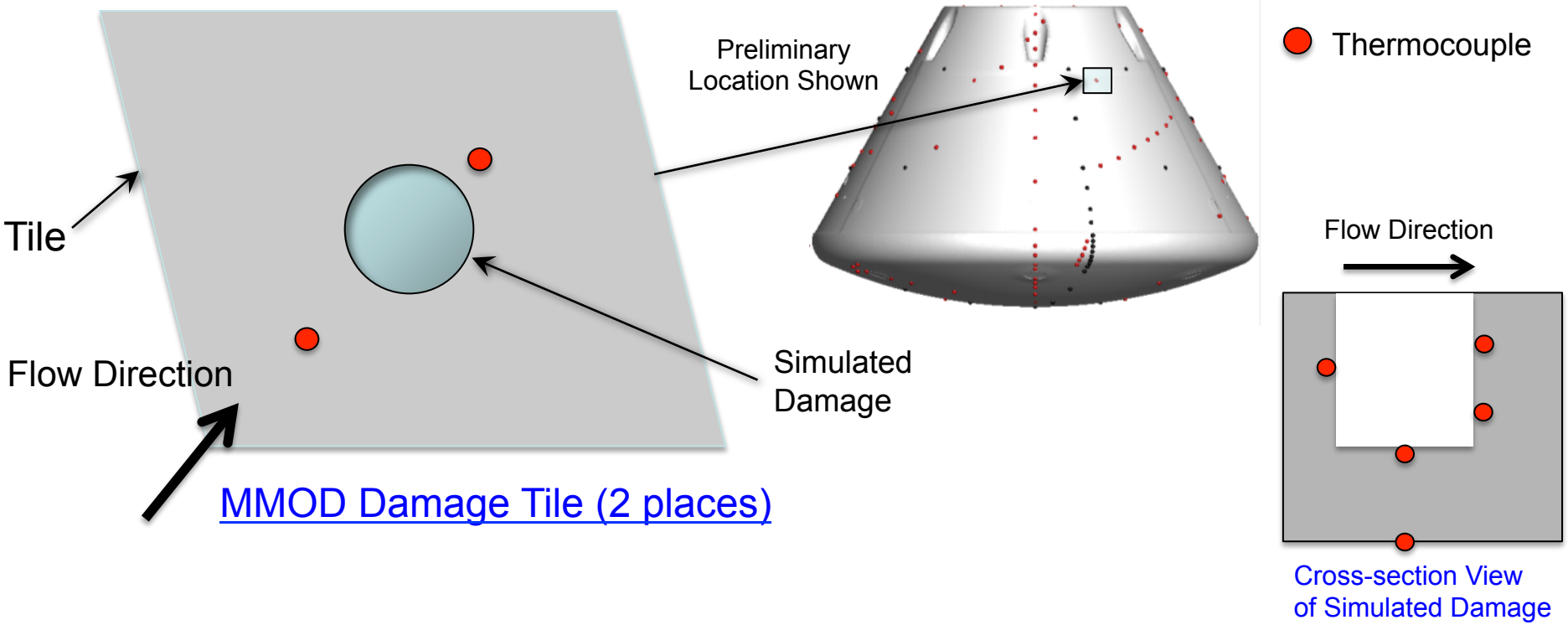


Tile with catalytic coating on Space Shuttle OV-103

- **OFT-1 FTO: Determine catalytic overshoot environments**
  - Determine aerothermal environment effects of isolated fully catalytic patches in non-catalytic acreage heatshield
  - Atomic nitrogen and oxygen recombine on catalytic surfaces increasing the heating relative to non-catalytic surfaces
  - Catalytic surfaces downstream of non-catalytic surfaces see an excess of atomic species
    - Amount of “catalytic overshoot” heating depends on the non-equilibrium chemical reaction rates that are poorly modeled
  - This phenomenon cannot be captured appropriately on the ground
  - OFT-1 provides unique opportunity to make measurements at greater than LEO reentry environment

Duplicates experience from Space Shuttle Program experiment and provides additional unique data

MMOD Damage Experiment



- OFT-1 FTO: Determine characteristics of MMOD cavity heating environment during re-entry
  - Determine aerothermal environments in cavities dimensionally similar to cavities resulting from MMOD impacts on orbit
  - Backshell tile thickness determined by MMOD requirements, and strongly coupled to aerothermal cavity heating environment
  - Current cavity heating model developed for shallow cavities (Shuttle heritage) and not for typical deep MMOD cavities

The Path Forward

- **The Orion MPCV is taking an incremental flight test approach to develop NASA's next crewed beyond-LEO spacecraft**
- **The first planned orbital flight test is Orion Flight Test-1 (OFT-1)**
- **The Orion Flight Test-1 crew module TPS will be instrumented with a variety of sensors to gather an unprecedented quantity and type of data during reentry to confirm beyond-LEO entry performance**

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