National Aeronautics and Space Administration

Exploration Operational Concepts

Microbiology Water Forum

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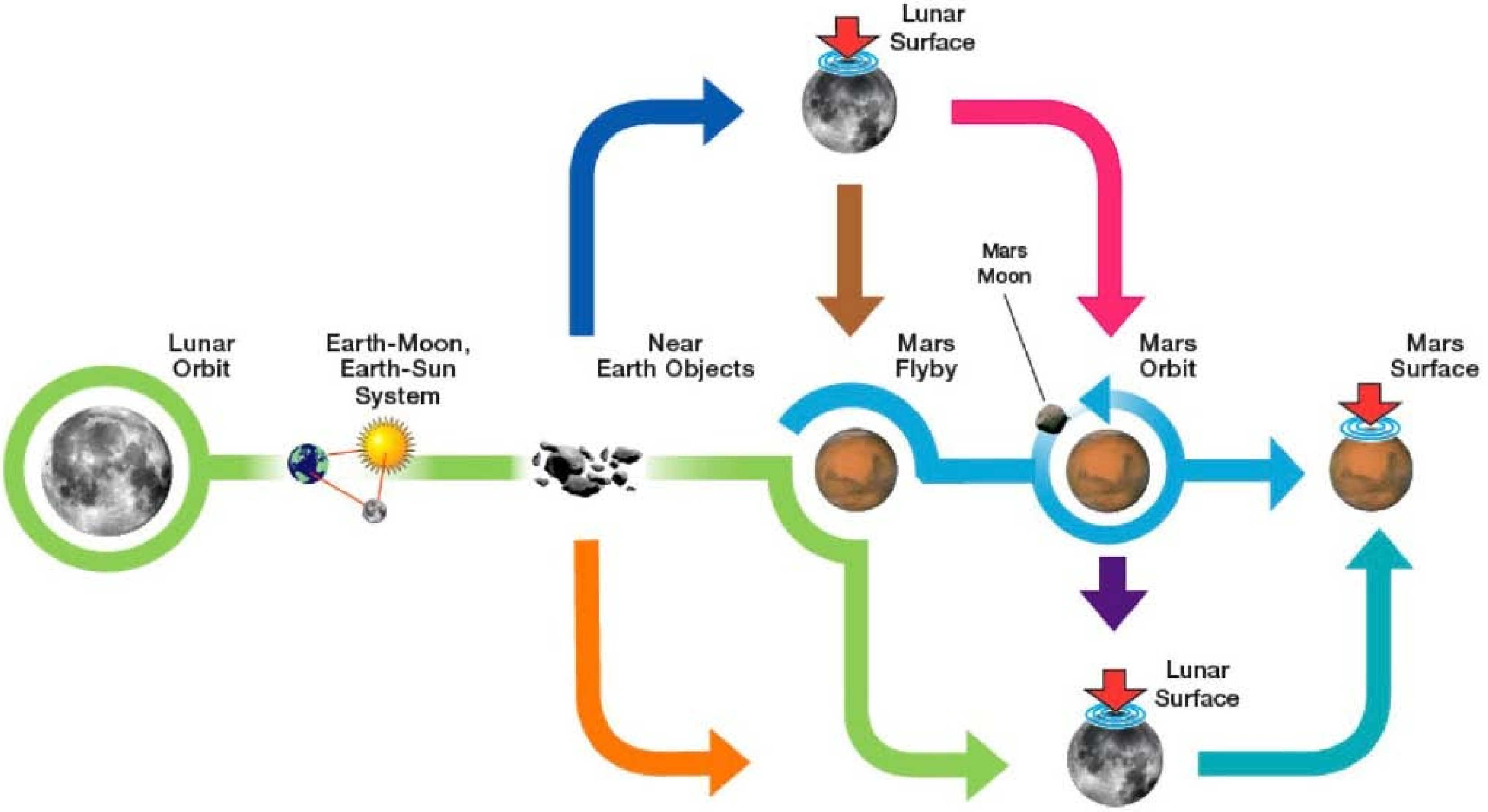
July 27, 2011

