Lunar Program Industry Briefing: Ares V Overview

Steve Cook
Manager, Ares Projects Office
Ares Projects Overview

♦ Deliver crew and cargo for missions to International Space Station (ISS), the Moon and beyond
♦ Continuing progress toward design, component testing, and early flight testing
♦ Ares I Crew Launch Vehicle
  • Carries 6 crew to ISS, 4 to Moon
  • First flight test scheduled in 2009
  • Initial Operational Capability in 2015
♦ Ares V Cargo Launch Vehicle
  • Launches Earth Departure Stage (EDS), Altair and Orion to Low Earth Orbit for lunar missions
  • Largest launch vehicle ever designed
  • Ongoing concept design work leading into detailed development work starting in 2011
  • First flight test planned in 2018
Ares V Cargo Launch Vehicle

Heavy Lift for Science and Exploration

Key transportation system for exploration beyond Low Earth Orbit

- Offers unique payload capabilities opening new doors to human exploration on the Moon and beyond
- Designed for routine crew and cargo transportation to the Moon
  - EDS + Altair to LEO
  - EDS + Altair + Orion to TLI
- Considered national asset creating new opportunities for science, national security and space business
- Capable of transporting more than 71 metric tons to the Moon
- Focal point for design and development located at MSFC with support across the Agency
Building on a Foundation of Proven Technologies

Launch Vehicle Comparisons

**Space Shuttle**
- Height: 56.1 m (184.2 ft)
- Gross Liftoff Mass: 2,041.1 mT (4,500.0K lbm)
- Payload Capability: 25.0 mT (55.1K lbm) to Low Earth Orbit (LEO)

**Ares I**
- Height: 99.1 m (325.0 ft)
- Gross Liftoff Mass: 927.1 mT (2,044.0K lbm)
- Payload Capability: 25.5 mT (56.2K lbm) to LEO

**Ares V**
- Height: 116.2 m (381.1 ft)
- Gross Liftoff Mass: 3,704.5 mT (8,167.1K lbm)
- Payload Capability:
  - 71.1 mT (156.7K lbm) to TLI (with Ares I)
  - 62.8 mT (138.5K lbm) to Direct TLI
  - ~187.7 mT (413.8K lbm) to LEO

**Saturn V**
- Height: 110.9 m (364 ft)
- Gross Liftoff Mass: 2,948.4 mT (6,500K lbm)
- Payload Capability:
  - 44.9 mT (99K kbm) to TLI
  - 118.8 mT (262K lbm) to LEO

**Core Stage**
- (6 RS-68 Engines)
- Width: 137.1 mT (302.2K lbm)
- LOX/LH₂

**Upper Stage**
- (1 J-2X)
- Height: 99.1 m (325.0 ft)
- Gross Liftoff Mass: 927.1 mT (2,044.0K lbm)
- LOX/LH₂

**S-IC**
- (5 F-1 engines)
- Height: 110.9 m (364 ft)
- Gross Liftoff Mass: 3,704.5 mT (8,167.1K lbm)
- LOX/RP-1

**S-II**
- (5 J-2 engines)
- Height: 91 m (300 ft)
- Gross Liftoff Mass: 453.6 mT (1,000.0K lbm)
- LOX/LH₂

**S-IVB**
- (1 J-2 engine)
- Height: 61 m (200 ft)
- Gross Liftoff Mass: 108.9 mT (240.0K lbm)
- LOX/LH₂

**5-Segment Reusable Solid Rocket Booster (RSRB)**

**Orion**

**Earth Departure Stage (EDS) (1 J-2X)**
- Height: 253.0 mT (557.7K lbm)
- LOX/LH₂

**Altair**
- Height: 137.1 mT (302.2K lbm)
- LOX/LH₂

**Crew**

**Lunar Lander**

**Overall Vehicle Height, m (ft)**
- 122 m (400 ft)
- 91 m (300 ft)
- 61 m (200 ft)
- 30 m (100 ft)
- 0 m (0 ft)
Ares V Element Heritage

Ares I
25.5 t (56.2K lbm) to Low Earth Orbit (LEO)

First Stage
(5-Segment RSRB)

Elements from
RSRB

Upper Stage Derived
Vehicle Systems

J-2X Upper Stage Engine

Ares V
71.1 t (156.7K lbm) to TLI (with Ares I)
63.0 t (138.5K lbm) to Direct TLI
187.7 t (413.8K lbm) to LEO

