Overview of the Orion Thermal Protection System Development

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Agenda

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

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
- 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 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

*trajectory
Backshell TPS Development
Backshell TPS Configuration

- Original baseline was SLA-561V with plasma sprayed aluminum coating for on-orbit thermal control

- TUF coated AETB-8 tiles have replaced SLA for Backshell TPS material
  - AETB-8 tiles provide more mass-efficient MMOD protection
  - A low $\alpha$/low $\varepsilon$ coating is still needed for tiles to provide on-orbit thermal control

- Tile thickness is determined by MMOD requirements, in addition to nominal thermal requirements
**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

Heat flux vs. time [sec]
- Panel C
- Panel A
- FBC

Panel C
Panel A
FBC
Backshell Tile Thickness Driven by MMOD Requirements

Thickness Ratio vs Panel

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)

Avcoat – Thermal Protection for Apollo

Apollo 11
Heat shield core

Material Recovery Challenges

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

Pad 1
0°

Pad 2
60°

Pad 3
120°

Pad 4
180°

Pad 5
240°

Pad 6
300°

CM/SM Attachment

Bracket to CM

Carrier Structure

TPS

Compression Pad

Separation Bolt

Bracket to SM

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

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

TPS Certification Plan

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

Verification Methods
- Test
- Analysis
- Similarity
- Inspection
- Demonstration

Risk Management
- Reliability calculations
- Failure Mode assessment
- Risk Mitigation
Test and Verification Progression

- Coupon
  - Material performance
  - Properties
  - Design allowables
  - Model development

- Element
  - Environmental Testing
    - 4-pt Bend

- Sub-component
  - Sub-system performance
    - Design development
  - Model validation

- Component/Vehicle
  - Design Verification
  - 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