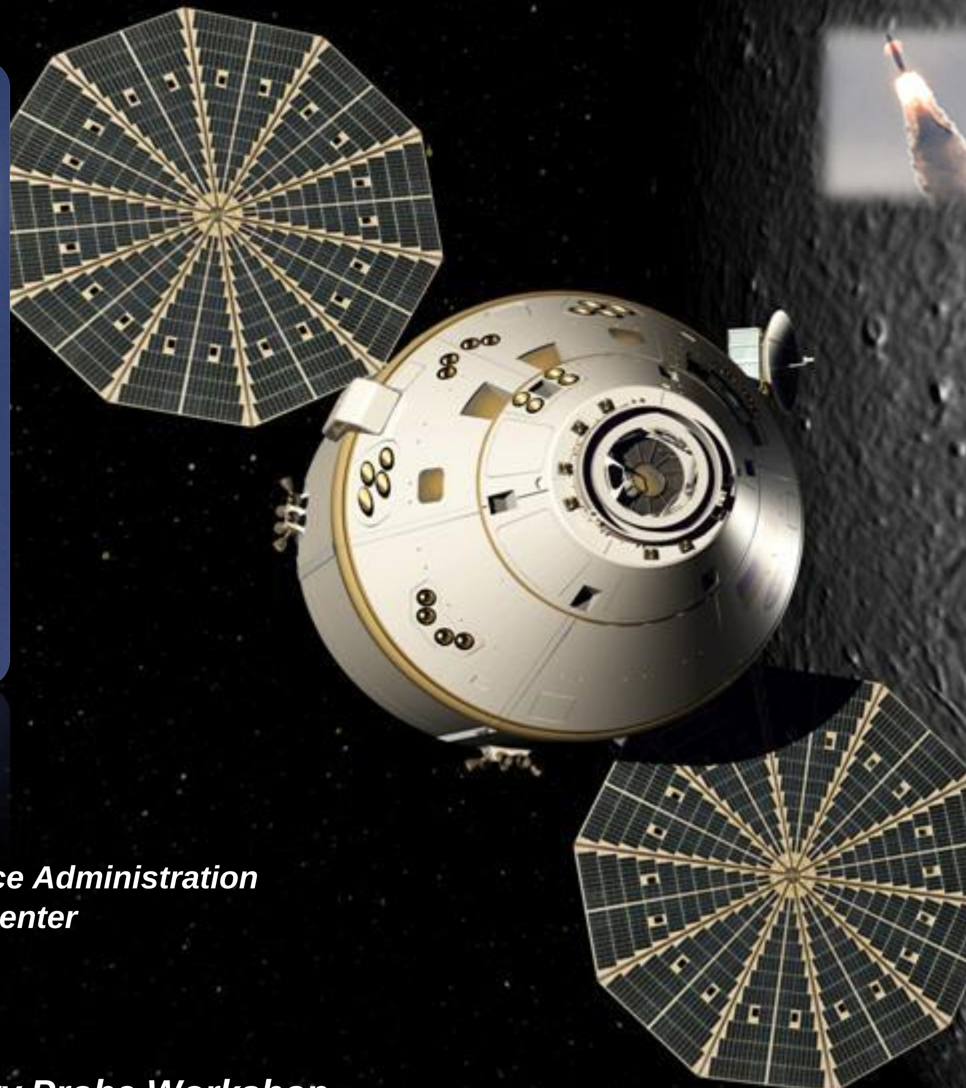
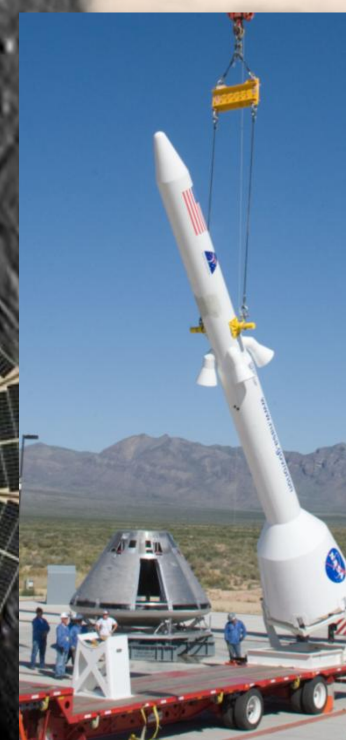
Overview of the Orion Thermal Protection System Development





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June 16, 2010
7th International Planetary Probe Workshop

Agenda

- **Background: Constellation & Orion Overview**
- **Backshell TPS Development**
- **Heatshield TPS Development**
- **Certification Approach**
- **Conclusions**

Crew Exploration Vehicle Project Office

The Constellation Program was born from the NASA Authorization Act of 2005 which stated….

The Administrator shall establish a program to develop a sustained human presence on the moon, including a robust precursor program to promote exploration, science, commerce and U.S. preeminence in space, and as a stepping stone to future exploration of Mars and other destinations.

NASA's Constellation Program Plan for Space Exploration

Crew Exploration Vehicle Project Office

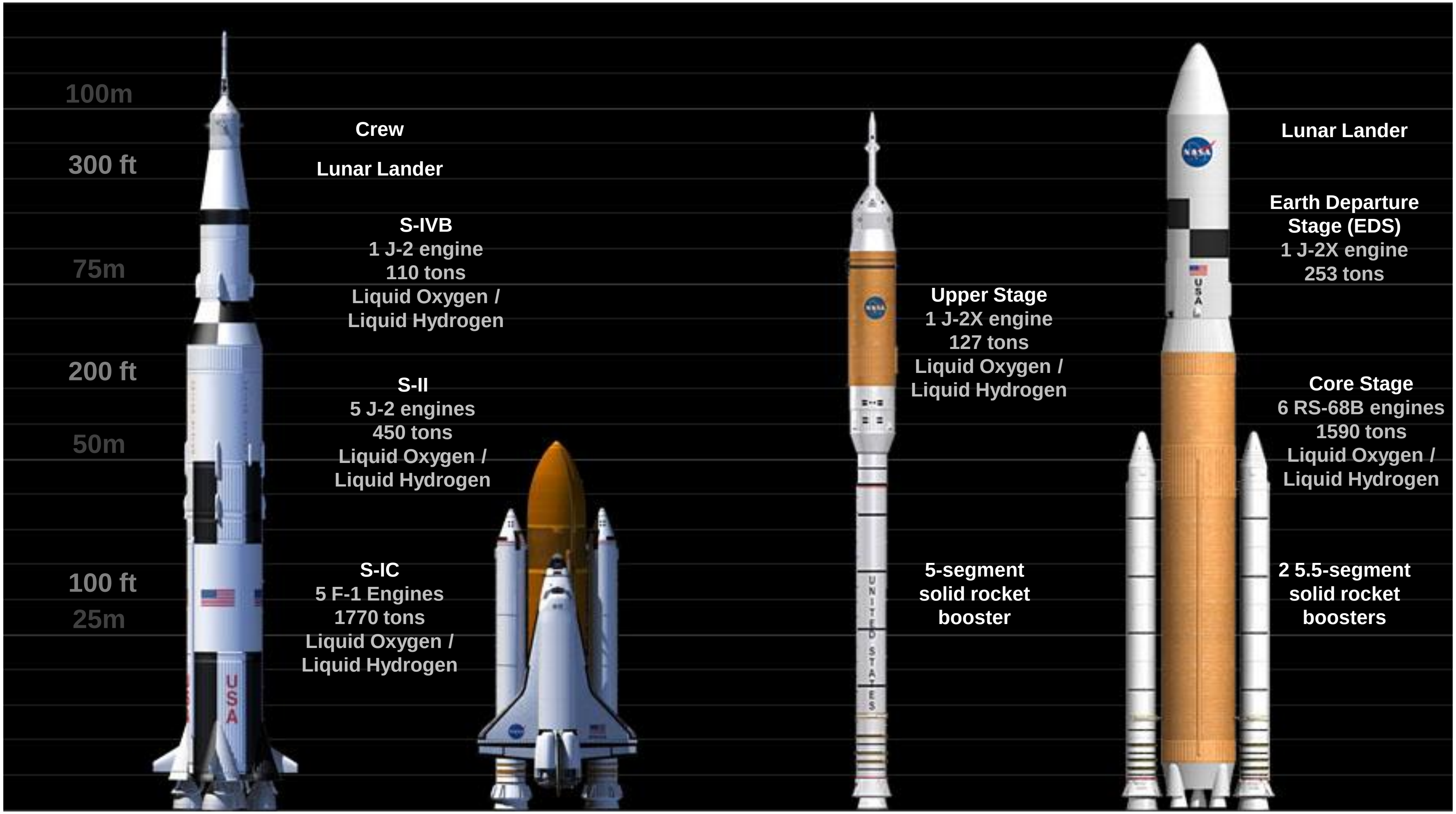
Safely fly the Space Shuttle and complete the International Space Station

