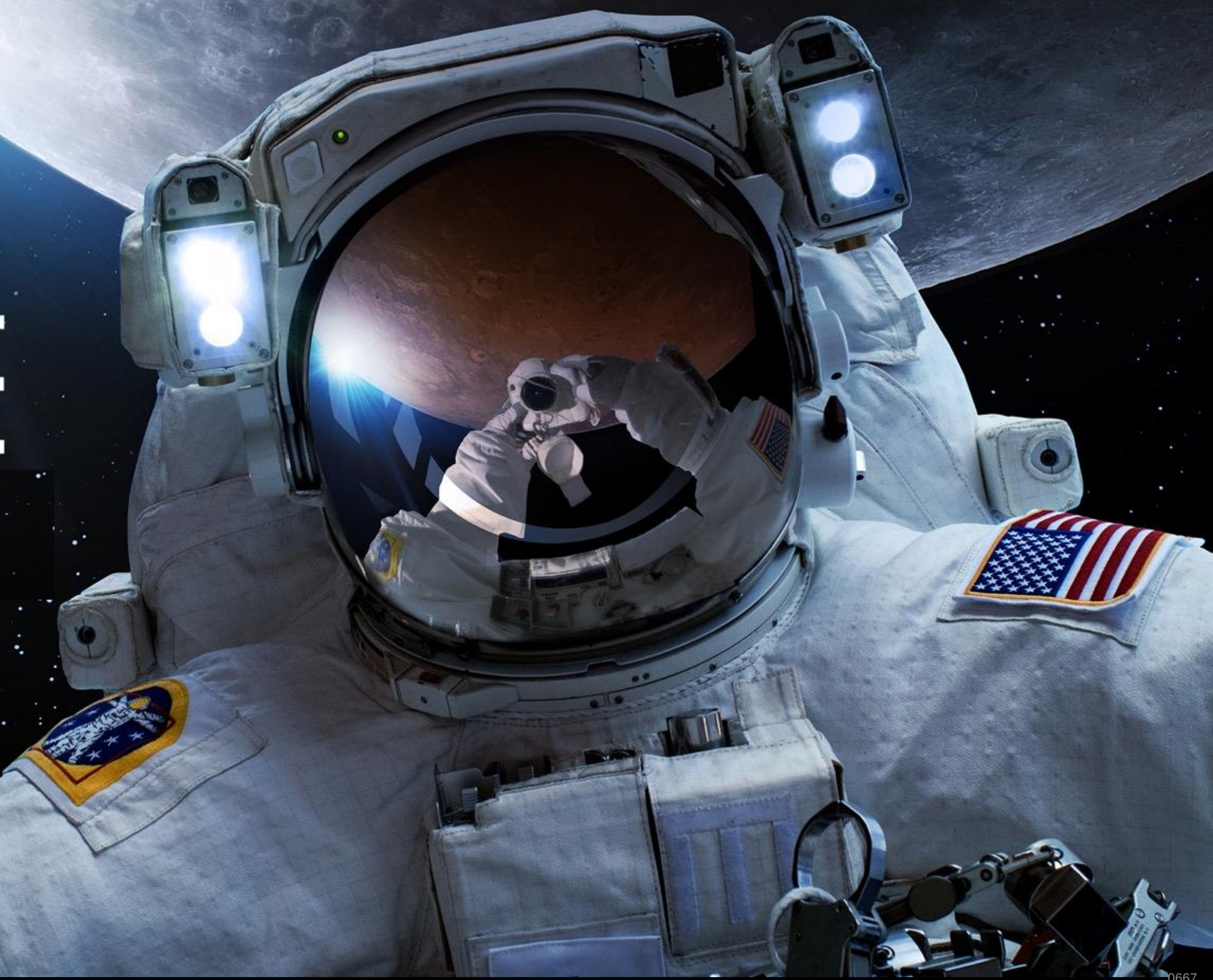
EXPLORE

Enabling a Near-Term Interstellar Probe with the NASA's Space Launch System

Robert Stough
SLS Utilization Manager



SLS LIFT CAPABILITIES

	SLS Block 1 Crew	SLS Block 1 Cargo	SLS Block 1B Crew	SLS Block 1B Cargo	SLS Block 2 Crew	SLS Block 2 Cargo
Payload to LEO	95 t (209k lbs)	95 t (209k lbs)	105 t (231k lbs)	105 t (231k lbs)	130 t (287k lbs)	130 t (287k lbs)
Payload to TLI/Moon	> 26 t (57k lbs)	> 26 t (57k lbs)	34–37 t (74k–81k lbs)	37–40 t (81k–88k lbs)	> 45 t (99k lbs)	> 45 t (99k lbs)
Payload Volume	N/A**	9,030 ft^3 ($256 m^3$)	10,100 ft^3 ($286 m^3$)**	18,970 ft^3 ($537 m^3$)	10,100 ft^3 ($286 m^3$)**	34,910 ft^3 ($988 m^3$)
Maximum Thrust	8.8M lbs	8.8M lbs	8.8M lbs	8.8M-9.8M lbs	11.9M lbs	11.9M lbs