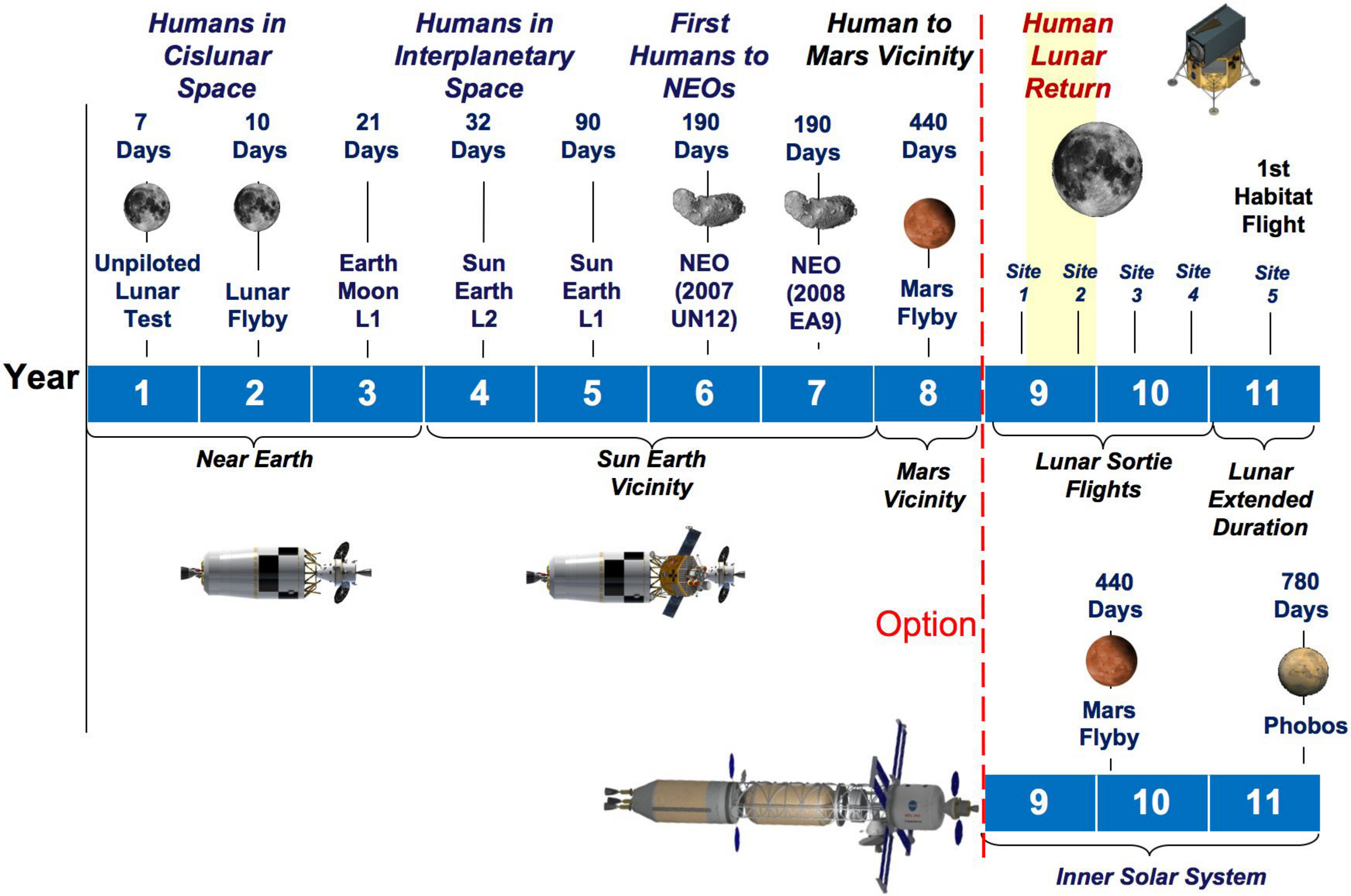
Where to Next?