Develop and fly the Orion crew exploration vehicle by 2015

Return to the moon by 2020

Promote international and commercial participation in exploration

Comparison of US Human Launch Vehicles

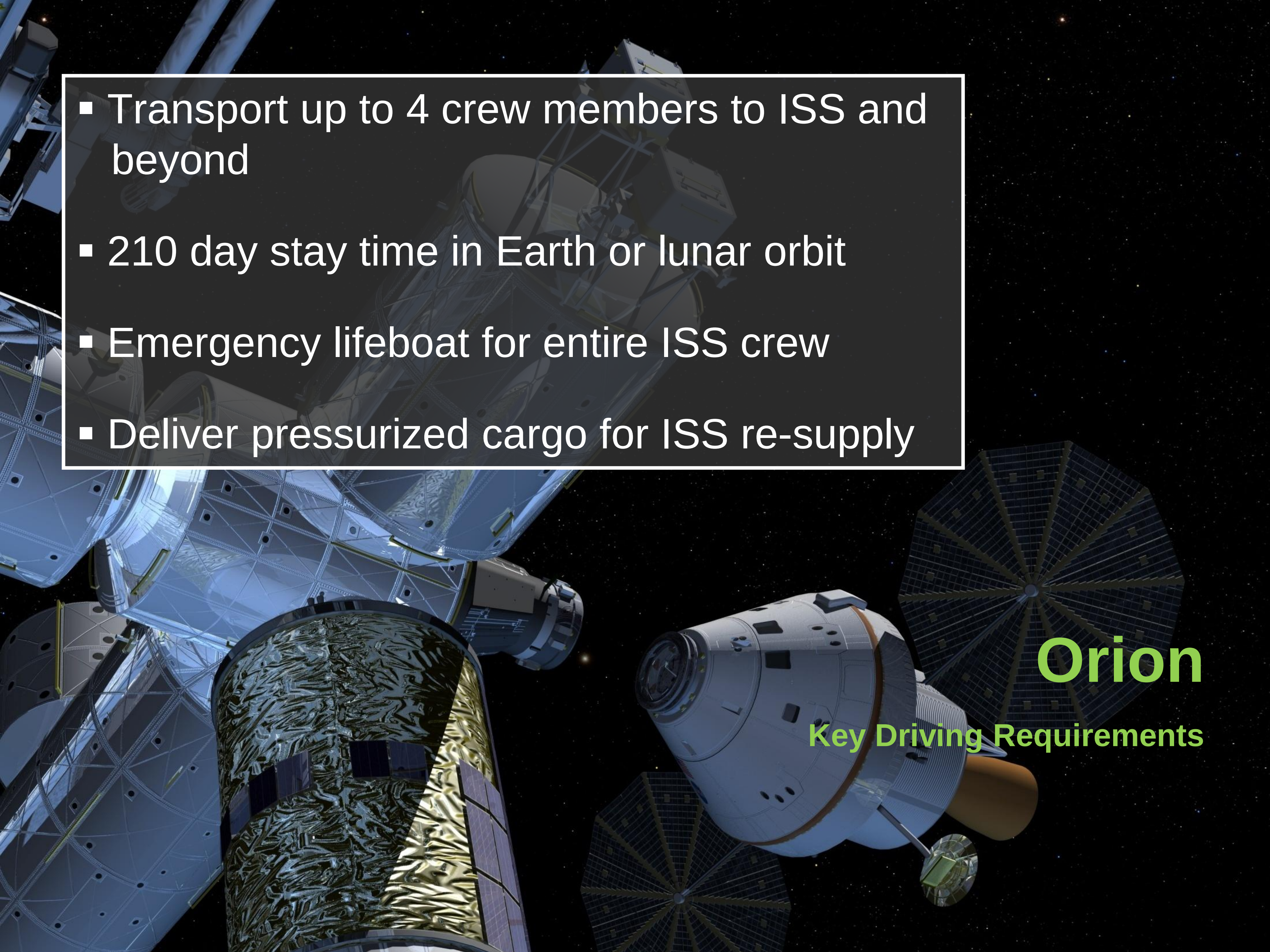


Saturn V
Height: 361 ft (110m)
119 tons to Low Earth Orbit
45 tons to the moon

US Space Shuttle
Height: 184 ft (56m)
25 tons to Low Earth Orbit

Ares I
Height: 322 ft (98m)
22 tons to Low Earth Orbit

Ares V
Height: 358 ft (109m)
175 tons to Low Earth Orbit
63 tons cargo to moon



Orion

Key Driving Requirements

- Transport up to 4 crew members to ISS and beyond
- 210 day stay time in Earth or lunar orbit
- Emergency lifeboat for entire ISS crew
- Deliver pressurized cargo for ISS re-supply