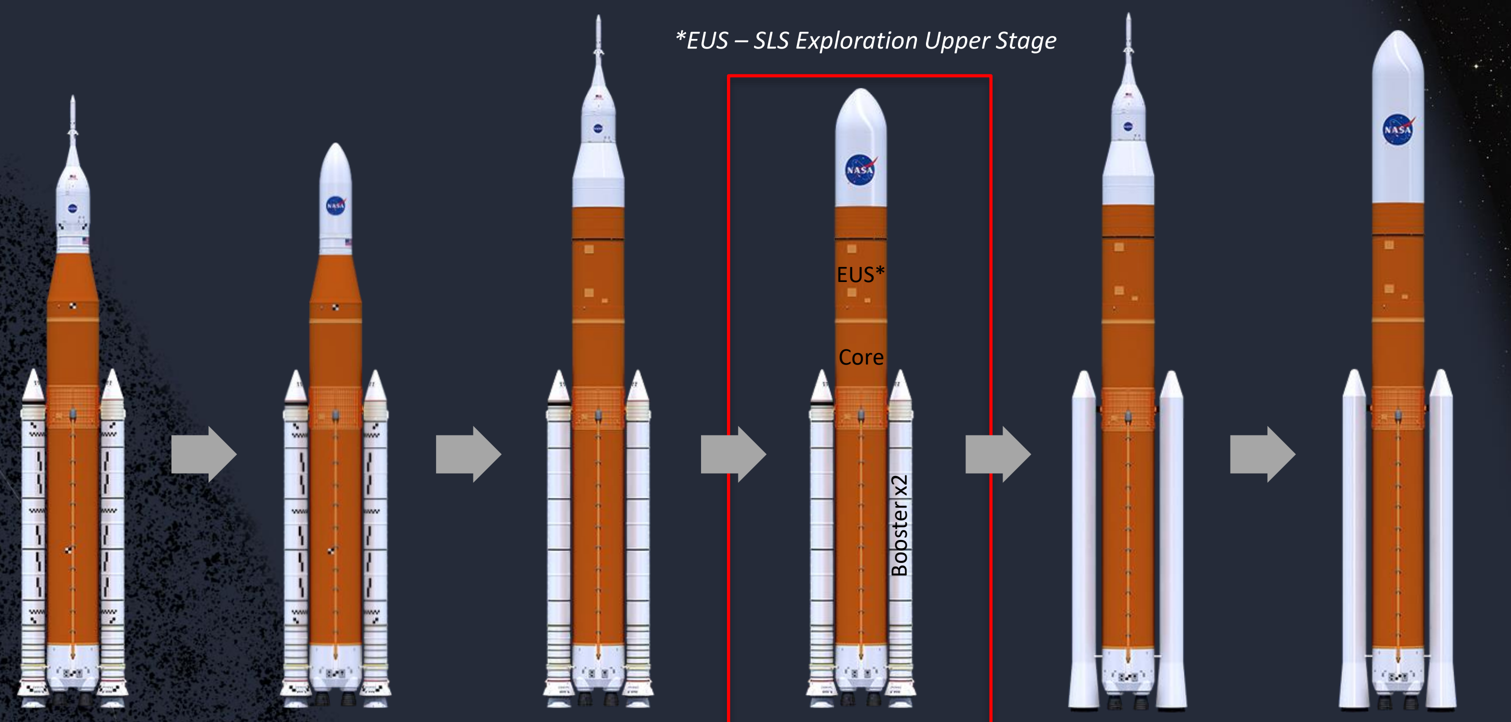
Low Earth Orbit (LEO) represents a typical 200 km circular orbit at 28.5 degrees inclination

Trans-Lunar Injection (TLI) is a propulsive maneuver used to set a spacecraft on a trajectory that will cause it to arrive at the Moon. A spacecraft performs **TLI** to begin a lunar transfer from a low circular parking orbit around Earth.

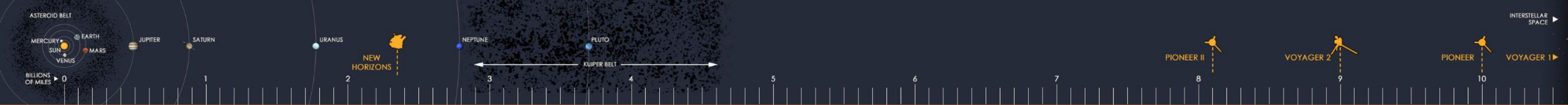
The numbers depicted here indicate the mass capability at the Trans-Lunar Injection point.

** Not including Orion/Service Module volume

EUS – SLS Exploration Upper Stage



SLS Block 1 Crew · SLS Block 1 Cargo · SLS Block 1B Crew · SLS Block 1B Cargo · SLS Block 2 Crew · SLS Block 2 Cargo



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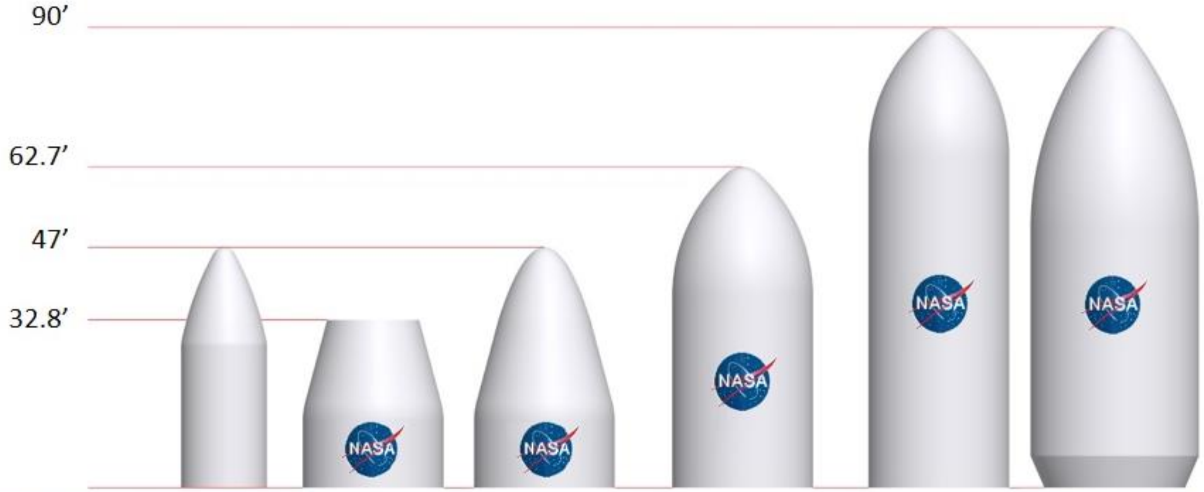
SPACE LAUNCH SYSTEM: MORE VOLUME

CONCEPTUAL



Enclosure	5.1m PLF	8.4m USA	8.4m USA PLF	8.4m PLF, Short	8.4m PLF, Long	10m PLF
Type	5m PPL	8.4m CPL	8.4m PPL	8.4m PPL	8.4m PPL	10m PPL
Length	47.0 ft	32.8 ft	47.2 ft	62.7 ft	90 ft	90 ft
	14.3 m	10.0 m	14.4 m	19.1 m	27.4 m	27.4 m
Diameter	16.7 ft	27.6 ft	27.6 ft	27.6 ft	27.6 ft	32.8 ft
	5.1 m	8.4 m	8.4 m	8.4 m	8.4 m	10.0 m
Internal Diameter	15.1 ft	24.6 ft	24.6 ft	24.6 ft	24.6 ft	29.9 ft
	4.6 m	7.5 m	7.5 m	7.5 m	7.5 m	9.1 m
Available Volume	6,274 ft^3	10,100 ft^3	11,260 ft^3	21,930 ft^3	34,910 ft^3	46,610 ft^3
	177.6 m^3	286.0 m^3	319 m^3	621 m^3	988 m^3	1,320 m^3
Potential Availability *(No Earlier Than)*	COTS	2022	2023	2023	2024	2028

