
# Ballistic Mission Trades

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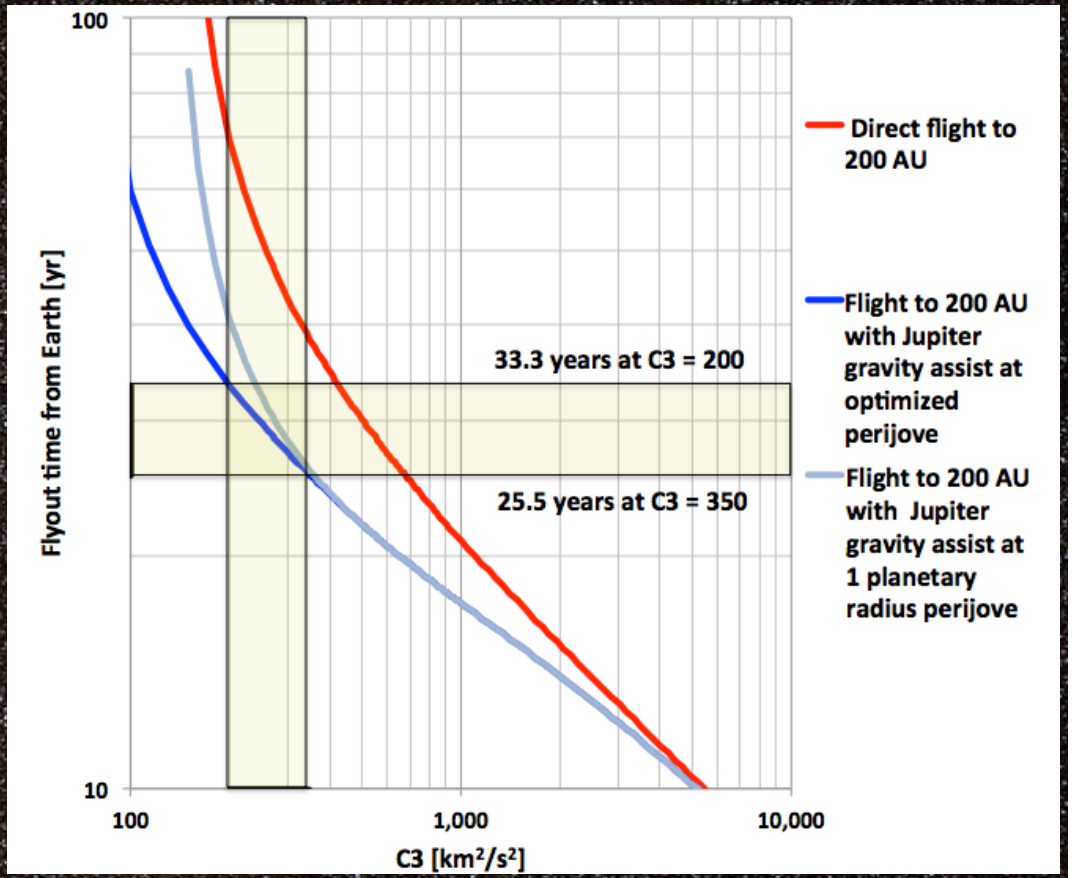
# *Consider Ballistic Launches Outward from 1 AU*

- No thermal issues inside of 1 AU
- Limits flyout speed
- Energy gain from Jupiter is significant and a flyby is required
- Multiple kick stages are required
- Where the kick stages are fired can affect the outcome
  - (1) Use all stages at launch – Jupiter flyby is passive
  - (2) Use only some stages at launch – burn at Jupiter periapsis
  - (3) In any case, launch the stack to C3 > 0 to minimize RPS safety issues