Orion System Elements

Orion consists of four functional modules

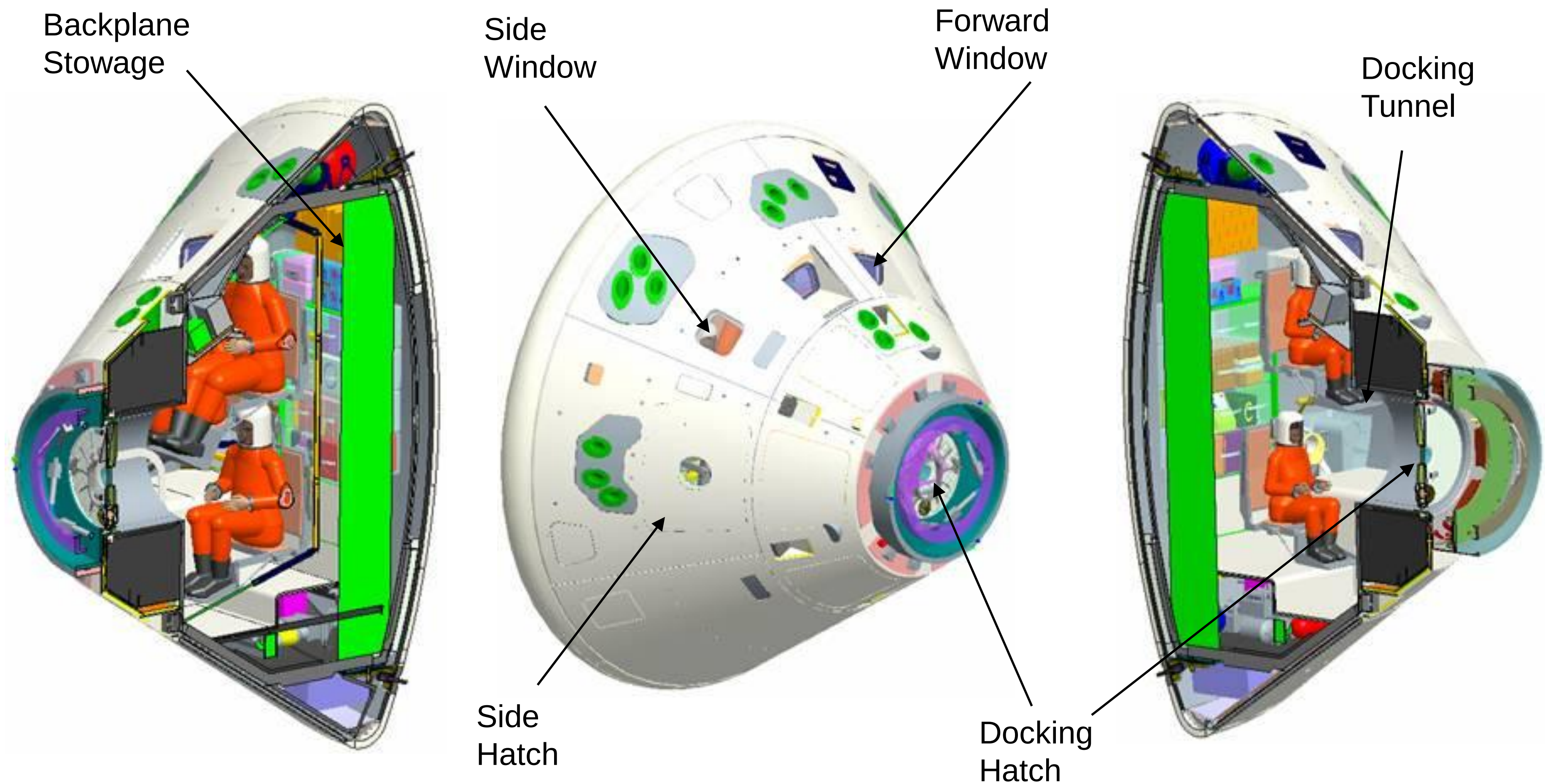
Launch Abort System --
emergency escape during launch

Crew Module –
crew and cargo transport

Service Module –
propulsion, electrical power, fluids storage

Spacecraft Adapter –
structural transition to launch vehicle

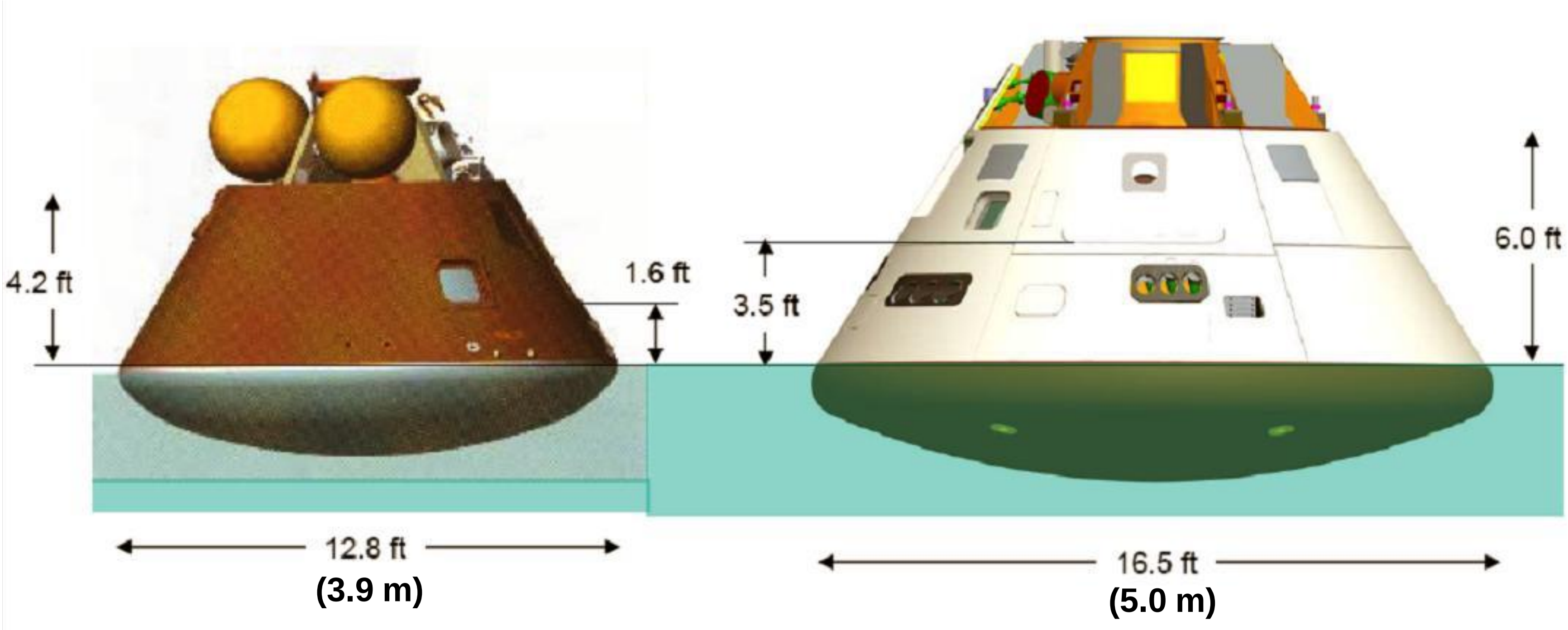
Crew Module Configuration Overview



Similar to Apollo but…..

Orion vs. Apollo

- Orion shape is derived from Apollo, but approximately 30% larger
  - Presents challenges to the TPS, including:
    - Increased heat loads
    - Manufacturing scale