COTS: Commercial Off-the-Shelf CPL: Co-manifested Payload PPL: Primary Payload PLF: Payload Fairing

5m Fairing with Science Payload

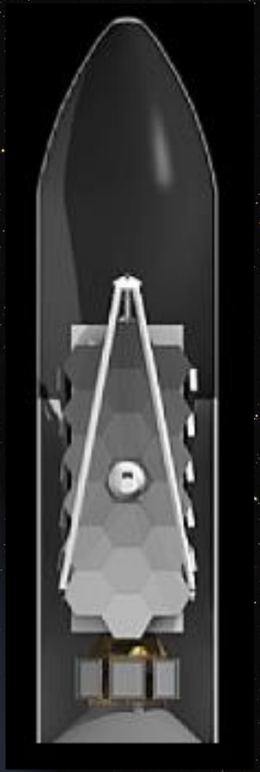
250m^3

Science Missions

400m^3

Orion with Science Missions

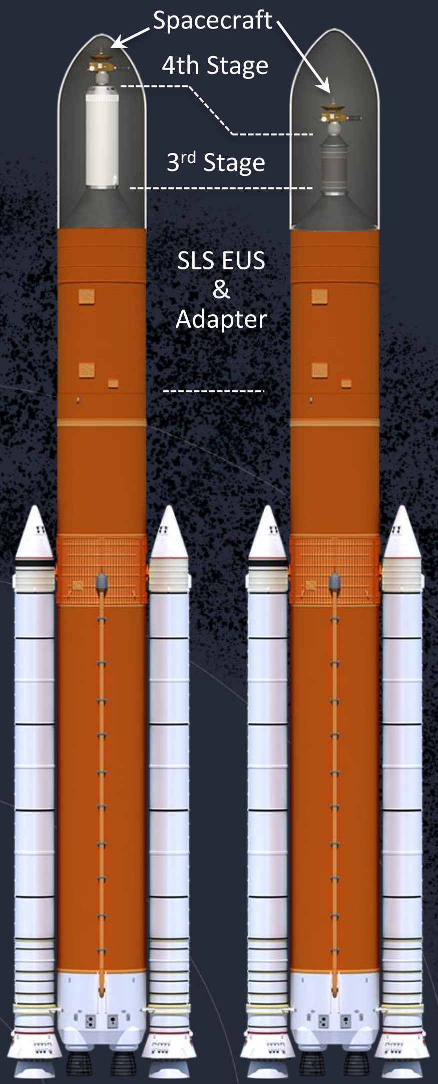
400m^3

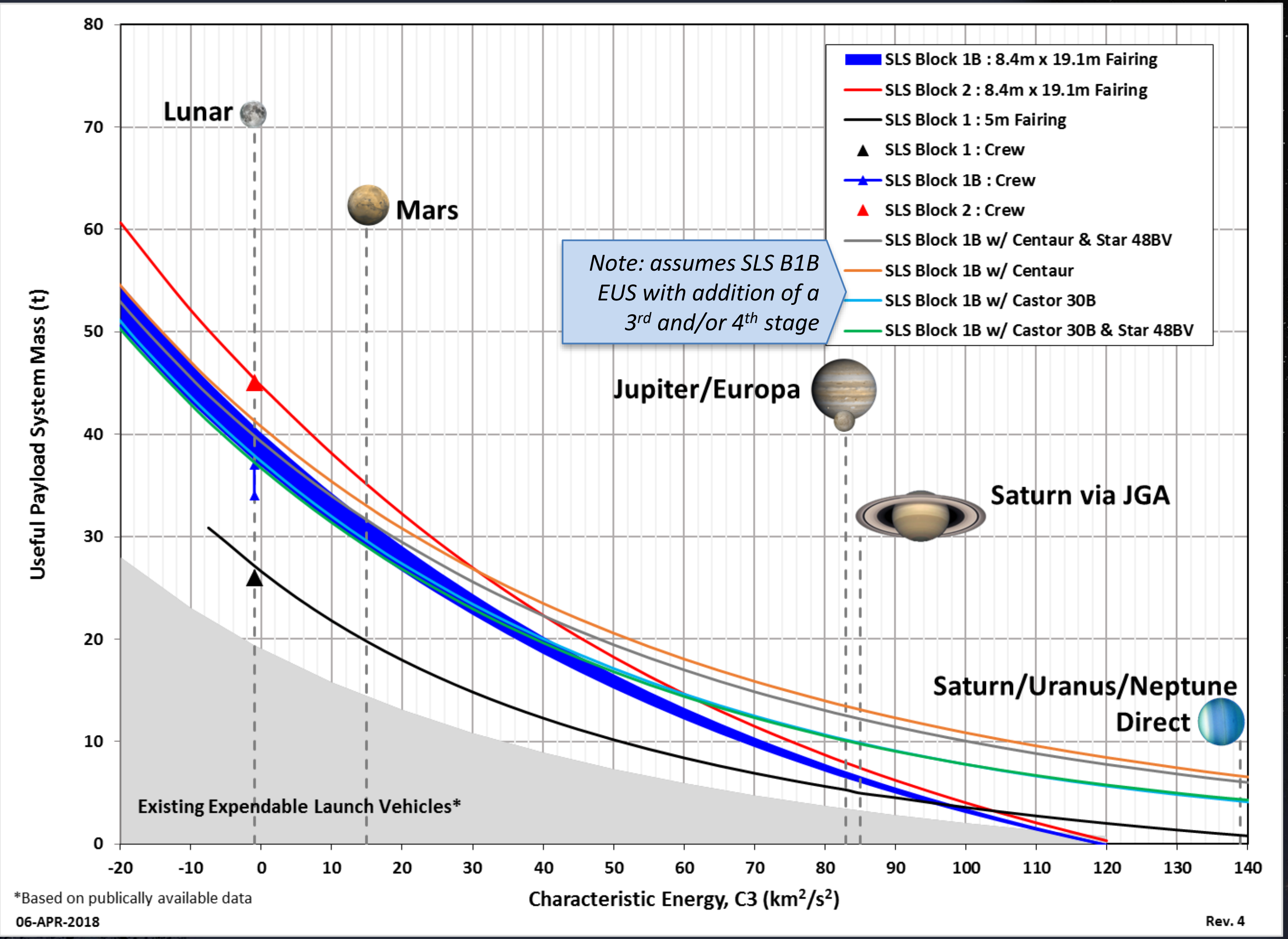


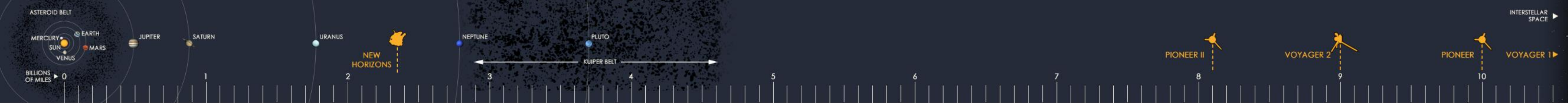
8.4m Fairing with Large Aperture Telescope

1,200m^3

SLS 3RD/4TH STAGES INCREASE C3 PERFORMANCE







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WHAT IS INTERSTELLAR PROBE?

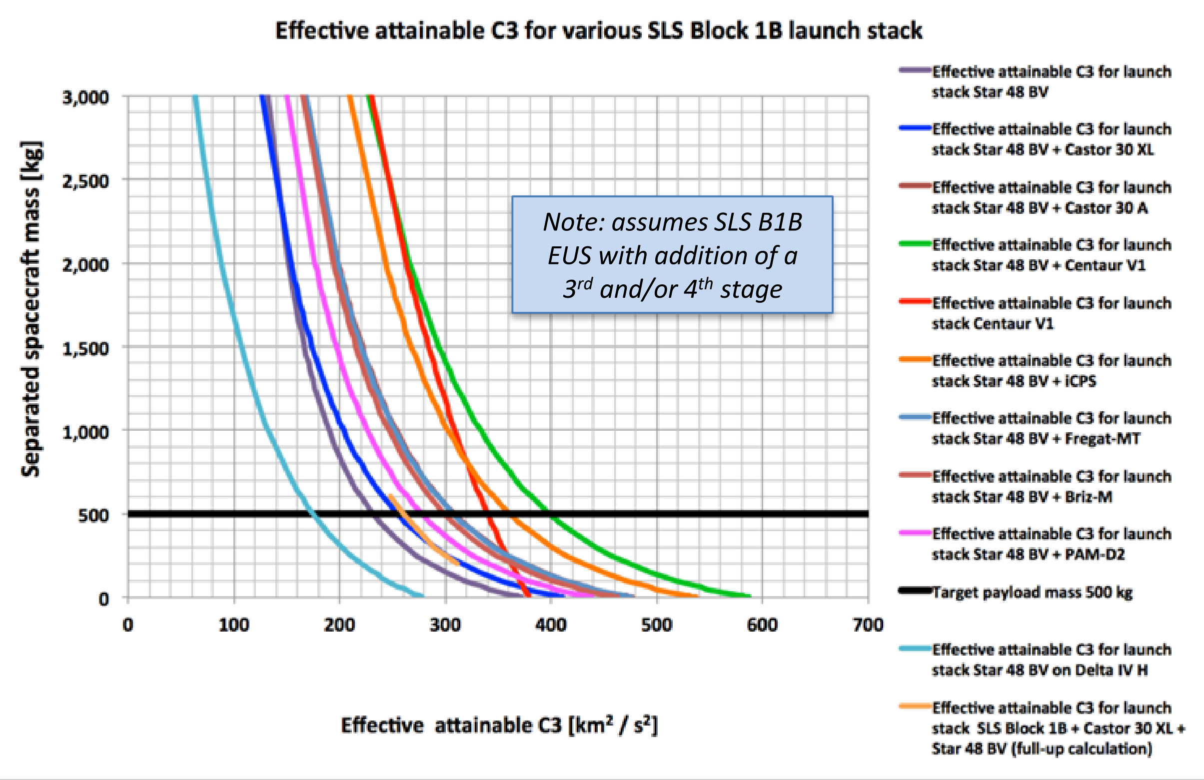
- **“Interstellar Probe” is a mission through the outer heliosphere and to the nearby “Very Local” interstellar medium or VLISM (up to 1000 AU)**

