ARES V: PROGRESS TOWARD UNPRECEDENTED HEAVY LIFT

Phil Sumrall
Advanced Planning Manager, Ares Projects
NASA Marshall Space Flight Center

ABSTRACT

Every major examination of America's spaceflight capability since the Apollo program has highlighted and reinforced the need for a heavy lift vehicle for human exploration, science, national security, and commercial development. The Ares V is NASA's most recent effort to address this gap and provide the needed heavy lift capability for NASA and the nation. An Ares V-class heavy lift capability is important to supporting beyond earth orbit (BEO) human exploration. Initially, that consists of exploration of the Moon vastly expanded from the narrow equatorial Apollo missions to a global capability that includes the interesting polar regions. It also enables a permanent human outpost. Under the current program of record, both the Ares V and the lunar exploration it enables serve as a significant part of the technology and experience base for exploration beyond the Moon, including Mars, asteroids, and other destinations. The Ares V is part of NASA's Constellation Program architecture. The Ares V remains in an early stage of concept development, while NASA focused on development of the Ares I crew launch vehicle to replace the Space Shuttle fleet. However, Ares V development has benefitted from its commonality with Ares I, the Shuttle, and contemporary programs on which its design is based. The Constellation program is currently slated for cancellation under the proposed 2011 federal budget, pending review by the legislative branch. However, White House guidance on its 2011 budget retains funding for heavy lift research. This paper will discuss progress to date on the Ares V and its potential utility to payload users.

• I. Introduction

Under the guidance of National Space Policy, NASA is working to retire the Space Shuttle fleet, develop its replacement, complete and operate the International Space Station (ISS), and resume human exploration of the Solar System starting with expansion of the lunar exploration begun by the Apollo missions. The goal of the Exploration Systems Architecture Study (ESAS), completed in 2005, was to define a safe, flexible, cost-effective architecture to accomplish those broad goals. Numerous exploration studies dating back decades informed the early analyses, as did the findings and recommendations of the Challenger and Columbia shuttle accident investigations. The missions for this new architecture were condensed into a set of design reference missions (DRMs), including ISS crew rotation, crewed lunar sortie, cargo lunar sortie, and crewed and cargo Mars missions. Those inputs manifested themselves in several ways in the ESAS architecture. Development cost would be contained by employing proven technology such as a ballistic reentry capsule, in-line vehicle design, a crew launch escape system, separation of crew and cargo transportation, reliance to the extent possible on Apollo, Shuttle, and contemporary technology such as the Solid Rocket Booster (SRB), the Space Shuttle Main Engine (SSME), the Saturn J-2 upper stage engine, the Delta IV RS-68. Perhaps the most ambitious drivers were an order of magnitude improvement in safety over the Shuttle and establishment of a permanent human presence on the Moon, characterized by global lunar access and an anytime-return capability.

The vehicles that emerged from ESAS and follow-on analyses immediately after were the Ares I crew launch vehicle, the Ares V cargo launch vehicle, the Orion crew exploration vehicle, a lunar lander, and a variety of lunar surface systems. That architecture is illustrated in figure 1.

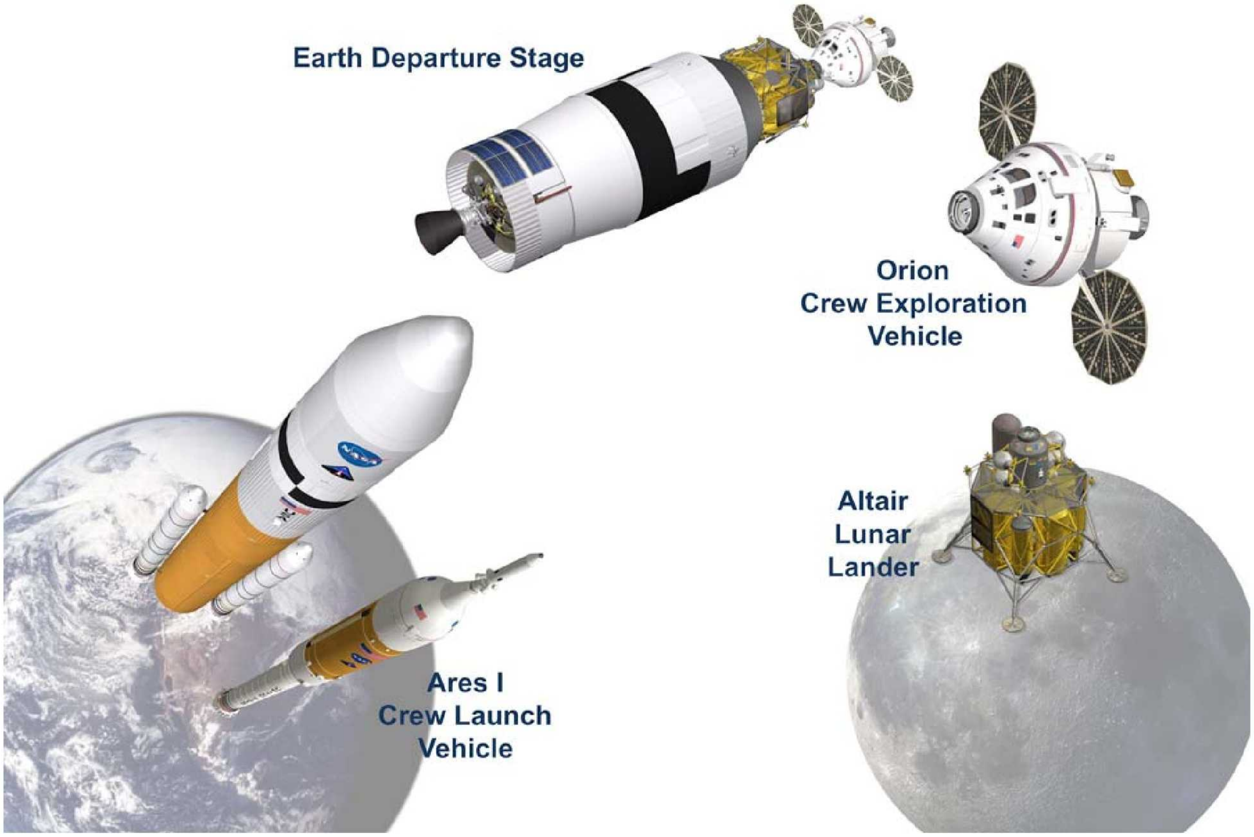


Figure 1 – Major elements of the current Constellation Program architecture

Ares I is currently designed to launch Orion with crews of up to four into low Earth orbit (LEO) on missions to ISS or the Moon. The Ares I five-segment solid fuel first stage is based on the Shuttle four-segment solid rocket booster. A new Ares I upper stage is powered by the J-2X liquid fuel engine, based on the proven J-2 engine that powered the Saturn I and Saturn V upper stages.

Ares V is designed to launch large payload into LEO. Its core stage is powered by five RS-68 liquid hydrogen/liquid oxygen (LH_2/LOX) engines similar to those in the Delta IV first stage. The core stage is flanked by two 5.5-segment SRBs based on the 5-segment Ares I first stage. The boosters use the same Polybutadiene Acrylonitrile (PBAN) propellant as the Ares I and Space Shuttle. The Ares V upper stage, called the Earth departure state (EDS) is powered by a single J-2X based on the Ares I upper stage engine. Atop the EDS is a payload shroud to protect payloads during ascent. For the crewed lunar sortie mission, Ares V will launch a lunar lander into LEO. The EDS will support the lander for up to four days until rendezvous with Orion. Then the J-2X will re-ignite and send the mated Orion/lander to lunar orbit. While the Ares V primary mission is the human lunar return, it also represents a national strategic capability that can serve other stakeholders in the scientific, national security and commercial sectors. This paper will provide a top-level view of Ares V origin, design philosophy, goals, requirements, development progress, and utilization potential.

• II. Ares V: Defined and Refined

Ares V will by most measures be the largest launch vehicle in history. In comparison with the Apollo-era Saturn V, the dual launch architecture will send 58 percent more payload to TLI. As currently configured, Ares V is 381 ft (116 m) tall and 33 feet (10 m) in diameter. It weighs approximately 8.1 million pounds (3,704.5 mT) fully fueled for launch. Its first stage will generate 11 million pounds of seal-level thrust. It will be capable of launching 413,800 pounds (187.7 mT) to LEO, 138,500 pounds (63 mT) direct to the Moon or 156,700 pounds (71.1 mT) in its dual-launch architecture role with Ares I. The current reference configuration is shown in figure 2.

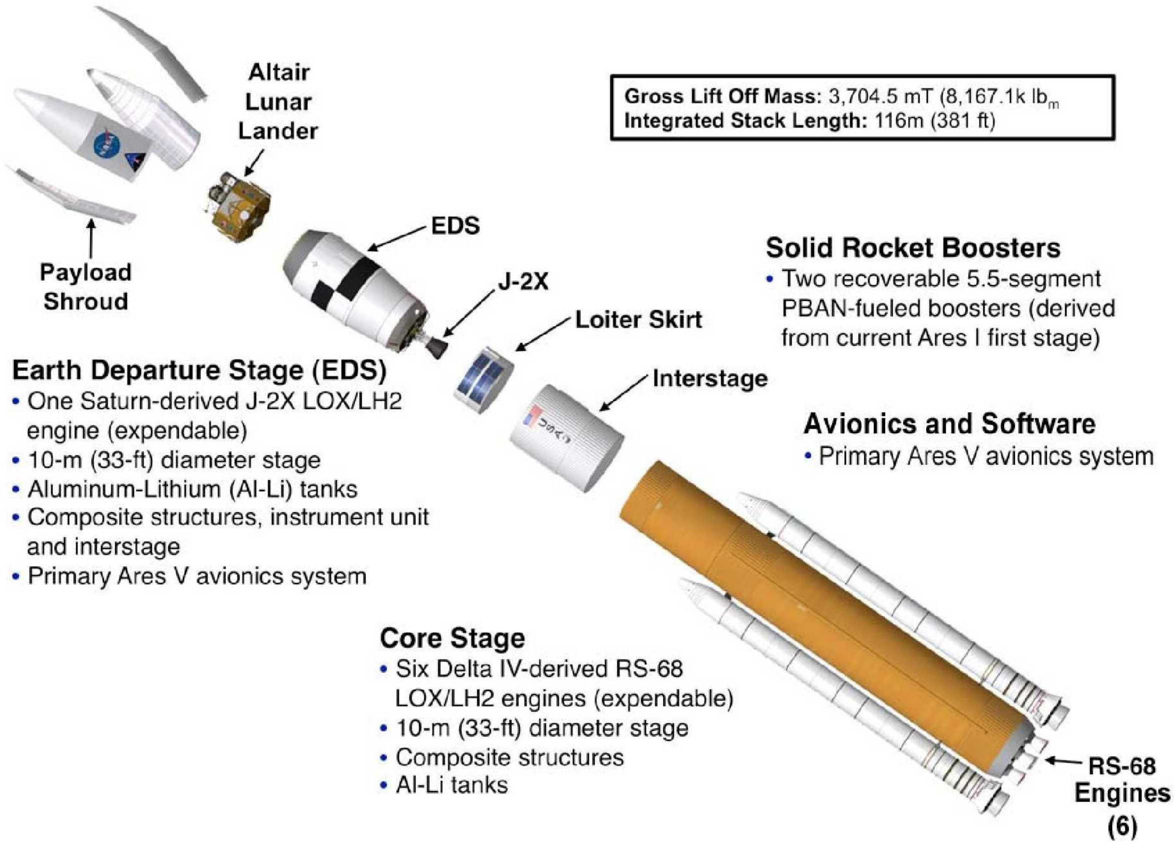


Figure 2 – Expanded view of the LCCR point-of-departure Ares V

Development of Ares I to replace the Shuttle and minimize any gap in U.S. crewed transportation capability is NASA's first priority for available funding. As a result, Ares V remains in an early concept definition stage, although it benefits from Ares I technical progress on the first stage booster, J-2X engine, and other common systems. The starting point for concept definition work is the Constellation Architecture Requirements Document (CARD). It contains mass requirements for both lunar sortie and lunar cargo DRMs. For the sortie mission, the CARD specifies an Orion control mass of 44,500 lb. (20.2 mT) and a lunar lander control mass of 99,208 (45 mT). The total TLI payload requirement is 147, 575 lb (66.9 mT). The lunar sortie mission assumes a LEO destination orbit of 130 nautical miles (nm) at 29 degrees inclination. For cargo missions, the CARD specifies a lander control mass of 118,168 lb (53.6 mT) and a total TLI payload mass of 120,372 lb (54.6 mT). In addition to the CARD, the Ares team added factors for safety, reliability, and cost to evaluate hundreds of configurations trading stages, engines, boosters, materials, selected technology upgrades and more.

To date, the team has evaluated more than 2,000 configurations, providing the Ares and Constellation teams with greater understanding of the vehicle, the architecture, and implications for ground and flight operations. Among those insights is the impact of the loiter period between launch and rendezvous of the Ares V EDS and Orion for the trans lunar injection (TLI) maneuver to send the mated spacecraft to the Moon. The loiter period imposes numerous performance losses and corresponding design requirements on the vehicle that translate into lost payload performance. The team also realized the need to carry performance margin associated with the Ares I/Orion launch prior to rendezvous. These factors continue to drive ongoing performance technology and trade studies. A summary of key milestones in the trade studies leading to the current point-of-departure (POD) is shown in figure 3. The current Ares V point of departure (POD) configuration, designated 51.00.48, was approved by the Constellation Program during the Lunar Capabilities Concept Review (LCCR) in 2008. The POD has served as a reference for subsequent trade studies and technical evaluations.

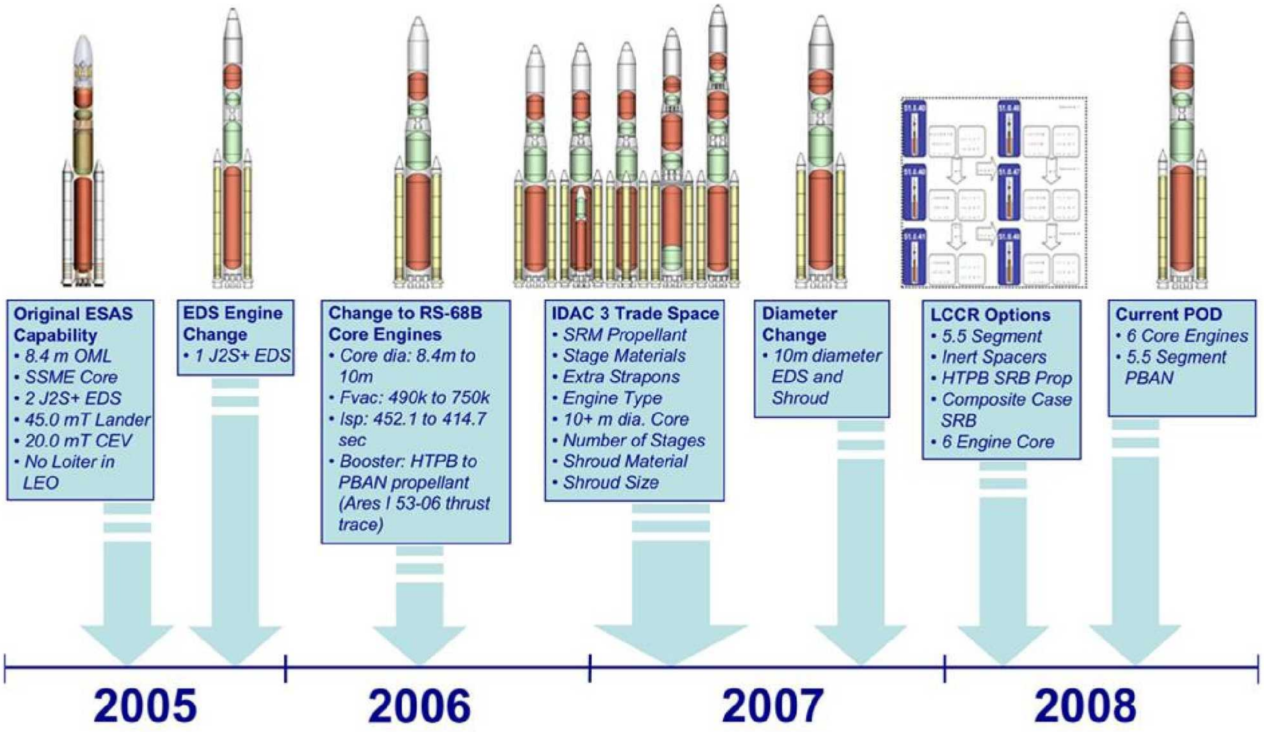


Figure 3 – Key milestones in Ares V development from ESAS to LCCR

III. Post-LCCR Analyses

The Ares V team has continued its analysis of the Ares V configuration, ground operations and mission details since the LCCR current POD was established. The team, which comprises members from NASA's Marshall, Kennedy, Johnson, Langley, and Glenn field centers, has conducted three program analysis cycles (PAC), essentially studies that provided increased levels of detail to the design and focused on topics of special study as needed.

