Constellation Lunar Capability
Point of Departure Architecture

Brian Muirhead
Constellation Chief Architect
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Constellation Architecture Elements

- Earth Departure Stage
- Ares I Crew Launch Vehicle
- Ares V Cargo Launch Vehicle
- Orion Crew Exploration Vehicle
- Altair Lunar Lander
Constellation’s Seven Projects

Ares - Launch Vehicle

Orion - Crew Exploration Vehicle

Extravehicular Activities

Mission Operations

Ground Operations

Altair

Lunar Surface
Ares I – Crew Launch Vehicle

- Serves as the long term crew launch capability for the U.S.
- 5 segment Shuttle-derived solid rocket booster
- New liquid oxygen/liquid hydrogen upper stage using J-2X engine
Orion – Crew Exploration Vehicle

- Orion will support both International Space Station (ISS) and lunar missions.
- Designed to operate for 180 days and up to 210 days docked to ISS or supporting outpost missions on the moon.
- Designed for lunar mission with 4 crew members.
- Can accommodate up to 6 crew members to the ISS.
- Potential to deliver pressurized and unpressurized cargo to the ISS.
Constellation conducted a Lunar Capability Concept Review (LCCR) in June 2008 to define an integrated Point of Departure (POD)* for the transportation architecture including capabilities to:

- Deliver and return crew to the surface of the moon for short durations, i.e. Human Lunar Return (HLR)
- Support a range of lunar exploration scenarios and possible surface system architectures, including establishment of a lunar outpost

Included in the LCCR were the Mission Concept Reviews for Ares V and Altair (crewed and cargo) including:

- Conceptual designs and key driving requirements
- Technology drivers and alternative designs
- Design concepts that meet mission and programmatic requirements

Current capabilities of Ares I and Orion for the lunar missions were assumed

Lunar Surface System concepts were explored but no POD selected

*This is a POD transportation architecture and NOT the final baseline
“Basis” Mission used to establish minimum content:

Sortie to Pole
7 day stay
4 crew members
500 kg p/l down
100 kg p/l up
Single Burn Lunar Orbit Insertion Burn at 891 m/s

Additional mission content evaluated during integrated architecture analysis

Crew of 4 + 500 kg cargo

100 kg return payload

Altair performs LOI

Orion performs 3 Burn TEI up to 1,492 m/s

Orion 20.185 t at TLI

EDS Performs TLI on FD5

ERØ

Ares-1 Ascent Target

Nominal Water Landing

Direct or Skip Entry

90 min. launch separation

Up to 4 days LEO Loiter

LLO 100 km
### Ares V 51 Series Trade Space Performance at Translunar Injection (Feb 08)

<table>
<thead>
<tr>
<th>Core Booster</th>
<th>Standard Core W/ 5 RS-68</th>
<th>Opt. Core Length / # Core Engines</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Segment PBAN Steel Case Reusable</td>
<td>51.0.39 63.6t -2.5t</td>
<td>+5.0t 51.0.46 68.6t +2.5t Engines: 6 Spacers: 1</td>
</tr>
<tr>
<td>5 Segment HTPB Composite Case Expended</td>
<td>51.0.40 69.7t +3.6t</td>
<td>+5.0t 51.0.47 74.7t +8.6t Engines: 6 Spacers: 1</td>
</tr>
<tr>
<td>5.5 Segment PBAN Steel Case Reusable</td>
<td>51.0.41 67.4t +1.3t</td>
<td>+3.7t 51.0.48 71.1t +5.0t Engines: 6 Spacers: 0</td>
</tr>
</tbody>
</table>

**Common Design Features**

- **Composite Dry Structures for Core Stage, EDS & Shroud**
  - Height = 116 m

- **Metallic Cryo Tanks for Core Stage & EDS**

- **RS-68B Performance:**
  - $I_{sp} = 414.2$ sec
  - Thrust = 3547 k N @ vac

- **J-2X Performance:**
  - $I_{sp} = 448.0$ sec
  - Thrust = 1308 k N @ vac

- **Shroud Dimensions:**
  - Barrel Dia. = 10 m
  - Usable Dia. = 8.8 m
  - Barrel Length = 9.7 m

**LCCR Study Reference**

**LCCR Study Upgrade**
Ares V Point of Departure Baseline

♦ **Vehicle 51.0.48**
  - 6 Engine Core, 5.5 Segment PBAN Steel Case Booster
  - Provides Architecture Closure with Margin

♦ **Maintaining Vehicle 51.0.47 with Composite HTPB Booster as future block change option**
  - Final Decision on Ares V Booster at Constellation Lunar SRR (2010)
  - Additional Performance Capability if needed for Margin or requirements
  - Allows for competitive acquisition environment for booster

