J. Craig McArthur
Ares I Upper Stage Deputy Manager
July 23, 2008

Ares I Crew Launch Vehicle
Upper Stage Element Overview
What is NASA’s Mission?

- Safely fly the Space Shuttle until 2010
- Complete the International Space Station
- Develop a balanced program of science, exploration, and aeronautics
- Develop and fly the Orion Crew Exploration Vehicle (CEV)
- Return to the Moon no later than 2020
- Promote international and commercial participation in exploration

“The next steps in returning to the Moon and moving onward to Mars, the near-Earth asteroids, and beyond, are crucial in deciding the course of future space exploration. We must understand that these steps are incremental, cumulative, and incredibly powerful in their ultimate effect.”

– NASA Administrator Michael Griffin
October 24, 2006
NASA’s Exploration Roadmap

What is our timeline?

- **Initial Capability Orion (CEV)**
- **Lunar Robotic Missions**
- **Science Robotics Missions**
- **Research and Technology Development on ISS**
- **Commercial Crew/Cargo for ISS**
- **Space Shuttle Operations**
- **SSP Transition**
- **Ares I and Orion Development**
- **Operations Capability Development** (EVA, Ground Operations, Mission Operations)
- **Ares I-X Test Flight** April 2009
- **Altair Development**
- **Ares V & Earth Departure Stage**
- **Orion and Ares I Production and Operation**
- **Lunar Outpost Buildup**
- **Mars Expedition ~2030**
- **Surface Systems Development**

National Aeronautics and Space Administration

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Building on a Foundation of Proven Technologies
– Launch Vehicle Comparisons –

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Height (m, ft)</th>
<th>Gross Liftoff Mass (kg, lbm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space Shuttle</strong></td>
<td>56.1 (184.2)</td>
<td>2,041,166 (4.5M)</td>
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</tr>
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<td><strong>Saturn V</strong></td>
<td>110.9 (364)</td>
<td>2,948,350 (6.5M)</td>
</tr>
</tbody>
</table>

Overall Vehicle Height

- **Space Shuttle**: 122 m (400 ft)
- **Ares I**: 91 m (300 ft)
- **Ares V**: 61 m (200 ft)
- **Saturn V**: 30 m (100 ft)

**Launch Vehicle Properties**

- **Space Shuttle**
  - Height: 56.1 m (184.2 ft)
  - Gross Liftoff Mass: 2,041,166 kg (4.5M lbm)
  - 25 MT (55k lbm) to Low Earth Orbit (LEO)

- **Ares I**
  - Height: 99.1 m (325 ft)
  - Gross Liftoff Mass: 907,185 kg (2.0M lbm)
  - 25.6 MT (56.5k lbm) to LEO

- **Ares V**
  - Height: 109.7 m (360 ft)
  - Gross Liftoff Mass: 3,374,910 kg (7.4M lbm)
  - 63.6 MT (140.2k lbm) to TLI (with Ares I)
  - 55.9 MT (123k lbm) to Direct TLI
  - ~143.4 MT (316k lbm) to LEO

- **Saturn V**
  - Height: 110.9 m (364 ft)
  - Gross Liftoff Mass: 2,948,350 kg (6.5M lbm)
  - 45 MT (99k lbm) to TLI
  - 119 MT (262k lbm) to LEO
Propellant Load: 138 k kg
Total Mass: 156 K kg
Dry Mass: 17.5 k kg (38.6 k lbm)
Dry Mass (Interstage): 4075 k kg (8,984 lbm)
Length: 25.6 m (84 ft)
Diameter: 5.5 m (18 ft)
LOX Tank Pressure: 344.7 k Pascal (50 psig)
LH₂ Tank Pressure: 289.6 k Pascal (42 psig)
Upper Stage Primary Products

1. Instrument Unit (IU)
2. Liquid Hydrogen (LH2) Tank
3. Common Bulkhead
4. Liquid Oxygen (LO2) Tank
5. Aft Skirt
6. Thrust Cone
7. Interstage
8. System Tunnel
9. Upper Stage Engine
10. LH2 System
11. LO2 System
12. Pressurization & Pneumatic System (cryogenic)
13. Pressurization & Pneumatic System (ambient)
14. IU Avionics
15. Aft Skirt Avionics
16. Upper Stage Reaction Control System (RoCS)
17. First Stage Roll Control System (RoCS)
18. Thrust Vector Control
19. Thermal Protection System
20. LH2 Feedline Fairing
21. IU Umbilical Panel
22. Aft Skirt Umbilical Panels
23. IU Purge & Hazardous Gas Detection System
25. Interstage Purge System
26. Ullage Settling Motors
Ares I Upper Stage Development Approach

Ames Research Center (ARC)
- Avionics & Software Support

Glenn Research Center (GRC)
- TVC
- Electrical Power System
- Developmental Flight Instrumentation
- Hazardous Gas Detection

Langley Research Center (LaRC)
- Structural Design Support
- Manufacturing Support

Marshall Space Flight Center (MSFC)
- US Mgt, Design, and Integration
- US Logistics and Operations Lead

Kennedy Space Center (KSC)
- Ground Umbilicals Development
- Propellant Systems Development @ MPTA Test Site
- Logistics and Operations Support

Michoud Assembly Facility (MAF)
- Facility Services and Planning Support to ILS and Manufacturing & Assembly IPTs

Johnson Space Center (JSC)
- Test Support at White Sands

Stennis Space Center (SSC)
- Test Planning and Support
What progress have we made?