- October 2009
- Delivered to NASA Administrator and Office of Science and Technology Policy
- Provides the context for discussing future destinations

The Flexible Path



One Path with a Fork

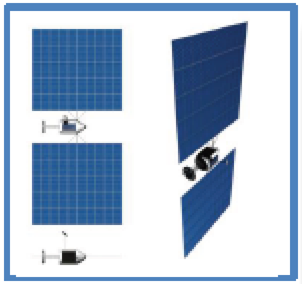


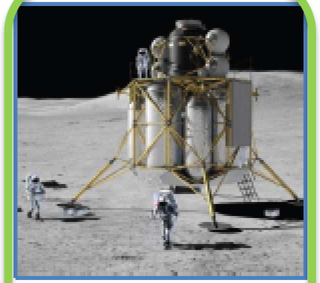
Notional Architecture Elements

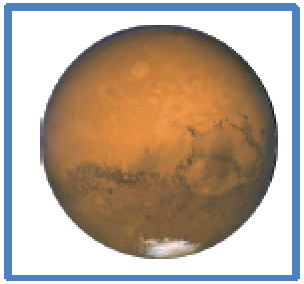

Space Launch System (SLS)-HLLV


Multi-purpose Crew Vehicle (MPCV)


Cryogenic Propulsion Stage (CPS)


Solar Electric Propulsion (SEP)


Lander


Mars Elements

Graphics are Notional Only – Design and Analysis On-going


EVA Suit


Multi-Mission Space Exploration Vehicle (MMSEV)


Deep Space Habitat (DSH)

Robotics & EVA Module (REM)


Kick Stage


NEA Science Package

Closed Loop ECLSS

Key Technical Architecture Observations To Date

- Advanced in-space propulsion (e.g., solar electric propulsion {SEP}) is a big enabler: Reduces launch mass by 50% (factor of 2) and mass growth sensitivity by 60%
- A balance of ELVs and HLLVs is optimal for varying mission needs
- Shuttle-derived HLLV option (100t-class evolvable to ~130t for deep space, full capability missions) meets more current FOMS than other options, although out-year affordability is still a fundamental challenge for long term exploration. Alternative design analysis continues to be part of NASA's strategy, coupled with an assessment of possible affordability initiatives.
- HLLV and crew vehicle should be a human-rated system
- ELV-only solution not optimal given all factors
- Staging at HEO or Earth-Moon L1 for deep space missions better than LEO
- Crew Transportation Vehicle (CTV) full ascent and entry capability is needed
- Additional capability, such as the MMSEV needed for EVA and robotics capability
- High reliability ECLSS is desired over fully closed loop ECLSS except for Mars missions
- In-Situ Resource Utilization (ISRU) is an enabler, particularly for surface missions
- Modularity and commonality aid key affordability FOM

- HLLV=Heavy Lift Launch Vehicle
- CTV=Crew Transportation Vehicle
- MMSEV=Multi-mission Space Exploration Vehicle
- EVA=Extravehicular Activity
- SEP=Solar Electric Propulsion
- ECLSS=Environmental Control and Life Support Systems

