National Aeronautics and Space Administration

Ares V Overview

presented at

Ares V Astronomy Workshop
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Introduction

- The NASA Ares Projects Office is developing the launch vehicles to move the Nation beyond low earth orbit
- Ares I is a crewed vehicle, and Ares V is a heavy lift vehicle being designed to place cargo on the Moon
- This is a work-in-progress and we are presenting a "snap-shot" of the ongoing effort
- The Ares V vehicle will be considered a national asset, and we look forward to opening a dialogue for potential applications with the astronomy community
- Our goal today is to introduce you to the Ares V vehicle
  - Mission and Vehicle Overview
  - Performance Description

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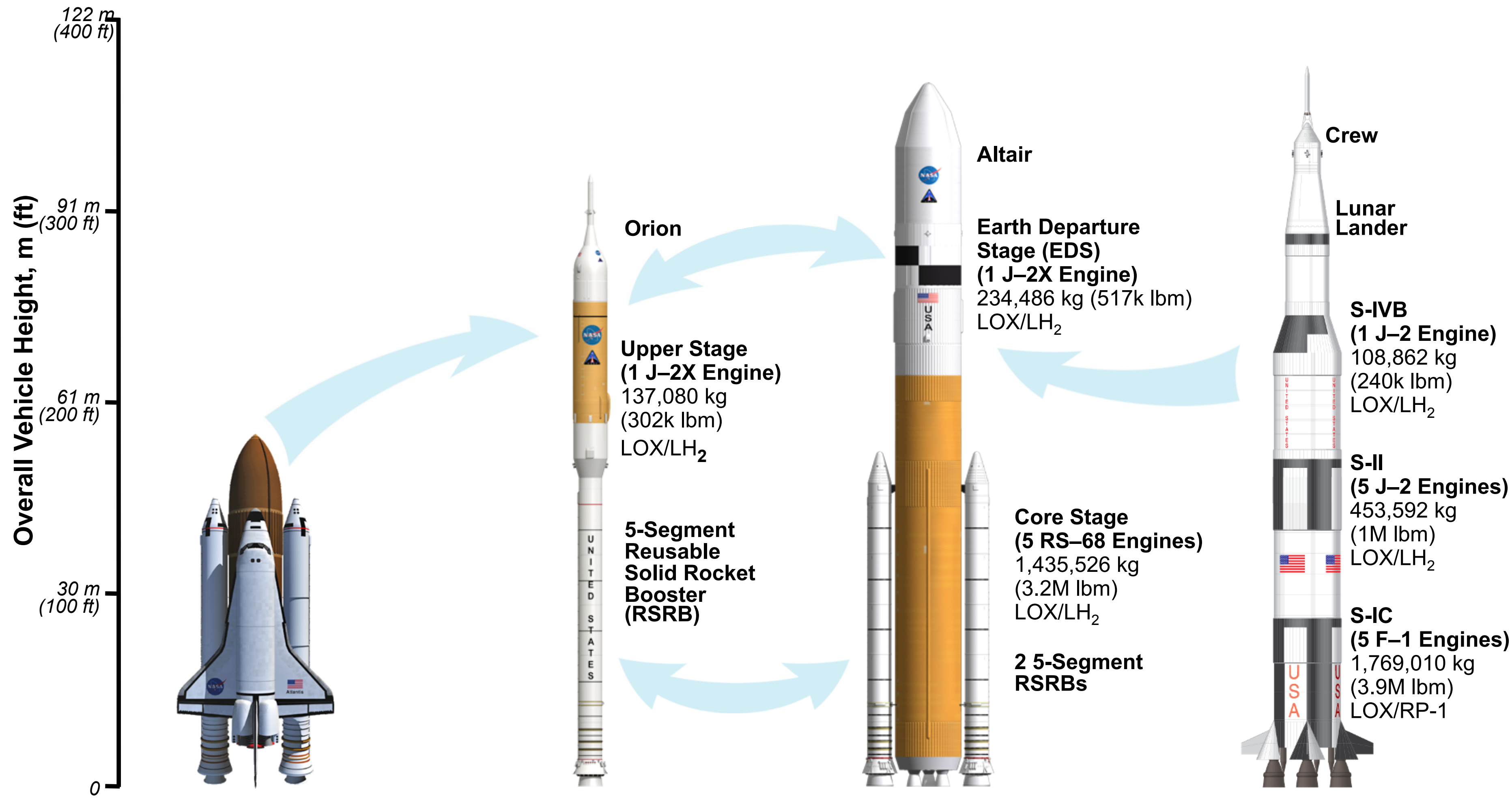
Ares V Mission and Vehicle Overview

www.nasa.gov

Building on a Foundation of Proven Technologies
– Launch Vehicle Comparisons –



Space Shuttle

Height: 56.1 m (184.2 ft)
Gross Liftoff Mass:
2,041,166 kg (4.5M lbm)
Payload Capability:
25 mT (55k lbm)
to Low Earth Orbit (LEO)

Ares I

Height: 99.1 m (325 ft)
Gross Liftoff Mass:
927,114 kg (2.0M lbm)
Payload Capability:
25.6 mT (56.5k lbm)
to LEO

Ares V

Height: 109.9 m (360.5 ft)
Gross Liftoff Mass:
3,374,875 kg (7.4M lbm)
Payload Capability:
63.6 mT (140.2k lbm) to TLI (with Ares I)
55.9 mT (123K lbm) to Direct TLI
~143.4 mT (316k lbm) to LEO

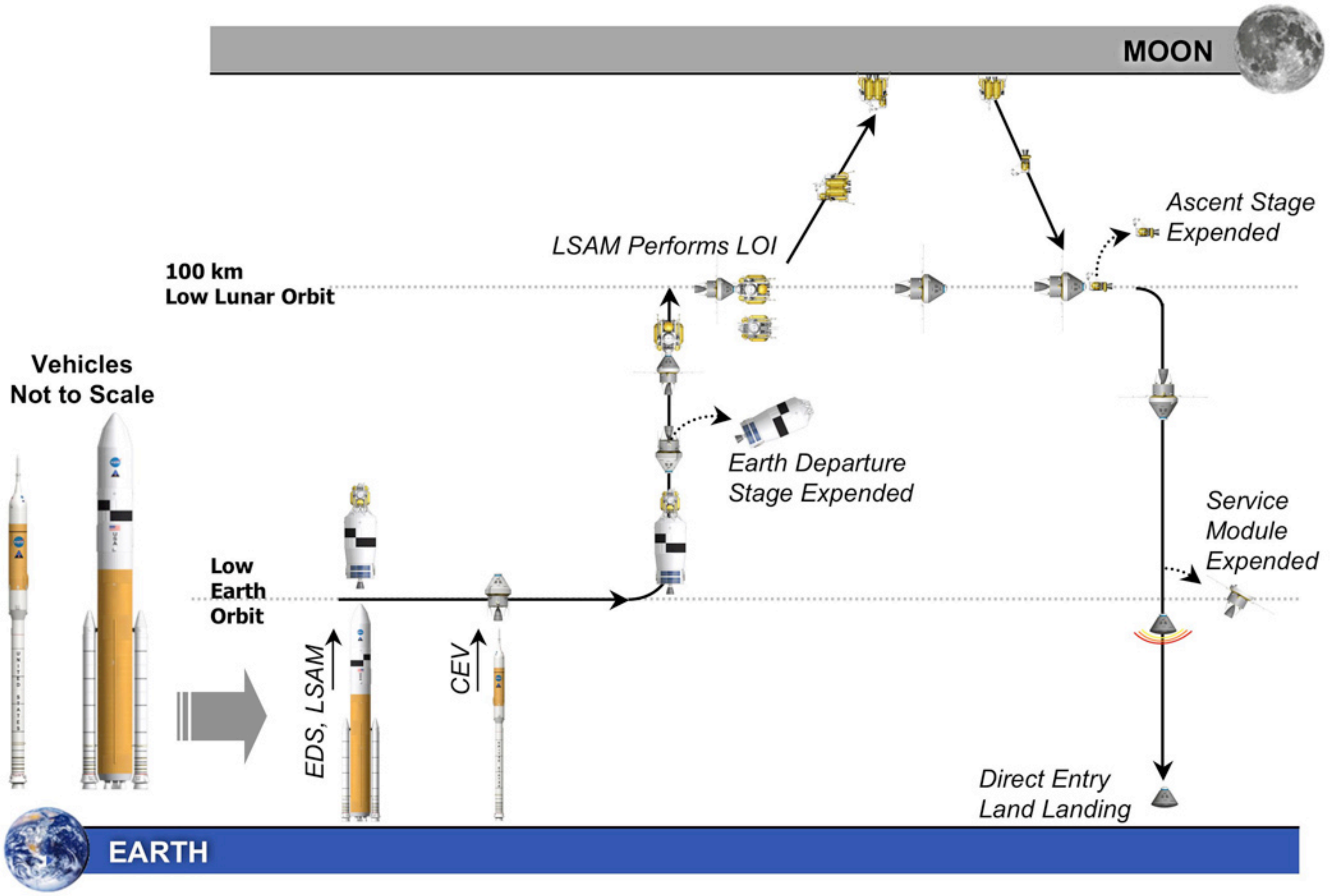
Saturn V

Height: 110.9 m (364 ft)
Gross Liftoff Mass:
2,948,350 kg (6.5M lbm)
Payload Capability:
45 mT (99k lbm) to TLI
119 mT (262k lbm) to LEO

DAC 2 TR 5

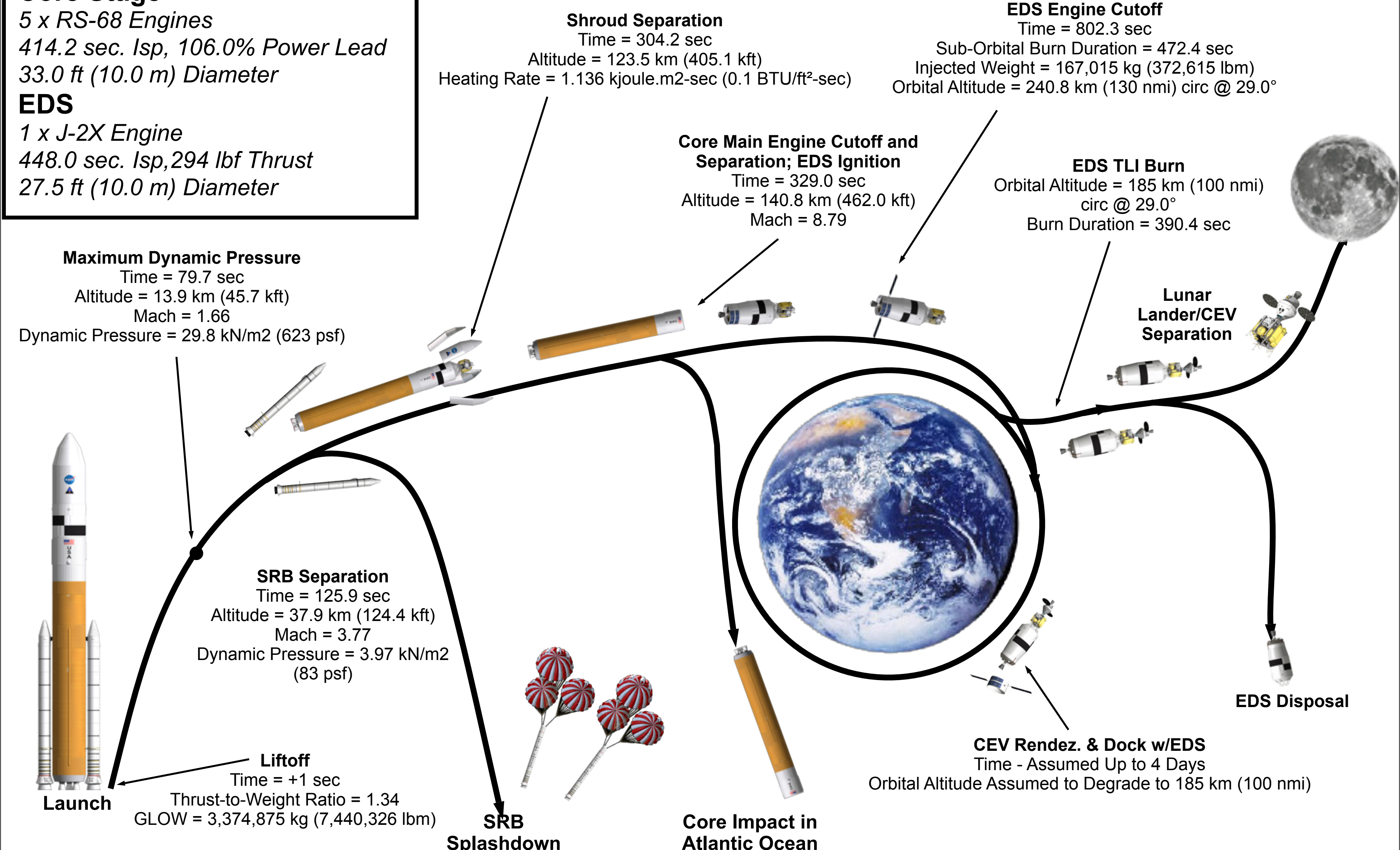
Constellation Lunar Sortie Mission
- 1.5 Vehicle Launch Solution -

