How might the Ares V change the need for future Mirror Technology

H. Philip Stahl

For over 30 years, science mission capabilities have been constrained by launch vehicles.

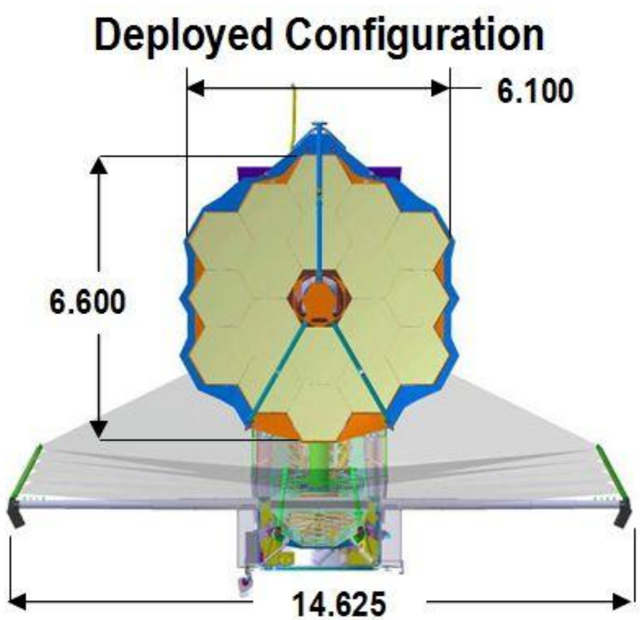
Hubble and Chandra were specifically designed to match Space Shuttle's payload volume and mass capacities.

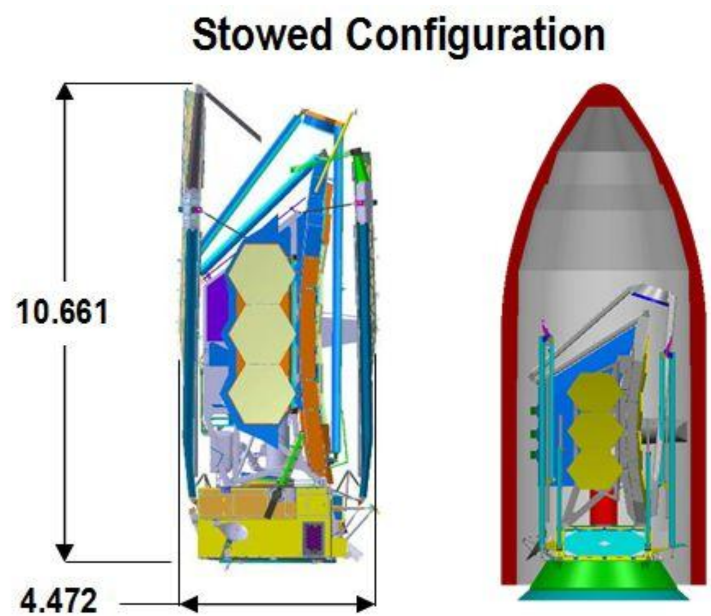
	Payload Mass	Payload Volume
Space Shuttle Capabilities	25,061 kg (max at 185 km) 16,000 kg (max at 590 km)	4.6 m x 18.3 m
Hubble Space Telescope	11,110 kg (at 590 km)	4.3 m x 13.2 m
Chandra X-Ray Telescope (and Inertial Upper Stage)	22,800 kg (at 185 km)	4.3 m x 17.4 m

Launch Vehicles Continue to Constrain Missions

Similarly, JWST is sized to the Capacities of Ariane 5

	Payload Mass	Payload Volume
Ariane 5	6600 kg (at SE L2)	4.5 m x 15.5 m
James Webb Space Telescope	6530 kg (at SE L2)	4.47 m x 10.66 m



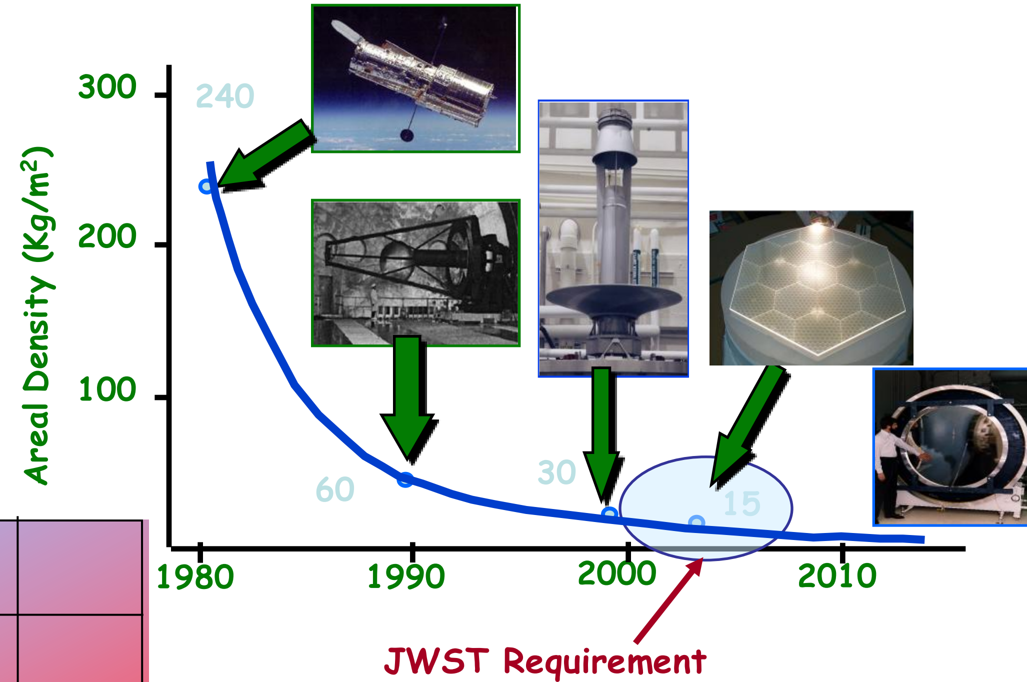


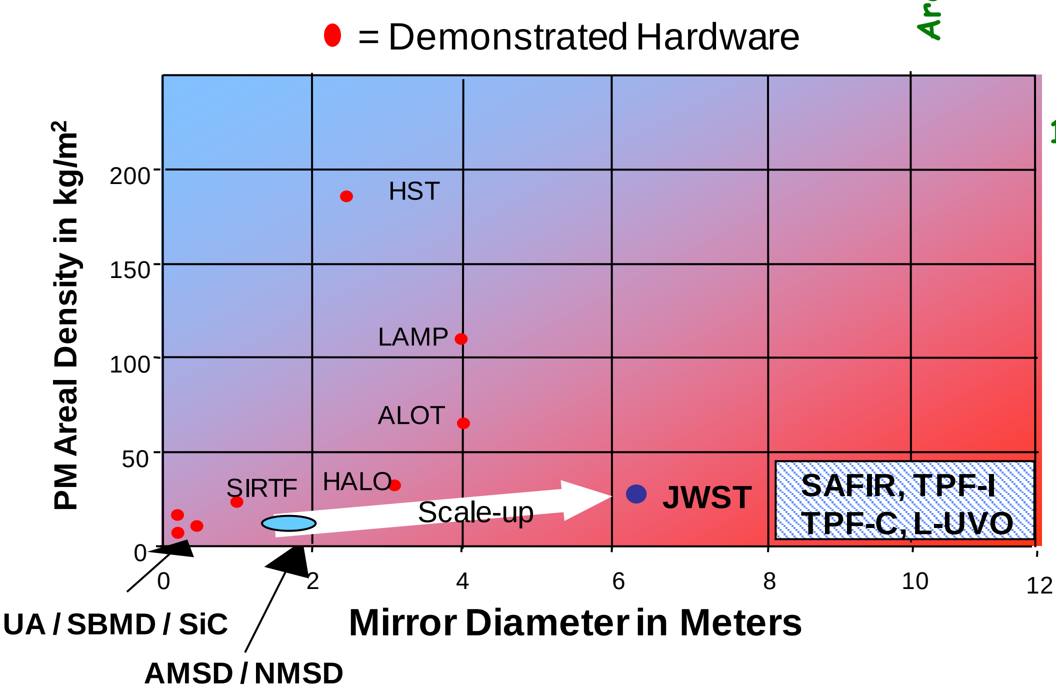
In the 9 years I've been at NASA the over riding mantra for Space Telescope has been Areal Density.

Challenges for Optical & X-Ray Telescopes:

Areal Density to enable up-mass for larger telescopes.

Cost & Schedule Reduction.





Primary Mirror	Time	& Cost
HST (2.4 m)	≈ 1 m²/yr	≈ $10M/m²
Spitzer (0.9 m)	≈ 0.3 m²/yr	≈ $10M/m²
AMSD (1.2 m)	≈ 0.7 m²/yr	≈ $4M/m²
JWST (6 m)	> 6 m²/yr	< $3M/m²

Note: Areal Cost in FY00 $

Ares V delivers 6X more Mass to Orbit

Current Capabilities can Deliver

23,000 kg to Low Earth Orbit
10,000 kg to GTO or L2TO Orbit

5 meter Shroud

Ares V can Deliver

~180,000 kg to Low Earth Orbit
~60,000 kg to L2TO Orbit
10 meter Shroud

Ares V offers a New Paradigm

The unprecedented volume and mass capabilities of an Ares V enables an entirely new design paradigm:

Simplicity

Simple high TRL technology offers:

lower mission cost and risk.

Simplicity = Cost Reduction

More Massive Missions do not need to be More Expensive.

