Constellation Lunar Capability Point of Departure Architecture

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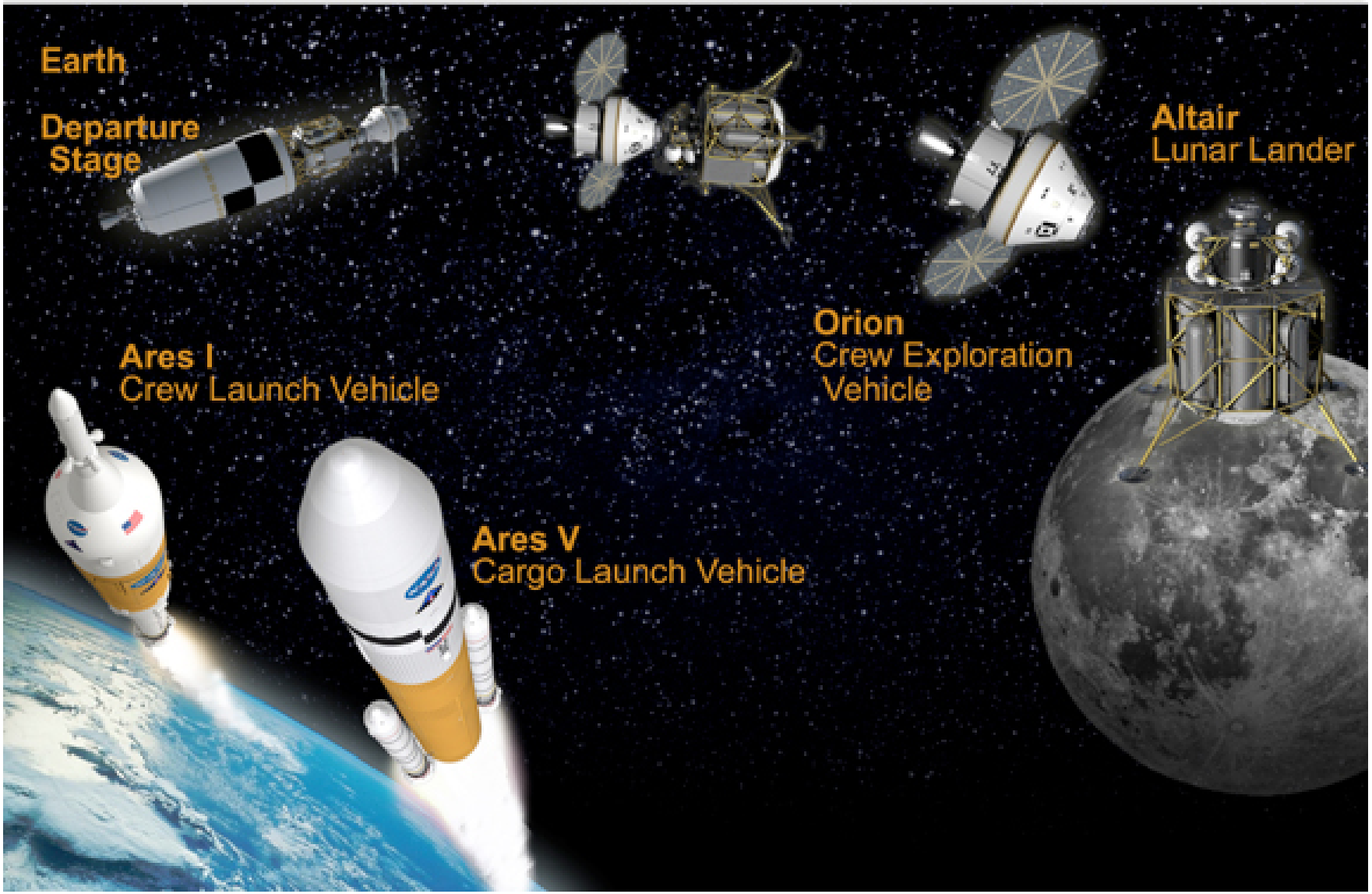
IEEE Aerospace Conference, 2009

CONSTELLATION

Constellation Architecture Elements



Constellation's Seven Projects

Ares- Launch Vehicle

Orion-Crew Exploration Vehicle

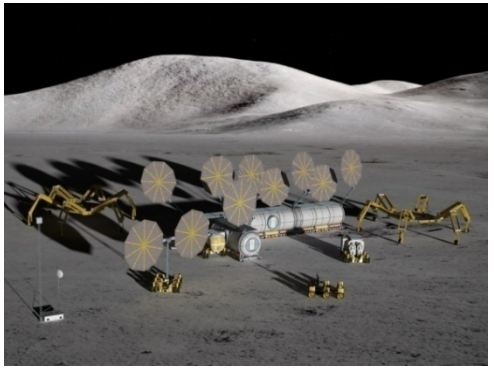
Extravehicular Activities

Mission Operations

Ground Operations

Altair

Lunar Surface



NASA's Exploration Roadmap

05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25

Science Robotic Missions

Lunar Robotic Missions

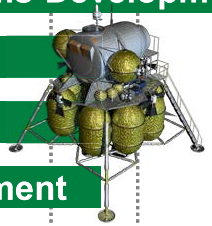
Lunar

Lunar Outpost Buildup

1st Human Orion Flt.

Surface Systems Development

Lunar Lander Development



Ares V Development

Earth Departure Stage Development

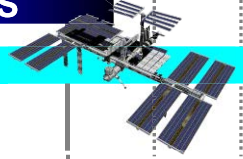
Orion Production and Operations

Orion Development

Initial Orion Capability

Ares I Development

Commercial Crew/Cargo for ISS

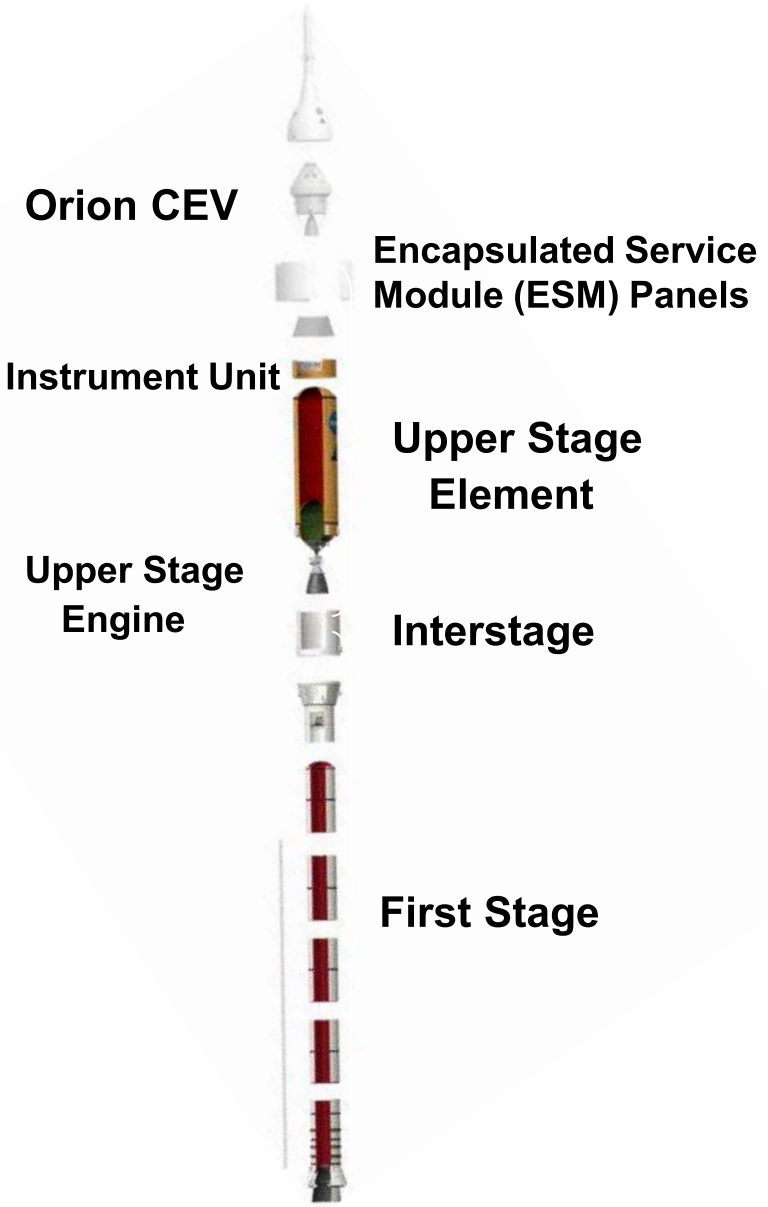


ISS Sustaining Operations

Space Shuttle Ops

SSP Transition...

