ARES V: A NATIONAL LAUNCH ASSET FOR THE 21ST CENTURY

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ABSTRACT

NASA is designing the Ares V cargo launch vehicle to carry NASA's exploration plans into the 21st century. The Ares V is the heavy-lift component of NASA's dual-launch architecture that will replace the current space shuttle fleet, complete the International Space Station (ISS), and establish a permanent human presence on the Moon as a stepping stone to destinations beyond. During extensive independent and internal architecture and vehicle trade studies as part of the Exploration Systems Architecture Study (ESAS), NASA selected the Ares I crew launch vehicle and the Ares V to support future exploration. The smaller Ares I will launch the Orion crew exploration vehicle with four to six astronauts into orbit. The Ares V is designed to carry the Altair lunar lander into orbit, rendezvous with Orion, and send the mated spacecraft toward lunar orbit. The Ares V represents a national asset offering opportunities for new science, national security, and commercial missions of unmatched size and scope. Ares V is currently in a pre-design cycle concept definition phase. The most recent major milestone was the Lunar Capabilities Concept Review/Ares V Mission Concept Review (LCCR/MCR) in June 2008. This paper presents the LCCR trade space related to Ares V. It describes the new point-of-departure (POD) concept approved at LCCR/MCR. It offers a glimpse of some of the paradigm-changing Ares V capabilities, and it presents some of the activities and issues facing the Ares V as it moves toward a planned authority to proceed (ATP) milestone in 2011.

INTRODUCTION

The Ares V Cargo Launch Vehicle (CaLV) provides the heavy lift capability for the Constellation Program's "1.5 Launch" architecture. A goal established during the ESAS for Ares V, as well as the Ares I, is to use proven technologies, components, and infrastructure from the Saturn, Space Shuttle, and contemporary Launch Vehicle programs. Also, where feasible, the Ares V Project is directed to seek commonality between the Ares vehicles to minimize development and operational costs and improve safety and reliability. The vehicle components of the Constellation architecture are shown in Figure 1.

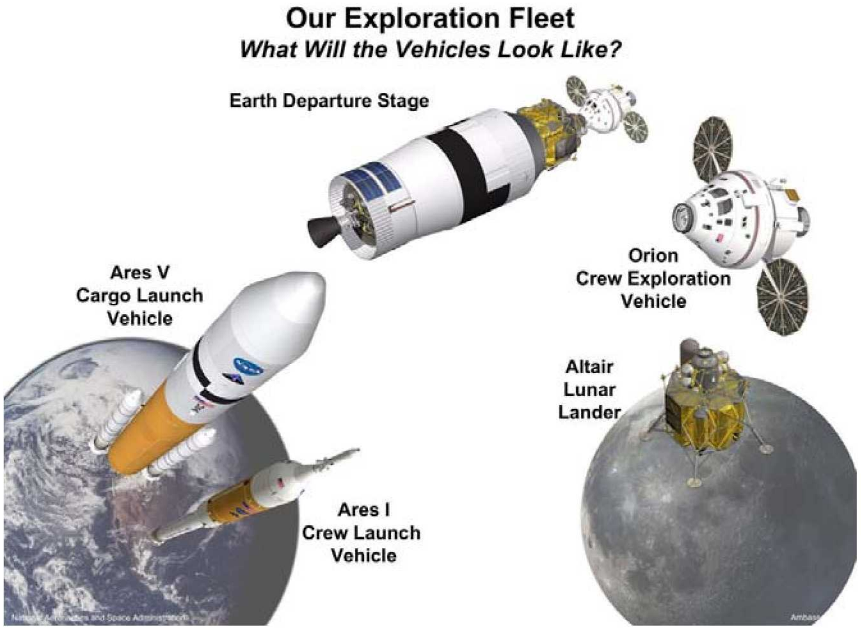

Figure 1. Constellation architecture components.

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In order to carry out the National Space Policy directive to replace the Space Shuttle and complete the ISS, the Constellation development plan focuses on developing the Ares I and making it operational by 2015. Ares V is scheduled for a 2011 authority-to-proceed (ATP) decision that would enable it to make its first flight in 2018 and support lunar exploration in 2020. A notional Ares V schedule for planning purposes is shown in Figure 2.

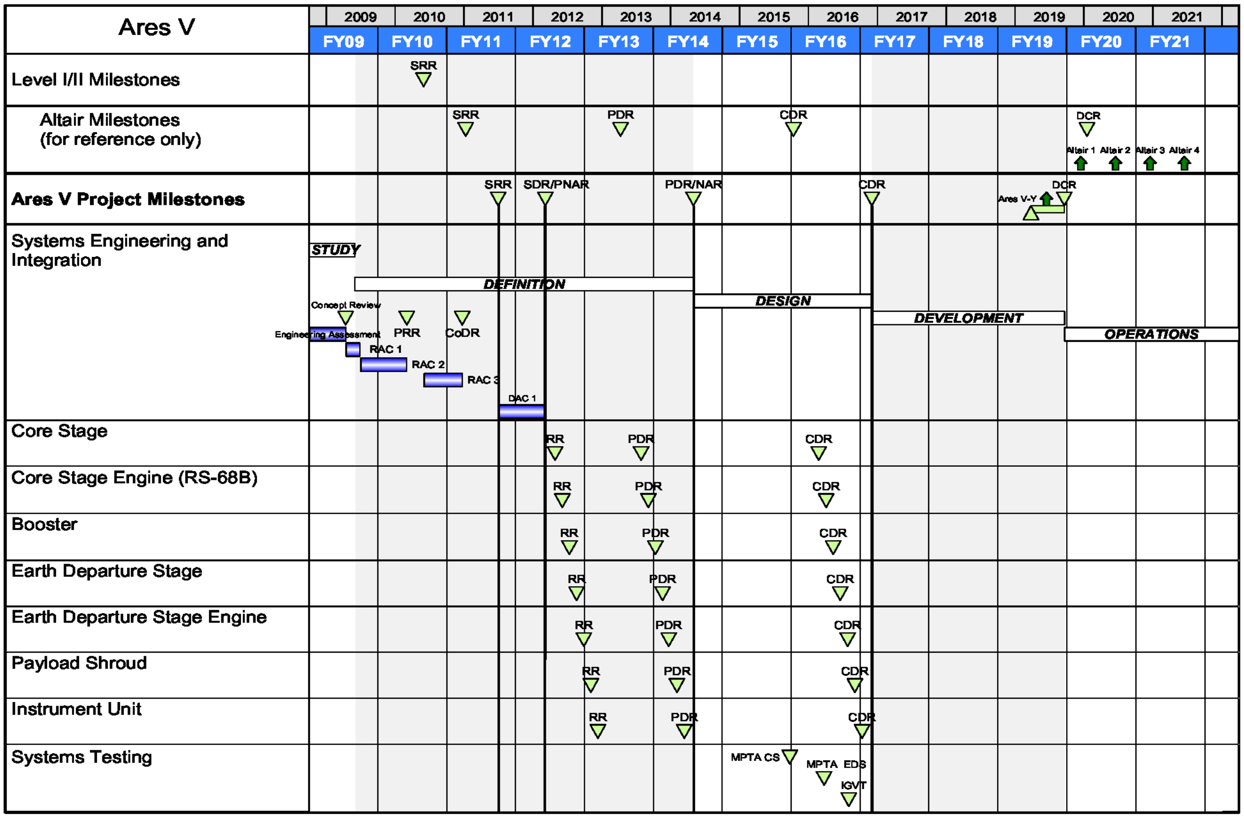


Figure 2. Ares V notional schedule for planning purposes.

