Ares V: Game Changer for National Security Launch

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Abstract

NASA is designing the Ares V cargo launch vehicle to vastly expand exploration of the Moon begun in the Apollo program and enable the exploration of Mars and beyond. As the largest launcher in history, Ares V also represents a national asset offering unprecedented opportunities for new science, national security, and commercial missions of unmatched size and scope.

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, 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 will be the largest and most powerful launch vehicle in history, providing unprecedented payload mass and volume to establish a permanent lunar outpost and explore significantly more of the lunar surface than was done during the Apollo missions.

The Ares V consists of a Core Stage, two Reusable Solid Rocket Boosters (RSRBs), Earth Departure Stage (EDS), and a payload shroud. For lunar missions, the shroud would cover the Lunar Surface Access Module (LSAM). The Ares V Core Stage is 33 feet in diameter and 212 feet in length, making it the largest rocket stage ever built. It is the same diameter as the Saturn V first stage, the S-IC. However, its length is about the same as the combined length of the Saturn V first and second stages. The Core Stage uses a cluster of five Pratt & Whitney Rocketdyne RS-68B rocket engines, each supplying about 700,000 pounds of thrust. Its propellants are liquid hydrogen and liquid oxygen.

The two solid rocket boosters provide about 3.5 million pounds of thrust at liftoff. These 5.5-segment boosters are derived from the 4-segment boosters now used on the Space Shuttle, and are similar to those used in the Ares I first stage. The EDS is powered by one J-2X engine. The J-2X, which has roughly 294,000 pounds of thrust, also powers the Ares I Upper Stage. It is derived from the J-2 that powered the Saturn V second and third stages. The EDS performs two functions. Its initial suborbital burns will place the lunar lander into a stable Earth orbit. After the Orion crew vehicle, launched separately on an Ares I, docks with the lander/EDS stack, EDS will ignite a second time to put the combined 65-metric ton vehicle into a lunar transfer orbit.

When it stands on the launch pad at Kennedy Space Center late in the next decade, the Ares V stack will be approximately 381 feet tall and have a gross liftoff mass of 8.1 million pounds. The current point-of-departure design exceeds Saturn V's mass capability by approximately 40 percent. Using the current payload shroud design, Ares V can carry 315,000 pounds to 29-degree low Earth orbit (LEO) or 77,000 pounds to a geosynchronous orbit.

Another unique aspect of the Ares V is the 33-foot-diameter payload shroud, which encloses approximately 30,400 cubic feet of usable volume. A larger hypothetical shroud for encapsulating larger payloads has been studied.

While Ares V makes possible larger payload masses and volumes, it may alternately make possible more cost-effective mission design if the relevant payload communities are willing to consider an alternative to the existing approach that has driven them to employ complexity to solve current launch vehicle mass and volume constraints. By using Ares V's mass and volume capabilities as margin, payload designers stand to reduce development risk and cost.

Significant progress has been made on the Ares V to support a planned fiscal 2011 authority-to-proceed (ATP) milestone. The Ares V team is actively reaching out to external organizations during this early concept phase to ensure that the Ares V vehicle can be leveraged for national security, science, and commercial development needs.

This presentation will discuss Ares V vehicle configuration, the path to the current concept, accomplishments to date, and potential payload utilization opportunities.

National Aeronautics and Space Administration

Ares V: Game Changer for National Security Launch

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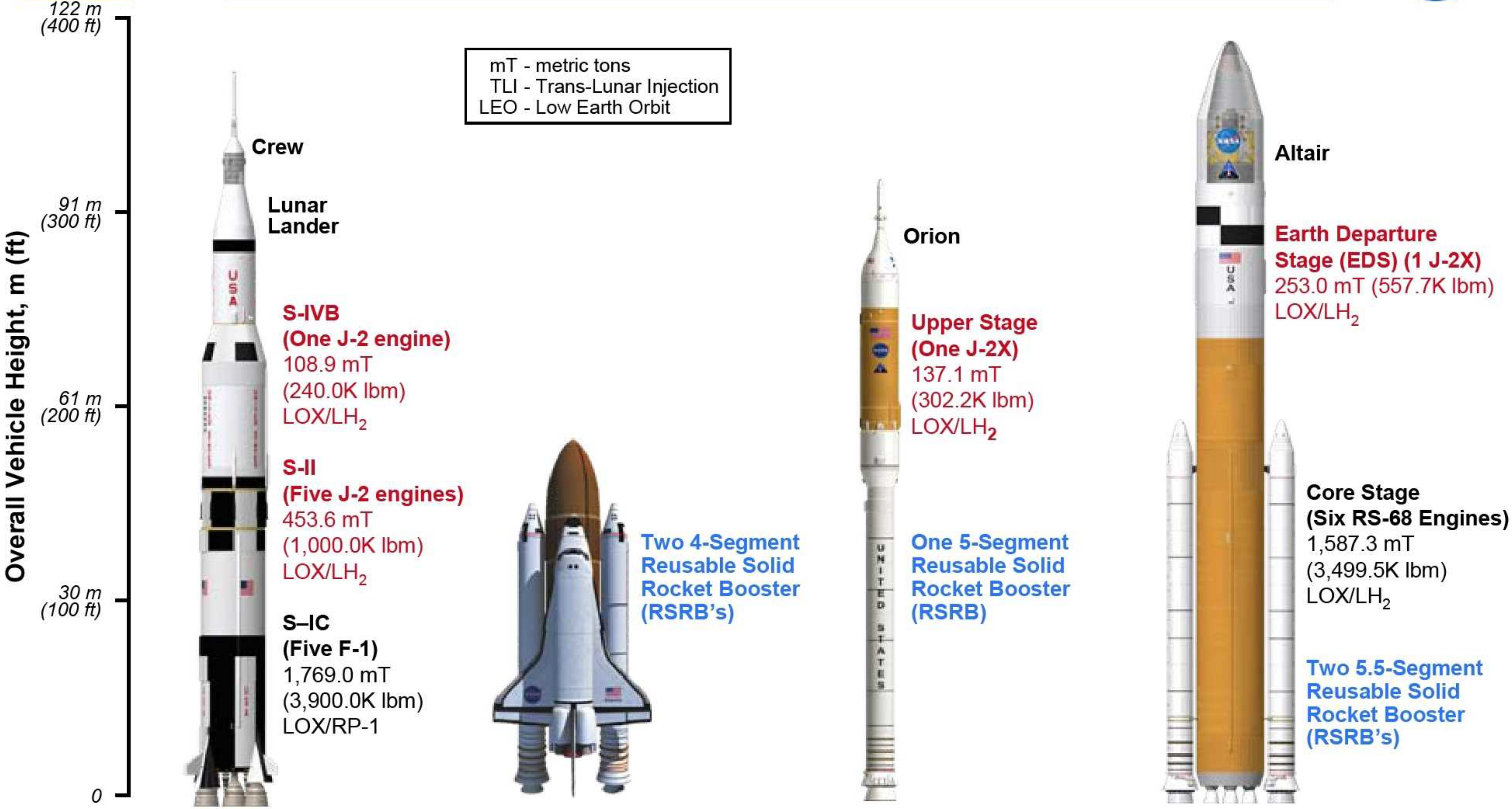
Introduction

- The NASA Ares Projects Office is developing the launch vehicles to move the United States and humanity beyond low earth orbit
- Ares I is a crewed vehicle, and Ares V is a heavy lift vehicle being designed to launch cargo into LEO and transfer cargo and crews to the Moon
- This is a snapshot of development. Ares V is early in the requirements formulation stage of development pending the outcome of the Review of U.S. Human Space Flight Plans Committee and White House action.
- The Ares V vehicle will be considered a national asset, creating unmatched opportunities for human exploration, science, national security, and space business
- My goal today is to update you on the status of the Ares V vehicle

