

Ares V: Enabling Unprecedented Payloads for Space in the 21st Century

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ABSTRACT

Numerous technical and programmatic studies since the U.S. space program began in the 1960s has emphasized the need for a heavy lift capability for exploration beyond low Earth orbit (LEO). The Saturn V once embodied that capability until it was retired. Now the Ares V cargo launch vehicle (CaLV) promises to restore and improve on that capability, providing unprecedented opportunities for human and robotic exploration, science, national security and commercial uses. This paper provides an overview of the capabilities of Ares V, both as an opportunity for payloads of increased mass and/or volume, and as a means of reducing risk in the payload design process.

The Ares V is part of NASA's Constellation Program, which also includes the Ares I crew launch vehicle (CLV), Orion crew exploration vehicle (CEV), and Altair lunar lander. This architecture is designed to carry out the national space policy goals of completing the International Space Station (ISS), retiring the Space Shuttle fleet, and expanding human exploration beyond LEO.

The Ares V is designed to loft upper stages and/or cargo, such as the Altair lander, into LEO. The Ares I is designed to put Orion into LEO with a crew of up to four for rendezvous with the ISS or with the Ares V Earth departure stage for journeys to the Moon.

While retaining the goals of heritage hardware and commonality, the Ares V configuration continues to be refined through a series of internal trades. The current reference configuration was recommended by the Ares Projects and approved by the Constellation Program during the Lunar Capabilities Concept Review (LCCR) June 2008.

The reference configuration defines the Ares V as 381 feet (116m) tall with a gross lift-off mass (GLOM) of 8.1 million pounds (3,704.5 mT). Its first stage will generate 11 million pounds of sea-level liftoff 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. It could

also launch 123,100 pounds (55.8 mT) to Sun-Earth L2.

Assessment of astronomy payload requirements since Spring 2008 has indicated that Ares V has the potential to support a range of payloads and missions. Some of these missions were impossible in the absence of Ares V's capabilities. Collaborative design/architecture inputs, exchanges, and analyses have already begun between scientists and payload developers. A 2008 study by a National Research Council (NRC) panel, as well as analyses presented by astronomers and planetary scientists at two weekend conferences in 2008, support the position that Ares V has benefit to a broad range of planetary and astronomy missions. This early dialogue with Ares V engineers is permitting the greatest opportunity for payload/transportation/mission synergy and with the least financial impact to Ares V development. In addition, independent analyses suggest that Ares V has the opportunity to enable more cost-effective mission design.

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Abstract—The need for a national heavy lift capability to support science, exploration, national security, and commerce has been highlighted by numerous technical and programmatic studies since the Apollo Program ended in the early 1970s.¹² Now the Ares V cargo launch vehicle (CaLV) promises to restore and improve on the Saturn capability, providing unprecedented capability, not only for larger, heavier payloads, but also as a means of reducing risk in payload design, and increase project sustainability through design and operations efficiencies. The Ares V is part of NASA’s Constellation Program, which seeks to provide an architecture to support the International Space Station, replace the current Space Transportation System, and expand human exploration beyond low Earth orbit (LEO). While Ares V is at an early point in its development, it benefits from significant progress on Ares I crew launch vehicle. In addition, Ares V physical design and operational concept have progressed through hundreds of iterations, largely through internal NASA analysis. NASA has reached out to potential users of a heavy-lift capability to begin a dialog that will improve vehicle/payload interactions. This paper provides an overview of the Ares V mission, development, design trades, current configuration, and implications for payload development.

TABLE OF CONTENTS

| | |
|--|-----------|
| 1. INTRODUCTION..... | 1 |
| 2. REQUIREMENTS AND DESIGN EVOLUTION..... | 2 |
| 3. POINT OF DEPARTURE CONFIGURATION..... | 4 |
| 4. TECHNICAL STATUS..... | 5 |
| 5. SUPPORTING HEAVY LIFT DEVELOPMENT | 6 |
| 6. POTENTIAL FOR SCIENCE AND EXPLORATION..... | 8 |
| 7. CONCLUSION | 13 |
| REFERENCES..... | 14 |
| BIOGRAPHY | 14 |

1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) is assigned the task of retiring the Space Shuttle, developing its successor, completing and operating the International Space Station (ISS), and resuming human exploration of the Solar System, beginning with a return to the Moon. Transportation is a key part of that assignment. The Exploration Systems Architecture Study (ESAS), completed in 2005, broadly defined the launch vehicles and spacecraft needed for NASA’s human exploration mission, based on basic ground rules and assumptions and a set of design reference missions (DRMs).³ Influencing those ground rules and DRMs were decades of studies into human exploration missions, as well as the findings and recommendations of the Challenger and Columbia shuttle accident investigations. These included crew safety as a key driver, establishment of a permanent human presence on the Moon, and the ability to land anywhere on the Moon and return anytime if necessary. ESAS outlined two launch vehicles, the Ares I crew launch vehicle and the Ares V cargo launch vehicle, to provide safe, reliable, flexible, cost-effective transportation to low Earth orbit and beyond.

Ares I is designed to launch the Orion crew exploration vehicle with crews of up to four in to LEO for missions to ISS or the Moon. The Ares I’s five-segment solid fuel first stage is based on the Shuttle four-segment solid rocket booster. The new 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. The simpler solid propellant first stage, the in-line launch vehicle configuration, ballistic reentry capsule and launch escape system provide escape system meet the significantly improved safety recommended by earlier studies.

Ares V is designed to launch a large payload into LEO. For its planned lunar mission, it will launch a lunar lander, support loiter, rendezvous with Orion, and perform a trans lunar injection (TLI) maneuver to send the mated

¹ U.S. Government work not protected by U.S. copyright.
² IEEEAC paper #1334, Version 2, Updated November 4, 2009

³ NASA ESAS Final Report, November 2005

Orion/lander to the Moon. For the Ares V point-of-departure configuration, the first stage propulsion consists of a 33-foot core stage powered by six RS-68 engines, currently in use on the Delta IV launch vehicle, and a pair of 5½ - segment solid propellant boosters similar to the Ares I first stage. The Earth departure stage (EDS) is also 33 feet in diameter and powered by a J-2X engine that is similar to the Ares I engine but modified for on-orbit loiter and ignition. Atop the EDS are a payload adaptor and a 33-foot-diameter payload shroud totally encapsulating the lander. This paper provides an overview of the requirements driving Ares V design efforts from ESAS to the present. The current reference configuration will be described, as well as ongoing concept design work, trades and challenges. Finally, the paper will discuss Ares V capabilities and opportunities for payload design community.

