Mars Transportation Assessment Study

MTAS NTP Overview

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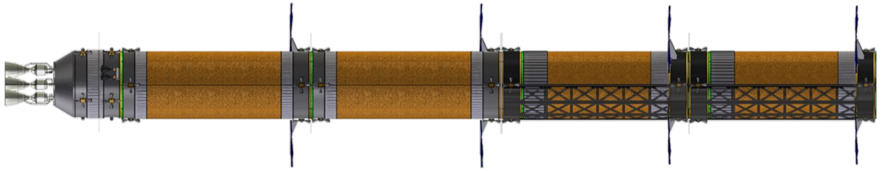
Office of Technology, Policy, and Strategy (OTPS)

MTAS NTP Design Evolution

Previous Conjunction-class Reference Vehicle

MTAS 1.1 Quick-Turn Design

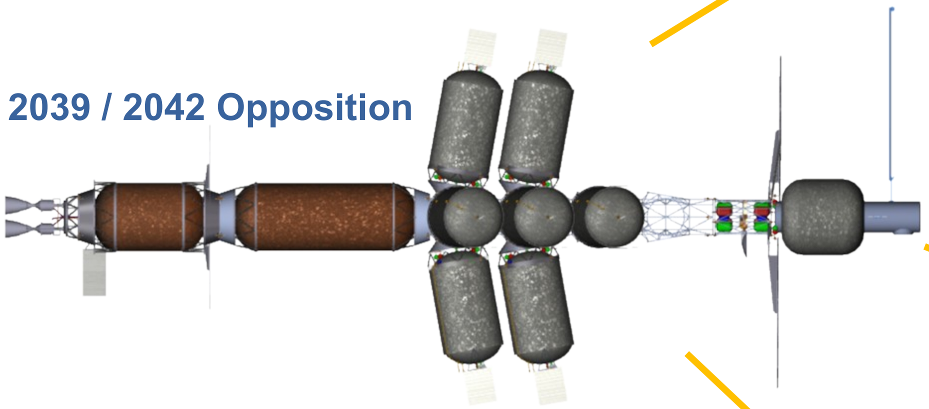


- Analysis leveraged previous Conjunction-class vehicle designs
- Requirement to aggregate in Cis-Lunar space presented a severe challenge
  - Forced solution away from “rocket equation optimal” conops (pushed 3 km/s of 11 km/s Earth-Mars roundtrip ΔV back onto the launch vehicle)
  - Severely limited the utility of Commercial launch vehicles
- <u>Opposition mission required > 900s Isp to close</u>

MTAS 1.2 Architecture Design

- All-new vehicle designs developed implementing latest technology assumptions
- Ground rules allowed for optimization of the aggregation orbit and conops