The primary mission of the Ares V is to launch the Altair lunar lander into Low Earth Orbit (LEO) and then send the lander and the Orion into a Trans-Lunar Injection (TLI) trajectory to the Moon. The Orion is launched separately on Ares I. In addition to crewed missions, Ares V will also launch automated cargo landers into LEO and on to specific lunar destinations. While retaining the goals of heritage hardware and commonality, the Ares V configuration continues to be refined through a series of internal trades to be discussed later in this paper. The most recent point-of-departure configuration was recommended by the Ares Projects and approved by the Constellation Program during the LCCR/Ares V MCR in June 2008.

In the current mission profile (Figure 3), the Ares V is launched from Kennedy Space Center (KSC) in Florida. Following booster and core stage separation, the Ares V Earth Departure Stage (EDS) engine ignites at altitude, followed by separation of the payload shroud. Shroud separation occurs last in the staging sequence prior to reaching LEO to avoid re-contact with the vehicle. The EDS delivers the EDS-Altair stack into a stable LEO loiter orbit. Concurrently, the Orion performs a rendezvous-and-dock maneuver with the Altair/EDS stack. After successful docking, ground controllers complete a system checkout of the EDS before it re-ignites its engine to perform the TLI burn and send the mated EDS-Altair-Orion stack to the Moon. The EDS is discarded after completion of the TLI burn, which marks the end of the Ares portion of the lunar mission. The current concept of operations calls for an Ares V launch as early as 90 minutes after Ares I, with three subsequent launch opportunities over the next 3 days, one launch opportunity per day. Ares V is currently designed for a 4-day loiter, with TLI on the fourth day.

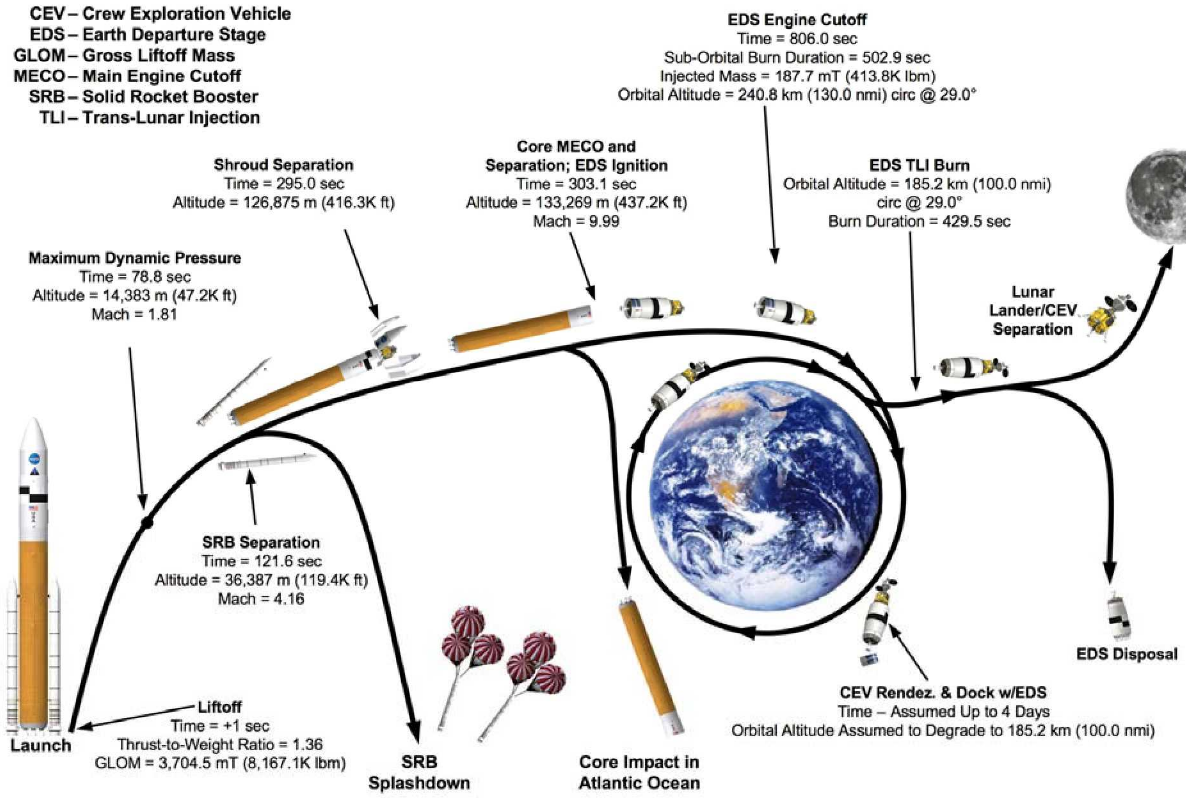


Figure 3. Ares V launch profile for the Lunar Sortie Mission.

The design of Ares V shapes, and is shaped by, the requirements and designs of the other Constellation components. The Ares V first stage booster is designed to share hardware, technologies, and manufacturing and operational facilities found in the Ares I first stage. The Ares V EDS will also share the J-2X engine and various subsystems now being developed for the Ares I upper stage. The Ares V design also employs the commercial RS-68 engine now used on the Delta IV. In the case of all those common components (Fig. 4), the Ares V application will require modifications for the Ares V mission that necessitate ongoing interface with the relevant hardware and management organizations.

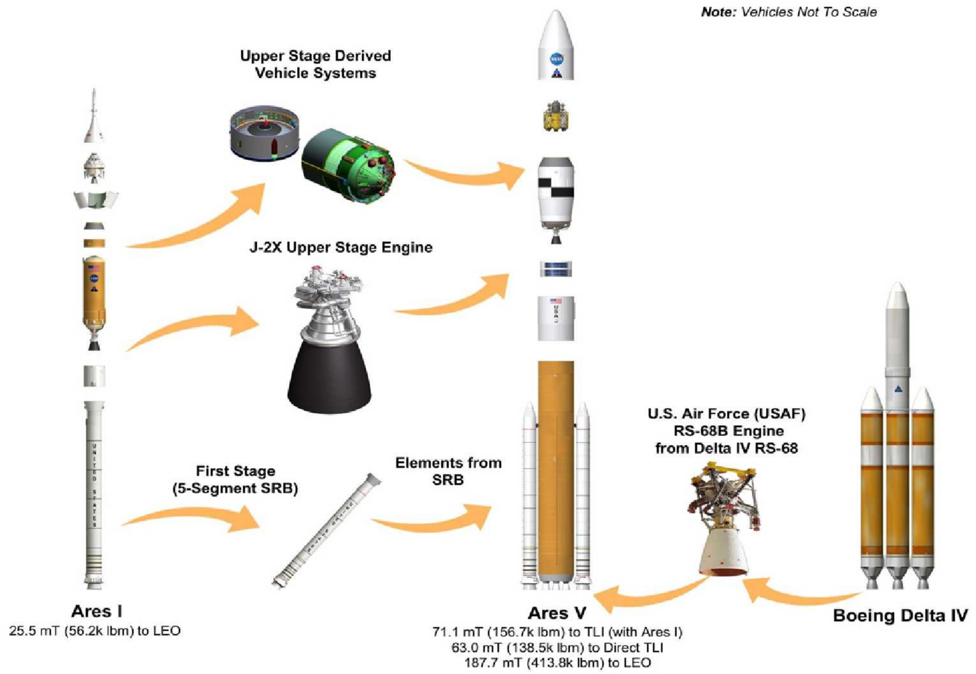


Figure 4. Heritage systems utilized on Ares V.