- **Current Ares V concept analyses are based on 67mt payload to TLI requirement (Lunar Lander + Crew Exploration Vehicle)**
  - Orbital Insertion at 130 nmi and 29.0° inclination
  - Orbital decay during maximum 4-day loiter period
  - Trans Lunar Injection (TLI) burn of 3175 m/s from 100 nmi



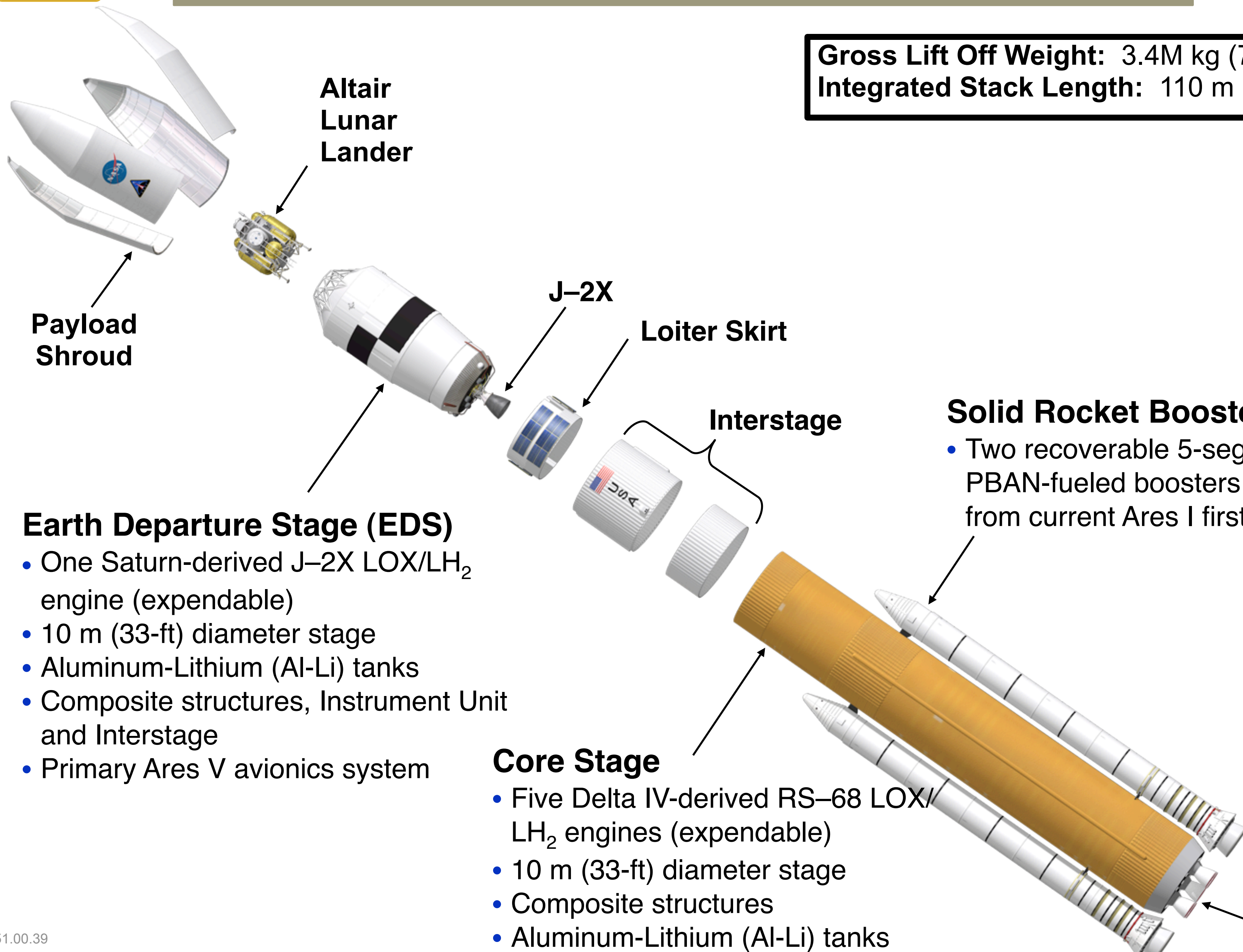
Ares V Ascent Profile for 1.5 Launch DRM
- Vehicle 51.0.39 -

Core Stage
5 x RS-68 Engines
414.2 sec. Isp, 106.0% Power Lead
33.0 ft (10.0 m) Diameter
EDS
1 x J-2X Engine
448.0 sec. Isp,294 lbf Thrust
27.5 ft (10.0 m) Diameter



Ares V Elements

Gross Lift Off Weight: 3.4M kg (7.4M lb)
Integrated Stack Length: 110 m (360 ft)



Solid Rocket Boosters (2)

- Two recoverable 5-segment PBAN-fueled boosters (derived from current Ares I first stage

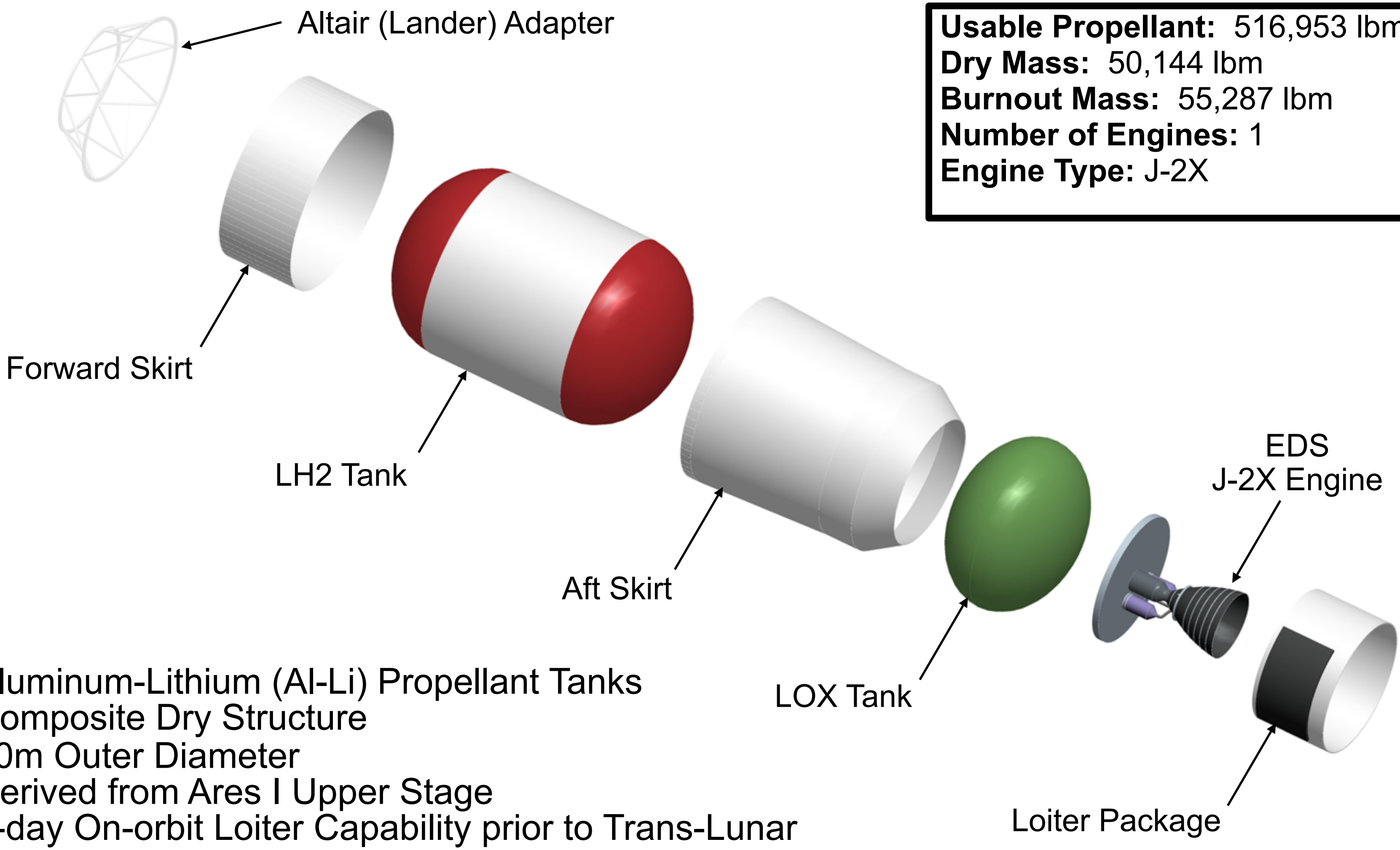
Earth Departure Stage (EDS)

- 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

Core Stage

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

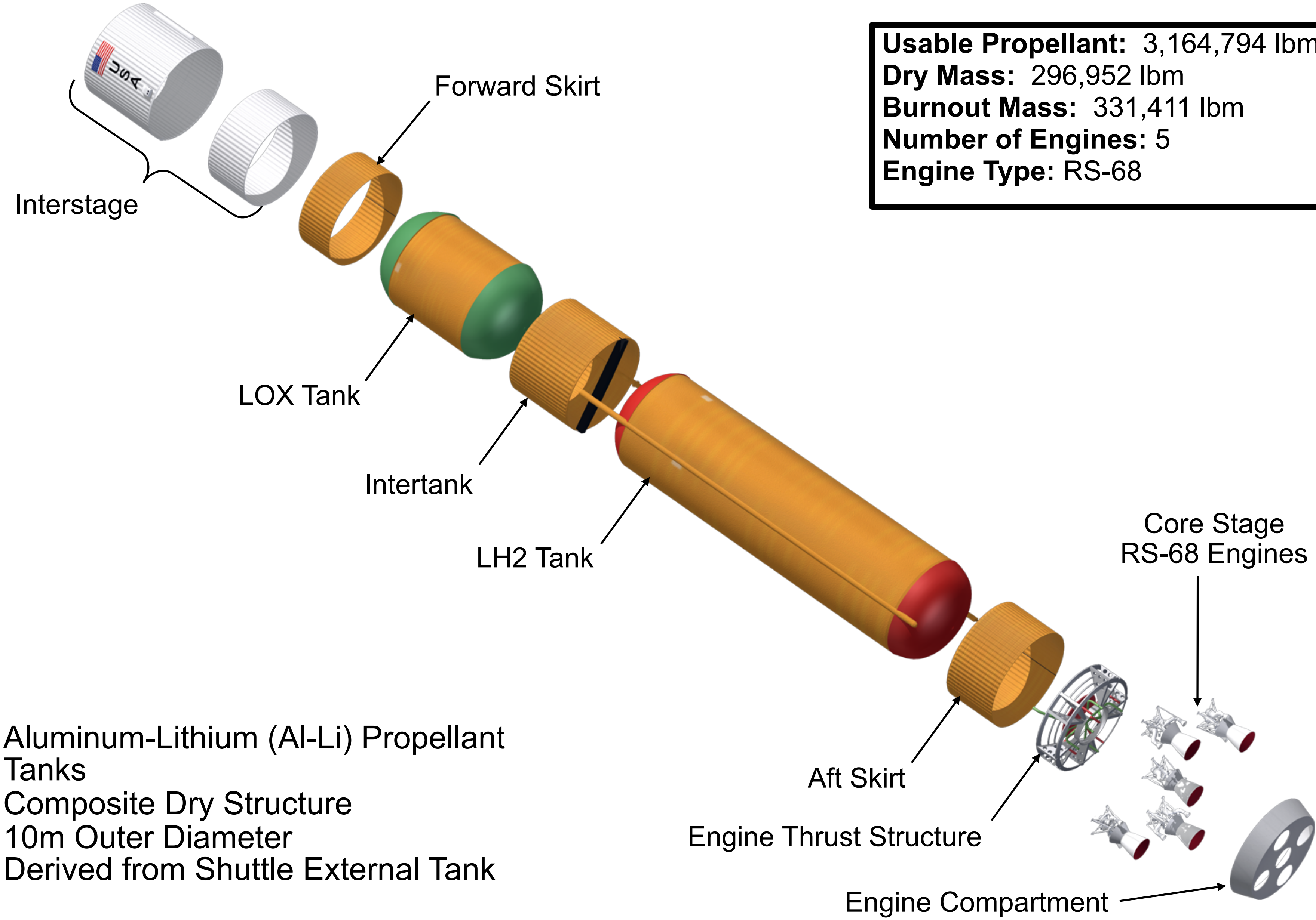
Earth Departure Stage Current Design Concept
- Expanded View -