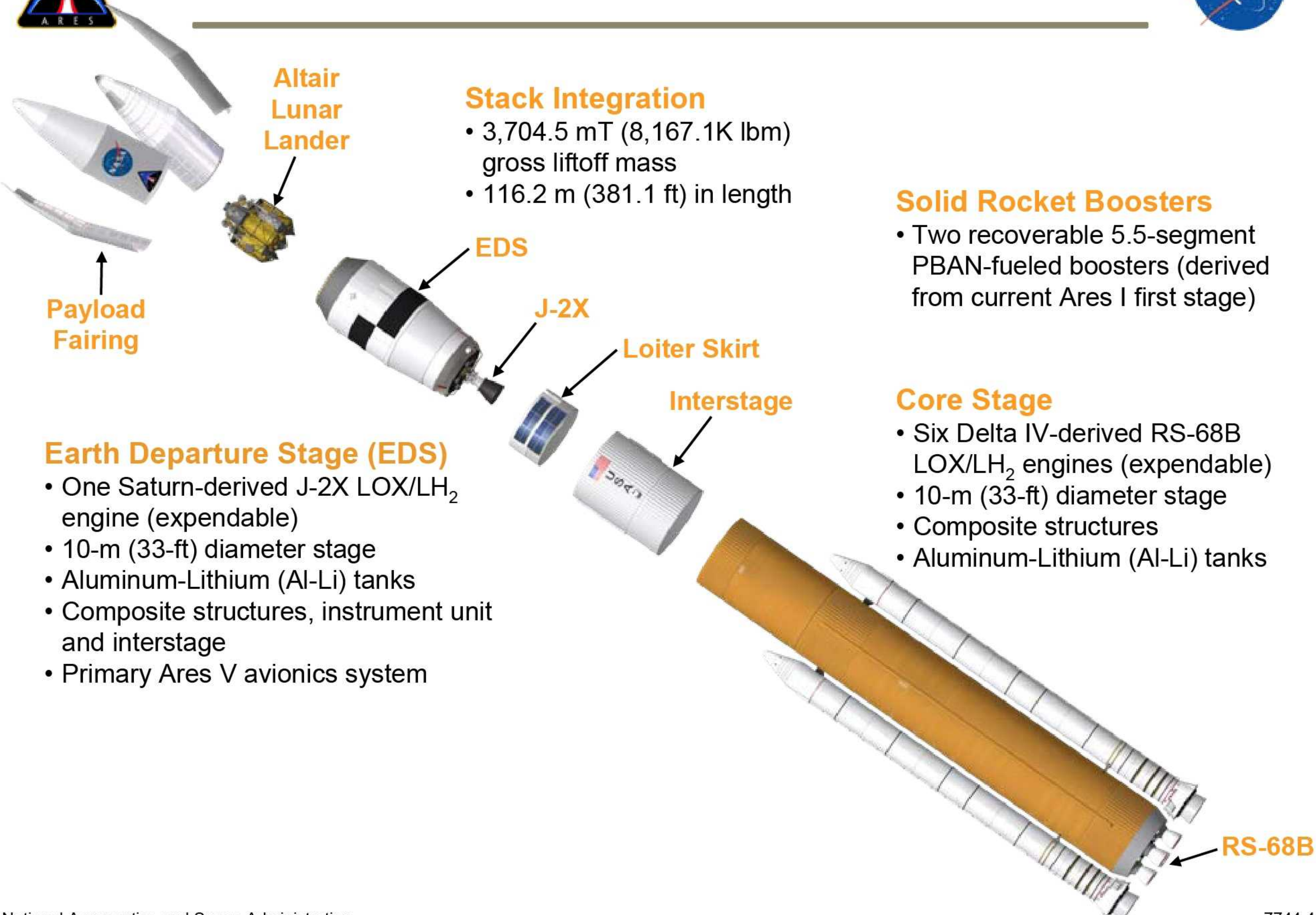
Building on a Foundation of Proven Technologies

- Launch Vehicle Comparisons -



Saturn V	Space Shuttle	Ares I	Ares V
1967–1972	*1981–Present*	*First Flight 2015*	*First Flight 2018*
Height: 110.9 m (364.0 ft)	**Height:** 56.1 m (184.2 ft)	**Height:** 99.1 m (325.0 ft)	**Height:** 116.2 m (381.1 ft)
Gross Liftoff Mass : 2,948.4 mT (6,500K lbm)	**Gross Liftoff Mass:** 2,041.1 mT (4,500.0K lbm)	**Gross Liftoff Mass :** 927.1 mT (2,044.0K lbm)	**Gross Liftoff Mass :** 3,704.5 mT (8,167.1K lbm)
Payload Capability: 44.9 mT (99.0K lbm) to TLI 118.8 mT (262.0K lbm) to LEO	**Payload Capability:** 25.0 mT (55.1K lbm) to Low Earth Orbit (LEO)	**Payload Capability:** 25.5 mT (56.2K lbm) to LEO	**Payload Capability:** 71.1 mT (156.7K lbm) to TLI (with Ares I) 62.8 mT (138.5K lbm) to TLI ~187.7 mT (413.8K lbm) to LEO

Ares V Elements



Stack Integration

- 3,704.5 mT (8,167.1K lbm) gross liftoff mass
- 116.2 m (381.1 ft) in length

Solid Rocket Boosters

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

Core Stage

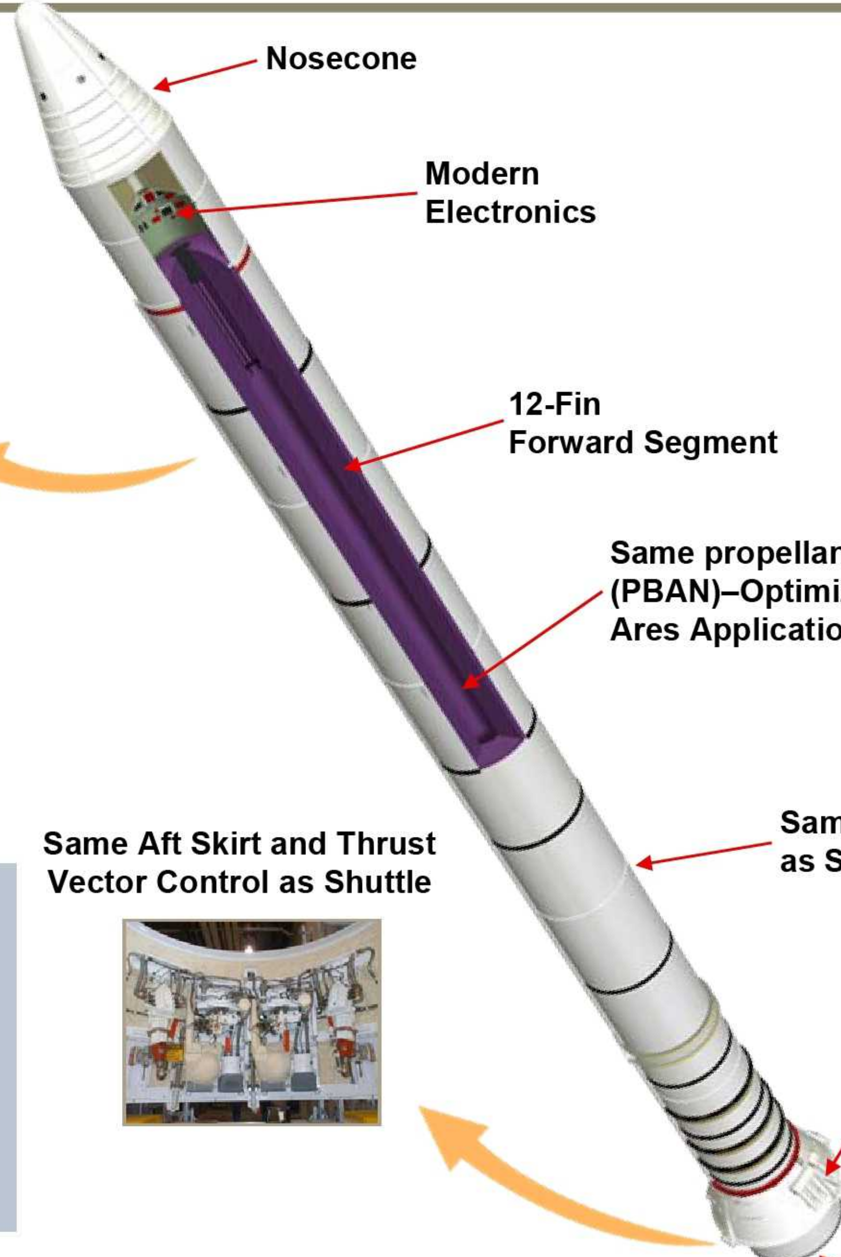
- Six Delta IV-derived RS-68B LOX/LH_2 engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Aluminum-Lithium (Al-Li) tanks

Earth Departure Stage (EDS)

- One Saturn-derived J-2X LOX/LH_2 engine (expendable)
- 10-m (33-ft) diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures, instrument unit and interstage
- Primary Ares V avionics system

Ares V Solid Rocket Booster (SRB)

Ares V SRB is similar to Space Shuttle and Ares I but optimized for lunar missions



Same Aft Skirt and Thrust Vector Control as Shuttle

Each Booster:

Mass: 791.5 t (1,744.9 klb_m)

Thrust: 16.86 MN (3.79 Mlb_f)

