National Aeronautics and
Space Administration

"Somewhere, something incredible is waiting to be known."

— Carl Sagan

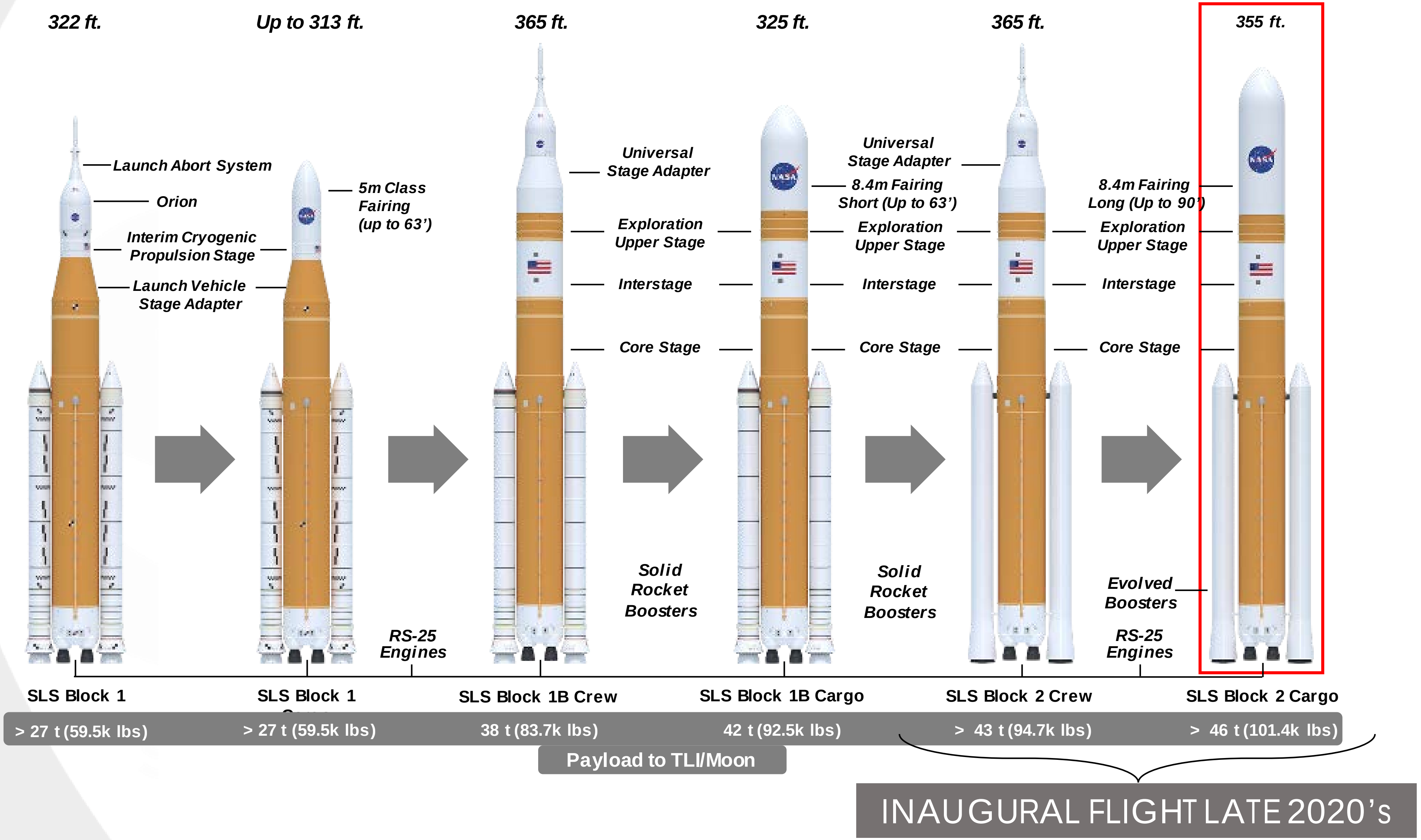
Space Launch System Capabilities and Availability

Robert Stough
SLS Payload Utilization and Vehicle Evolution

July 7, 2021

SLS EVOLVABILITY

FOUNDATION FOR A GENERATION OF DEEP SPACE EXPLORATION



ARTEMIS I VEHICLE: TOWERING MORE THAN 250 FEET IN VAB HIGH BAY 3 ON MOBILE LAUNCHER

☑ MOST POWERFUL SRBs EVER BUILT FOR FLIGHT INTEGRATED, STACKED

- 177 ft. (54.1 m) tall (equivalent to 12-story building)
- Five propellant segments
- 75 percent of thrust during first two minutes of flight, 7.2 million lbf (32,027 kN)

☑ CORE STAGE MATED TO BOOSTERS

- Tallest stage NASA has ever built
- 212 ft. (64.7 m) tall (equivalent to 15-story building)
- 27.6 ft. (8.4 m) diameter
- 537,000 gal. (2 million liters) LH2, 196,000 gal. (742,000 liters) LOX
- Four RS-25s generating 2,049,200 lbf (9,115 kN) (vacuum) at 109 percent power level