Usable Propellant: 516,953 lbm
Dry Mass: 50,144 lbm
Burnout Mass: 55,287 lbm
Number of Engines: 1
Engine Type: J-2X

- Aluminum-Lithium (Al-Li) Propellant Tanks
- Composite Dry Structure
- 10m 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

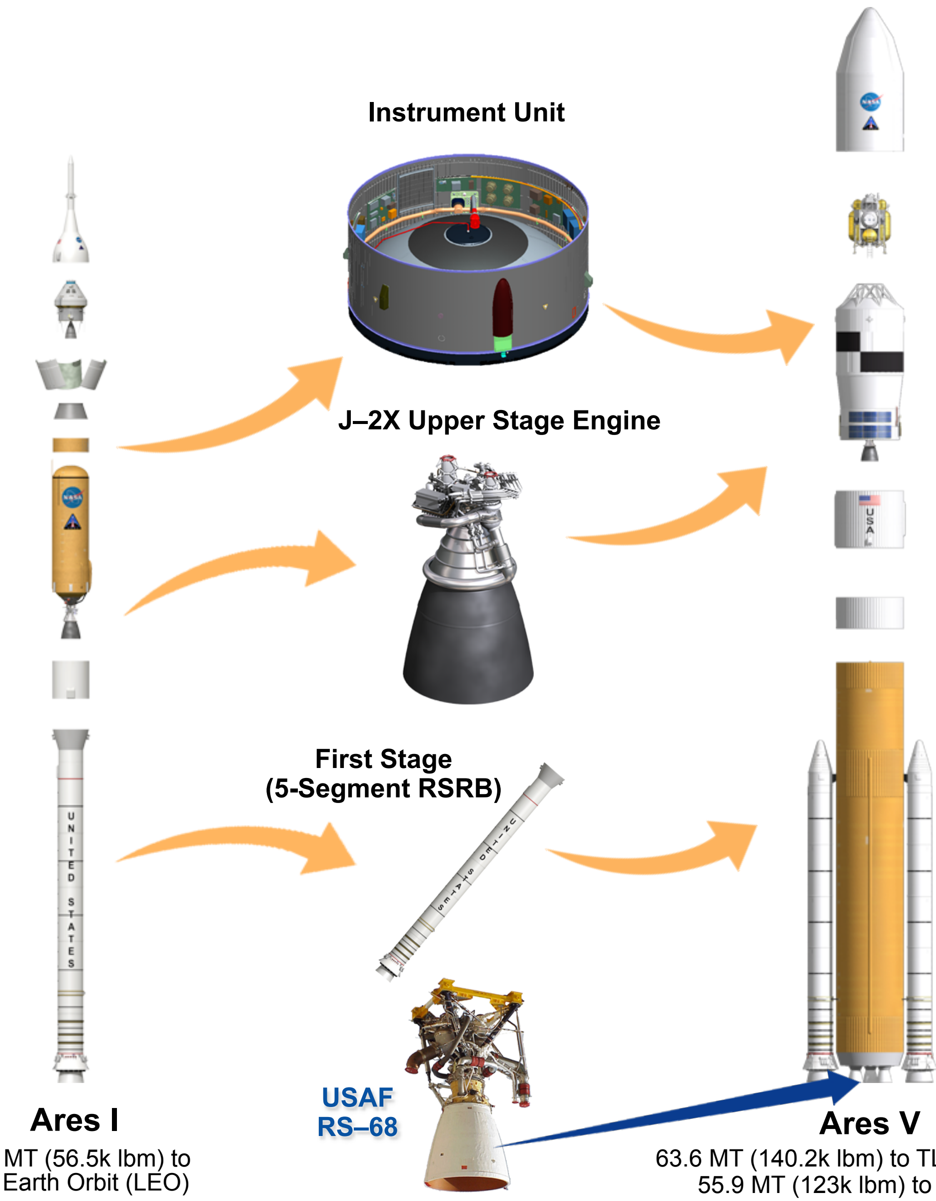
Core Stage Current Design Concept
- Expanded View -



Usable Propellant: 3,164,794 lbm
Dry Mass: 296,952 lbm
Burnout Mass: 331,411 lbm
Number of Engines: 5
Engine Type: RS-68

- Aluminum-Lithium (Al-Li) Propellant Tanks
- Composite Dry Structure
- 10m Outer Diameter
- Derived from Shuttle External Tank

Ares I/Ares V Connection



Ares I

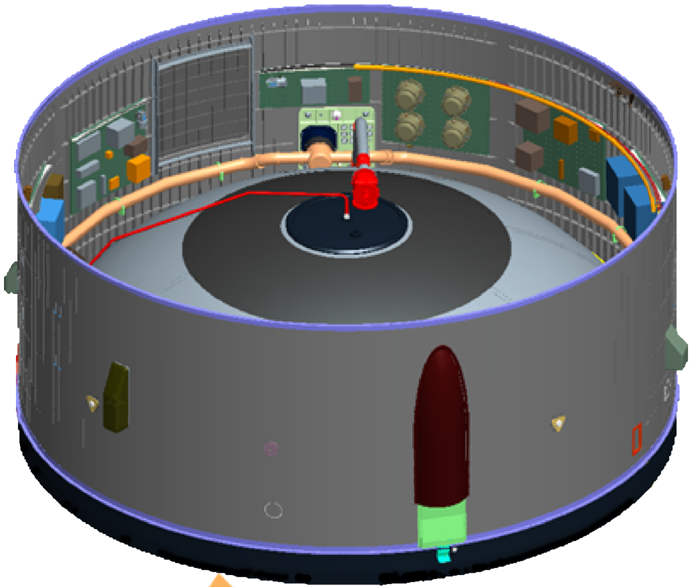
25.6 MT (56.5k lbm) to
Low Earth Orbit (LEO)

Ares V

63.6 MT (140.2k lbm) to TLI (with Ares I)
55.9 MT (123k lbm) to Direct TLI
~143.4 MT (316k lbm) to LEO

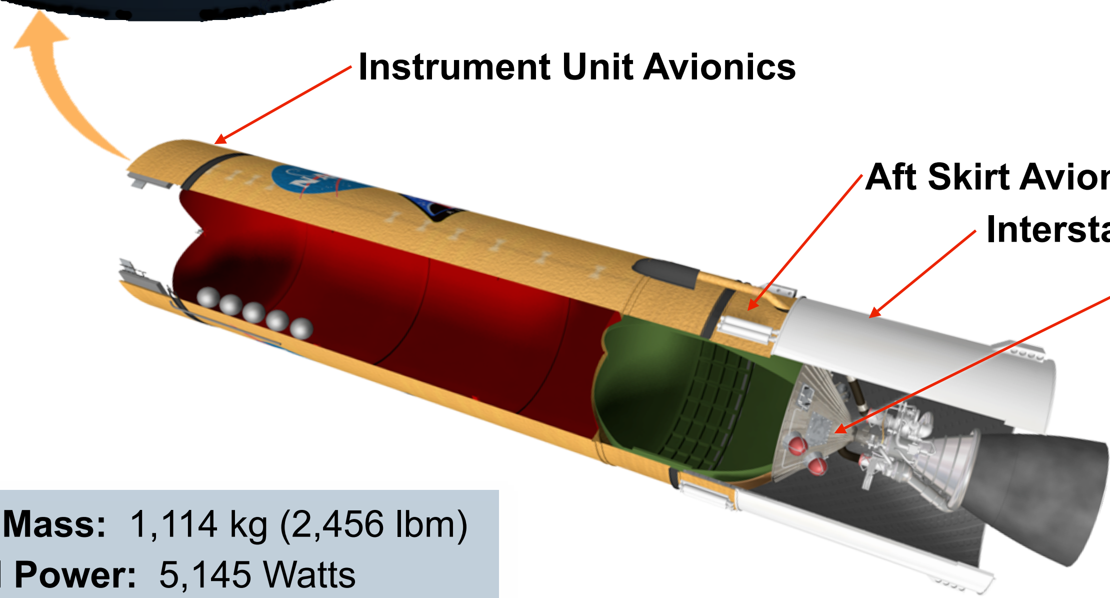
DAC 2 TR 5

Notional Instrument Unit



The Ares I Upper Stage Avionics will provide:

- Guidance, Navigation, and Control (GN&C)
- Command and data handling
- Pre-flight checkout
- *Basic design to be extended to Ares V*



Avionics Mass: 1,114 kg (2,456 lbm)
Electrical Power: 5,145 Watts

BOEING

Earth Departure Stage J-2X Engine

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

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

Gas Generator
- Based on RS–68 design

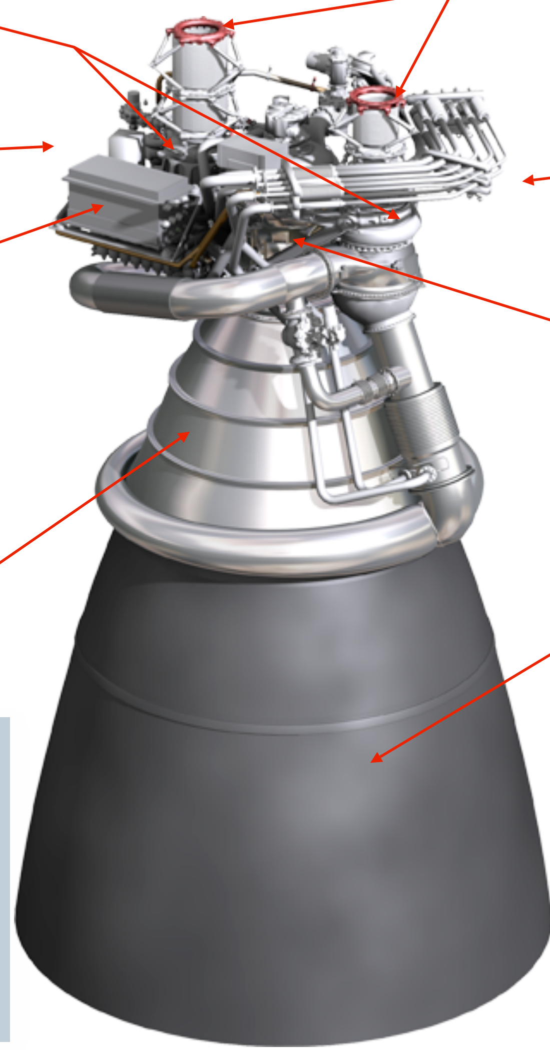
Open-Loop Pneumatic Control
- Similar to J–2

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

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

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

Nozzle Extension
- Based on RL10–B2



Mass: 2,472 kg (5,450 lbm)
Thrust: 1.3M N (294k lbm) (vac)
Isp: 448 sec (vac)
Height: 4.7 m (185 in)
Diameter: 3.0 m (120 in)

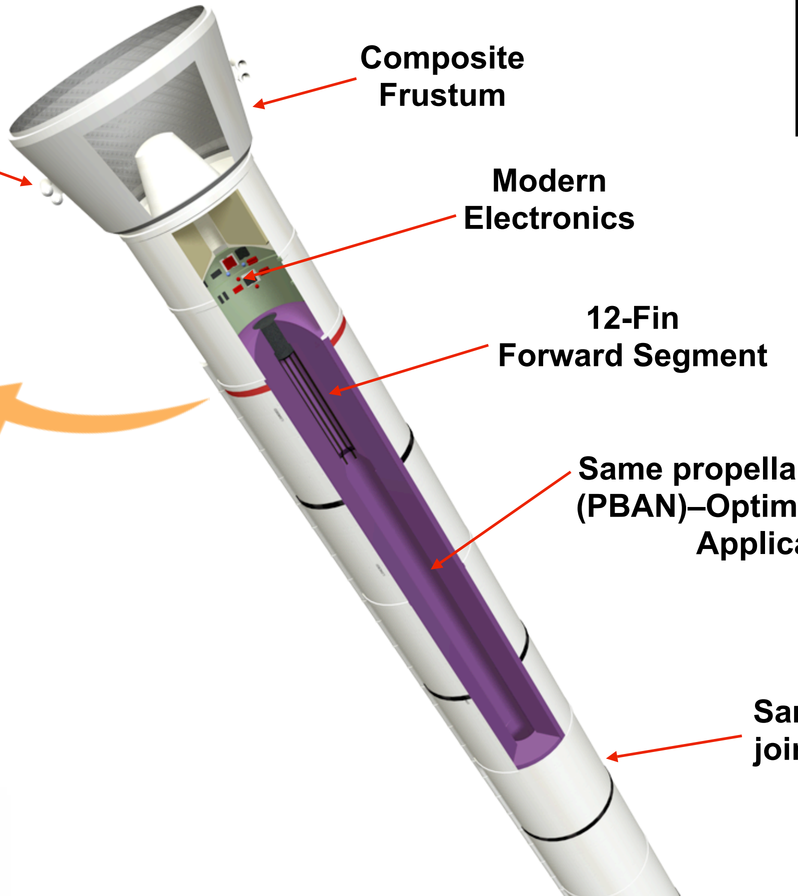
Pratt & Whitney
A United Technologies Company