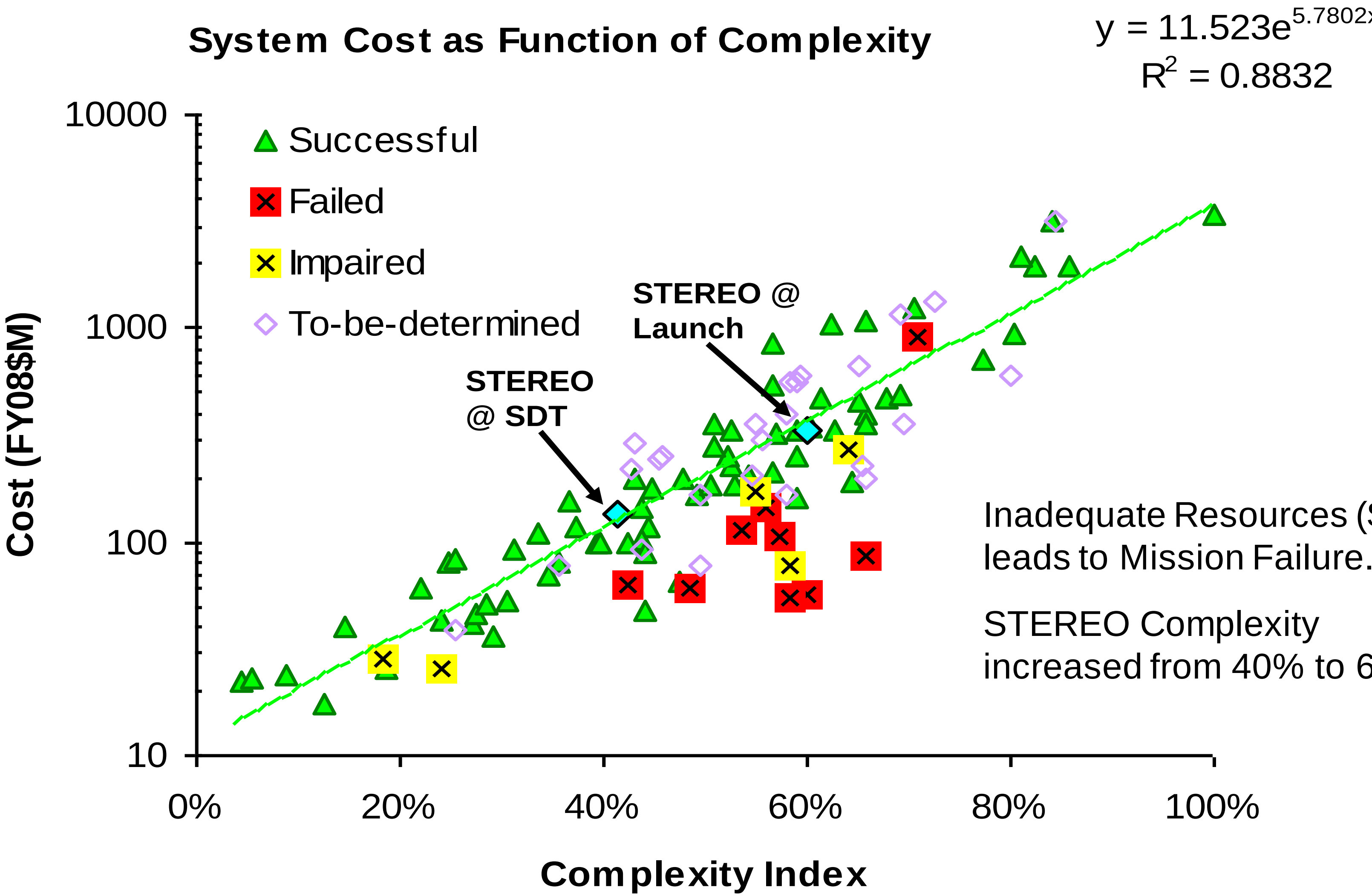
Simple, robust, low-risk, high-TRL mission is likely to be low cost.

It is also likely to be more massive than a complex, high-risk, low TRL mission.

The challenge will be to overcome human nature.

Launch Date Constrained Missions Cost Less

Effect of Increased Complexity on Flight System Cost and Mission Success

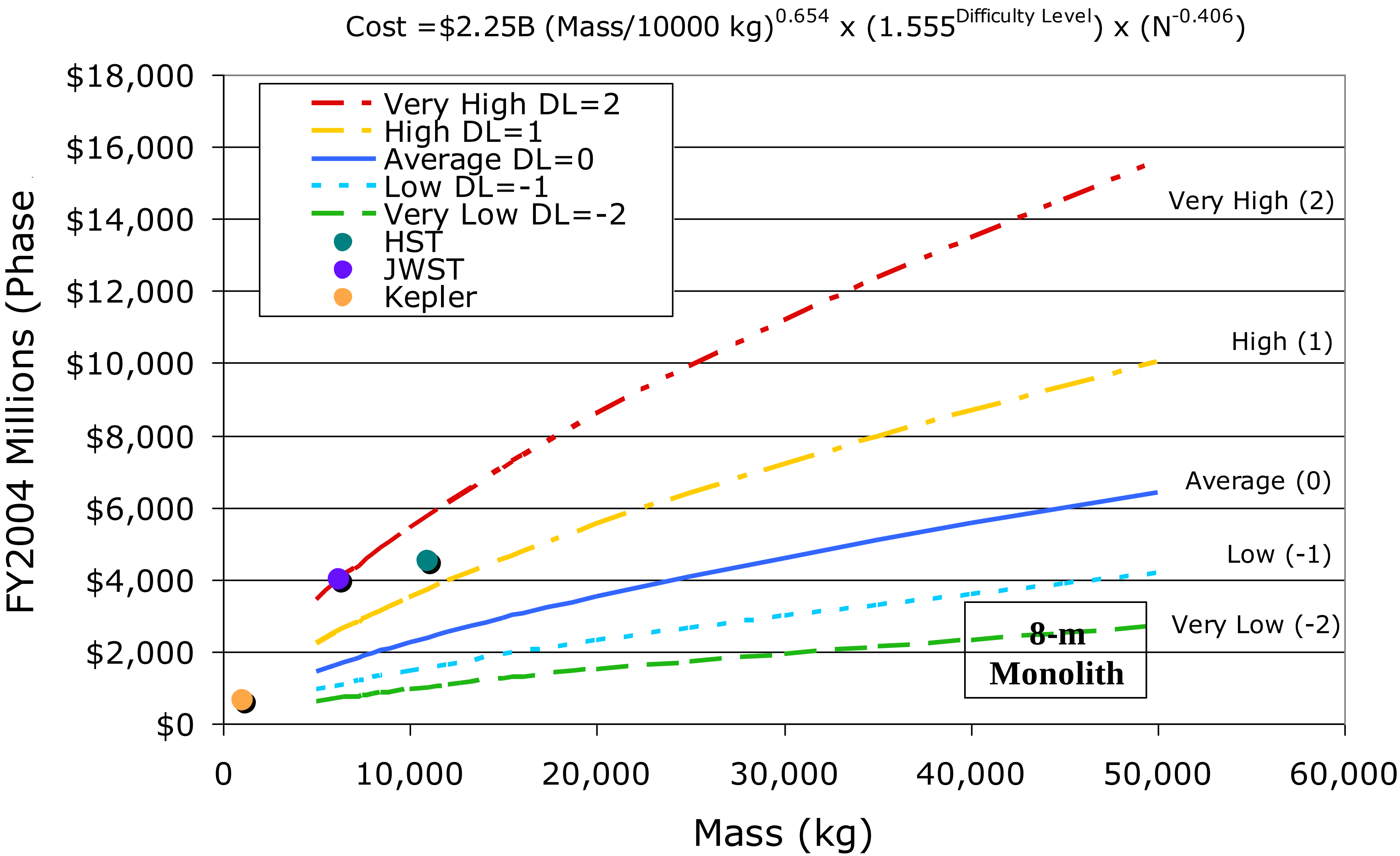


Inadequate Resources ($) leads to Mission Failure.

STEREO Complexity increased from 40% to 60%.

Bearden, David, “Perspectives on NASA Mission Cost and Schedule Performance Trends”, copyright Aerospace Corp., GSFC Symposium, 3 June 2008.

Cost is driven more by Complexity than Mass



NASA JSC COST MODEL

Simplicity = Cost Reduction

Cost models typically estimate that engineering design, AI&T, management, fees and program reserve is 2.5X to 3X the component costs.

Thus, every $1 spent at the component level = $3.5 to $4 at the program level.

Consider an 8 meter (50 m2) 500 nm diffraction limited primary mirror
- HST’s $10M/m2 areal cost yields a $500M 8-m primary mirror
- JWST’s $6M/m2 (2 μm DL) areal cost yields a $300M PM
- 8-m Ground Telescope mirrors cost $20M to $40M.

A $250M to $450M savings in the cost of a primary mirror translates into a $800M to $1.8B potential total program cost savings.

The total cost for an 8-meter observatory (excluding science instruments and operations is estimated to be $1B to $1.5B.