☑ LAUNCH VEHICLE STAGE ADAPTER MATED TO CORE STAGE

- Changes diameter of vehicle from 8.4 m to 5 m
- Includes frangible joint assembly to separate core, upper stages

☐ INTERIM CRYOGENIC PROPULSION STAGE INTEGRATION IN PROGRESS

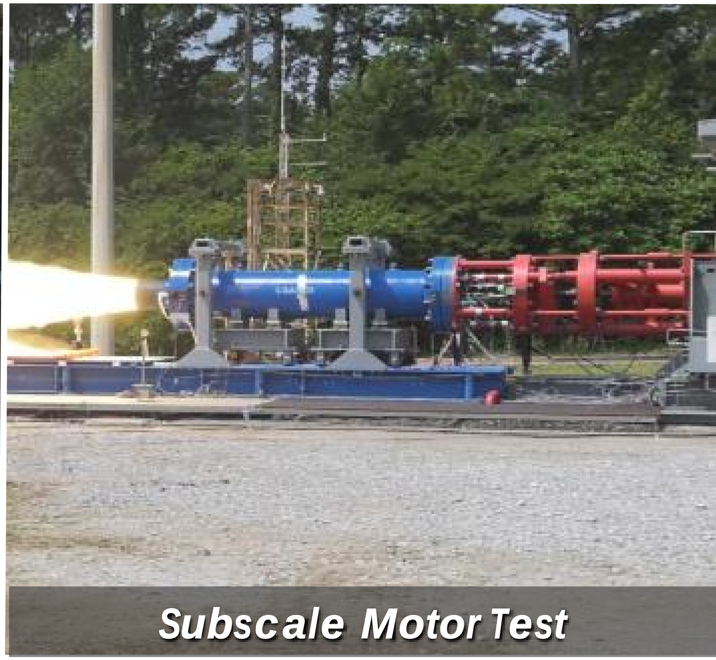
- Modified ULA Delta Upper Stage
- Provides 24,750 lbf (110 kN), TLI burn