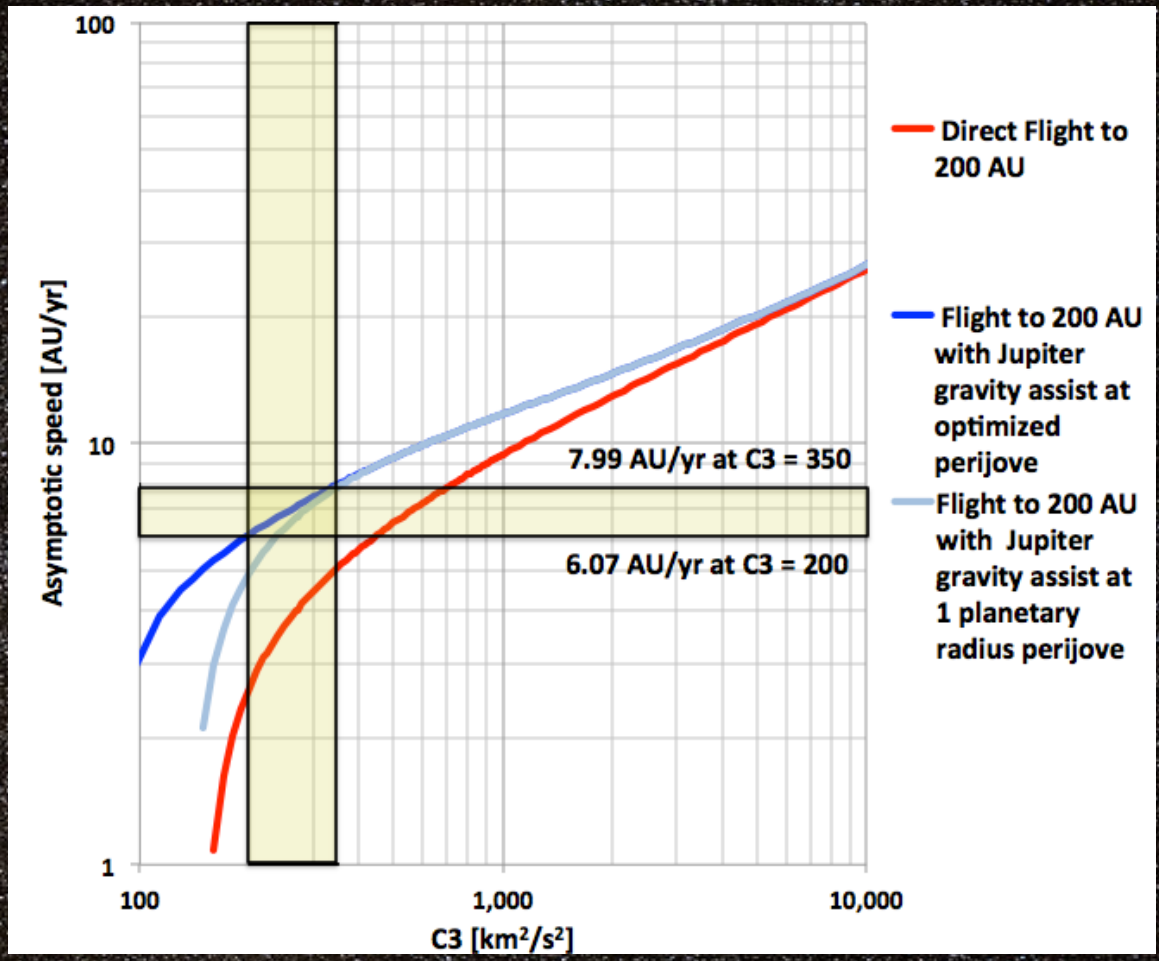
# Physics Limits - Distance

- Transit times from Earth to 200 AU
  - Ballistic trajectories both with and without Jupiter gravity assists
- Optimized gravity assist cuts transit time by factor >2 for C3 < 350 $km^2/s^2$
- Voyager 1
  - 129.5 AU (18 light hours)
  - 37 years en route
  - C3 ~100 $km^2/s^2$
  - Jupiter and Saturn assists