Ares V must also interface with the Orion and Altair projects regarding basic weight and volume requirements, as well as numerous other design parameters, such as the payload adapter and utilities supplied to Altair, structural, thermal and acoustic loads, on-orbit power and thermal requirements, etc.

ARES V TOP-LEVEL GOALS

The Constellation Architecture Requirements Document (CARD) provides the mass requirements for both the Lunar Sortie (crewed) and Lunar Cargo Design Reference Missions (DRMs).

For the sortie mission, the CARD specifies an Orion control mass of 20.2 t (44,500 lbm) and a Lunar Lander control mass of 45 t (99,208 lbm). The total TLI payload requirement is 66.9 t (147,575 lbm). The sortie mission assumes a LEO destination orbit of 242 km (130 nmi) at 29 degrees inclination. The CARD loiter duration is not specified but has continued to evolve with program and project trades from 95 days to 14 days. For the LCCR trades, it was further reduced to 4 days. The TLI maneuver begins at a minimum 185 km (100 nmi) altitude with a Delta Velocity (ΔV) requirement of 3,175 m/s (10,417 f/s) plus gravity loss.

For the cargo mission, the CARD specifies a Cargo Lander control mass of 53.6 t (118,168 lbm) and a total TLI payload mass of 54.6 t (120,372 lbm). The cargo mission assumes a phasing orbit Earth-To-Orbit (ETO) destination. Because Orion is not part of the cargo mission operations concept, a loiter requirement is unnecessary; however, a few orbits in LEO is anticipated to allow for system checkout prior to the TLI burn. It is worth noting that the Saturn V TLI payload capability was 48.6 t (107,445 lbm) for the Apollo 17 mission.

The CARD also imposes additional requirements on the Ares V, such as the use of the five-segment solid rocket booster and five RS-68B engines in the Core Stage and the Mars mission mass requirements.

ARES V EVOLUTION FROM EXPLORATION SYSTEMS ARCHITECTURE TO LCCR/MCR

The first designs for a heavy lift capability that would come to be dubbed as Ares V were studied during the ESAS, which began in 2005. From ESAS to the concept approved during LCCR as the new Ares V POD concept, NASA has studied more than 1,700 configurations of the Ares V. This section will summarize the evolution of Ares V from the ESAS trades up to the POD concept that served as the entry point to the LCCR trade study. An overview of the Ares V development history is shown in Figure 5 below, including the LCCR trade space options and recommended POD concept approved by Constellation. A description of the major trades leading to the LCCR entry POD concept follows.

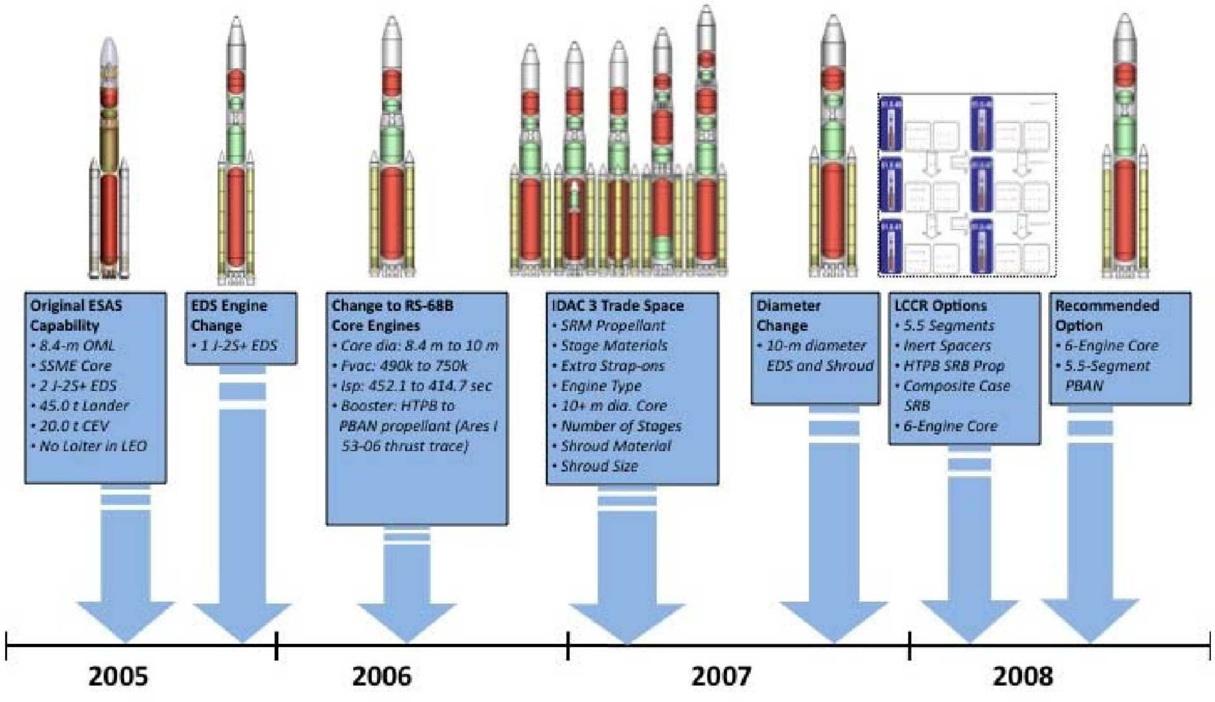


Figure 5. Ares V concept evolution from ESAS to LCCR.

NASA studied hundreds of commercial, government, and concept launch vehicle architecture systems prior to 2005, culminating in the release of the ESAS final report. Figures of Merit (FOMs) used in the studies were: cost, reliability, human safety, programmatic risk, mission performance, and schedule. These FOMs were applied to drive out the best option in the analysis. Additional considerations included legal requirements from the NASA Authorization Act of 2005, workforce skills, and industrial capabilities. After a thorough analysis of the entire exploration architecture requirements, Evolved Expendable Launch Vehicle (EELV) solutions were determined to be less safe, less reliable, and more costly than the Shuttle-derived solutions. The ESAS concluded that NASA should pursue a Shuttle-derived architecture for exploration due to several advantages relating to safety, reliability, and cost. The Shuttle-derived approach also allowed NASA to leverage significant existing ground infrastructure investments and personnel with significant human spaceflight experience. Overall, the Shuttle-derived approach was found to be the safest, most affordable and reliable, both by leveraging proven human-rated vehicles and infrastructure elements and by using common elements across the architecture.