2039 / 2042 Opposition

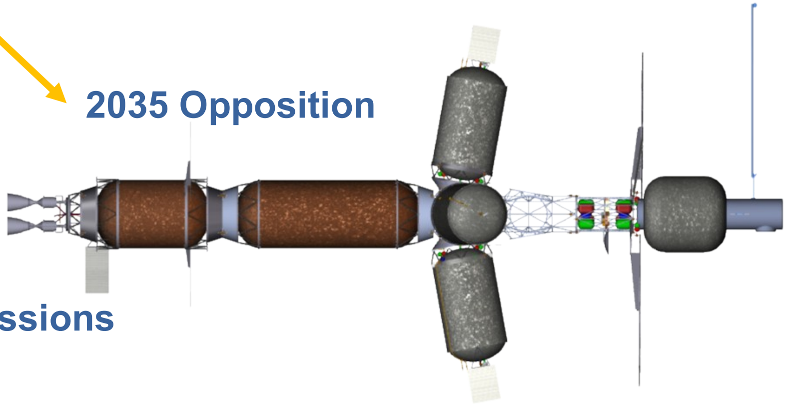


All Conjunction Opportunities

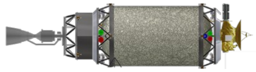
Dual Lander Delivery

Single Lander Delivery

2035 Opposition

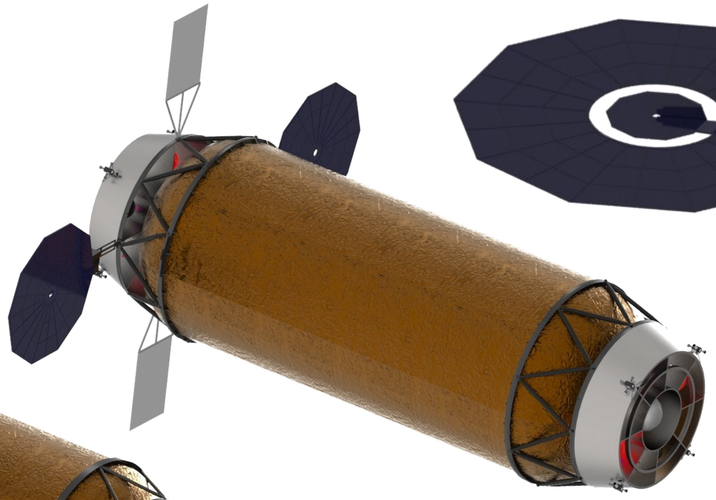


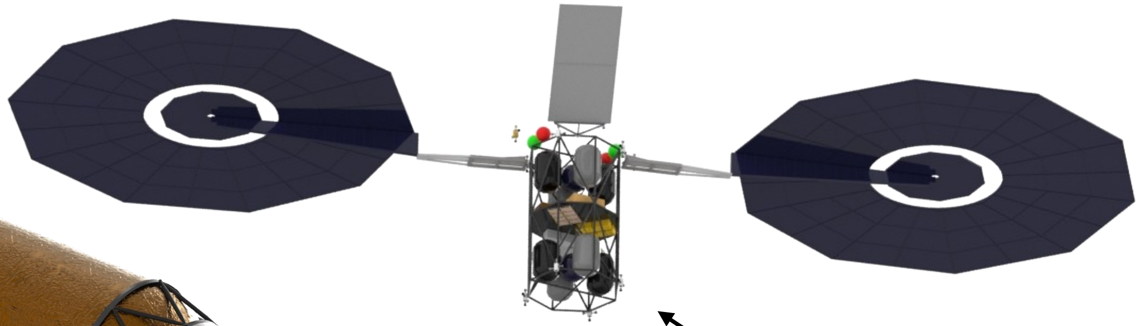
Robotic Science Missions

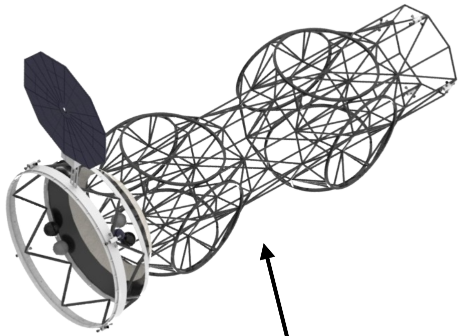


- Modular vehicle design provides "right sizing" flexibility for many different mission profiles and objectives
- <u>Opposition mission closes with < 900s Isp</u>

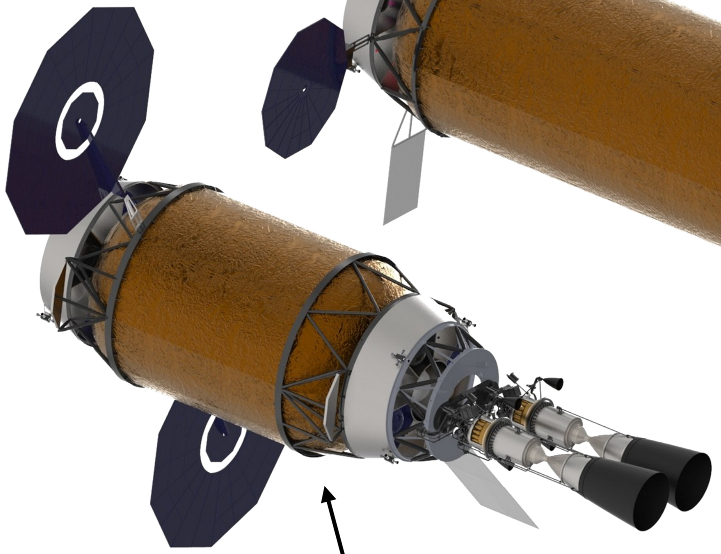
Nuclear Thermal Propulsion System Elements