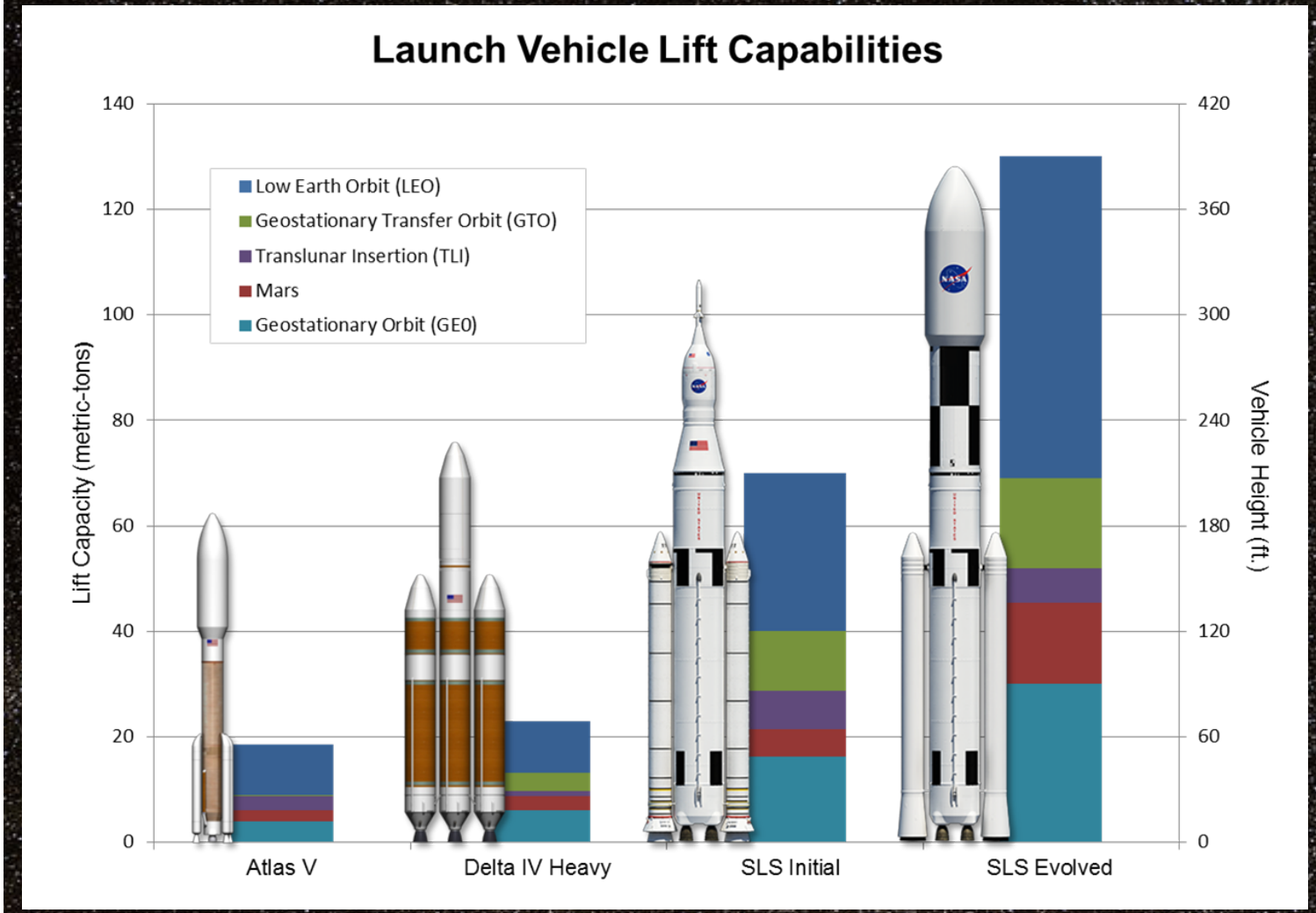


# Physics Limits - Speed

- Voyager 1 is the fastest object leaving the solar system
  - Speed is 3.6 AU per year (17 km/s)
- Twice that speed is 7.2 AU/yr (34 km/s)
  - Achieved for a launch C3 of 278 $km^2/s^2$



# Launch Vehicles



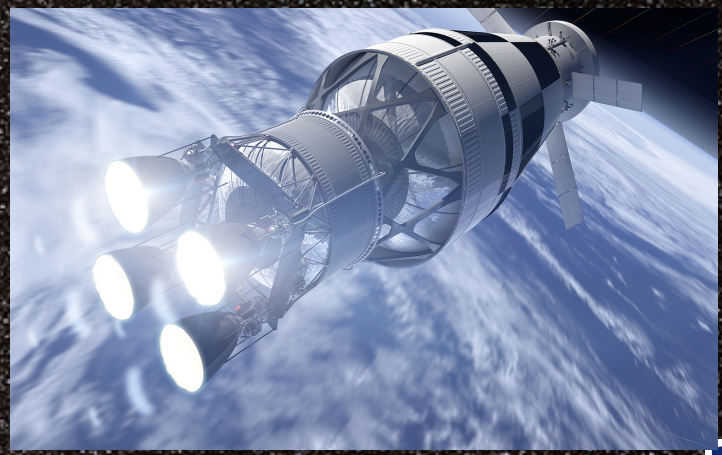

Comparison of current and notional launch vehicle capabilities for some of the vehicles usable for high-C3 robotic space missions

# *Appropriate Kick Stages*

- Staging configurations are mass optimized - at the same specific impulses - for each stage providing the same ΔV
- This implies that higher stages in the stack need to be smaller in order to try to keep the stage effects about the same
- The approach is to minimize risk by using existing hardware, preferably with flight heritage

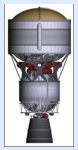
- The SLS 1B consists of solid strap-ons, core and an upper-stage EUS (2nd stage) which is currently envisioned as using 4 RL-10 engines

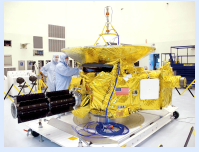
**Notional: SLS Block 1B Exploration Upper Stage with an Orion capsule following separation from the booster**