RS-25 PRODUCTION RESTARTED

PROGRESS TOWARD SLS BLOCK 2 BOOSTERS


Successful Solid Rocket Motor Hotfire


BOLE Booster Machining

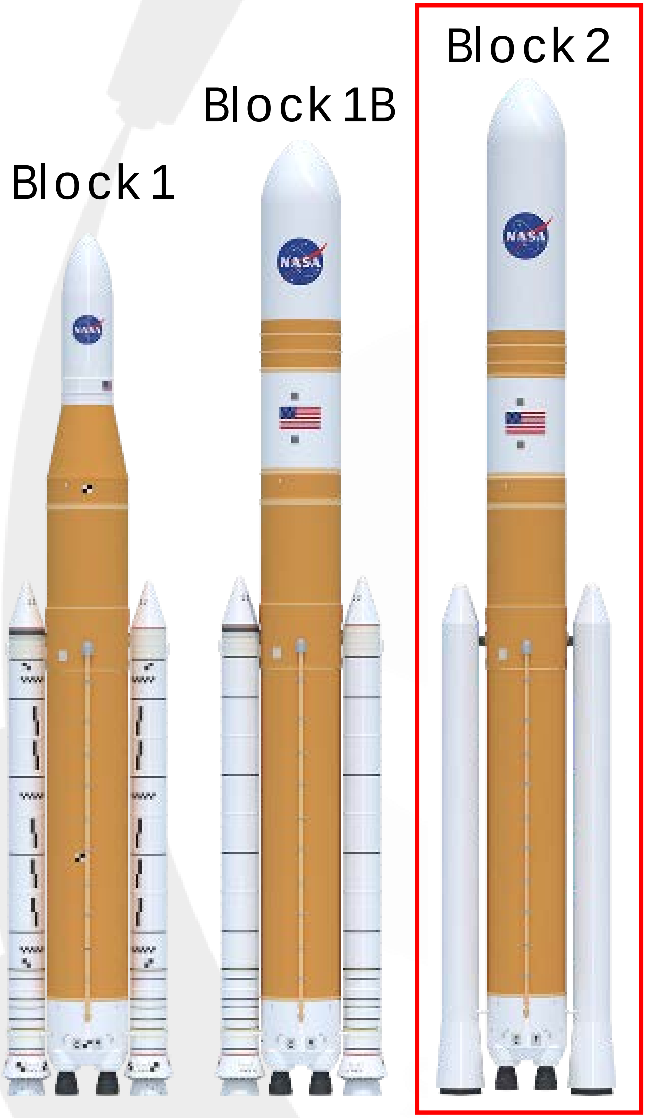

Subscale Motor Test


Aft Cylinder Aft Dome Machining


Nozzle Forward End Ring


Forward Cylinder Tang End Ring

SLS VEHICLE AND PERFORMANCE

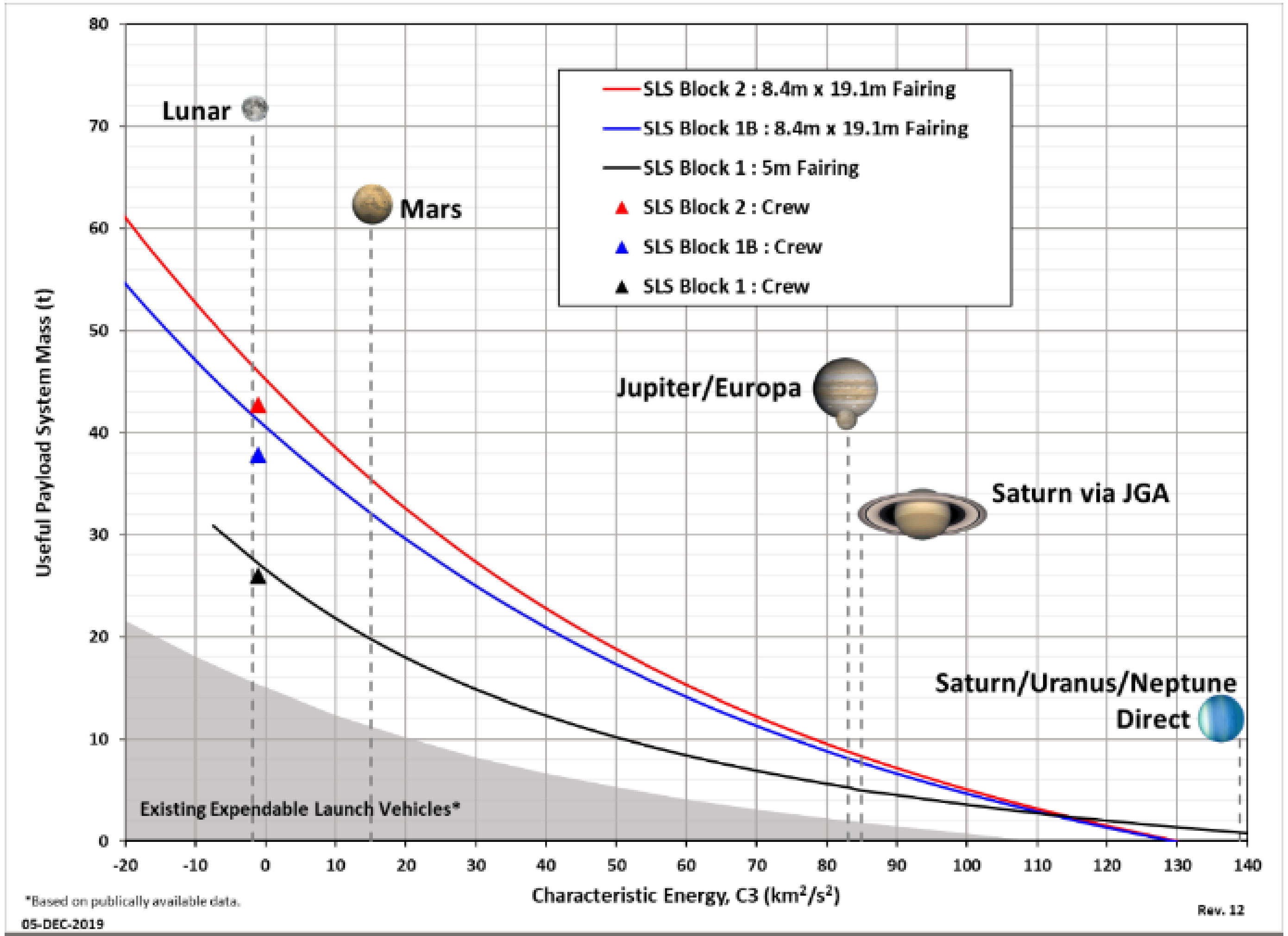


- Block 1B/2 evolution path:
  - Initial configuration Block 1B (2025)
    - Heritage RS-25 running at 109% RPL
    - RSRMV Boosters
  - Intermediate Block 1B (2026-2028)
    - Transitioning to new production RS-25 engines running at 111% RPL
  - Block 2 (2029-)
    - Evolved boosters with enhanced performance

- Vehicle Predicted Performance
  - Vehicle mass includes mass growth allowance and manufacturing variation
  - Nominal performance for RS25s and RL10s (mean Isp and Thrust)
  - Low performing booster
  - Manager's reserve is held back

SLS Block 1B/2 future upgrades further increase performance
SLS quoted performance is conservative