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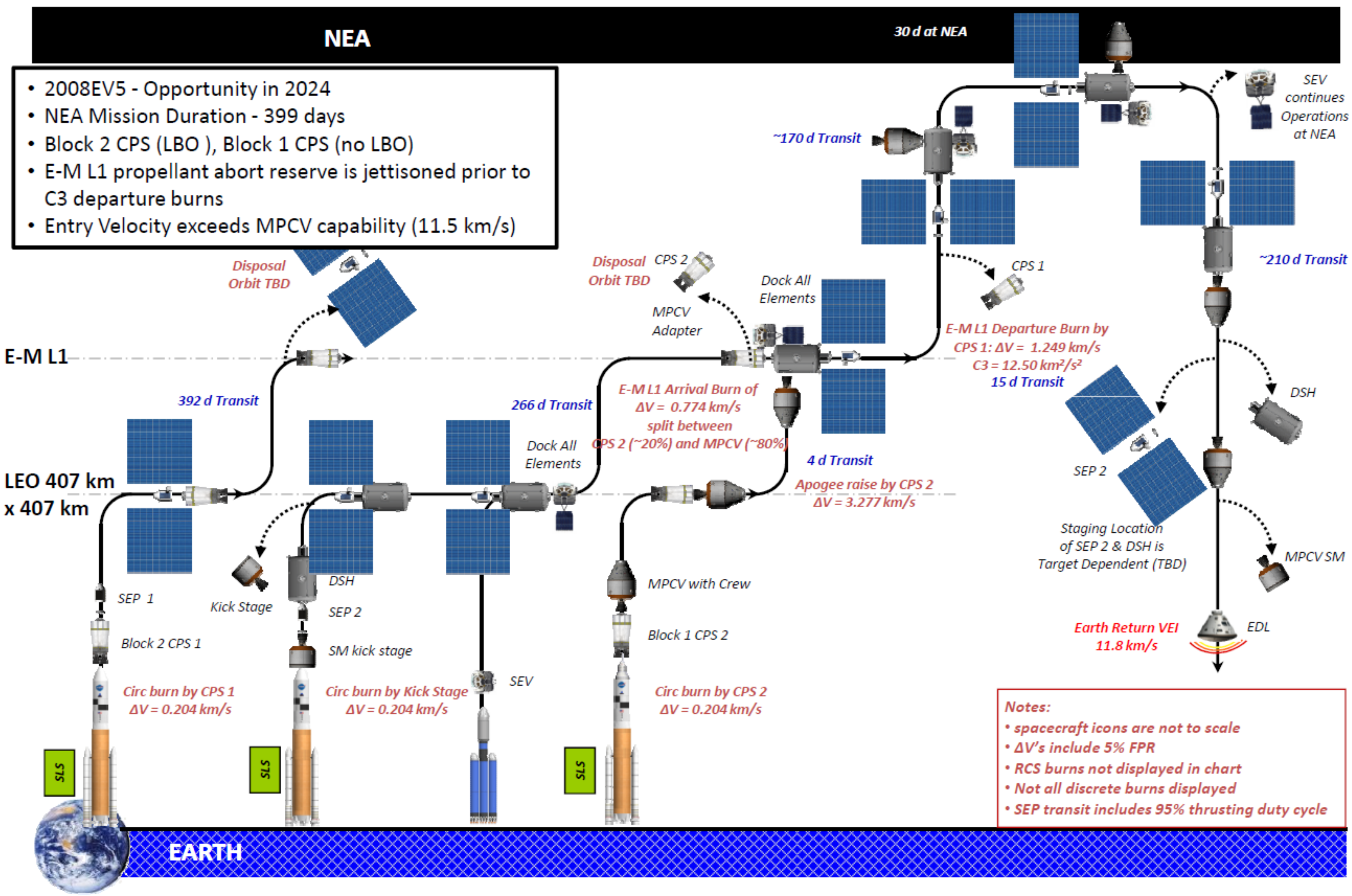
A Sequence for an Asteroid

Reference NEA Mission: DRM 34B (NEA 2008EV5 with SEP)



Technology Applicability to Destination (1)