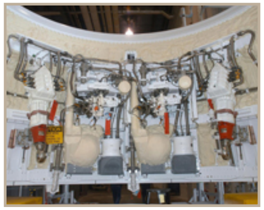
Pratt & Whitney Rocketdyne

Ares I Solid Rocket Booster (SRB)

ATK

Ares I SRB design will be utilized for Ares V



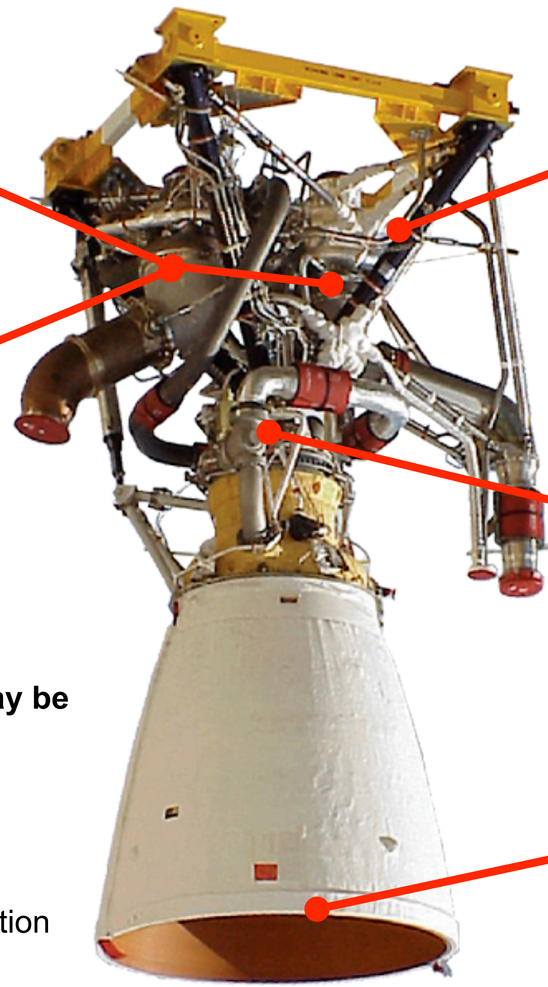


Same Aft Skirt and Thrust Vector Control as Shuttle

Mass: 731k kg (1.6M lbm)
Thrust: 15.8M N (3.5M lbm)
Burn Duration: 126 sec
Height: 53 m (174 ft)
Diameter: 3.7 m (12 ft)

DAC 2 TR 5

Core Stage Upgraded USAF RS-68 Engine



* 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%

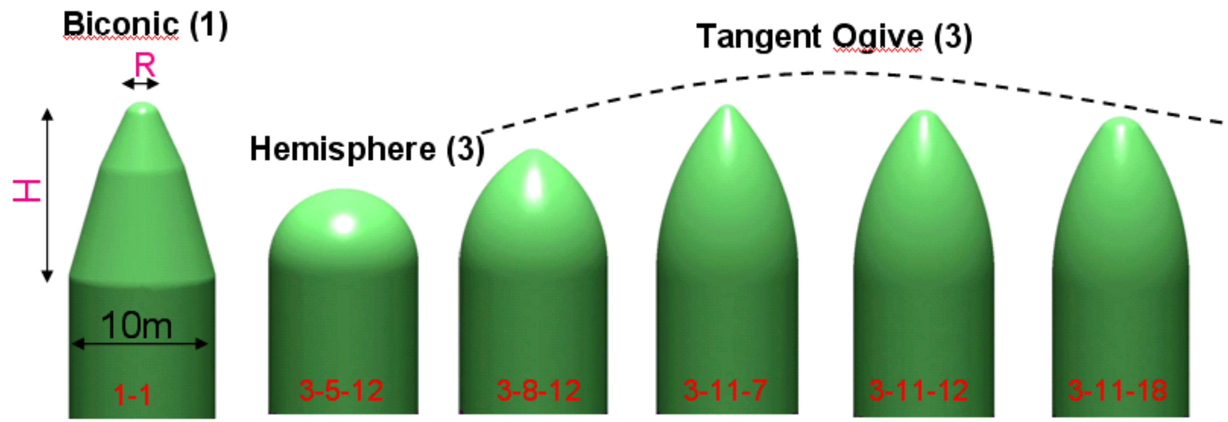
Increased duration capability ablative nozzle

Other RS-68A upgrades or changes that may be included:

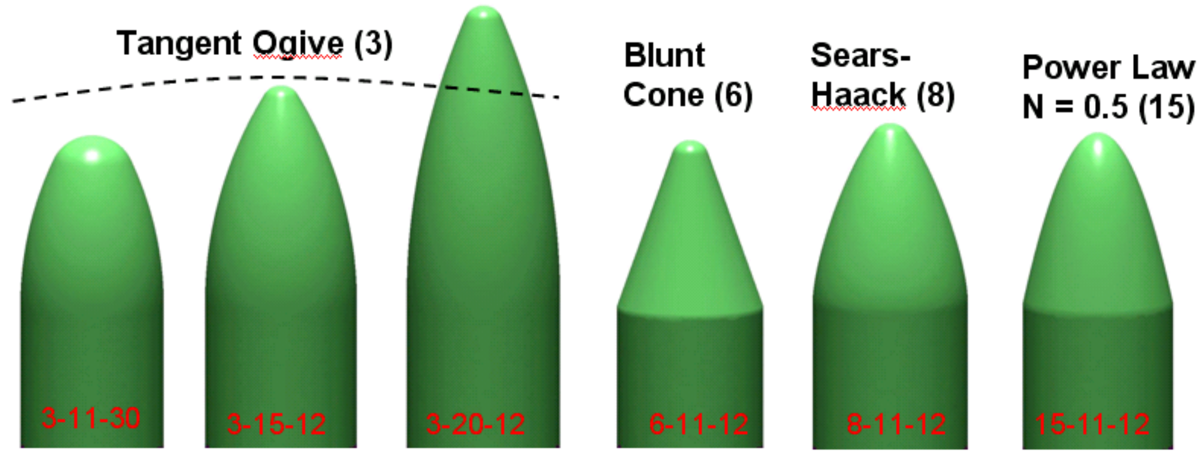
- Bearing material change
- New Gas Generator igniter design
- Improved Oxidizer Turbo Pump temp sensor
- Improved hot gas sensor
- 2nd stage Fuel Turbo Pump blisk crack mitigation
- Cavitation suppression
- ECU parts upgrade

* **RS-68A Upgrades**

Shroud Shape Trade Study
- Initial Trade Space -



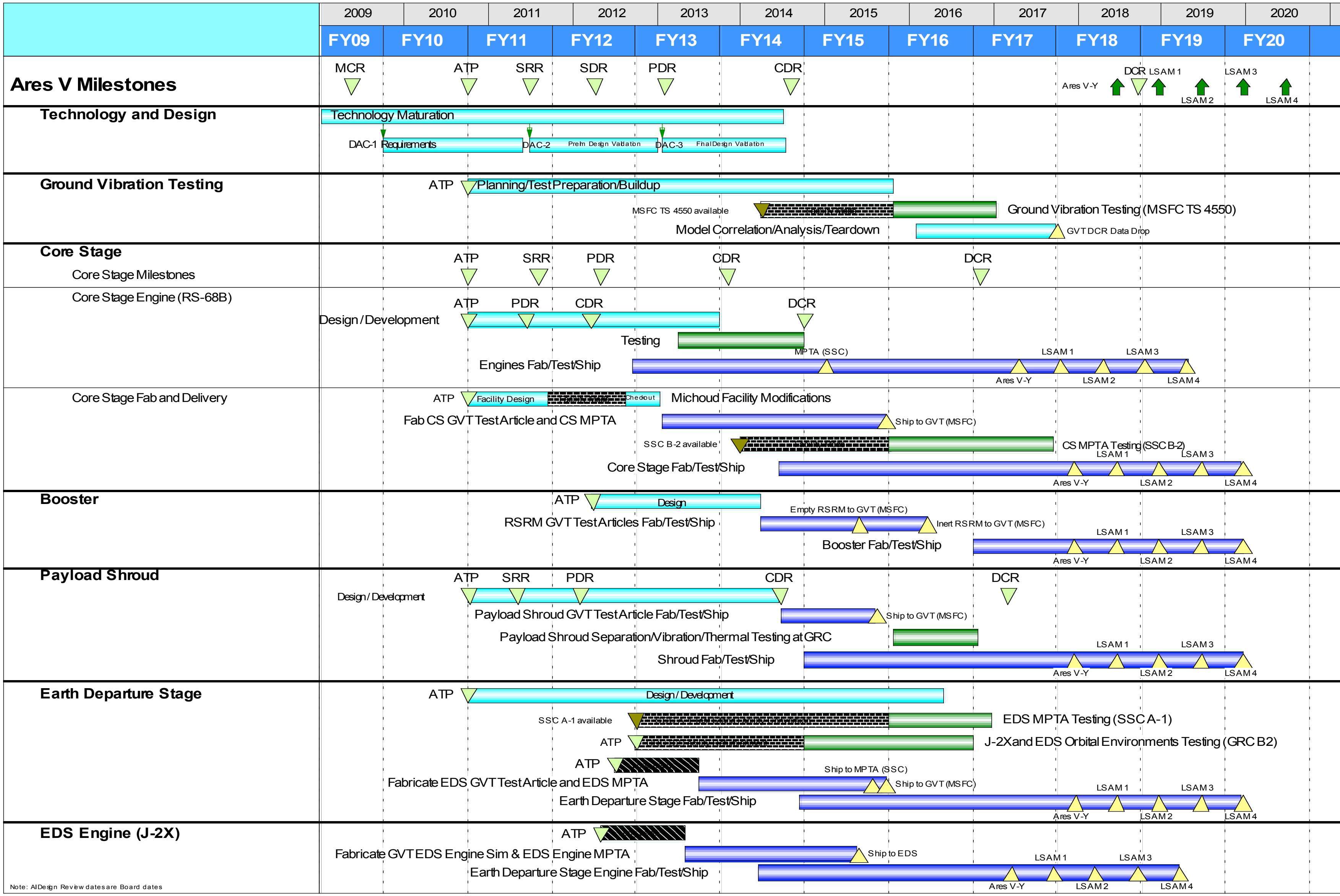
H (mm) :	11,923	5,000	8,000	11,923	11,923	11,923
R (mm) :	1,280	1,280	1,280	750	1,280	1,800



H (mm) :	11,923	15,000	20,000	11,923	11,923	11,923
R (mm) :	3,000	1,280	1,280	1,280	1,280	1,280

All shroud options have 9.7m barrel height to accommodate current Lunar Lander configuration.