2. REQUIREMENTS AND DESIGN EVOLUTION

The focus of NASA's launch vehicle design work since ESAS has been Ares I and Orion due to the decisions to retire the Shuttle and support ISS operations, as well as funding constraints. However, Ares V benefits from its commonality with the Ares I components, such as the first stage and the upper stage engine. Work done for Ares I on these components can be applied to Ares V, providing cost savings and shortening development time. The design of Ares V remains in the conceptual stage. Its configuration and operational concept have undergone successive and increasingly refined internal analyses since ESAS. The Ares team has evaluated more than 2,000 vehicle configurations. The current configuration is shown in Figure 1.



Figure 1 – Ares V on the launch pad shown in an artist's concept

The starting point for all trades has been the Constellation Architecture Requirements Document (CARD).⁴ Of particular relevance to the Ares V, the CARD contains the mass requirements for both the Lunar Sortie (crewed) and Lunar Cargo (automated) design reference missions (DRMs). The CARD requirements are shown in Figure 2.

Additional requirements for the Ares V and the other

components of the Constellation architecture are shown in Figure 3.

For the sortie mission, the CARD specifies an Orion control mass of 44,500 lb (20.2 metric tons) (mT) and a lunar lander control mass of 99,208 lb (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

| 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 |

| 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 |

Figure 3 – Ares V performance requirements for lunar crew and lunar cargo missions

| CARD Req't | Requirement | Rationale |
|------------|--|---|
| CA0391-HQ | The CaLV shall utilize twin shuttle-derived 5-segment SRBs along with a core stage that employs 5 modified RS-68 engines for first stage propulsion. | <ul style="list-style-type: none"> Draws Performance Constraints around Booster Selection and Core Stage Design Boosters and Core Stage Provide ~70% of Delta V for LEO Insertion |
| CA0847-PO | The CaLV EDS shall deliver at least 66,939 (TBR-001-076) kg (147,266 lbm) from Earth Rendezvous Orbit (ERO) to the start of the Trans-Lunar Coast (TLC) for crewed lunar missions. | <ul style="list-style-type: none"> Defines TLI Payload most strenuous performance parameter TLI Payload Sizes EDS |
| CA0836-PO | The LSAM shall have a Control Mass of 45,000 (TBR-001-075) kg (99,180 lbm) at the time of launch for Lunar Sortie and Lunar Outpost crew missions | <ul style="list-style-type: none"> Defines LEO Payload for Crew Mission Contribute ~2/3 Mass for TLI Payload TLI Payload Sizes EDS |
| CA4139-PO | The CEV shall have a Control Mass of 20,185 (TBR-001-159) kg (44,500 lbm) at the time of CaLV rendezvous. | <ul style="list-style-type: none"> Contribute ~1/3 Mass for TLI Payload TLI Payload Sizes EDS |
| CA0051-PO | The CaLV EDS shall provide a minimum translational delta-V of 3,150 (TBR-001-258) m/s (10,335 ft/s) for the TLI for crewed lunar missions. | <ul style="list-style-type: none"> Defines Delta V thus propellant Needed for Delta V TLI Delta V Sizes EDS |
| CA0850-PO | The CaLV EDS shall meet its requirements after loitering in low Earth orbit (LEO) at least (TBD-001-975) days after orbit insertion for crewed lunar missions. | <ul style="list-style-type: none"> Defines Propellant Reserves for EDS Stage Major Factor in subsystem Selection and Design for EDS |
| CA0282-PO | The CaLV shall deliver at least 125,000 (TBR-001-220) kg (275,578 lbm) to a (TBD-001-072) Earth orbit for Mars exploration missions. | <ul style="list-style-type: none"> Defines Mars Mission Max Payload per launch Orbit and Payload size the Ares V |
| CA3215-PO | The CaLV shall launch cargo into a (TBD-001-565) Earth orbit for Mars missions. | <ul style="list-style-type: none"> Further defines performance capability of Ares V |

All Missions
 Lunar Requirements
 Mars Requirements

Figure 2 – Additional CARD requirements for Ares V and Constellation components

⁴ Constellation Architecture Requirements Document, NASA, July 2006

miles (nmi) at 29 degrees inclination. The TLI maneuver begins at a minimum 100 nmi altitude with a ΔV requirement of 10,417 ft (3,175 m) per second (m/s) plus gravity loss.

For the cargo mission, 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). The Lunar Cargo mission assumes a phasing orbit Earth-To-Orbit (ETO) destination.

In addition to the CARD, the Ares team added considered factors for safety, reliability, and cost to evaluate hundreds of combinations: two- vs. three-stages, five vs. six core stage engines, five vs. five-and-a-half segment boosters, 27.5- vs. 30-foot core and upper stages, extended core and earth departure stages, materials for “wet” and “dry” structural applications, and other technologies intended to improve performance.

As the design has progressed, the Ares V team and the Constellation Program, which manages the overall architecture have gained greater understanding of the two-vehicle launch architecture and its implications for ground and flight operations. Of particular importance to the Ares V design is the loiter period between launch and rendezvous of the Ares V EDS and Orion for the TLI burn 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. Additionally, the team 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 4.

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 trade studies and technical evaluations since then.

3. ARES POINT OF DEPARTURE CONFIGURATION

The LCCR reference Ares V configuration is 381 feet (116m) tall with a gross lift-off mass (GLOM) of 8.1 million pounds (3,704.5 mT). Its first stage will generate 11 million pounds of sea-level liftoff thrust. It will be capable of launching

413,800 pounds (187.7 mT) to low Earth orbit (LEO), 138,500 pounds (63 mT) direct to the Moon, or 156,700

