THERMAL & FLUIDS ANALYSIS WORKSHOP 2007
ARES THERMAL OVERVIEW – SEPT 13, 2007

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ABSTRACT:

As part of a Constellation session at the 2007 Thermal & Fluids Analysis Workshop (TFAWS), an overview of the Crew Launch Vehicle (CLV), Crew Exploration Vehicle (CEV) and Lunar Lander systems will be given. This presentation provides a general description of the CLV (also known as Ares-I) and Ares-V vehicles portion of the session. The presentation will provide an overview of the thermal requirements, design environments, challenges and thermal modeling examples.
TFAWS
Ares Thermal Overview
Sept. 13, 2007

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Topics

- Ares in CxP Hierarchy
- General Ares Description/Orientation
- Ares I Thermal Overview
  - Requirements
  - Design Environments
  - Challenges
  - Thermal Modeling
  - Status
Ares in CxP Hierarchy

- Ares I is Two-Stage Launch System for the Orion Crewed Vehicle (CEV)
  - The first test flight, Ares I-1, will be a suborbital test of the booster with an inert fifth SRB segment and a dummy second stage with mock-up engines. April 2009

- Ares V is Cargo “heavy lift” launch system for the Lunar Surface Access Module (LSAM)
Ares in CxP Schedule

- Initial Orion (CEV) Capability
- Lunar Robotic Missions
- Science Robotic Missions
- Commercial Crew/Cargo for ISS
- Space Shuttle Operations
- Orion Development
- Ares I Development
- Lunar Lander Development
- Ares V & Earth Departure Stage
- Surface Systems Development
- Lunar Outpost Buildup
- Mars Expedition
General Ares Description/Orientation

Space Shuttle
- Height: 184.2 ft
- Gross Liftoff Mass: 4.5M lb
- 55k lbm to LEO

Ares I
- Height: 328 ft
- Gross Liftoff Mass: 2.0M lb
- 52k lbm to LEO

Ares V
- Height: 362 ft
- Gross Liftoff Mass: 7.3M lb
- 133-144k lbm^{*} to TLI in Dual-Engined Mode, 171k lbm in Single-Engine Mode

Saturn V
- Height: 364 ft
- Gross Liftoff Mass: 6.5M lb
- 99k lbm to TLI

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Lunar Lander
- Upper Stage (1 J-2X)
  - 305k lb LOx/LH\(_2\)
- Core Stage
  - (5 RS-68 Engines)
  - 3.1M lb LOx/LH\(_2\)
- Two 5-Segment RSRBs

Earth Departure Stage (EDS) (1 J-2X)
- 493k lb LOx/LH\(_2\)

Crew Lander
- S-IVB
  - (1 J-2 engine)
  - 240k lb LOx/LH\(_2\)
- S-II
  - (5 J-2 engines)
  - 1M lb LOx/LH\(_2\)
- S-IC
  - (5 F-1 engines)
  - 3.9M lb LOx/RP

\(^{*}\)body mass to TLI
General Ares Description/Orientation

**Ares-I**

- **Orion**
  - 16.5 ft diameter

- **Instrument Unit**
  - 7075-AL alloy Structure
  - USPC
  - Avionics boxes
  - NASA Design / Contractor Production
  - Flight Software Development
  - NASA Design / Contractor Production

- **Upper Stage**
  - 305 klb LOx/LH₂ stage
  - 18 ft diameter
  - Aluminum-Lithium (Al-Li) structures
  - Instrument unit and interstage
  - Reaction Control System (RCS) / roll control for 1st stage flight
  - Primary Ares 1 avionics system
  - NASA Design / Contractor Production

  **Upper Stage Engine**
  - Saturn J-2 derived engine (J-2X)
  - Expendable
  - Pratt and Whitney Rocketdyne

- **Stack Integration**
  - 2M lb gross liftoff weight
  - 328 ft length
  - NASA-led

- **First Stage**
  - Derived from current Shuttle RSRM/B
  - Five segments/Polybutadiene Acrylonitrile (PBAN) propellant
  - Recoverable
  - New forward adapter
  - Avionics upgrades
  - ATK Launch Systems

- **Interstage Cylinder**

- **LAS**

- **Spacecraft Adapter**
General Ares Description/Orientation

**Ares-V**

- **Composite Shroud**
- **Earth Departure Stage**
  - LOx/LH2
  - One J2X+ Engine
  - Al-Li Tanks/Structures
- **Interstage**
- **Upper Stage Engine**
  - Saturn J-2 Derived Engine (J-2X)
  - Expendable
- **Core Stage**
  - LOx/LH2
  - Five RS68 Engines
  - Al-Li Tanks/Structures
- **Five Segment RSRBs**