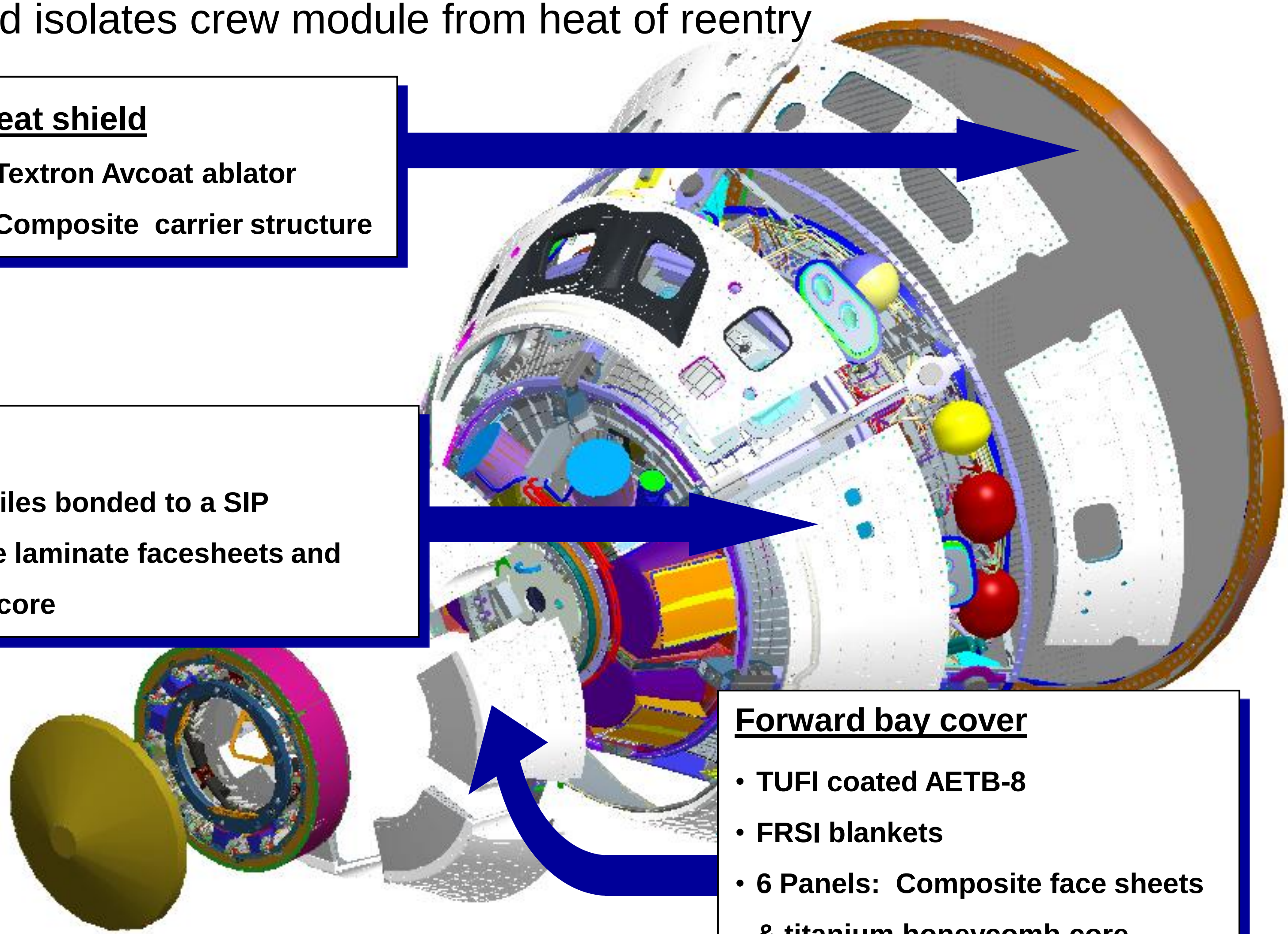


Comparison of Apollo to Orion floating in still water

Crew Module Thermal Protection System (TPS) Overview

Thermal protection system

- Defines OML aeroshape
- Dissipates and isolates crew module from heat of reentry



Heat shield

- **Textron Avcoat ablator**
- **Composite carrier structure**

Backshell

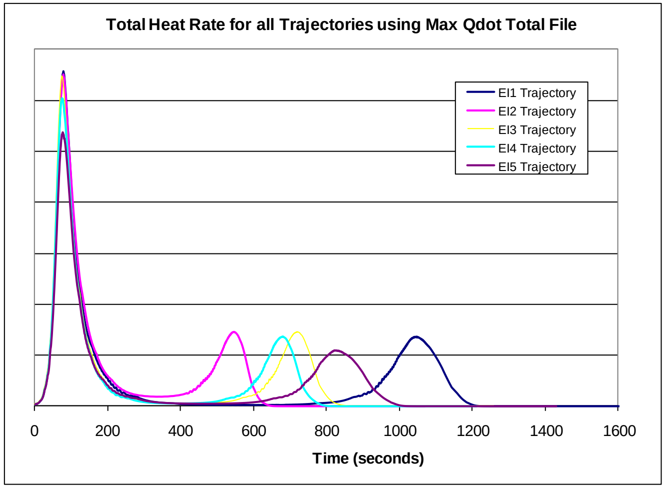
- **TUFI coated AETB-8 tiles bonded to a SIP**
- **10 panels : composite laminate facesheets and titanium honeycomb core**

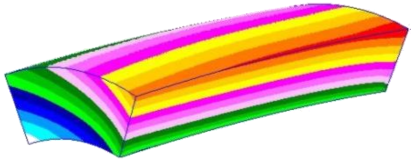
Forward bay cover

- **TUFI coated AETB-8**
- **FRSI blankets**
- **6 Panels: Composite face sheets & titanium honeycomb core**

Driving TPS Requirements

- Thermally sized for Lunar return 2500 nmi skip trajectory* to maintain bondline and structure below allowable temperature limits
  - Also assess direct entry, aborts and emergency return modes
- Single use system; nominal water landing
- Provide and maintain vehicle outer mold line (OML), within allowable tolerances
- Structurally designed for structural deflections, vibro-acoustic loads, pressure loads, thermal stress and pyro loads for all flight phases (ascent, ascent abort, on-orbit and entry)
- Satisfy subsystem allocations for:
  - Mass
  - Reliability
  - MMOD

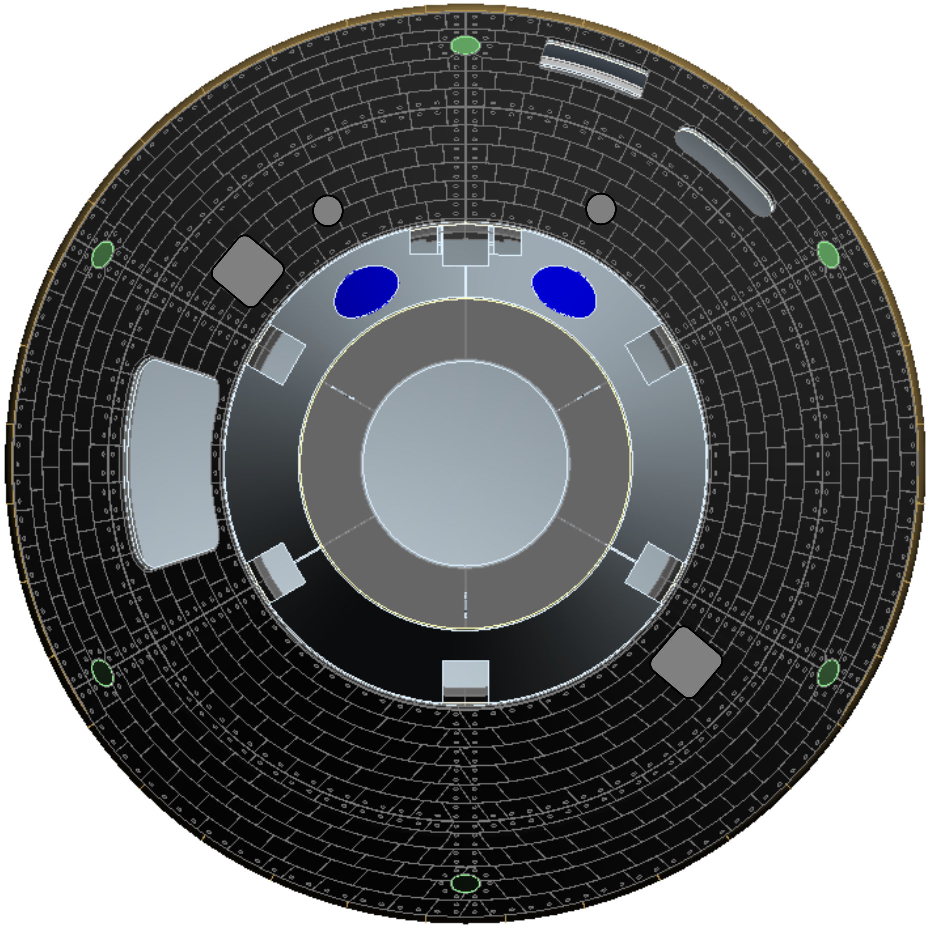




Backshell TPS Development

Backshell TPS Configuration

- Original baseline was SLA-561V with plasma sprayed aluminum coating for on-orbit thermal control
- TUFI coated AETB-8 tiles have replaced SLA for Backshell TPS material
  - AETB-8 tiles provide more mass-efficient MMOD protection
  - *A low α/low ε coating is still needed for tiles to provide on-orbit thermal control*
- Tile thickness is determined by MMOD requirements, in additional to nominal thermal requirements