The ESAS-recommended Ares V vehicle included two five-segment steel-case solid rocket boosters (SRBs) with Hydroxyl-Terminated Polybutadiene (HTPB) propellant, which has a higher specific impulse (Isp), density, and better mechanical properties than the Polybutadiene Acrylonitrile- (PBAN-) fueled Space Shuttle SRB. This Ares V concept had an 8.4-m- (27.5-ft-) diameter Space Shuttle External

Tank-derived Core Stage powered by five RS-25 Space Shuttle Main Engines (SSME) redesigned to be low-cost and expendable. The 8.4-m- (27.5-ft-) diameter EDS was powered by two Liquid Oxygen (LOX)/Liquid Hydrogen (LH2) J-2S+ engines. Based on the 1970's-era J-2S development program, the J-2S+ was intended to be a simplified version of the J-2 engine used for the Saturn upper stages. Both the Core Stage and EDS had Aluminum-Lithium (Al-Li) structures and propellant tanks. The Ares V variant had a Gross Liftoff Mass (GLOM) of nearly 2,900 t (6.4M lb). It was based on a 45-t (99,000 lbm) lunar lander, a 20-t (44,000 lbm) CEV, and no loiter capability in LEO.

In the subsequent NASA studies to refine the ESAS recommendations, the architecture was simplified to reduce the number of new development programs. Further analysis of EDS performance showed that the utilization of a single J-2S+ provided more performance than two J-2S+ engines, since the additional thrust provided by two engines during the ascent burn did not make up for the second engine's mass during the less-thrust-to-weight-sensitive TLI burn. When Ares I propulsion changed from a four-segment booster to a five-segment booster for the first stage and from the RS-25 to a more powerful evolution of the J-2, dubbed J-2X, for the upper stage, it opened the trade space on Ares V. A single J-2X replaced the J-2S+ engine on the Ares V EDS. The RS-68B, a variant of the commercial engine flying on the Boeing Delta IV vehicle, was leveraged for the Ares V core stage. The RS-68 was designed as a simple, expendable engine with a high production rate. Using the RS-68 offered the opportunity to partner with the Department of Defense (DoD) to lower unit costs and gain flight maturity on Delta IV engine upgrades prior to Ares V flights. Program savings were estimated to be approximately $4.25 billion over the RS-25 SSME-based ESAS concept due to the high cost of producing a non-recovered, non-refurbished SSME.

Because of the RS-68B's lower efficiency, the core stage was enlarged from 8.4 m (27.5 ft) to 10 m (33.0 ft) in diameter to hold the additional required propellants and to accommodate the larger nozzle and exhaust clearances needed for the larger engine cluster. The lower initial and recurring costs of the RS-68B, as well as the cost, technical, schedule, and reliability risks involved with redesigning the RS-25 for altitude start, outweighed the cost of developing Saturn-class tooling and facilities needed to manufacture and process the larger Core Stage. The booster design also reverted from HTPB to PBAN solid propellant for its better technical maturity. The resulting Ares V configuration had a GLOM of 3,300 t (7.3M lbm) and was nearly 110 m (362 ft) tall. It exceeded the payload performance of the RS-25 solution by approximately 4 t (8,800 lbm) to TLI and enhanced the commonality between the Ares vehicles, improving both development and operational efficiencies.

Ares V has undergone hundreds of trade studies since that point. Trades conducted involved shroud diameter, direct lunar missions, placement of the Orion and upper stage on the Ares V, added gravity losses on TLI burns, and Flight Performance Reserve (FPR) allocation change. Another round of trades determined the effects of engine upgrades, SRB variations, alternate materials, added stages, added boosters, added engines, and increased stage diameter. Those efforts established the impact of several changes that would be important to later trades, including composite tanks and structures, additional core stage engines, additional SRBs or Liquid Rocket Boosters (LRBs), and the addition of an S-II-class second stage.

The development phase also included studies of three-stage vehicles with four- and five- J-2X engine second stages, and shortened and lengthened core stages. Variants within those studies traded the use of the commercial RL-10B2 engine on the third stage, six RS-68B core engines, nested tanks, and other changes. The three-stage designs offered improved performance and other advantages. However, the addition of a second stage with four to five J-2X engines (instead of one), and a unique third stage, added significant costs. The cost benefits to the Altair Project resulting from Ares V assuming the LOI functionality were shown to be minimal. Propulsion systems, particularly the number of engines, are primary contributors to launch vehicle reliability, and the increased number of engines for these three-stage options resulted in an overall lower vehicle reliability.

The concepts that would become the single POD for the LCCR trade space had in common: a 10-m- (33-ft-) diameter Outer Mold Line (OML), composite materials for the payload shroud and all core stage and EDS dry structures, and metallic (Al-Li) propellant tanks for the EDS and core stage. The concepts also reflected the following changes in configuration, ground rules, and assumptions: 4-day to 14-day loiter period, 222-km (120-nmi) to 242-km (130-nmi) injection orbit, 8.4-m (27.5-ft) to 10-m (33-ft) EDS diameter, and 8.4-m (27.5-ft) to 10-m (33-ft) payload shroud.

The concept selected as the starting point for the LCCR was characterized by its 10-m (33-ft) standard Core Stage with five RS-68B engines and two 5-segment steel-case PBAN-propellant reusable SRBs. Its TLI payload capability in conjunction with Ares I was 63.6 t (140,214 lbm).

LUNAR CAPABILITIES CONCEPT REVIEW TRADE SPACE

The Ares V LCCR trade space focused on six vehicle concepts. Features common to all were: 10-m (33-ft) diameter OML for the central stack; composite dry structures for core stage, EDS, and shroud; metallic propellant tanks for core stage and EDS; a single J-2X EDS engine; at least five core stage RS-68B engines; and 9.7-m (31.8-ft) shroud barrel length.

The trade space was created by combining several options in different combinations. Two variations of the core stage were considered. The first variation consists of a standard size core stage with five RS-68B engines and the second variation represents an extended core stage with six RS-68B engines. As the second dimension of the trade space, three booster variations were studied. These were: the 5-segment, PBAN, steel booster, the 5.5-segment, PBAN, steel booster, and the 5-segment, HTPB, composite booster. Figure 6 illustrates the LCCR trade space, including the concept designator, characteristics, and the impact on payload.