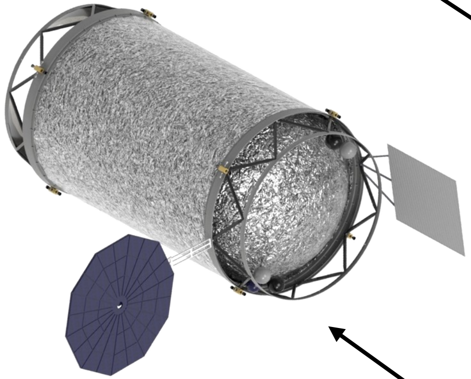






Drop Tank Truss Element
- Provides propellant and power interfaces for up to 8 commercial inline stages





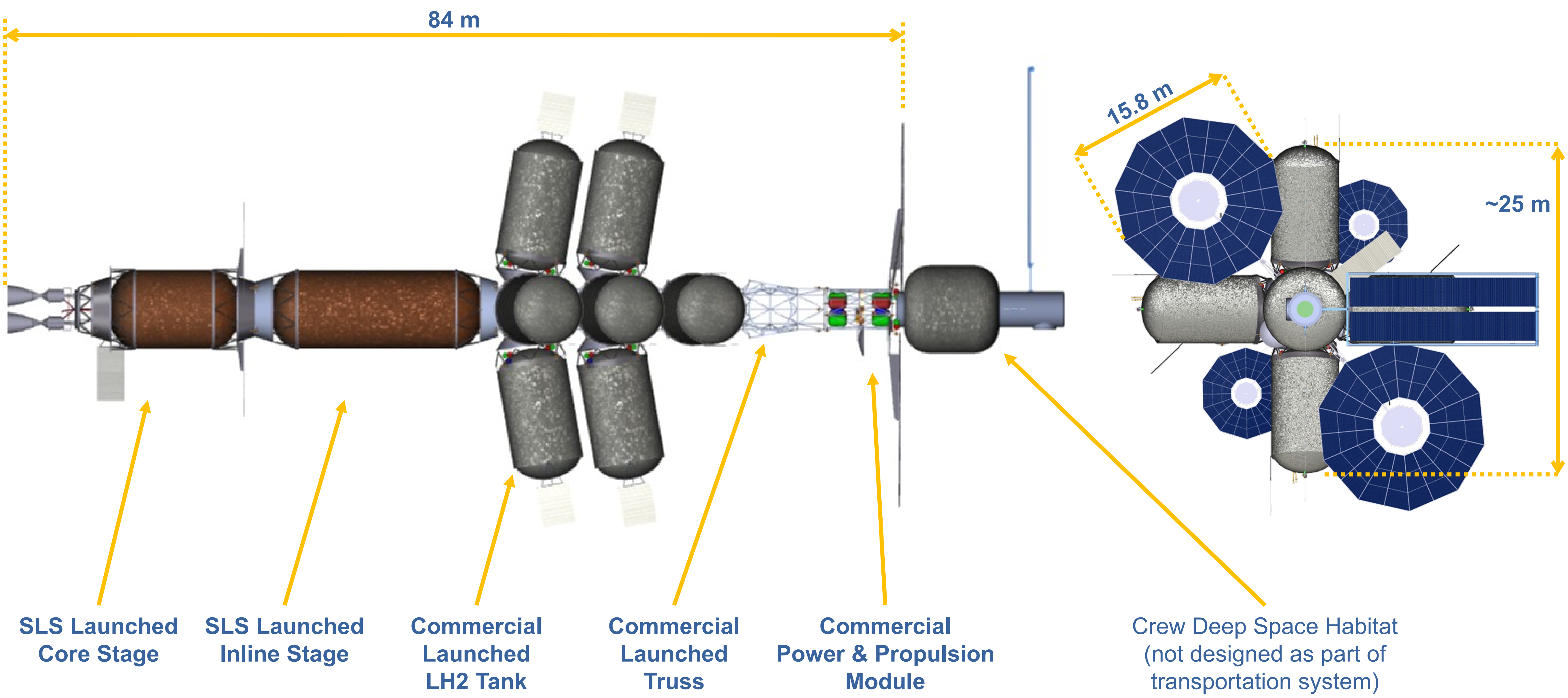
NTP Core Stage
- 2x 25k lbf Nuclear Thermal Rockets, 900s Isp
- 18 kWe EOL Solar Array
- Two-stage cryocooling (90K and 20K) to achieve Zero Boil-off LH2
- MMH/NTO RCS

SLS Inline Stage
- 11 kWe EOL Solar Array
- 90K and 20K cryocoolers to achieve Zero Boil-off LH_2
- MMH/NTO RCS