From Delta IV RS-68

Delta IV

Elements from
From Delta IV RS-68

7603.5
ESAS to LCCR Major Events

Original ESAS Capability
- 45.0 mT Lander
- 20.0 mT CEV
- No Loiter in LEO
- 8.4m OML
- 5 SSMEs / 2J2S

CY-06 Budget Trade to Increase
- Ares I / Ares V Commonality
- Ares I : 5 Seg RSRB / J2-X instead of Air-Start SSME
- Ares V: 1 J2-X

Detailed Cost Trade of SSME vs RS-68
- ~$4.25B Life Cycle Cost Savings for
- 5 Engine Core
- Increased Commonality with Ares I Booster
- 30-95 Day LEO Loiter Assessed

IDAC 3 Trade Space
- Lunar Architecture Team 1/2 (LAT) Studies
- Mission Delta V's increased
- Increase Margins From TLI Only to Earth through TLI
- Loiter Penalties for 30 Day Orbit Quantified

EDS Diameter Change from 8.4m to 10m
- Lunar Architecture Team 1/2 (LAT) Studies
- Core Engine / SRB Trades to Increase Design Margins
- Increase Subsystem Mass Growth Allowance (MGA)

Incorporate Ares I Design Lessons Learned / Parameters
- Core Engine / SRB Trades to Increase Design Margins
- Tank Assembly Tooling Commonality

Recommended Option
- 6 Core Engines
- 5.5 Segment PBAN

Updated Capability
- 45.0t Lander
- 20.2t CEV
- ~6t Perf. Margin
- 4 Day LEO Loiter
- Ares I Common MGAs
- HTPB Decision End of FY09

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220 Concepts Evaluated 2005

320 Concepts Evaluated 2006

730 Concepts Evaluated 2007

460 Concepts Evaluated 2008

Ares I ATP 2005

Orion ATP 2006

Ares I SRR 2007

Orion SRR 2007

Ares I SDR 2008

Ares V MCR 2008

ESAS Complete

National Aeronautics and Space Administration
Ares V Elements
New LCCR Point-of-Departure (51.0.48)

Earth Departure Stage (EDS)
- One Saturn-derived J–2X LOX/LH₂ engine (expendable)
- 10-m (33-ft) diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures, Instrument Unit and Interstage
- Primary Ares V avionics system

Core Stage
- Six Delta IV-derived RS–68B LOX/LH₂ engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Aluminum-Lithium (Al-Li) tanks

Solid Rocket Boosters (2)
- Two recoverable 5.5-segment PBAN-fueled, steel-case boosters (derived from current Ares I First Stage)
- Option for new design

Gross Lift Off Mass: 3,704.5 mT (8,167.1k lbm)
Integrated Stack Length: 116.2 m (381.1 ft)
**Ares V Technology Needs**

**ETDP Technology Prioritization Process (TPP)**

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<thead>
<tr>
<th>Ares V Technology Priorities</th>
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<tbody>
<tr>
<td>1. Large Composite Manufacturing</td>
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<td>2. HTPB Propellant</td>
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<td>3. Long Term CFM</td>
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<td>4. Composite Damage Tolerance/Detection</td>
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<td>5. EDS State Determination &amp; Abort</td>
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<td>6. Composite Joining Technology</td>
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<td>7. Liquid Level Measurement</td>
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<td>8. Multi Layer Insulation</td>
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<td>9. Leak Detection</td>
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<td>10. Non Autoclave Composites</td>
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<td>11. SRM Composite Metal Technology</td>
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<td>12. Composite Dry Structure Development</td>
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<td>13. Composite Damage Failure Detection for Abort</td>
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<td>14. Nozzle Sensitivity to Pocketing (High Heat Flux from HTPB)</td>
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<td>15. LH2 Tank Micro Cracking</td>
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</table>

**Key Technology Areas**

| Composites                                         |
| Cryo Fluid Management                              |
| Solids                                             |
| Automation                                         |
| Liquid Propulsion                                  |
| Control/Separation                                 |

**Ares Value Stream**

- Nose Cone/Forward Skirt
- Loaded Motor
- Core Stage Aft Skirt
- Point of Departure Shroud (Biconic)
- National Aeronautics and Space Administration
## Ares V Summary Schedule