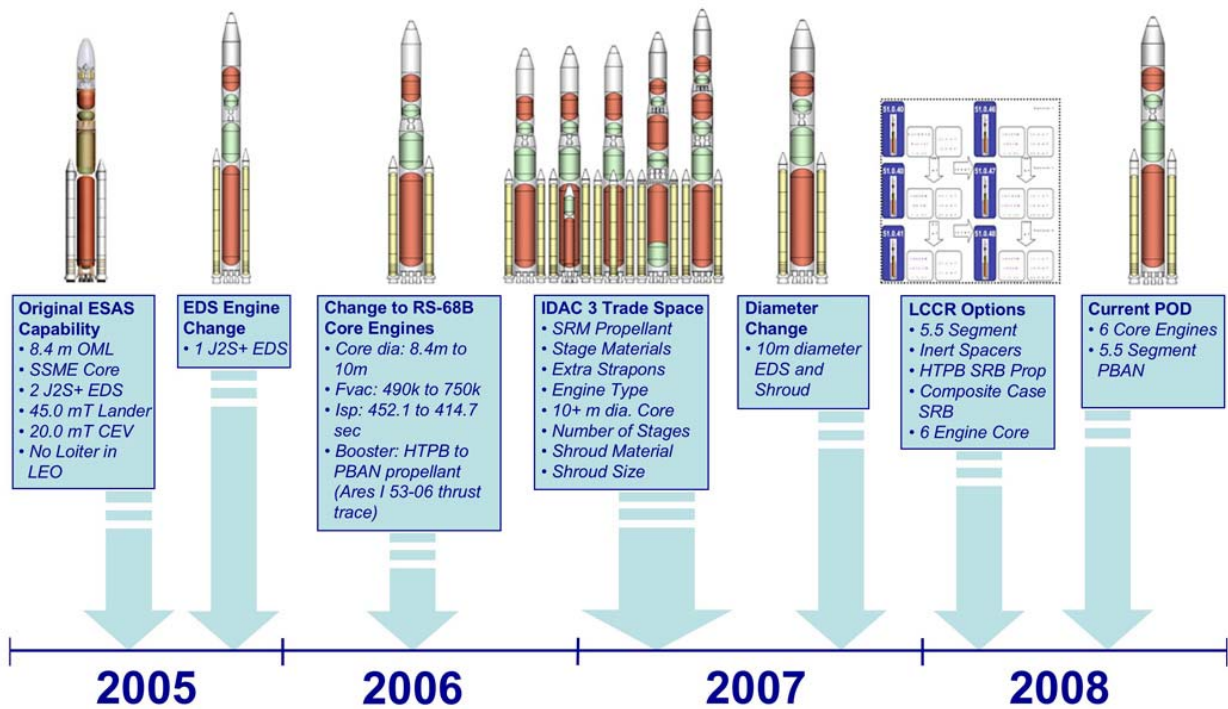


Figure 4 – Key milestones in the development of Ares V from ESAS to present

pounds (71.1 mT) in its dual-launch architecture role with Ares I. 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 shown in Figure 5, the Ares V first stage propulsion system consists of a core stage powered by six commercial liquid hydrogen/liquid oxygen (LH₂/LOX) RS-68 engines, flanked by two 5.5-segment solid rocket boosters (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. Atop the core stage is the Earth departure stage (EDS), powered by a single J-2X upper stage engine based on the Ares I upper stage engine.

This configuration is expected to be capable of carrying out the lunar sortie mission based on the CARD requirements. However, it falls short of the Ares Projects internal TLI payload goal of 165,567 pounds (75.1 mT) that attempts to accommodate the magnitude of mass increases and performance losses for the Ares vehicles, Orion and the lander typical in new vehicle development in addition to the loiter penalty and Ares I margin noted above. The Ares Projects are carrying an option for a new composite case

booster with more energetic Hydroxyl-terminated Polybutadiene (HTPB) propellant that would meet the desired TLI goal. That concept is designated 51.00.47.

In the current mission profile, the Ares V launches from Kennedy Space Center, Florida. The boosters separate, followed by the core stage. The EDS ignites and places the stage and its payload into LEO. Shroud separation occurs following EDS ignition to avoid shroud re-contact with the vehicle. The Orion, launched by the Ares I, rendezvous and docks with the EDS/lander. Following automated and ground checkouts, the EDS performs the TLI burn to send the EDS/lander toward the Moon. The EDS is discarded into solar orbit, completing the Ares portion of the lunar mission. Ares V is currently designed to sustain a 4-day loiter, with TLI on the fourth day.

4. ARES V TECHNICAL STATUS

Internal NASA design teams assigned to the key components of Ares V – core stage, core stage engine, boosters, EDS, upper stage engine, shroud, and vehicle

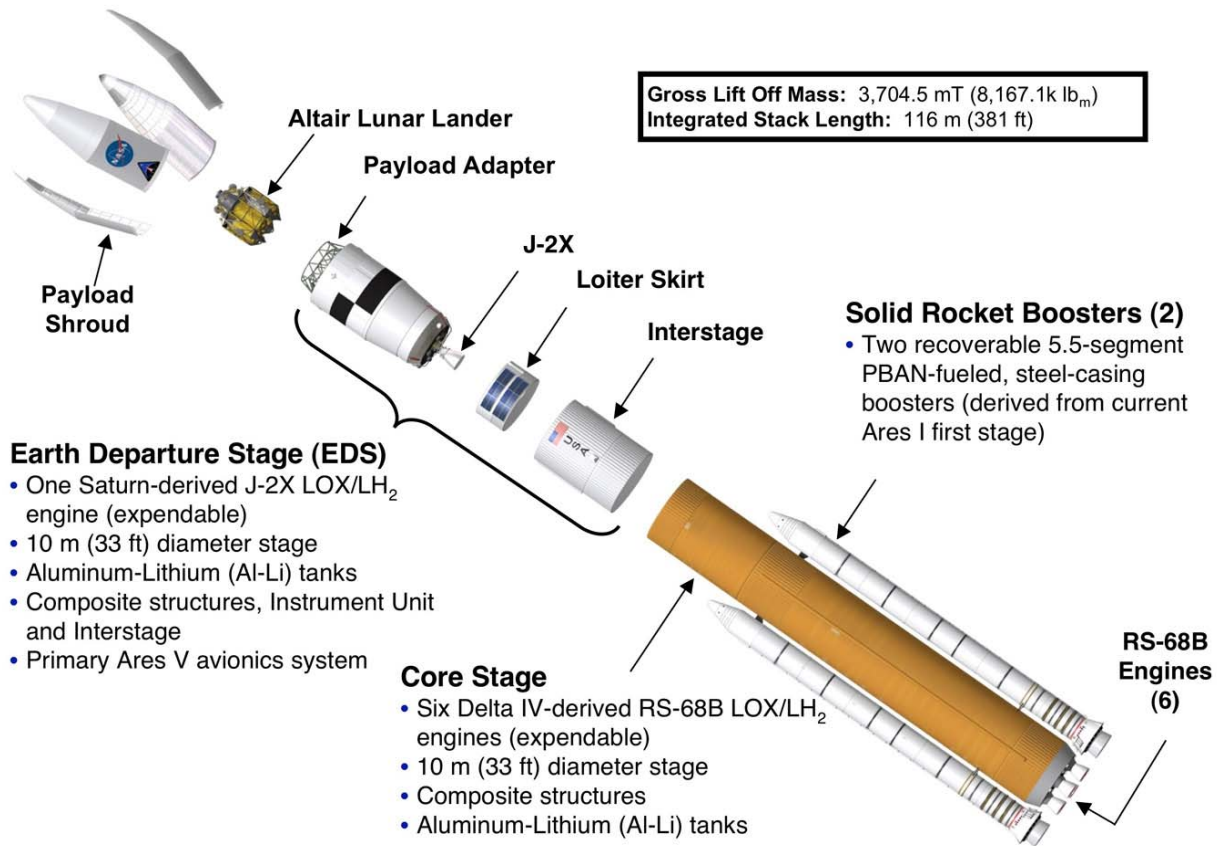


Figure 5 – Expanded view of current 51.00.48 reference vehicle

integration – continue to perform analyses and trades pending approval to begin the formal design phase. Technical readiness to support design and development also benefits from the decision to employ as many components, manufacturing capability, and facilities as possible already in development for Ares I.