Program Analysis Cycle 1 (PA-C1) refined the LCCR configuration and served as a transition to additional studies in an effort to provide a heavy lift capability with the desired payload margins. This configuration was used to establish a basic concept and a set of internal requirements. The team developed and fine-tuned the vehicle design and requirements analysis process and planned for future design cycles.

PA-C2 retained the LCCR POD's six RS-68 core stage engines but departed from it by using a proposed upgraded variant with a regeneratively-cooled nozzle, as well as a "short burn" booster that provided the same thrust over a shorter burn time. The study focused on verifying the design process, validating requirements, and identifying vehicle sensitivities. The reference configuration met and exceeded performance requirements with 73.7 mT payload to TLI. The team refined the design, risks, and requirements. Among the issues requiring attention noted in the study were base heating, plume impingement during booster separation, internal and external acoustic/vibroacoustic environments, understanding of separation events, assessment of throttle vs. loads, load stabilization on the mobile launch platform (MLP), and refined definition of trajectories to understand performance space.

One product created in PA-C2 – which illustrates the ongoing systems engineering emphasis – was an integrated functional schematic, shown in figure 4. It provides an overview of functions that flow across interfaces. It will help mature functional flow block diagrams, stimulate functional design discussions, and identify functional and interface trade space options. It will also help standardize symbols across elements and refine various vehicle program documents. The results were applicable to future design trades.

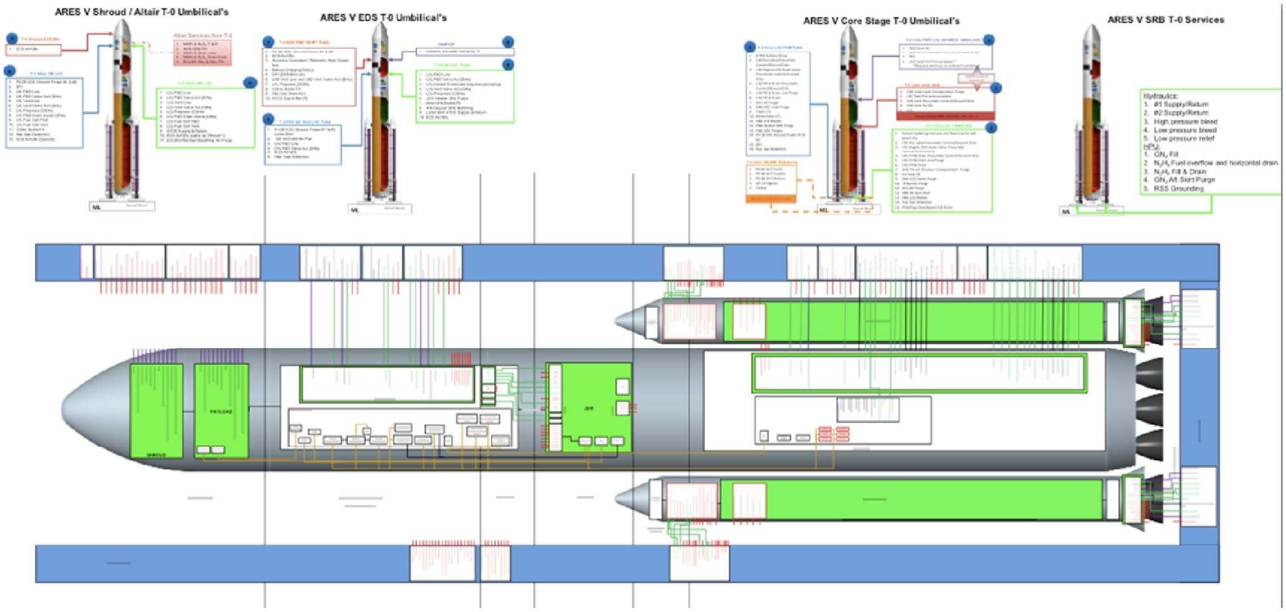


Figure 4 – Ares V integrated functional schematic

Following this second review, an exercise was undertaken to refine the study with respect to known threats and 0pportunities. The resulting vehicle TLI payload was reduced to 70 mT with more conservative estimates for ullage, core and EDS thermal protection systems, the addition of helium pressurization and hardware to the EDS, reduced core stage engine efficiency, the addition of acoustic blankets to the shroud, and reducing the EDS boil-off rate, effectively adding mass to the vehicle.

The most recent design cycle, PA-C3, from October 2009 to March 2010, was intended to match refined performance targets to programmatic cost and schedule requirements. The results were also applicable to potential changes in the Ares architecture. In fact, four vehicle configurations were analyzed. The major change from PA-C2 to PA-C3 was engine layout. PA-C2 had six engines positioned in the core stage base. PA-C3 has 5 engines with four engines positioned on the outer boundary of the core stage which require engine flare fairings to protect the four engines. All configurations also used two 5-segment Ares I SRBs. Changes in engines and boosters were the main differences between configuration trades aimed at more performance and shortest development time. In the PAC-3 trades the "D" variant was considered the performance version and was rated at 64.8 mT to TLI. Figure 5 graphically represents the analysis cycles since LCCR and key configuration changes and study objectives.

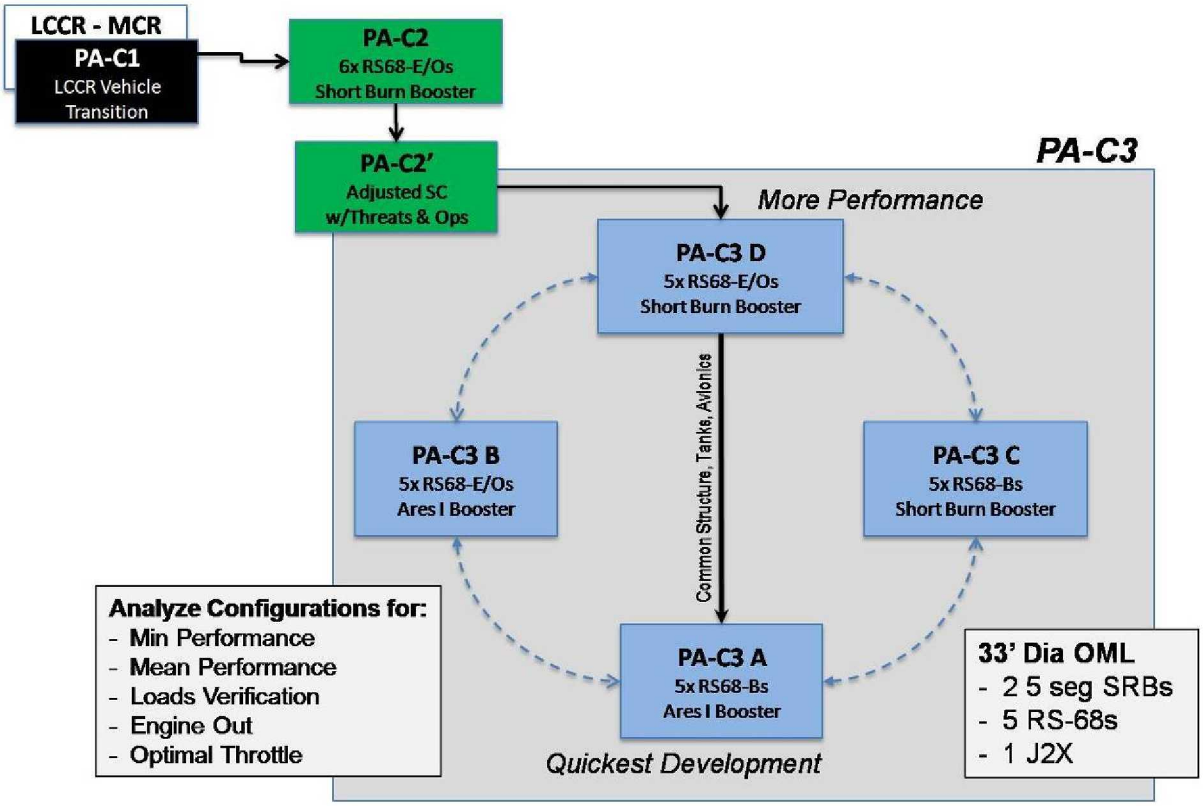


Figure 5 – Key milestones in Ares V development from ESAS to LCCR

The four PA-C3 configurations were analyzed for minimum performance, mean performance, loads verification, engine out, and optimal throttle. The team continued to evaluate booster options including the current PBAN baseline or hydroxyl-terminated polybutadiene (HTPB) propellant, composite vs. metal booster cases, the number of segments per booster, thrust trace, and options involving core stage/booster layout. A mass study included baseline mass, center of mass and cargo mass for the core stage, EDS, interstage, payload shroud, and propellants. The team continued analyzing vehicle aerodynamics. The study assessed crew risk, including abort effectiveness and loss of crew for various Ares V failures, and it proposed failure mitigation technologies.

Payload shroud studies examined geometry and sizing for the shroud and possible acoustic blanket insulation materials. The shroud concept of operations was refined to include ground operations issues such as fabrication, assembly, payload encapsulation, internal environments during transportation, VAB stacking, purge, human access, payload umbilicals, and payload servicing. The study also covered various launch operations issues, including health monitoring, separation system and flight ops issues such as umbilical line release, shroud jettison, and reentry. The basis for these studies was the 4-petal tangent ogive shroud. Other shroud studies covered vibroacoustics, ascent venting, loads, and a geometry trade study to determine the sensitivity of Ares V TLI payload mass to the payload shroud outer mold line geometry. Sample payloads included the lunar lander, vertical and horizontal habitats, and the All-Terrain, Hex Limbed, Extra-Terrestrial Explorer (AHTLETE) carrier vehicle. These payload packaging studies are illustrated in figure 6.

Lunar Electric Rovers

Logistics Carrier with ATHLETE

Vertical Habitat with ATHLETE

Horizontal Habitat with ATHLETE

Figure 6 – Ares V payload shroud packaging

The EDS team examined J-2X impacts for various loiter and other scenarios, as well as composite/metallic structure trades, and cryo fluid management issues such as ascent boil-off and ullage characterization. The core stage team examined the impact of reverting from six engines to five, engine layout options, fairings, hydrogen routing, and upgraded performance for the RS-68. The team also examined overall performance, cost and risk, pad shutdown approach, engine replacement capability, throttle and engine-out, and base heating.

The first stage booster team studied thrust trace tailoring, booster separation, nozzle size, case materials, propellant types, aft skirt, and attach methods. They also refined the previous study's forward skirt work on positioning it at the correct height or attaching the core stage and accommodating structural loads. The study redesigned the aft motor segment cylinders to move the existing Shuttle external tank attach point. Also studied were the nose and aft skirt booster separation motor configuration.

The core stage team studied the return to the five-engine layout, the use of engine fairings and hydrogen routing. It also looked at the benefits of a more advanced variant of the RS-68 with a regeneratively-cooled nozzle. Overall performance, cost, and risk were examined. The study also covered pad shutdown approach, engine replacement capability, throttle and engine out, structures, cryo fluid management, and base heating. The engine layout study tried to determine the viability of several core stage engine configurations based on the design of the thrust structure, ring frame, engine attach point, fluid inlet, gimbal area, acoustics, aerodynamics, base heating, manufacturing, controllability, operability, acoustics, ground transportation, accessibility, main propulsion system design, and other factors. Figure 7 illustrates an example of one study.

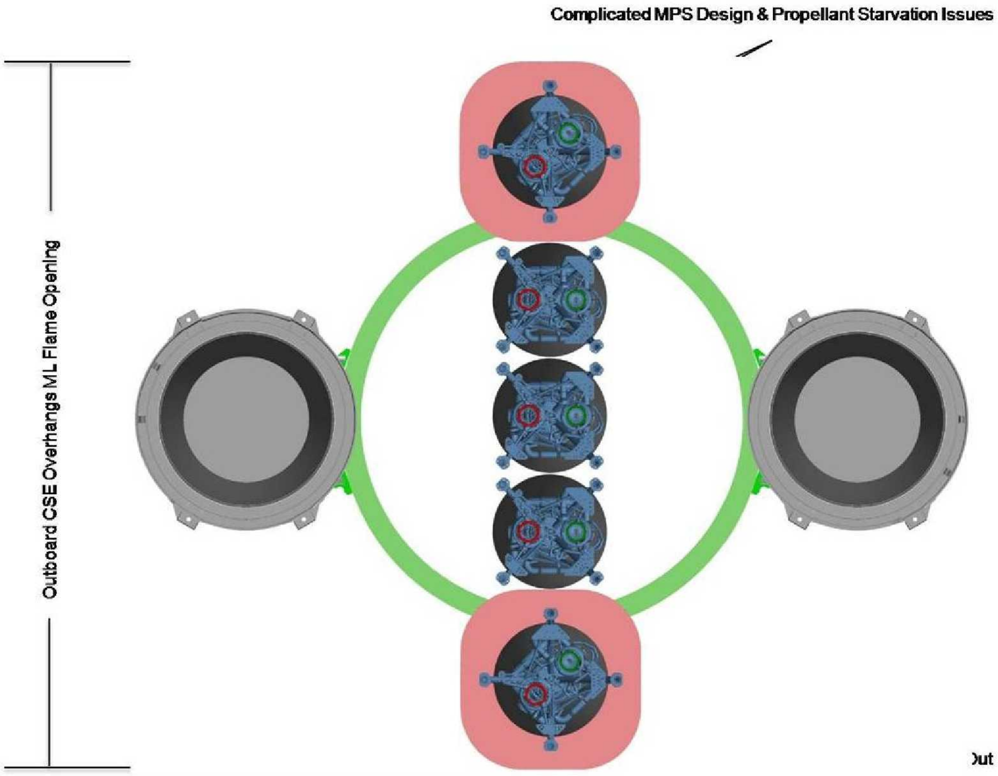


Figure 7 – Ares V core stage in-line engine configuration

The third design cycle again examined Ares V related technology development, including options for using variants of existing engines or evolutions of existing engines, variations of the current RSRB or other solids, materials trades for aluminum, composites, insulations, thermal protection systems , and acoustic dampening and power system trades with solar arrays batteries and fuel cells.

Vehicle-level computational fluid dynamics (CFD) analyses of ascent plumes, engine layout factoring thrust structure, ring frame, engine attach point, fluid inlets, and gimbal area. Various engine layouts were also evaluated for issues regarding structure, acoustics, aerodynamics, base heating, manufacturing, controllability, operability, acoustics, ground transportation, accessibility, main propulsion system design and more.

Mars Transfer Vehicle (MTV) assembly was examined for its implications for Ares V. Two MTVs will be assembled in LEO, one crewed and one uncrewed. Each Ares V will deliver a different type and size of MTV component. Rendezvous will be required for each launch after the first. The first launch will be to a circular orbit. Subsequent launches will be to elliptical phasing orbit. Ares V would be responsible for rendezvous proximity operations and docking (RPOD) with orbiting components. Ares V should be capable of performing this job with modification, although launching an RPOD vehicle pre-attached to each MTV component will significantly increase the mass to LEO requirement for Ares V or decrease effective payload. The cost of a multi-use "space tug" is significant for such limited utilization. Other concerns related to ground operations include crawler way capacity, the number of buildings required for assembly of six or more Ares Vs per year, and the need to operate multiple on-orbit assets simultaneously. The Ares V/MTV assembly scenario is illustrated in figure 8.