Ares V Changes Paradigms

Ares V Mass & Volume enable entirely new Mission Architectures:

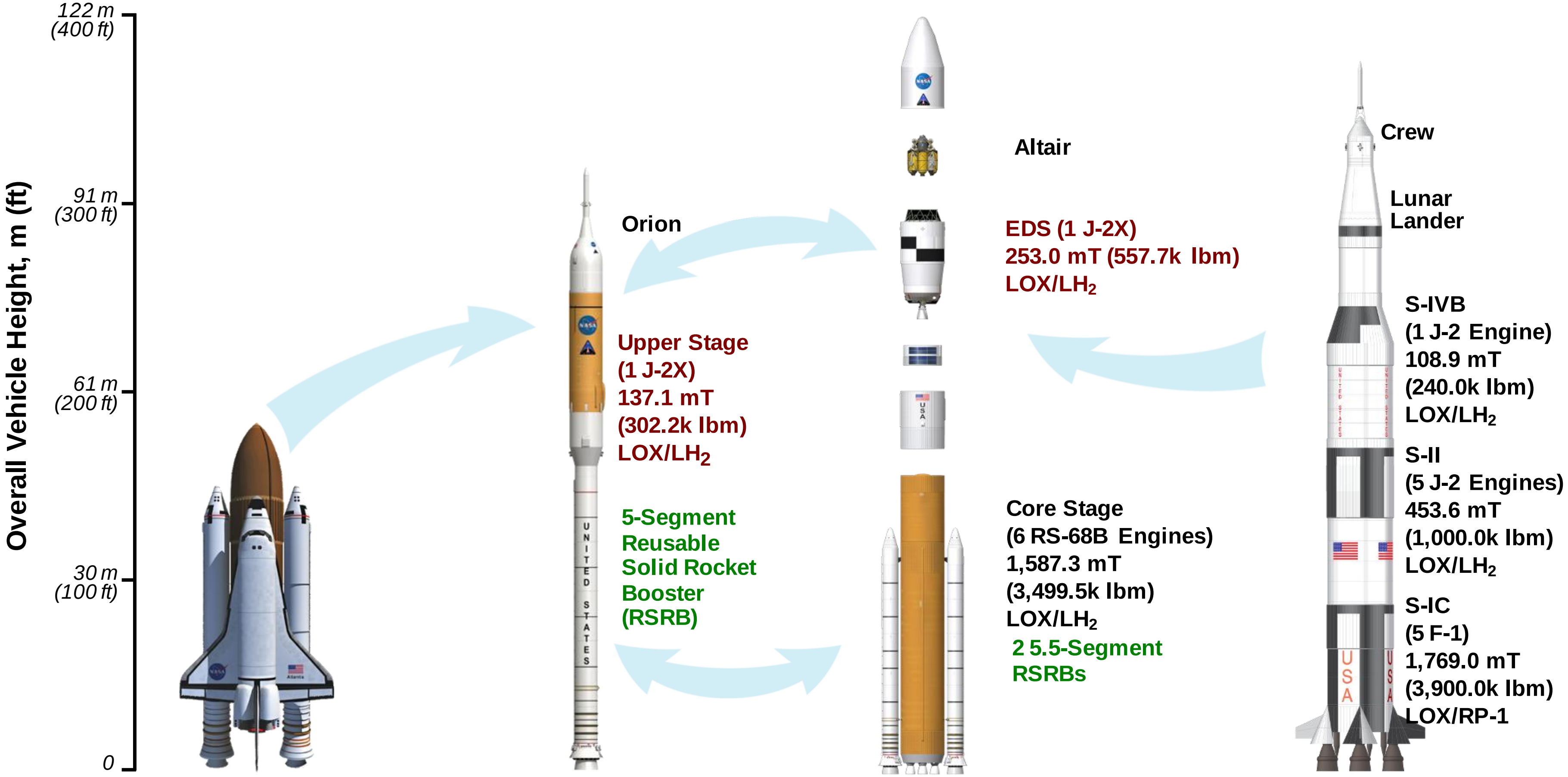
- 8 meter class Monolithic UV/Visible Observatory

Ares V Performance Capability

(at this point in time)

Building on a Foundation of Proven Technologies

- Launch Vehicle Comparisons -



Space Shuttle

Height: 56 m (184 ft)
Gross Liftoff Mass:
2,041 mT (4.5M lbm)

Payload Capability:
25.0 mT (55k lbm)
to Low Earth Orbit (LEO)

Ares I

Height: 99 m (325 ft)
Gross Liftoff Mass:
927.1 mT (2.0M lbm)

Payload Capability:
25.5 mT (56.2k lbm)
to LEO

Ares V

Height: 116 m (381 ft)
Gross Liftoff Mass:
3,704.5 mT (8,167.1k lbm)

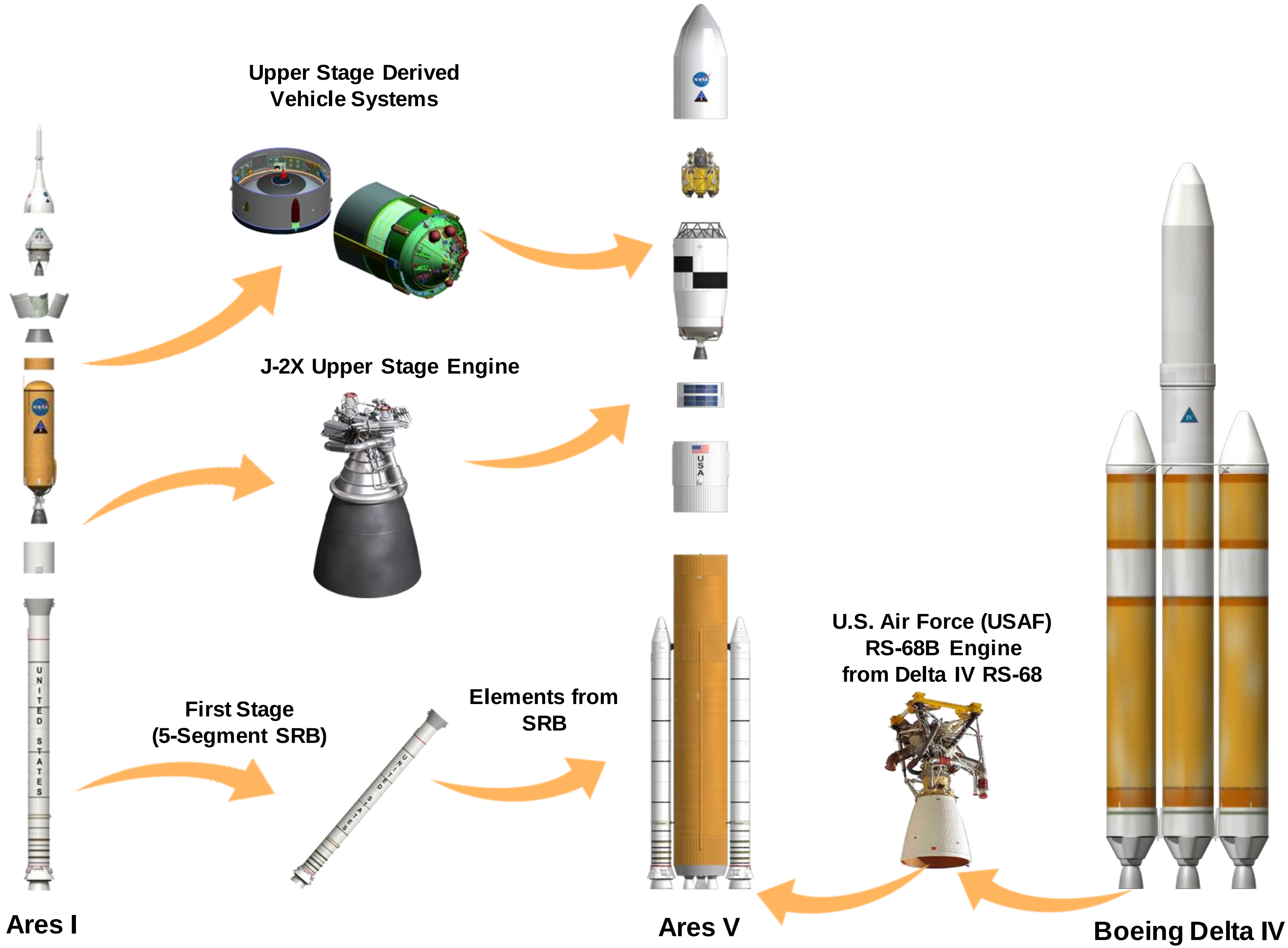
Payload Capability:
62.8 mT (138.5k lbm) to TLI
~187.7 mT (413.8k lbm) to LEO

Saturn V

Height: 111 m (364 ft)
Gross Liftoff Mass:
2,948.4 mT (6,500k lbm)

