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
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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-boost Mode at KSC

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

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**Upper Stage (1 J-2X)**
- 305k lb LOx/LH₂

**Lunar Lander**
- Earth Departure Stage (EDS) (1 J-2X)
- 493k lb LOx/LH₂

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**Crew Lander**
- S-IVB
  - (1 J-2 engine)
  - 240k lb LOx/LH₂
- S-II
  - (5 J-2 engines)
  - 1M lb LOx/LH₂
- S-IC
  - (5 F-1 engines)
  - 3.9M lb LOx/RP
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

- **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**

- **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 I avionics system
  - NASA Design / Contractor Production

- **Upper Stage Engine**
  - Saturn J-2 derived engine (J-2X)
  - Expendable
  - **Pratt and Whitney Rocketdyne**
General Ares Description/Orientation

• Ares-V

Composite Shroud

Ascent Stage

Descent Stage

{LSAM

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
General Ares Description/Orientation

Earth Departure Stage
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

- Ogive Heating
- RSRM Joint Shocks
- SRB Shock And Bolt Catcher Area
- 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
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 I Thermal Modeling Examples:

Integrated Upper Stage
Ares Thermal Modeling

- Ares I Thermal Modeling Examples:
  - J-2X
  - Common Bulkhead Joint