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<td>Altair Milestones (for reference only)</td>
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### Notations:
- **SRR**: System Requirements Review
- **SDR**: System Design Review
- **PDR**: Preliminary Design Review
- **CDR**: Critical Design Review
- **RR**: Review
- **FY**: Fiscal Year
Ares V Profile
51.00.48 Recommended POD (Lunar Sortie)

<table>
<thead>
<tr>
<th>Event</th>
<th>Time (sec)</th>
<th>Altitude (km)</th>
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<tr>
<td>Liftoff</td>
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<td>Maximum Dynamic Pressure</td>
<td>78.8</td>
<td>14.4</td>
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<td>SRB Separation</td>
<td>121.6</td>
<td>36.4</td>
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<td>Shroud Separation</td>
<td>295.0</td>
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<td>Main Engine Cutoff</td>
<td>303.1</td>
<td>133.3</td>
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<td>EDS Ignition</td>
<td>303.1</td>
<td>133.3</td>
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<td>EDS Engine Cutoff</td>
<td>806.0</td>
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<td>EDS TLI Burn Duration</td>
<td>424.9</td>
<td>TBD</td>
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<tr>
<td>LSAM/CEV Separation</td>
<td>TBD</td>
<td>TBD</td>
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- **EDS Engine Cutoff**: Time = 806.0 sec
  - Sub-Orbital Burn Duration = 502.9 sec
  - Injected Weight = 187.7 mT
  - Orbital Altitude = 240.8 km circ @ 29.0°
- **EDS TLI Burn**: Orbital Altitude = 185.2 km circ @ 29.0°
  - Burn Duration = 424.9 sec
- **CEV Rendez. & Dock w/EDS**: Time - Assumed Up to 4 Days
  - Orbital Altitude Assumed to Degrade to 185.2 km
- **Core Stage Separation & EDS Ignition**: Time = 303.1 sec
- **Core Stage Impact**: 
- **Shroud Separation**: Time = 295.0 sec
- **SRB Separation**: Time = 121.6 sec
- **Liftoff**: Time = +1 sec
  - Thrust-to-Weight Ratio = 1.36
  - GLOM = 3,704.5 mT
- **LSAM/CEV Separation**: 
- **EDS Disposal**: 
- **EDS Rendez. & Dock**: 
- **Core Stage Impact**: 
- **SRB Splashdown**: 

National Aeronautics and Space Administration
Payload Utilization
Ares V as a National Asset

♦ Ares V offers the largest payload capability than all other existing launch vehicles
  • Over 40% more lift capability than Saturn V
  • 3-5 times for volume than most other launch systems

♦ These unique capabilities open new worlds and create unmatched opportunities
  • Human exploration
  • Science
  • Space Business

♦ Ares V is actively engaged with external organizations during this early concept phase to ensure its utilization for other missions
  • National Security
  • Astronomy and Solar System Science
Our Achievements

♦ Programmatic Milestones

• Completed Ares I System Requirements Review (SRR) – Jan 2007
• Awarded contracts for Ares I First Stage, J-2X Engine, Upper Stage and Instrument Unit
• Completed Ares I System Definition Review (SDR) – Oct 2007
• Completed Ares V Mission Concept Review (MCR) – Jun 2008
• Completed Constellation Lunar Capability Concept Review (LCCR) – Jun 2008
• Released Ares V Request For Information (RFI) and evaluating responses – Aug 2008
• Completion of Ares I Preliminary Design Review (PDR) – Sep 2008

♦ Technical Accomplishments

• Ares I Drogue Chute Drop Test – July 2008
• Ares I First Stage Separation and Re-entry Wind Tunnel Tests
• J-2X Injector and Power Pack Tests
• A-3 Test Stand Construction for J-2X Engine at Stennis Space Center
• MSFC Dynamic Test Stand 4550 Refurbishment for Ares I and Ares V Integrated Vehicle Ground Vibration Testing
• Established Ares V Design Concept Which Fully Supports the Constellation Architecture
Summary

♦ Key elements of Ares V are under development as a part of Ares I and the Air Force RS-68

♦ Ares V Point of Departure (POD) vehicle has ~ 40% more payload capability than Saturn V which closes the lunar architecture with 6 MT of margin to Trans-Lunar Injection (TLI)

♦ Ares V concept design and development is underway

♦ Ares V completed its Mission Concept Review (MCR) in June of this year and is proceeding into Phase A

♦ Industry involvement in Ares V Phase I will support element definition to assure robust system level requirements

♦ After System Definition Review (SDR) timeframe Ares V element prime contract awards will begin Phase II
Payload Shroud Design Concept