Ascent Stage

Descent Stage

{LSAM}
Ares I NASA Field Centers & Prime Contractors

GRC
US Haz Gas & Purge
Thrust Vector Control
Ares 1-X US Development

ATK Thiokol
Thrust Vector Control
Ares 1-X US Development

MSFC
Ares Project
US In-House Dev

LaRC
Ares 1-X Lead
Wind Tunnels

Pratt & Whitney Rocketdyne

SSC
Rocket Propulsion Testing

KSC
Ares Ground Ops
& Launch Processing

MSFC’s MAF
Ares 1 US Manufacturing
Ares 5 Stages
Ares Thermal Requirements

Top Level Thermally-Related Ares I Requirements:

- Maintain Structural Temperatures
- Maintain Component Temperatures
  - Avionics, thrust vector control system, reaction control hypergolic thrusters, solid motors, parachutes, pyros, etc.)
- Liquid Hydrogen/Liquid Oxygen Propellant Quality
  - J-2X propellant thermodynamic “start box” & “run box”
  - Stratification in propellant tanks
  - Heat leak allowable for tanks & feedlines
- Preclude “hazardous” ice (allowable mass/locations TBD)
Top Level Thermally-Related Ares I Environments:

- KSC Natural Environments (VAB, rollout, On-Pad)
  - Design Specification for Natural Environments
  - KSC ambient air temperature range, humidity, wind, solar, sky radiation, etc.
  - Natural Environments Definition for Design
  - Operability/Logistics Goal to eliminate roll-out power/purge

- Ascent Aerothermodynamic and Plume Heating Environments
  - Ares-I Thermal Environments Data Book
Ares Thermal Challenges

♦ Ares I First Stage:
  - Base Heating from 5-segment Solid Rocket Booster Plume (Thermal Curtain)
  - Re-entry environments (significantly higher than STS RSRB)
  - Re-qualification of TPS materials
Ares Thermal Challenges

♦ Ares I Upper Stage:
  • Common Bulkhead between Liquid Hydrogen & Liquid Oxygen tanks
  • Liquid Hydrogen/Liquid Oxygen heat leak & stratification
  • Protuberance aero-thermal heating (various fairings, feedlines, systems tunnel)
  • Hydrazine temperatures for Reaction & Roll Control Thruster systems
  • Plume impingement from Solid Motors, RCS, J-2X
  • Passive avionics thermal control
Ares Thermal Challenges

- External Tank Separation Photo Illustrating Plume Heating Charring/Ablation

- RSRM Joint Shocks
- SRB Shock And Bolt Catcher Area
- Ogive Heating
- BSM Plume Impingement
Ares Thermal Challenges

- **Ares V**
  - Severe base heating environments for 5 RS-68 engines combined with 2 five-segment SRBs
  - Potential long duration orbital environment for EDS – maintaining cryogenic propellants

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**Composite Shroud**

**Ascent Stage**
- LOx/LH2
- Five RS68 Engines
- Al-Li Tanks/Structures

**Descent Stage**

**Earth Departure Stage**
- LOx/LH2
- One J2X+ Engine
- Al-Li Tanks/Structures

**Interstage**

**Upper Stage Engine**
- Saturn J-2 Derived Engine (J-2X)
- Expendable

**Five Segment RSRBs**

**Core Stage**
- LOx/LH2
- Five RS68 Engines
- Al-Li Tanks/Structures
Ares Thermal Modeling

Ares I Thermal Modeling Tools:

- **First Stage (ATK)**
  - IDEAS-TMG, CMA, SINDA/G with proprietary Ablation routines
- **J-2X (Pratt & Whitney Rocketdyne)**
  - TSS, SINDA/FLUINT, ANSYS, PATRAN
- **Upper Stage (Marshall Space Flight Center)**
  - Thermal Desktop 5.0 (with AutoCAD 2007, SINDA/FLUINT, FloCAD)
  - PATRAN, P/Thermal
  - SINDA/G with ABL (in-house Ablation code)
  - FEMAP (as front end mesher to Thermal Desktop or SINDA/G)
  - CFD (various in-house CFD codes for compartment purge analyses)
  - CHCHVENT (in-house venting code)
  - GFSSP (in-house thermo fluid dynamics code)
  - MEIT - Momentum/Energy Integral Technique (Rocket Nozzles)
  - NAT (nozzle ablation)
  - ACE - Aerotherm Chemical Equilibrium
  - CMA - Charring Material Thermal Response and Ablation
Ares Thermal Modeling

• Ares I Thermal Modeling Examples:

Integrated Upper Stage
Ares Thermal Modeling

- Ares I Thermal Modeling Examples:

  - J-2X
  - Common Bulkhead Joint
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