Payload Capability:
44.9 mT (99.0k lbm) to TLI
118.8 mT (262.0k lbm) to LEO

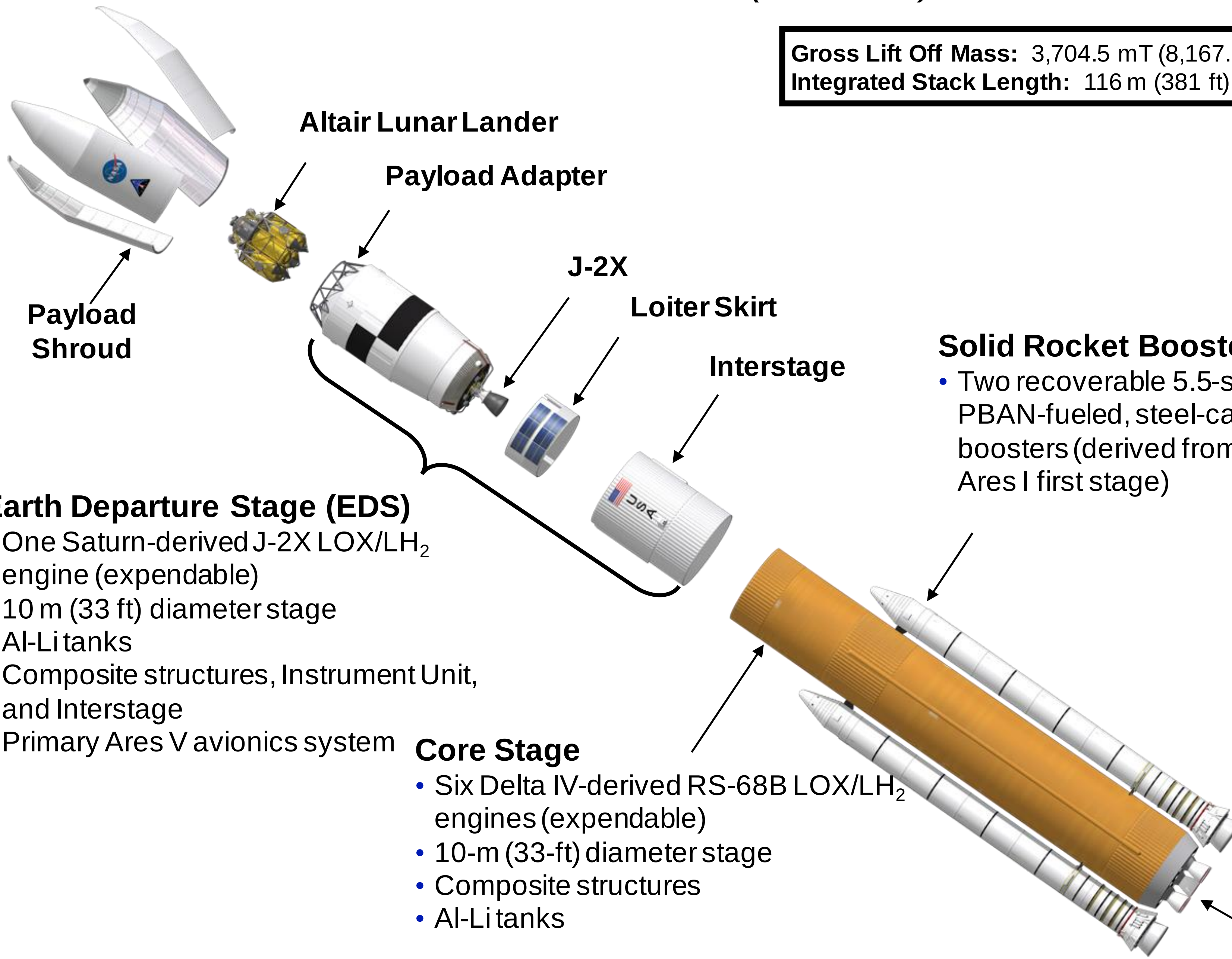
Ares V Element Heritage



Ares V Elements

New POD Vehicle (51.00.48)

Gross Lift Off Mass: 3,704.5 mT (8,167.1k lbm)
Integrated Stack Length: 116 m (381 ft)



Solid Rocket Boosters (2)

- Two recoverable 5.5-segment PBAN-fueled, steel-casing 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
- Al-Li tanks
- Composite structures, Instrument Unit, and Interstage
- Primary Ares V avionics system

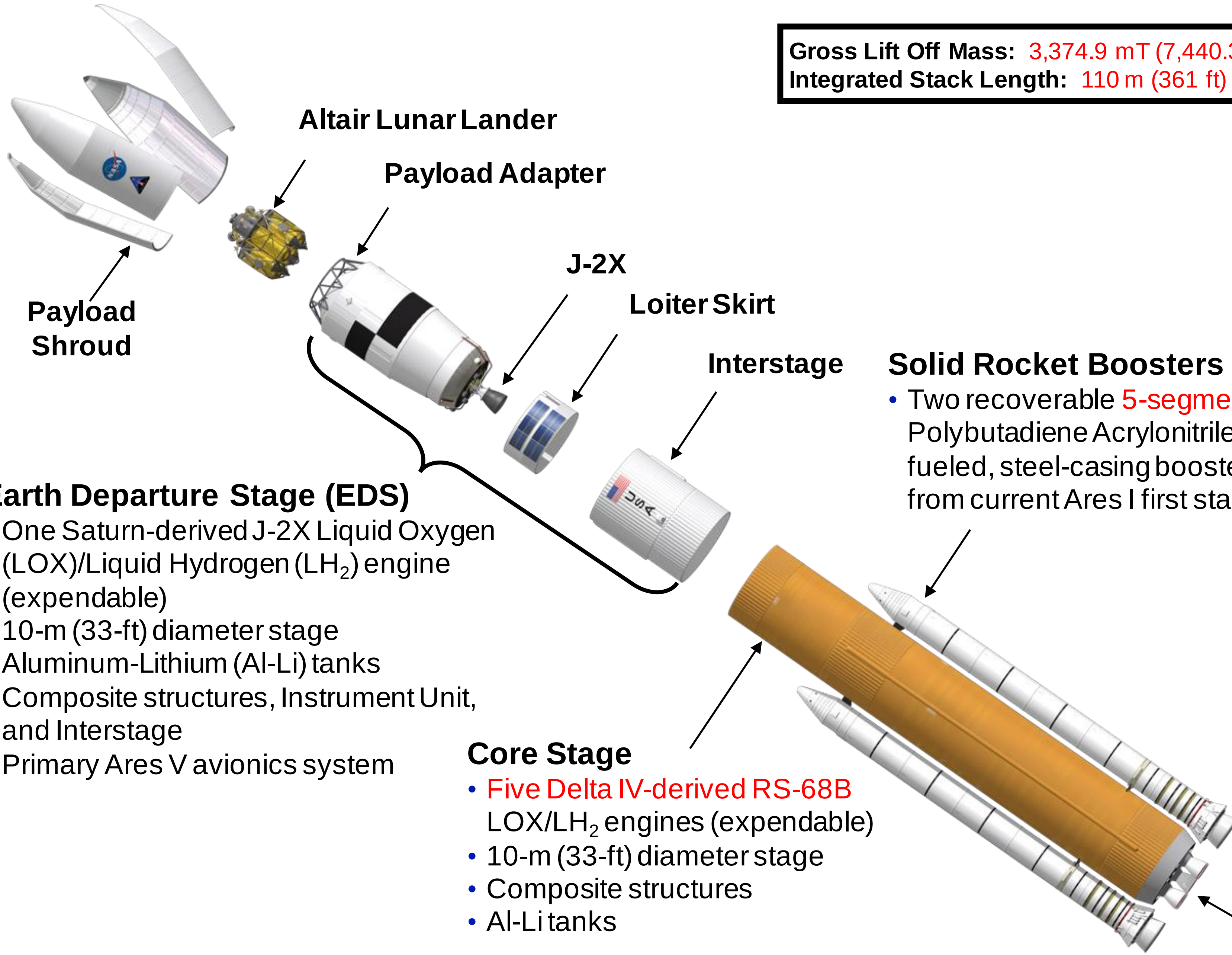
Core Stage

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

Ares V Elements

Initial POD Vehicle (51.00.39)

Gross Lift Off Mass: 3,374.9 mT (7,440.3k lbm)
Integrated Stack Length: 110 m (361 ft)



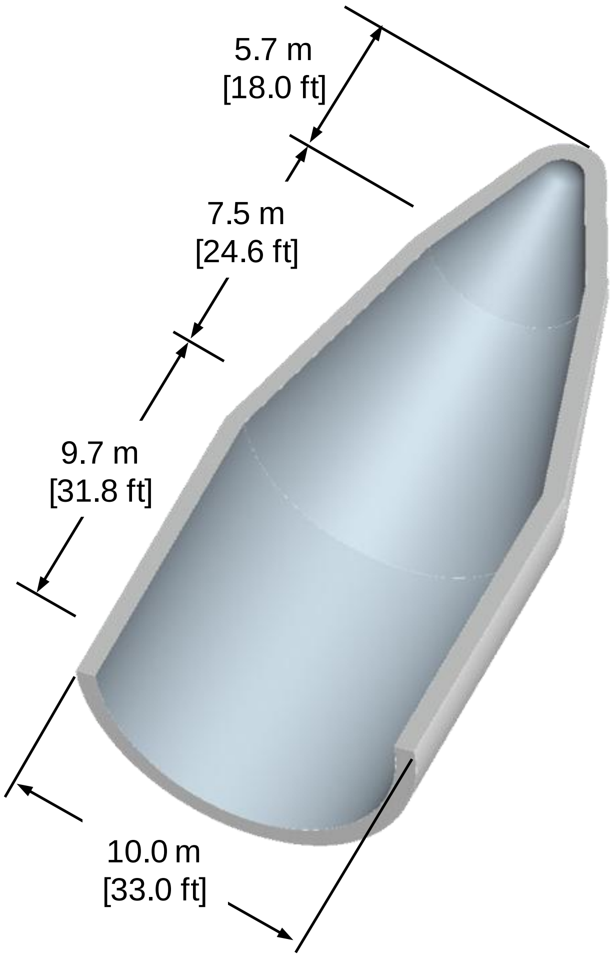
Solid Rocket Boosters (SRB) (2)
- Two recoverable 5-segment Polybutadiene Acrylonitrile (PBAN)-fueled, steel-casing boosters (derived from current Ares I first stage)

Earth Departure Stage (EDS)
- One Saturn-derived J-2X Liquid Oxygen (LOX)/Liquid Hydrogen (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

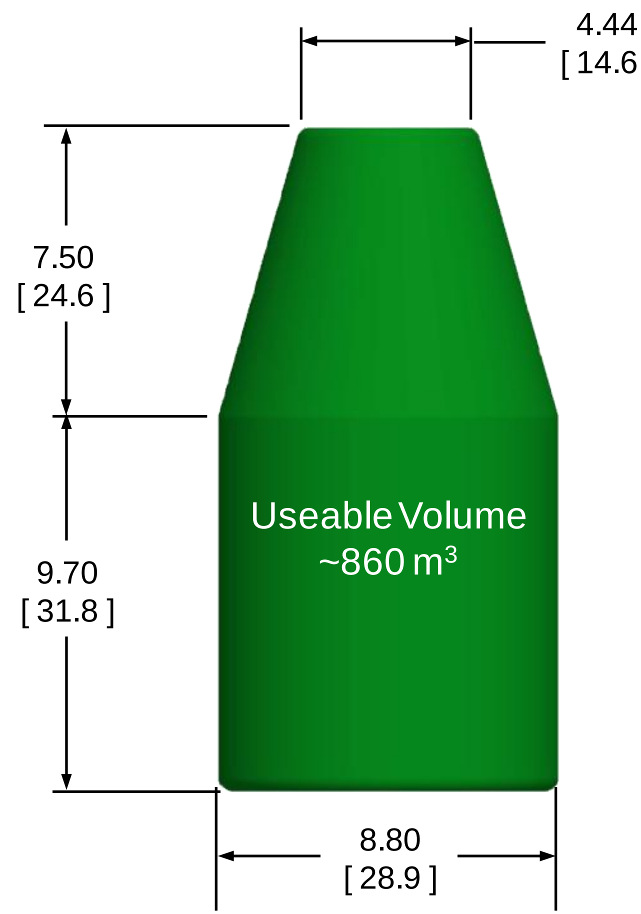
Core Stage
- Five Delta IV-derived RS-68B LOX/LH_2 engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Al-Li tanks

