Update on the Ares V to Support Heavy Lift for U.S. Space Exploration Policy

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Integration Manager, Ares V
Ares Projects Office
Marshall Space Flight Center, NASA
The NASA Ares Projects are developing the launch vehicles to move the United States and humanity beyond low earth orbit.

Ares V is a heavy lift vehicle being designed to send crews to the Moon together with Ares I or to send cargo only in a single launch.

The Ares V design is evolving and maturing toward an authority-to-proceed milestone in 2011.

The Ares V vehicle will be considered a national asset, opening new worlds and creating unmatched opportunities for human exploration, science, national security, and space business.
Our Exploration Fleet

What will the vehicles look like?

- Earth Departure Stage
- Orion Crew Exploration Vehicle
- Ares V Cargo Launch Vehicle
- Ares I Crew Launch Vehicle
- Altair Lunar Lander
Building on a Foundation of Proven Technologies

Launch Vehicle Comparisons

**Space Shuttle**
- **Height:** 56 m (184 ft)
- **Gross Lift off 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 ft)
- **Gross Lift off 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 Lift off 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:** 111 m (364 ft)
- **Gross Lift off Mass:** 2,948.4 mT (6,500K lbm)
- **Payload Capability:**
  - 44.9 mT (99.0K lbm) to TLI
  - 118.8 mT (262.0K lbm) to LEO

**Orion**
- **Upper Stage**
  - (1 J-2X)
  - 137.1 mT (302.2K lbm) LOX/LH₂

**Core Stage**
- (6 RS-68B Engines)
- 1,587.3 mT (3,499.5K lbm) LOX/LH₂

**EDS (1 J-2X)**
- 253.0 mT (557.7K lbm) LOX/LH₂

**Altair**
- **Upper Stage**
  - (1 J-2X)
  - 137.1 mT (302.2K lbm) LOX/LH₂

**Core Stage**
- (6 RS-68B Engines)
- 1,587.3 mT (3,499.5K lbm) LOX/LH₂

**S-IVB**
- (1 J-2 Engine)
- 108.9 mT (240.0K lbm) LOX/LH₂

**S-II**
- (5 J-2 Engines)
- 453.6 mT (1,000.0K lbm) LOX/LH₂

**S-IC**
- (5 F-1)
- 1,769.0 mT (3,900.0K lbm) LOX/RP-1

National Aeronautics and Space Administration
Ares V Element Heritage

Upper Stage Derived Vehicle Systems

J-2X Upper Stage Engine

First Stage (5-Segment RSRB)

RSRB Elements

Ares I
25.5 mT (56.2 klbm) to Low Earth Orbit (LEO)

Ares V (51.00.48)
71.1 mT (156.7 klbm) to TLI (with Ares I)
63.0 mT (138.5 klbm) to Direct TLI
187.7 mT (413.8 klbm) to LEO

USAF RS-68B From Delta IV RS-68

Delta IV
The New 51.00.48 Point-of-Departure

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-casing boosters (derived from current Ares I first stage)

Gross Lift Off Mass: 3,704.5 mT (8,167.1k lbm)
Integrated Stack Length: 116 m (381 ft)
### Ares V Profile for 1.5 Launch DRM