- **Interstellar Probe uses today’s technology to take the first explicit step on the path of interstellar exploration**
  - **Heliosphere:** How does the heliosphere interact with our galactic surroundings?
  - **Kuiper Belt Objects:** Discover new worlds to understand the origin of our solar system
  - **Circum-Solar Dust Disk:** Reveal the unseen 3D dust distribution to understand planetary formation

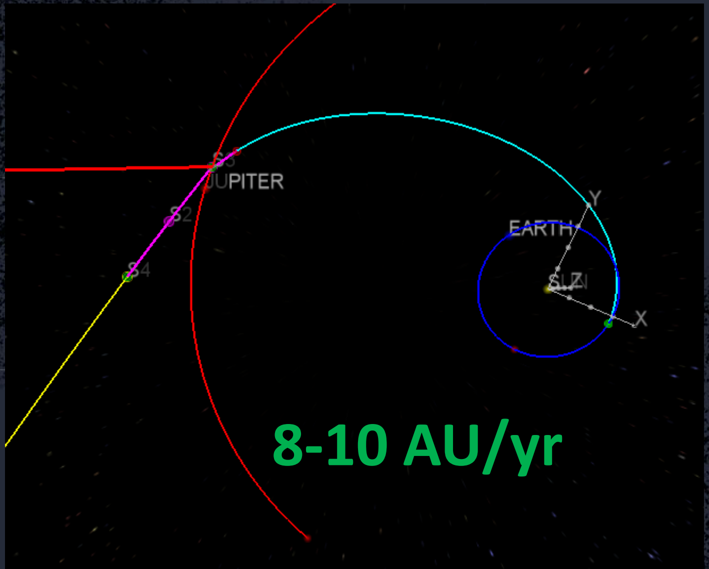
- **Interstellar Probe can pave the way, scientifically, technically, and programmatically for longer interstellar journeys that would require future propulsions systems**