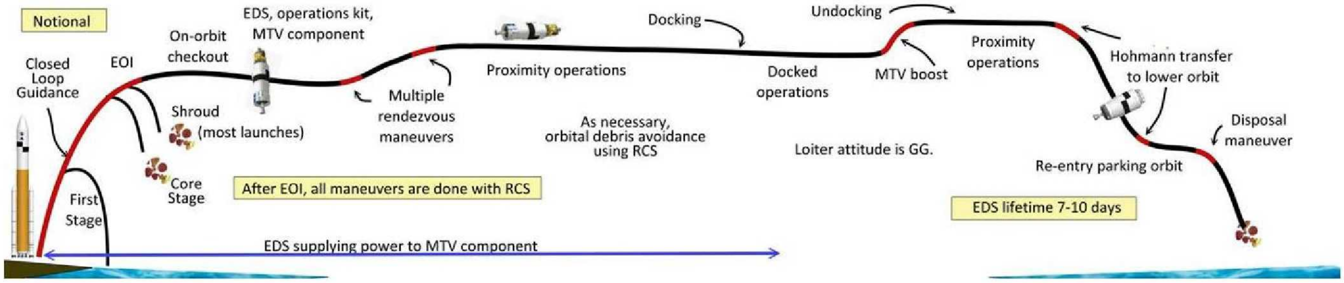


Figure 8 – Ares V/MTV assembly scenario

The Ares V team also provided support to the Review of U.S. Human Space Flight Plans Committee in 2009. The team provided the review with a technical status of the Ares V as currently designed and provided options for optional capabilities, including replacement of the Ares I/Ares V architecture with a pair of smaller Ares V launchers. Options provided are shown in Figure 9, with the LCCR baseline at the far left. Along the top, options include a crew capability using the Ares I upper stage initially and evolving to an EDS-type upper stage. Along the bottom, the options include the Ares I crew vehicle and an Ares V limited to the Ares I booster initially and growing with the switch to more energetic HTPB propellant. At the right side is the Ares V direct launch capability (with PBAN boosters) to TLI to show cargo launch capability.

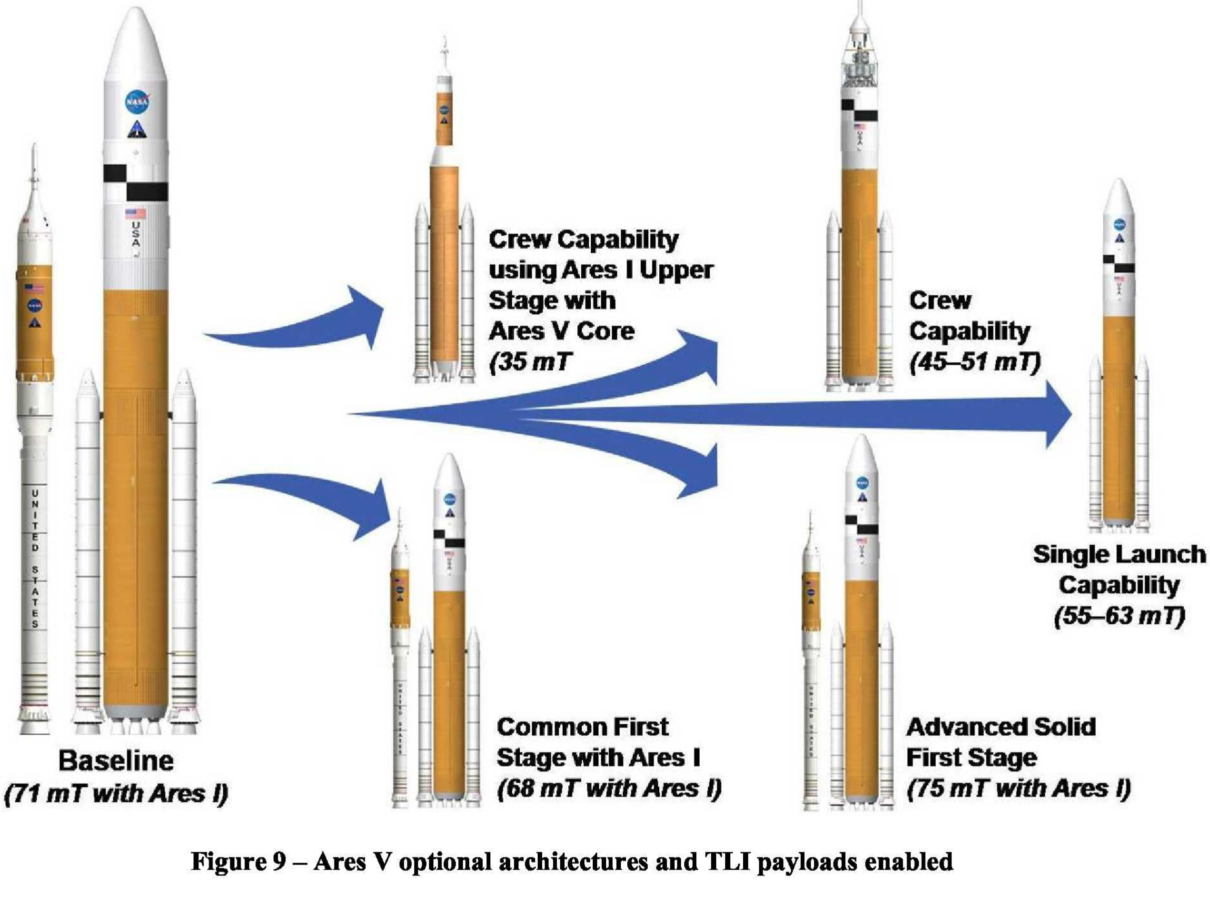


Figure 9 – Ares V optional architectures and TLI payloads enabled

• IV. Progress Via Commonality

While Ares V itself remains in concept development, it benefits from its commonality with Ares I, which has made progress in several areas since development began.

In May 2009, the Ares I first stage team conducted a drop test of the first stage deceleration system, including the largest rocket parachute ever manufactured. Development Motor 1 (DM-1), the first five-segment solid rocket motor built to Ares specifications, was test-fired in September 2009. The team collected data from 650 sensors from the test, shown in figure 10.

Figure 10 – DM-1 static firing

The upper stage team conducted structural buckling tests on barrel panel tests in 2010, verifying predictions on the behavior of the aluminum-lithium panels under pressure. A candidate monopropellant hydrazine roll control thruster was hot-fired in 2009 at Aerojet, demonstrating operation in pulse and sustained firing modes over a wide range of operability. Two heavyweight solid motors were tested in 2009 for ullage settling application on the upper stage. The test, shown in figure 11, demonstrated the propellant, propellant grain, structure, and propellant geometry.

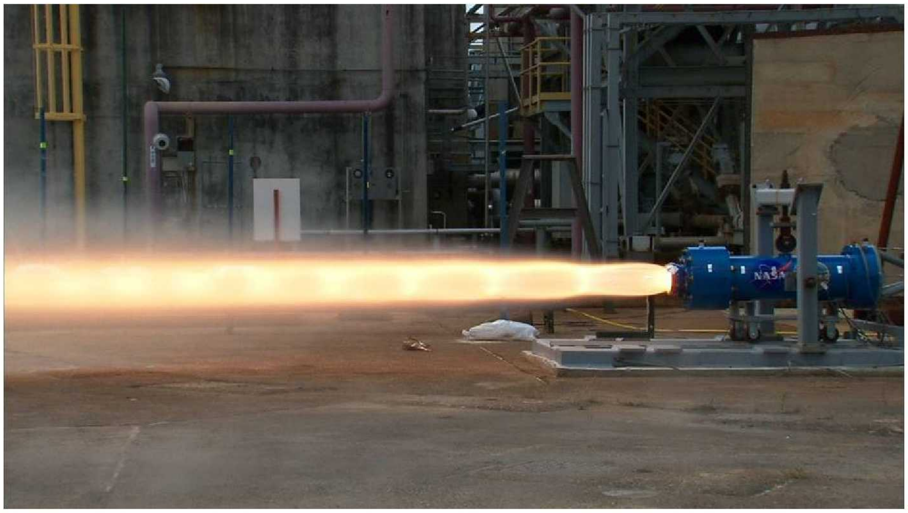


Figure 11 – MSFC test of a solid propellant motor for ullage settling

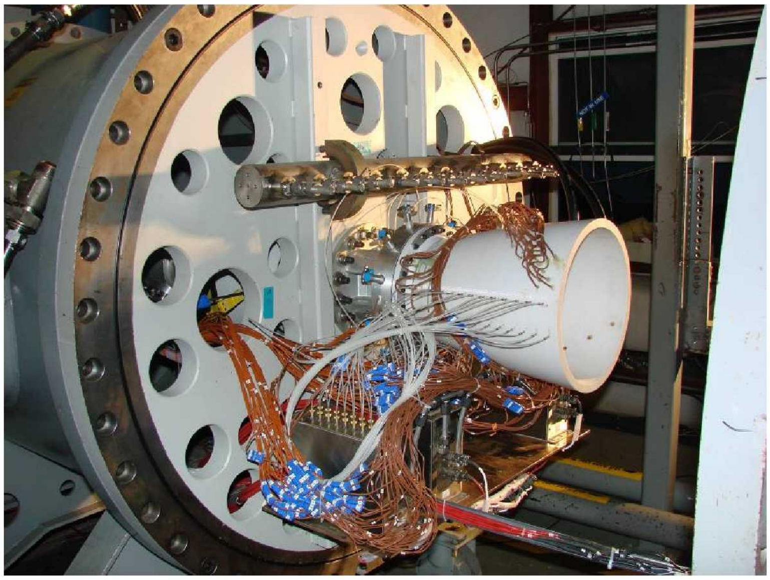
The Constellation program also launched the Ares I-X flight in October 2009, achieving five primary objectives:

- Control of a dynamically similar vehicle using similar flight software;
- In-flight, first stage separation event;
- Assembly and recovery of a new Ares I-like first stage;
- First stage separation sequencing, and quantifying First Stage atmospheric entry dynamics, and parachute performance; and
- Measuring and controlling the amount of roll torque throughout first stage flight.

The flight test also provided an opportunity to exercise the processing crews at NASA's Kennedy Space Center (KSC), as well as the logistics operations of shipping and integrating a new vehicle configuration. Special arrangements were required to transport these elements to KSC, and stacking operations and facilities had to be modified to accommodate the vehicle architecture. Launch Complex 39B also had to undergo extensive modifications to accommodate the new rocket's design.

Figure 12 – Ares I-X launch

The Ares I upper stage engine has led vehicle development, reaching critical design review (CDR) before any other element. Numerous tests of Apollo-era J-2 hardware and J-2X development components have been completed, and manufacturing is under way or completed on some 100,000 parts. The engine team has set a goal to complete first development engine assembly by Dec. 24, 2010 in preparation for hot fire tests in early 2011. In addition, modifications to the A1 and A2 test stands at NASA's Stennis Space Center, MS are under way to support J-2X testing. Significant progress has been made on the new A3 stand, which will provide the nation with its first full altitude, full-duration, full gimbal range test capability for large, upper stage liquid rocket engines. The launch of the Ares I-X mission provided valuable information and experience on the solid propellant booster, the configuration, and recovery. Examples of the testing and facility progress are shown in figure 13.

- 

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- **Figure 13 – Turbine exhaust gas film cooling cold flow test hardware, top, and a March 2010 photo of the A3 altitude test stand at Stennis Space Center, bottom**

V. Heavy Lift Utilization

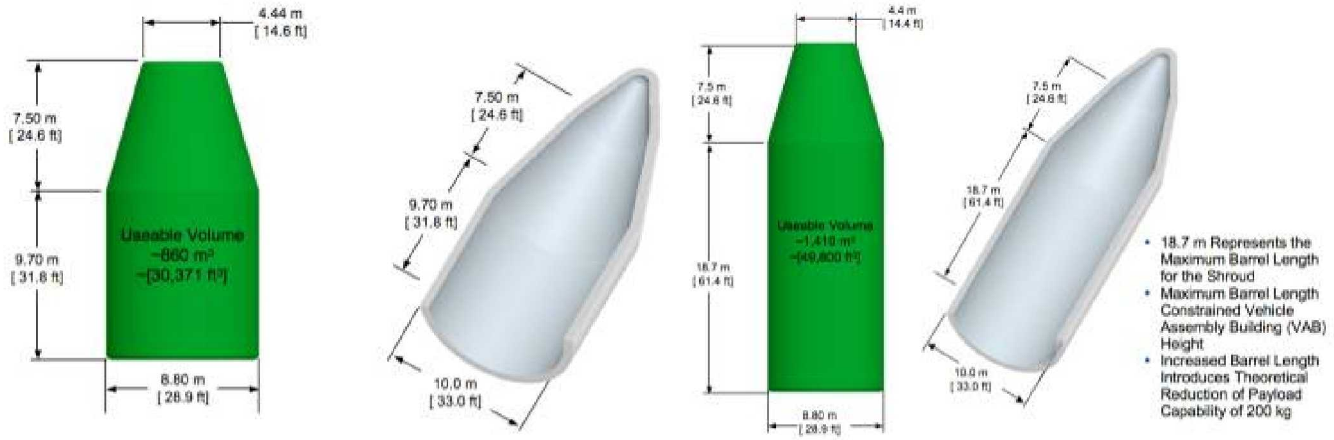
Several independent panels since Apollo have pointed out the need for a national heavy-lift launch capability for human and robotic exploration and science, national security, and commercial use. The heavy-lift capability represented by the Ares V surpasses even the 1960s-era Saturn V by a large margin in both mass and volume. Compared to current systems, it will offer approximately five times the mass and volume to most orbits and locations. This should allow prospective mission planners to build robust payloads with margins that are three to five times today's industry norm.

Figure 14 shows a performance analysis for selected missions using a pre-LCCR configuration of the Ares V. The LCCR configuration – effectively the addition of an extra half-segment to the booster and a sixth core stage engine - is expected to have slightly higher performance. As indicated, this capability can deliver tremendous payloads to a wide variety of orbital parameters. While having the capability of delivering over 57 mT of lunar cargo & over 48 mT tons of Mars cargo, it can also provide approximately 69.5 mT to geosynchronous transfer orbit (GTO) and 35 mT to geosynchronous orbit (GEO). This is approximately 6 times that of any currently manufactured launch vehicle.

Mission Profile	Target	Constellation POD Shroud		Extended Shroud	
		Payload (lbm)	Payload (mt)	Payload (lbm)	Payload (mt)
1) LEO (@29º inclination)	241 x 241 km	315,000	143	313,000	142
2) GEO	Transfer DV 14,100 ft/s	77,000	35	76,000	34.5
3) Cargo Lunar Outpost (TLI Direct), Reference	C3 of -1.8 km^2/s^2	126,000	57	125,000	57
4) Sun-Earth L2 Transfer Orbit Injection	C3 of -0.7 km^2/s^2	124.000	56.5	123,000	56
5) Earth-Moon L2 Transfer Orbit Injection	C3 of -1.7 km^2/s^2	126,000	57.0	125,000	57
6) GTO Injection	Transfer DV 8,200 ft/s	153,000	69.5	152,000	69
7) Mars Cargo (TMI Direct)	C3 of 9 km^2/s^2	106,000	48	105,000	48

- **Figure 14 – Ares V performance for selected missions.**

Analysis shows this potentially opens up direct missions to the outer planets that are currently only achievable using indirect flights with gravity assist trajectories. An Ares V with an upper stage could perform these missions using direct flights with shorter interplanetary transfer times, which enables extensive in-situ investigations and potentially sample return. Another unique aspect of this configuration is the large 8.8-m interior diameter of its fairing. This enables the launch of very large monolithic mirrors, arrays of precision flying mirrors, or extremely large deployable telescopes. Figure 15 illustrates the Ares V shroud's enormous volume available for various missions. Both its baseline shroud and a notional extended shroud are shown. The reference Ares shroud has a usable volume of 860 cubic meters, which is more than three times the volume of the Delta IV fairing. For larger payloads, the cylindrical portion of the reference shroud could be extended by 9 m, to provide usable volume of 1,410 cubic meters.



- 18.7 m Represents the Maximum Barrel Length for the Shroud
- Maximum Barrel Length Constrained Vehicle Assembly Building (VAB) Height
- Increased Barrel Length Introduces Theoretical Reduction of Payload Capability of 200 kg

Figure 15 – Payload shroud volume for point-of-departure Ares V, left, and notional science payload shroud.

The NASA heavy-lift team is already reaching out to the payload community early in the design stage to better understand the potential limitations and/or additional requirements that could be added to a heavy-lift vehicle from the mission planning community. If a viable mission is determined and added to the heavy lifter as a design case, tradeoffs will be conducted to determine if other mission design requirements can be included in the system. Engaging potential users now can potentially have the greatest impact for payload design at the least technical and fiscal cost.