♦ US Programmatic Milestones
  • Completed US System Requirements Review and System Definition Review, and currently in the midst of Preliminary Design Review
  • Contracts awarded for building the upper stage and instrument unit
  • Request for Proposal released for Manufacturing Support and Facility Operations Contract (MSFOC) at Michoud Assembly Facility

♦ US Technical Accomplishments
  • Robotic Weld Tool now in operation at MSFC
  • US TVC Testing
  • US Structural Test Panels
  • Avionics Computer Test
  • First foam spray for cryogenic systems
  • First Heavy Weight Motor Test and first Ullage Settling Motor Igniter Hot-Fire
  • Al-Li 2014 dome qualification article

For more information go to www.nasa.gov/ares
Upper Stage Subsystem Highlights

♦ Small Solids
  • Separation analysis and trade study
  • Heavy weight motor test
  • Propellant tailoring and testing
  • PDR Kickoff

♦ Structures and Thermal
  • Final Layout Out Reviews
  • Panel test analysis

♦ Main Propulsion System
  • Terminal drain analysis
  • Ullage collapse analysis
  • Bench testing of Saturn Components
  • Cryo regulator testing

♦ Reaction Control System
  • Producibility upgrades (DFMA Thruster)
  • Water Hammer Testing in the CDA

♦ Thrust Vector Control System
  • Hydraulic Breadboard Test
  • PDR Kickoff

♦ Avionics and Software
  • Boeing Integration
  • Specification Development
  • Software Reviews
  • Industry Day with Supply Chain
Structural Testing

SD01- AL-Li Small Panel
SD02- AL-Li Large Panel

SD06-SD07-SD08
Composite Panel Test

SD03- Common Bulkhead Dev Test

SQ01- IU Qualification Test

SD05, SQ06- Interstage Qualification Test

SQ02A- Core US Qualification & Life Test

SD05, SQ07- LOX Tank Aft Dome with Thrust Structure and Aft Skirt
Common Bulkhead Processing
Stage Installation at Stennis Space Center
Boeing has been selected as USPC and the IUAC

- Producibility and Design Support
- Manufacturing
- Operations
- Sustaining Engineering

Program Manager – Jim Chilton
- IUAC Manager – Dwight Potter

Team is engaged with the NASA Design Team (NDT)

- Manufacturing Value Stream Mapping
- Producibility Summit
- Tooling Design Support
- Schedule Development
- Component Cost Updates
- Test Article Planning Support
- Special Studies
Upper Stage Low Cost Strategy

♦ Upper Stage acquisition strategy maximizes price competition
  - Minimal proprietary items
    - NASA in-house design with commercial production
  - Large supplier base for components
    - Boeing approach maintains competition from large supplier base
  - Procure Sustaining Engineering and Operations using IDIQ (buy it by the yard)

♦ Total cost of ownership is addressed early in the design cycle
  - Safety emphasized in all phases of design and production
  - Value Stream Mapping of the entire manufacturing, test, and operations flow
    - Design Production and Ops flows along with the Upper Stage product
  - Design for Production and Operations
    - Boeing provides "Producibility" input to the NASA Design Team
  - Optimized Manufacturing and Production Plans
    - Design for low cost manufacturing to minimize "monuments" in the production flow
  - Operation Concept Analysis - to minimize "monuments" in the operations flow
    - Depots (no depot at KSC or SSC)
    - Support equipment (flexible support equipment)
    - Workforce (no standing army)
Merged Manufacturing Flow

- Manufacturing Value Stream Map
  - Vertical Tack and Weld
  - Horizontal TPS Application
- Producability Summit
- Manufacturing Plan
- Manufacturing Floor Plan at Michoud
- Tooling Design and Fabrication

**Common Test Cell**

**Metrics**
- NASA Baseline: 420 days
- Boeing Contract: 347 days
- Merged VSM: 320 days
- With learning: <300 days

**Critical Path**

Boeing, working with NASA, Reduced Assembly Flow Over 100 days
Manufacturing & Assembly Weld Tools

Robotic Weld Tool (RWT)
MSFC Bldg 4755
- gore-gore, dome-y ring, dome-fitting
- Self-Reacting Friction Stir Welding (FSW)

Vertical Weld Tool (VWT)
Barrel-Barrel, Conventional FSW

Vertical Circumferential Weld Tool Concept
Conclusion

♦ Building on the heritage of the Apollo and Space Shuttle Programs, the Ares I Upper Stage team is utilizing extensive lessons learned to place NASA and the United States into another great era of space exploration
  • Ares I team must build beyond its current capability to ferry astronauts and cargo to Low Earth Orbit
  • To reach for Mars and beyond, the team must first reach for the moon
  • We are using the best of NASA to design the stage, and the best of industry to build the stage

♦ NASA and Boeing Upper Stage teams are now integrated, working together, and making good progress
  • Designing and building the Ares I Upper to minimize:
    – Cost risks
    – Technical risks
    – Schedule risks

“This Nation has tossed its cap over the wall of space, and we have no choice but to follow it.”

-- President John F. Kennedy, 1962