**51.00.48 Point Of Departure (Lunar Sortie)**

<table>
<thead>
<tr>
<th>Event</th>
<th>Time (sec)</th>
<th>Altitude (km)</th>
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<td>Liftoff</td>
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<tr>
<td>Maximum Dynamic Pressure</td>
<td>78.8</td>
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<tr>
<td>SRB Separation</td>
<td>121.6</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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<tr>
<td>EDS Ignition</td>
<td>303.1</td>
<td>133.3</td>
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<tr>
<td>EDS Engine Cutoff</td>
<td>806.0</td>
<td>243.5</td>
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<td>EDS TLI Burn Duration</td>
<td>424.9</td>
<td>TBD</td>
</tr>
<tr>
<td>LSAM/CEV Separation</td>
<td>TBD</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Event Details:**
- **Liftoff**
  - Time: +1 sec
  - Thrust-to-Weight Ratio: 1.36
  - GLOM: 3,704.5 mT (8,167.1K lbm)
- **SRB Separation**
  - Time: 121.6 sec
  - Altitude: 36,387 m (119.4K ft)
  - Mach: 4.16
- **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°
- **Core Stage Separation & EDS Ignition**
  - Time: 303.1 sec
- **EDS TLI Burn**
  - Orbital Altitude: 185.2 km circ @ 29.0°
  - Burn Duration: 424.9 sec
- **LSAM/CEV Separation**
  - Time TBD
  - Altitude TBD
- **EDS Disposal**
  - Time – Assumed Up to 4 Days
- **CEV Rendez. & Dock w/EDS**
  - Time – Assumed Up to 4 Days
  - Orbital Altitude Assumed to Degrade to 185.2 km (100.0 nmi)

**Launch Point of Departure (Lunar Sortie):**
- **Event Time**
  - Altitude
  - Liftoff 0.0 0.0
  - Maximum Dynamic Pressure 78.8 14.4
  - SRB Separation 121.6 36.4
  - Shroud Separation 295.0 126.9
  - Main Engine Cutoff 303.1 133.3
  - EDS Ignition 303.1 133.3
  - EDS Engine Cutoff 806.0 243.5
  - EDS TLI Burn Duration 424.9 TBD
  - LSAM/CEV Separation TBD TBD

**Orbital Altitude:**
- **Orbital Altitude Assumed to Degrade to 185.2 km (100.0 nmi)**
- **Core Impact in Atlantic Ocean**
- **SRB Splashdown**
- **CEV Rendez. & Dock w/EDS**
- **EDS Disposal**
- **LSAM/CEV Separation**
EDS Current Design Concept
Expanded View

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

• 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 TLI
• Maintains Orion/Altair/EDS stack attitude in LEO prior to TLI
• EDS provides 1.5 kW of power to Altair from launch to TLI
Earth Departure Stage J-2X Engine

**Mass:** 2.5 mT (5.5k lbm)
**Thrust:** 1.3M N (294.0k lbm) @ vac
**Isp:** 448 sec (vac)
**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

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

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

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

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

- **Metallic Nozzle Extension**
  - New design

**Pratt & Whitney**

A United Technologies Company

Pratt & Whitney Rocketdyne
Core Stage Design Concept
Expanded View

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

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Usable Propellant</td>
<td>1,587.3 mT (3,499.5k lbm)</td>
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<tr>
<td>Dry Mass</td>
<td>157.6 mT (347.5k lbm)</td>
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<tr>
<td>Burnout Mass</td>
<td>173.9 mT (383.4k lbm)</td>
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<tr>
<td>Number of Engines</td>
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<tr>
<td>Engine Type</td>
<td>Upgraded RS-68B</td>
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</table>
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 and thrust

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

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

Increased duration capability ablative nozzle
Ares V (51.00.48)
Solid Rocket Booster (SRB)

Mass: 794 mT (1.8M lbm)
Thrusted: 15.8M N (3.5M lbf)
Burn Duration: 126 sec
Height: 55 m (180 ft)
Diameter: 3.7 m (12 ft)

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

Same propellant as Shuttle (PBAN) – Optimized for Ares Application

Same cases and joints as Shuttle

Booster Deceleration Motors

Wide Throat Nozzle

Nosecone

Modern Electronics

12-Fin Forward Segment

New 150 ft diameter parachutes

Same Aft Skirt and Thrust Vector Control as Shuttle
Payload Shroud Point Of Departure

- 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)

Mass: 9.1 mT (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)
# Ares V Summary Schedule

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For reference only:
- Altair 1
- Altair 2
- Altair 3
- Altair 4