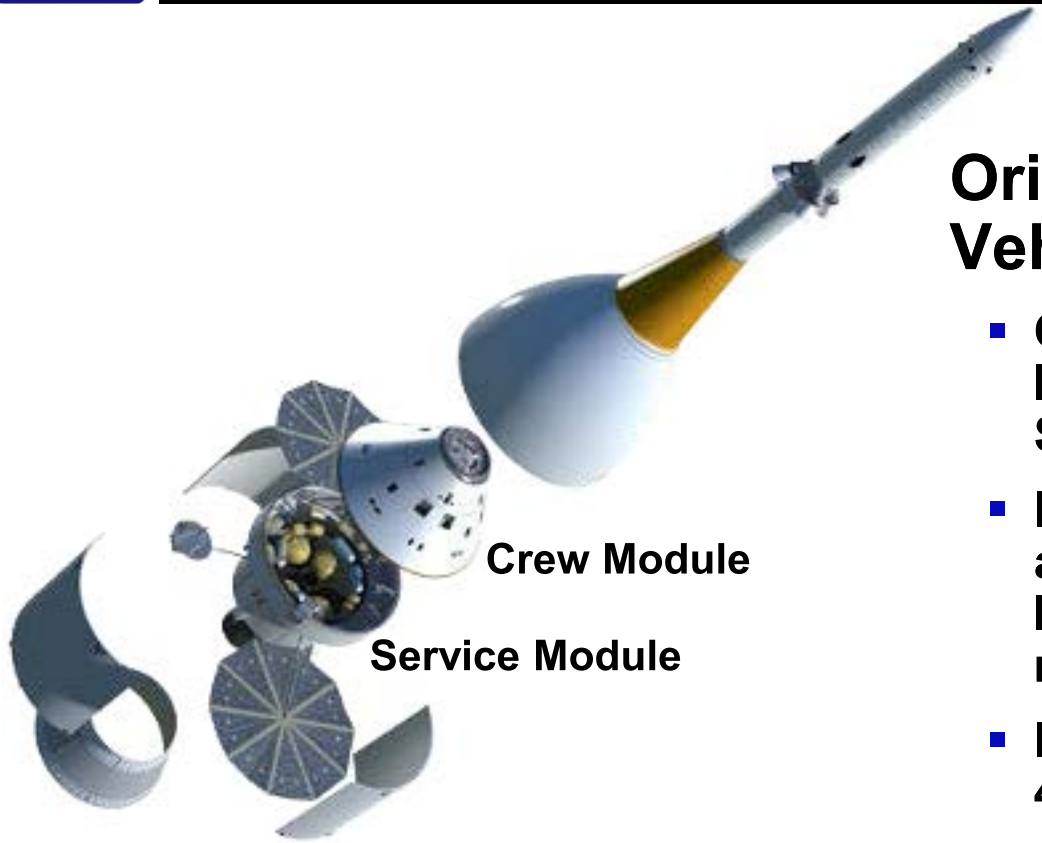
Ares Project



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

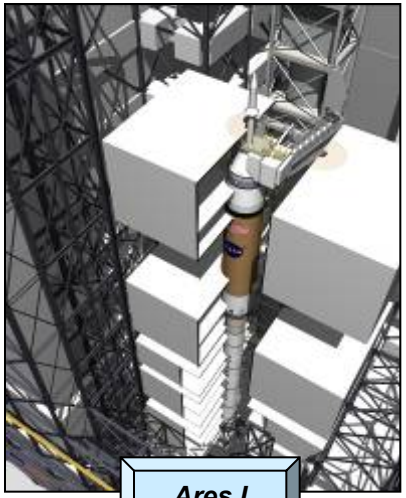
Orion Project



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

Ground Operations Project

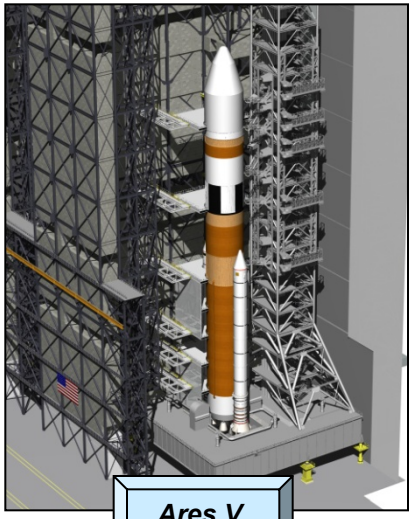


Ares I
VAB HB3

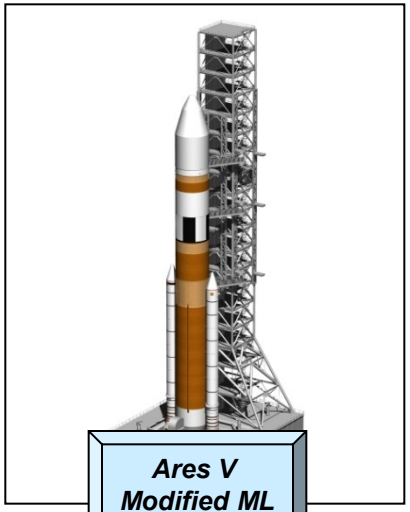
Ares I
New ML

Ares I
Crawler-Transporter

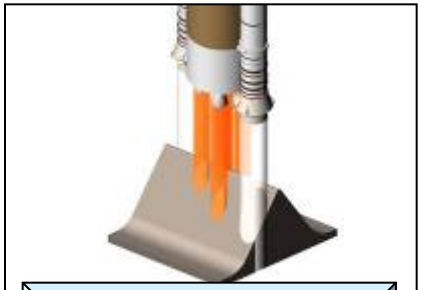
Ares I
LC 39B