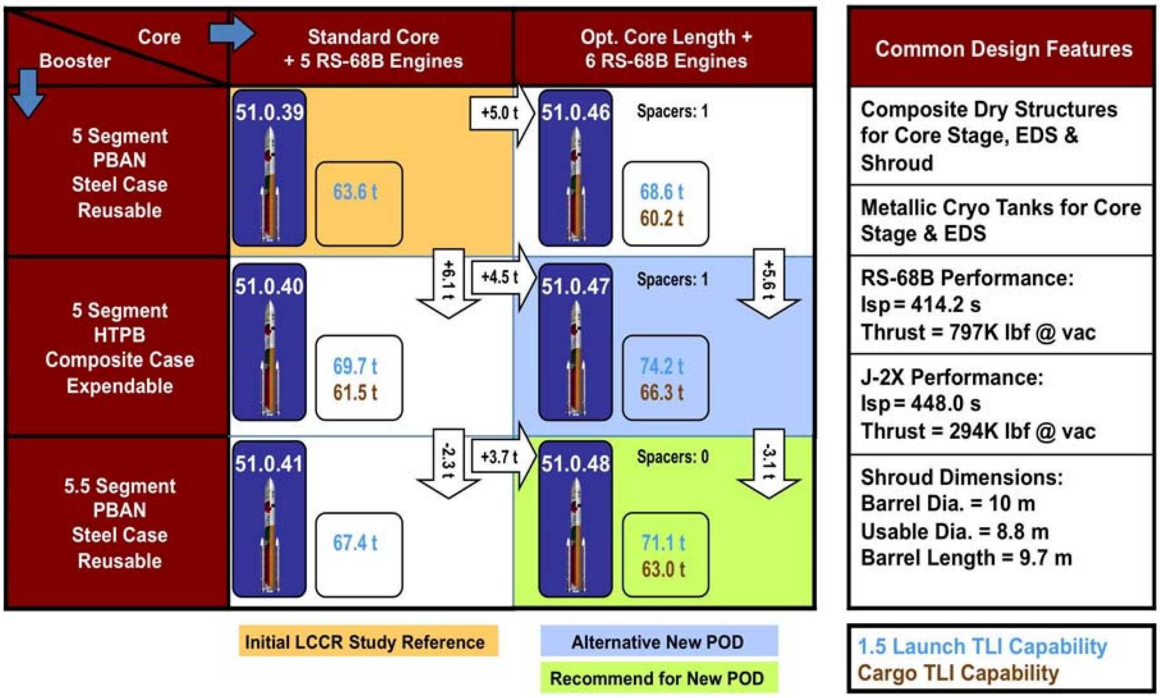


Figure 6. Ares V LCCR Trade Space, showing design options, concept designator, and payload impact.

The design chosen as the new POD concept at the LCCR, designated 51.0.48, was characterized by: the extended core stage and the 5.5-segment, PBAN, steel booster. This POD vehicle will support up to 71.1 t (156,700 lbm) of payload to TLI for crewed missions. This concept was maintained in the LCCR trade space because it provides a competitive level of TLI performance. It also does not require significant funding for technology development nor does it incur the largest production and Design, Development, Test, and Evaluation (DDT&E) costs. While it provides architecture closure with additional margin, it does not fully meet the desired TLI payload goal of 75 t (165,300 lbm). Design details of the approved POD concept are shown in Figure 7. The Constellation Program also approved continuing to carry the 51.0.47 concept as an option for continued study, despite its higher technical complexity, because it provided additional performance margin.

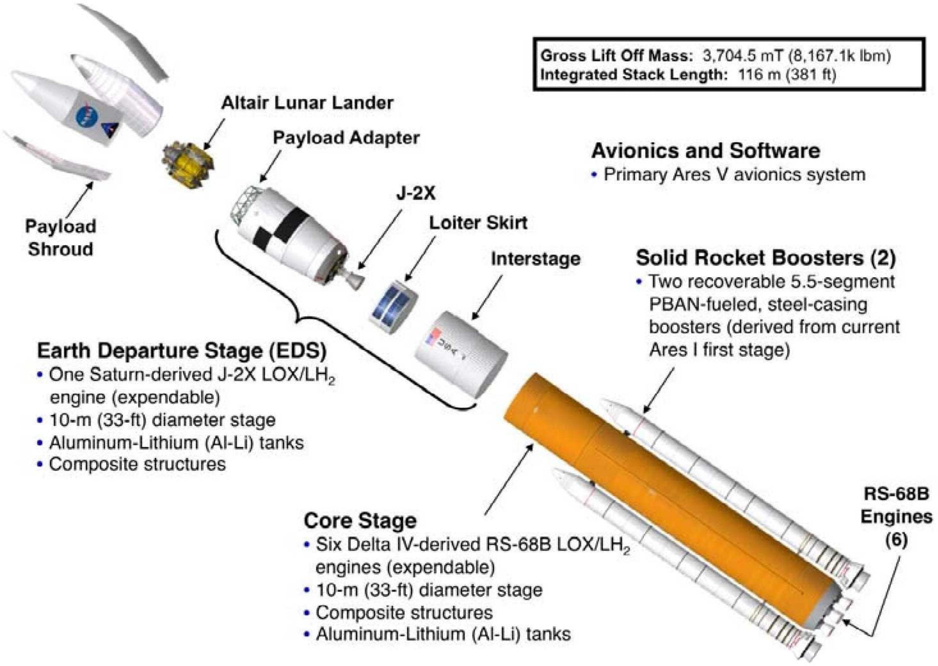


Figure 7. Expanded view of the LCCR POD concept: 51.00.48.

FORWARD WORK

Significant concept design work has been accomplished for the Ares V. During the course of the LCCR, discussions regarding both of these concepts with NASA Headquarters, the Constellation Program, and other Constellation projects, several key issues were identified as forward work that the Ares V team had to accomplish.

A decision on the 51.0.47 concept, specifically the composite HTPB booster option, is scheduled for a final decision at the System Requirements Review in June 2010. It provides additional performance capability, if needed, for margin or requirements and continuing to carry it as an option allows for a competitive acquisition environment for the booster. In the interim, it requires further study and technology investment funding.

One of the LCCR exit directives called for an Ares V out year (post 2020) manifest flight rate of four flights per year. This was a change to the LCCR entry manifest that assumed an out year flight rate of two flights per year. Preliminary analysis indicates that a flight rate of four flights per year could be achieved starting in 2024 by ramping from two to three flights per year in 2021 through 2023.

The NASA Administrator indicated that the flight manifest would have to increase from two Ares I/Ares V flights per year to four flights per year to sustain a meaningful presence on the Moon. The Constellation Program is investigating the impacts to increasing the flight rate.

The NASA Administrator also expressed interest in exploring the possibility of leveraging the Ares I flight tests as a possible opportunity for implementing testing for the Ares V. The Constellation Program is assessing which Ares V flight test objectives can be accomplished during the Ares I flight tests. This assessment also includes understanding the impacts to the Ares V flight manifest/schedule.

The Ares V team continues to study several additional vehicle-specific and architecture-wide issues in 2009. Related to facilities, the shroud quad sector configuration will likely preclude partial encapsulation in the Space Shuttle Processing Facility at KSC. Ground Operations and Ares V teams will continue to study shroud ground processing alternatives. The Crawler is currently limited to a rollout weight of approximately 12.5 million pounds. The Ares V launcher and vehicle configurations rollout loads will approach 16.8 million to 18 million pounds. The crawlerway foundation also will be affected by the higher loads. A lightweight mobile launcher or removing the launch umbilical tower from the mobile launcher might mitigate the effects. Crawler and Phase I crawlerway studies are underway to determine capacity; Phase 2 would assess the Vehicle Assembly Building (VAB) and pad transitions.