NASA's Ames Research Center hosted two weekend workshops devoted to Ares V's potential for astronomy and planetary science. These meetings brought together payload and vehicle designers to examine the Ares V design and payloads that might take advantage of its capabilities. The reports from both workshops concluded Ares V would benefit both fields of exploration.

The National Research Council (NRC) took note of Ares V in its report, Launching Science: Science Opportunities Provided by NASA's Constellation System. The Ares V provides significantly greater launch mass and C3 performance over present U.S. expendable launchers. For LEO missions, Ares V provides four to seven times the mass to orbit of the other systems. Similarly, the Ares V, with or without the Centaur upper stage, offers dramatically greater performance for interplanetary missions than the Delta IV.

Heavy lift also offers payload designers and scientists a possible opportunity to reduce development times and costs. Though history suggests that bigger payloads cost more than smaller payloads and that payload mass usually expands to fill the available vehicle capability, NASA's Advanced Missions Cost Model shown in Figure 16 indicates that design complexity is also a significant cost driver. The model plots estimated spacecraft costs as a function of payload mass for three classes of complexity for solar system exploration missions.

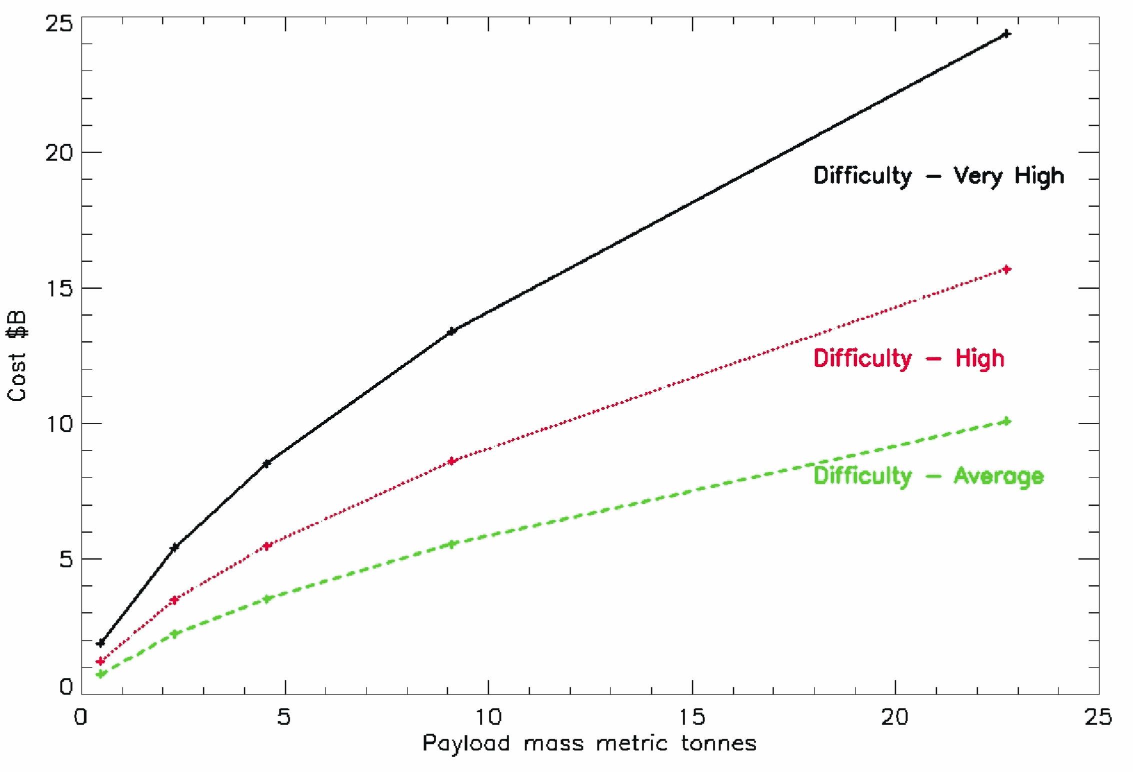
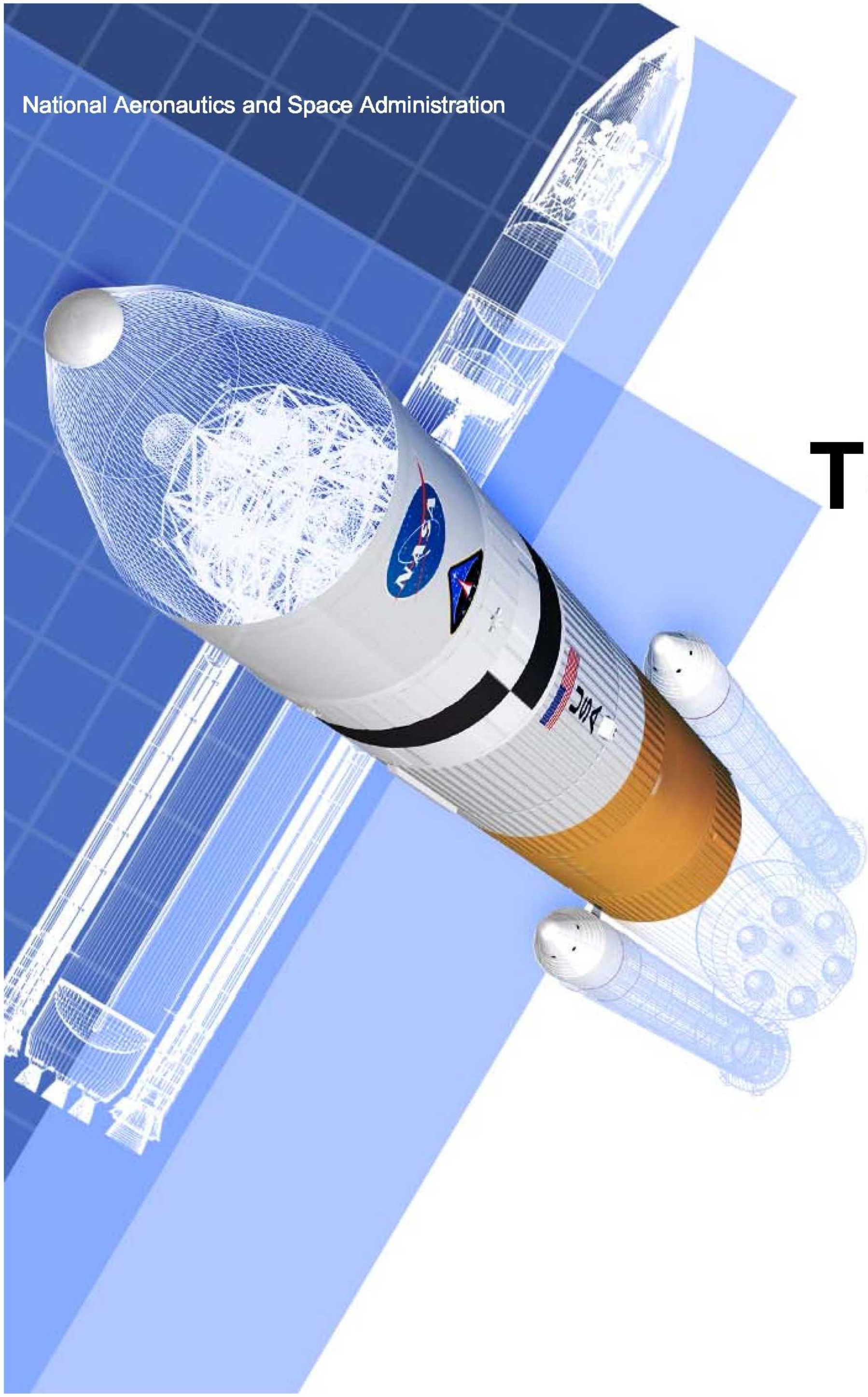


Figure 10 – NASA's Advanced Missions Cost Model

Ares V's "excess" mass and volume could be used to reduce technical complexity, redesign cycles, and cost. The NRC report concluded that program managers will then be faced with a different problem. "The capabilities of the Ares V will enable even larger, more complex, and more capable systems than these—systems that can dramatically increase scientific return. With the advent of the Ares V, the challenge for program managers will be to temper the appetites of scientists who will clearly recognize the dramatic scientific benefits enabled by the launch system. There will need to be an enforced paradigm shift where cost, rather than launch system capability, is the design limiter.

• V. Conclusion

While Ares V remains in concept development NASA has made significant progress in developing a comprehensive understanding of the challenges and potential for multiple configurations and missions for a heavy lift vehicle. A multi-center design team has worked for six years to understand the relationships between and among propulsion options, materials, structures, trajectories, mission phasing, ground operations, manufacturing, safety, and much more. The current reference Ares V vehicle configuration has been shaped by all those factors and the ongoing design cycles continue to bank knowledge for a future decision on a heavy lift vehicle. The Constellation Program is slated for cancellation in the 2011 budget. However, a heavy lift capability continues to figure prominently in the budget proposal and in subsequent information from the current presidential administration. NASA's heavy lift team is prepared to support whatever capability the nation requires to continue its leading role in space exploration.



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Phil Sumrall
Advanced Planning Manager,
Ares Projects
NASA Marshall Space Flight Center

Space Propulsion 2010
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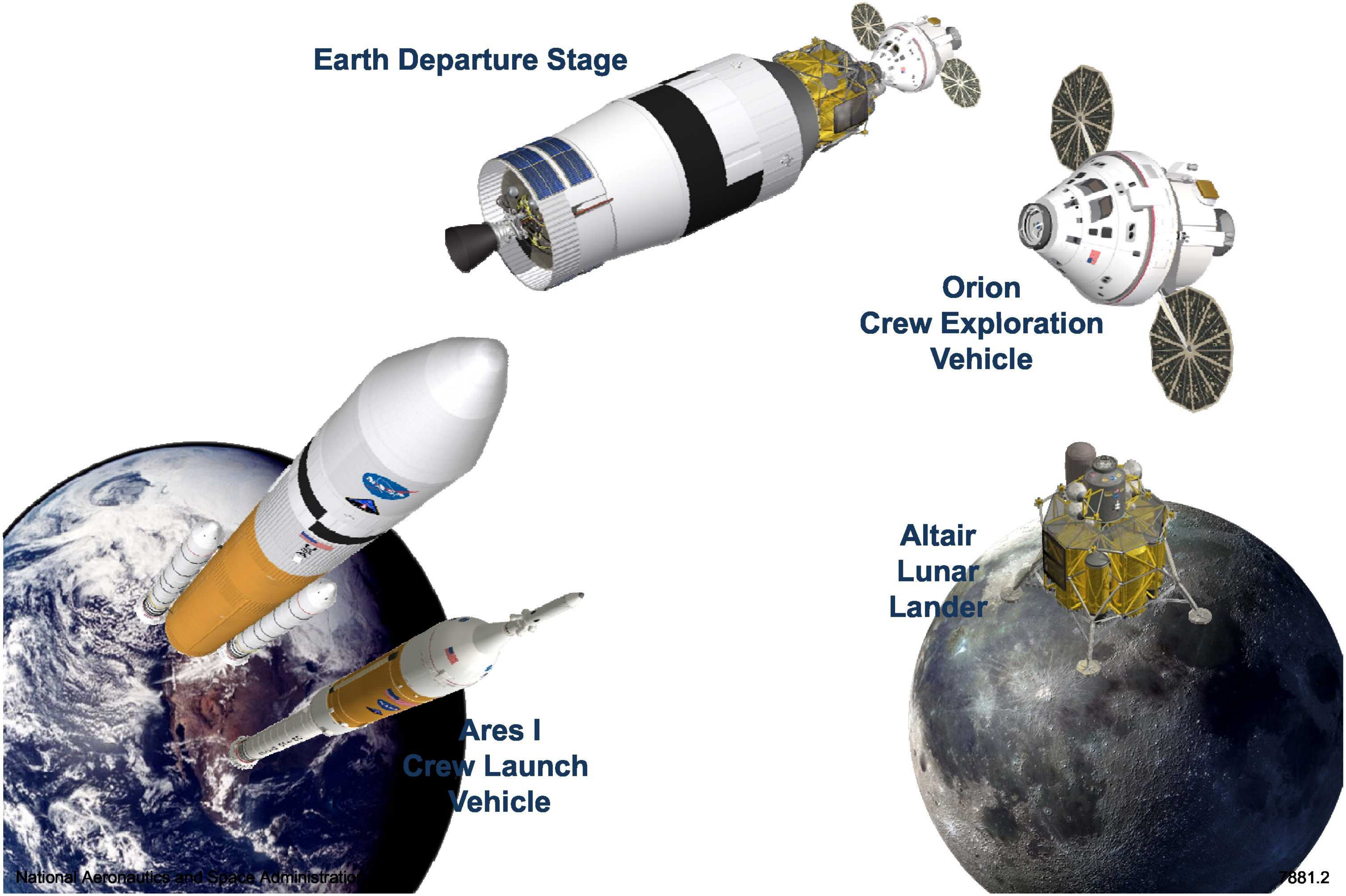
Constellation Architecture Program of Record



Earth Departure Stage

Orion Crew Exploration Vehicle

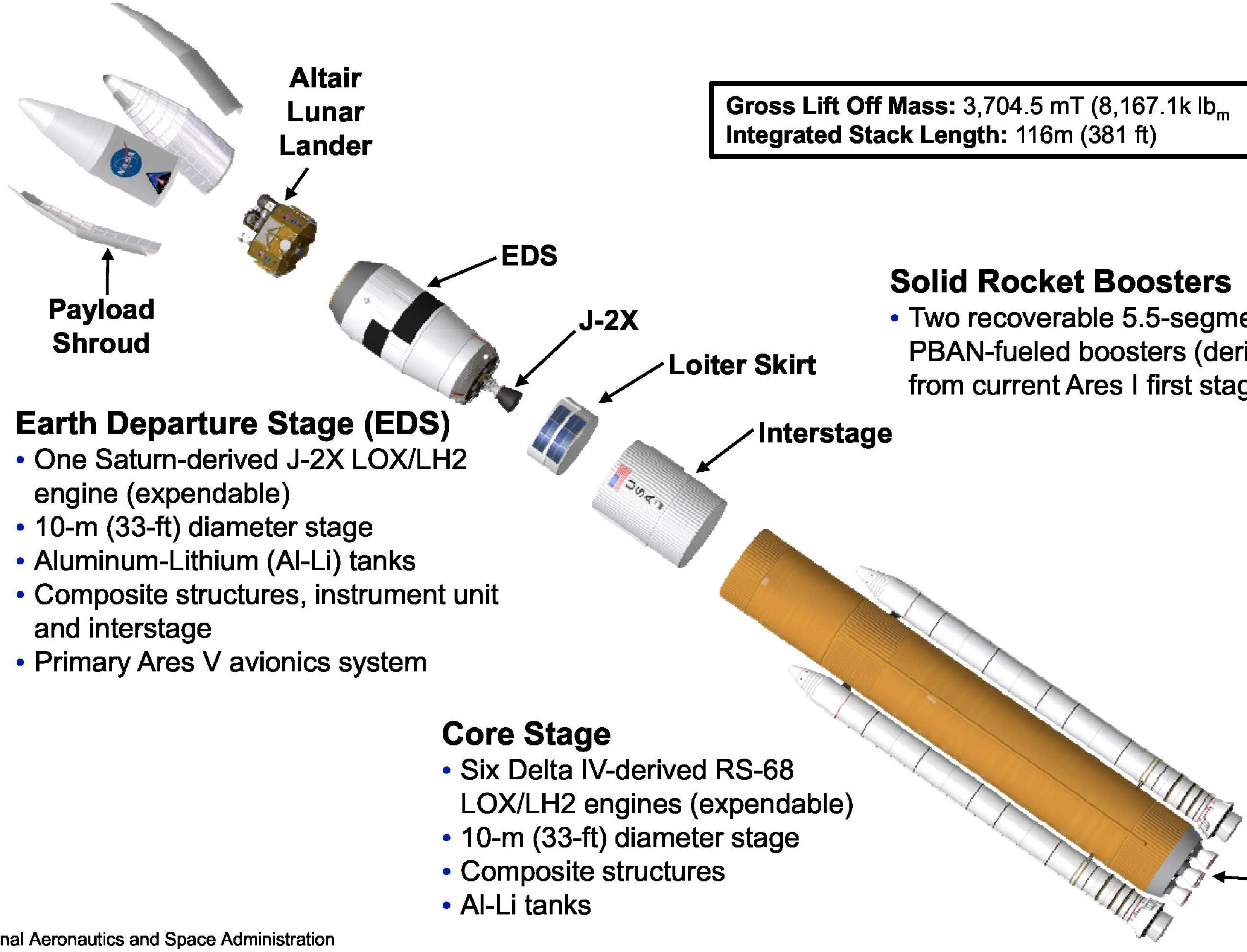
Altair Lunar Lander

Ares I Crew Launch Vehicle

Ares V
LCCR Point-of-Departure

Gross Lift Off Mass: 3,704.5 mT (8,167.1k lb_m

Integrated Stack Length: 116m (381 ft)