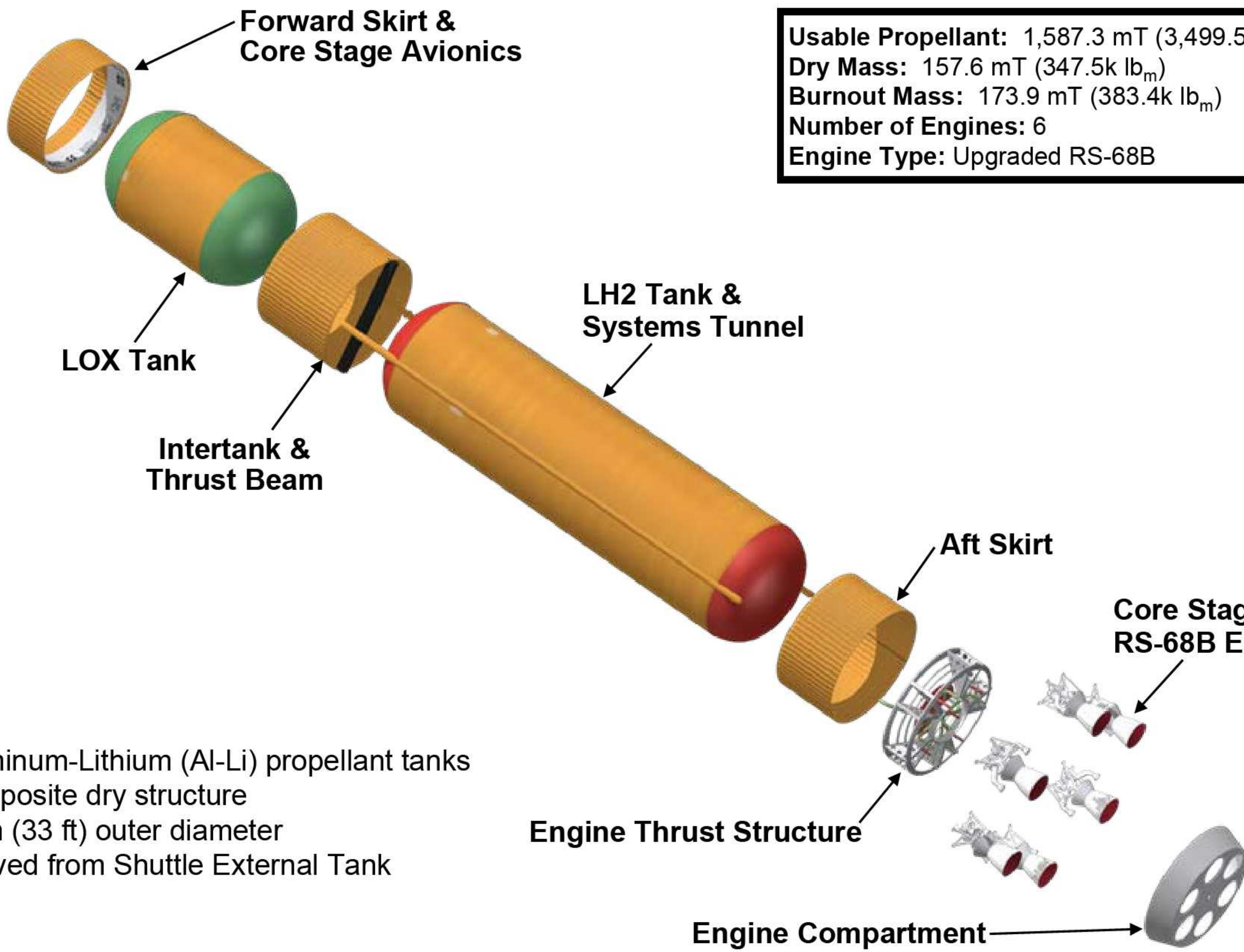
Burn Duration: 126 sec

Height: 59 m (193 ft)

Diameter: 3.7 m (12 ft)

Ares V Core Stage

Usable Propellant: 1,587.3 mT (3,499.5k lb_m)
Dry Mass: 157.6 mT (347.5k lb_m)
Burnout Mass: 173.9 mT (383.4k lb_m)
Number of Engines: 6
Engine Type: Upgraded RS-68B

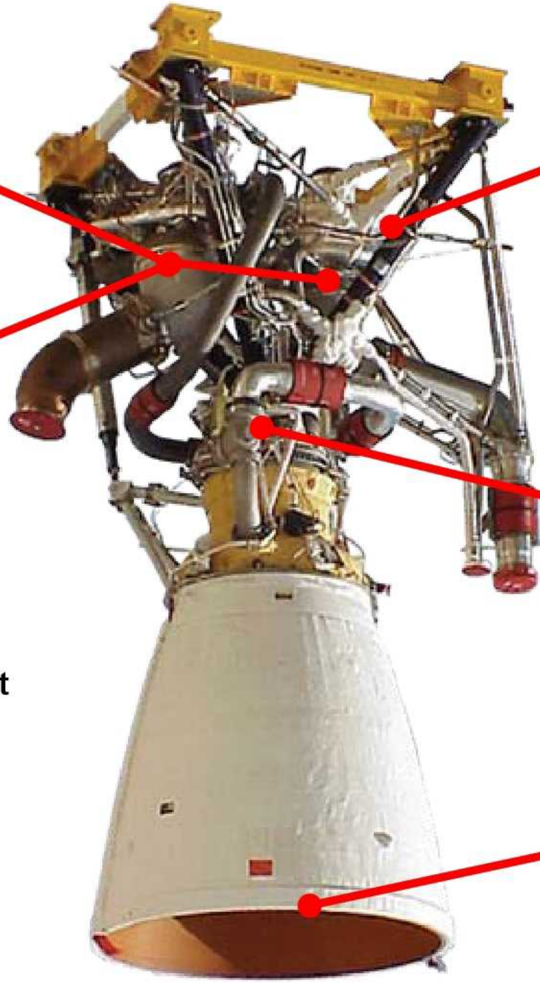


- Aluminum-Lithium (Al-Li) propellant tanks
- Composite dry structure
- 10 m (33 ft) outer diameter
- Derived from Shuttle External Tank

RS-68 to RS-68B

* Redesigned turbine nozzles to increase maximum power level by ≈ 2%

Redesigned turbine seals to significantly reduce helium usage for pre-launch



Helium spin-start duct redesign, along with start sequence modifications, to help minimize pre-ignition free hydrogen

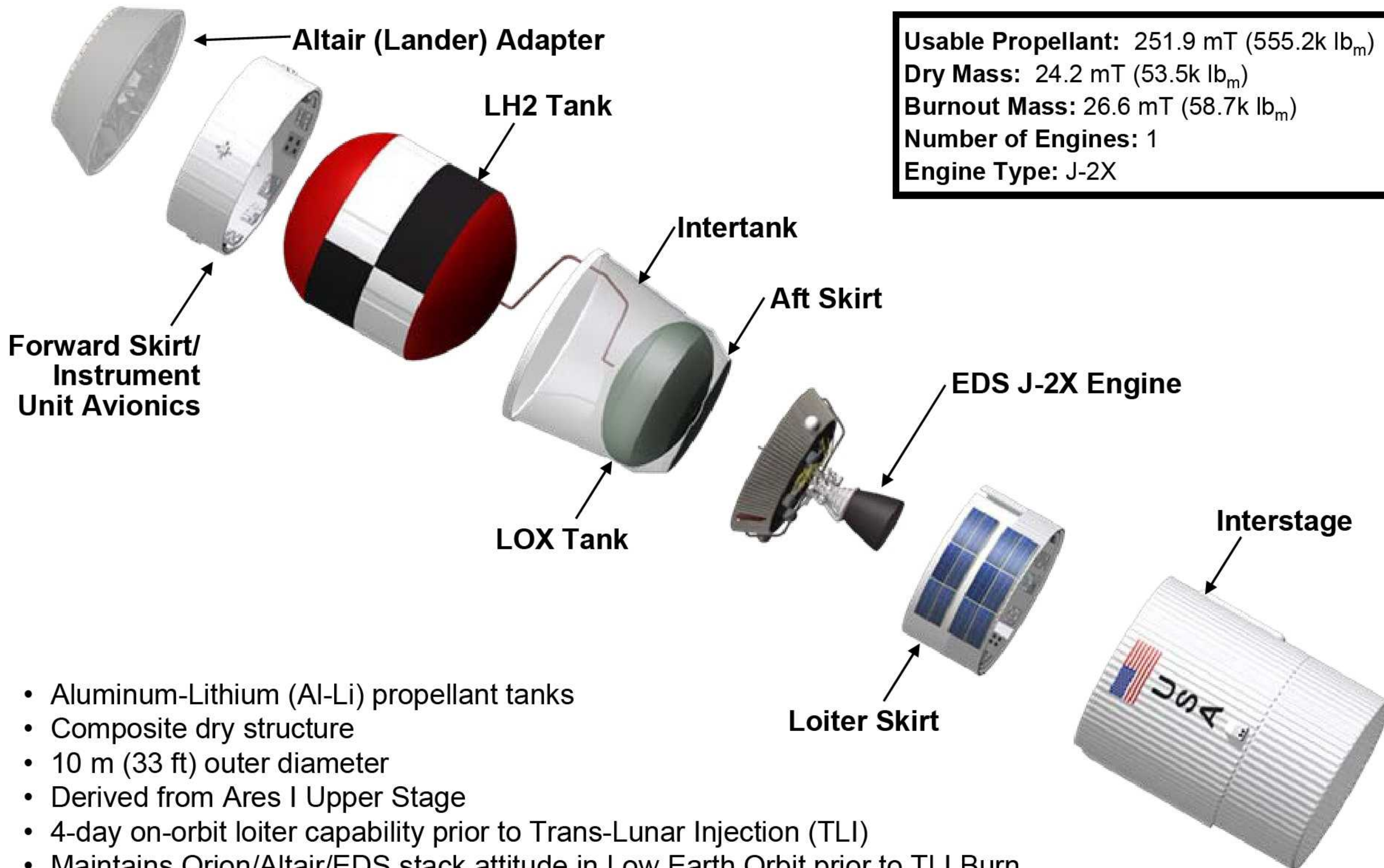
* Higher element density main injector improving specific impulse by ≈ 2% and thrust by ≈ 4%