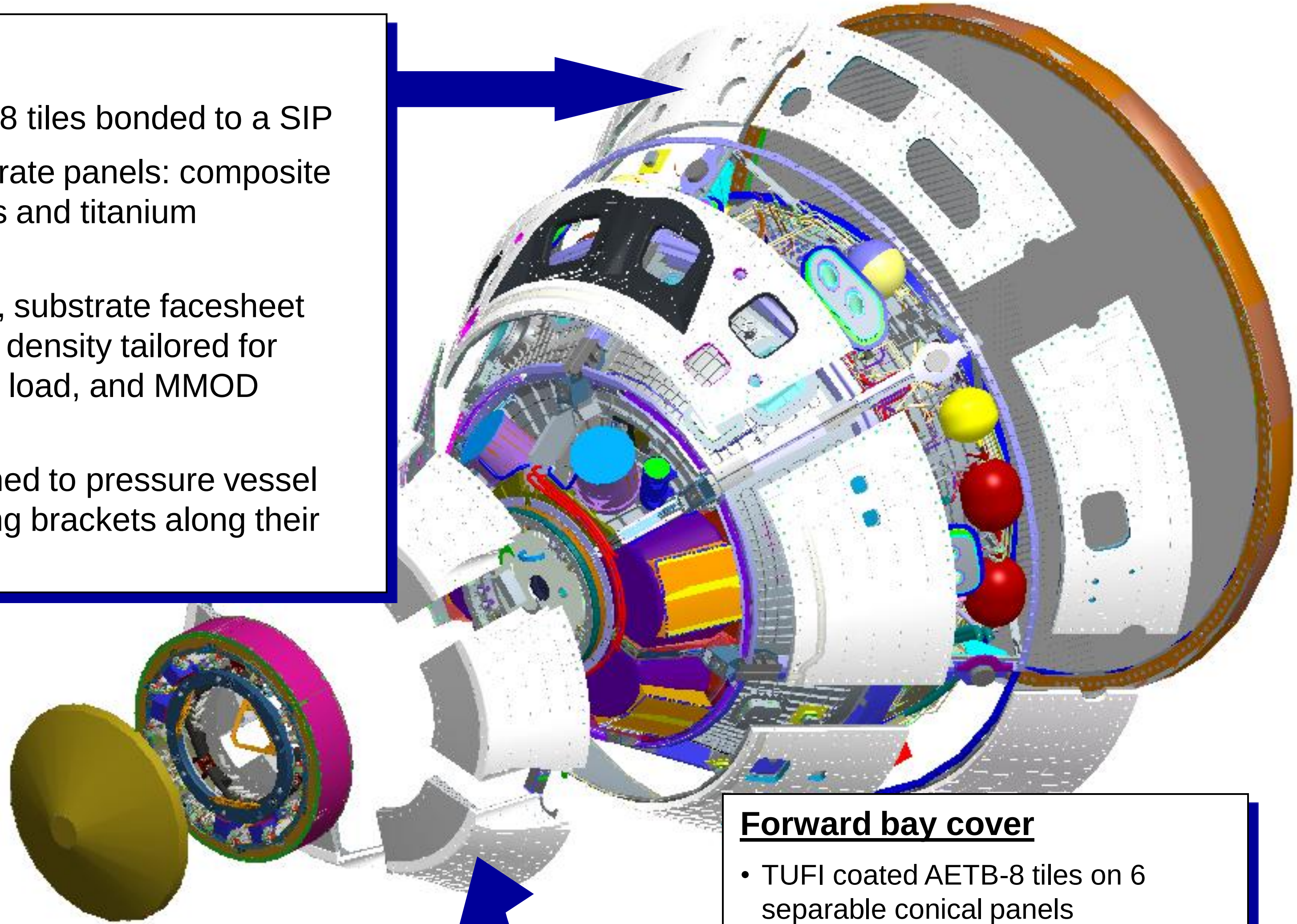


Pad Abort Test 2 (PA-2) Backshell Configuration

Backshell Thermal Protection System (TPS) Overview

Backshell

- TUFI coated AETB-8 tiles bonded to a SIP
- 10 composite substrate panels: composite laminate facesheets and titanium honeycomb core
- Panel tile thickness, substrate facesheet thickness, and core density tailored for thermal & structural load, and MMOD requirements
- Mechanically attached to pressure vessel with thermal isolating brackets along their edges