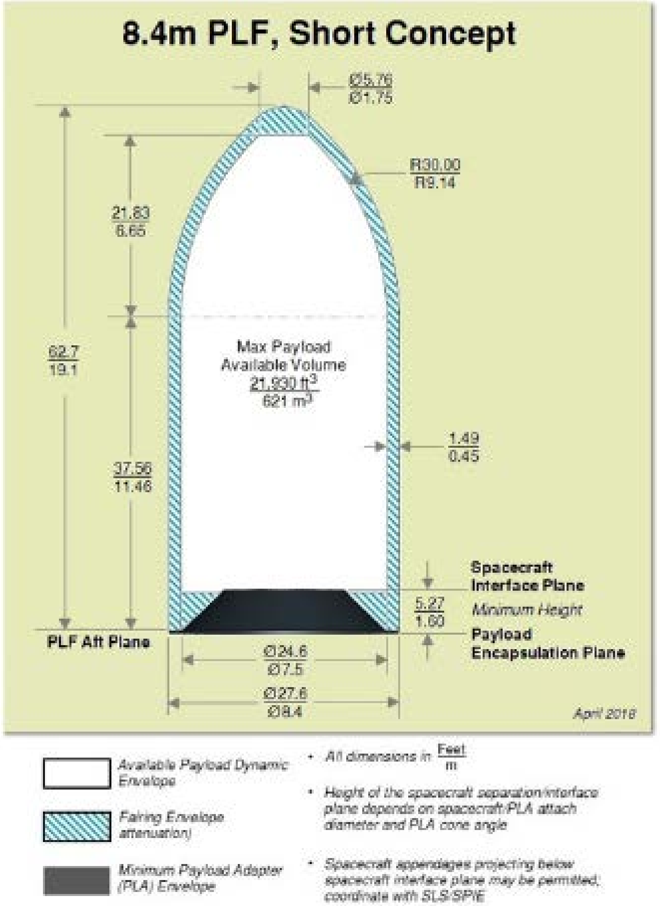
SLS C3 PERFORMANCE



SLS performance is optimized for lunar destinations
Additional stages are needed for higher C3 destinations

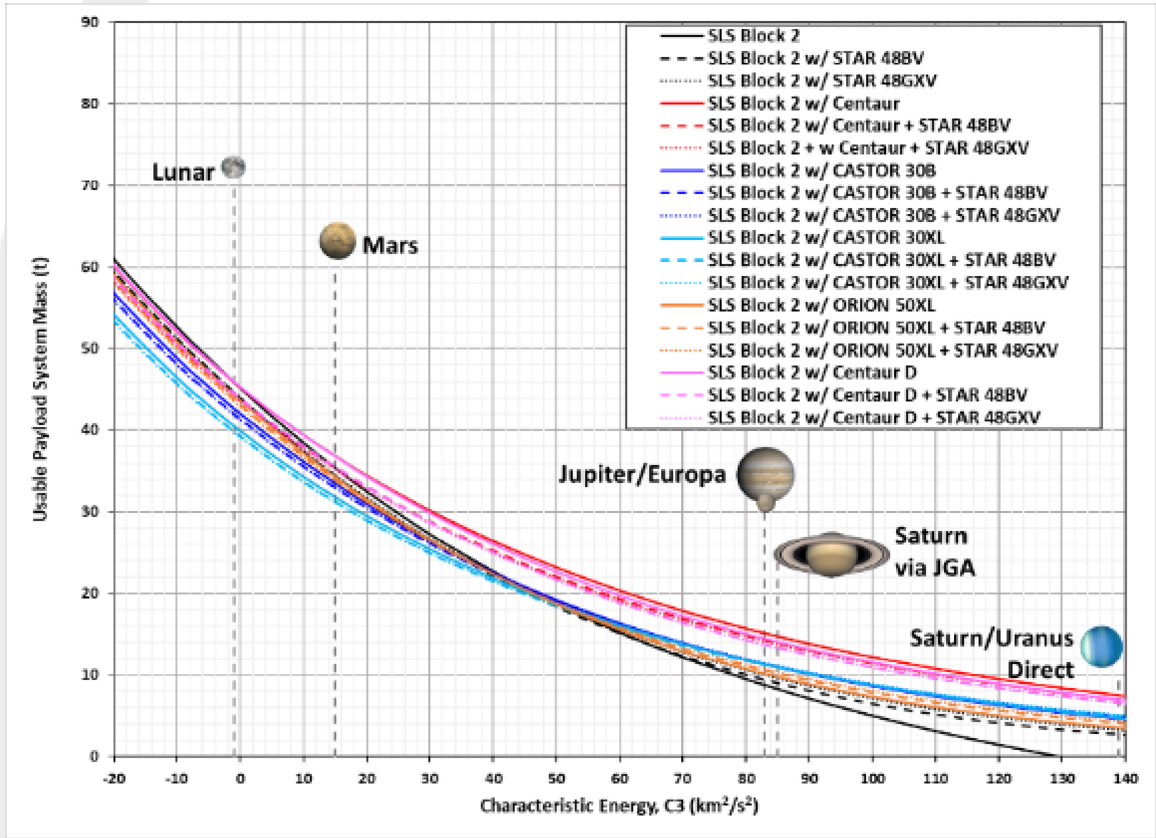
ADDITIONAL STAGES FOR HIGHER C3 DESTINATIONS

- Manager's Reserve
  - Allocated across all upper stages (incl. EUS) based on the stage wet mass
  - Approach preserves staging benefits at varying C3s
- Fairing:
  - All 3rd and 4th stages are encapsulated under the 8.4m short Payload Fairing (PLF)
  - Minimizes the risk of stage requalification
  - Removes alternate configurations for the SLS vehicle (OML changes)
- Upper stages:
  - Existing stages in production
  - Estimated Flight Performance Reserve
  - Solid performance nominal
  - 3rd Stages Assessed:
    - Castor 30B (NGIS provided data)
    - Castor 30XL (NGIS provided data)
    - Centaur (Government Estimate)
  - 4th Stages Assessed:
    - Star 48 BV (NGIS provided data)
    - Star48 GXV (NGIS provided data)
- Stage adapters:
  - Sized with NASA MSFC sizing tool, Launch Vehicle Analysis (LVA)
    - 35 years of heritage
  - Composite Adaptor (CF + Al-HC) with interface rings
  - 18% MGA