Increased duration capability ablative nozzle

- **Other RS-68A upgrades or changes that may be included:**
  - Bearing material change
  - New Gas Generator igniter design
  - Improved Oxidizer Turbo Pump temp sensor
  - Improved hot gas sensor
  - 2nd stage Fuel Turbo Pump blisk crack mitigation
  - Cavitation suppression
  - ECU parts upgrade

* **RS-68A Upgrades**

Ares V Earth Departure Stage



Usable Propellant: 251.9 mT (555.2k lb_m)
Dry Mass: 24.2 mT (53.5k lb_m)
Burnout Mass: 26.6 mT (58.7k lb_m)
Number of Engines: 1
Engine Type: J-2X

- Aluminum-Lithium (Al-Li) propellant tanks
- Composite dry structure
- 10 m (33 ft) outer diameter
- Derived from Ares I Upper Stage
- 4-day on-orbit loiter capability prior to Trans-Lunar Injection (TLI)
- Maintains Orion/Altair/EDS stack attitude in Low Earth Orbit prior to TLI Burn
- EDS provide 1.5 kW of power to Altair from launch to TLI

J-2X Engine

Used on Ares I and Ares V

Turbomachinery
- Based on J-2S MK-29 design

Gas Generator
- Based on RS-68 design

Engine Controller
- Based directly on RS-68 design and software architecture

Regeneratively Cooled Nozzle Section
- Based on long history of RS-27 success

Flexible Inlet Ducts
- Based on J-2 & J-2S ducts

Open-Loop Pneumatic Control
- Similar to J-2

HIP-bonded MCC
- Based on RS-68 demonstrated technology

Metallic Nozzle Extension
- New design

Mass: 2.5 mT (5,511 lbm)

Height: 4.7 m (15.4 ft)

Diameter: 3.05 m (10 ft)

Thrust: 1,308K N (294K lbm) (vac)

Isp: 448 sec (vac)

Operation Time: 500 sec.

Altitude Start / On-orbit Restart

Operational Life: 8 starts/ 2,600 sec

Pratt & Whitney
A United Technologies Company

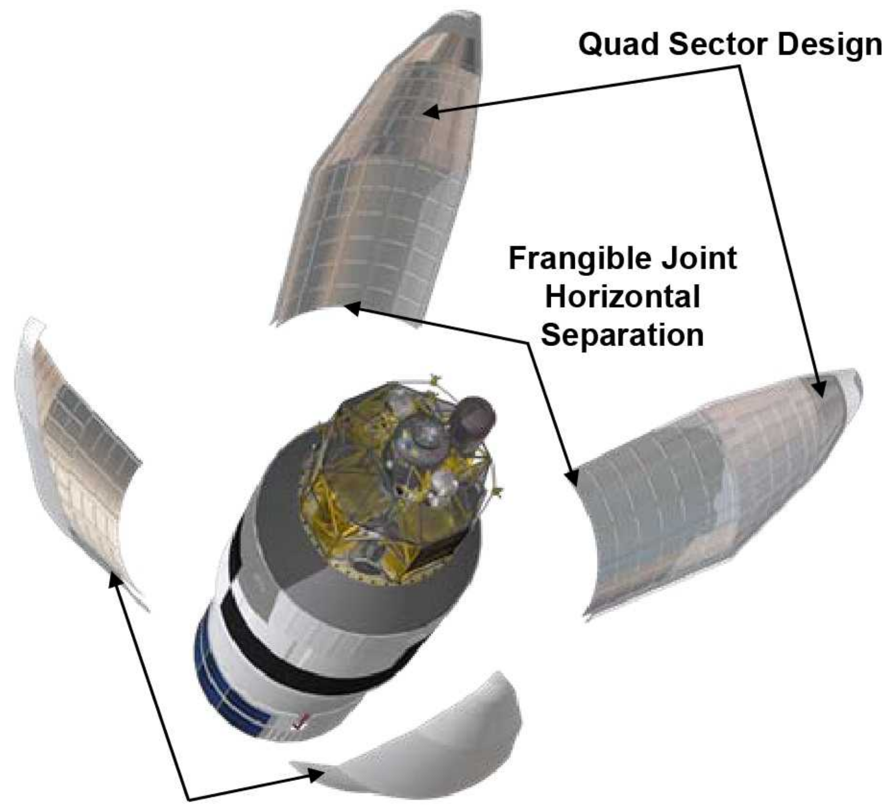
Pratt & Whitney Rocketdyne, Inc.

Payload Shroud Point Of Departure

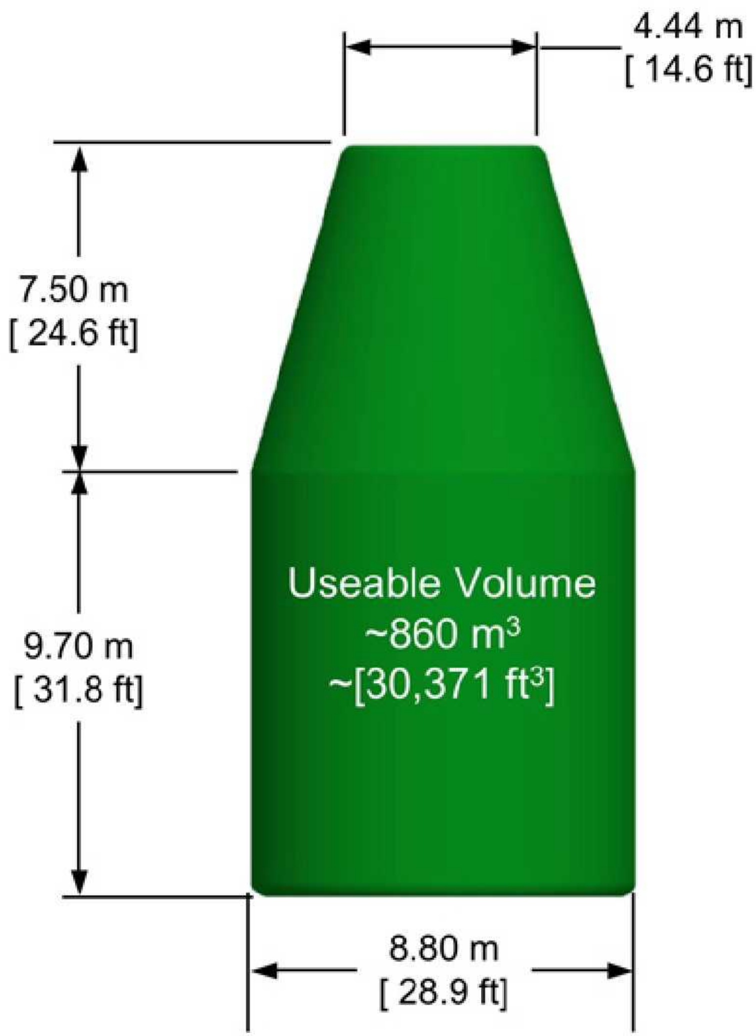
Mass: 9.1 mT (20.0k lbm)
POD Geometry: Biconic
Design: Quad sector
Barrel Diameter: 10 m (33 ft)
Barrel Length: 9.7 m (32 ft)
Total Length: 22 m (72ft)