Current Ares V 10 meter Shroud - Biconic

Shroud Dimensions



Usable Dynamic Envelope

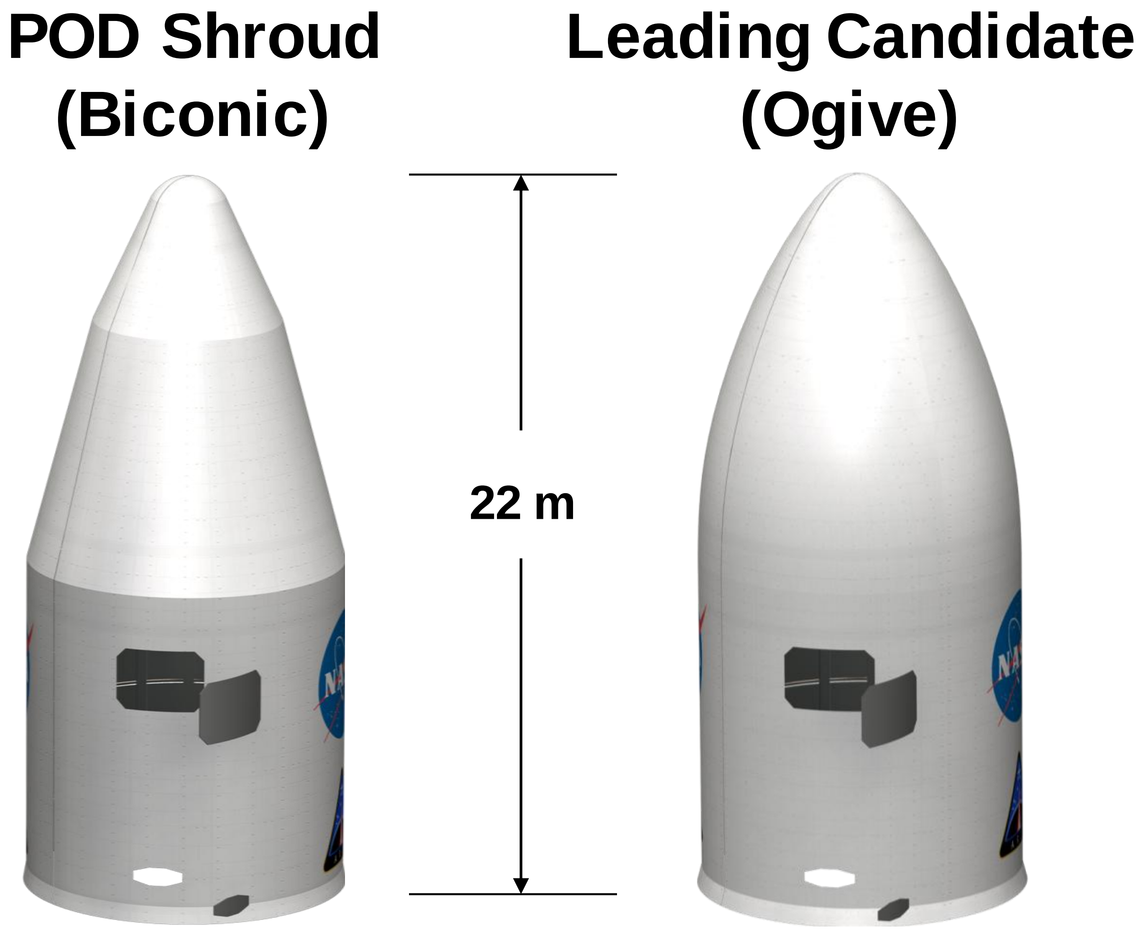


Mass: 9.1 mT (20.0k lbm)

Total Height: 22 m (72 ft)

meters [feet]

Alternative Payload Shroud Design Concept



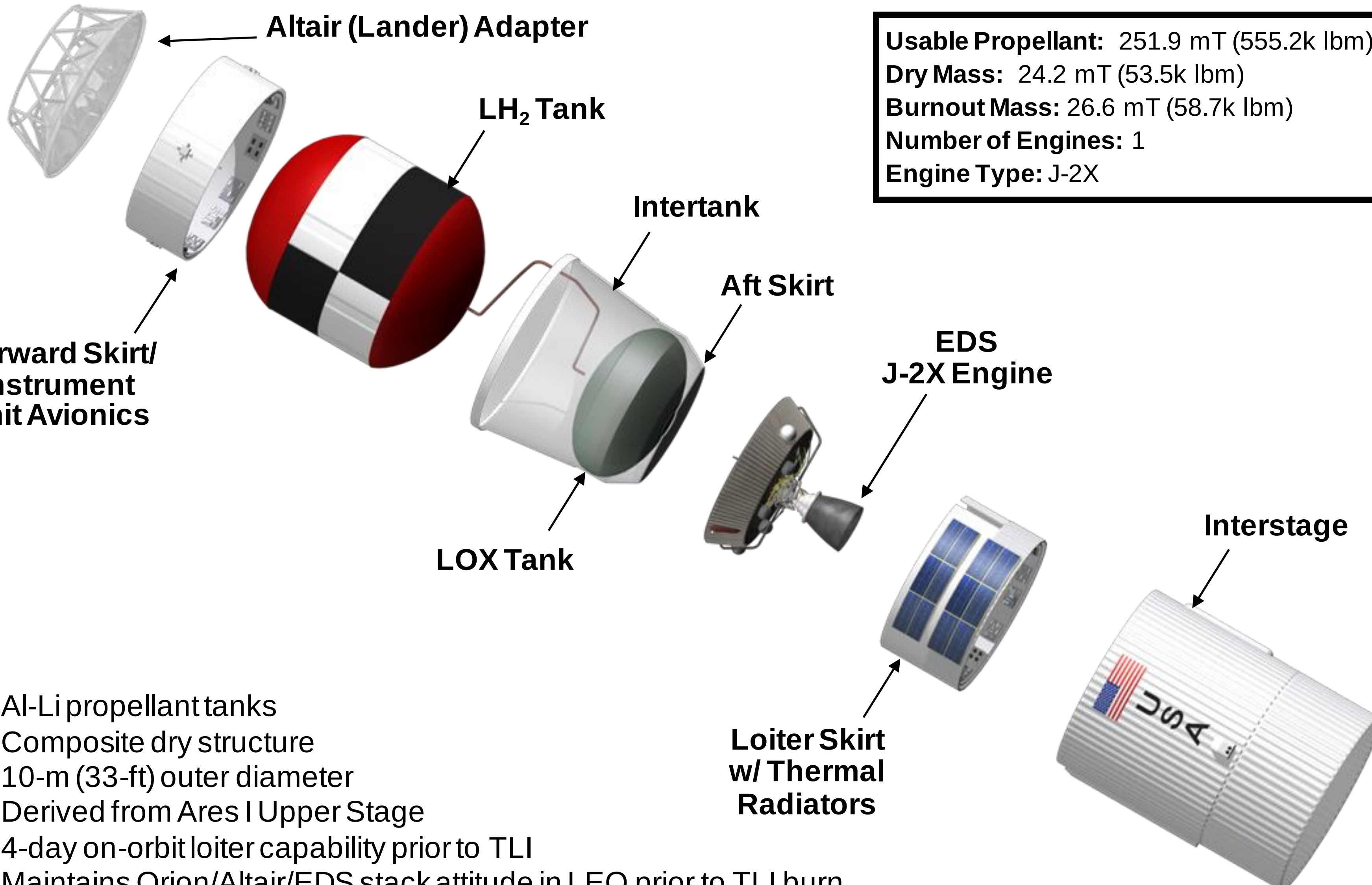
Ogive Shroud provides more usable vertical payload height than Biconic