- Composite sandwich construction (Carbon-Epoxy face sheets, Al honeycomb core)
- Painted cork TPS bonded to outer face sheet with RTV
- Payload access ports for maintenance, payload consumables and environmental control (while on ground)

**Quad Sector Design**

**Frangible Joint**

**Horizontal Separation**

**Thrust Rail Vertical Separation System**

**Payload umbilical separation**

**Mass:** 9.1 t (20.0k lbm)
**POD Geometry:** Biconic
**Design:** Quad sector
**Barrel Diameter:** 10 m (33 ft)
**Barrel Length:** 9.7 m (32 ft)
**Total Length:** 22 m (72 ft)
Earth Departure Stage Current Design Concept
Expanded View

- Usable Propellant: 251.9 t (555.2K lbm)
- Dry Mass: 24.2 t (53.5K lbm)
- Burnout Mass: 26.6 t (58.7K lbm)
- Number of Engines: 1
- Engine Type: J-2X

- Aluminum-Lithium (Al-Li) propellant tanks
- Composite dry structure
- 10-m (33-ft) outer diameter
- Derived from Ares I Upper Stage
- 4-day on-orbit loiter capability prior to Trans-Lunar Injection (TLI)
- Maintains Orion/Altair/EDS stack attitude in Low Earth Orbit prior to TLI Burn
- Provides 1.5 kW of power to Altair from launch to TLI
Core Stage Current Design Concept  
- Expanded View -

- Aluminum-Lithium (Al-Li) propellant tanks
- Composite dry structure
- 10-m (33-ft) outer diameter
- Derived from Shuttle External Tank

**Usable Propellant:** 1,587.3 t (3,499.5K lbm)  
**Dry Mass:** 157.6 t (347.5K lbm)  
**Burnout Mass:** 173.9 t (383.4K lbm)  
**Number of Engines:** 6  
**Engine Type:** Upgraded RS-68B
Earth Departure Stage J-2X Engine

**Mass:** 2.5 t (5,450 lbm)
**Thrust:** 1,300 kN (294k lbf) @ vac (100%)
**Isp:** 448 sec @ vac (100%)
**Height:** 4.7 m (185 in)
**Diameter:** 3.0 m (120 in)

**Turbomachinery**
- Based on J–2S MK–29 design

**Gas Generator**
- Based on RS–68 design

**Engine Controller**
- Based directly on RS–68 design and software architecture

**Flexible Inlet Ducts**
- Based on J–2 & J–2S ducts

**Open-Loop Pneumatic Control**
- Similar to J–2

**Regeneratively Cooled Nozzle Section**
- Based on long history of RS–27 success

**HIP-bonded MCC**
- Based on RS–68 demonstrated technology

**Nozzle Extension**
- Essentially identical to Ares I
  - Earth orbit loiter
  - On-orbit restart
Ares V Solid Rocket Booster (SRB)

Each Booster:
- **Mass**: 791.5 t (1,744.9K lbm)
- **Thrust**: 16.86 MN (3.79M lbf)
- **Burn Duration**: 126 sec
- **Height**: 59 m (193 ft)
- **Diameter**: 3.7 m (12 ft)

Ares V SRB is similar to Space Shuttle and Ares I but optimized for lunar missions.

- **Modern Electronics**
- **12-Fin Forward Segment**
- **Same propellant as Shuttle (PBAN) – Optimized for Ares Application**
- **Same Aft Skirt and Thrust Vector Control as Shuttle**
- **Same cases and joints as Shuttle**
- **New 150-ft diameter parachutes**
- **Booster Deceleration Motors**
- **Wide Throat Nozzle**
Core Stage Upgraded USAF RS-68B Engine

- Redesigned turbine nozzles to increase maximum power level by \( \approx 2\% \)
- Higher element density main injector improving specific impulse
- Redesigned turbine seals to significantly reduce helium usage for pre-launch
- Helium spin-start duct redesign, along with start sequence modifications, to help minimize pre-ignition free hydrogen
- Increased duration capability ablative nozzle

Other RS-68A upgrades or changes that may be included:
- Bearing material change
- New Gas Generator igniter design
- Improved Oxidizer Turbo Pump temp sensor
- Improved hot gas sensor
- 2nd stage Fuel Turbo Pump blisk crack mitigation
- Cavitation suppression
- ECU parts upgrade

RS-68A Upgrades