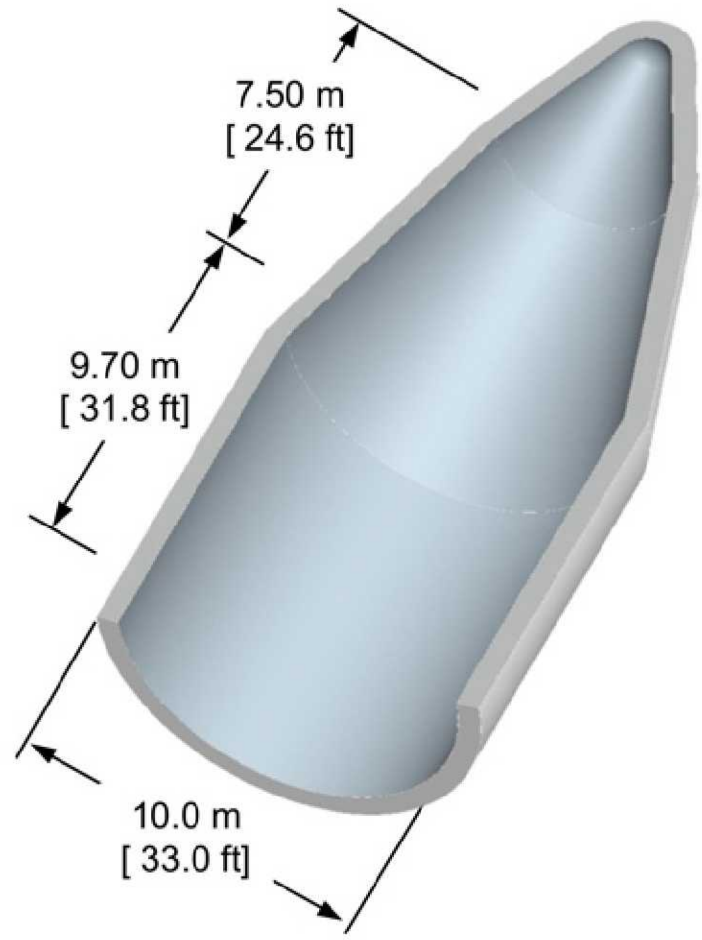
Point of Departure (Biconic) | **Leading Candidate (Ogive)**

- 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)