Both have extra space below the official volume ‘Reserved’ for Altair Adapter

EDS Current Design Concept

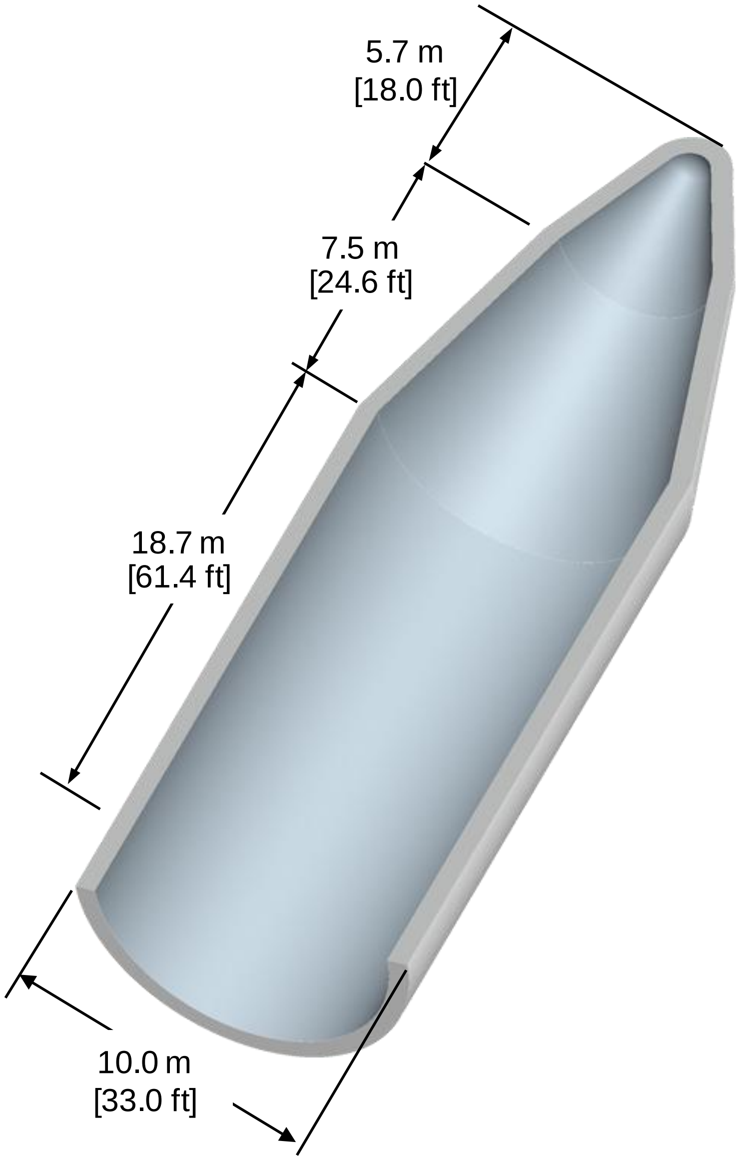
Expanded View

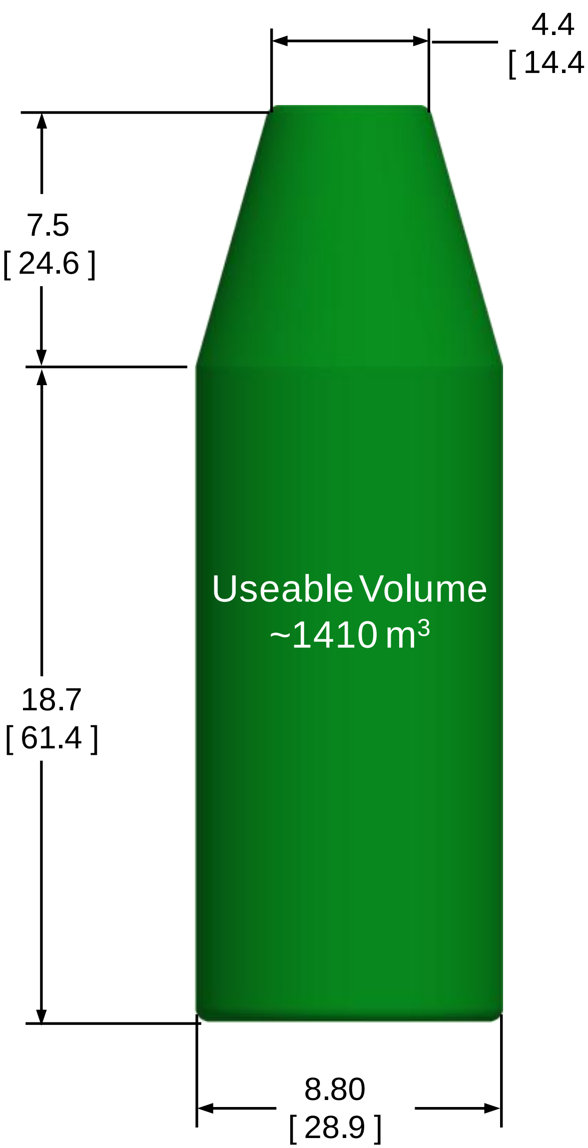
Usable Propellant: 251.9 mT (555.2k lbm)
Dry Mass: 24.2 mT (53.5k lbm)
Burnout Mass: 26.6 mT (58.7k lbm)
Number of Engines: 1
Engine Type: J-2X



- 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 TLI
- Maintains Orion/Altair/EDS stack attitude in LEO prior to TLI burn
- EDS provides 1.5 kW of power to Altair from launch to TLI

Notional Ares V Shroud for Other Missions





Note: The height of the shroud is limited by the height of the Vertical Assembly Building (VAB)

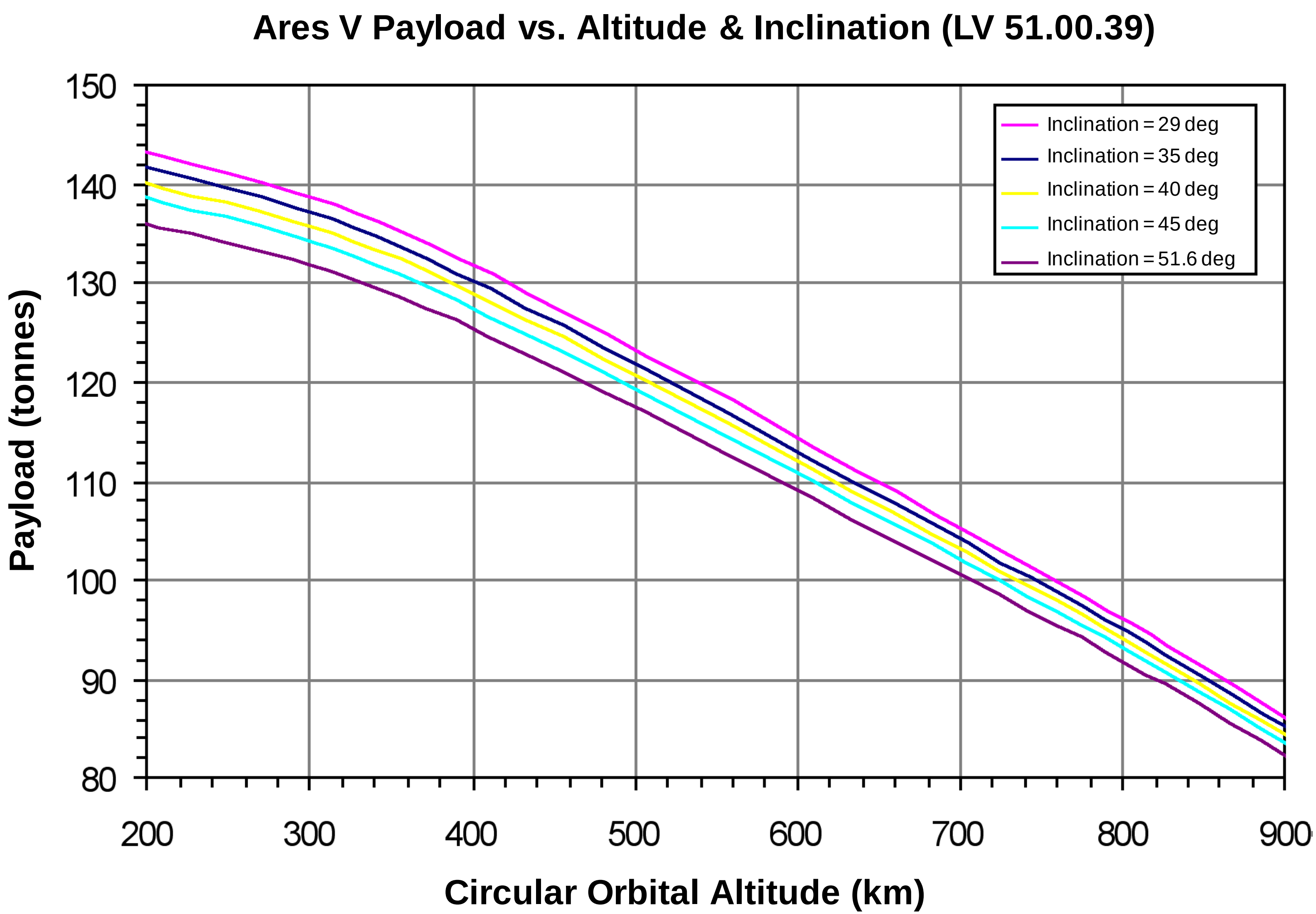
Ares V (51.00.39) Performance for Selected Missions

Comparison of POD and Extended Shrouds

Mission Profile	Target	POD Shroud	Extended Shroud
		Payload (mT)	Payload (mT)
Sun-Earth L2	**C3 of -0.7 km^2/s^2 @ 29 deg**	**55.8**	**55.1**
GTO Injection	**Transfer ΔV 8,200 ft/s 185 km x 35,786 km @ 27 deg**	**70.3***	**69.7***
GEO	**Transfer ΔV 14,100 ft/s 35,786 km circular @ 0 degrees**	**36.2**	**35.7**
Lunar Outpost (TLI Direct)	**C3 of -1.8 km^2/s^2 @ 29.0 degrees**	**56.8**	**56.1**