Ares V Summary Schedule



National Aeronautics and Space Administration

Ares V Performance Description

www.nasa.gov

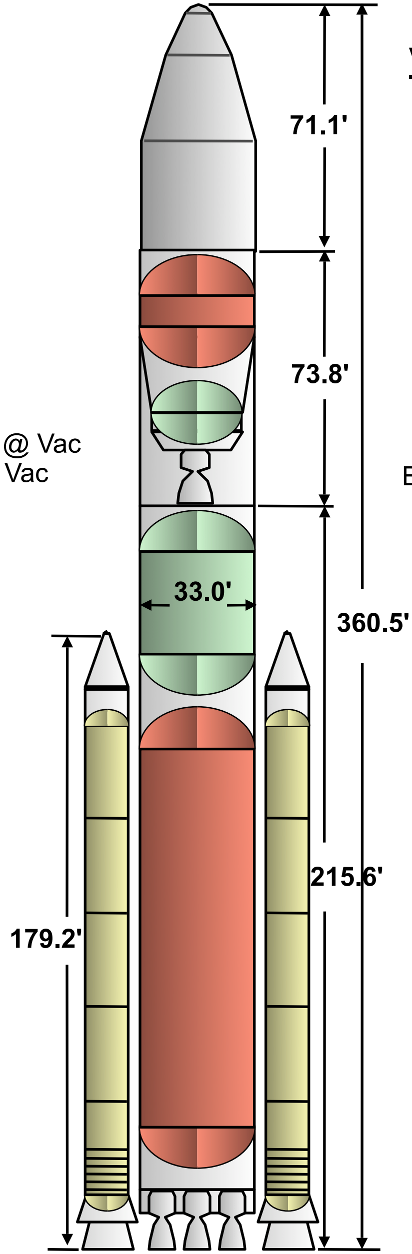
Ares V 51.0.39 Reference Baseline

EDS Stage — 4 day LEO loiter

Propellants	LOX/LH2
Usable Propellant	516,953 lbm
Propellant Offload	0.0 %
Stage liftoff pmf	0.8808
Launch Dry Mass	50,144 lbm
TLI Burnout Mass	55,287 lbm
Suborbital Burn Propellant	310,000 lbm
Pre-TLI Jettison Mass	6,895 lbm
LEO FPR	7,804 lbm
# Engines / Type	1 / J-2X
Engine Thrust (100%)	294,000 lbf / 238,000 lbf @ Vac
Engine Isp (100%)	448.0 sec / 449.0 sec @ Vac
Mission Power Level	100.0 % / 81.0 %
Suborbital Burn Time	472.4 sec
TLI Burn Time	390.4 sec

Delivery Orbit — 1.5 Launch TLI

LEO Delivery	130 nmi circular @ 29.0°
TLI Payload from 100 nmi	140,177 lbm (63.6 t)
CEV Mass	44,500 lbm (20.2 t)
LSAM Mass	95,677 lbm (43.4 t)
Insertion Altitude	131.6 nmi
T/W @ Liftoff + 1 sec	1.34
Max Dynamic Pressure	623 psf
Max g's Ascent Burn	3.90 g
T/W @ SRB Separation	1.32
T/W Second Stage	0.43
T/W @ TLI Ignition	0.58



Vehicle Concept Characteristics

GLOW	**7,440,326 lbf**
Payload Envelope L x D	25.3 ft x 30.0 ft
Shroud Jettison Mass	19,388 lbm

Booster (each)

Propellants	PBAN (262-07 Trace)
Overboard Propellant	1,390,548 lbm
Stage pmf	0.8628
Burnout Mass	221,175 lbm
# Boosters / Type	2 / 5 Segment SRM
Booster Thrust (@ 1.0 sec)	3,571,974 lbf @ Vac
Booster Isp (@ 1.0 sec)	272.8 sec @ Vac
Burn Time	125.9 sec

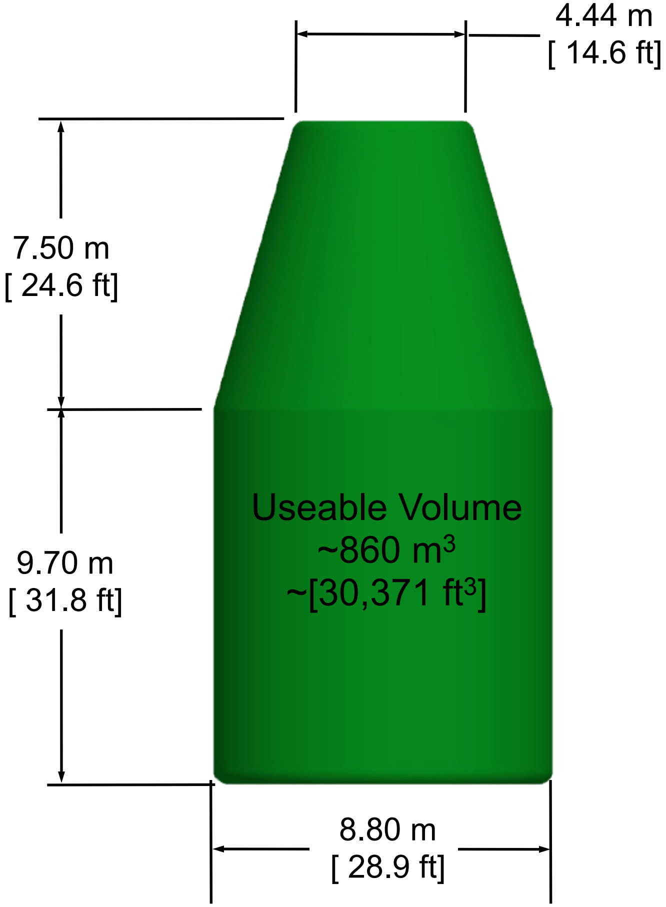
Core Stage

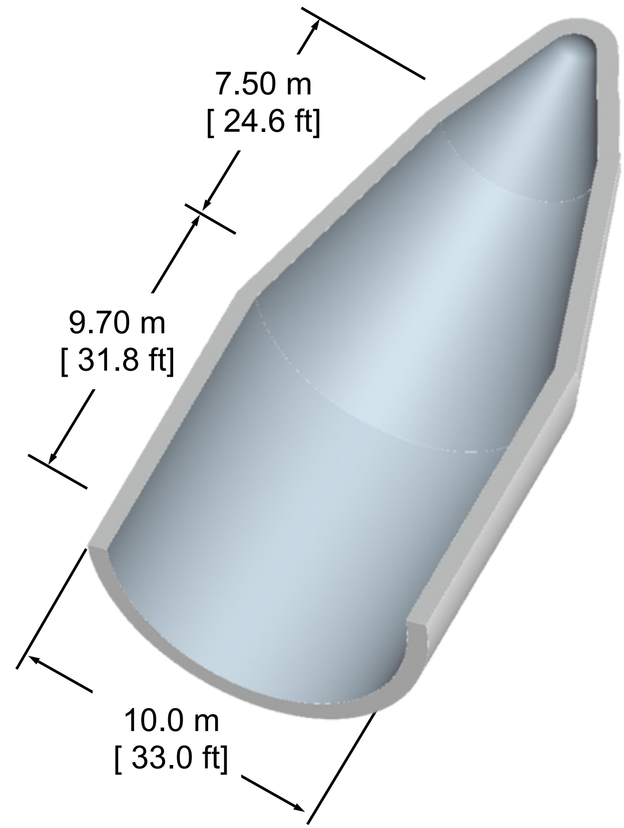
Propellants	LOX/LH2	
Usable Propellant	3,164,794 lbm	
Propellant Offload	0.0 %	
Stage pmf	0.9052	
Dry Mass	296,952 lbm	
Burnout Mass	331,411 lbm	
# Engines / Type	5 / RS-68	
Engine Thrust (108%)	702,055 lbf @ SL	797,000 lbf @ Vac
Engine Isp (108%)	360.8 sec @ SL	414.2 sec @ Vac
Mission Power Level	108.0 %	
Core Burn Time	328.9 sec	

Interstage — Core/EDS

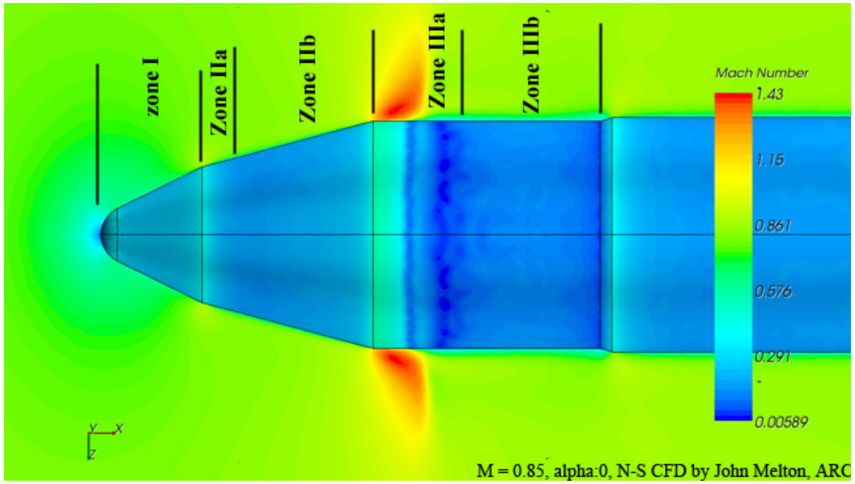
Dry Mass	18,672 lbm

Current Ares V Shroud Concept





Preliminary Aero-acoustic Analysis
- Transonic and Max-Q Acoustics -

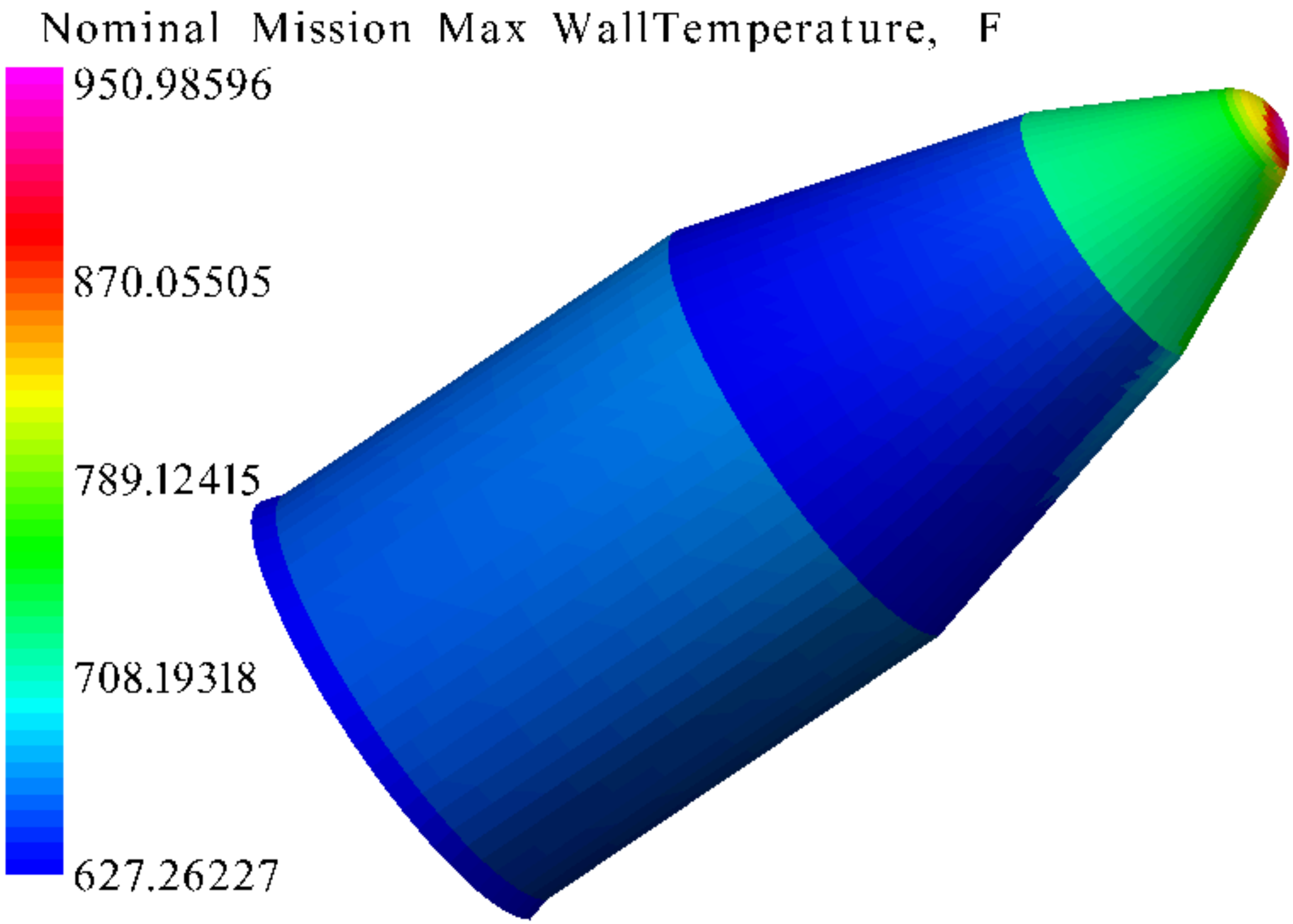


- Predicted ascent max-acoustic levels
- Conceptual design based on acoustic blanket thicknesses used on Cassini mission