	LEO (31A)	Adv. LEO (31B)	Cis-Lunar (32A,B & 33A,B)	Lunar Surface - Sortie (33C)	Lunar Surface - GPOD (33X)	Min NEA (34A)	Full NEA (34B)	Mars Orbit	Mars Moons (35A)	Mars Surface (35B)
LO2/LH2 reduced boiloff flight demo	Not applicable	Not applicable	May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
LO2/LH2 reduced boiloff & other CPS tech development	Not applicable	Not applicable	May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
LO2/LH2 Zero boiloff tech development	Not applicable	Not applicable	Not applicable	Not applicable	May be required	May be required	May be required	Probably required	Probably required	Probably required
In-Space Cryo Prop Transfer	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Energy Storage	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Electrolysis for Life Support (part of Energy Storage)	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Fire Prevention, Detection & Suppression (for 8 psi)	Not applicable	May be required	May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Environmental Monitoring and Control	Not applicable	May be required	May be required	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
High Reliability Life Support Systems	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Closed-Loop, High Reliability, Life Support Systems	Not applicable	Not applicable	Not applicable	Not applicable	Probably required	May be required	May be required	Probably required	Probably required	Probably required
Proximity Communications	Not applicable	Not applicable	Probably required	Required technology	Required technology	Required technology	Required technology	Probably required	Required technology	Required technology
In-Space Timing and Navigation for Autonomy	Not applicable	Not applicable	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
High Data Rate Forward Link (Ground & Flight)	Not applicable	Not applicable	May be required	May be required	May be required	Required technology	Required technology	Required technology	Required technology	Required technology
Hybrid RF/Optical Terminal (Communications)	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology
Behavioral Health	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Optimized Exercise Countermeasures Hardware	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Human Factors and Habitability	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Long Duration Medical	Not applicable	Not applicable	May be required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Biomedical countermeasures	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Protection – Galactic Cosmic Rays (GCR)	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Protection – Solar Proton Events (SPE)	Required technology	Required technology	Required technology	Required technology	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Space Radiation Shielding – GCR & SPE	Not applicable	Not applicable	Required technology	Required technology	Required technology	[illegible]	[illegible]	[illegible]	[illegible]	Required technology
Vehicle Systems Mgmt	Not applicable	Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Crew Autonomy	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Mission Control Autonomy	Not applicable	Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Common Avionics	May be required	Probably required	Probably required	Probably required	Probably required	Required technology	Required technology	Required technology	Required technology	Required technology
Advanced Software Development/Tools	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	May be required	May be required	Required technology	Required technology	Required technology
Thermal Management (e.g., Fusible Heat Sinks)	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Mechanisms for Long Duration, Deep Space Missions	Not applicable	Not applicable	Not applicable	Not applicable	Required technology	Required technology	Required technology	Required technology	Required technology	Required technology
Lightweight Structures and Materials (HLLV)	Not applicable	Not applicable	Not applicable	Not applicable	May be required	May be required	May be required	Required technology	Required technology	Required technology
Lightweight Structures and Materials (In-Space Elements)	Not applicable	Not applicable	Not applicable	Not applicable	May be required	May be required	May be required	Required technology	Required technology	Required technology

Not applicable	(white)	Probably required	(light green)
May be required	(yellow)	Required technology	(green)