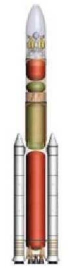


Solid Rocket Boosters
- Two recoverable 5.5-segment PBAN-fueled boosters (derived from current Ares I first stage)

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

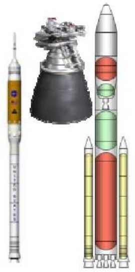
Core Stage
- Six Delta IV-derived RS-68 LOX/LH2 engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Al-Li tanks

ESAS (2005) to LCCR (2008) Major Events



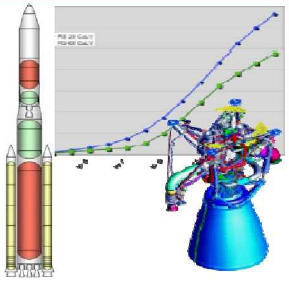
Original ESAS Capability

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



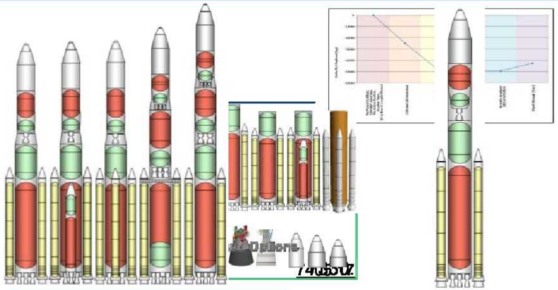
CY-06 Budget Trade to Increase

- 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

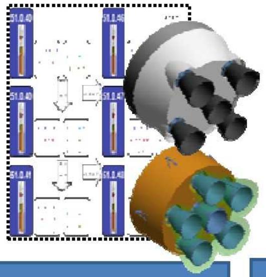


IDAC 3 Trade Space

- 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

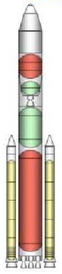
EDS Diameter Change from 8.4m to 10m

- Lunar Architecture Team 1/2 (LAT) Studies
- Lunar /Mars Systems Benefits
- Tank Assembly Tooling Commonality



Incorporate Ares I Design Lessons Learned/Parameters

- Core Engine / SRB Trades to Increase Design Margins
- Increase Subsystem Mass Growth Allowance (MGA)



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
- Booster Decision Summer 2010

220 Concepts Evaluated

320 Concepts Evaluated

730 Concepts Evaluated

460 Concepts Evaluated

2005

2006

2007

2008

Ares I ATP

Orion ATP

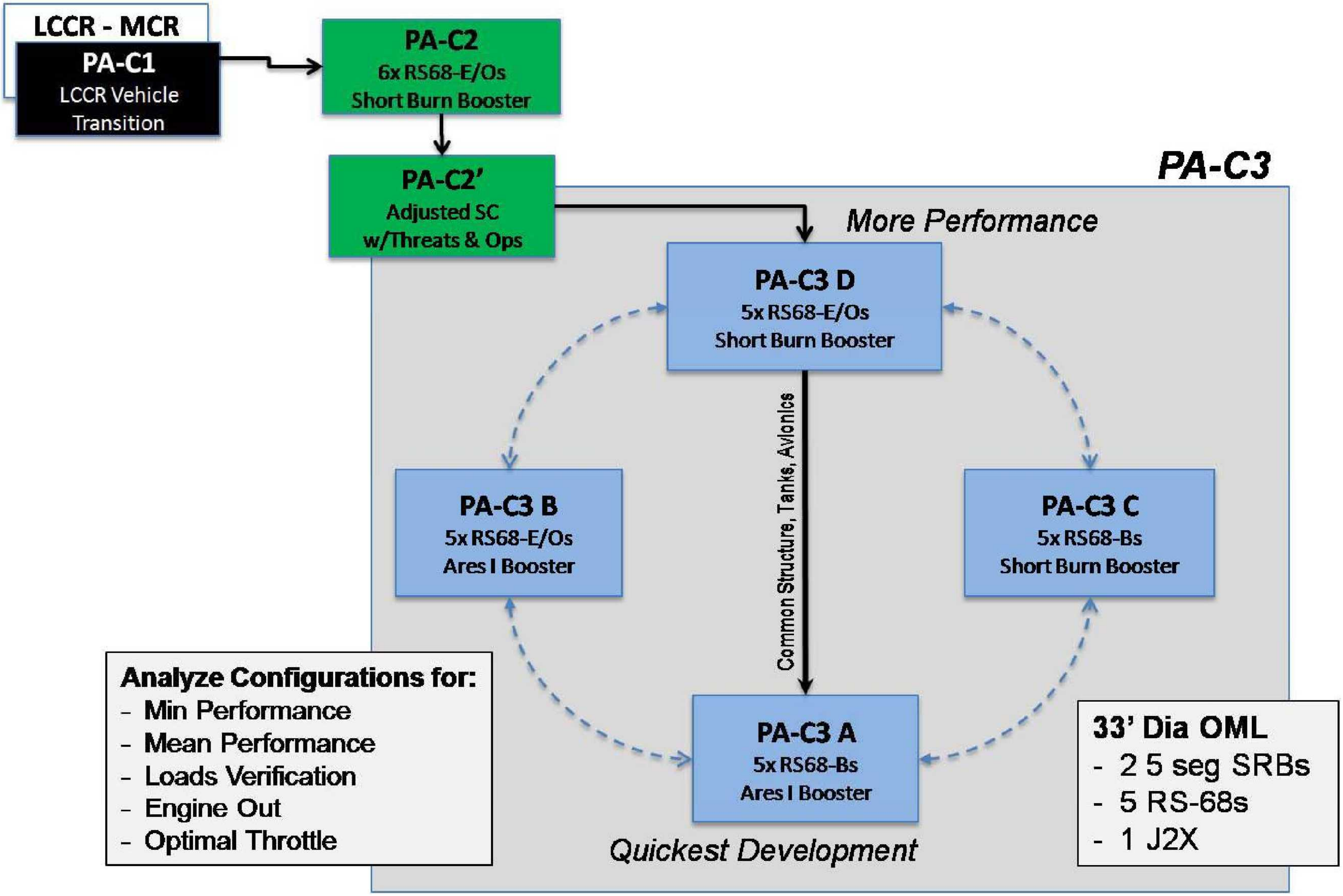
Ares I SRR

Orion SRR

Ares I SDR

Ares V MCR

Post-LCCR Internal Design Exercises



LCCR - MCR

PA-C1
LCCR Vehicle Transition

PA-C2
6x RS68-E/Os
Short Burn Booster

PA-C2'
Adjusted SC
w/Threats & Ops

PA-C3

More Performance

PA-C3 D
5x RS68-E/Os
Short Burn Booster

PA-C3 B
5x RS68-E/Os
Ares I Booster

PA-C3 C
5x RS68-Bs
Short Burn Booster

Common Structure, Tanks, Avionics

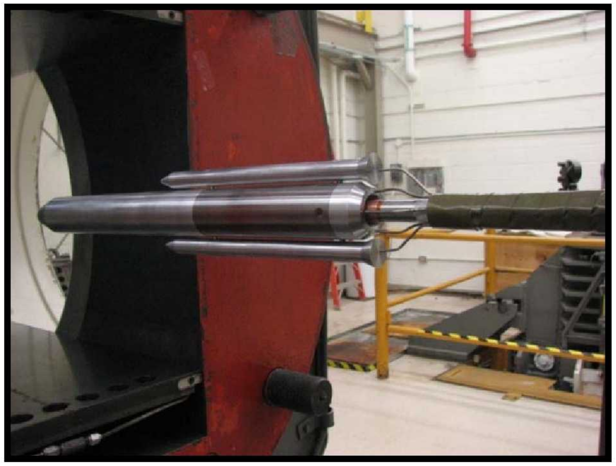
PA-C3 A
5x RS68-Bs
Ares I Booster

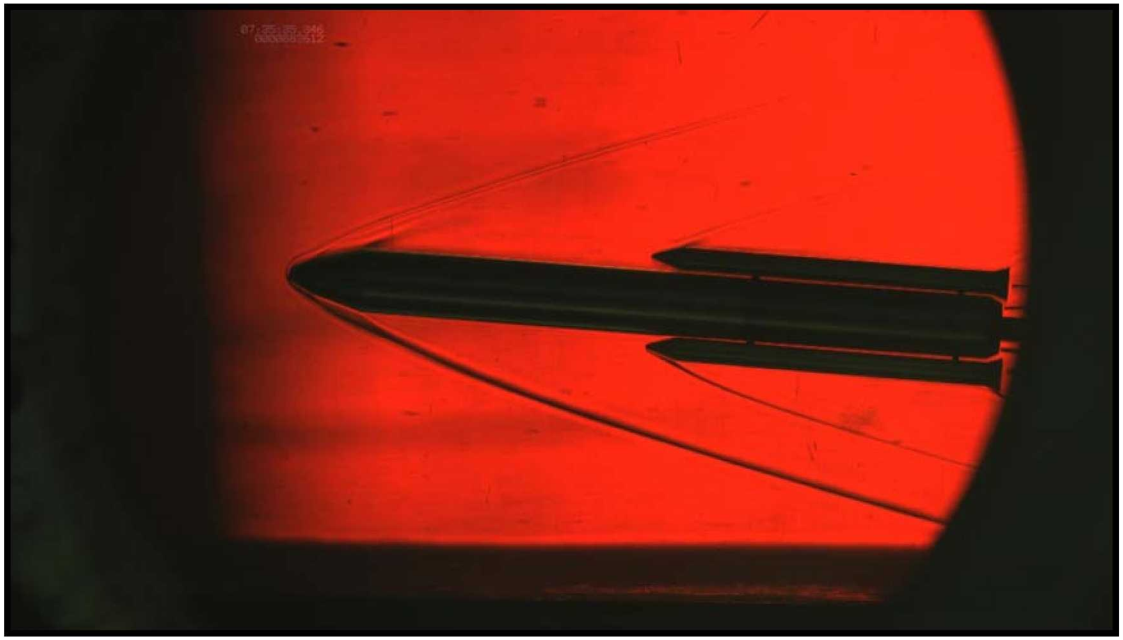
Quickest Development

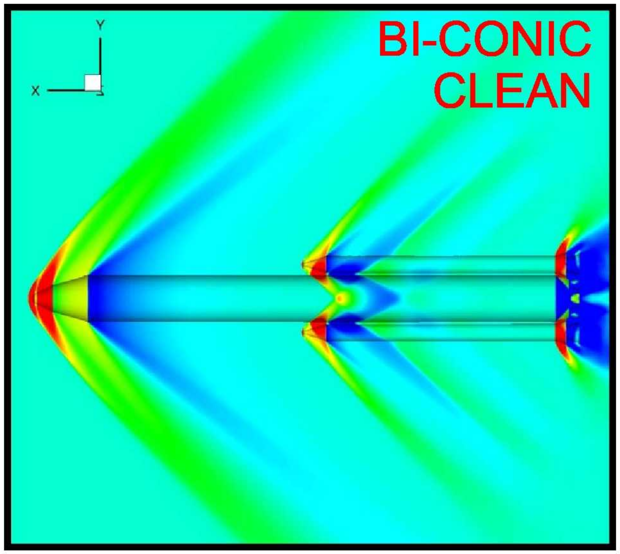
Analyze Configurations for:
- Min Performance
- Mean Performance
- Loads Verification
- Engine Out
- Optimal Throttle

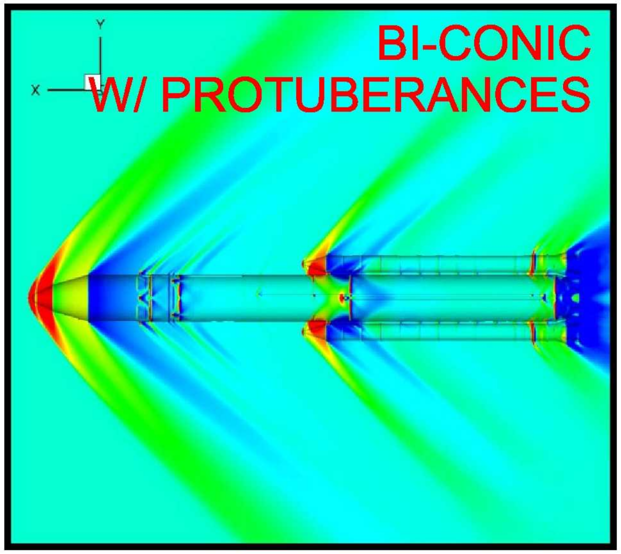
33' Dia OML
- 2 5 seg SRBs
- 5 RS-68s
- 1 J2X