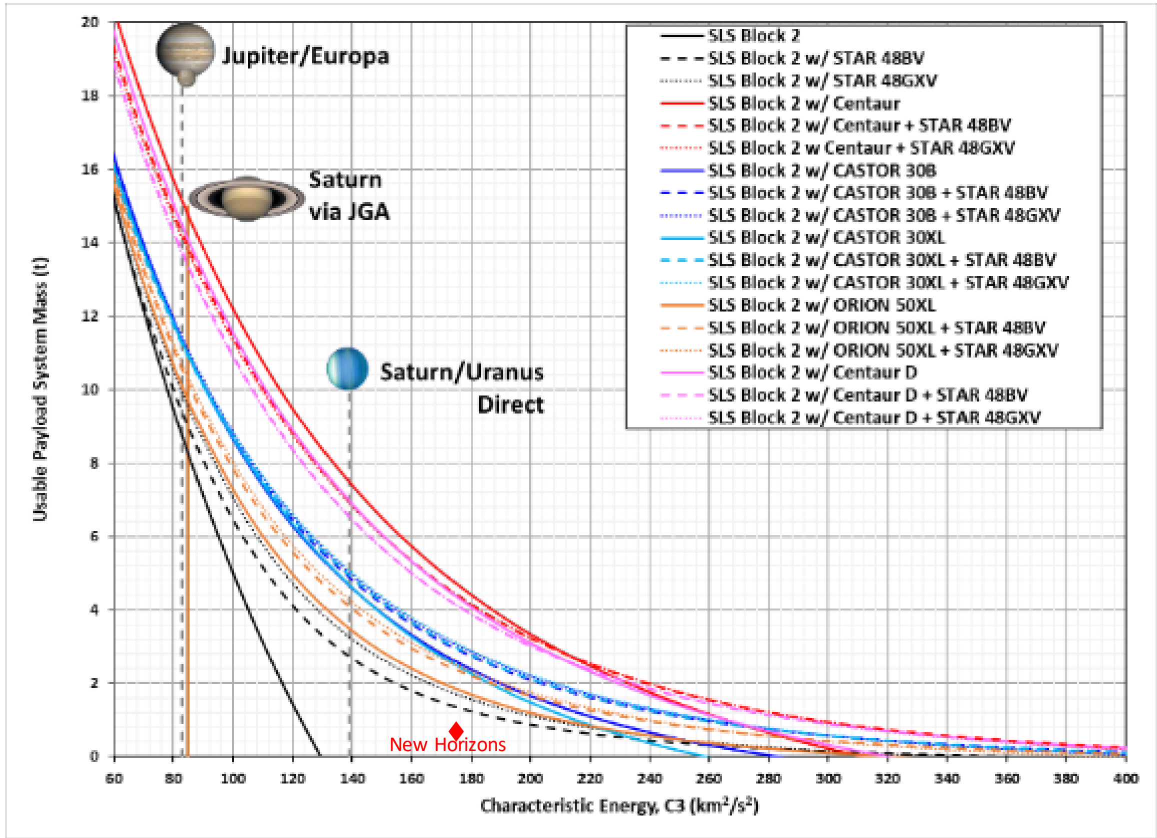


Using existing hardware and a low-risk engineering approach

SLS C3 PERFORMANCE WITH ADDITIONAL STAGES



Low C3 Range



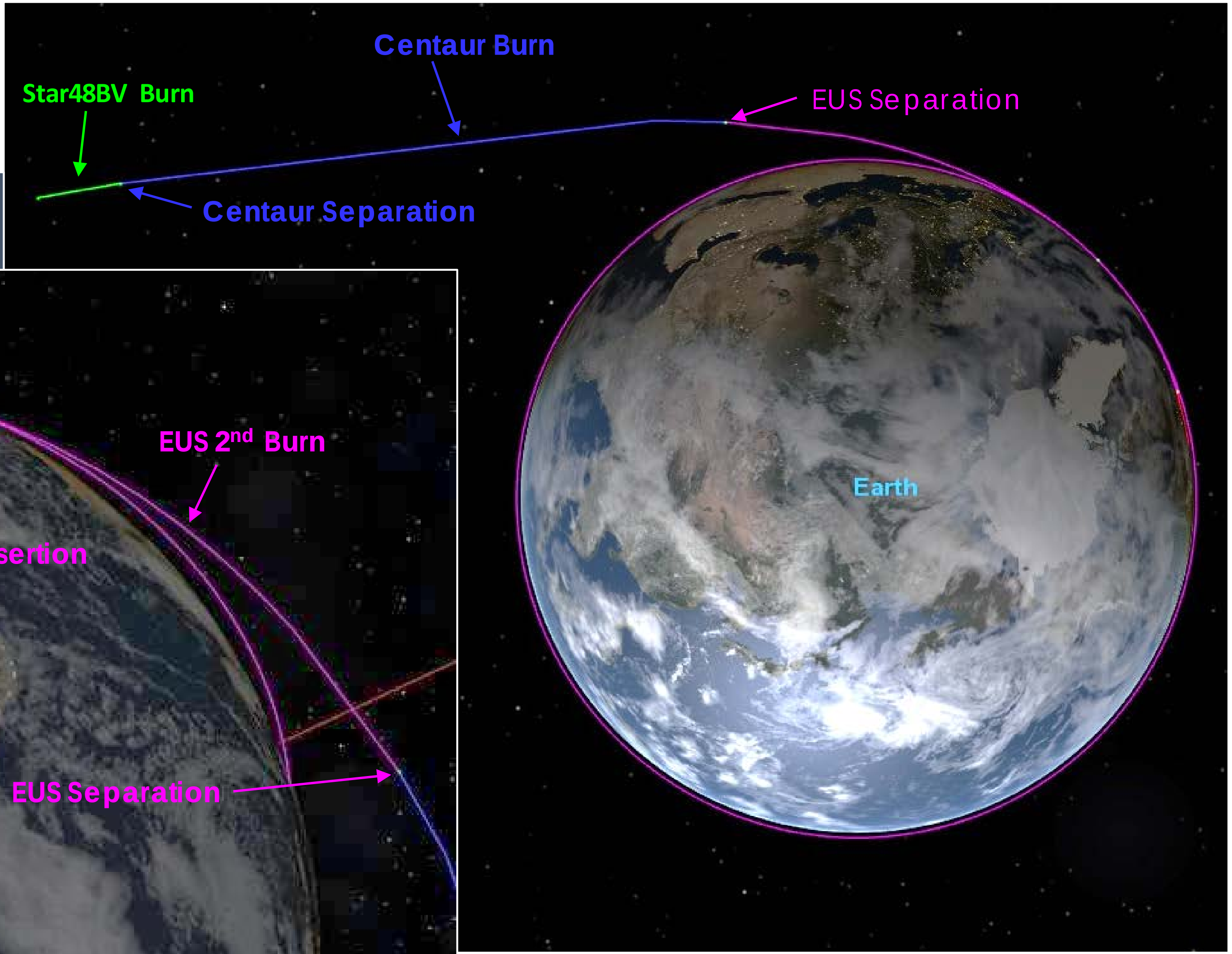
High C3 Range

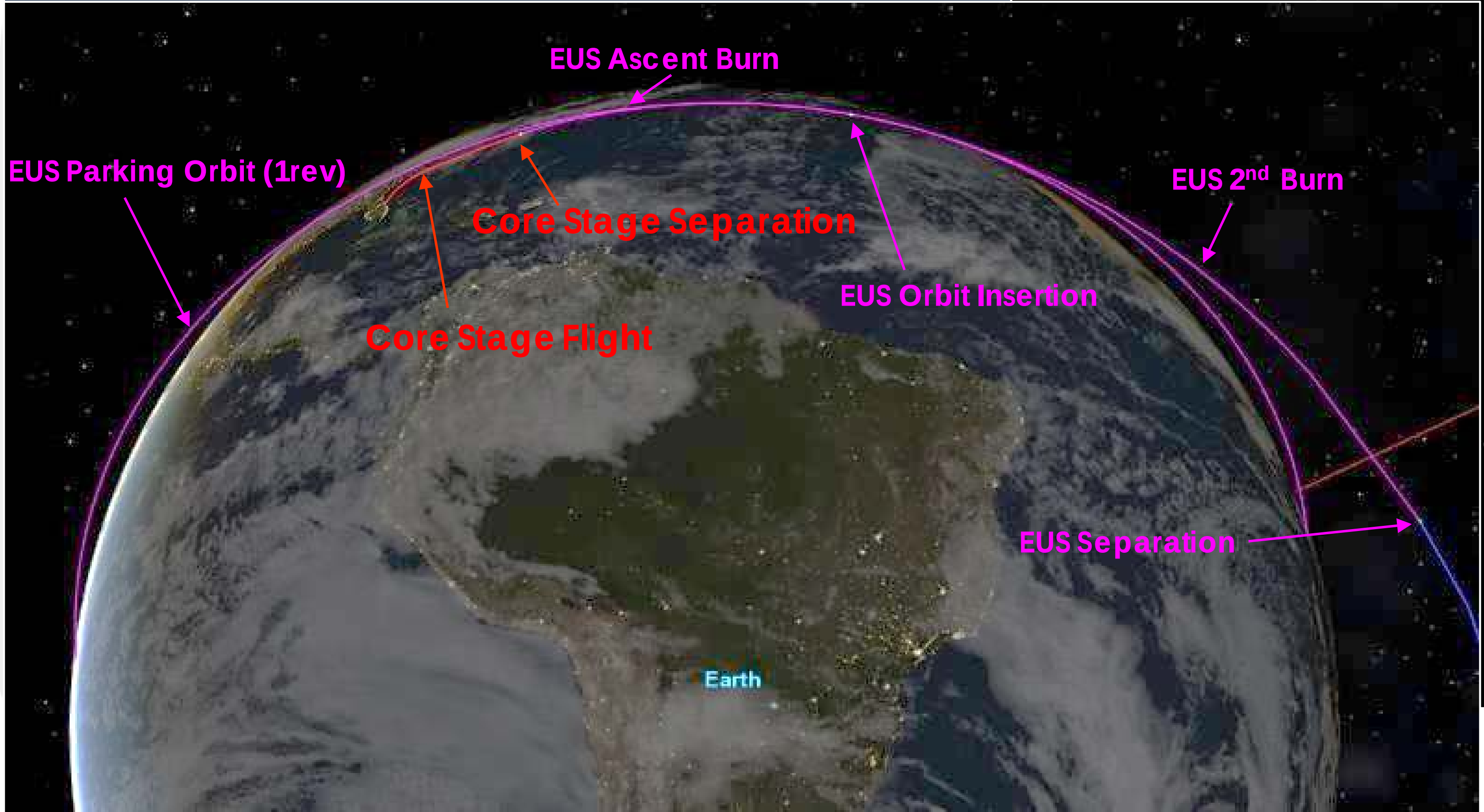
REPRESENTATIVE TRAJECTORY

Recall Specific Energy of the Orbit

$$\mathcal{E} = \frac{(v+\Delta v)^2}{2} - \frac{\mu}{r} = \frac{C3}{2}$$

The deeper in the gravity well the maneuver
the greater the increase in orbital energy (Oberth Effect)





SLS AVAILABILITY FOR SCIENCE

- Requirements:

  HEO-004: ESD-R-15: Launch Rate

  The ESD elements shall support a surge capability of up to three launches, two crewed and one cargo, in any 24-month period with crewed launches separated by at least 12 months, no more than two launches in a 12-month period, and all launches separated by at least 120 days.