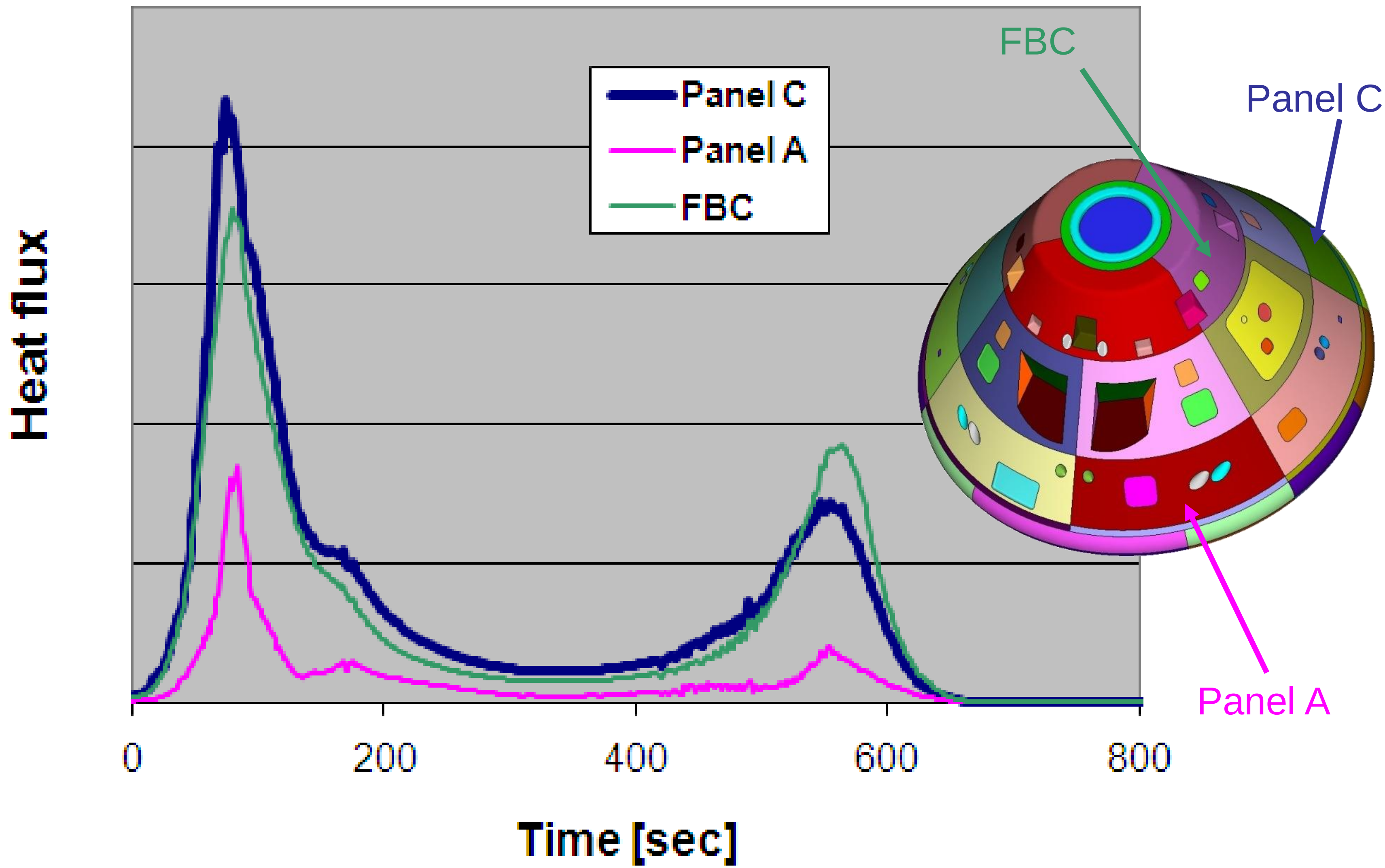


Forward bay cover

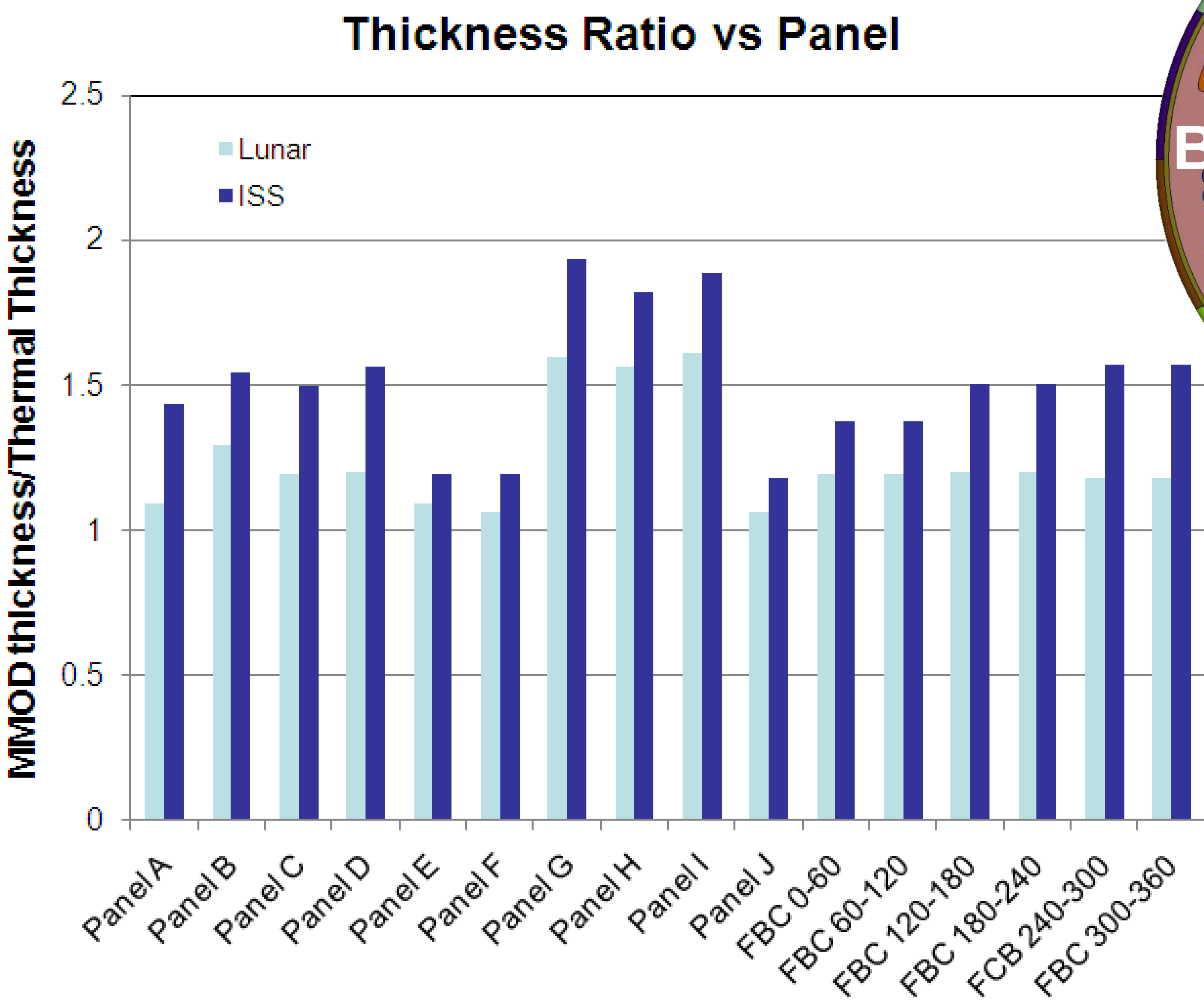
- TUFI coated AETB-8 tiles on 6 separable conical panels
- FRSI blankets on forward deck & docking hatch
- Composite face sheets & titanium honeycomb core