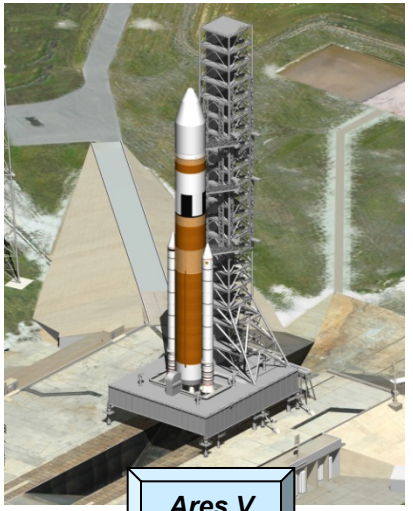
Ares V
VAB HB1



Ares V
Modified ML



Ares V
Pad 39A Flame Deflector



Ares V
Pad 39A

Architecture Definition Introduction

- **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**

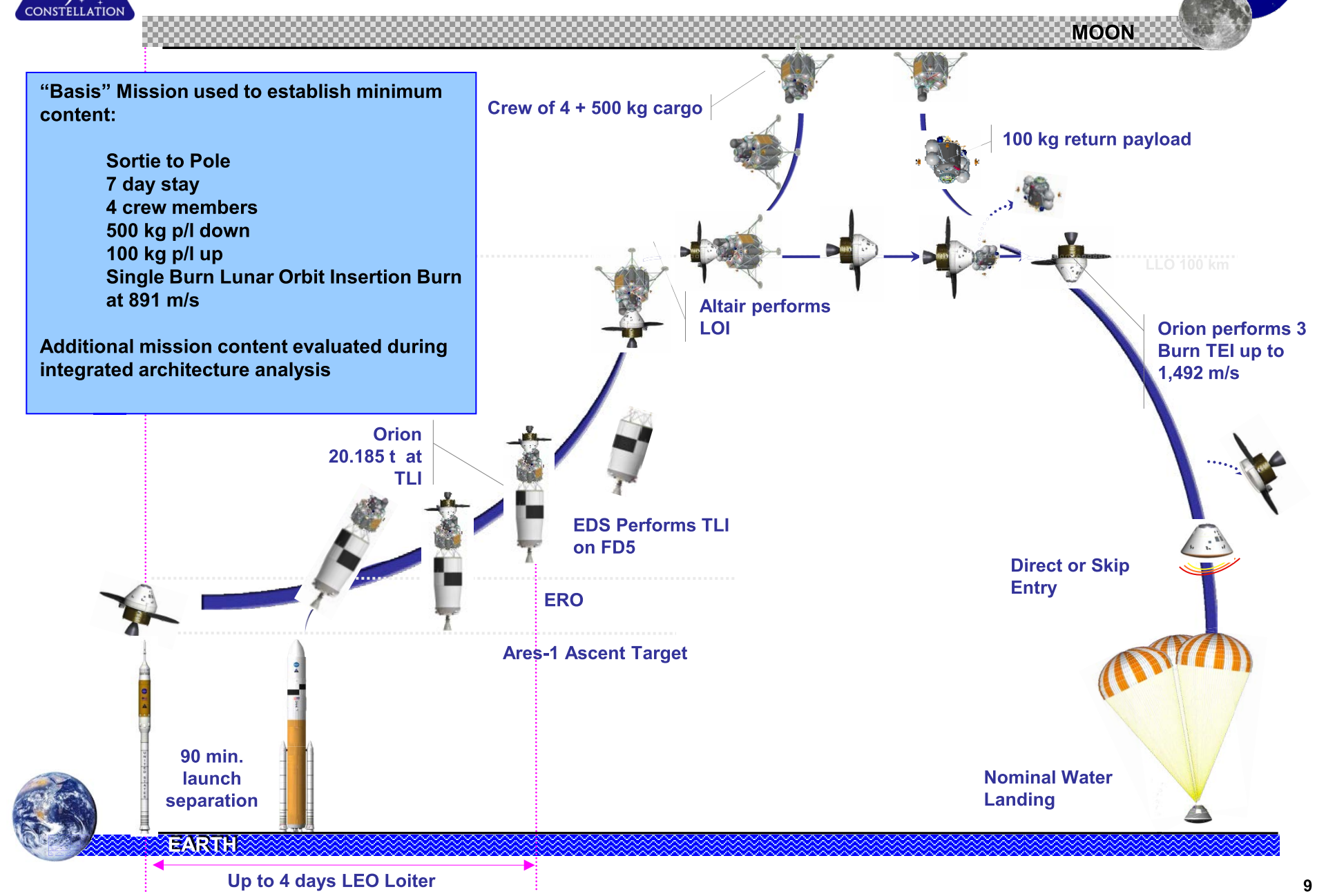
***This is a POD transportation architecture and NOT the final baseline**

Lunar Crewed Mission Profile

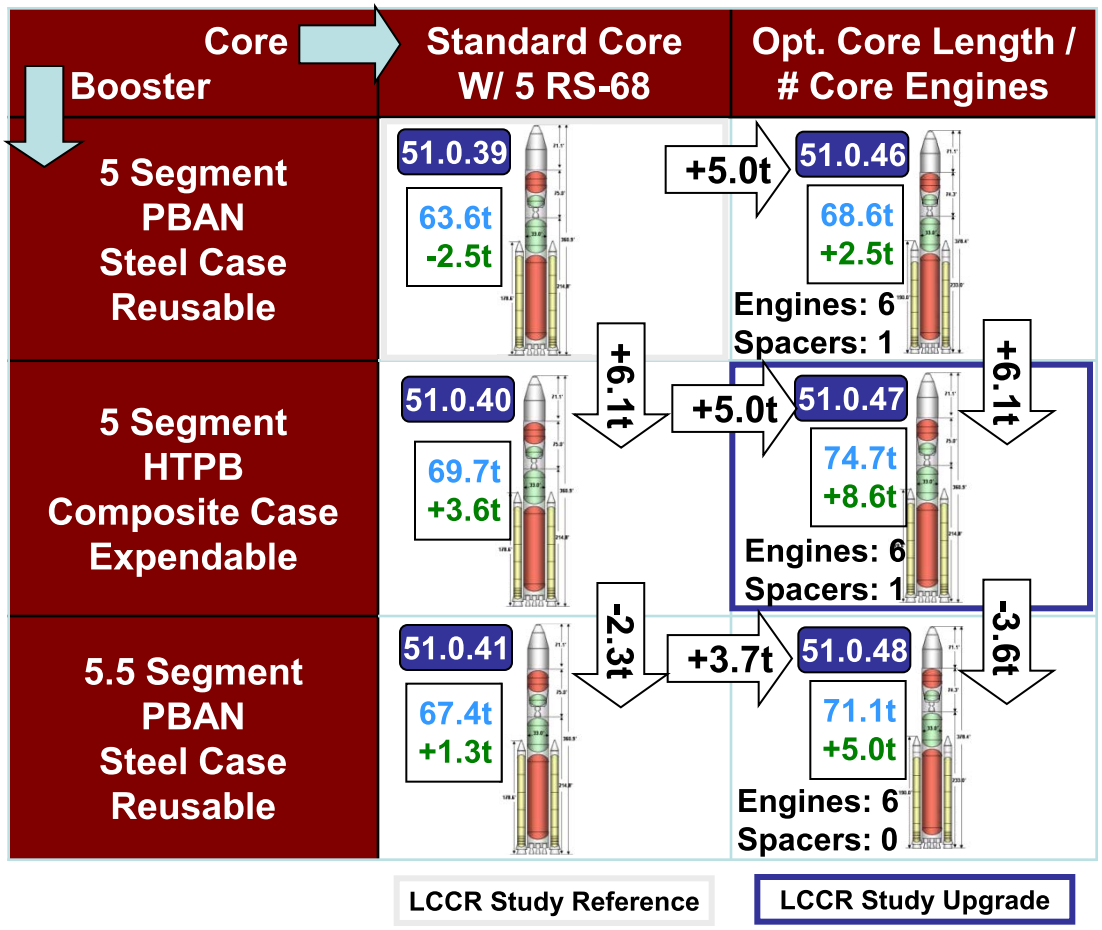
"Basis" Mission used to establish minimum content:

- 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

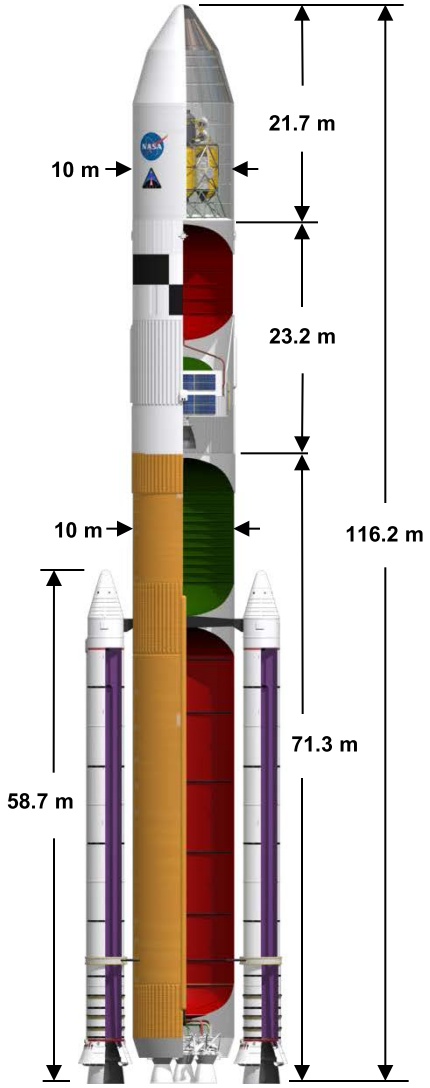


Ares V 51 Series Trade Space Performance at Translunar Injection (Feb 08)



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

Ares V Point of Departure Baseline

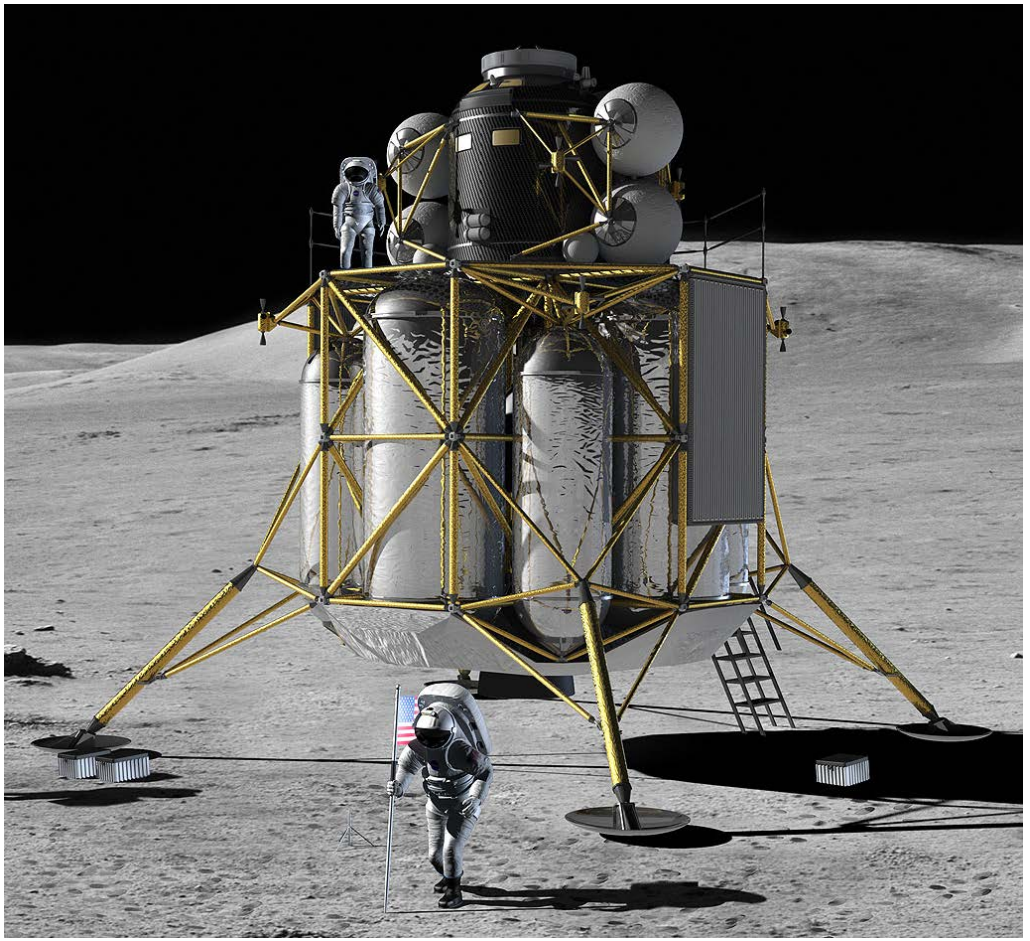


NOTE: These are MEAN numbers

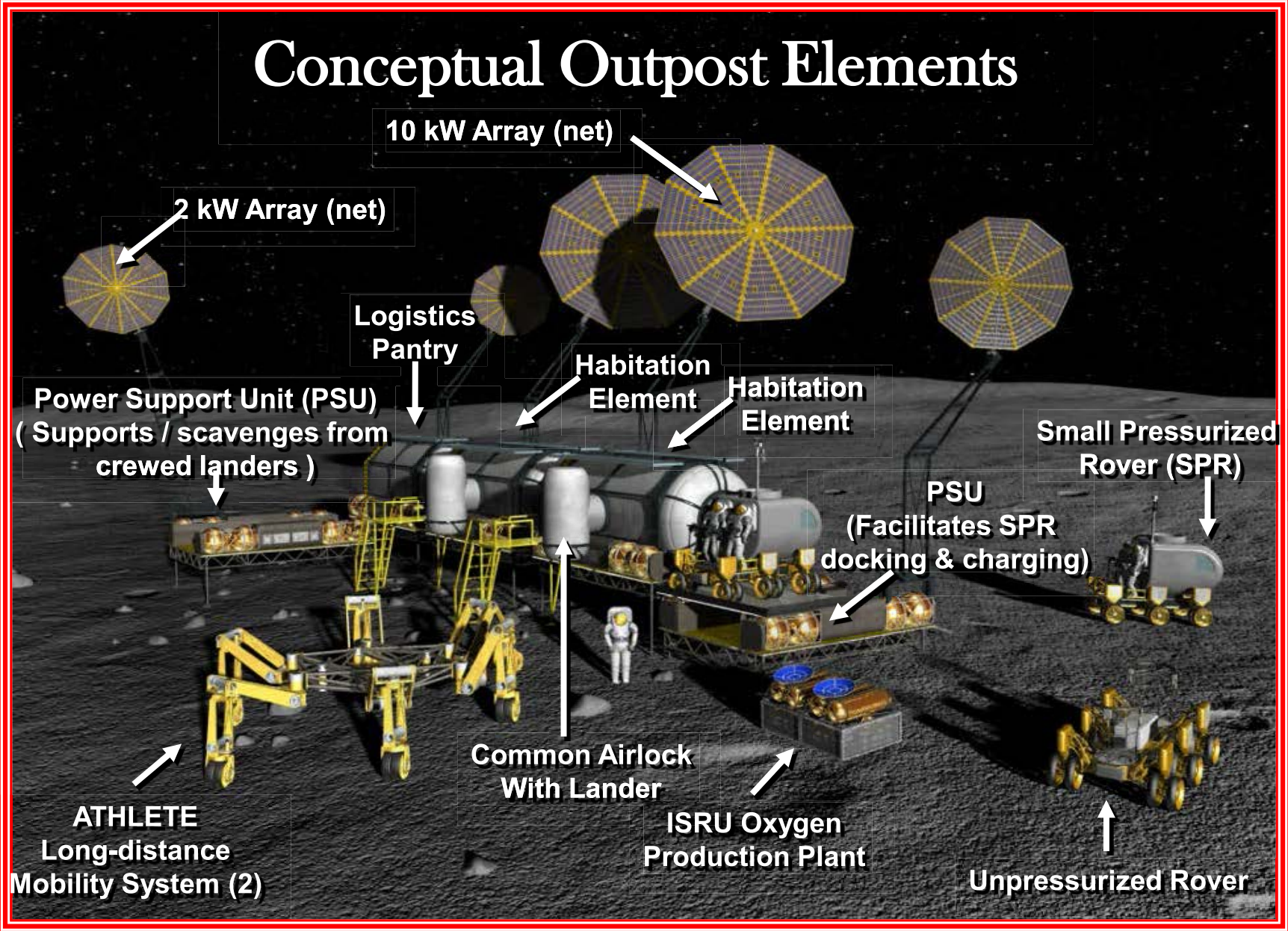
- ***Vehicle 51.0.48***
  - 6 Engine Core, 5.5 Segment PBAN Steel Case Booster
  - Provides Architecture Closure with Margin
- **Maintaining Vehicle 51.0.47 with Composite HTPB Booster as future block change option**
  - Final Decision on Ares V Booster at Constellation Lunar SRR (2010)
  - Additional 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