Commercial Inline Stage
- 11 kWe EOL Solar Array
- 90K and 20K cryocoolers to achieve Zero Boil-off LH2
- MMH/NTO RCS

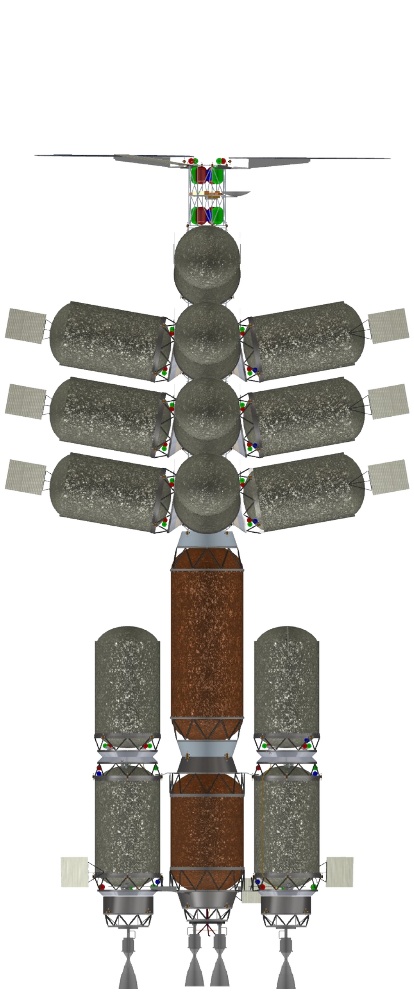
Power & Propulsion Module
- 110kW EOL Solar Array to power integrated stack
- Large MMH/NTO auxiliary propulsion system to support station-keeping and integrated stack control