Since selection of the LCCR configuration, the Ares V team had conducted two additional rounds of analysis and was preparing for a third at the time of this writing. The first, from January to April 2009, transitioned work from an architecture baseline to a specific study configuration used to create an operational concept and a set of design requirements for the team. It also refined the vehicle design and the requirements analysis process for later studies.

From May to September 2009, the study was focused on verifying design processes, validating requirements, and identifying vehicle sensitivities. The team met at the end of this phase to outline a plan toward a third round of study. The meeting helped refine key products, identify gaps and overlap and develop solutions and strategies in planning the next design cycle.

Although not a formal review, the meeting provided a snapshot of development. As expected, it provided additional details on known challenges in the design. The core stage will be the largest stage in history, 18 feet longer

than the Saturn V first and second stages combined. The loiter requirement will have a major impact on EDS design, including issues such as propellant boil-off, debris protection, thermal control, conditioning the J-2X engine for TLI restart, orbital decay. The shroud as designed will be the largest composite shroud in history. It has to protect payloads from the severe launch and ascent environment and deploy without re-contacting the vehicle.

Among the products generated in the second round of analysis – which is also illustrative of the ongoing systems engineering effort – is an integrated functional schematic, shown in Figure 6. 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 planned October 2009 to March 2010 studies will match refined performance targets to programmatic and schedule requirements. The results will be applicable to potential changes in Ares V architecture.

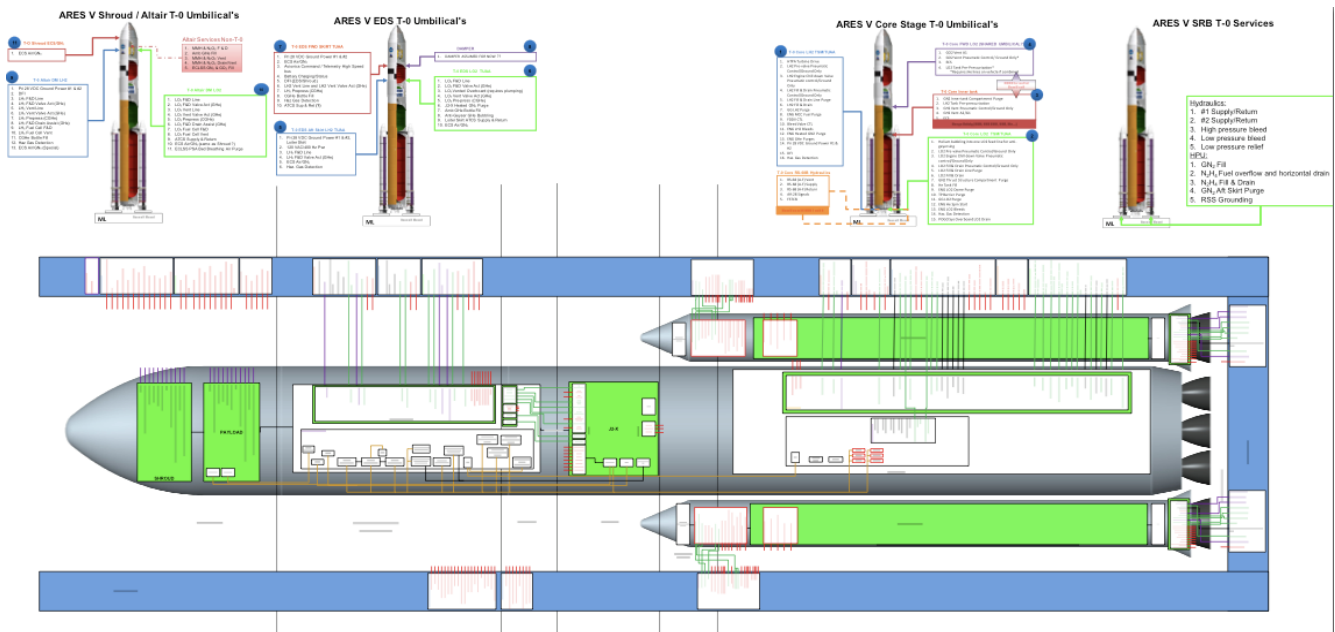


Figure 6 – Ares V Integrated Functional Schematic

5. SUPPORTING HEAVY-LIFT DEVELOPMENT

Much of the Ares V development team's effort in 2009 was devoted to supporting the work of the Review of U.S. Human Space Flight Plans Committee. 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 7, 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.