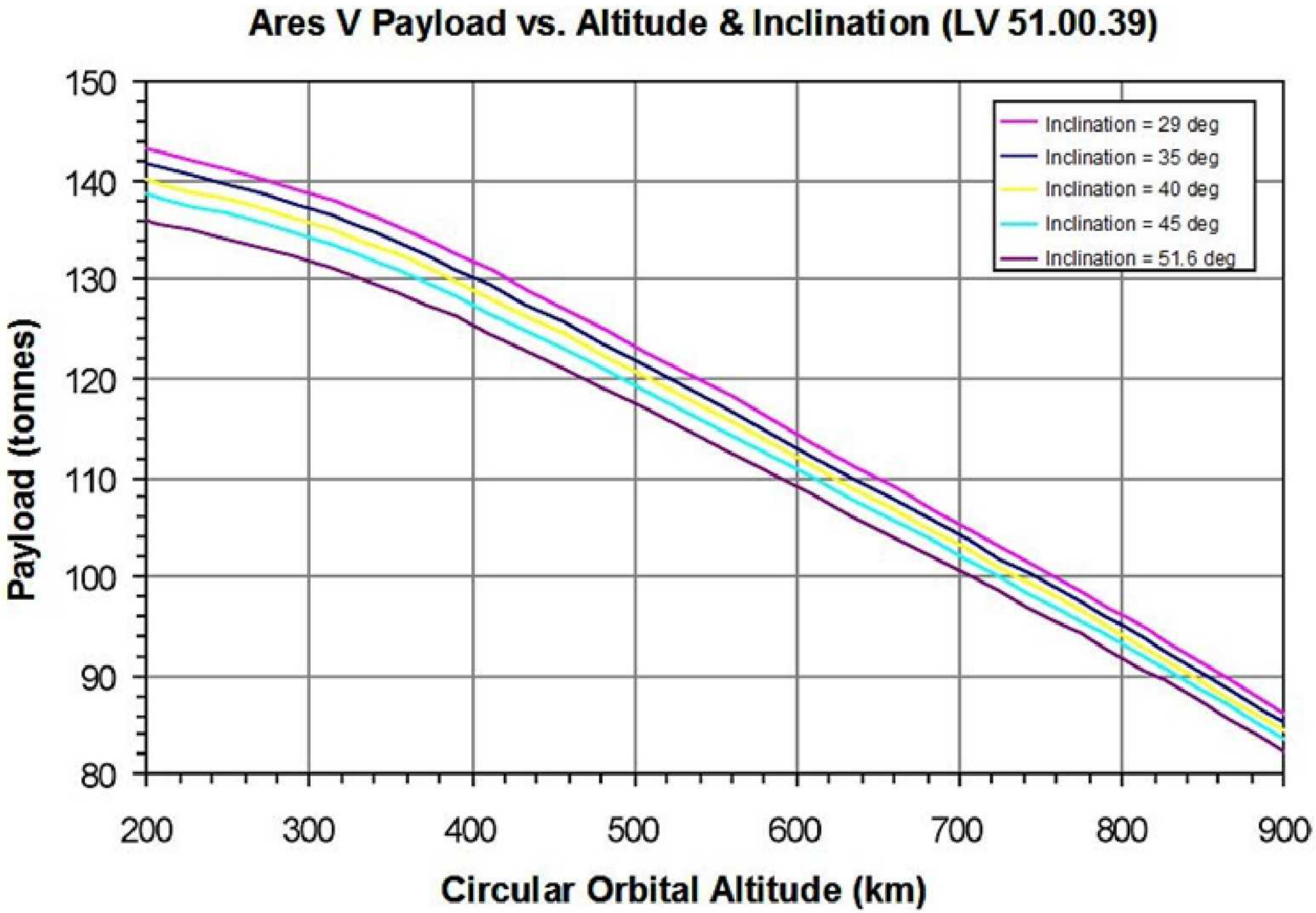


Current Ares V Shroud Concept



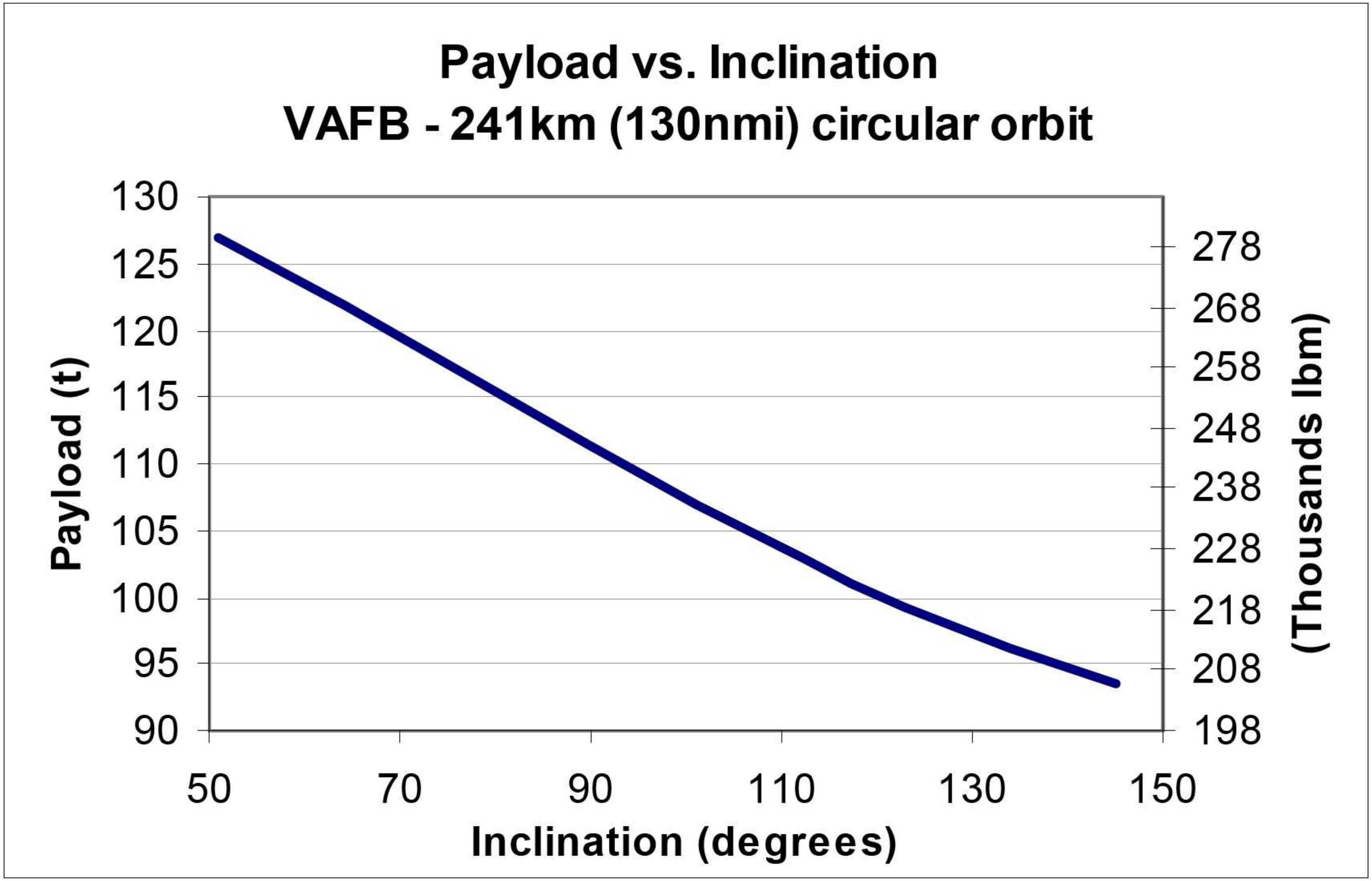


Ares V Payload vs. Altitude and Inclination



*based on LV 51.00.39

Ares V LEO Capability from VAFB

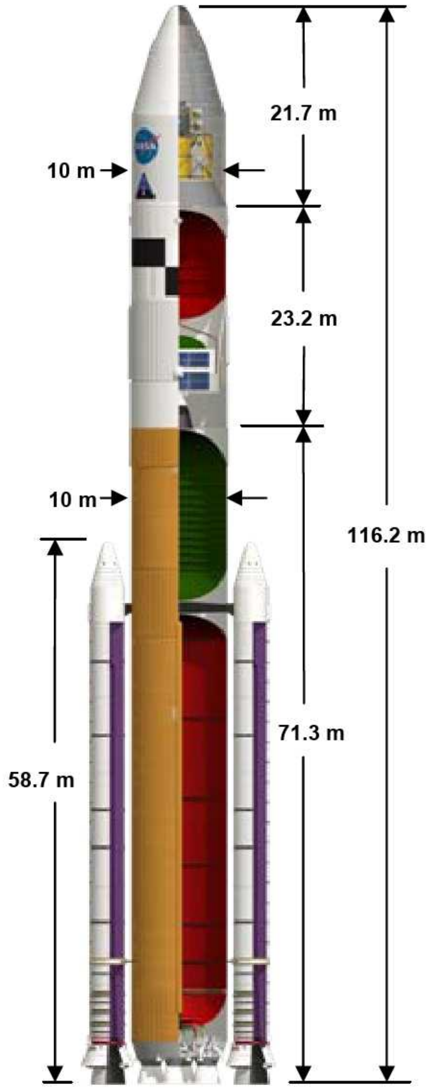


Approximate Performance – does not take into account land over-flight

*based on LV 51.00.39

LCCR/MCR-Approved Point of Departure

- Vehicle 51.0.48 -

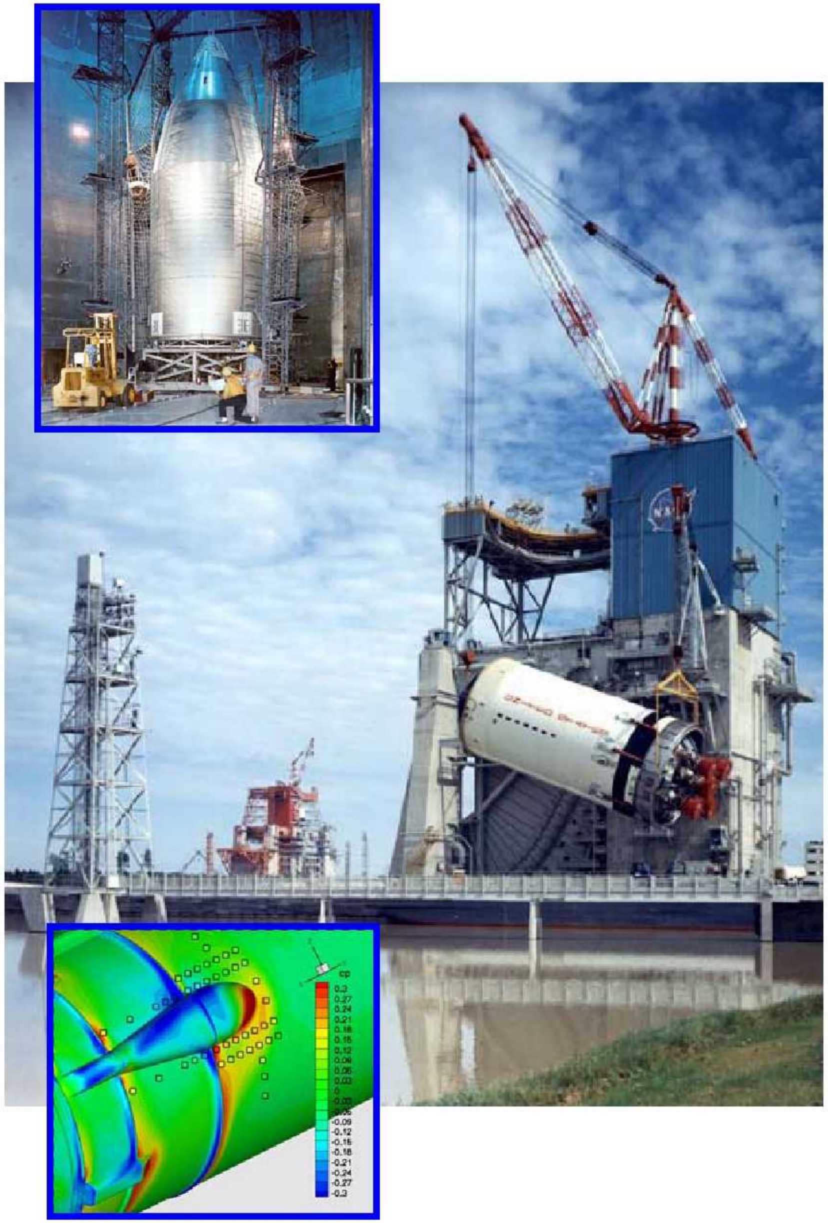


NOTE: These are MEAN numbers

- **Vehicle 51.0.48 approved in 2008**
  - 6 Engine Core, 5.5 Segment PBAN steel case booster
  - Provides architecture closure with margin
- **Approved maintaining Vehicle 51.0.47 with composite HTPB booster as Ares V option**
  - Final decision on Ares V booster at Constellation Lunar SRR (2010)
  - Additional performance capability if needed for margin or requirements
  - Allows for competitive acquisition environment for booster
- **Near Term Plan to Maintain Booster Options**
  - Fund key technology areas: composite cases, HTPB propellant characterization
  - Competitive Phase 1 industry concept definition proposals submitted early 2009.

Current Activities

- Ares V concept definition/requirements development industry proposals
- Structural test approach
- Structural test articles
- Ares V-Y flight test objectives
- Ares V aerodynamic characterization
- Manufacturing, test, and launch facilities
- Core Stage and EDS propulsion test approach and facilities assessment
- Technology prioritization
- Ares V Cost threat risk assessment
- Ares V performance risk assessment