  Rationale: The maximum rate of 3 launches in 24 months and/or 2 flights in a single year is not considered to be a sustainable rate and is not to be construed as a production capability. During these periods, nominal flight activity will be suspended to enable this surge capability and storage of assets may be required. This allows for 1 flight every 12-month period for Gateway buildup and utilization (assumed to include Orion with a co-manifested payload and/or a cargo only flight), plus protecting for an additional SLS flight not associated with Gateway buildup and utilization (e.g. a dedicated SLS cargo flight for a science or other user mission) in that 12-month period.

- Supply Chain
  - Production capability of 1 flight unit a year on average in the 2020's with plans for the production capability expanding to 2 flight units a year in the early 2030s.

- 3rd/4th Stages
  - HEOMD has interest in SLS payloads with cryogenic propellant. There may be a risk that the capability is not available by 2032. Coordination with HEOMD will be required.
  - Sunset of the Atlas V Centaur is likely in the next 2-3 years. However, a shortened Vulcan Centaur may be a possibility and a good alternative.
  - No sunset period has been identified for CASTOR 30 and STAR48 Stages.

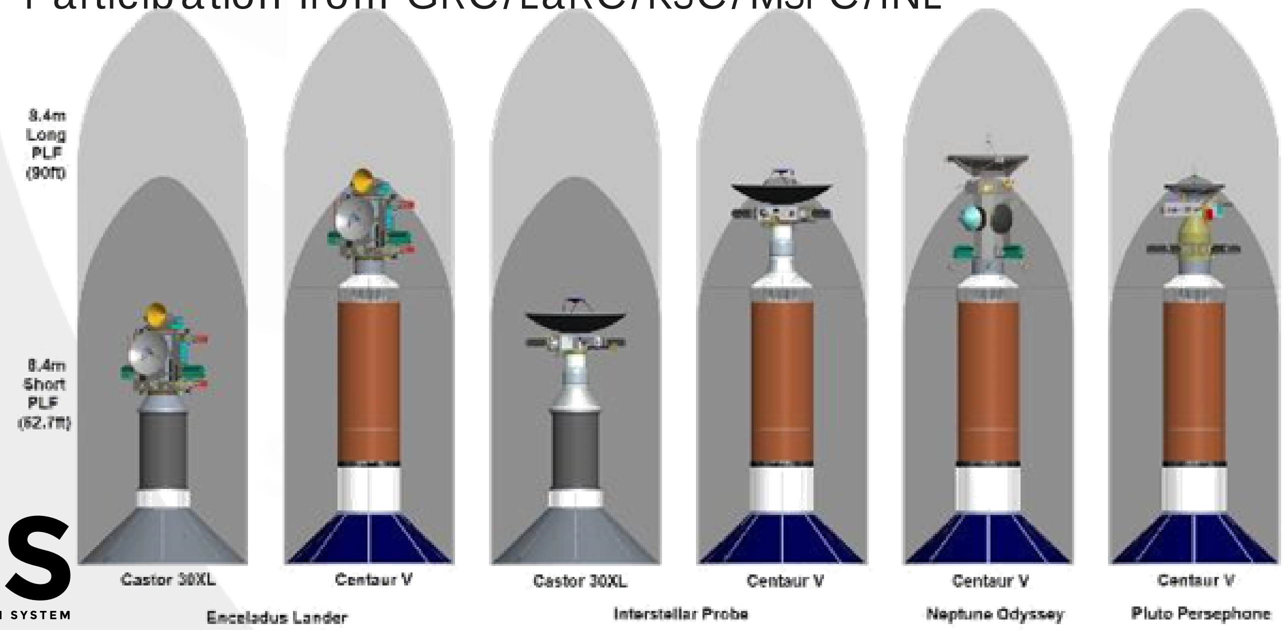
- Manifest for SLS is not fully established for the late 2020s and 2030s. Now is the time for SMD to engage HEOMD on future sciences missions for SLS.
  - While Artemis will likely use most SLS launch vehicles. It is possible and reasonable to assume that up to 3 SLS' could be used between now and 2034 for science missions. Establishing mission priority is essential for decision making by NASA leadership.