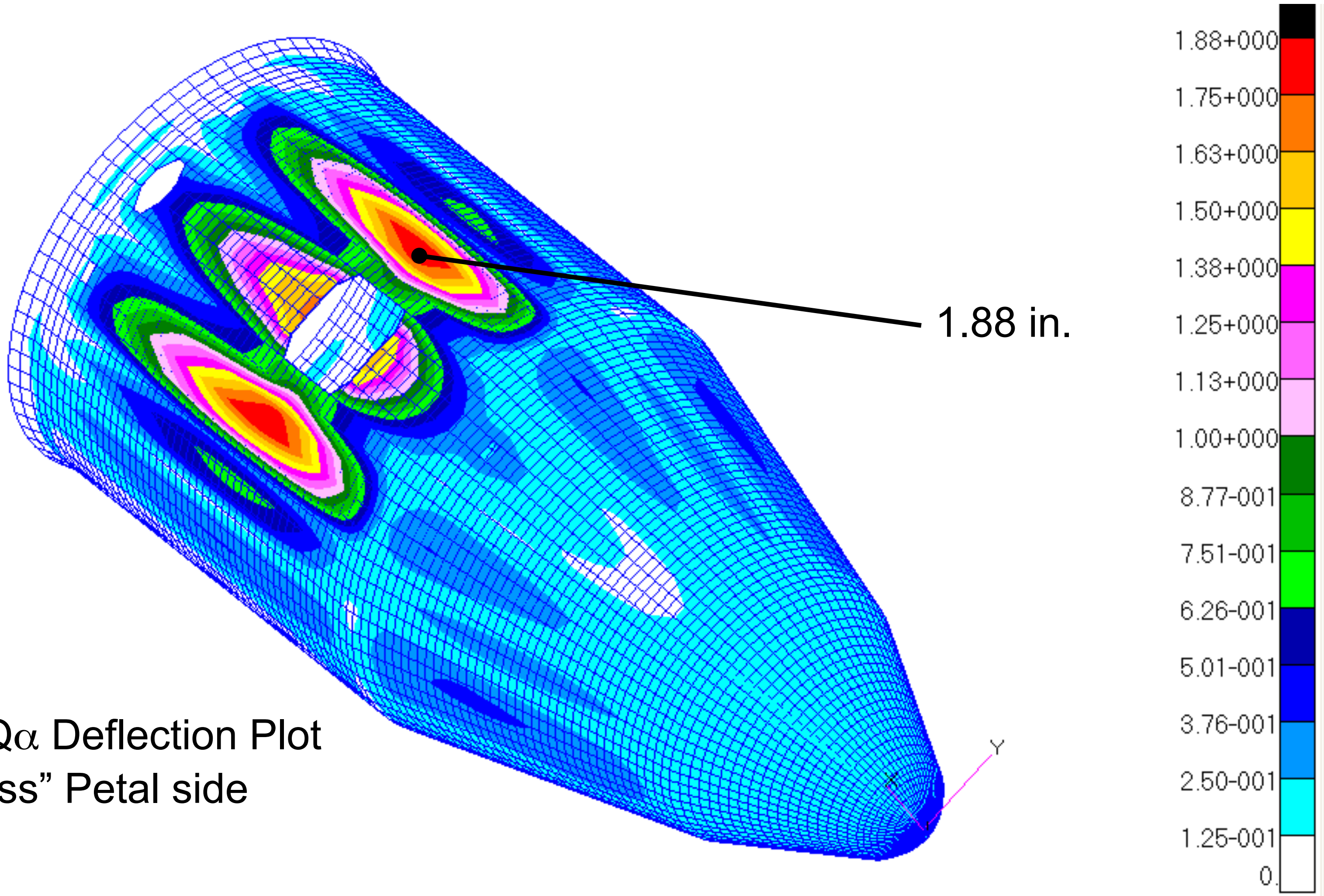
Table I. Estimated max Overall Fluctuating Pressure Level (OAFPL) on Shroud external regions

Zone	I	IIa	IIb	IIIa	IIIb
Criteria for Max OAFPL	Attached Turbulent Boundary Layer	Weak Transonic Shock	Attached Turbulent Boundary Layer	Strong Transonic Shock & Separation	Weak Transonic Shock
Expected Mach # for max OAFPL	1.65	0.93	1.65	0.85	0.85
Q (psf)	707	520	707	475	475
Crms	0.007	0.07	0.007	0.12	0.035
OAFPL (dB)	142	159	142	163	152

Preliminary Aerothermal Analysis
- Mission Maximum Temperature -



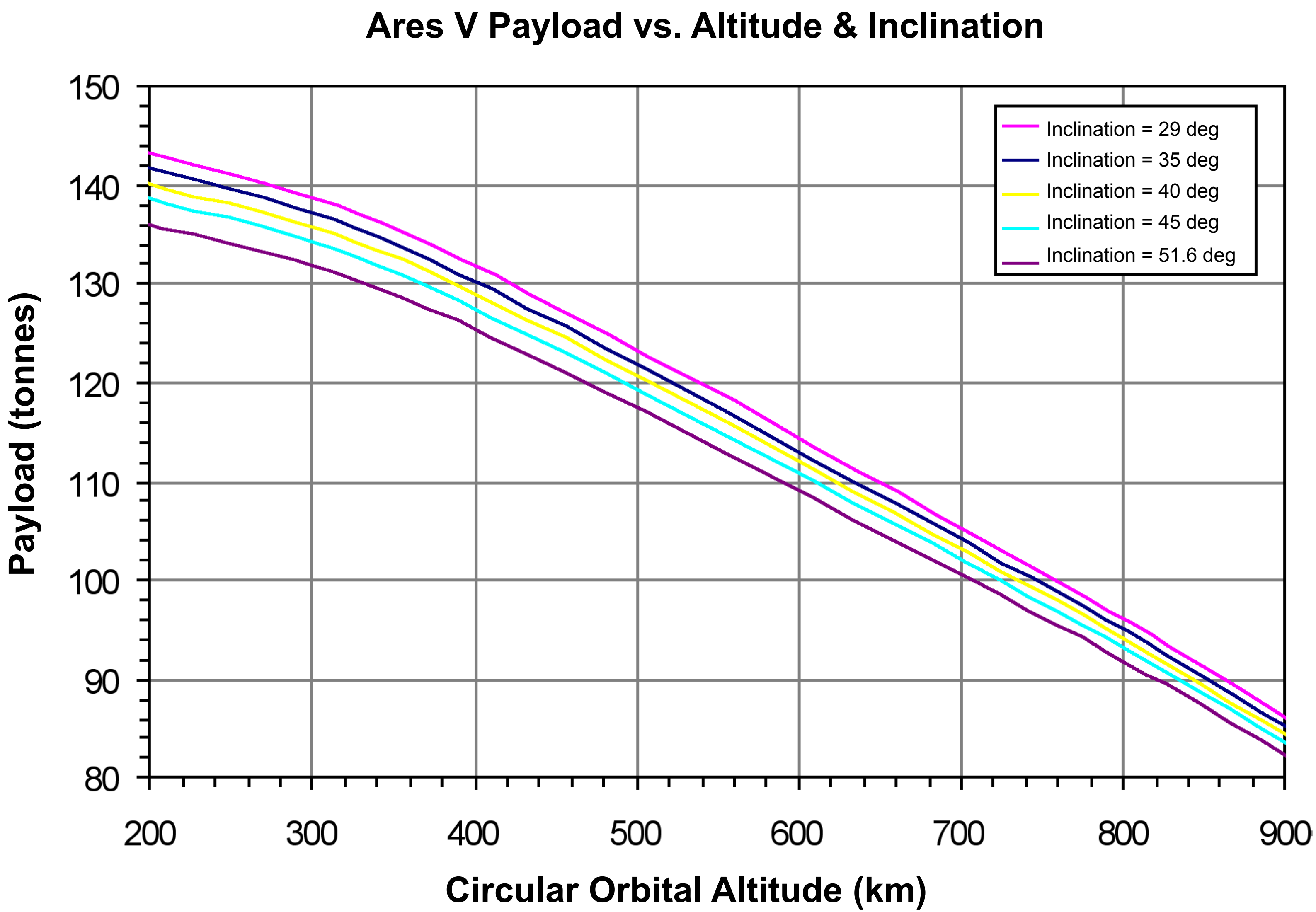
Preliminary Structural Analysis
- Maximum Static Deflection -