JOHN HOPKINS APL: INDEPENDENT LAUNCH VEHICLE STUDY

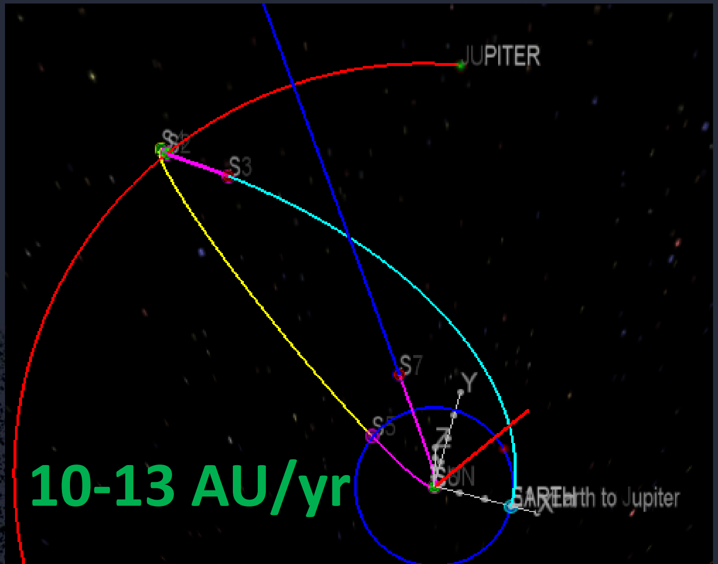
- **Key Decision Points**
  - Asymptotic Velocity leaving the Solar System of 2x that of Voyager's 7.2 AU/yr
  - >300 km^2/s^2 launch energy
  - Pragmatic approach to achieving high C3 energy
  - Fit within typical spacecraft and payload constraints
    - Adequate payload, launch vehicle, and ancillary hardware margins for mass and volume
- **SLS was selected given that that it was the only vehicle to achieve C3s greater than 300 km^2/s^2**