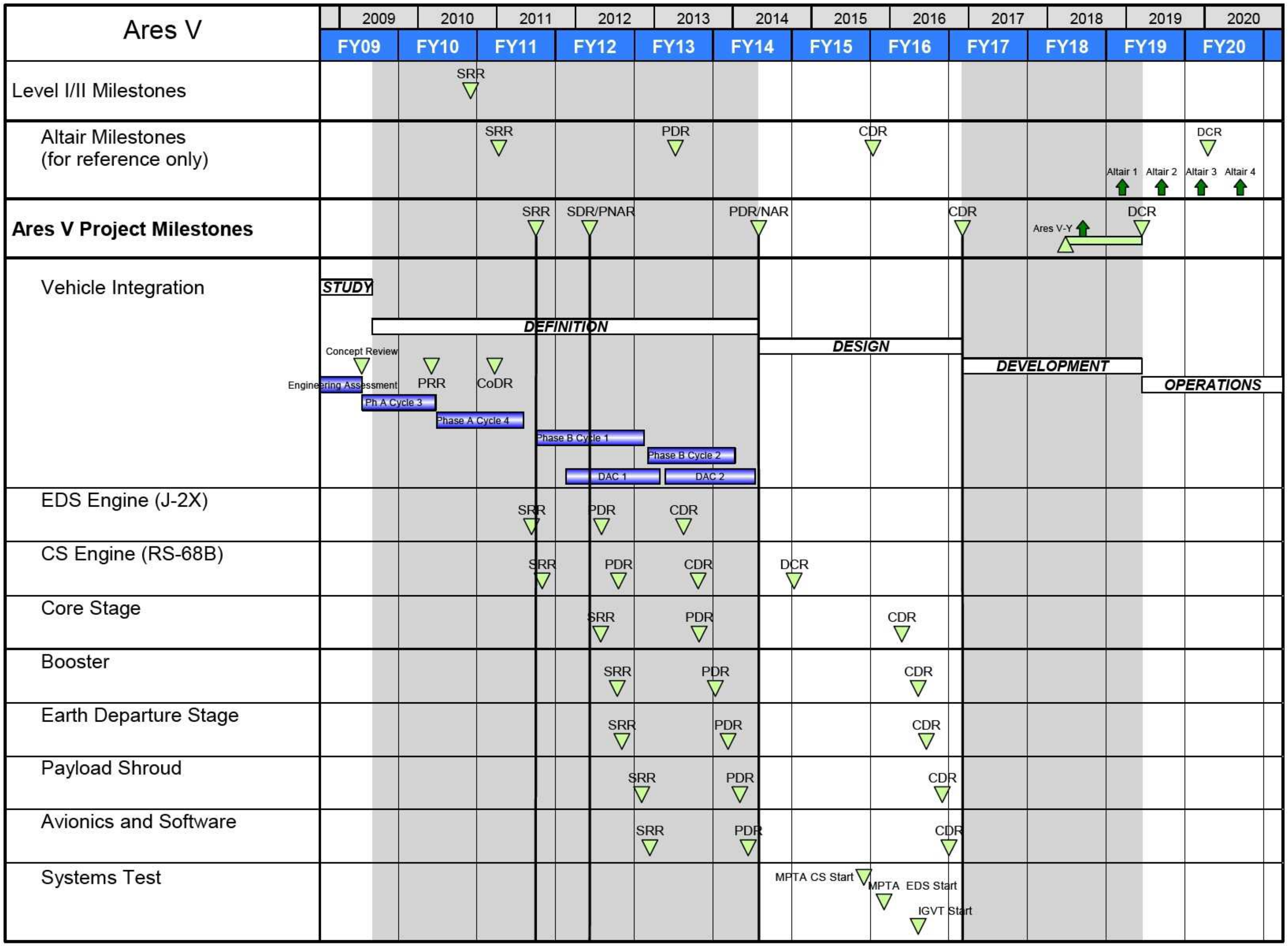
Conclusions

- Ares V current concept (51.00.48) exceeds Saturn V mass capability to trans lunar injection by almost 40% alone or almost 60% with Ares I
- This concept vehicle can meet current Human Lunar Return requirements with ~6 mT of Margin
- 2009 activities focused on refining vehicle and operational concept, refining requirements, working with potential non-Constellation users to understand vehicle/payload benefits and design issues
- Ares V is sensitive to loiter time, attitude, power, and altitude requirements, in addition to payload performance

www.nasa.gov/ares

Backup

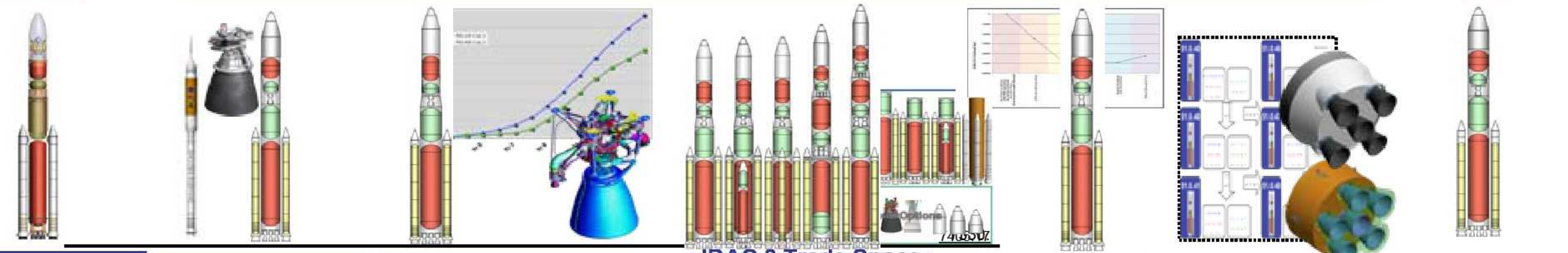
Ares V Summary Schedule



Ground Rules and Assumptions

- All trajectories analyzed using POST3D (Program to Optimize Simulated Trajectories - 3 Dimensional)
- Flight performance reserve is based on the Ares V LEO mission, and is held constant for all cases
- No gravity assists
- Interplanetary trip times are based on Hohmann transfers (limited to ~24 years max.)
- Payload mass estimates are separated spacecraft mass, and include payload adapter and any mission peculiar hardware (if required)
- Ares V vehicle based on configuration 51.00.39, but w/ Upper Stage burnout mass from configuration 51.00.34 (propellant tanks not resized for high C3 missions)
- For cases incorporating a kick stage:
  - Ares I and Ares V employ 2-engine Centaur from Atlas V
  - Additional adapter mass of 6,400 lbm assumed
  - No adjustments to aerodynamic data
- Propellant mass for:
  - Ares V LEO missions: held constant at 310,000 lbm
  - Ares I and V C3 missions and Ares I LEO missions: maximum propellant load
- No Upper Stage propellant off-loading for Ares I and Ares V C3 cases
- Transfer orbit to Sun-Earth L2 point is a direct transfer w/ C3 = -0.7 km2/s2
  - Payload can be increased by using a lunar swingby maneuver
- All cases targeting a C3 are of longer duration than the J-2X constraint of 500 seconds

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

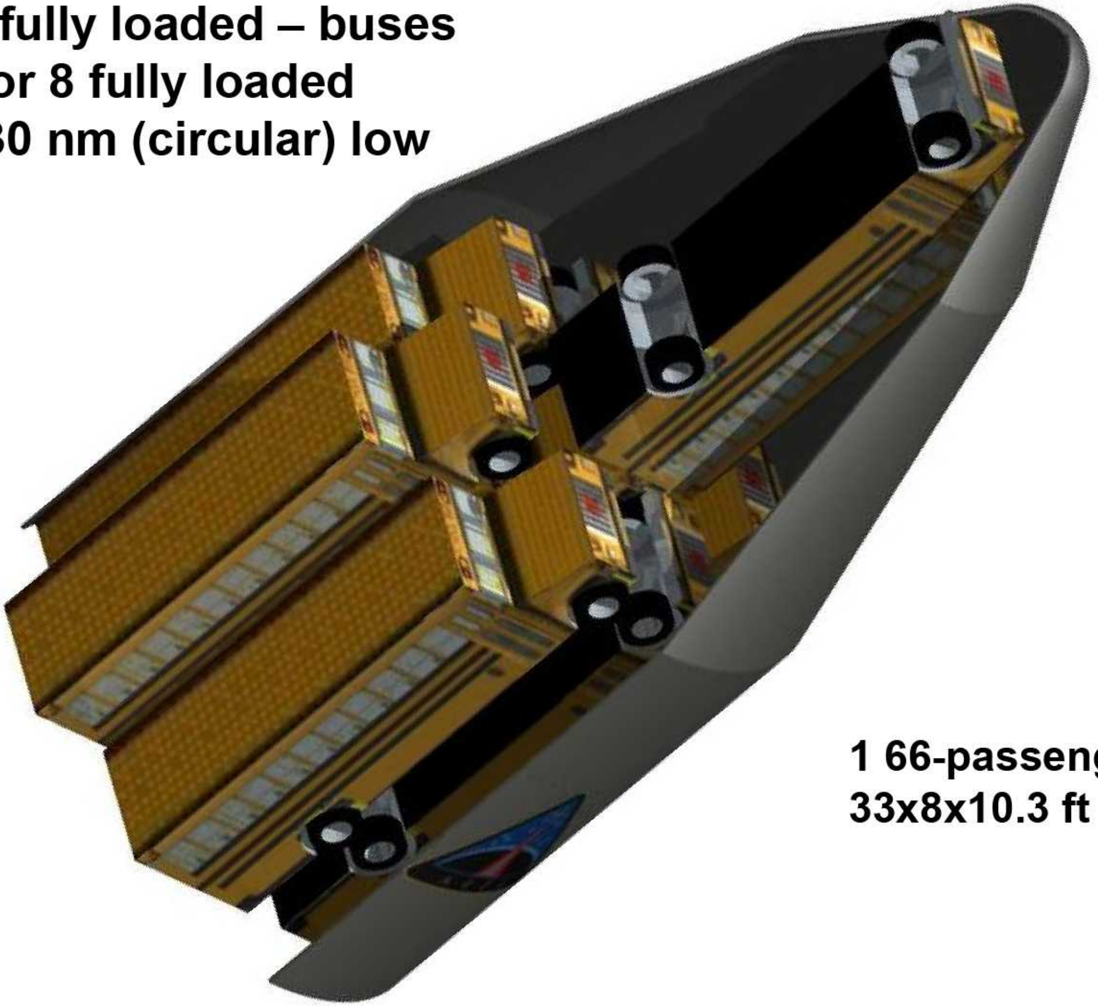
460 Concepts Evaluated

2005 **2006** **2007** **2008**

Ares I ATP
Orion ATP
Ares I SRR
Orion SRR
Ares I SDR
Ares V MCR

Re-Defining "The Box"