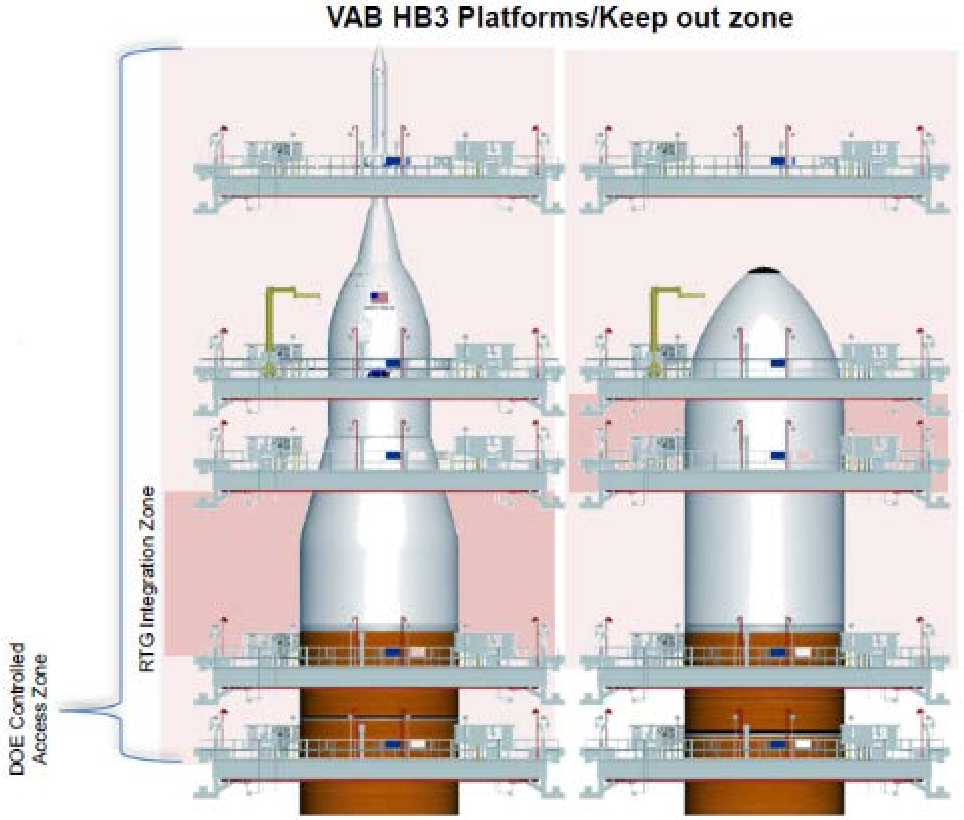
- The marginal cost of an SLS (additional flight unit per year) is much lower than the total program cost for SLS. A higher flight rate could offer lower flight unit costs. Furthermore, future planned improvements to the SLS design and production have the potential to significantly reduce flight unit cost.

SLS SPACE LAUNCH SYSTEM

SLS NUCLEAR LAUNCH

- SLS has engaged the RPS Office on the topic of Nuclear Certification.
  - Nuclear Certification, which satisfies NSPM-20, is the responsibility of the payload
  - Work begins 6 years before the mission
  - Payload cooling is critical
  - DDT&E may be required for the fairing
- SLS RTG Assessment (Underway)
  - Assessed Numerous permutations given input from the science
  - No major disconnects identified.
  - Participation from GRC/LaRC/KSC/MSFC/INL





SPACE LAUNCH SYSTEM

BENEFITS OF LAUNCH ON SLS

SLS Features

- Unrivaled Payload Mass
- Benign Launch Loads
- Ultra-High Departure Energy
- Large-Diameter Payload Fairings
- Human-Rated Safety Standards
- Proven Propulsion Systems
- Real-Time Mishap Recovery
- Heritage of Operational Success

These capabilities enable:

- Larger Science Payloads
- More Trajectory Options
- Reduced Payload Complexity
- Larger Monolithic Structures
- More Launch Opportunities
- Multiple Science Targets
- Longer Science Life
- Low-Cost Rideshares
- Access to New Destinations
- Fewer Launches Needed
- Avoid Inner Solar System Environment
- Reduced Transit Time
- Earlier Science Return
- Reduced Operational Costs
- Fewer New Developments
- Lower-Speed Orbital Insertion

This provides:

- **Greater Science Return**
- **Lowered Mission Costs**
- **Reduced Risk**
- **Making "Impossible" Missions Possible**

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