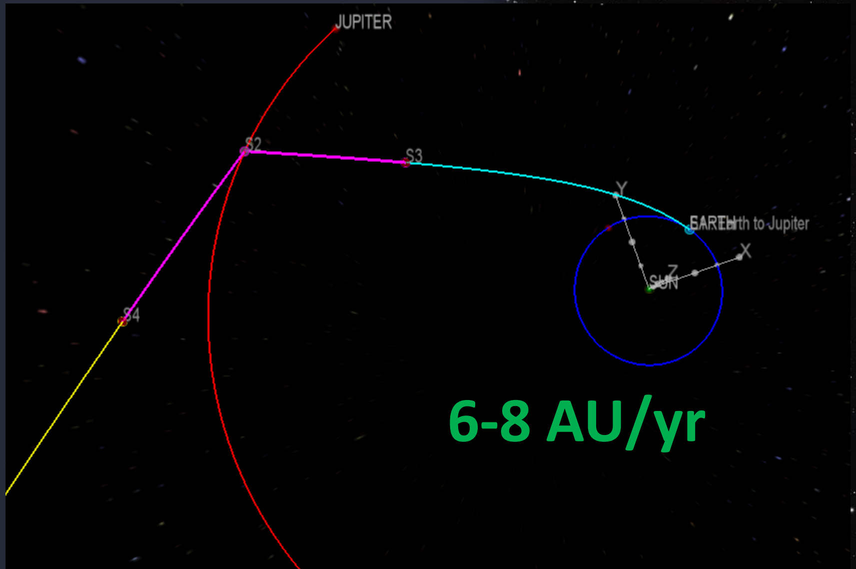
MISSION DESIGN OPTIONS



OPTION 1: Jupiter Powered Flyby

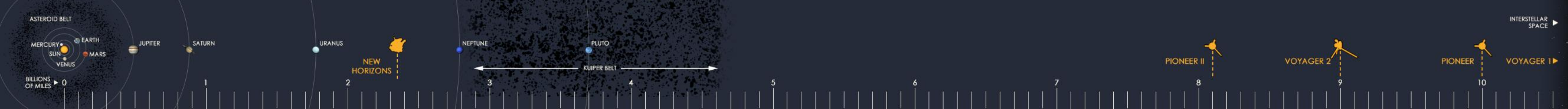


OPTION 2: Solar Oberth

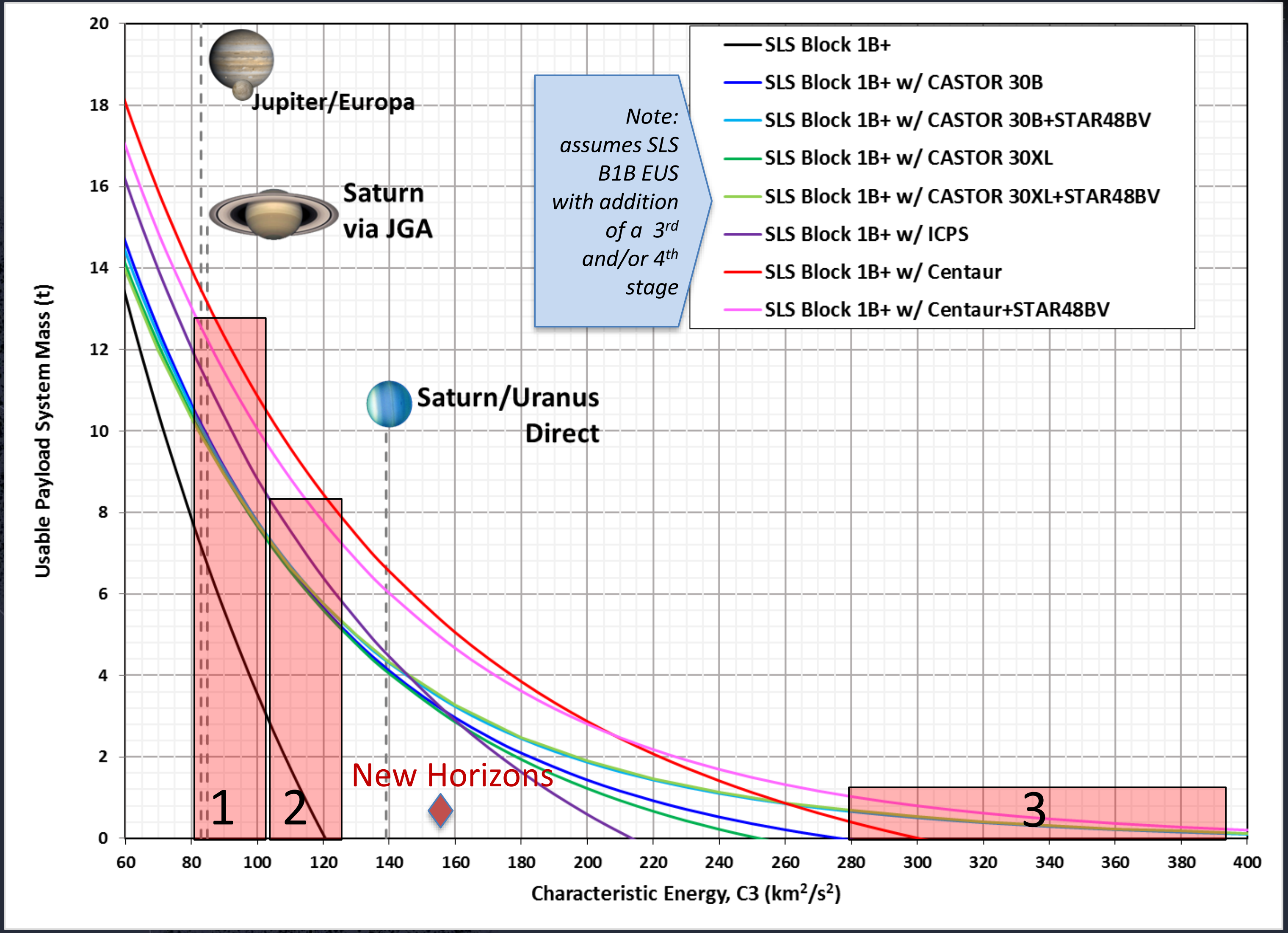


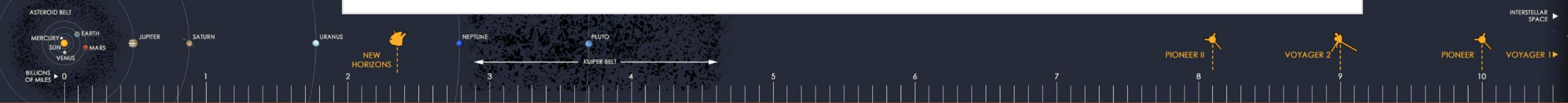
OPTION 3: Passive Jupiter Flyby

DVEGA Mission Option Has Not Been Traded



MISSION DESIGN OPTIONS





SPACECRAFT DESIGN

- **Assuming a New Horizons-like spacecraft**
  - Mass 400-900kg
    - Based on New Horizons, Pioneer, Parker Solar Probe, and Voyager Spacecraft
  - Targeting a 50-year lifetime
  - Ulysses/New Horizons RTG
  - Solar shield concepts developed by Parker Solar Probe Design Team

Fig. 17. A depiction of New Horizons on its STAR 48B-powered upper stage.

Option 1: Jupiter Powered Flyby

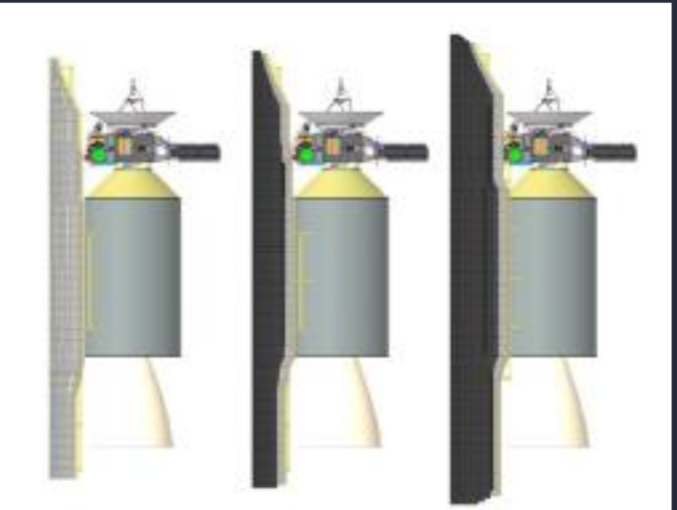


Fig. 19. New Horizons spacecraft on a CASTOR 30XL. From left to right are configurations for perihelia at 5 R_s, 4 R_s, and 3 R_s. The progression of shield complexity is obvious along with required shield size growth with the increasing solid angle subtended by the Sun with decreasing perihelion distance.

Option 2: Solar Oberth

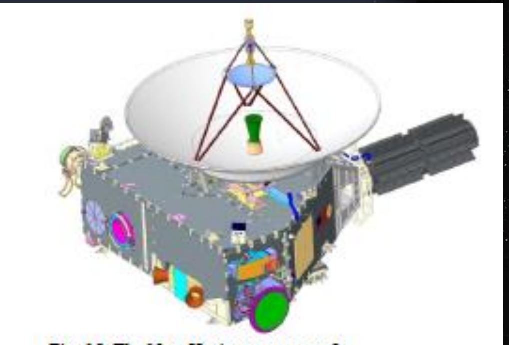
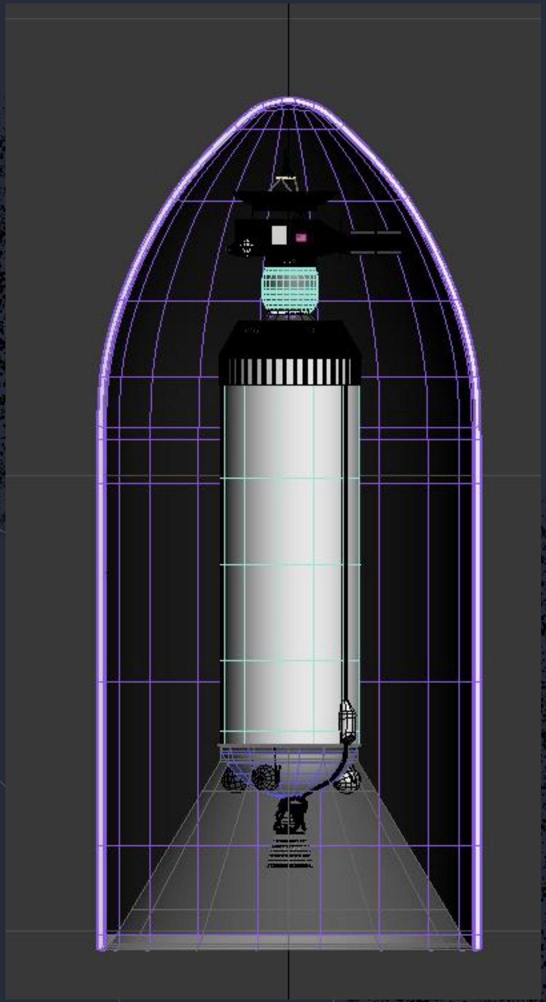
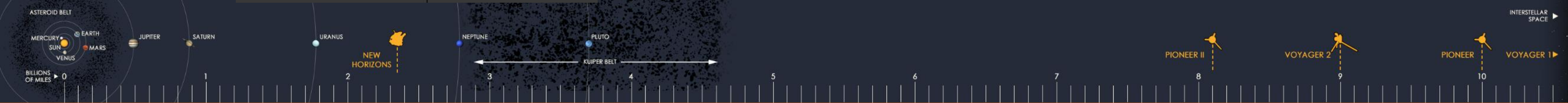