The 1.5 vehicle architecture also has implications for the VAB. The VAB reference concept is one Ares I high bay and one Ares V bay. The CARD flight rate objective requires a second Ares V VAB bay. The VAB is also limited to the amount of SRB propellant it can store. The current limit for Shuttle during operations is 16 segments total. Any increase would require an approved engineering analysis with blast/fragmentation and thermal mitigation in place. A VAB assessment study is under way. A dimensional comparison is shown in Figure 8.

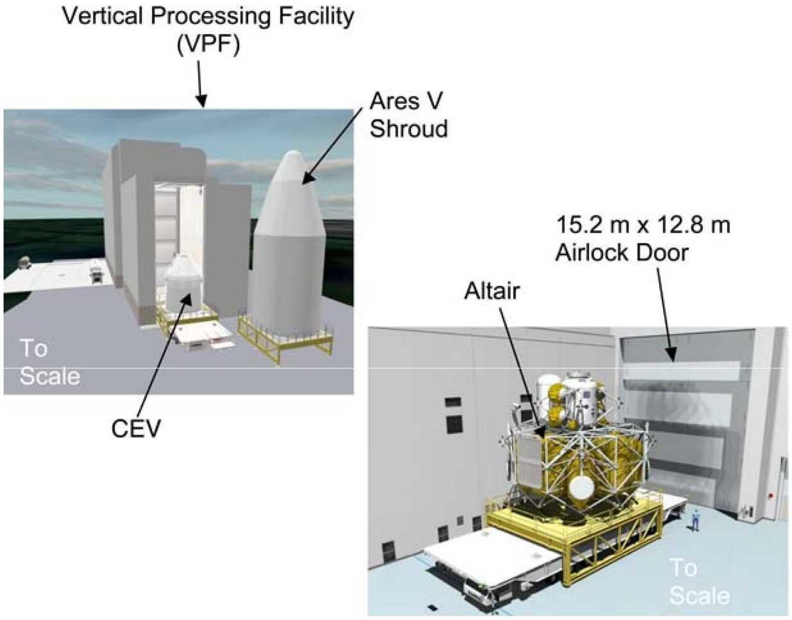


Figure 8. Notional Ares processing facilities at KSC.

Another impact on the architecture is the tight worldwide helium market. Current KSC and Stennis Space Center usage alone exhaust the government helium allotment in 10 years. Both government and commercial customers are finding it difficult to obtain helium when contracts come up for re-competition. Tighter markets are resulting in shorter-term contacts and high pricing. The KSC is also limited in the amount of gaseous helium it can supply to launch vehicles. These issues require additional studies, from reducing the RS-68's use of helium to reclaiming and recycling helium to additional storage capacity to support the planned launch rate. KSC also faces availability issues with its gaseous nitrogen supply and pipeline.

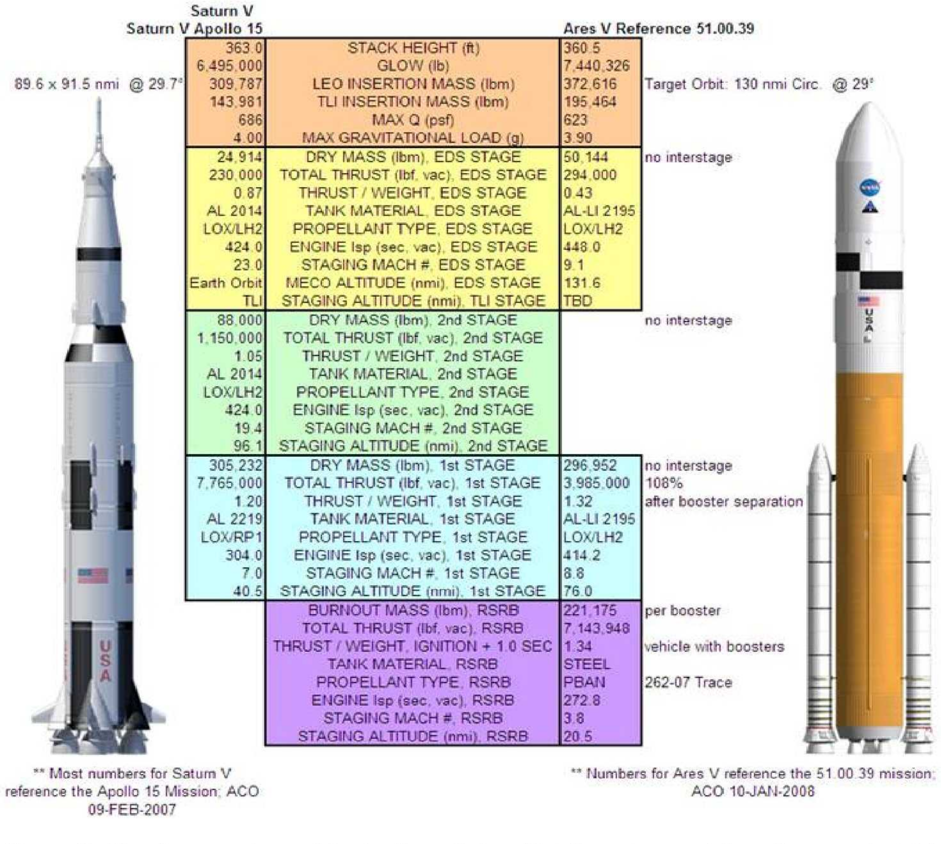
Ares V also requires several technology investigations to support concept design, more broadly categorized as materials-related issues. Technology priorities in composites include shell-buckling, large composite manufacturing, damage tolerance and detection, and joining. Other priorities include friction-stir welding of spun form domes for Ares V propellant tanks, long-term cryogenic fluid storage and leak detection for the on-orbit portion of the Ares V mission, HTPB propellant, and SRB nozzle sensitivities to HTPB propellant.

Early efforts have begun on the approach, test articles, and facilities required for Ares V testing. For the EDS, these include sea-level propulsion testing, J-2X certification to the Ares V requirement, orbital environments testing, and stage acceptance testing. For the core stage, this includes the main propulsion test article, RS-68B development and certification testing, and stage acceptance testing. The Ares V shroud, the largest composite structure for any launch vehicle, will require test articles for development testing, as well as structural, acoustic, and dynamic separation testing.

Aerodynamic testing also continues on the Ares V configuration to examine booster separation, booster reentry and decent, ground wind loads, aerodynamic buffeting, base heating, plume effects, etc.

ARES V UTILIZATION POTENTIAL AND OUTREACH

The Ares V represents a reconstruction of “Heavy Lift” that surpasses the Saturn V by a sizeable margin. This capability is viewed by NASA as a national asset. The Ares V launch vehicle will replace and exceed the transportation capability of the Apollo-era Saturn V launch vehicle, both in terms of volume and mass. As such, it will be an unmatched national asset for exploration, science, national security, and commercial payloads. Developing this capability provides a unique critical piece of the U.S. mission to return to the Moon and go to Mars. The Ares V is also an enabler of a large class of space missions not thought possible by scientists and engineers since the Saturn V program ended over 30 years ago. The Ares V will offer unprecedented performance to all known orbits both in terms of 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 the industry norm. It will also have unique environments and present potential testing and verification challenges to a mission user due to these same performance benefits. The scale of the Ares V will be larger than the Saturn V. A detailed comparison of Saturn V to the LCCR entry concept is shown in Figure 9.