PA-C1 Analysis

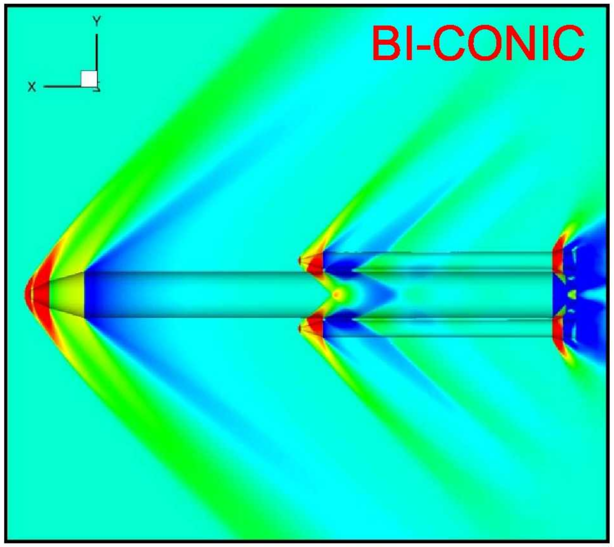


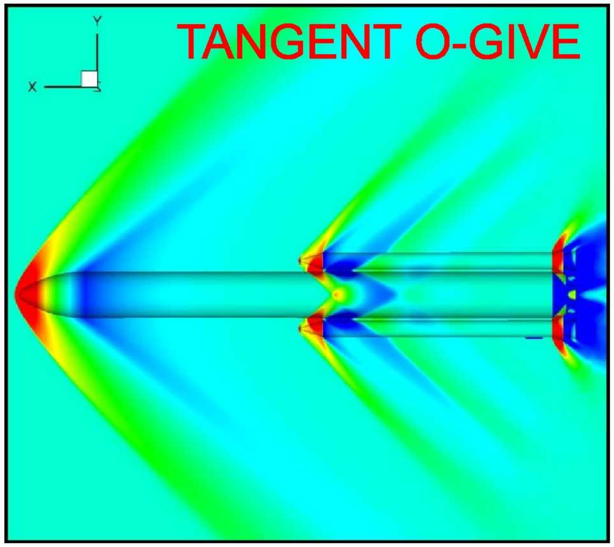


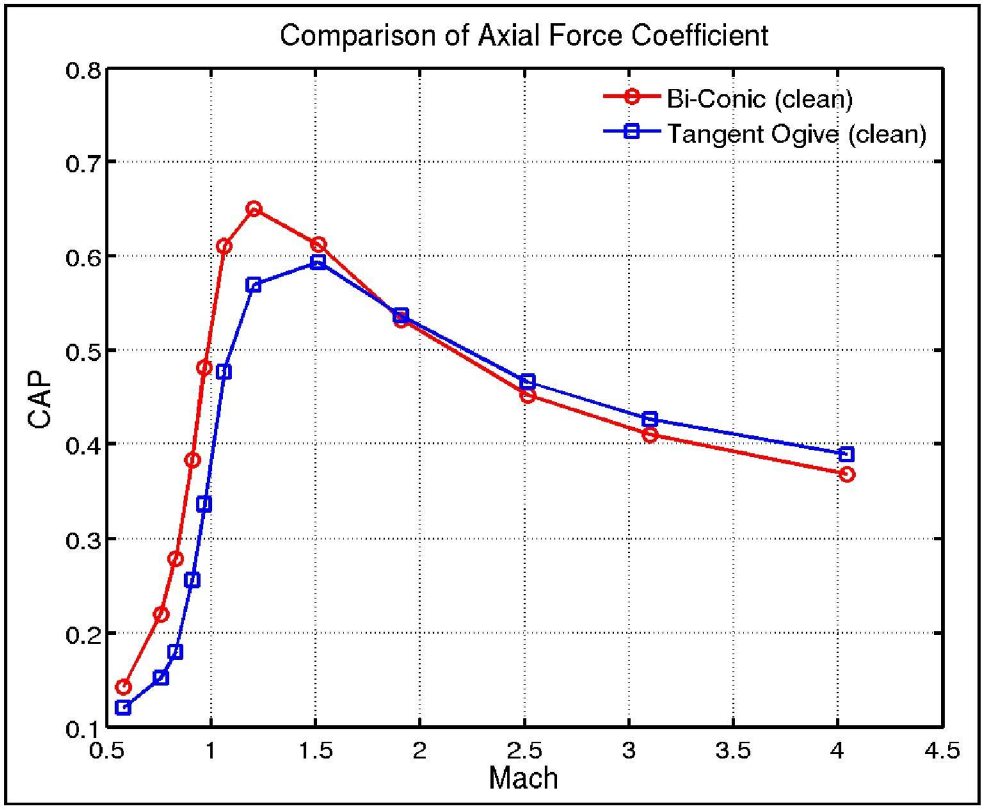




PA-C1 Analysis

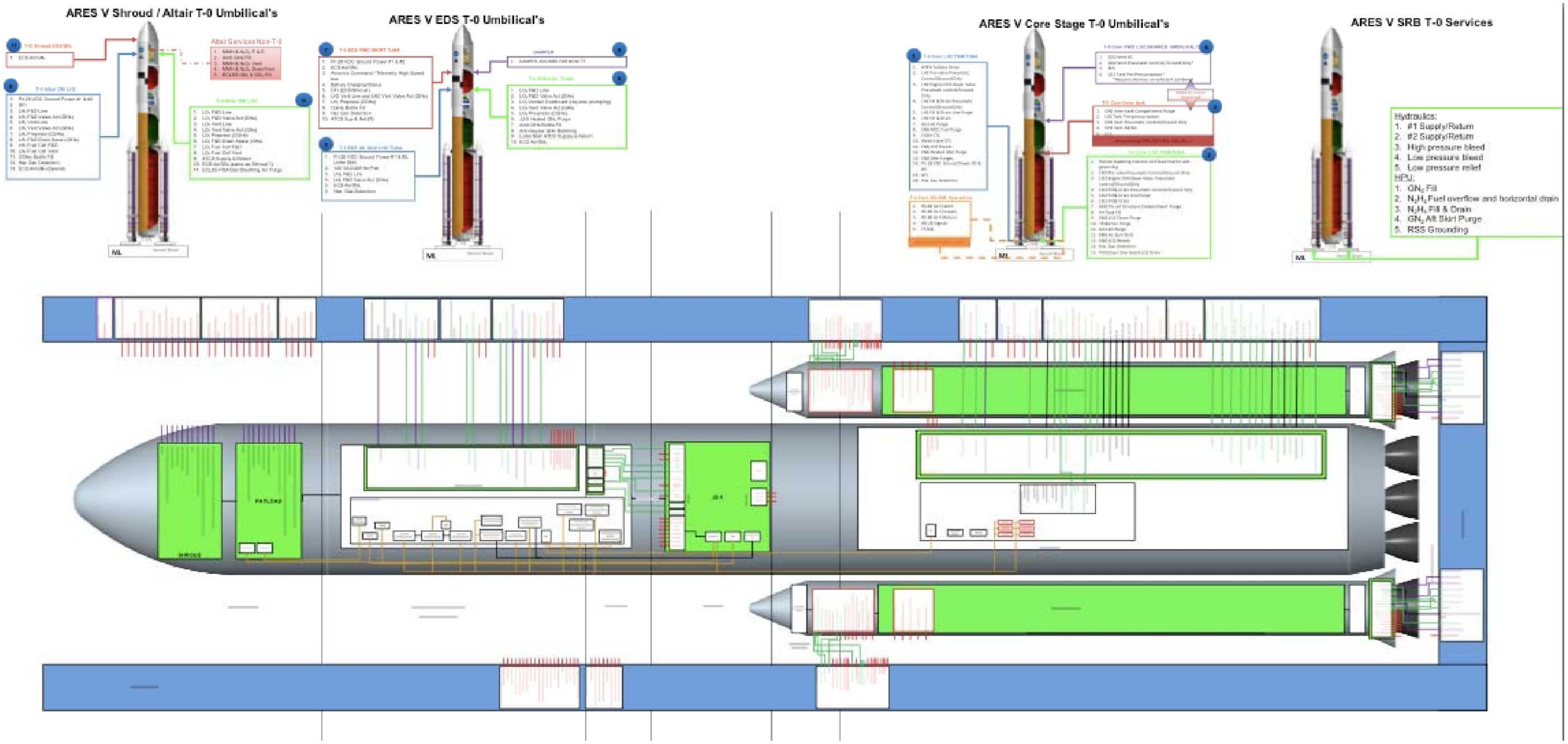






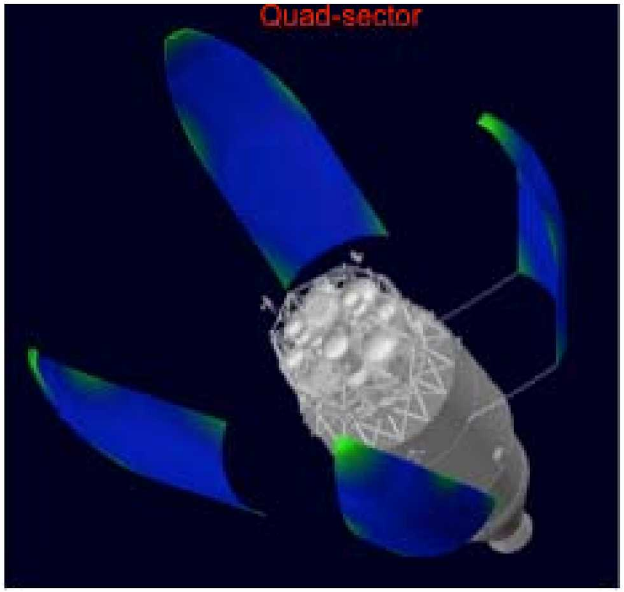
Ares V Shroud Geometry Trade Study

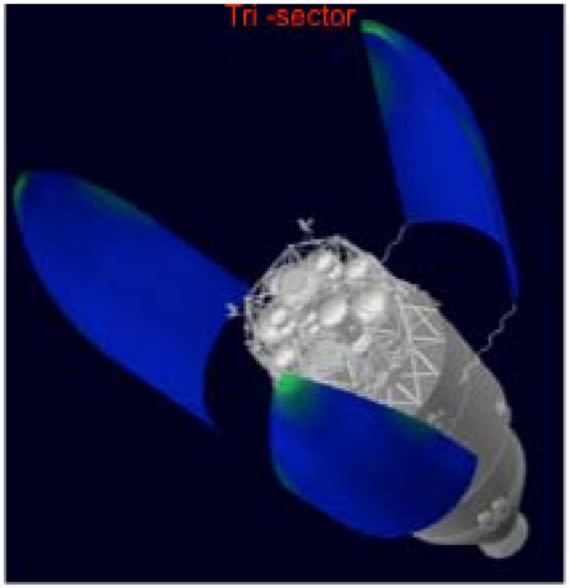
PA-C2 Analysis

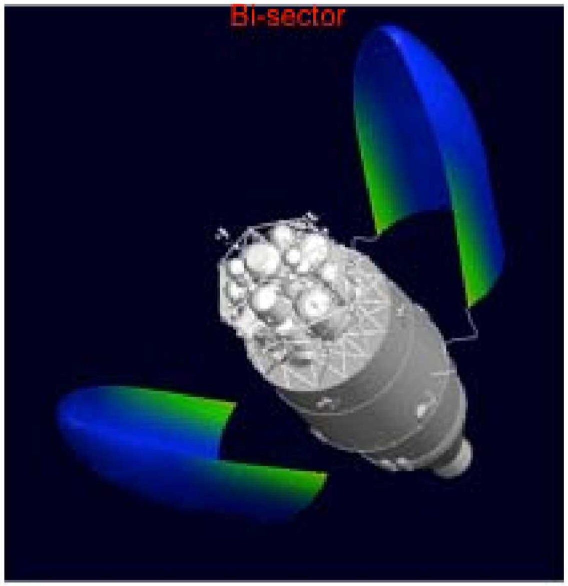


Integrated Functional Schematic

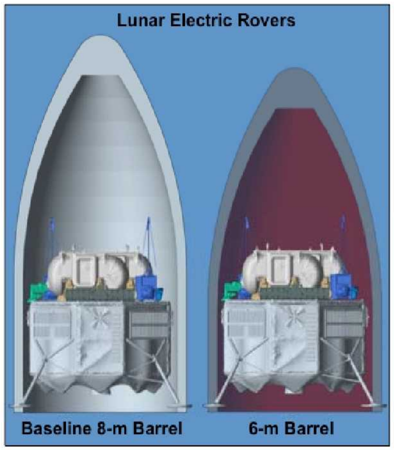
PA-C2 Trade Studies

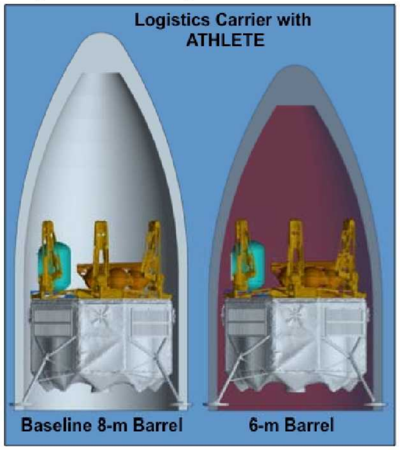




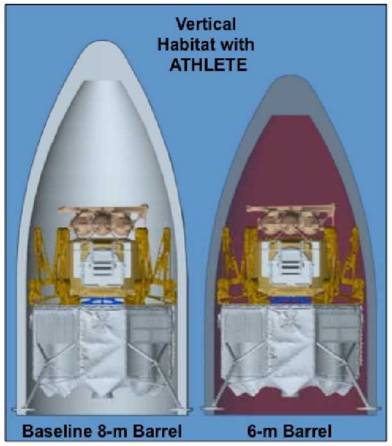


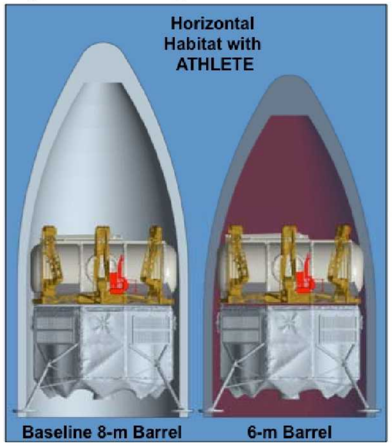
LDAC-3 Altair with largest LSS cargos





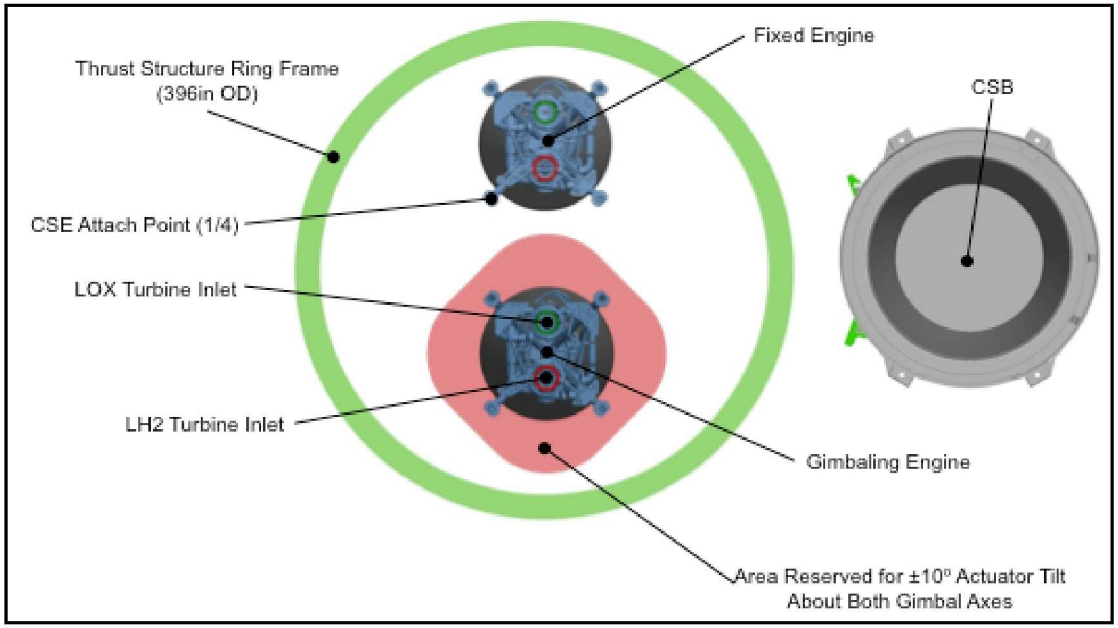
LDAC-3 Altair with largest LSS cargos

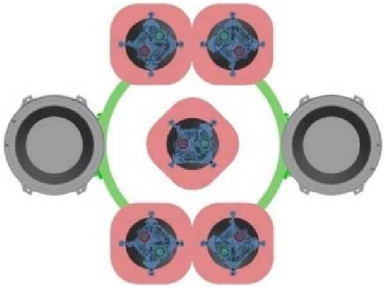




Shroud Separation Analysis & LSS Packaging Analysis

PA-C3 Ongoing Work





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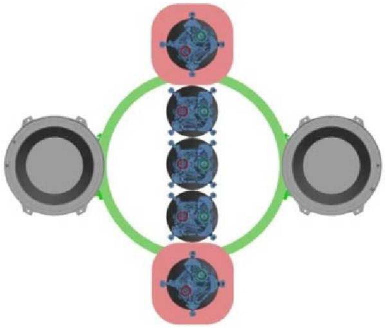

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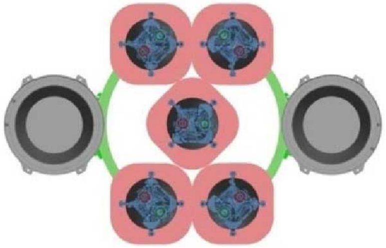

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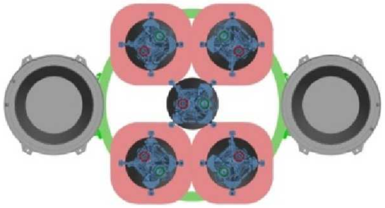

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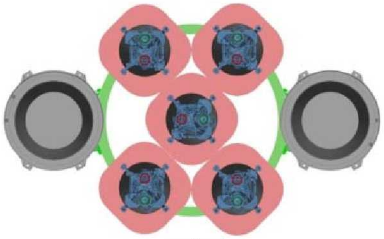

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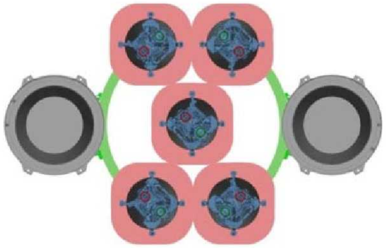