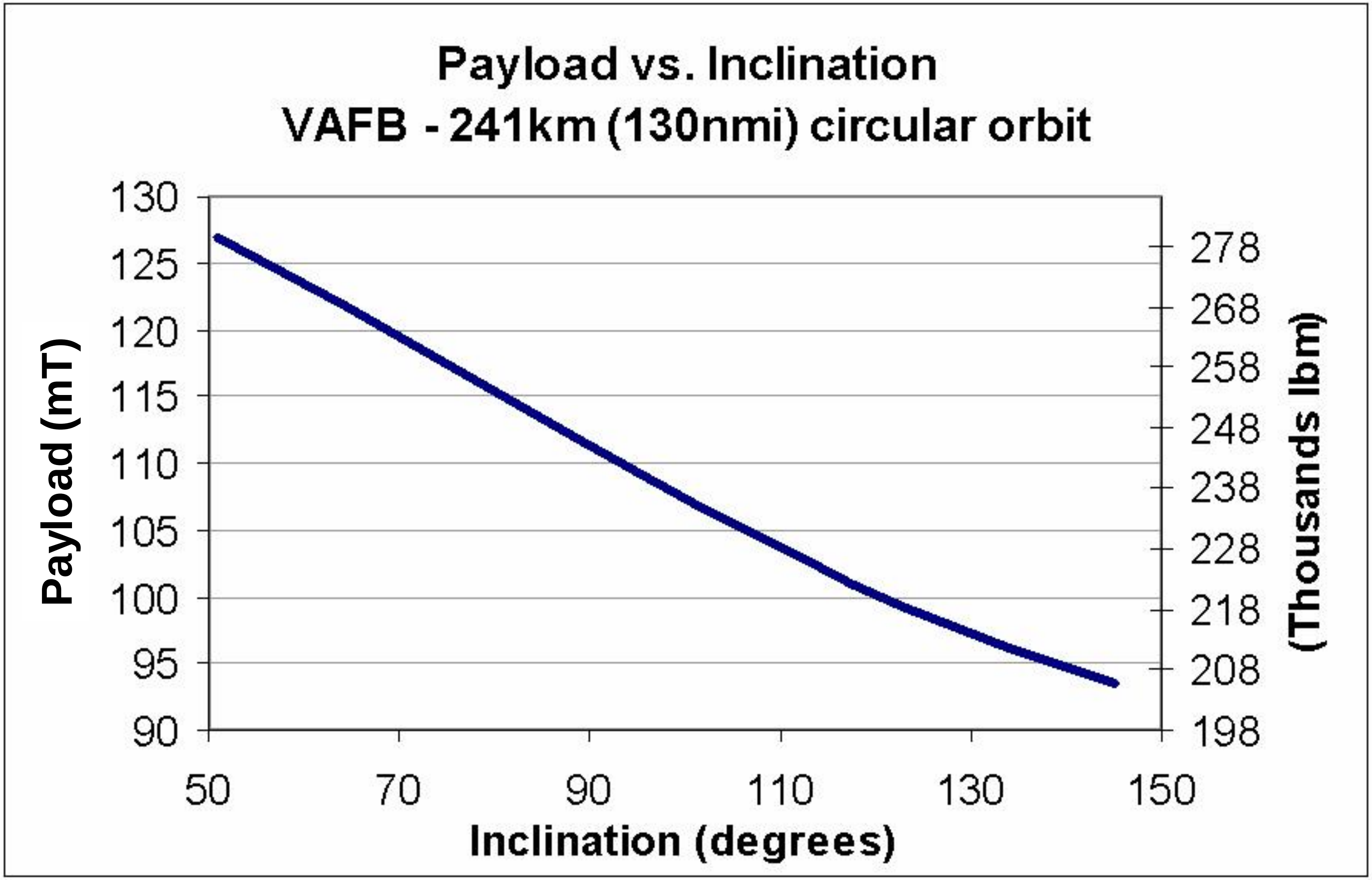
* Performance impacts from structural increases due to larger payloads have not been assessed

Ares V (LV 51.00.39) LEO Performance



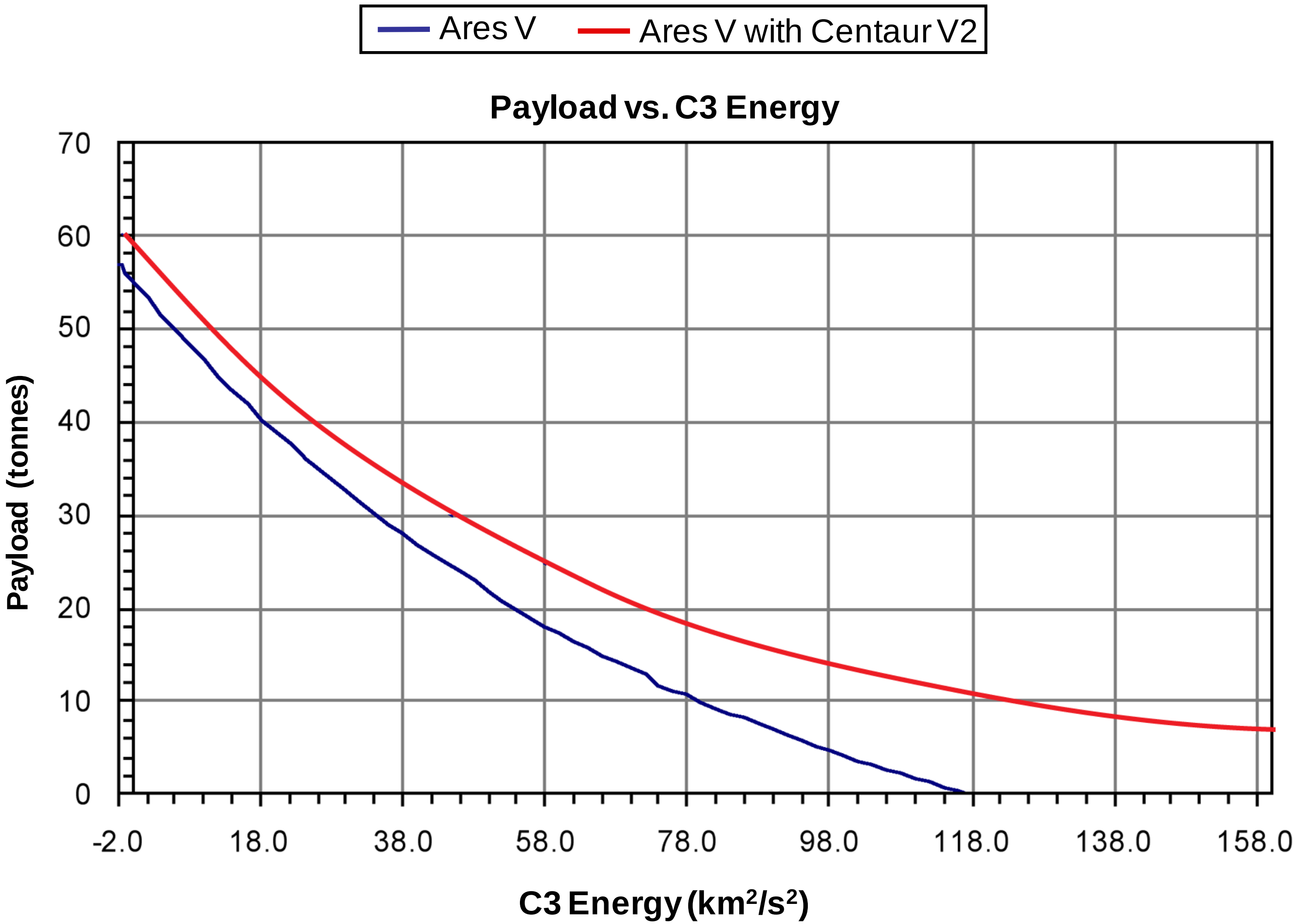
LEO performance for 51.00.48 point of departure vehicle is expected to exceed 180 mT