	Saturn V Saturn V Apollo 15		Ares V Reference 51.00.39	
	363.0	STACK HEIGHT (ft)	360.5	
	6,495,000	GLOW (lb)	7,440,326	
89.6 x 91.5 nmi @ 29.7°	309,787	LEO INSERTION MASS (lbm)	372,616	Target Orbit: 130 nmi Circ. @ 29°
	143,981	TLI INSERTION MASS (lbm)	195,464	
	686	MAX Q (psf)	623	
	4.00	MAX GRAVITATIONAL LOAD (g)	3.90	
	24,914	DRY MASS (lbm), EDS STAGE	50,144	no interstage
	230,000	TOTAL THRUST (lbf, vac), EDS STAGE	294,000	
	0.87	THRUST / WEIGHT, EDS STAGE	0.43	
	AL 2014	TANK MATERIAL, EDS STAGE	AL-LI 2195	
	LOX/LH2	PROPELLANT TYPE, EDS STAGE	LOX/LH2	
	424.0	ENGINE Isp (sec, vac), EDS STAGE	448.0	
	23.0	STAGING MACH #, EDS STAGE	9.1	
	Earth Orbit	MECO ALTITUDE (nmi), EDS STAGE	131.6	
	TLI	STAGING ALTITUDE (nmi), TLI STAGE	TBD	
	88,000	DRY MASS (lbm), 2nd STAGE		no interstage
	1,150,000	TOTAL THRUST (lbf, vac), 2nd STAGE		
	1.05	THRUST / WEIGHT, 2nd STAGE		
	AL 2014	TANK MATERIAL, 2nd STAGE		
	LOX/LH2	PROPELLANT TYPE, 2nd STAGE		
	424.0	ENGINE Isp (sec, vac), 2nd STAGE		
	19.4	STAGING MACH #, 2nd STAGE		
	96.1	STAGING ALTITUDE (nmi), 2nd STAGE		
	305,232	DRY MASS (lbm), 1st STAGE	296,952	no interstage
	7,765,000	TOTAL THRUST (lbf, vac), 1st STAGE	3,985,000	108%
	1.20	THRUST / WEIGHT, 1st STAGE	1.32	after booster separation
	AL 2219	TANK MATERIAL, 1st STAGE	AL-LI 2195	
	LOX/RP1	PROPELLANT TYPE, 1st STAGE	LOX/LH2	
	304.0	ENGINE Isp (sec, vac), 1st STAGE	414.2	
	7.0	STAGING MACH #, 1st STAGE	8.8	
	40.5	STAGING ALTITUDE (nmi), 1st STAGE	76.0	
		BURNOUT MASS (lbm), RSRB	221,175	per booster
		TOTAL THRUST (lbf, vac), RSRB	7,143,948	
		THRUST / WEIGHT, IGNITION + 1.0 SEC	1.34	vehicle with boosters
		TANK MATERIAL, RSRB	STEEL	
		PROPELLANT TYPE, RSRB	PBAN	262-07 Trace
		ENGINE Isp (sec, vac), RSRB	272.8	
		STAGING MACH #, RSRB	3.8	
		STAGING ALTITUDE (nmi), RSRB	20.5	

** Most numbers for Saturn V reference the Apollo 15 Mission; ACO 09-FEB-2007

** Numbers for Ares V reference the 51.00.39 mission; ACO 10-JAN-2008

Figure 9. Direct comparison of the heritage Saturn V, left, and current Ares V concept, right.

The thrust at take-off will be approximately 40% more than any other vehicle ever built. This will likely create induced environments outside the normal range of payload planners. However, it is likely that the unprecedented mass and volume afforded will allow for material choices and induced environment mitigation not normally considered possible on existing launch vehicles. The Ares V team is engaging the potential payload community now (2-3 years before the Systems Requirements Review (SRR), in order to better understand the potential limitations and/or additional requirements that could be added to the Ares V from the mission planning community. If a viable mission is determined and added to the Ares V as a design case, tradeoffs will be conducted to determine if other mission design requirements can be included in the system.

The space inside the reference configuration Ares V shroud has enough usable volume to launch the volumetric equivalent of approximately 10 Apollo Lunar Excursion Modules (LEMs) or approximately 5 Hubble Space Telescopes. This mass and volume capability to LEO enables a host of new scientific and observation platforms, such as telescopes, satellites, and planetary and solar missions, as well as being able to provide the lift for future large in-space infrastructure missions, such as space-based power and mining, Earth asteroid defense, propellant depots, etc.

Multiple shroud options for the Ares V have been analyzed to identify their impact on performance. While larger shrouds allow for increased usable volume, the mass of these large structures has a net negative effect on payload mass. In addition, the height of the vehicle is increased accordingly. This may cause existing facilities to be modified in order to accommodate the launch vehicle. While individual missions have unique requirements, one thing remains a constant—the Ares V will launch more mass with more volume to anywhere than any launch vehicle currently being manufactured. Some sample shrouds past and present are shown in Figure 10.

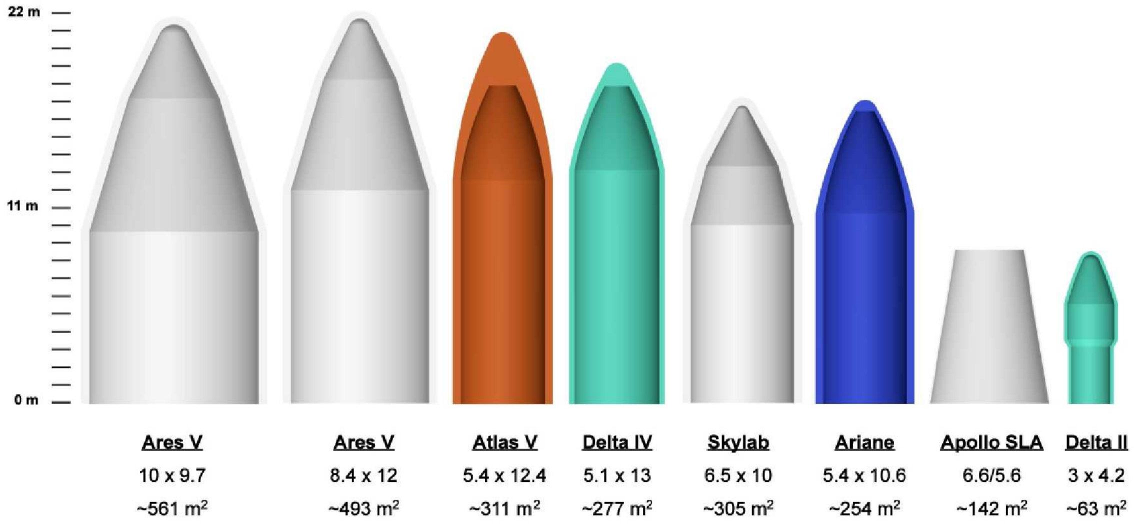


Figure 10. Representative shroud options for the Ares V launch vehicle

Analysis of the Ares V mass and volume in relation to mission design give a better idea of its capabilities. Figure 11 below shows Ares V payload mass (metric tons) to Low Earth Orbit 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 data is for an earlier configuration. Current configuration capability is expected to be approximately 40,000 kg more or approximately 180,000 kg to LEO.