Milestones:
- SRR
- SDR/PNAR
- PDR/NAR
- CDR
- DCR

Specialized Projects:
- MPTA CS
- MPTA EDS
- KOVT
Current Ares V Status

- Current Ares V Point-of-Departure (51.00.48) exceeds Saturn mass capability by ~40%
- Ares V Lunar Capabilities Concept Review analysis focused on meeting lunar requirements and developing margin
- Ares V is sensitive to Loiter, Attitude, Power, and Altitude requirements in addition to payload performance
- LCCR-approved 51.00.48 POD 5.5-segment steel case booster/6 engine core) Ares V can meet current Human Lunar Return requirements with ~6 mT of Margin
- LCCR-approved 51.00.47 option maintained (5 segment HTPB composite case booster/6 engine core) can meet HLR requirement with more than 9 mT Margin
- Ares V team is actively reaching out to external organizations during this early concept phase to ensure that the Ares V vehicle can be leveraged for national security, scientific and commercial development needs
Ares V Mission Performance
Ares V Delivers 6 Times More Mass to Orbit

Current Capabilities can Deliver
~ 25,000 kg to Low Earth Orbit
~ 10,000 kg to GTO or L2TO Orbit
5 meter Shroud

Ares V can Deliver
~ 185,000 kg to Low Earth Orbit
~ 60,000 kg to L2TO Orbit
10 meter Shroud

*LEO performance for new Constellation point of departure vehicle (51.00.48) is expected to exceed values shown here. Performance analysis will be updated for the 51.00.48 vehicle.*
Shroud Point Of Departure Dimensions

Useable Volume
~860 m³
~[30,000 ft³]
Ares V (51.00.39) LEO Performance

Ares V Payload vs. Altitude & Inclination

- Inclination = 29 deg
- Inclination = 35 deg
- Inclination = 40 deg
- Inclination = 45 deg
- Inclination = 51.6 deg

LEO performance for new Constellation point of departure vehicle (51.00.48) is expected to exceed values shown here. Performance analysis will be updated for the 51.00.48 vehicle.
Ares V (51.00.39) Escape Performance

At 5.7 mT, the Cassini spacecraft is the largest interplanetary probe and required a C3 of 20 km²/s². Ares V can support about 35 mT for this same C3.

LEO performance for new Constellation point of departure vehicle (51.00.48) is expected to exceed values shown here. Performance analysis will be updated for the 51.00.48 vehicle.
The Ares V can support an order of magnitude more science instrumentation for outer planetary exploration missions.

Can also reach outer planets such as Neptune and other high energy insertion destinations.
Ares V Enabling Science Missions

♦ JPL D-41883 “Ares V Application to Solar System Exploration”: “In summary, there appears to be a wide range of science missions that could be launched by Ares V that would not be possible otherwise.”

♦ NASA/CP-2008/214588, Workshop Report on Astronomy Enabled by Ares V: “The large fairing and lift capabilities of the Ares V opens up new design concepts, e.g. large monolithic mirrors that reduce complexity and have no risk of deployment.”

<table>
<thead>
<tr>
<th>Space Telescope Mission</th>
<th>Current Space Telescope Designs (scaled to 8m)</th>
<th>Low Cost / High Margin Space Telescope</th>
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<tbody>
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<td>Payload</td>
<td>6,400kg (LW Optics eg Hubble)</td>
<td>23,000kg (Ground Based Optics)</td>
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<tr>
<td>Spacecraft</td>
<td>4,000kg</td>
<td>12,500kg</td>
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<tr>
<td>Fuel</td>
<td>600kg</td>
<td>2,100kg</td>
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<tr>
<td>Total</td>
<td>11,000kg</td>
<td>37,600kg</td>
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NASA Sponsored Study on Ares V Science Missions (Aerospace Corp 2008)
Summary

♦ The focus of design efforts in the near future will be on the primary Lunar mission
♦ We are currently just beginning to integrate the design functions from the various centers for this mission
♦ We appreciate all thoughts and ideas for different ways to use the Ares V platform