Fig. 15. The New Horizons spacecraft.

Option 3: Jupiter Passive Flyby

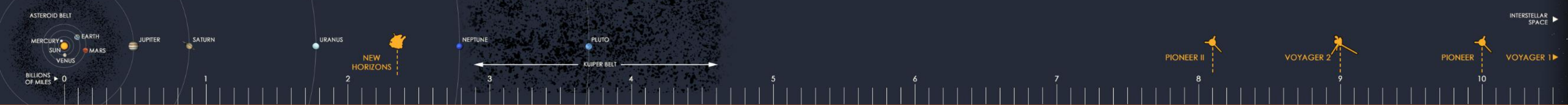
INTEGRATED SPACECRAFT/ PAYLOAD ELEMENT PACKAGING





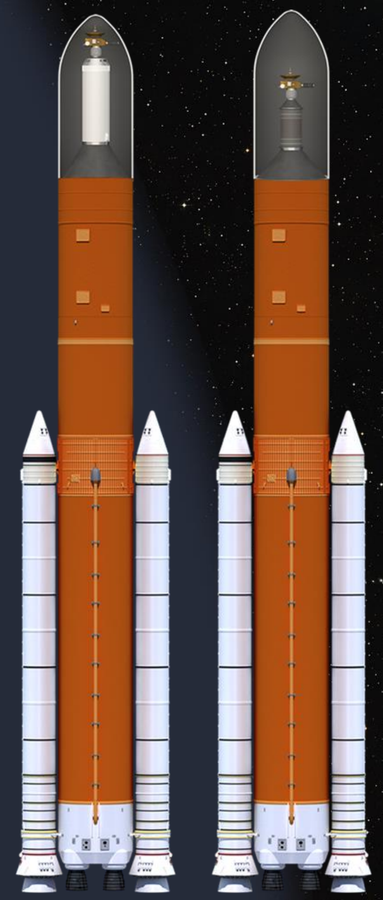
NOTIONAL PROJECT SCHEDULE

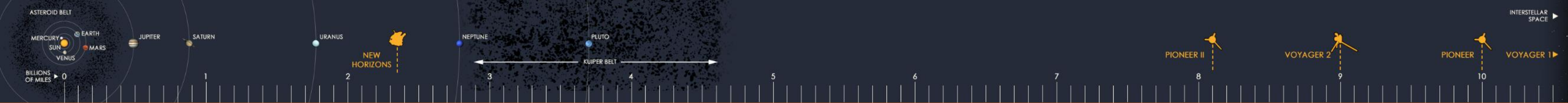
Interstellar Probe Parallels — L-Years	Notional Dates	Note: Dates are Task Start Dates	L-Months	L-Years (Parker Solar Probe)
11	1-Jun-18	Mission Formulation Start	132	11
10	30-Jul-18	Launch System Configuration and Performance Trades (start)	125	10
9	9-Jun-20	Engagement Studies with launch Vehicle and Stage Providers	103	9
9	9-Jun-20	Launch System Configuration, Trajectory and Performance Trades (w/NASA KSC)	103	9
9	9-Jun-20	Spacecraft Phase "A" Start	103	9
8	2-Mar-21	ISP Performs Program Cost, Performance, and Risk Trade Studies	94	8
7	24-May-22	Spacecraft Phase B Start	79	7
3	6-Aug-25	Launch Chicken system Selection (by NASA)	41	3
3	6-Aug-25	Spacecraft Mission Phase C Start	41	3
2	20-Sep-26	Spacecraft Integration and Test Start	27	2
1	15-Feb-28	Spacecraft Environmental Testing start	11	1
0	27-Jul-28	Launch Campaign Start at the Launch Site	5	0
	1/1/2029	Launch Date	0	0



SLS ENABLES SCIENCE

- SLS is America’s heavy-lift vehicle for strategic human exploration and scientific missions
- Manufacturing is complete for the first flight; SLS is nearing the integration phase
- SLS has a flexible architecture and an evolvable upgrade path
- Discussions with the science community are ongoing to determine how SLS can enable breakthrough science missions, such as sending a probe to interstellar space
- **SPIE serves as a front door for parties interested in flying SLS; in addition to Interstellar Probe, we are working with Europa Clipper and Lander, Gateway, Human Landers, CubeSats, space-based solar power, large telescopes, and others**





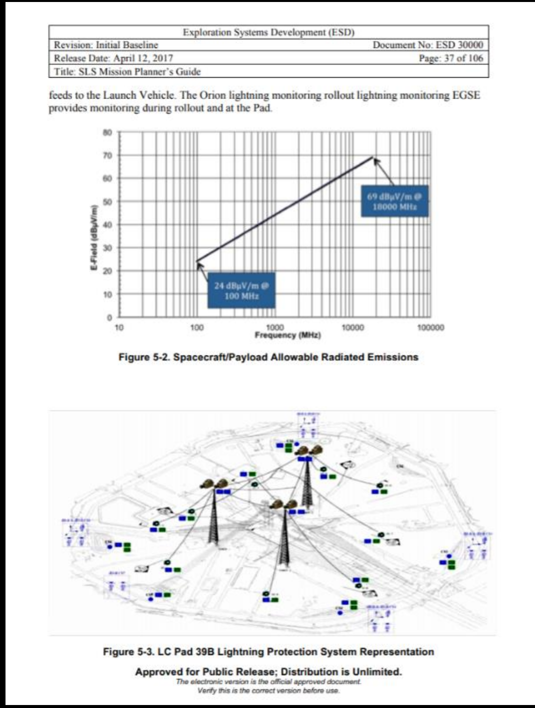
MORE TECHNICAL INFORMATION
SLS MISSION PLANNER'S GUIDE

- **SLS Mission Planner's Guide (ESD 30000)**
  - Google or email: NASA-slspayloads@mail.nasa.gov
  - www.nasa.gov/opportunities for payload opportunities and announcements

National Aeronautics and Space Administration

SPACE LAUNCH SYSTEM (SLS)
MISSION PLANNER'S GUIDE

ESD 30000
REVISION A
RELEASE DATE: TBD



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feeds to the Launch Vehicle. The Orion lightning monitoring rollout lightning monitoring EGSE provides monitoring during rollout and at the Pad.