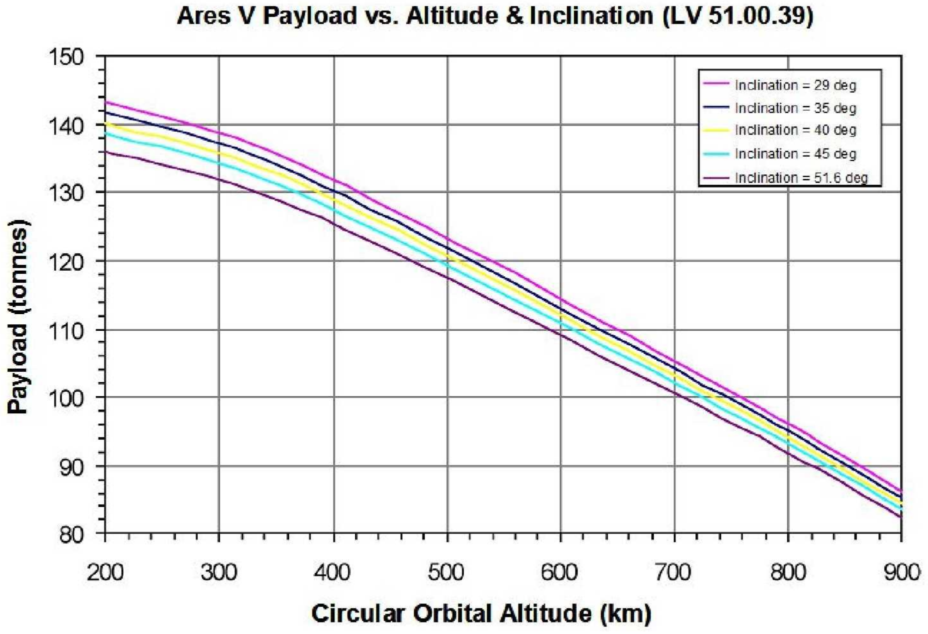


Figure 11. Ares V payload mass vs. altitude and inclination.

Figure 12 shows that Ares V alone or with a Centaur Upper Stage can accelerate previously unachievable masses (metric tones) to extremely large C3 energy values, thus enabling and enhancing deep space planetary missions or missions outside of the ecliptic plane. Again, this data is for an earlier configuration.

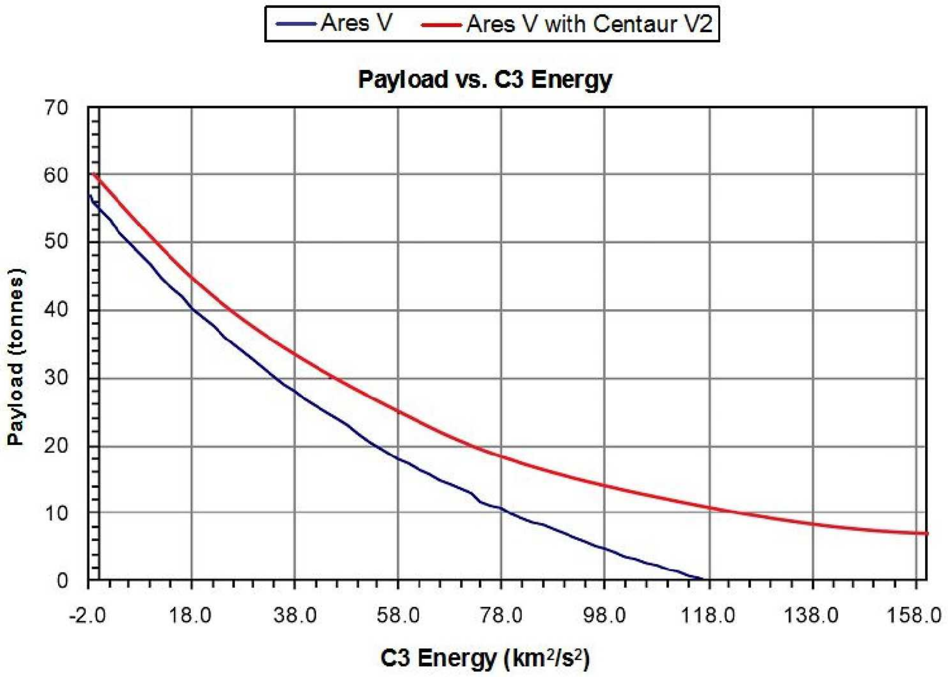


Figure 12. Ares V payload mass vs. C3 Energy.

Figure 13 shows Ares V performance for selected missions employing the reference payload shroud. As indicated, the Ares V can deliver tremendous payloads to a wide variety of orbital parameters.

While having the capability of delivering over 57 metric tons of lunar cargo & over 48 metric tons of Mars cargo, it can also provide approximately 69.5 metric tons to GTO and 35 metric tons to GEO. This is approximately 6 times that of any currently manufactured launch vehicle. The ground rules assumptions for these calculations are: no gravity assists, interplanetary trip times based on Hohmann transfers, payload mass estimates comprise spacecraft, payload adapter and mission peculiar hardware, two-engine Centaur for kick stage.

Mission Profile	**Target**	**Constellation POD Shroud**		**Extended Shroud**	
		Payload (lbm)	**Payload (t)**	**Payload (lbm)**	**Payload (t)**
1) Cargo Lunar Outpost (TLI Direct), Reference	C3 of -1.8 km^2/s^2	126,000	57.0	122,000	55.5
2) Mars Cargo (TMI Direct)	C3 of 9 km^2/s^2	106,000	48.0	102,000	46.0
3) GTO Injection	Transfer DV 8,200 ft/s	153,000	69.5	148,000	67
4) GEO	Transfer DV 14,100 ft/s	77,000	35.0	74,000	33.5
5) LEO (@29° inclination)	24.1 x 24.1 km	315,000	143.0	308,000	140
6) Earth-Moon L2	C3 of -1.7 km^2/s^2	126,000	57.0	122,000	55.5
7) Sun-Earth L2	C3 of -0.7 km^2/s^2	124,000	56.5	120,000	55

Figure 13. Ares V performance for selected missions.

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 the Ares V rocket 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.

SUMMARY AND CONCLUSIONS

Ares V is currently in a pre-design phase. The latest approved configuration was affirmed during the LCCR/MCR in June 2008. This design meets the official payload requirement, but work continues to provide Ares and Constellation management with the payload margin desired for this early stage in the development of both Ares V and its primary payloads – the Altair lunar lander and the Orion crew vehicle. Work is also ongoing in the wider systems aspects of the design, such as manufacturing and launch facilities. Its unprecedented size presents challenges to vehicle and facility designers. But Ares V also offers unprecedented opportunities for the resumption of exploration beyond LEO, for larger, more capable payloads, or for controlling the complexity and cost of today’s payloads constrained by the mass and volume limits of today’s space launch fleet. Ares V truly represents a national asset for exploration, science, national security, and economic development in the future.