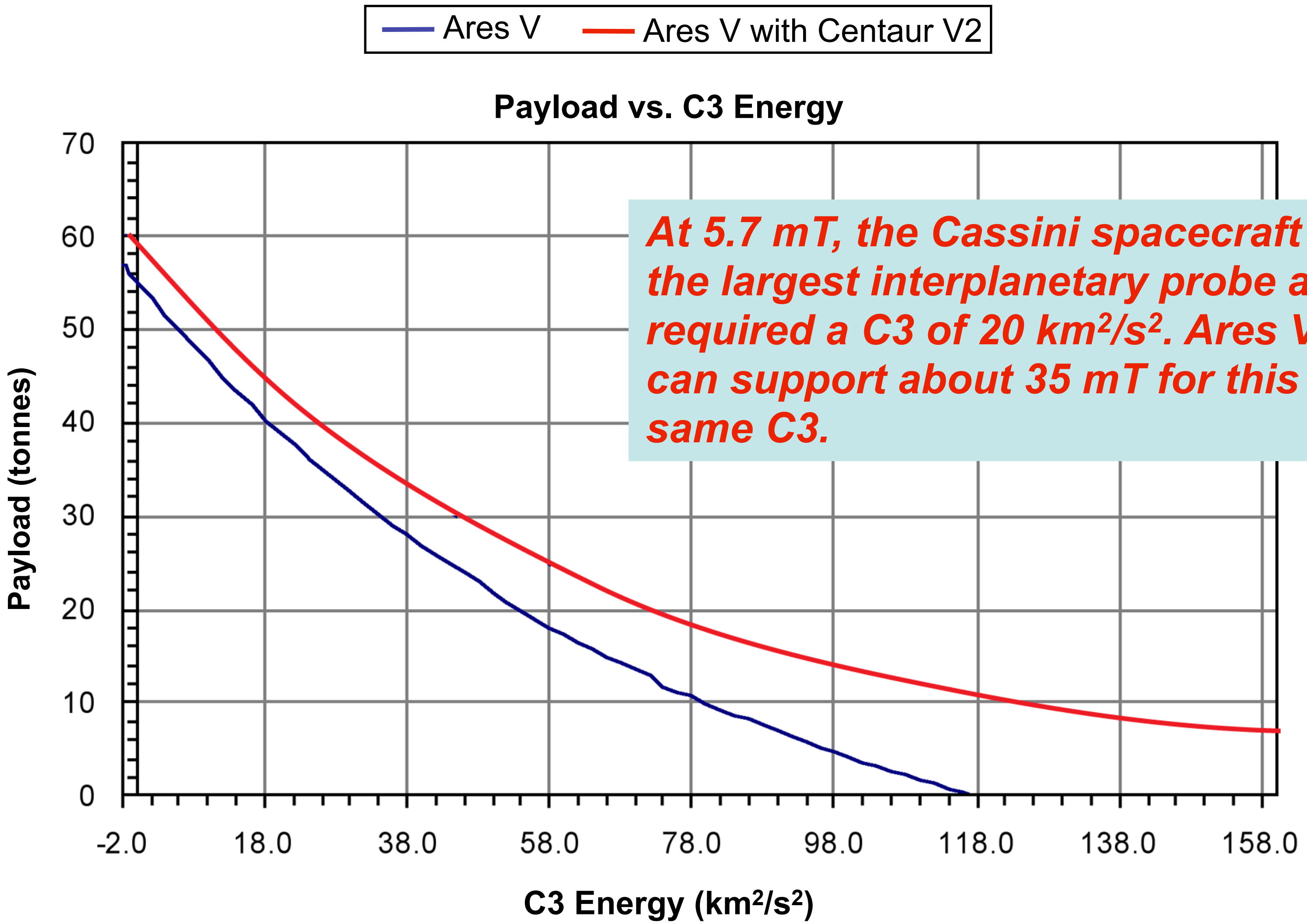
inches

Max Qα Deflection Plot
"Access" Petal side

Ares V LEO Performance

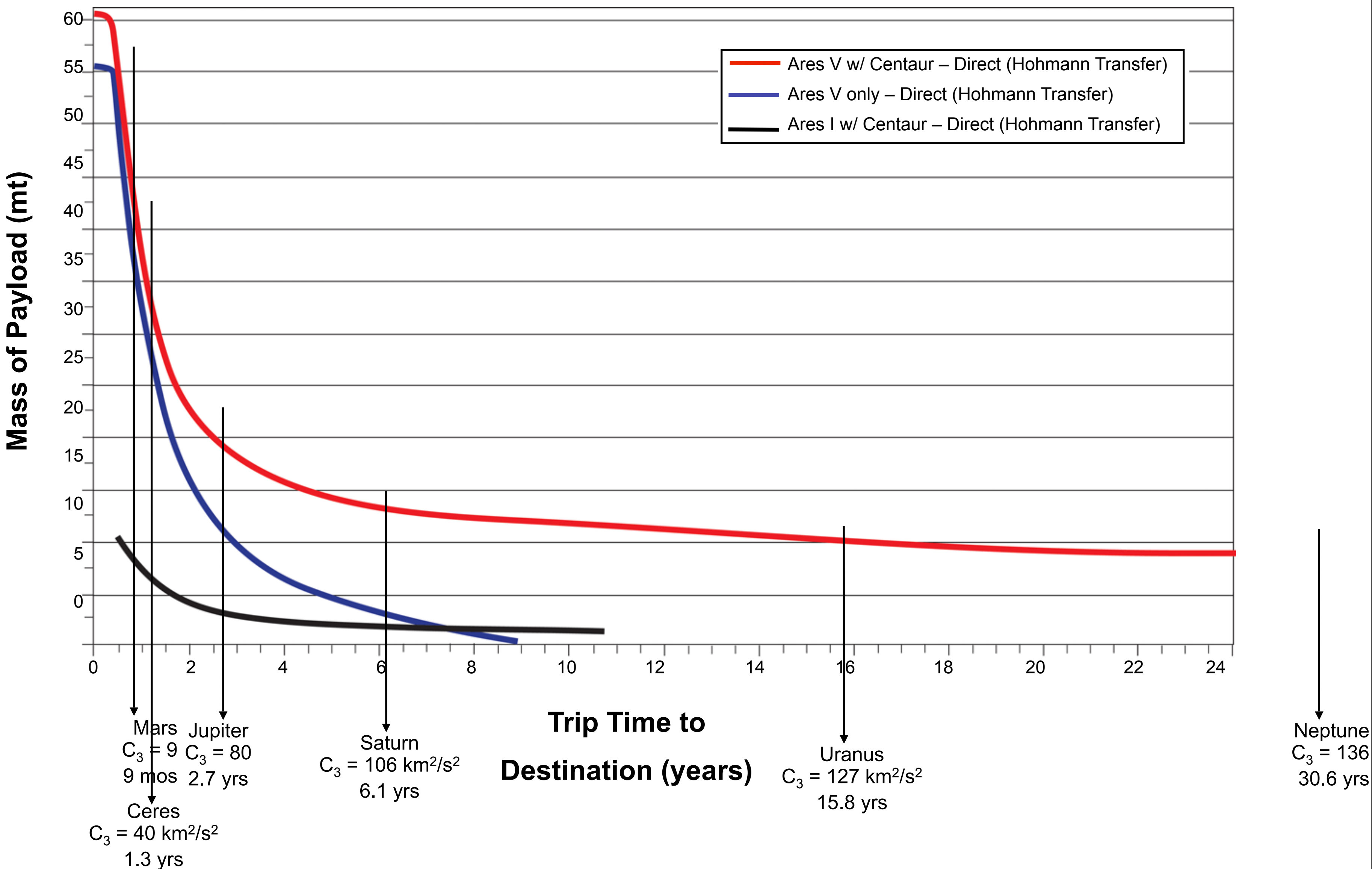


Ares V Escape Performance

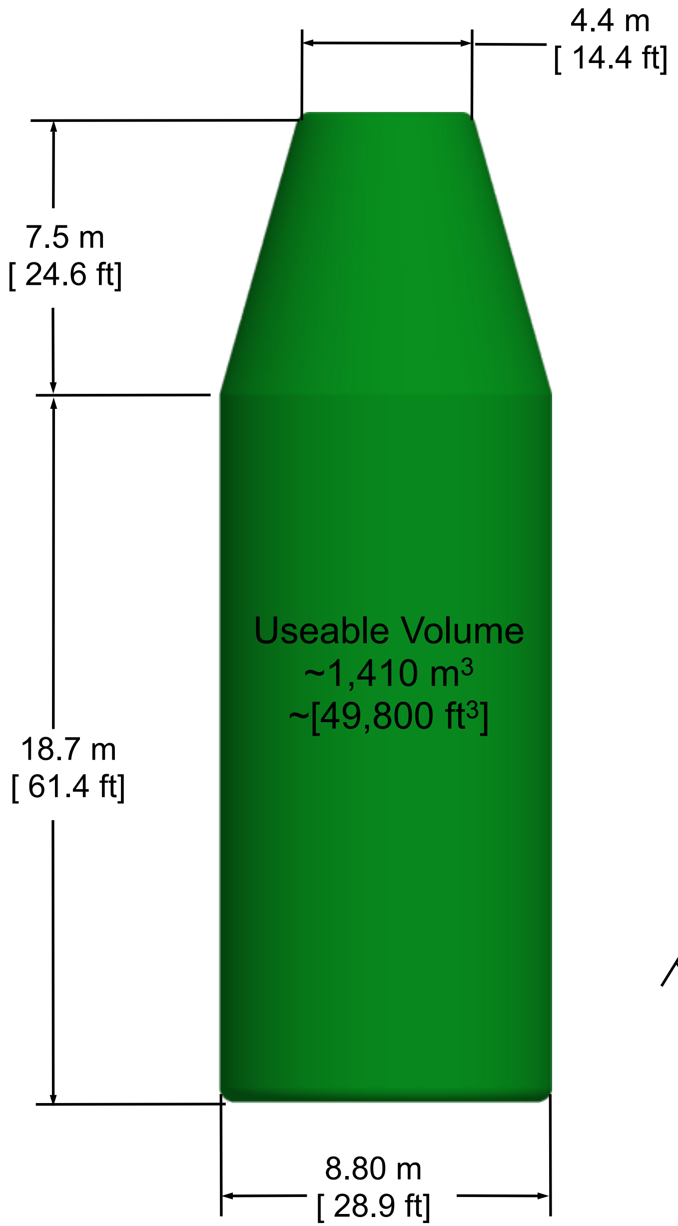


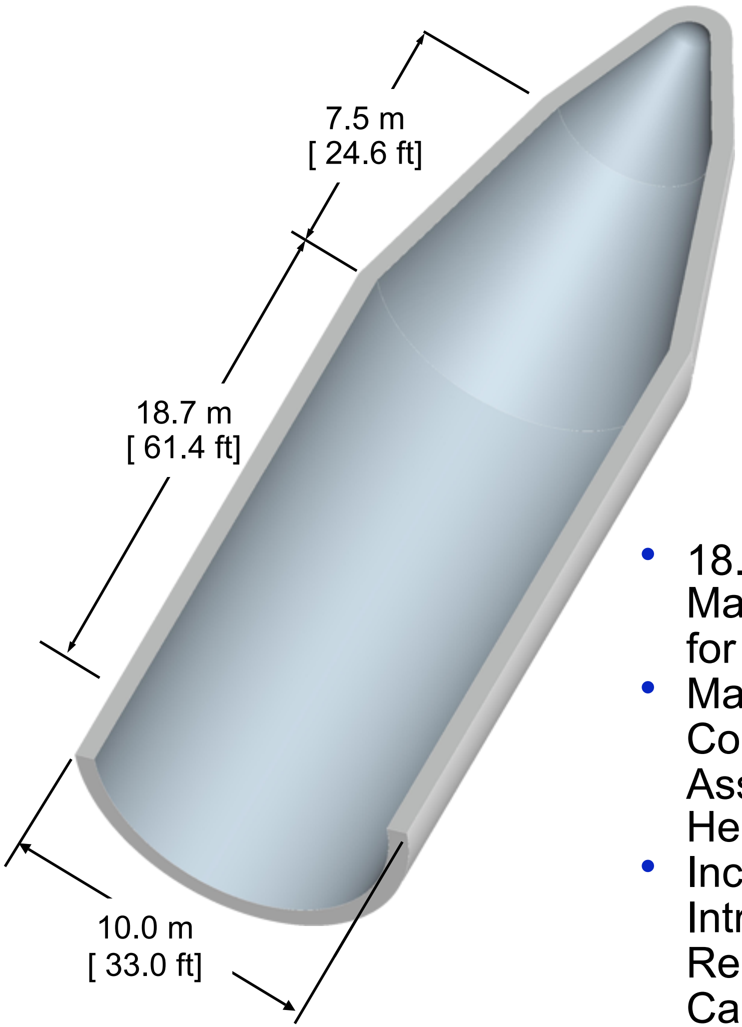
At 5.7 mT, the Cassini spacecraft is the largest interplanetary probe and required a C3 of 20 km^2/s^2. Ares V can support about 35 mT for this same C3.

Payload vs. Trip Times for Representative Missions
- Constellation POD Shroud -



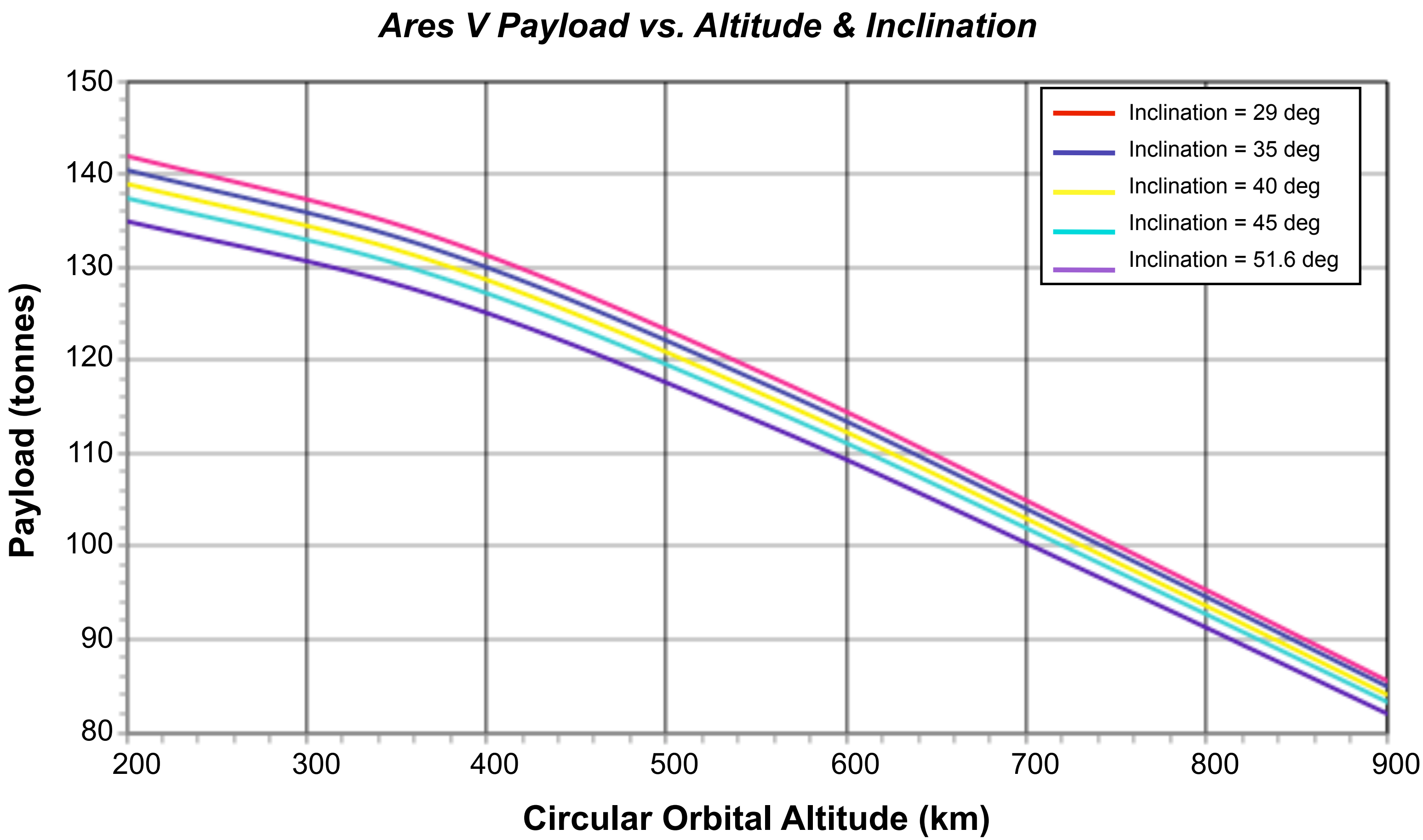
Notional Ares V Shroud for Other Missions