Configuration at Earth Departure for 2039 Opposition Mission

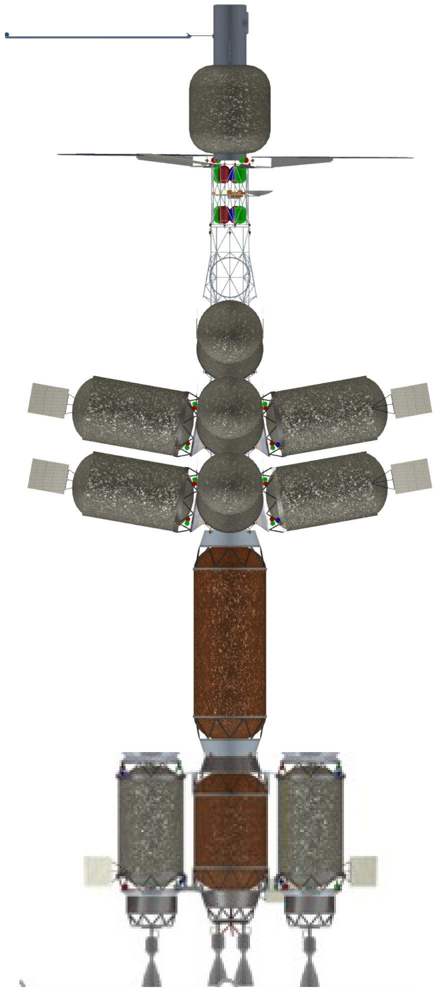


Vehicle Configuration Throughout 2039 Mission

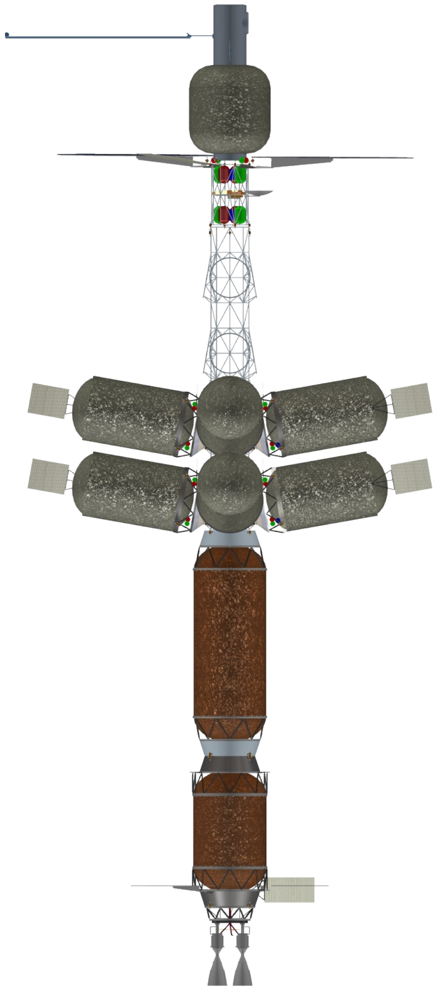
Immediately prior to
1st Orbit Raise



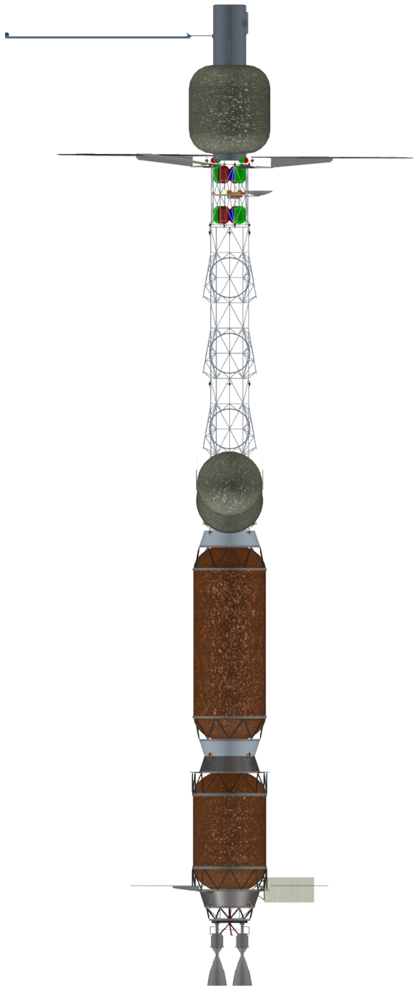
Immediately prior to
Earth Departure



Immediately prior to
Deep Space Maneuver

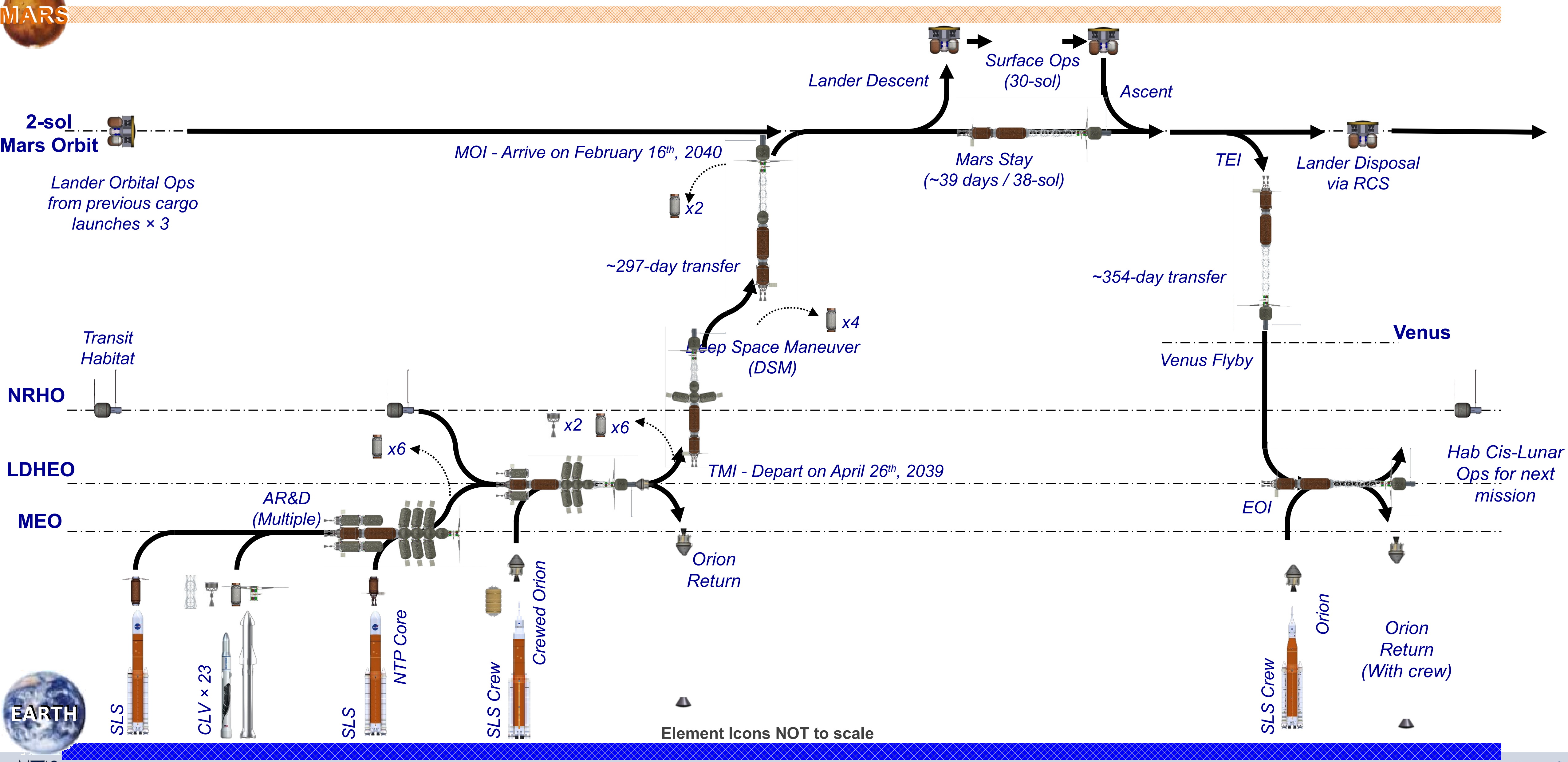


Immediately prior to
Mars Arrival



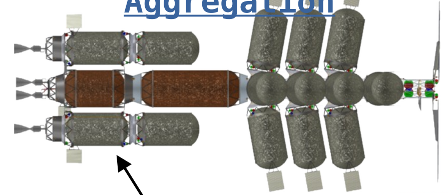
Immediately prior to
Mars Departure

Baseline 2039 NTP Crew Mission Profile & Conops

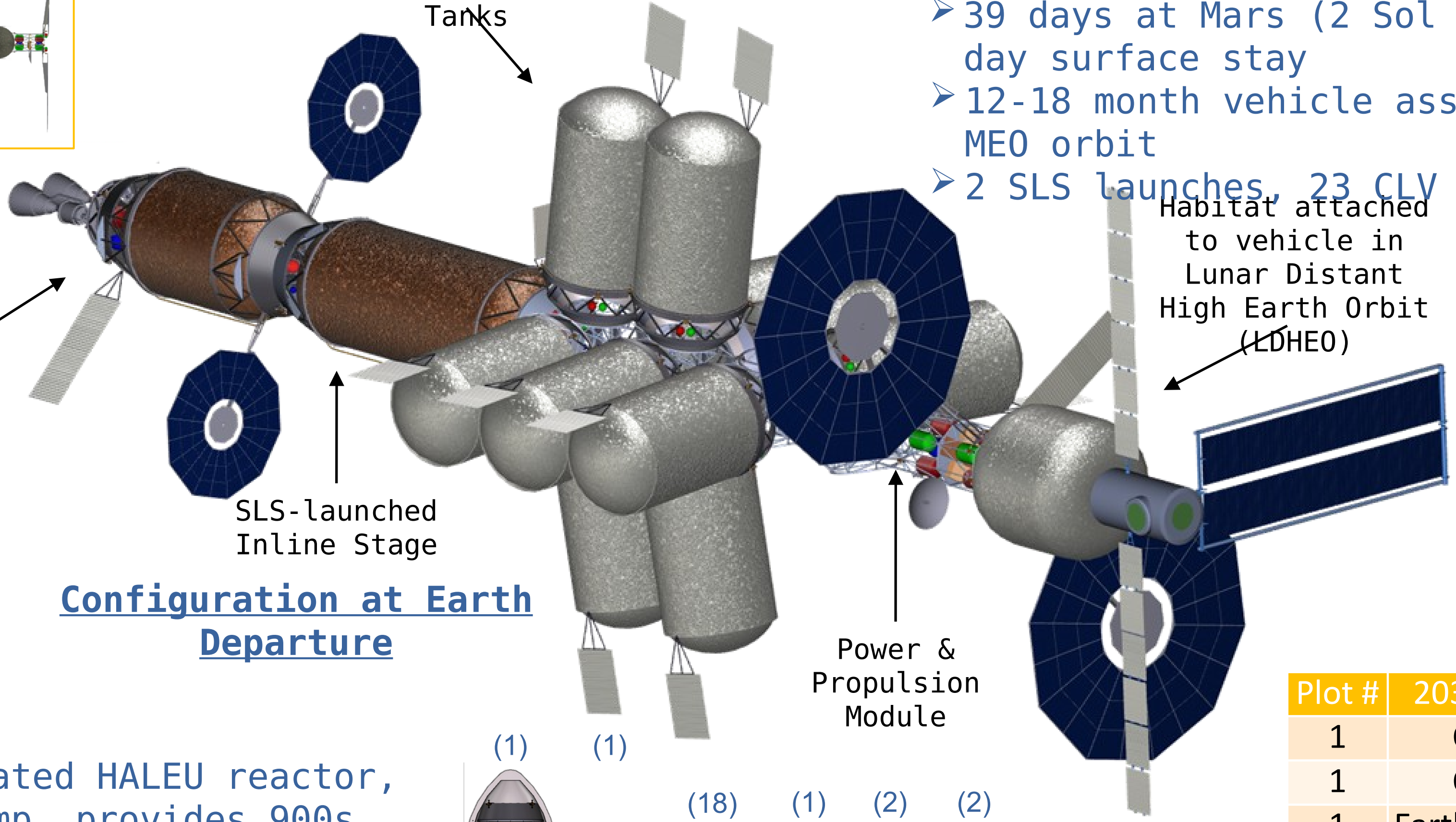


NTP Spacecraft For 2039 Opposition Class Crew Mission

Configuration at Aggregation



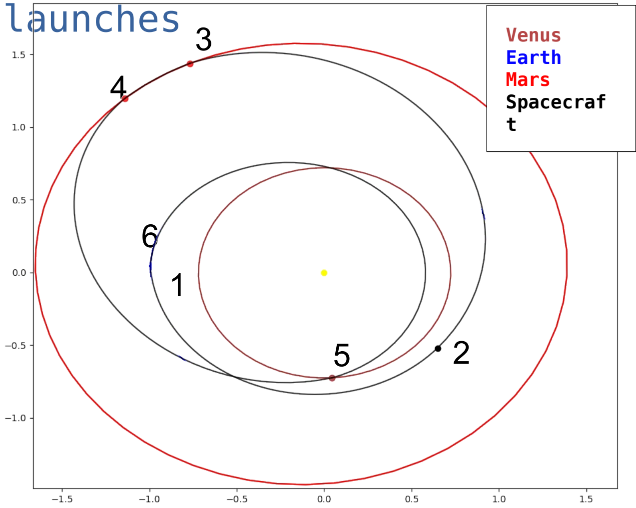
Commercially-launched Strap-on Core Stages



Configuration at Earth Departure

Key Mission Specs