Altair Lunar Lander POD Baseline

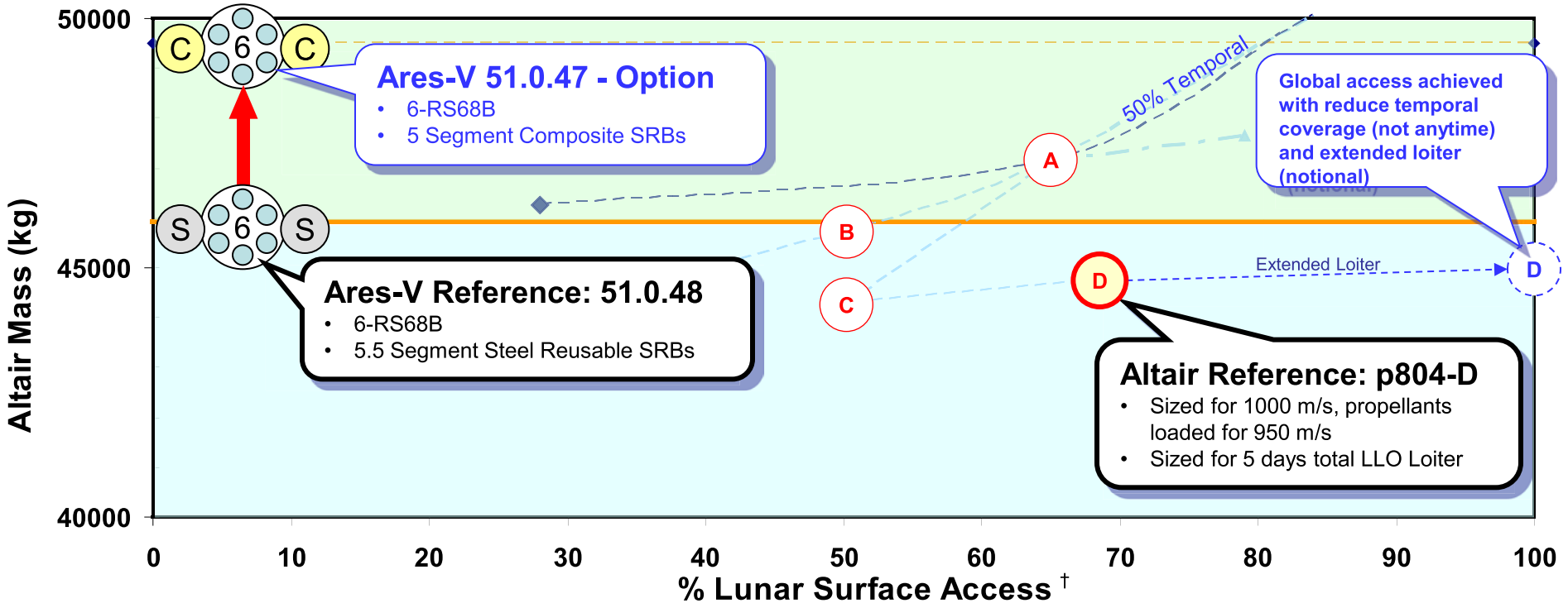
- **4 crew to and from the surface**
  - Seven days on the surface
  - Lunar outpost crew rotation
- **Global access capability**
- **Anytime return to Earth**
- **Capability to land 14 to 17 metric tons of dedicated cargo**
- **Airlock for surface activities**
- **Descent stage:**
  - Liquid oxygen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



Lunar Surface System Concept Elements



System and Mission Recommendation

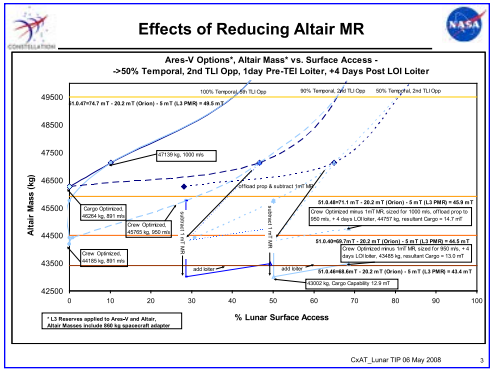


- Point D is the nominal baseline design point which includes 950 m/s load and 5 day low lunar orbit loiter
- Points B & C are with Altair 950 m/s load without loiter
- Point A would be enabled by Ares 51.0.47 and allow Altair to load to 1000 m/s
- Full global access can be achieved with combination of mission timing, duration and/or additional loiter