♦ **Near Term Plan to Maintain Booster Options**
  - Fund key technology areas: composite cases, HTPB propellant characterization
  - Competitive Phase 1 Industry Studies

*NOTE: These are MEAN numbers*
Altair Lunar Lander POD Baseline

- 4 crew to and from the surface
  - Seven days on the surface
  - Lunar outpost crew rotation
- Global access capability
- Anytime return to Earth
- Capability to land 14 to 17 metric tons of dedicated cargo
- Airlock for surface activities
- Descent stage:
  - Liquid oxygen / liquid hydrogen propulsion
- Ascent stage:
  - Hypergolic Propellants or Liquid oxygen/methane
Lunar Surface System Concept Elements

Conceptual Outpost Elements

10 kW Array (net)

2 kW Array (net)

Power Support Unit (PSU) (Supports / scavenges from crewed landers)

Logistics Pantry

Habitation Element

Habitation Element

Common Airlock With Lander

ISRU Oxygen Production Plant

Small Pressurized Rover (SPR)

PSU (Facilitates SPR docking & charging)

Unpressurized Rover

ATHLETE Long-distance Mobility System (2)
Point D is the nominal baseline design point which includes 950 m/s load and 5 day low lunar orbit loiter

Points B & C are with Altair 950 m/s load without loiter

Point A would be enabled by Ares 51.0.47 and allow Altair to load to 1000 m/s

Full global access can be achieved with combination of mission timing, duration and/or additional loiter
Lunar Transportation Figures of Merit

- **Performance**
  - Ability to support the lunar outpost
  - Mass to surface: crew & cargo
  - Robustness of margins by system
  - Surface coverage: global access

- **Affordability**
  - DDT&E
  - Recurring
  - Budget wedge left for surface systems
  - Cost confidence

- **Risk**
  - LOC / LOM
  - Technical performance risk
  - Schedule risk
  - Commonality

- **Operations / Extensibility**
  - Facilities impacts
  - Operational flows
  - Mars feed-forward
Stochastic Margins Analysis @TLI

- Stochastic analysis focused around trans-lunar injection (TLI)
PDFs for Ares-V Delivery Capability

PDF with the 95th percentile at 65.2 mt and the 5th percentile at 62 mt, developed from a Monte Carlo analysis by SpaceWorks Engineering.

PDF with the 95th percentile at 74.7 mt, the 5th percentile at 69.7 mt, and some negative skewness. This was developed using engineering judgment.
CDFs for Ares-V Delivery Capability

CDF for Ares-V Delivery Capability (Various Designs)

mt

Probability

Ares 51.0.39
Ares 51.0.48
Ares 51.0.47
Ares 51.0.48 and Various Altair ΔV Capabilities

CDFs for 51.0.48 Ares-V Capability Minus TLI Stack Mass (With Orion = 20,185 kg)
DM Cargo/PMR Mass (in Excess of 500 kg) = 0 kg, Indexed by ΔV

Probability

Mass (kg)

-10,000 -5,000 0 5,000 10,000 15,000 20,000 25,000

-1 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1

891 m/s, 950 m/s, 1000 m/s
Ares 51.0.47 and Various Altair ΔV Capabilities
Critical Probability for Various LVs and Altair Loadings

Stochastic margins assessment indicates high probability of having adequate Program/Project margins and reserve

DM Cargo/PMR (In Excess of 500 kg)

Probability

Ares 51.0.39 + Altair 804-D @ 891 m/s
Ares 51.0.48 + Altair 804-D @ 891 m/s
Ares 51.0.47 + Altair 804-D @ 891 m/s
Ares 51.0.48 + Altair 804-D @ 950 m/s
Ares 51.0.48 + Altair 804-D @ 1000 m/s
Lunar Transportation Architecture Summary

♦ Ares-V
- **Ares-V 51.0.48**, maximizes commonality between Lunar and Initial Capabilities:
  - 6 engine core, 5.5 segment PBAN steel case booster
  - Provides architecture closure with additional margin
  - High commonality with Ares I
- Continue to study the benefits/risk of improved performance of **Ares-V 51.0.47**

♦ Altair
- Robust capability to support Lunar Outpost Missions:
  - Optimize for crew missions (**500 kg + airlock with crew**)
  - Lander cargo delivery: ~ **14,500 kg** in cargo only mode
- Size the system for global access while allowing future mission and system flexibility
  - Size Altair tanks for **1,000 m/s LOI delta-v**
  - Size for an additional **4 days of Low-Lunar Orbit loiter**

♦ Orion
- Continue to mature Orion vehicle concept
- Maintain strong emphasis on mass control
  - Continue to hold Orion control mass to **20,185 kg** at TLI
- Maintain emphasis on evolution of Orion Block 2 to support lunar Outpost missions