A Sequence for Mars

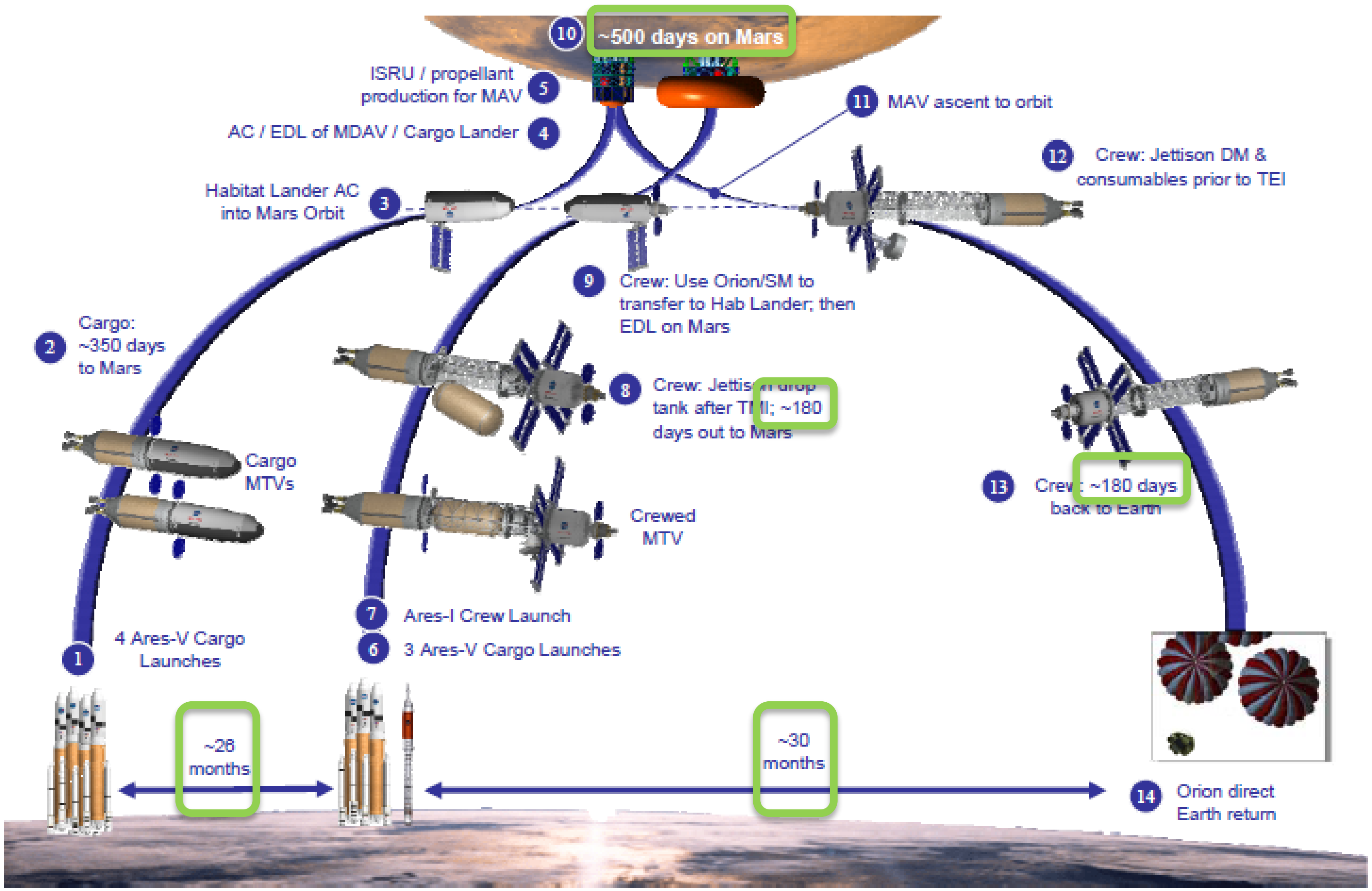
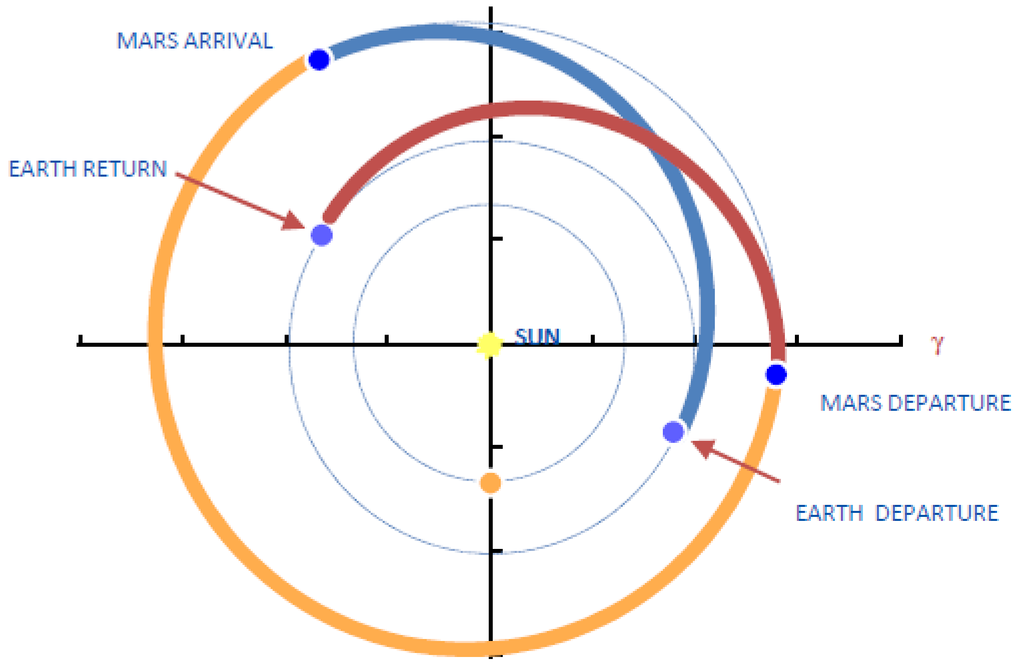