Combining mass and volume capability, Ares V could launch 5 empty – or 3 fully loaded – buses to the Moon or 8 fully loaded buses to a 130 nm (circular) low Earth orbit

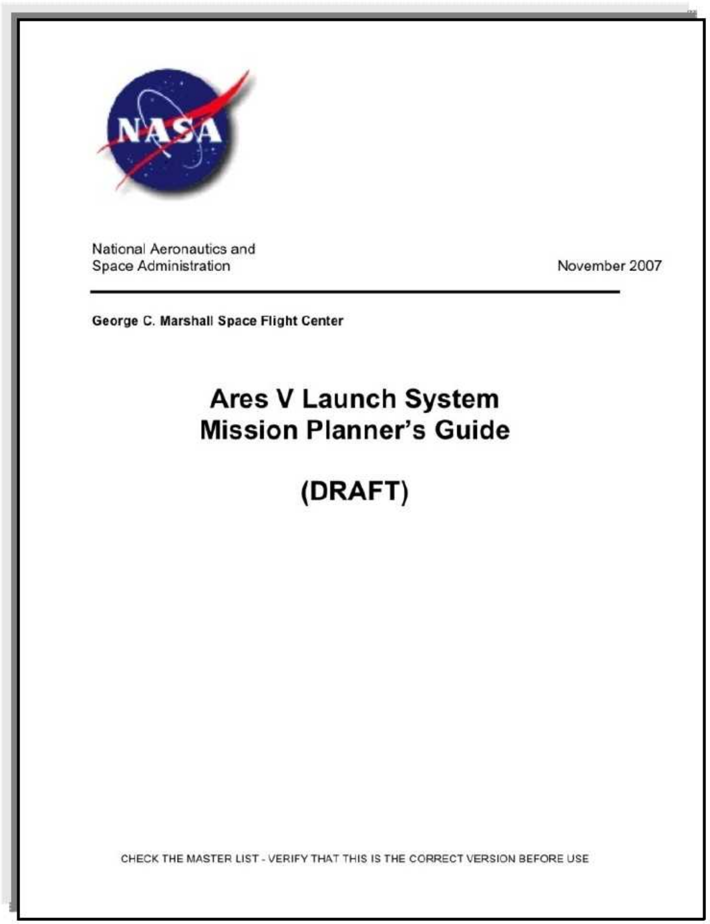


1 66-passenger school bus = 33x8x10.3 ft / 20,100 lb empty

Ares V Performance for Selected Trajectories from KSC

Mission Profile	Target	Constellation POD Shroud		Extended Shroud	
		Payload (lbm)	Payload (mt)	Payload (lbm)	Payload (mt)
1) LEO (@29° 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) GTO Injection	Transfer DV 8,200 ft/s	153,000	69.5	152,000	69
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) 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

*based on LV 51.00.39



National Aeronautics and
Space Administration

November 2007

George C. Marshall Space Flight Center

Ares V Launch System
Mission Planner's Guide

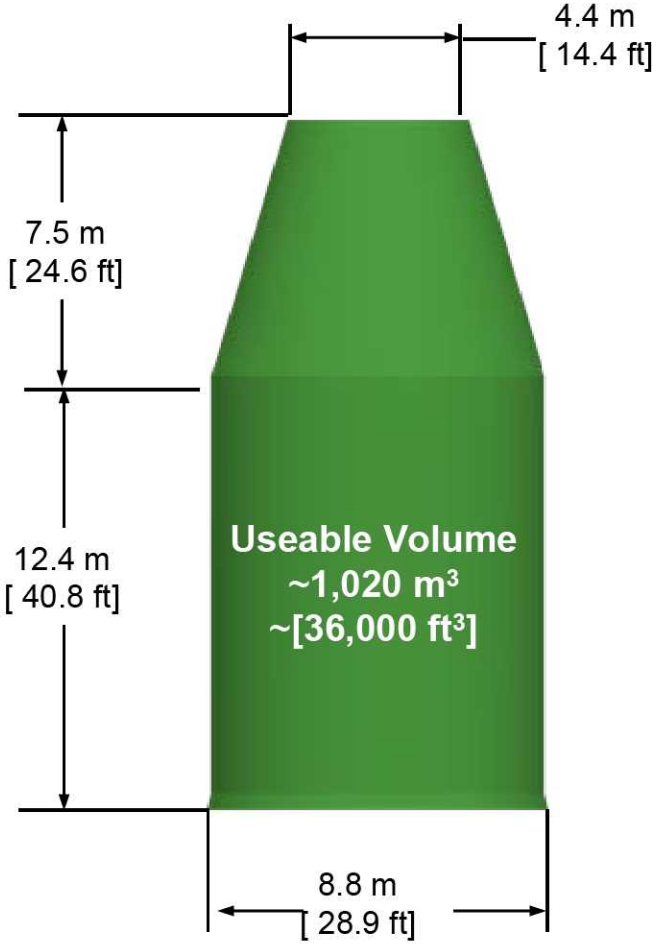
(DRAFT)

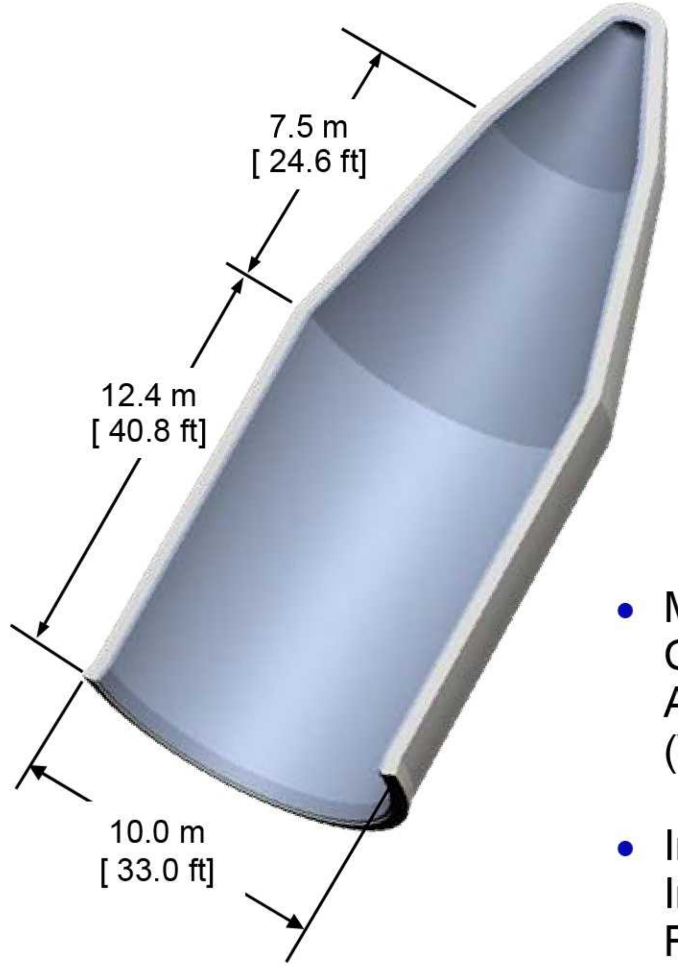
CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

♦ Mission Planner's Guide In Development

- Interface Definitions
  - Fairings, Adapters…
- Mission Performance
- Development Timelines
- Concept of Operations
- Potential Vehicle Evolution and Enhancements
- Need Past Astronomy Mission Data
- Based on 51.00.39 concept

Notional Ares V Shroud for Other Missions





- Maximum Barrel Length Constrained Vehicle Assembly Building (VAB) Height
- Increased Barrel Length Introduces Theoretical Reduction of Payload Capability of 200 kg

Employing Common Hardware to Reduce Operations Costs