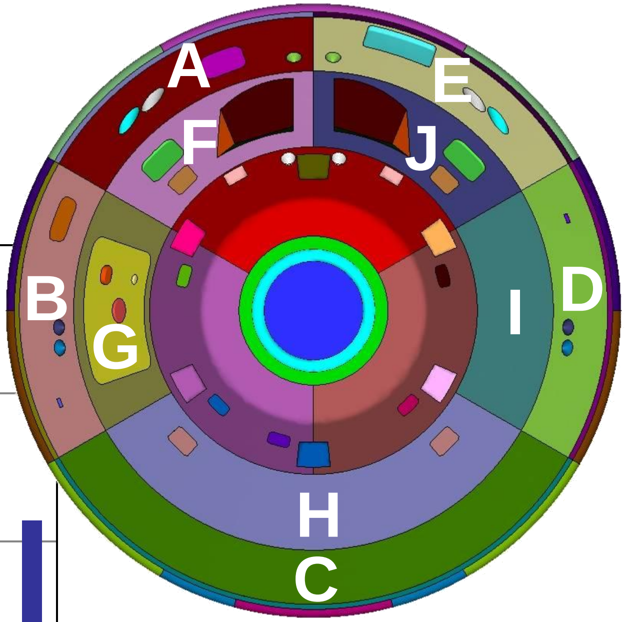
Heat Flux Distribution on Backshell

Nominal Skip Entry



Backshell Tile Thickness Driven by MMOD Requirements

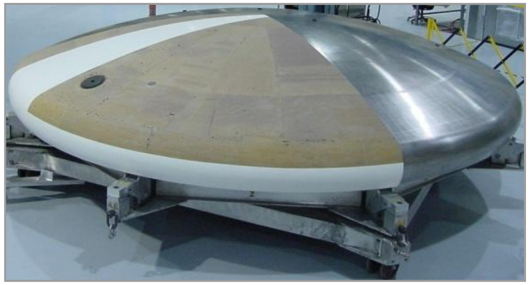




Note: Thermal thickness is Lunar-driven

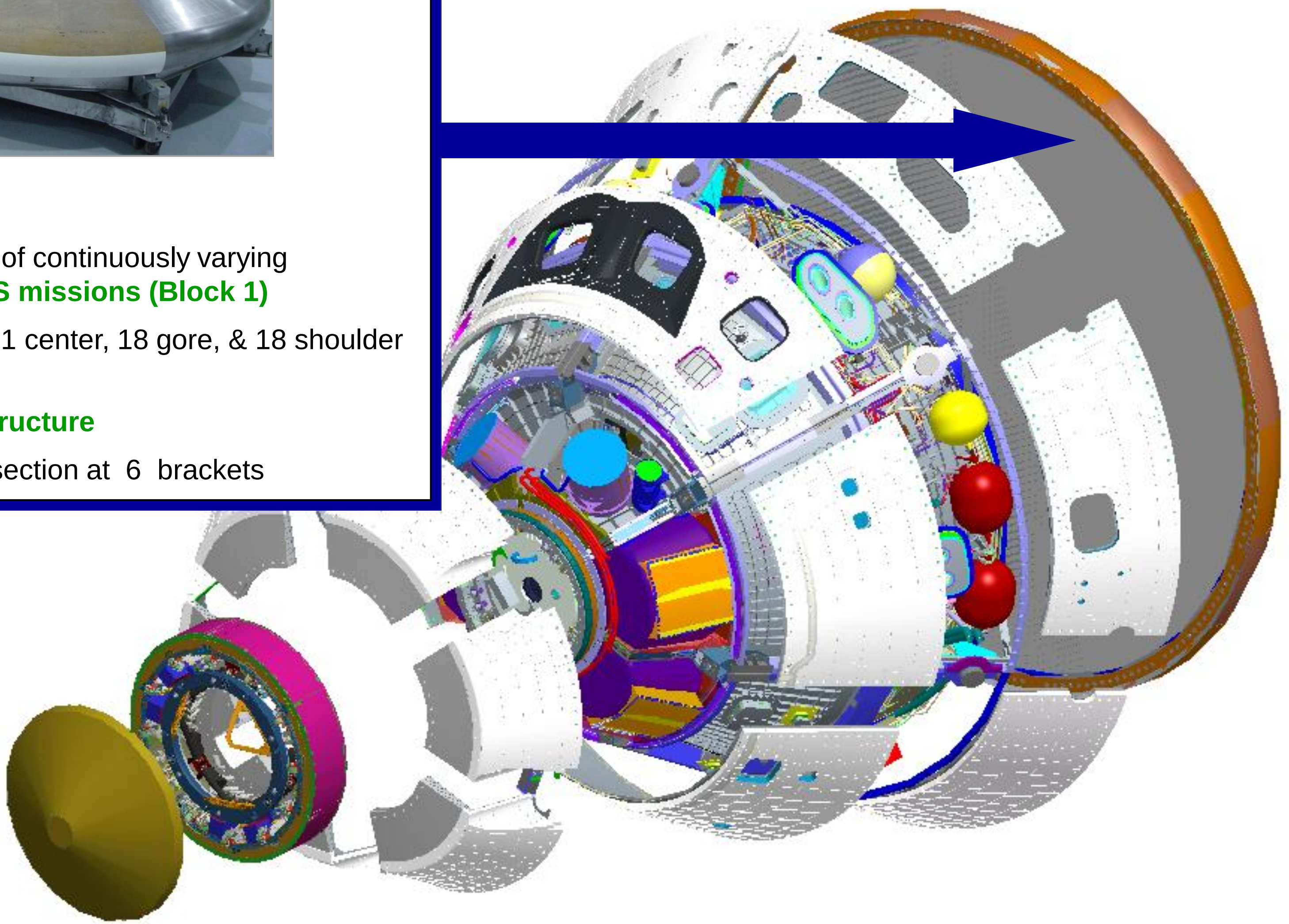
Heatshield TPS Development

Heatshield Thermal Protection System (TPS) Overview



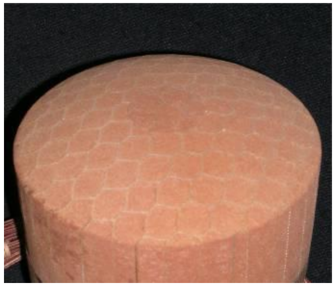
Heat shield

- Textron Avcoat ablator of continuously varying thickness **sized for ISS missions (Block 1)**
- Honeycomb applied in 1 center, 18 gore, & 18 shoulder panels
- **Composite carrier structure**
- Mounted to PV barrel section at 6 brackets



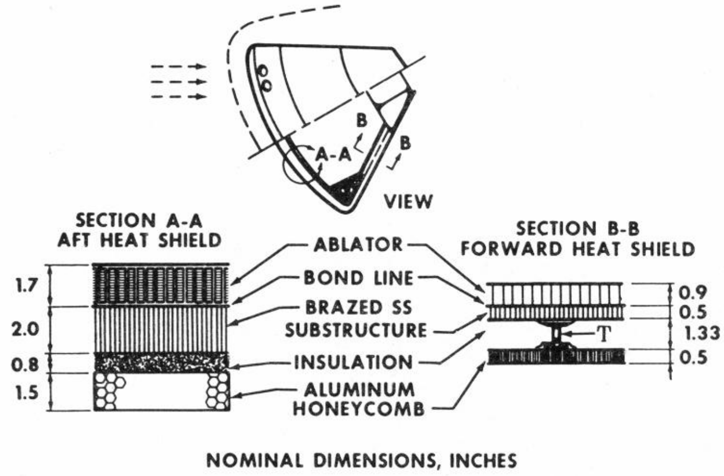
Avcoat Overview

AVCO 5026-39 HCG (Filled Epoxy Novalac in Fiberglas-Phenolic Honeycomb)



Apollo 11 Heat shield core

Avcoat – Thermal Protection for Apollo

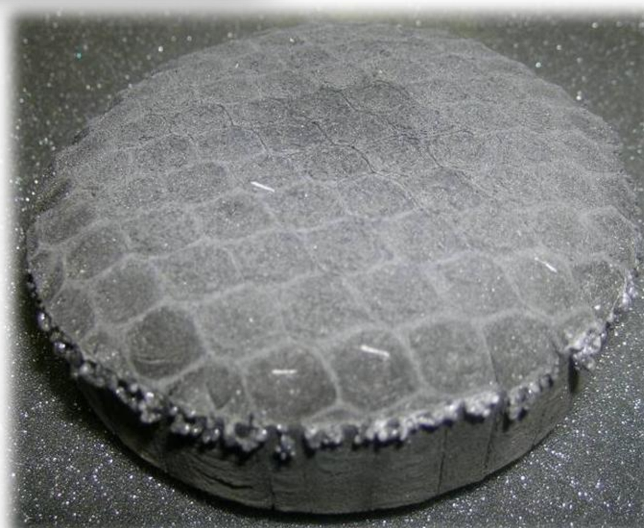


Material Recovery Challenges

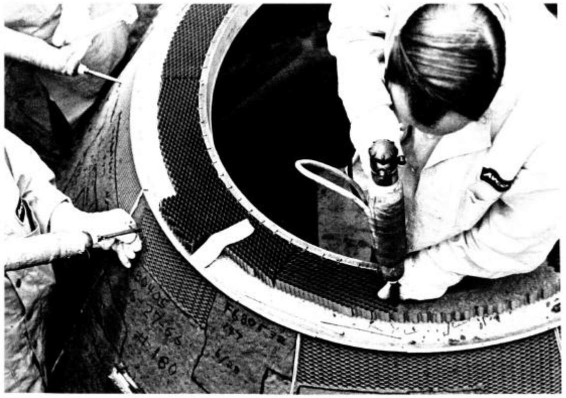
- **Some ingredients no longer available**
- **Re-developing manufacturing processes**
- **Training technicians to fill cells**

Crew Exploration Vehicle Project Office

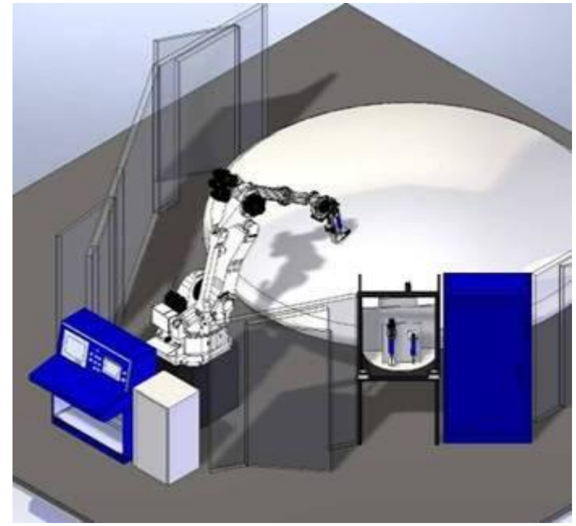
Comparison of Current Avcoat with Heritage Avcoat

Spring '07 Avcoat	March 1968 Avcoat
 	  

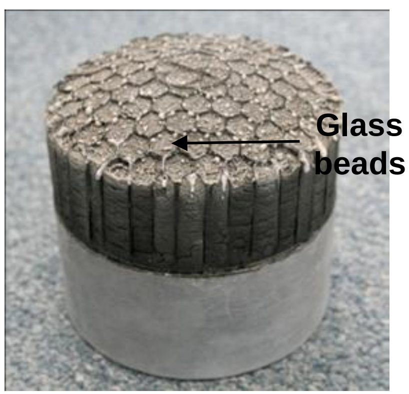
Avcoat Design/Manufacturing Challenges



AVCO technicians injecting ablator into honeycomb
(Apollo command module had 300,000 cells)



Automated cell-filling is being investigated



Silica in material complicates analytical modeling.