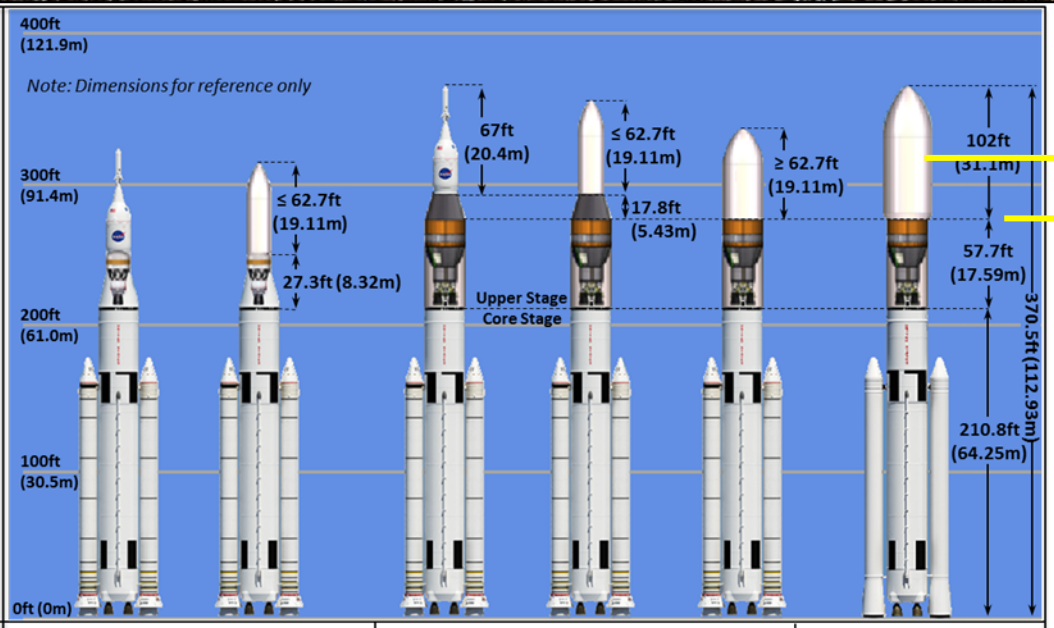


# SLS Core Vehicle
# ICPS and Caster 30B and SC "stack" = the SLS Payload

ICPS and Adaptor ~ 28 feet + CASTOR 30B and Adaptor ~ 13 feet + Spacecraft and Adaptor ~ 9 feet = ~ 50 feet








| SLS Configuration | Block 1 (89t LEO) | | Block 1B (117t IMLEO) (93t LEO) | | | Block 2B (138/140/152t IMLEO) (119/120/137t LEO) |
|---|---|---|---|---|---|---|
| Vehicle ID | 10003 | 10500 | 28000 | 27500 | 27000 | 25000A/26000A/26001A |
| Core | 8.4m Common Core 4 RS-25D | | 8.4m Common Core 4 RS-25E | | | 8.4m Common Core 4 RS-25E |
| Booster | 5 Segment Shuttle Booster RSRMV | | 5 Segment Shuttle Booster RSRMV | | | Advanced Booster ASB/GG/ORSC |
| Upper Stage | ICPS 1 RI-10B2 | | Common Upper Stage 4 RL-10C2 | | | Common Upper Stage 4 RL-10C2 |
| Payload | Orion | 5m Payload | Orion | 5m Payload | 8.4m Payload | 10m Payload |

Revision: 4-25-14

Payload Stack

Core Vehicle

*Bottom Line: The ICPS, CASTOR 30B, Adaptors and Spacecraft are treated as a single "payload" for SLS*

# *Various Kickstage Combinations Considered Passive Jupiter Flyby*

## SLS Block 1B with CASTOR-30B and STAR-48B
**SLS / EUS (2nd Stage) / 3rd Stage / 4th Stage / Payload**

## SLS Block 1B/EUS w Delta-4 Upper Stage & CASTOR-30B
**SLS / EUS (2nd Stage) / 3rd Stage / 4th Stage / Payload**

## SLS Block 1B: With CASTOR 30B Solid Third Stage
**SLS / EUS (2nd Stage) / 3rd Stage / Payload**

## SLS Block 1B with Four Stages: Options
**SLS / EUS (2nd Stage) / 3rd Stage / 4th Stage / Payload**

Delta – 4 / STAR 48B / 500 kg spacecraft
C3 = 387.1 $km^2/s^2$  24.4 years to 200 AU  8.3 AU per year

- **Spacecraft masses of 200 kg to 500 kg considered**
- **PAM-D2 not a good trade**
- **5 stage can fit (in shroud): Delta 4 / CASTOR 30B / STAR-48B**
  - **Case not yet studied**