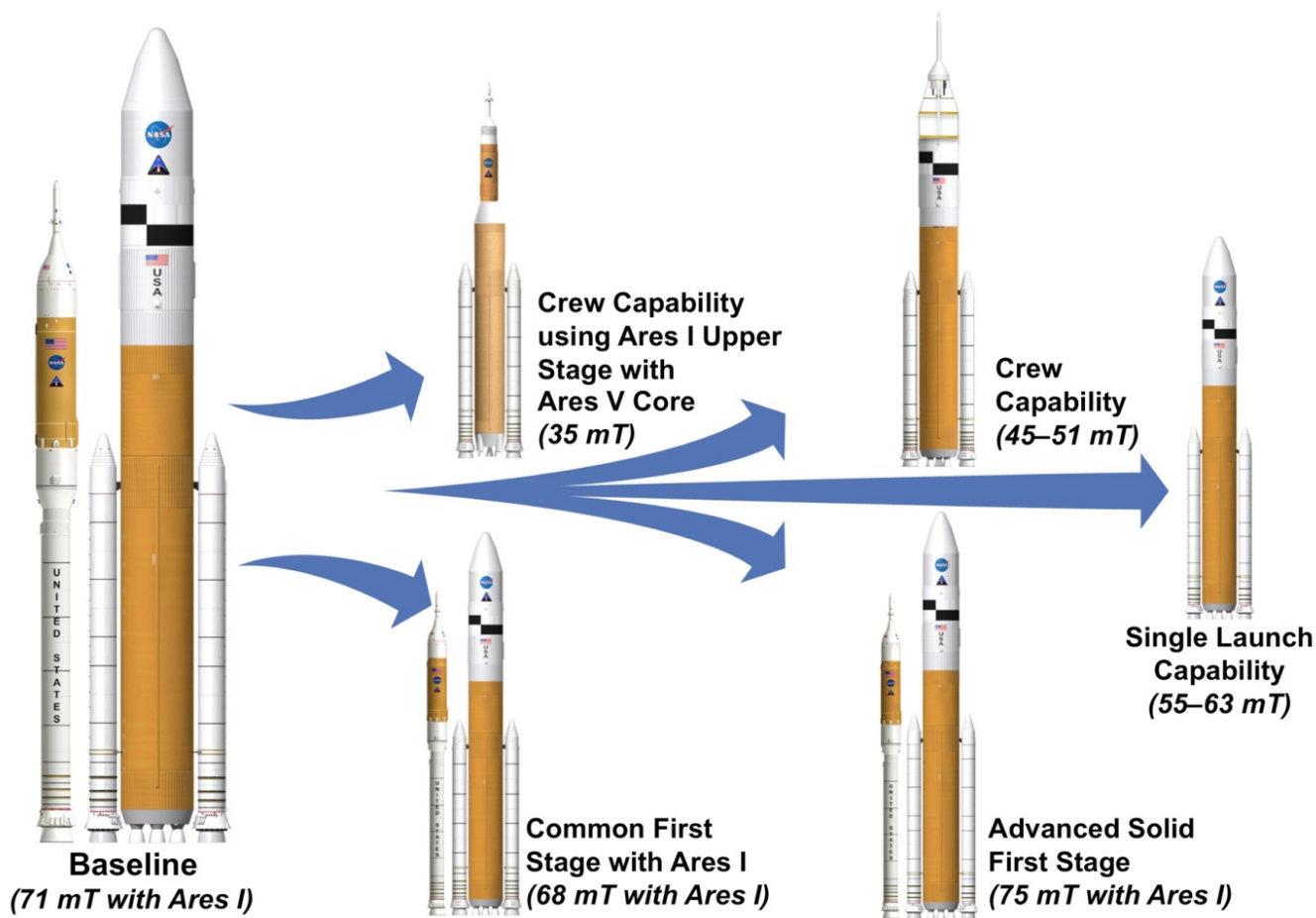


Figure 7 – Ares V option for the Augustine panel

6. POTENTIAL FOR ROBOTIC SCIENCE AND EXPLORATION

Numerous studies and panels at different times since Apollo have cited the benefits and the need for a national heavy lift launch capability for human and robotic exploration and science, national security, and commercial endeavors. One component of Ares V's capability is its unprecedented payload mass mentioned earlier. Equally unprecedented is its payload volume, shown in Figure 8, along with a notional extended shroud for science missions. The reference Ares shroud has a usable volume of 860 m³, 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.

Most recently the Review of U.S. Human Space Flight Plans Committee, also known as the "Augustine Committee," considered heavy-lift important enough to include it as one of the five "key questions" for inquiry, and the need for heavy-lift vehicle was one of the panel's major

findings in its summary report, released as this paper was in preparation.⁵

"No one knows the mass or dimensions of the largest piece that will be required for future exploration missions, but it will likely be significantly larger than 25 metric tons (mT) in launch mass to low-Earth orbit, the capability of current launchers," the panel concluded. "As the size of the launcher increases, fewer launches and less operational complexity to assemble and/or refuel them results, and the net availability of launch capability increases. Combined with considerations of launch availability and on-orbit operations, the Committee finds that exploration will benefit from the availability of a heavy-lift vehicle. In addition, heavy lift would enable the launching of large scientific observatories and more capable deep-space missions. It may also provide benefit in national security applications."

The Ares team has engaged potential users at the early conceptual stage when an exchange of information can have the greatest impact at the least technical and fiscal cost. While the human lunar mission is the primary purpose for

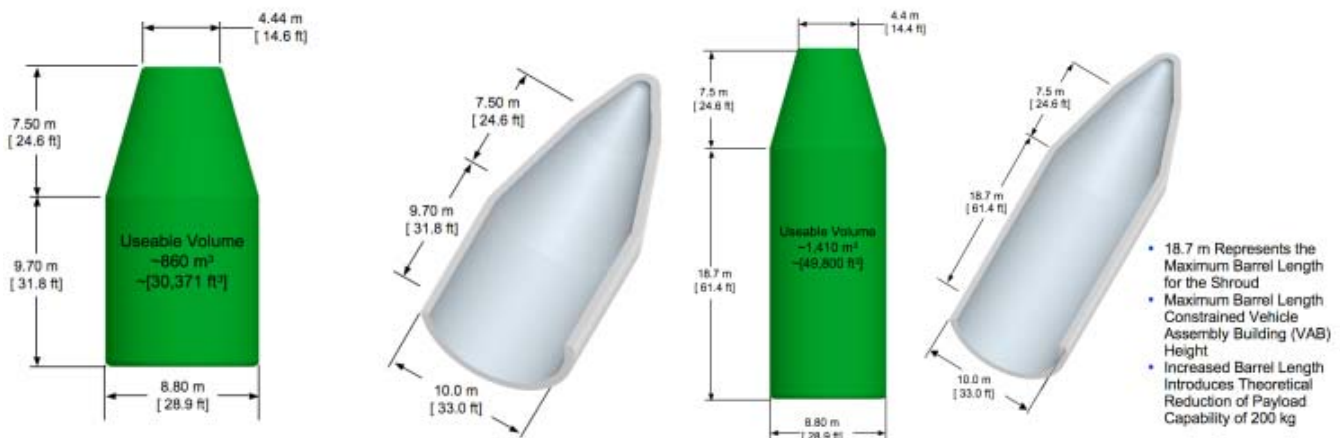


Figure 8 – Payload volume and dimensions for Ares V reference shroud, left, and notional science shroud, right

⁵ Summary Report of the Review of U.S. Human Space Flight Plans Committee, September 8, 2009

the Ares V, outreach efforts to the payload community have attempted to quantify unique requirements that vehicle designers can incorporate or at least not preclude in exploring design solutions for the human lunar mission.

Figure 9 shows Ares V payload mass (metric tons) to LEO as a function of orbit altitude and inclination angle. The higher the orbit or greater the inclination angle, the less mass can be launched. This analysis was based on the pre-LCCR 51.00.39 configuration.