Honeycomb shaping and filling procedures around shoulder need development

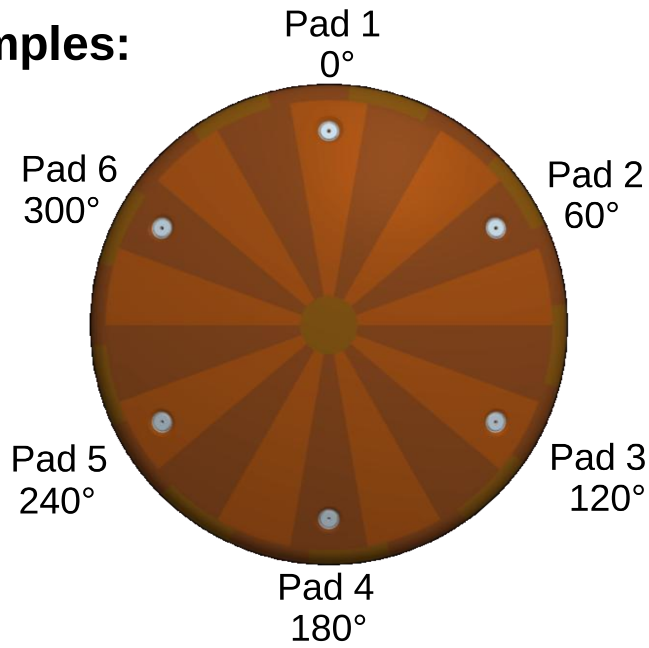
Ground Test Article Hardware

Backshell Panel C Tile Installation Complete

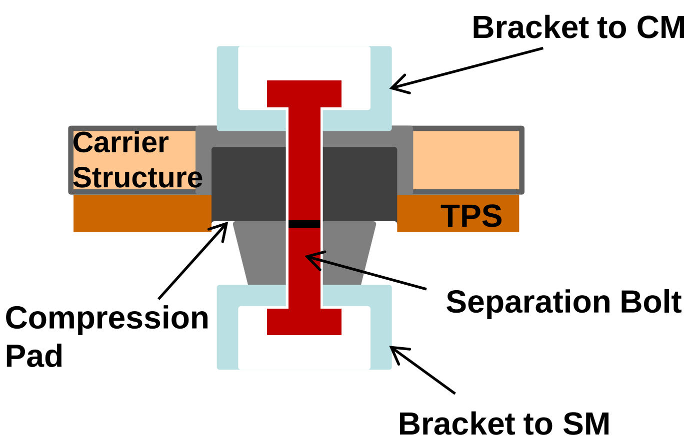
Heatshield Removed from Layup Mold

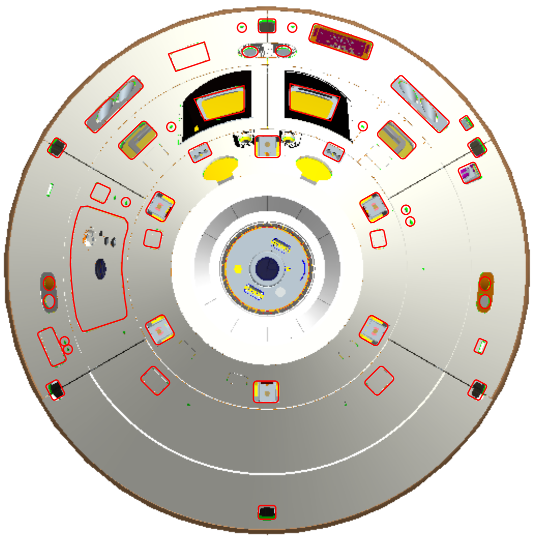
Current Design Challenges Leading to CDR

Examples:



CM/SM Attachment





Multiple penetrations present additional TPS tile and seal design challenges during final design phase

Certification Approach

Inputs to the TPS Certification Plan

Project Phases

Development → *Qualification* → *Acceptance*

TPS Certification Plan

Flight Phases

- Ground
- Transport
- Launch Pad
- Ascent
- Launch Abort
- On-orbit
- Entry
- Entry Abort
- Post-landing

Verification Methods

- Test
- Analysis
- Similarity
- Inspection
- Demonstration

Environments

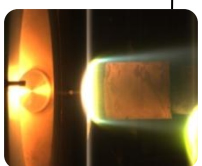
- Induced
  - Structural Deflections
  - Mechanical Loads
  - Acoustic Loads
  - Aerodynamic Loads
    - Convective Htg
    - Radiative Htg
    - Pressure
    - Shear Stress
  - Vibration Loads
  - Shock Loads
  - Accelerations
  - Venting
- Natural

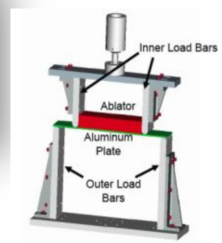
Risk Management

- Reliability calculations
- Failure Mode assessment
- Risk Mitigation

Test and Verification Progression

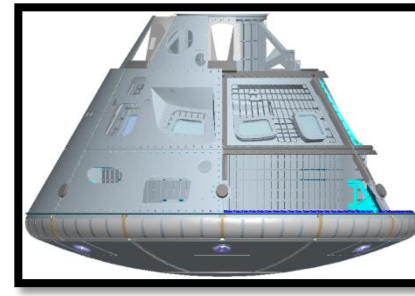

Coupon





4-pt Bend

Environmental Testing



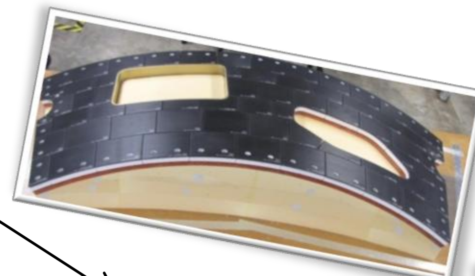
Ground Test Article

Material performance

Properties

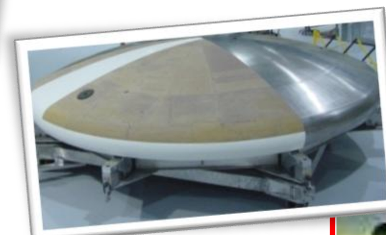
Design allowables

Element



Model development

Sub-component



Sub-system performance

Design development

Model validation

Design Verification

Component/Vehicle

Qualification

Acceptance

Conclusions

- The Orion thermal protection system (TPS) design successfully supported the vehicle preliminary design review (PDR) in Jun-Aug 2009
  - Backshell TPS consists of TUFI-coated AETB-8 tiles
  - Heatshield TPS is Apollo-heritage Avcoat ablator
- The Orion project is in Phase C – developing the “build-to” design
  - CDR currently scheduled for February 2011
- The overall Agency approach to future exploration, including the role of the Orion vehicle, is under revision at this time