Figure 2-2. Mars Design Reference Architecture 5.0 mission sequence summary (NTR reference).

Mars Mission Length



ISRU on Mars

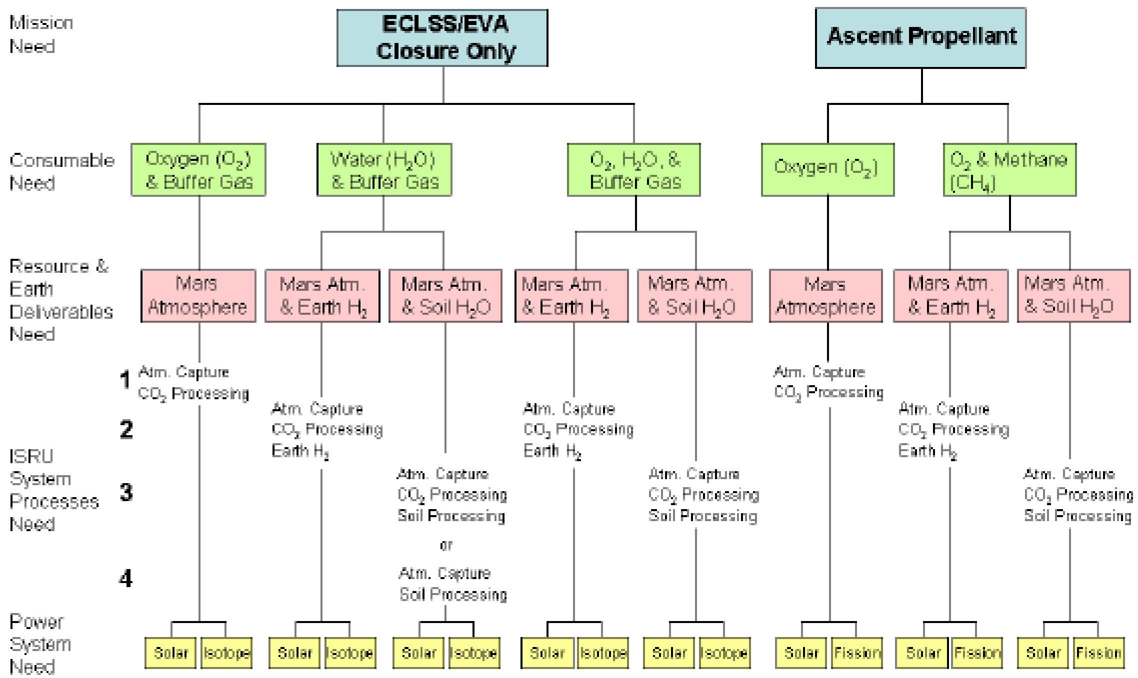


Figure 6-5. ISRU trade tree.

Summary

- Systems
  - Capsule
  - (Lander)
  - EVA Suit
  - Exploration Vehicle
  - Deep Space Habitat
- Mission Duration
- ISRU on Mars
- Fully closed loop ECLSS for Mars