- 690 days roundtrip crew time away from Earth
- 39 days at Mars (2 Sol parking orbit), including 30 day surface stay
- 12-18 month vehicle assembly in 1,200km x 7,000km MEO orbit
- 2 SLS launches, 23 CLV launches



Plot #	2039 Mission Event	Date	ΔV
1	Orbit Raise #1	12/17/2038	908
1	Orbit Raise #2	1/6/2039	1,243
1	Earth Departure (TMI)	4/26/2039	1,460
2	Deep Space Maneuver	7/27/2039	2,693
3	Mars Arrival (MOI)	2/16/2040	1,443
4	Mars Departure (TEI)	3/26/2040	2,632
5	Venus Flyby	10/6/2040	-
6	Earth Arrival (EOI)	3/16/2041	1,039

Key Technologies

- 530 MWth moderated HALEU reactor, ~2750K exit temp. provides 900s Isp
- 90K and 20K cryocoolers
- Low-leak cryogenic valves and cryo couplers
- Autonomous Rendezvous, Proximity Operations, and Docking (RPOD)

Observations & Conclusion

- Key Observations
  - Tailoring the aggregation orbit significantly improves architecture feasibility and “optimality”
  - Launch vehicles are a significant constraint in the NTP architecture
    - Commercial launch vehicle fairing volumes limit LH2 tank volumes
    - Limited SLS launch and production rates prevent taking full advantage of its capabilities
- Opportunities for Improvement
  - Incorporate cost analysis insights to capture opportunities for significant cost savings
  - Leverage excess performance on Cargo missions to pre-position return propellant at Mars

- MTAS has developed a highly capable NTP architecture providing multiple approaches to enabling a human Mars mission in the 2030s
  - Modular vehicle design provides "right sizing" flexibility for many different mission profiles and objectives
  - NTP performance delivers shorter roundtrip times, reducing cumulative crew radiation dose