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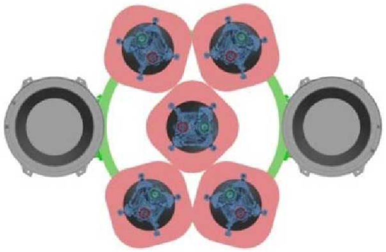
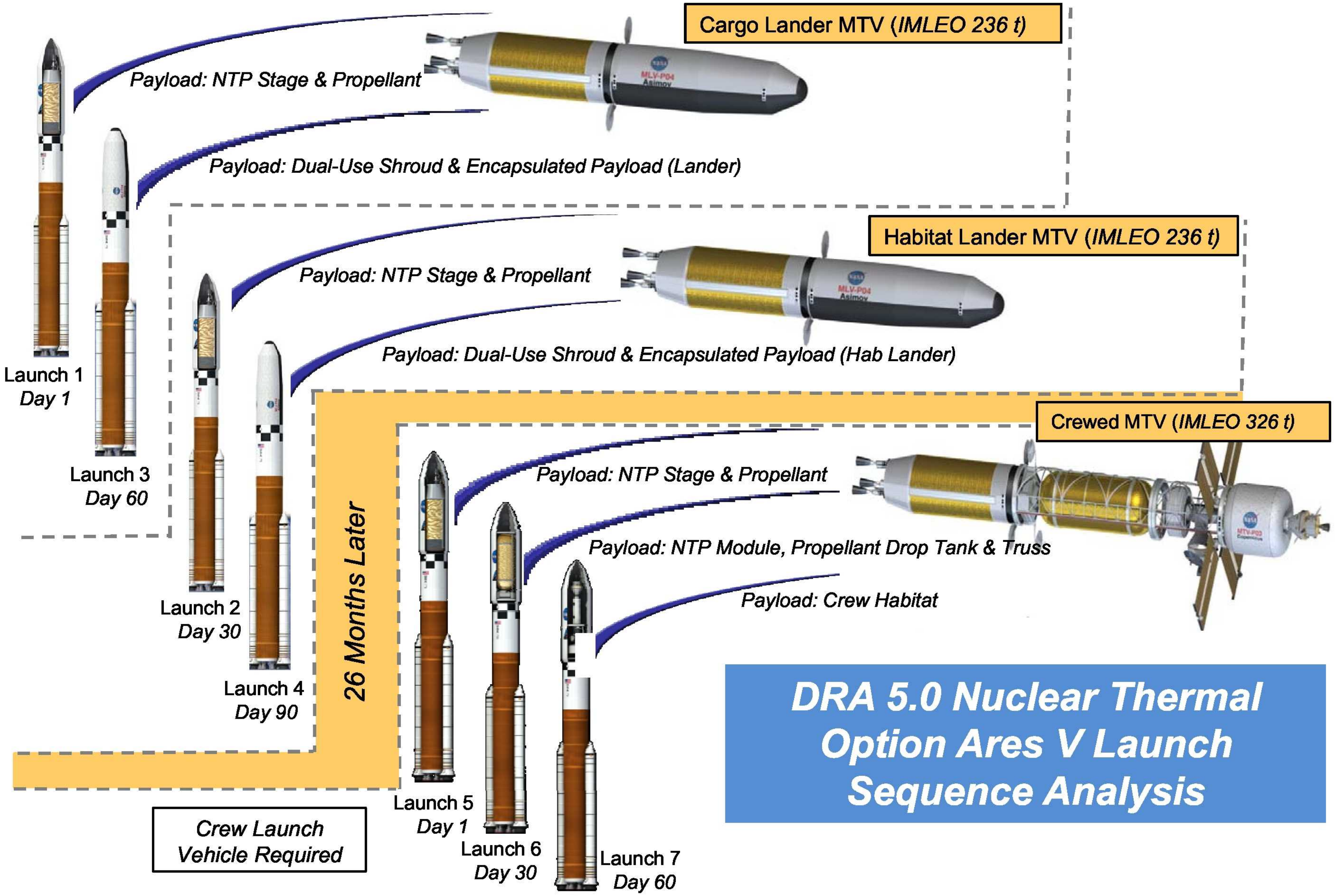


GG

Ares V Core Stage Base Engine Layout Trade

Exploring the Core Stage engine arrangement trade space by taking controllability, base heating, MPS design, aerodynamics, structures, transportation, manufacturing and other disciplines into account.

PA-C3 Analysis



Cargo Lander MTV (*IMLEO 236 t)*

Payload: NTP Stage & Propellant

Payload: Dual-Use Shroud & Encapsulated Payload (Lander)

Launch 1
Day 1

Launch 3
Day 60

Habitat Lander MTV (*IMLEO 236 t)*

Payload: NTP Stage & Propellant

Payload: Dual-Use Shroud & Encapsulated Payload (Hab Lander)

Launch 2
Day 30

Launch 4
Day 90

26 Months Later

Crewed MTV (*IMLEO 326 t)*

Payload: NTP Stage & Propellant

Payload: NTP Module, Propellant Drop Tank & Truss

Payload: Crew Habitat

Launch 5
Day 1

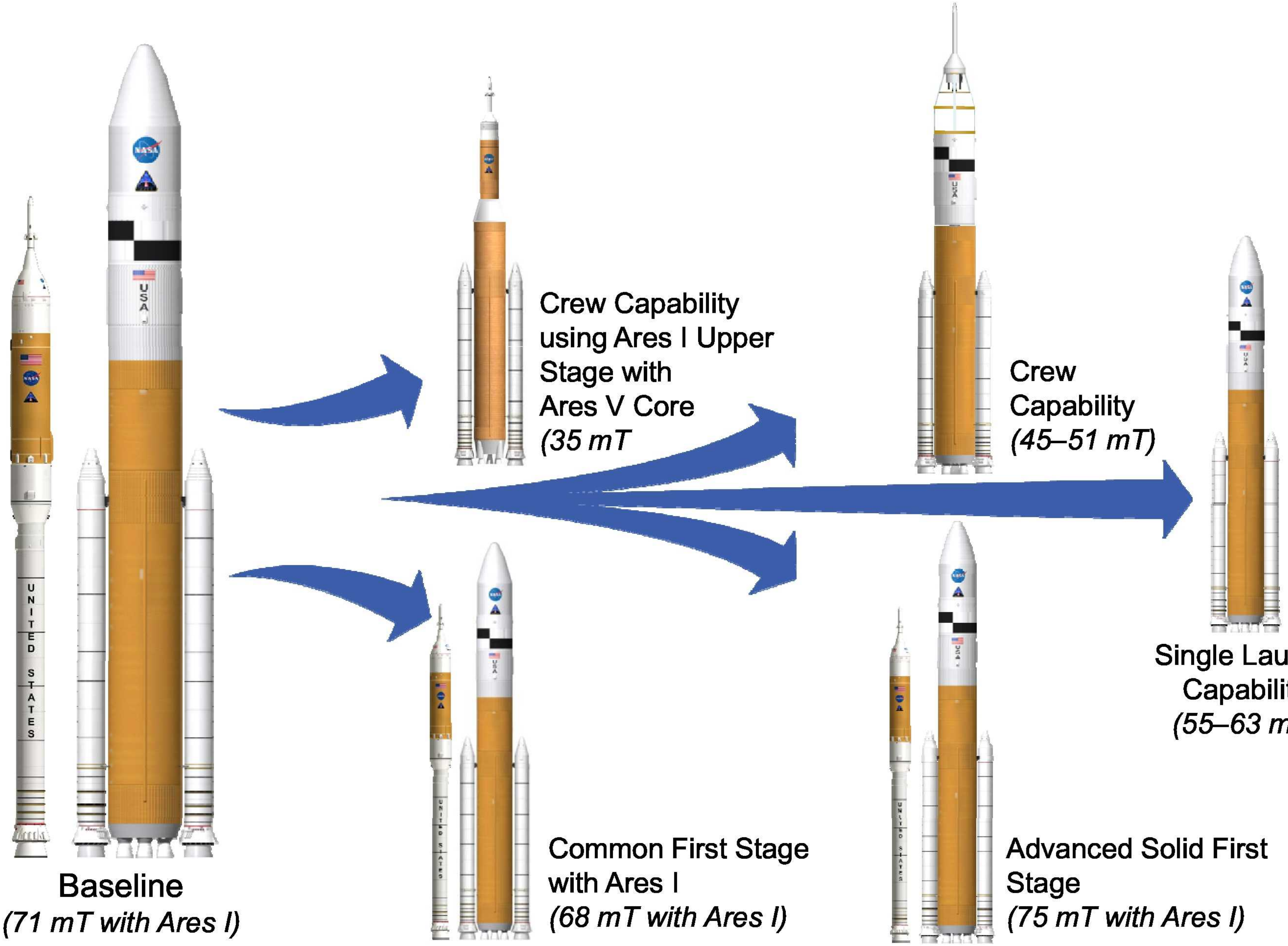
Launch 6
Day 30

Launch 7
Day 60

*Crew Launch
Vehicle Required*

***DRA 5.0 Nuclear Thermal
Option Ares V Launch
Sequence Analysis***

Review of U.S. Human Space Flight Plans Committee Architecture Options *(TLI payload)*



Baseline
(71 mT with Ares I)

Crew Capability using Ares I Upper Stage with Ares V Core
(35 mT

Common First Stage with Ares I
(68 mT with Ares I)

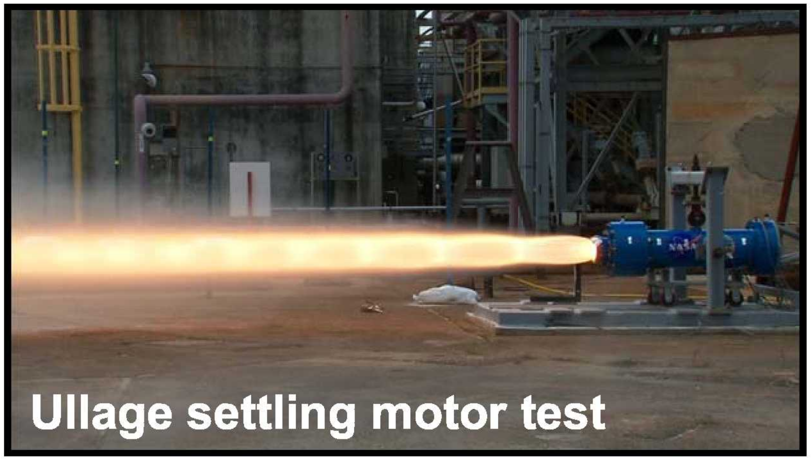
Crew Capability
(45–51 mT)

Advanced Solid First Stage
(75 mT with Ares I)

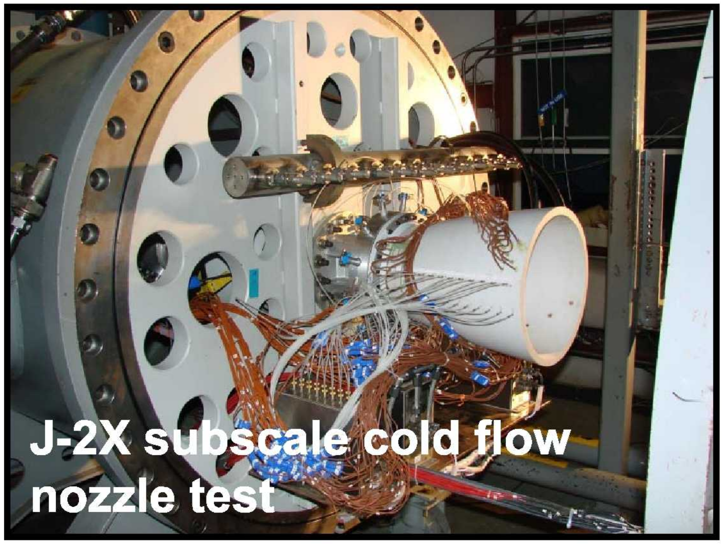
Single Launch Capability
(55–63 mT)

Ares I Progress Benefits Ares V


DM-1 test firing


Ullage settling motor test


A3 A3 test stand construction


J-2X subscale cold flow nozzle test

Ares I-X Launch

Ares V Mission Performance Analysis

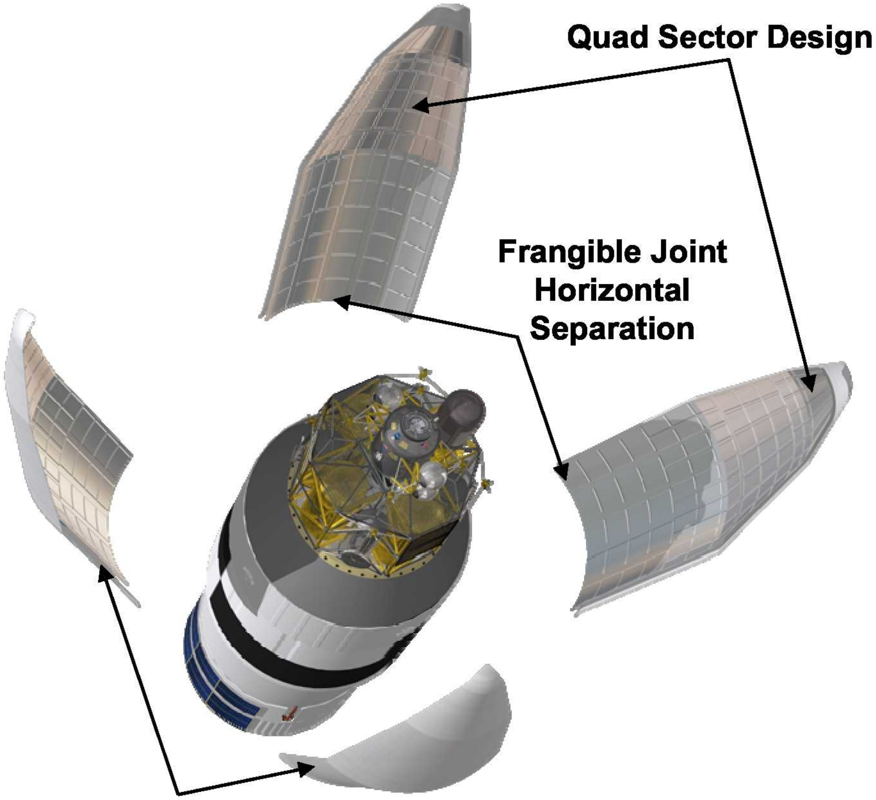
Mission Profile	Target	Constellation POD Shroud		Extended Shroud	
		Payload (lbm)	Payload (mt)	Payload (lbm)	Payload (mt)
1) LEO (@29º inclination)	241 x 241 km	315,000	143	313,000	142
2) GEO	Transfer DV 14,100 ft/s	77,000	35	76,000	34.5
3) Cargo Lunar Outpost (TLI Direct), Reference	C3 of -1.8 km^2/s^2	126,000	57	125,000	57
4) Sun-Earth L2 Transfer Orbit Injection	C3 of -0.7 km^2/s^2	124.000	56.5	123,000	56
5) Earth-Moon L2 Transfer Orbit Injection	C3 of -1.7 km^2/s^2	126,000	57.0	125,000	57
6) GTO Injection	Transfer DV 8,200 ft/s	153,000	69.5	152,000	69
7) Mars Cargo (TMI Direct)	C3 of 9 km^2/s^2	106,000	48	105,000	48

Payload Shroud Point Of Departure

Point of Departure (Biconic)

Leading Candidate (Ogive)

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 (72ft)



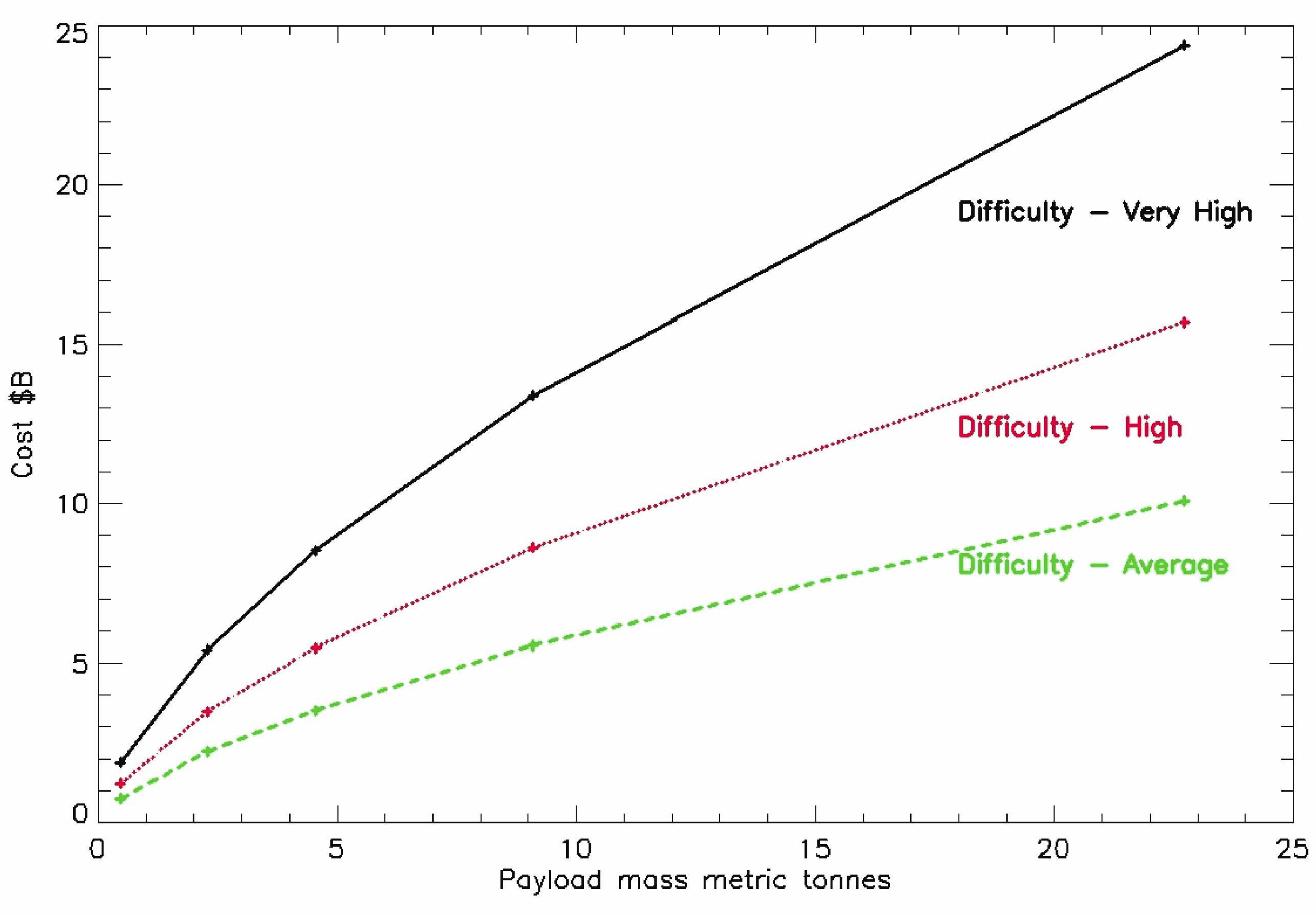
Quad Sector Design

Frangible Joint Horizontal Separation

Thrust Rail Vertical Separation System
Payload umbilical separation

- 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)