Figure 5-2. Spacecraft/Payload Allowable Radiated Emissions

Figure 5-3. LC Pad 39B Lightning Protection System Representation

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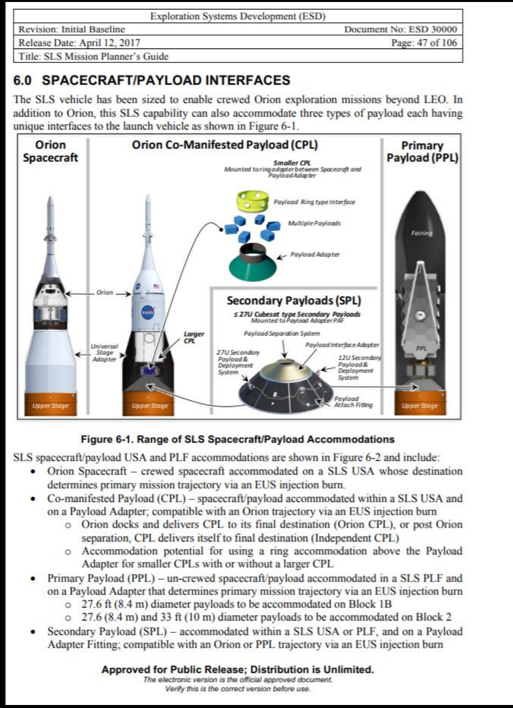

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6.0 SPACECRAFT/PAYLOAD INTERFACES

The SLS vehicle has been sized to enable crewed Orion exploration missions beyond LEO. In addition to Orion, this SLS capability can also accommodate three types of payload each having unique interfaces to the launch vehicle as shown in Figure 6-1.

Figure 6-1. Range of SLS Spacecraft/Payload Accommodations

SLS spacecraft/payload USA and PLF accommodations are shown in Figure 6-2 and include:

- Orion Spacecraft – crewed spacecraft accommodated on a SLS USA whose destination determines primary mission trajectory via an EUS injection burn.
- Co-manifested Payload (CPL) – spacecraft/payload accommodated within a SLS USA and on a Payload Adapter; compatible with an Orion trajectory via an EUS injection burn
  - Orion docks and delivers CPL to its final destination (Orion CPL), or post Orion separation, CPL delivers itself to final destination (Independent CPL)
  - Accommodation potential for using a ring accommodation above the Payload Adapter for smaller CPLs with or without a larger CPL
- Primary Payload (PPL) – un-crewed spacecraft/payload accommodated in a SLS PLF and on a Payload Adapter that determines primary mission trajectory via an EUS injection burn
  - 27.6 ft (8.4 m) diameter payloads to be accommodated on Block 1B
  - 27.6 (8.4 m) and 33 ft (10 m) diameter payloads to be accommodated on Block 2
- Secondary Payload (SPL) – accommodated within a SLS USA or PLF, and on a Payload Adapter Fitting; compatible with an Orion or PPL trajectory via an EUS injection burn

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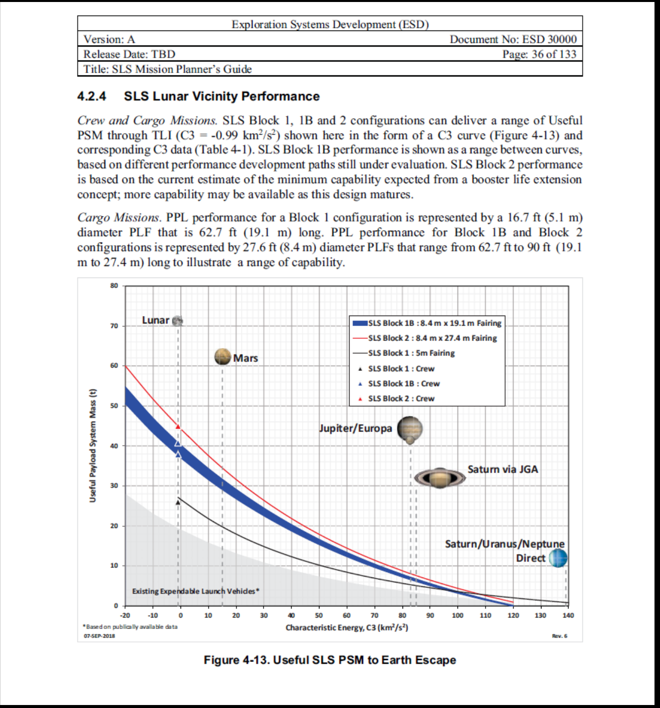

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4.2.4 SLS Lunar Vicinity Performance

Crew and Cargo Missions. SLS Block 1, 1B and 2 configurations can deliver a range of Useful PSM through TLI ($C3 = -0.99\ km^2/s^2$) shown here in the form of a C3 curve (Figure 4-13) and corresponding C3 data (Table 4-1). SLS Block 1B performance is shown as a range between curves, based on different performance development paths still under evaluation. SLS Block 2 performance is based on the current estimate of the minimum capability expected from a booster life extension concept; more capability may be available as this design matures.

Cargo Missions. PPL performance for a Block 1 configuration is represented by a 16.7 ft (5.1 m) diameter PLF that is 62.7 ft (19.1 m) long. PPL performance for Block 1B and Block 2 configurations is represented by 27.6 ft (8.4 m) diameter PLFs that range from 62.7 ft to 90 ft (19.1 m to 27.4 m) long to illustrate a range of capability.

Figure 4-13. Useful SLS PSM to Earth Escape


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