Ares V (LV 51.00.39) LEO Capability from VAFB

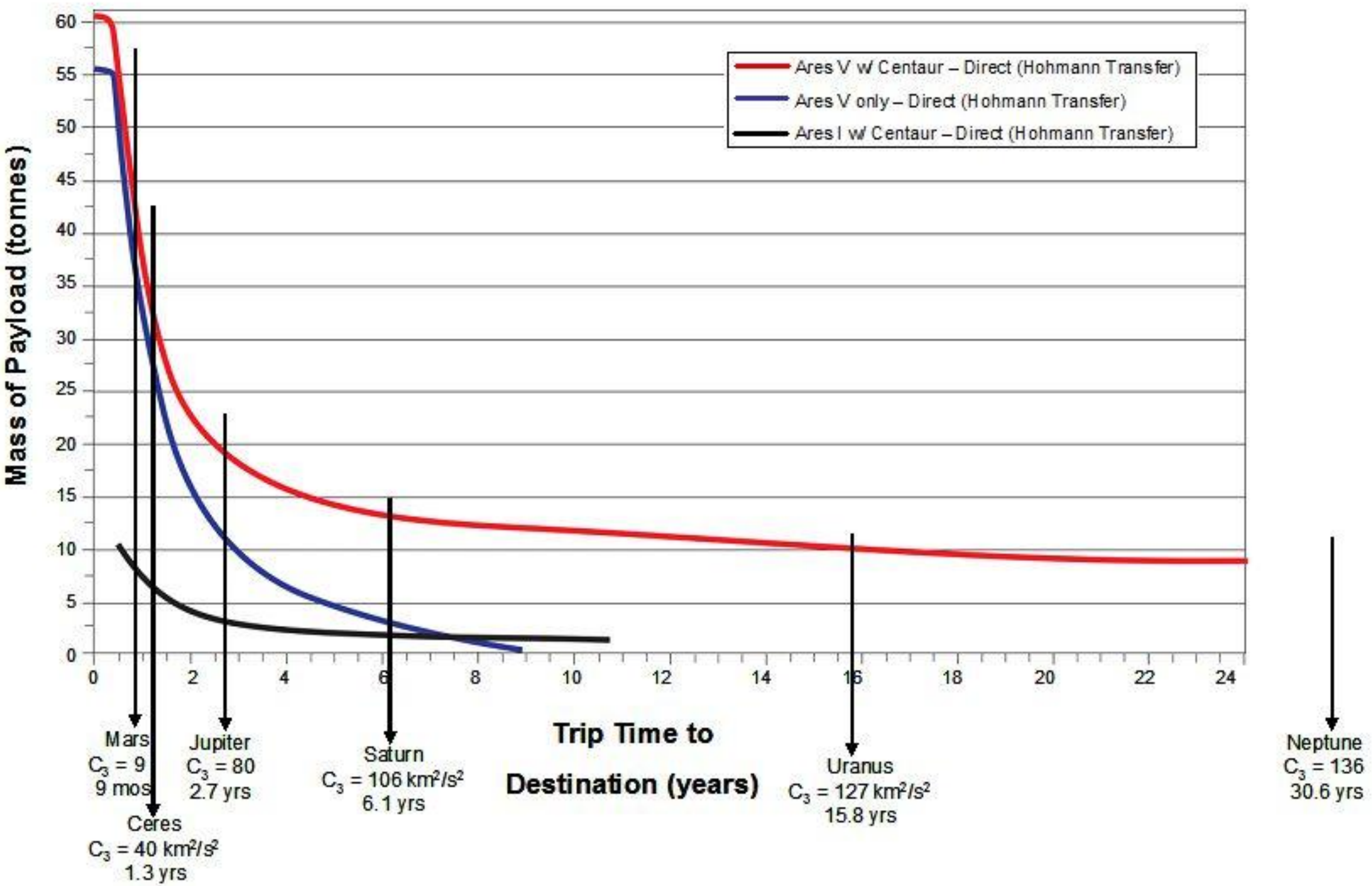


Approximate Performance – does not take into account land over-flight

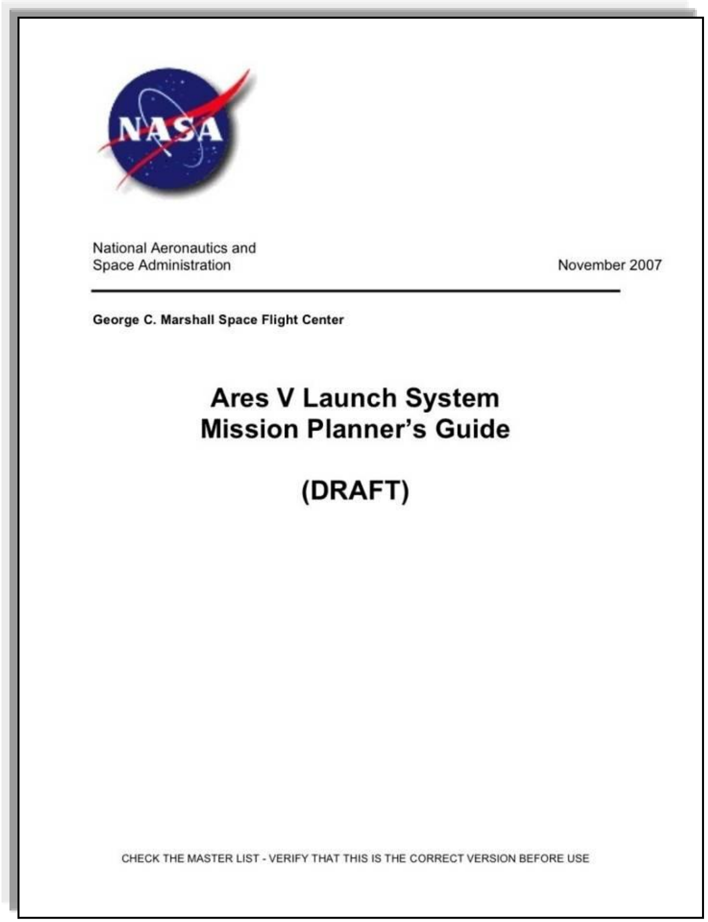
Ares V (LV 51.00.39) Escape Performance



Ares V C3 allows shorter missions to Outer Planets



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 August 2008

- 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

Ground Rules and Assumptions

All trajectories analyzed using POST3D (Program to Optimize Simulated Trajectories – 3 Dimensional)

Flight Performance Reserve (FPR) based on LEO mission

No gravity assists

Interplanetary trip times use Hohmann transfers (limited ~24 yrs max)

Payload mass estimates represent the separated spacecraft mass, and include payload adapter and any mission peculiar hardware

Ares V vehicle 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:

- Use 2-engine Centaur from Atlas V
- Additional adapter mass of 6.4 mT
- No adjustments to aerodynamic data

Propellant mass for:

- Ares V LEO missions are held constant at 310.0 mT
- C3 and LEO missions utilize maximum propellant load

No Upper Stage propellant off-loading for C3 cases

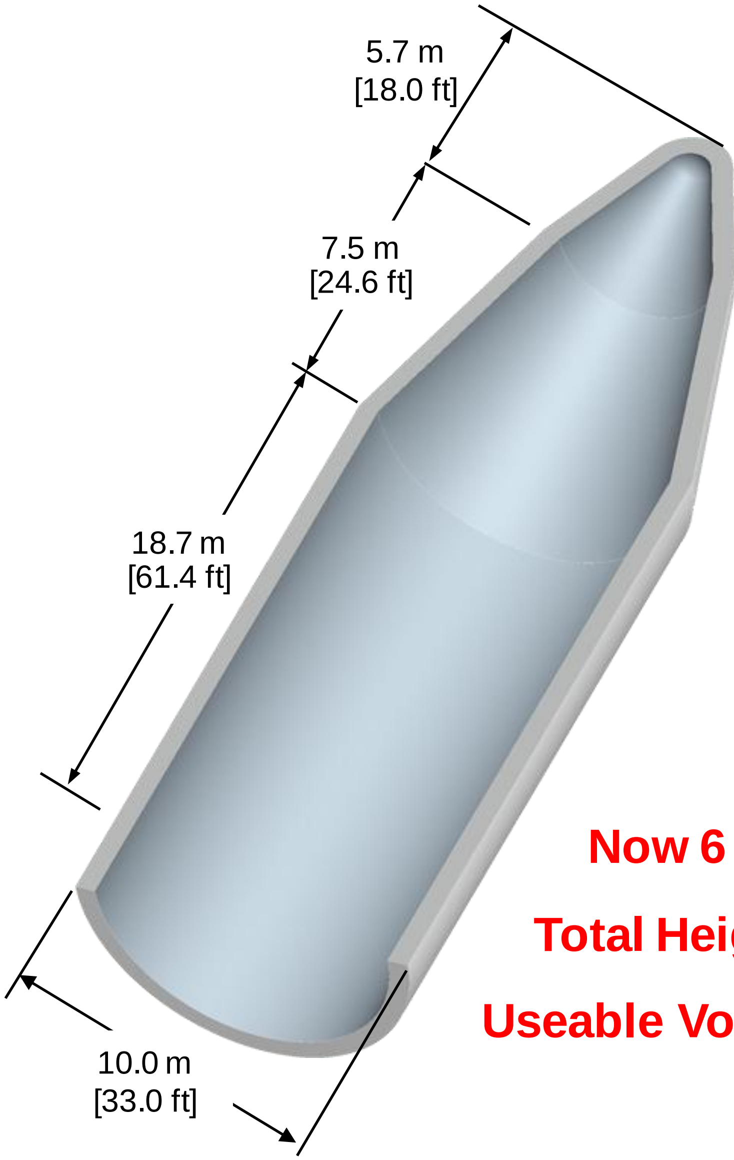
Access to Sun-Earth L2 is direct transfer w/ C3 = -0.7 km2/s2

- Payload can be increased by using a lunar swing-by maneuver

All C3 cases require longer duration than J-2X 500 sec constraint

Any Questions?

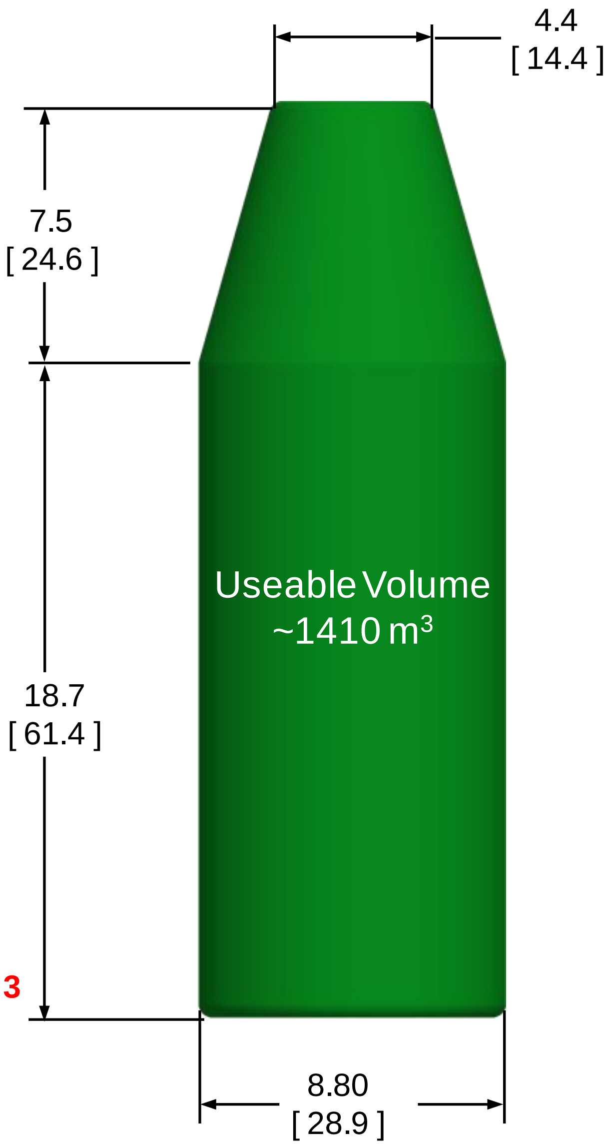
Notional Ares V Shroud for Other Missions



Now 6 m shorter

Total Height of ~26 m

Useable Volume ~1045 m^3



Note: The height of the shroud is limited by the height of the Vertical Assembly Building (VAB)