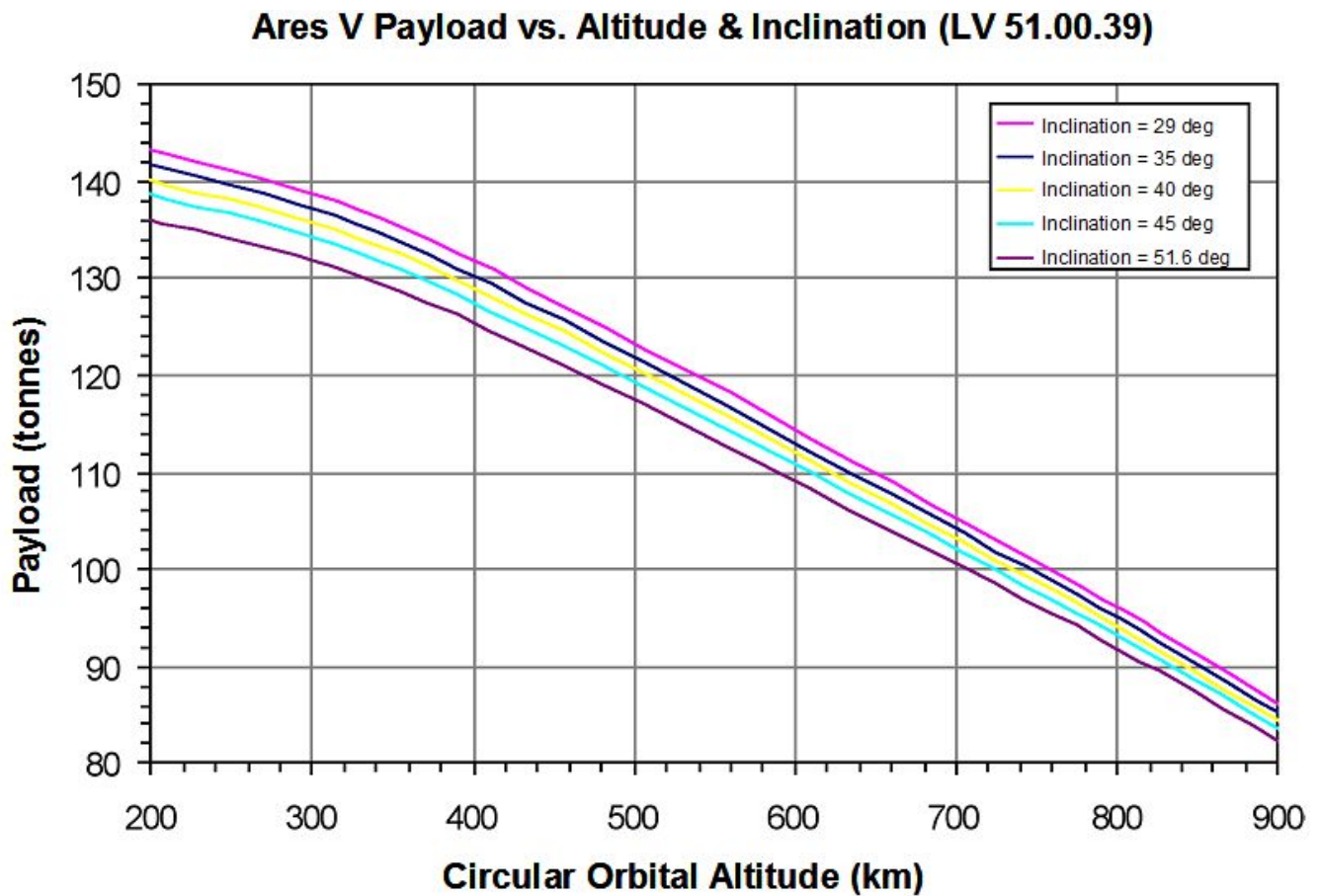


Figure 9 – Payload mass vs. altitude and inclination for the 51.00.39 Ares V Configuration

Figure 10, again based on pre-LCCR configuration (LV 51.00.39), shows potential capability for science missions expressed as C3 energy. C3 is a measure of energy required for an interplanetary mission that requires achieving an excess orbital velocity over an escape velocity required for additional orbital maneuvers. Ares V, alone or with a

Centaur Upper Stage, can accelerate larger payloads to large C3 energy values, thus enabling and enhancing deep space planetary missions. For example, preliminary performance assessments indicate that an Ares V could deliver a Mars sample return mission payload approximately five times greater than the most capable current vehicles.