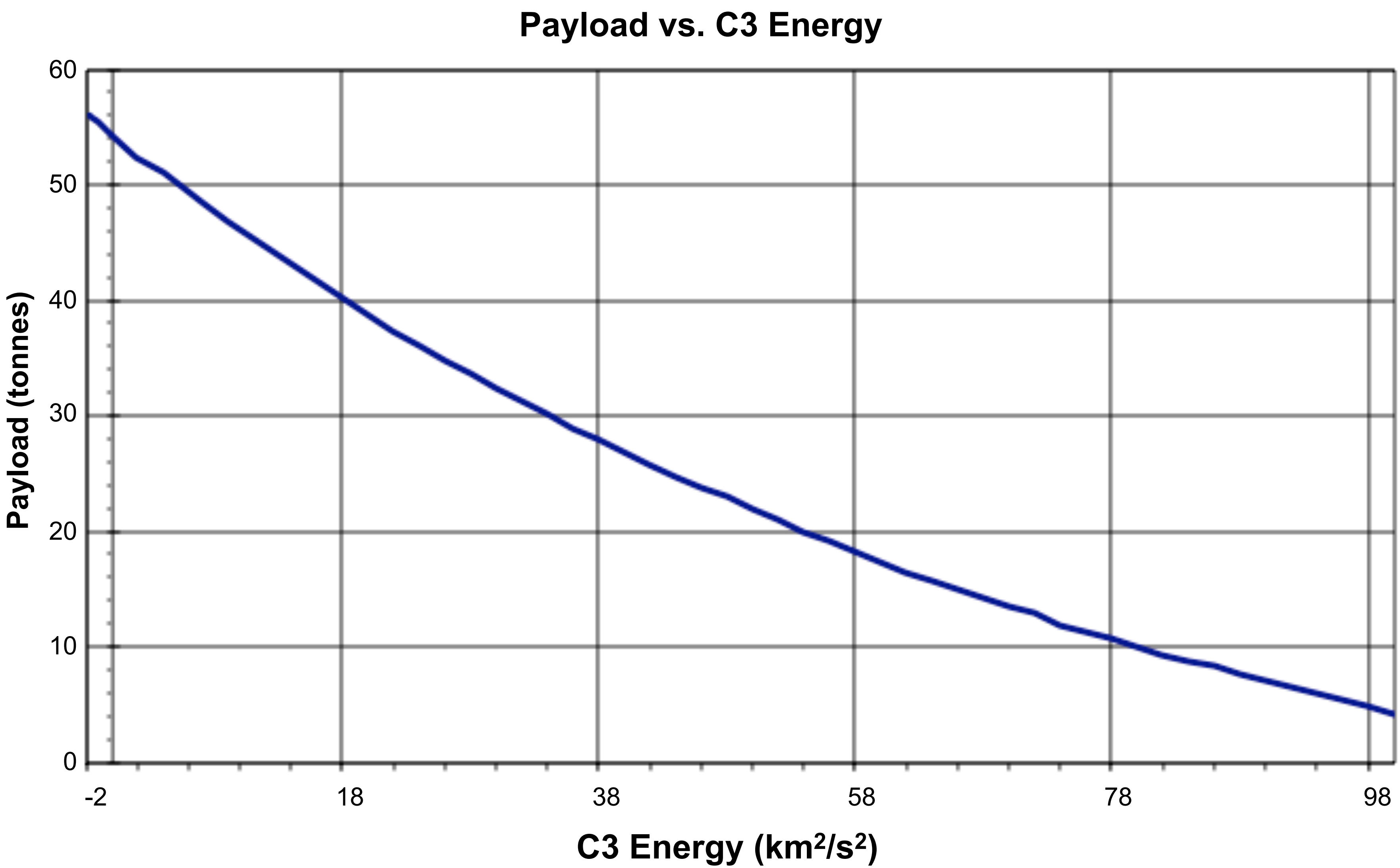


- 18.7 m Represents the Maximum Barrel Length for the Shroud
- Maximum Barrel Length Constrained Vehicle Assembly Building (VAB) Height
- Increased Barrel Length Introduces Theoretical Reduction of Payload Capability of 200 kg

Ares V LEO Performance
- Extended Shroud -



Ares V Escape Performance
- Extended Shroud -



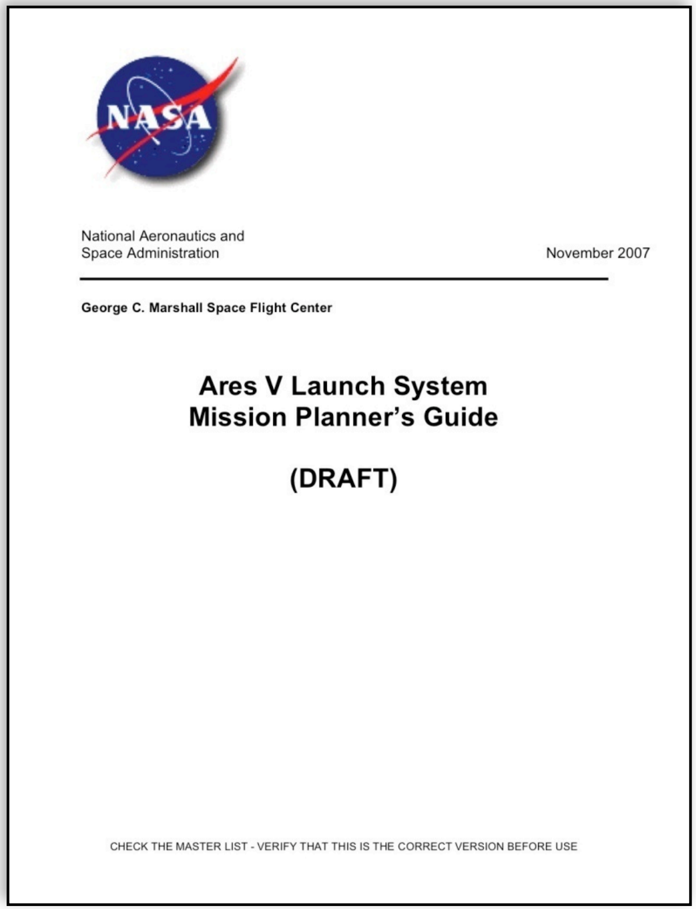
Ares V Performance for Selected Missions

1) **Sun-Earth L2 Mission**
   - Target C3 energy of -0.7 km^2/s^2 @ 29.0 degrees
2) **Geosynchronous Transfer Orbit (GTO)**
   - Final orbit: 185 km x 35,786 km @ 27 degrees
   - Intermediate orbit: LEO insertion at 185 km circ. @ 28.5 degrees
3) **Geosynchronous Earth Orbit (GEO)**
   - Final orbit: 35,786 km circular @ 0 degrees
   - Intermediate orbit: LEO insertion at 185 km circ. @ 28.5 degrees
     - Note: assessed as single burn; no boil-off assumed between burns; 500 lb_m knock-down included for additional engine restart
4) **Lunar Outpost Cargo (Direct TLI), Reference**
   - Target C3 energy of -1.8 km^2/s^2 @ 29.0 degrees

Mission Profile	Target	Constellation POD Shroud		Extended Shroud	
		Payload (lb_m)	Payload (t)	Payload (lb_m)	Payload (t)
1) Sun-Earth L2	C3 of -0.7 km^2/s^2	123,100	55.8	121,600	55.1
2) GTO Injection	Transfer DV 8,200 ft/s	155,100*	70.3*	153,700*	69.7*
3) GEO	Transfer DV 14,100 ft/s	79,700	36.2	78,700	35.7
4) Cargo Lunar Outpost (TLI Direct), Reference	C3 of -1.8 km^2/s^2	125,300	56.8	123,700	56.1

* Performance impacts from structural increases due to larger payloads has not been assessed

Developing Ares V Launch System Mission Planner's Guide


National Aeronautics and Space Administration

November 2007

George C. Marshall Space Flight Center

Ares V Launch System
Mission Planner's Guide

(DRAFT)

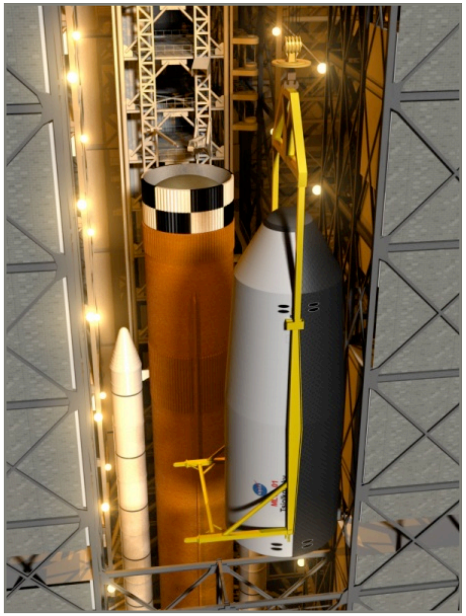
CHECK THE MASTER LIST - VERIFY THAT THIS IS THE CORRECT VERSION BEFORE USE

- **Mission Planner Guide Planned for Draft Release in Summer 2008**
  - Interface Definitions
    - Fairings, Adapters…
  - Mission Performance
  - Development Timelines
  - Concept of Operations
  - Potential Vehicle Evolution and Enhancements
  - Need Past Astronomy Mission Data

National Aeronautics and Space Administration

Summary

- The focus of design efforts in the near future will be on the primary Lunar mission.
- We are currently just beginning to integrate the design functions from the various centers for this mission.
- We appreciate all thoughts and ideas for different ways to us the Ares V platform



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Backup

www.nasa.gov

Ground Rules and Assumptions

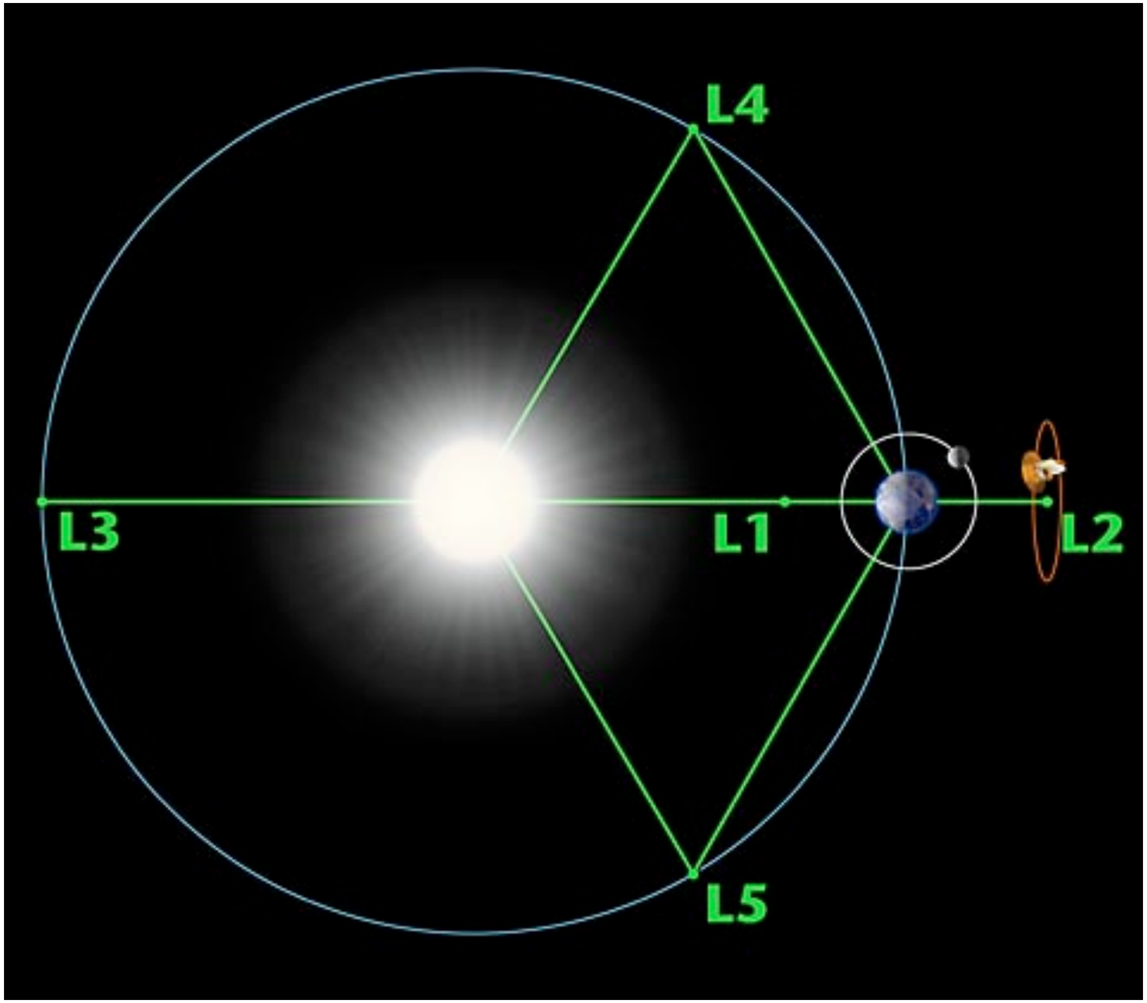
- All trajectories analyzed using POST3D (Program to Optimize Simulated Trajectories - 3 Dimensional)
- Flight performance reserve is based on the Ares V LEO mission, and is held constant for all cases
- No gravity assists
- Interplanetary trip times are based on Hohmann transfers (limited to ~24 years 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)

Ground Rules and Assumptions (Cont'd)

- **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**

Sun-Earth Lagrange Points

- The figure shows the Lagrange points associated with the Sun-Earth system
- L2 roughly 1.5 million kilometers beyond Earth
- L1, L2, and L3 are unstable, so any spacecraft placed there must do stationkeeping
- Typically insert the spacecraft into a halo orbit about the Lagrange point, such as shown about L2.



Shapes Delivered to MSFC (2/25/08) to Support Upcoming Wind Tunnel Test