Lunar Transportation Figures of Merit

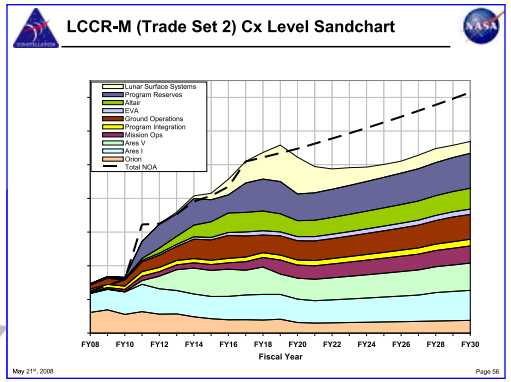
Performance

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



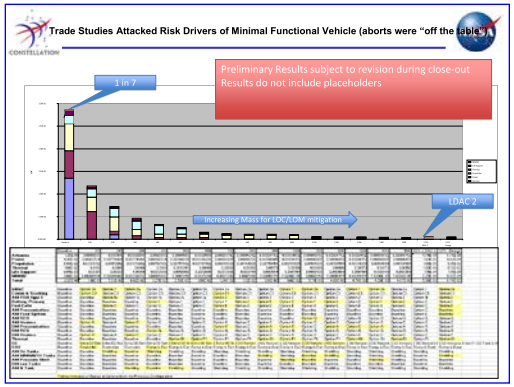
Affordability

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



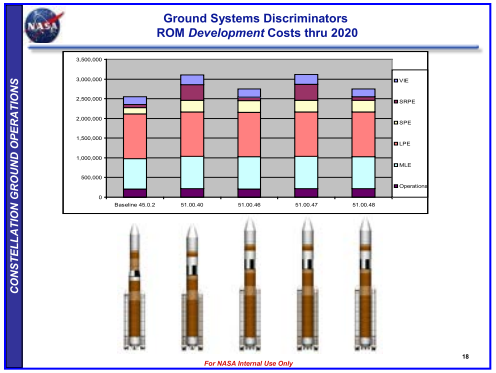
Risk

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

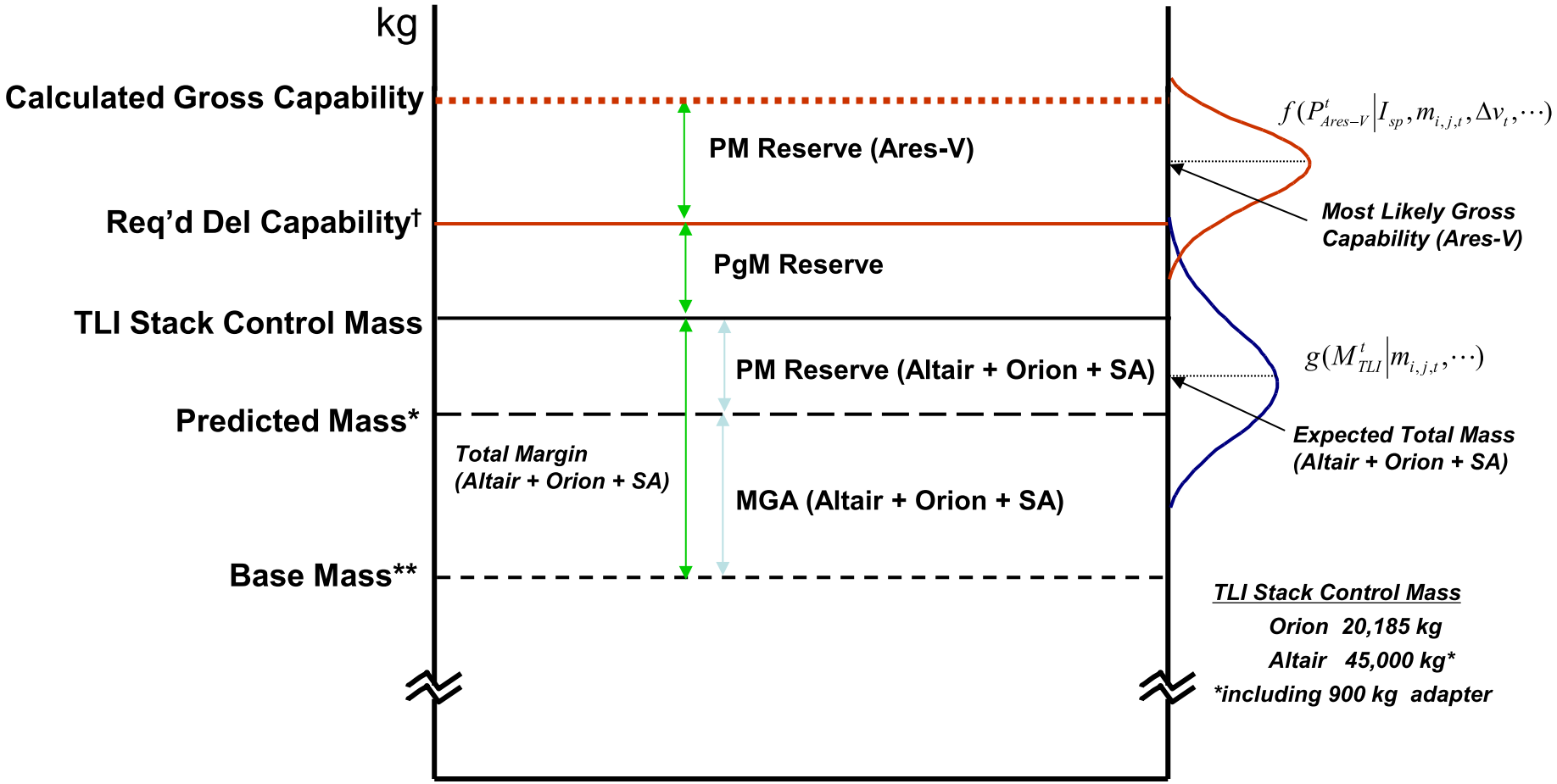


Operations / Extensibility

- Facilities impacts
- Operational flows
- Mars feed-forward

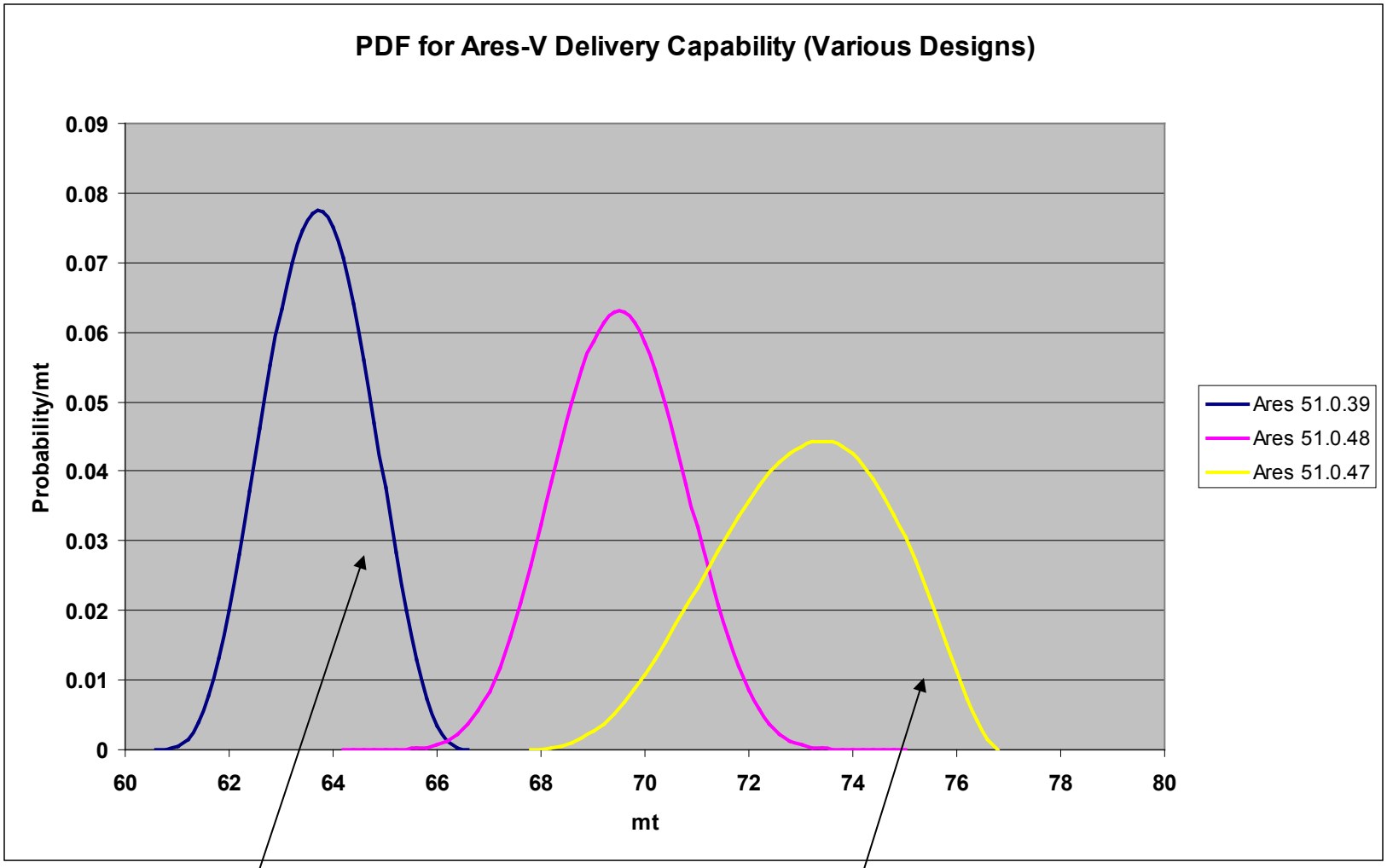


Stochastic Margins Analysis @TLI



- Stochastic analysis focused around trans-lunar injection (TLI)