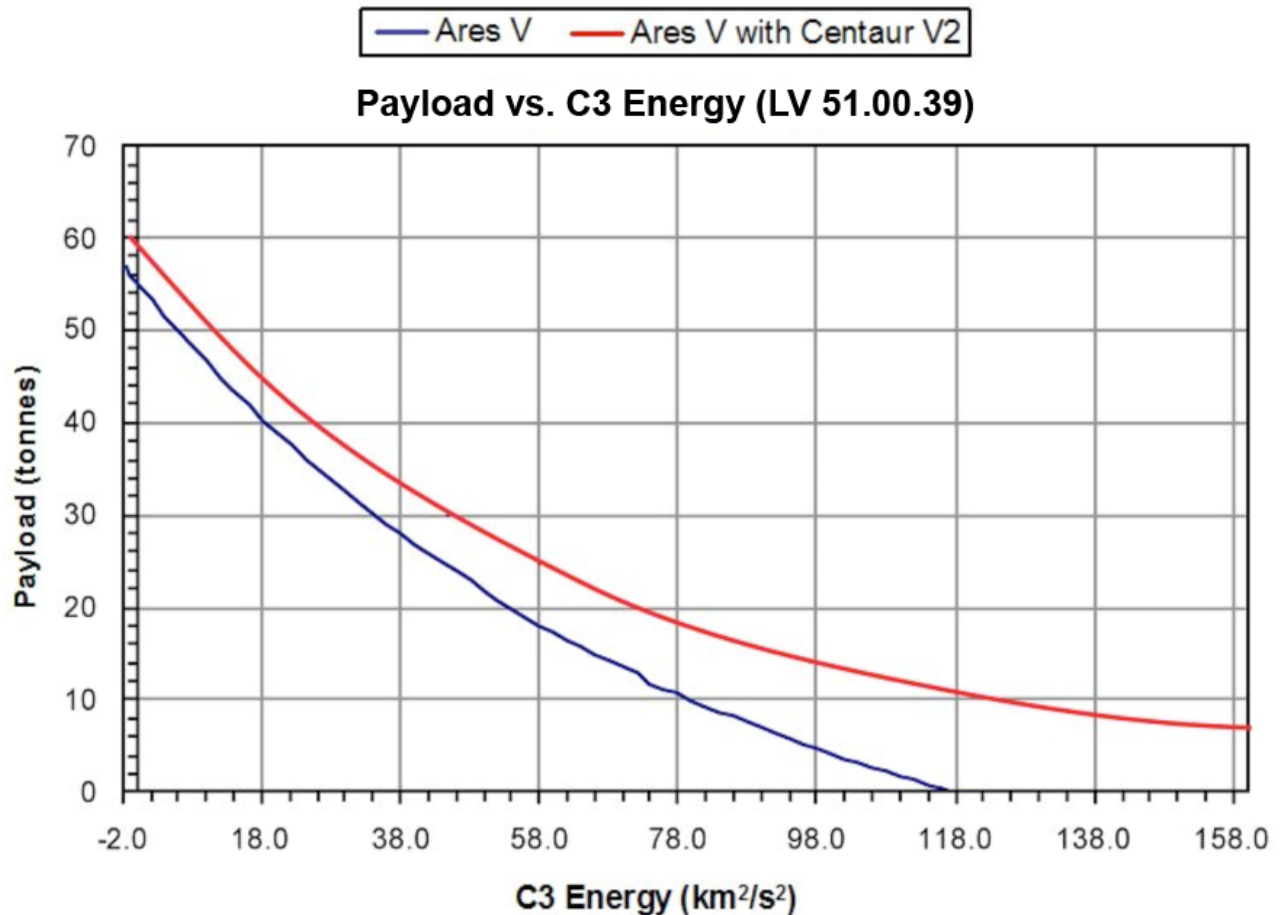


Figure 10 – Payload vs. C3 energy for the 51.00.39 Ares V configuration

Ares V can deliver tremendous payloads to a wide variety of orbital parameters, as shown in Table 1. Again, based on the pre-LCCR concept, Ares V can deliver 56.5 metric tons to a Sun-Earth L2 transfer orbit and 57 metric tons to an Earth-Moon L2 transfer orbit. It can also carry approximately 69.5 metric tons to geosynchronous transfer orbit (GTO) and 35 metric tons to geosynchronous orbit (GEO). This is approximately six times that of any currently manufactured launch vehicle. Payloads for additional transfer orbits are also shown.

Performance is expected to improve for the current concept (LV 51.00.48) when the performance analysis is completed. Among the ground rules assumptions for these calculations were: no gravity assists, interplanetary trip times based on Hohmann transfers, payload mass estimates comprise spacecraft, payload adapter, and mission peculiar hardware, and a two-engine Centaur for the kick stage. The payloads shown for the extended shroud as shown in Table 1 are a conceptual exercise. Only the POD shroud is included in the design baseline.

Table 1 -- Performance for selected missions using the 51.00.39 configuration

| Mission Profile | Target | Constellation POD Shroud | | Extended Shroud | |
|--|--|--------------------------|--------------|-----------------|--------------|
| | | Payload (lbm) | Payload (mT) | Payload (lbm) | Payload (mt) |
| 1) Sun-Earth L2 Transfer Orbit Injection | C3 of -0.7 km ² /s ² | 124,000 | 56.5 | 123,000 | 56 |
| 2) Earth-Moon L2 Transfer Orbit Injection | C3 of -1.7 km ² /s ² | 126,000 | 57.0 | 125,000 | 57 |
| 3) GTO Injection | Transfer DV 8,200 ft/s | 153,000 | 69.5 | 152,000 | 69 |
| 4) GEO | Transfer DV 14,100 ft/s | 77,000 | 35 | 76,000 | 34.5 |
| 5) LEO (@29° inclination) | 241 x 241 km | 315,000 | 143 | 313,000 | 142 |
| 6) Cargo Lunar Outpost (TLI Direct), Reference | C3 of -1.8 km ² /s ² | 126,000 | 57 | 125,000 | 57 |
| 7) Mars Cargo (TMI Direct) | C3 of 9 km ² /s ² | 106,000 | 48 | 105,000 | 48 |

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 workshop clearly showed that the Ares V has considerable potential to do breakthrough astronomy," the astronomy workshop final report said.⁶ "It is also likely that it could advance the Earth science and planetary science goals of NASA.

Likewise, the planetary workshop final report noted that Ares V changes the paradigm of the possible for payloads because its C3 versus payload is far greater than that of any current vehicle.⁷ The massive payload shroud permits the launch of large, multi-element systems, larger power supplies, and more low-tech mass for shielding or propellants. "This translates into an earlier return on science, a reduction in mission times, and greater flexibility for extended science missions," the report states. "It is particularly enabling for sample return, which takes advantage of all of the Ares V capabilities. We encourage the science community to think big, because an Ares V expands the envelope of what can be done in planetary science.

The National Research Council (NRC) took note of Ares V in its report, *Launching Science: Science Opportunities Provided by NASA's Constellation System*.⁸ 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.

The report cautioned that astronomy and astrophysics payloads will require cleanliness, vibration, and noise levels at least as low as the space shuttle. The Ares V team is investigating designs to meet those levels. Planetary missions will need a way to remove waste heat from radioisotope power sources inside the payload shroud, as well as access to the payload through the shroud. Again,

the design team is investigating how to incorporate those requirements.

Although history indicates bigger payloads cost more than smaller payloads and that payload mass usually expands to fill the available vehicle capability, Ares V represents a potential departure from that paradigm. NASA's Advanced Missions Cost Model⁹ shown in Figure 11 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.

With Ares V's "excess" mass and volume could be used to reduce technical complexity, redesign cycles, and cost. The

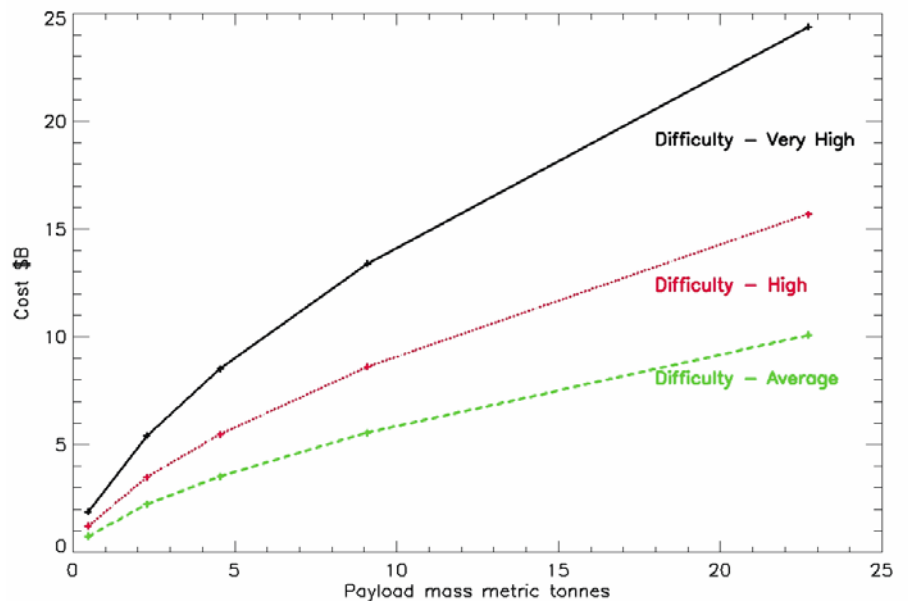


Figure 11 – NASA's Advanced Missions Cost Model

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.