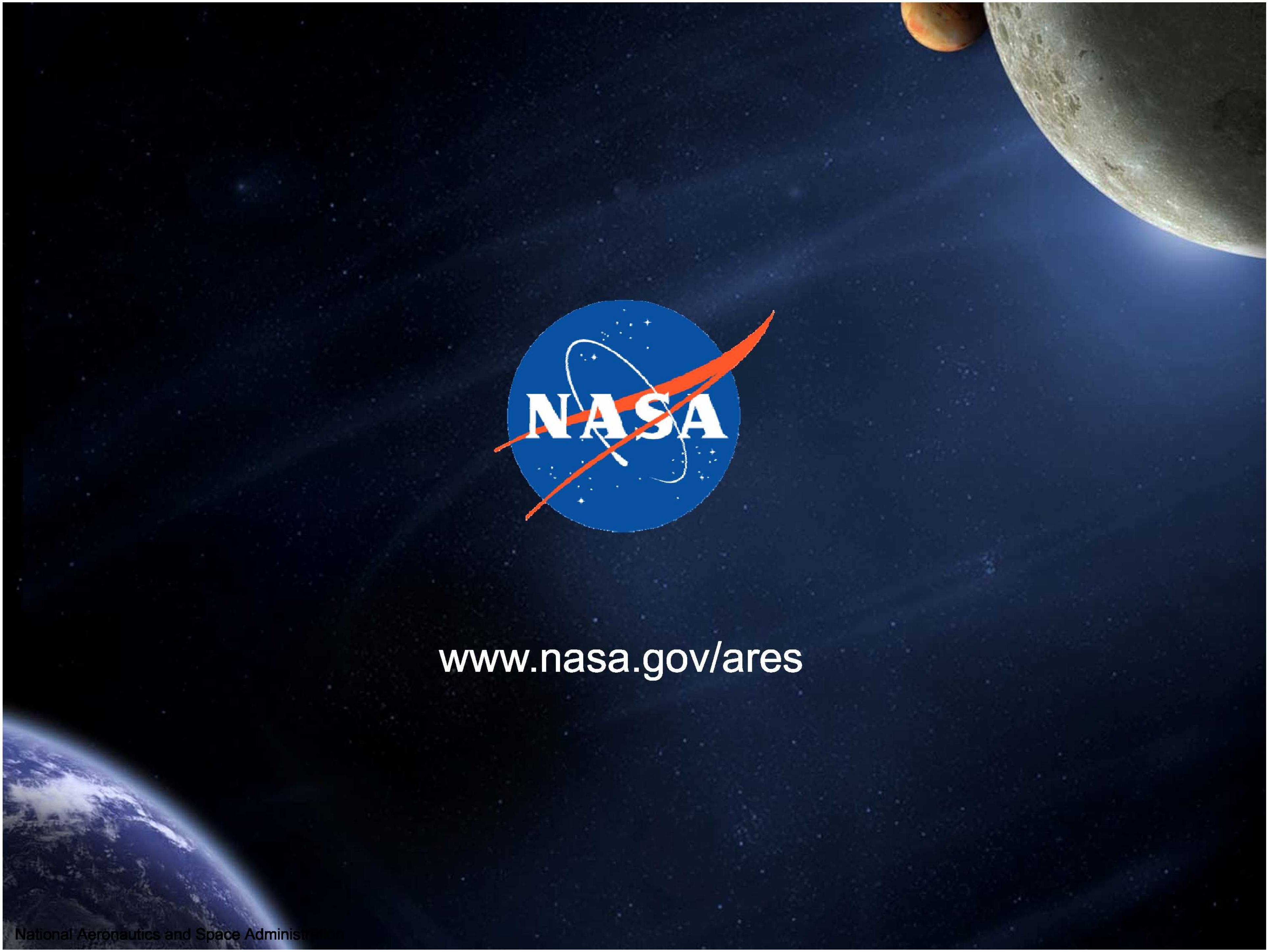
NASA Advanced Missions Cost Model



Summary

- Ares team has completed more than 2,000 heavy-lift design exercises on Ares V design
- Team has also analyzed alternative heavy-lift designs and supported the Review of U.S. Human Space Flight Plans Committee
- Analysis indicates heavy lift provides a significant capability for science and potentially changes the typical development cycle
- Ares heavy-lift database and expertise applicable to any future direction for U.S. space exploration requiring large payload delivery

QUESTIONS?

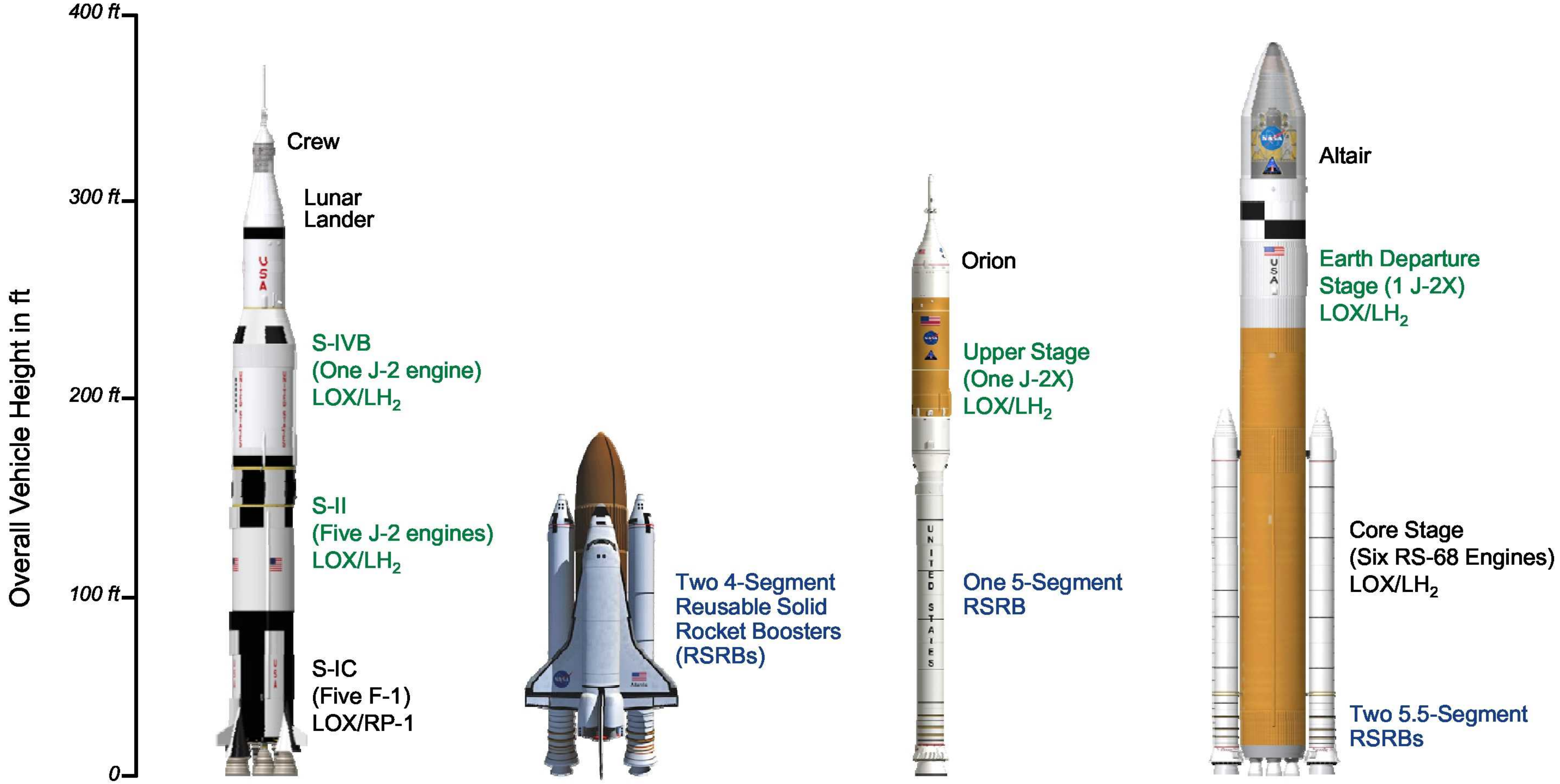


www.nasa.gov/ares

Backup

Ares V in Context

– Launch Vehicle Comparisons –



	Saturn V: 1967–1972	**Space Shuttle:** 1981–Present	**Ares I:** First Flight 2015	**Ares V:** First Flight 2018
Height	360 ft	184.2 ft	325.0 ft	381.1 ft
Gross Liftoff Mass (GLOM)	2,948.4 mT (6,500K lbm)	2,041.1 mT (4,500.0K lbm)	933.2 mT (2,057.3K lbm)	3,704.5 mT (8,167.1K lbm)
Payload Capability	99.0K lbm to TLI 262.0K lbm to LEO	55.1K lbm to LEO	54.9K lbm to LEO	156.7K lbm to TLI with Ares I 413.8K lbm to LEO

Requirements for Lunar Crew, Cargo Missions

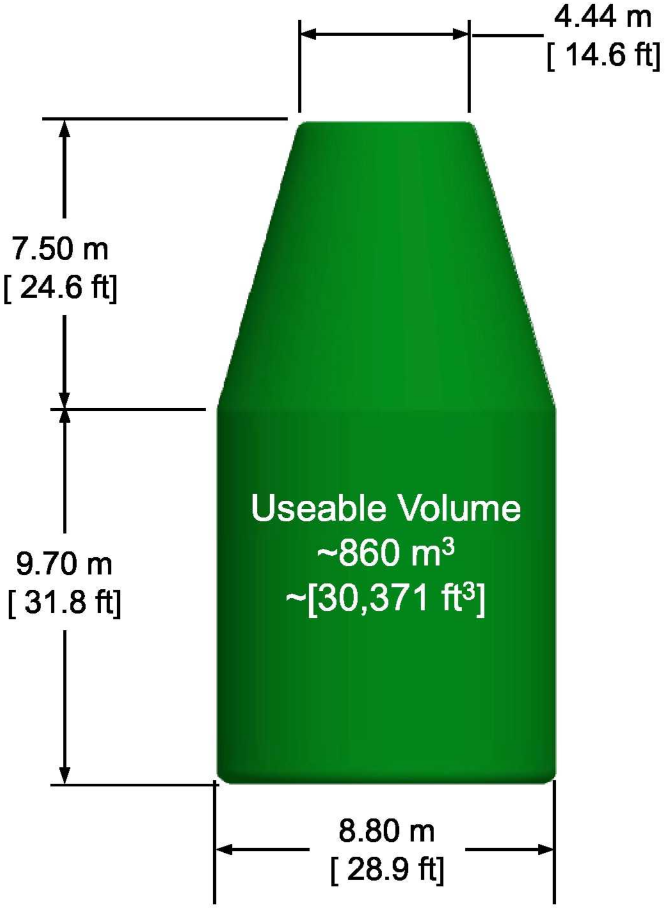
LUNAR SORTIE MISSION			
CARD Requirement	**Mass (t)**	**Mass (lb_m)**	**Derived Performance Rqt.**
Orion [CA4139]	20.2	44,500	
Crewed Lander [CA0836]	45.0	99,208	
Total TLI [CA0848]	66.9	147,575	Derived TLI > 66.9 t
	45.0	99,208	Derived ETO > 45.0 t

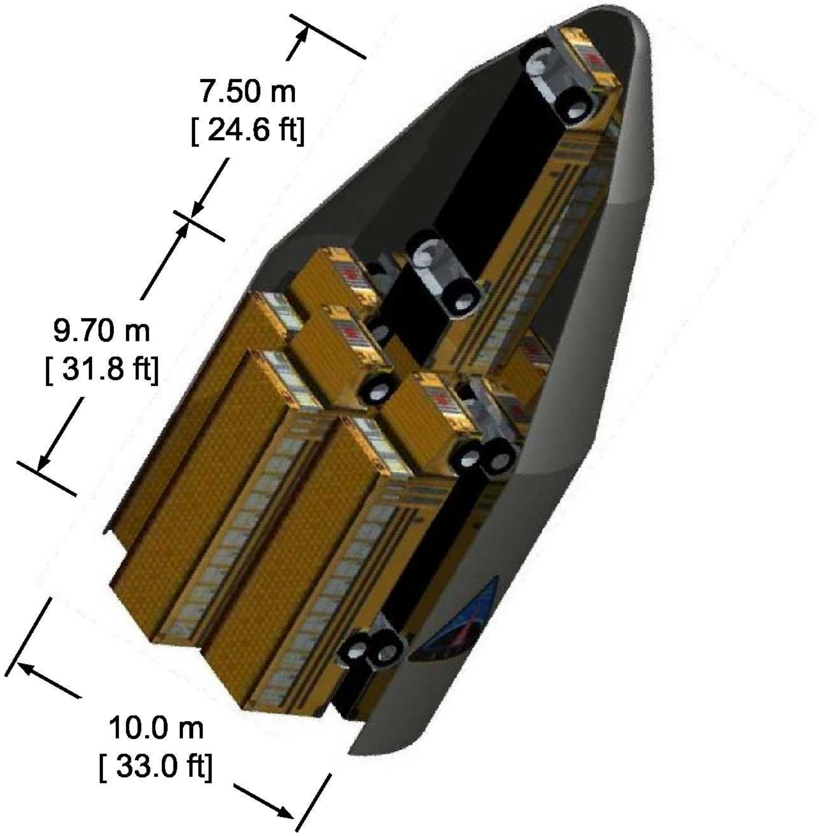
- ETO Mission Destination: 130 nmi, 29°
- Loiter Duration: 4 days (CARD TBD)
- TLI Maneuver Starting Conditions: 100 nmi, 29°
- TLI ΔV = 3175 m/s + Gravity Loss

LUNAR CARGO MISSION			
CARD Requirement	**Mass (t)**	**Mass (lb_m)**	**Derived Performance Rqt.**
Cargo Lander [CA5231]	53.6	118,168	
Total TLI [CA0847]	54.6	120,372	Derived TLI > 54.6 t
Total ETO Goal [CA0847]	54.6	120,372	Derived ETO > 54.6 t

- ETO Mission Destination: Phasing Orbit
- Loiter Duration: None (no loiter capability on EDS)
- Note that Saturn V TLI payload capability was 48.6 t (Apollo 17 - CM/SM/ LM/SLA) and
- Ares V Earth-to-TLI requirement exceeds Saturn V Capability by 31%

Current Ares V Shroud Concept





One 66-passenger school bus
= 33x8x10.3 ft / 20,100 lb empty