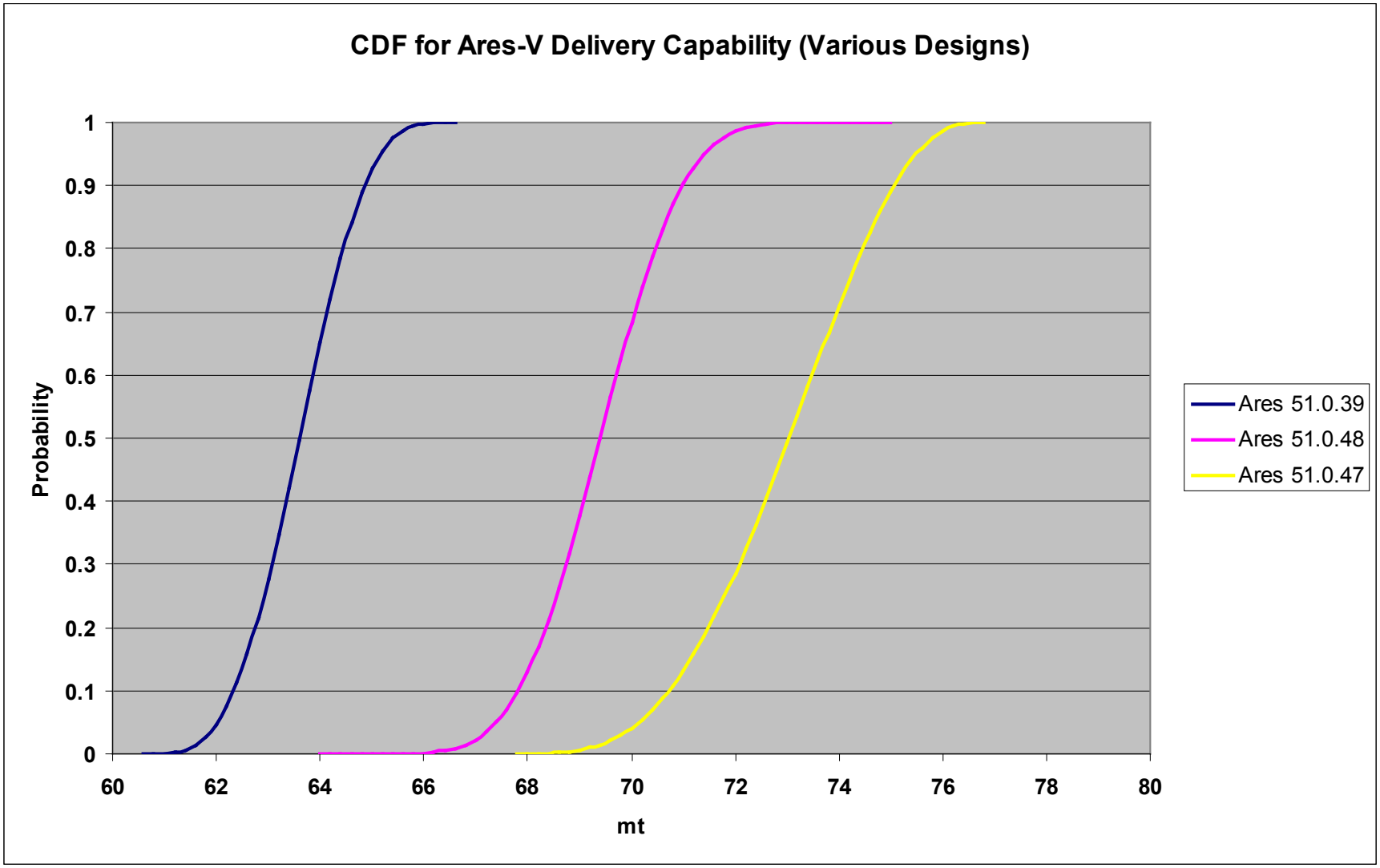
PDFs for Ares-V Delivery Capability



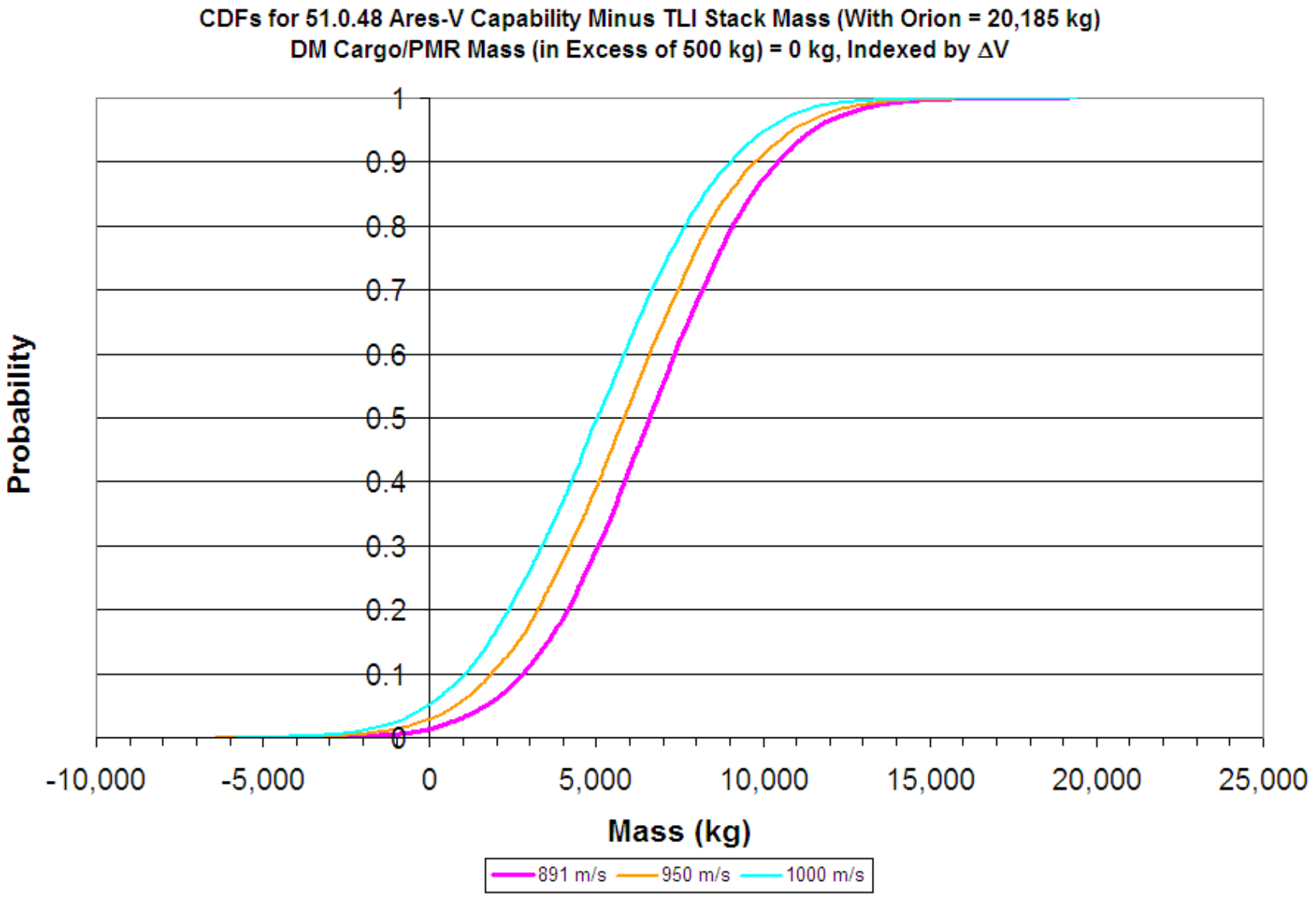
PDF with the 95th percentile at 65.2 mt and the 5th percentile at 62 mt, developed from a Monte Carlo analysis by SpaceWorks Engineering.

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.