⁶ Workshop report on Astronomy Enabled by Ares V, August 2008

⁷ Workshop Report on Ares V Solar System Science, December 2008

⁸ *Launching Science: Science Opportunities Provided by NASA's Constellation System*, 2008

⁹ NASA Advanced Missions Cost Model

Ares V allows the payload community to go either direction in the cost-versus-capability conflict. Figure 12 below shows the Hubble Space Telescope primary mirror. Hubble, launched in 1990, was limited to the size of the Space Shuttle cargo bay. To its right is the James Webb Space Telescope, which features a complex folding aperture that will be launched by the Arienne 5. Next is the proposed 8-Meter Monolithic Space Telescope that would use simple, heavy, ground-based telescope technology to take full advantage of Ares V volume and mass capability. Finally, there is the Advanced Technology large-Aperture Space Telescope, a complex segmented telescope designed to push Ares V's volume capability to the limit. The difference between the 8-meter monolithic and the 16-meter ATLAST is a \$3 billion to \$10 billion comparison.

The NRC report recommended that NASA should conduct a comprehensive systems-engineering-based analysis to assess the possibility that the relaxation of weight and volume constraints enabled by Ares V for some space science missions might make feasible a significantly different approach to science mission design, development, assembly, integration, and testing, resulting in a relative decrease in the cost of space science missions.

7. CONCLUSION

Understanding of the Constellation requirements and architecture and how they impact the design of the Ares V cargo lift vehicle has matured significantly since the ESAS. Hundreds of concepts have been studied and refined in an effort to make Ares V as technically and operationally safe, simple, and affordable as current technology can make it. The Ares V team is prepared to provide a heavy lift vehicle tailored to any future national direction that requires the capability. While NASA's current focus is on beyond-LEO exploration, starting with the Moon and evolving to Mars, Ares V represents a national asset for science, national security, and commerce. In that light, the Ares Projects are also reaching out to the academic and government community for payload and design inputs on science and military missions that may benefit from the Ares V capabilities. Ares V's capabilities open the doors of imagination and offer crosscutting solutions to a wide range of payloads. It can launch more capable science spacecraft farther, shorten trip times, and increase scientific return on missions that otherwise might be launched on today's launchers. It could also enable certain kinds of missions, such as sample return, that would be impossible on today's fleet. Payload and mission designers certainly can use traditional technical complexity to fully exploit Ares V capabilities. Additionally, though, they stand to gain greater scientific benefits and better manage technical and program risks by using Ares V's mass and volume capabilities in innovative ways.

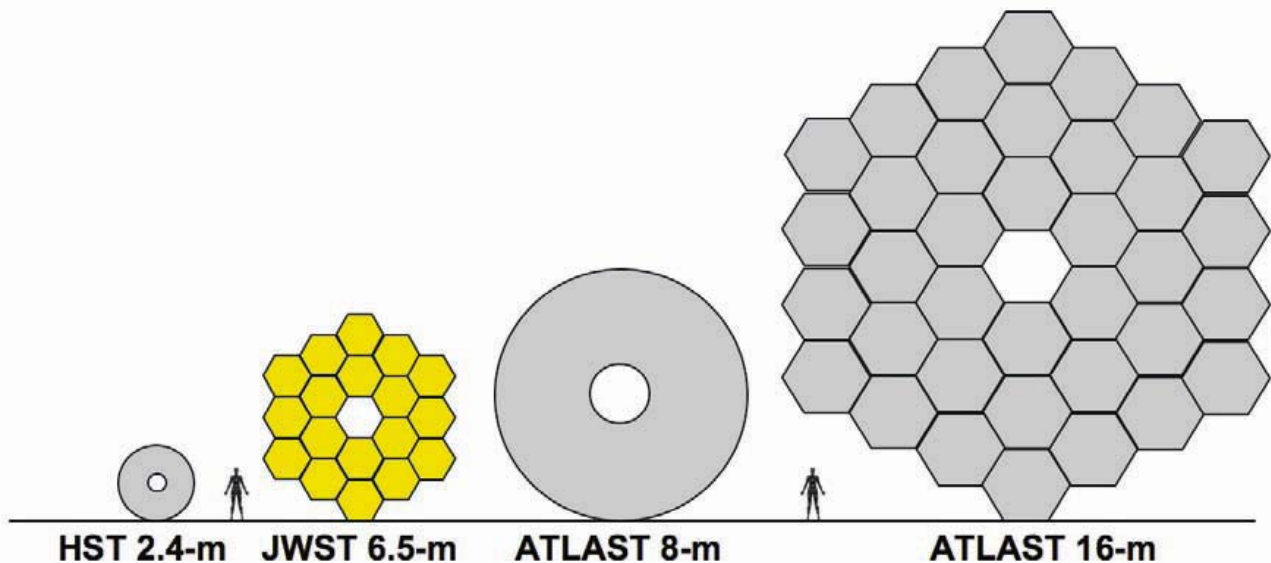


Figure 12 – The representative growth in space telescope apertures enabled by Ares V

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BIOGRAPHY



Steve Creech is Ares V Integration Manager for the Ares Projects at NASA's Marshall Space Flight Center, Huntsville, AL. He is responsible for formulation of the Ares V launch vehicle program and focal point for all programmatic and technical activities, including concept system design, requirements development, program planning, architecture development, verification, and facility planning, budget formulation, and acquisition

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ACRONYMS

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|---------------------------|--|
| ATLAST | Advanced Technology large-Aperture Space Telescope |
| CaLV | Cargo Launch Vehicle |
| CARD | Constellation Architecture Requirements Document |
| DRM | Design Reference Mission |
| EDS | Earth Departure Stage |
| ESAS | Exploration Systems Architecture Study |
| ETO | Earth to Orbit |
| GEO | Geosynchronous Orbit |
| GLOM | Gross Lift Off Mass |
| GTO | Geosynchronous Transfer Orbit |
| HTPB | Hydroxyl-Terminated Polybutadiene |
| LCCR | Lunar Capabilities Concept Review |
| LEO | Low Earth Orbit |
| LH₂/LOX | Liquid Hydrogen/Liquid Oxygen |
| mT | Metric Ton |
| nmi | Nautical Miles |
| NRC | National Research Council |
| PBAN | Polybutadiene Acrylonitrile |
| POD | Point of Departure |
| TLI | Trans Lunar Injection |