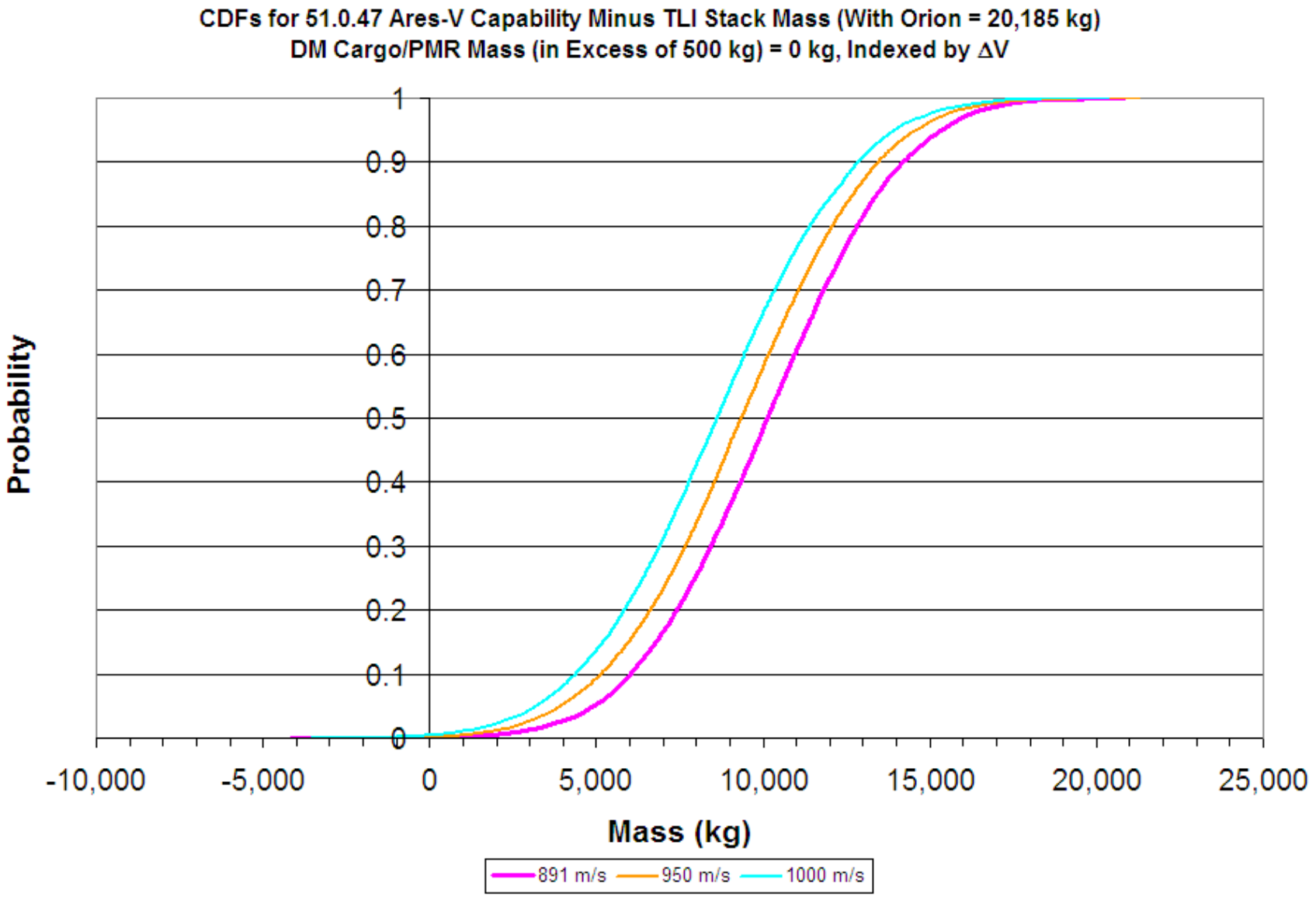
CDFs for Ares-V Delivery Capability



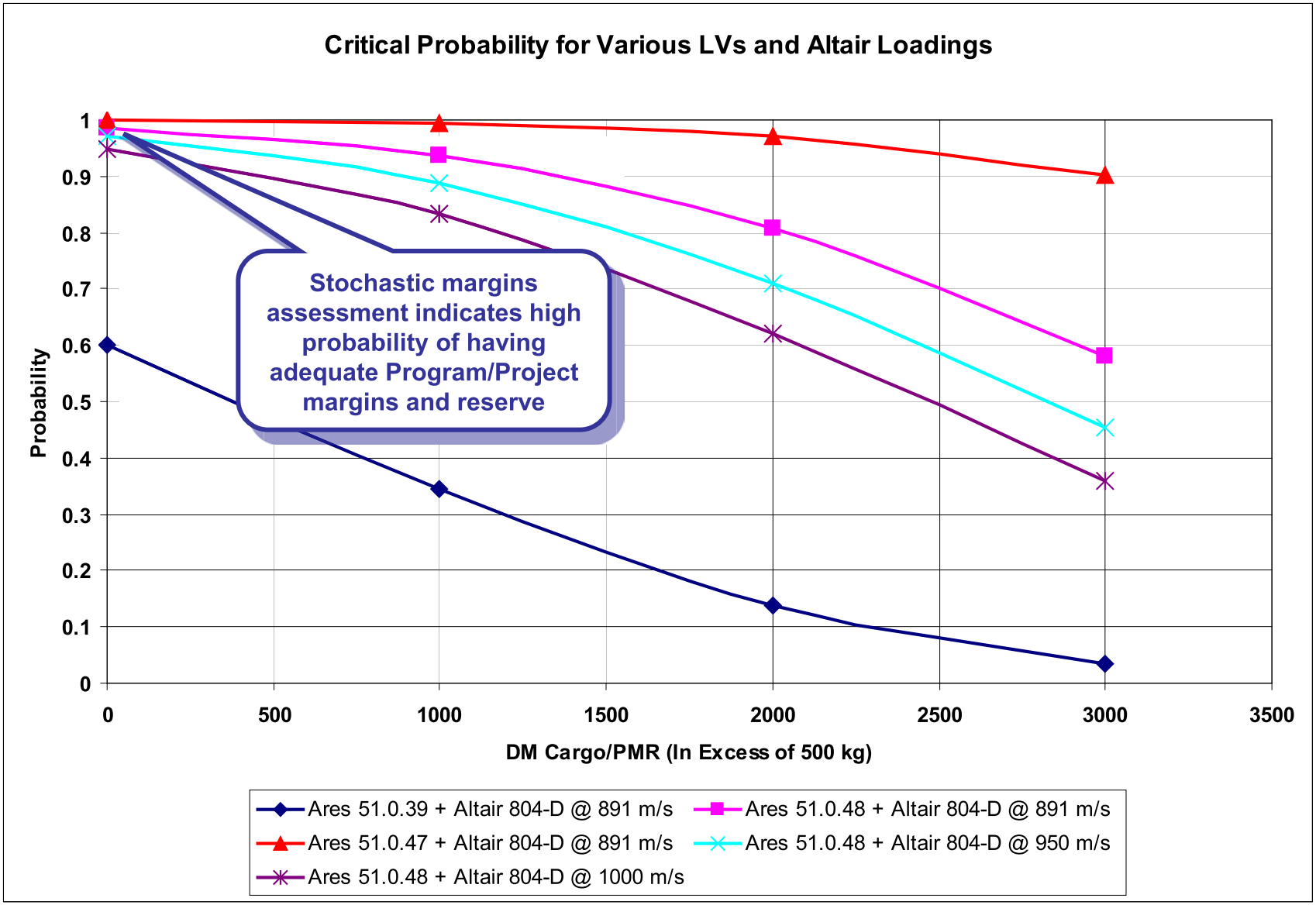
Ares 51.0.48 and Various Altair ΔV Capabilities



Ares 51.0.47 and Various Altair ΔV Capabilities



Probabilities of Having Adequate Margin: By Launch Vehicle and Cargo for Sortie and Outpost Missions



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