National Aeronautics and Space Administration

NASA's Moon to Mars Architecture Workshop

Mars Transportation

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WHEN WILL WE ACHIEVE LUNAR OBJECTIVES?

Multi-decadal campaign

Support annual cadence of crewed missions

Development of permanent infrastructure

Expansion of economic sphere to the Moon

Earth-Mars Transportation System is one of the most visible and significant parts of the Mars architecture

"Mars Transportation" white paper outlines the challenges of extending human exploration from the Moon to Mars

WHAT FOUNDATIONAL CAPABILITIES ARE NEEDED

Long-duration microgravity systems

Partial gravity destination platforms

Low Earth Orbit assets and infrastructure

WHERE SHOULD SYSTEMS BE?

Ensure access to the Lunar South Pole

Capability for non-polar expeditions

HOW WILL WE GET THERE AND RETURN?

Lunar Microgravity staging in NRHO

Earth ⟷ NRHO ⟷ Lunar surface

Surface Mobility

WHY EXPLORE?

- SCIENCE -

Understand the universe
Direct observations

- INSPIRATION -

"Artemis Generation"
Overcome challenges
Succeed with hard work

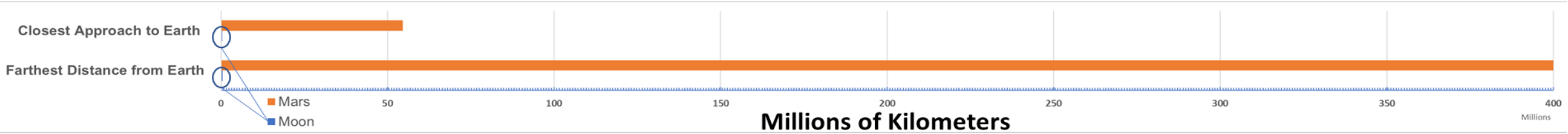
- NATIONAL POSTURE -

Enrich lives on Earth
Technology development
International partnerships

Perspective: Distance and Risk

Mars is *much* farther from Earth than the Moon is

	Closest Approach to Earth	Farthest Distance from Earth	Typical Round-Trip "Odometer" Reading	Round-trip Duration
Moon	360,000 km	405,000 km	1,900,000 km	**Weeks**
Mars	54,600,000 km	400,000,000 km	1,800,000,000 km	**Years**



- **Round-trip Mars missions may be *twice as long* as our longest duration experience base**
- **There will be no way to abort quickly to Earth**
- **On-demand resupply will not be possible**

Video File Provided Separately

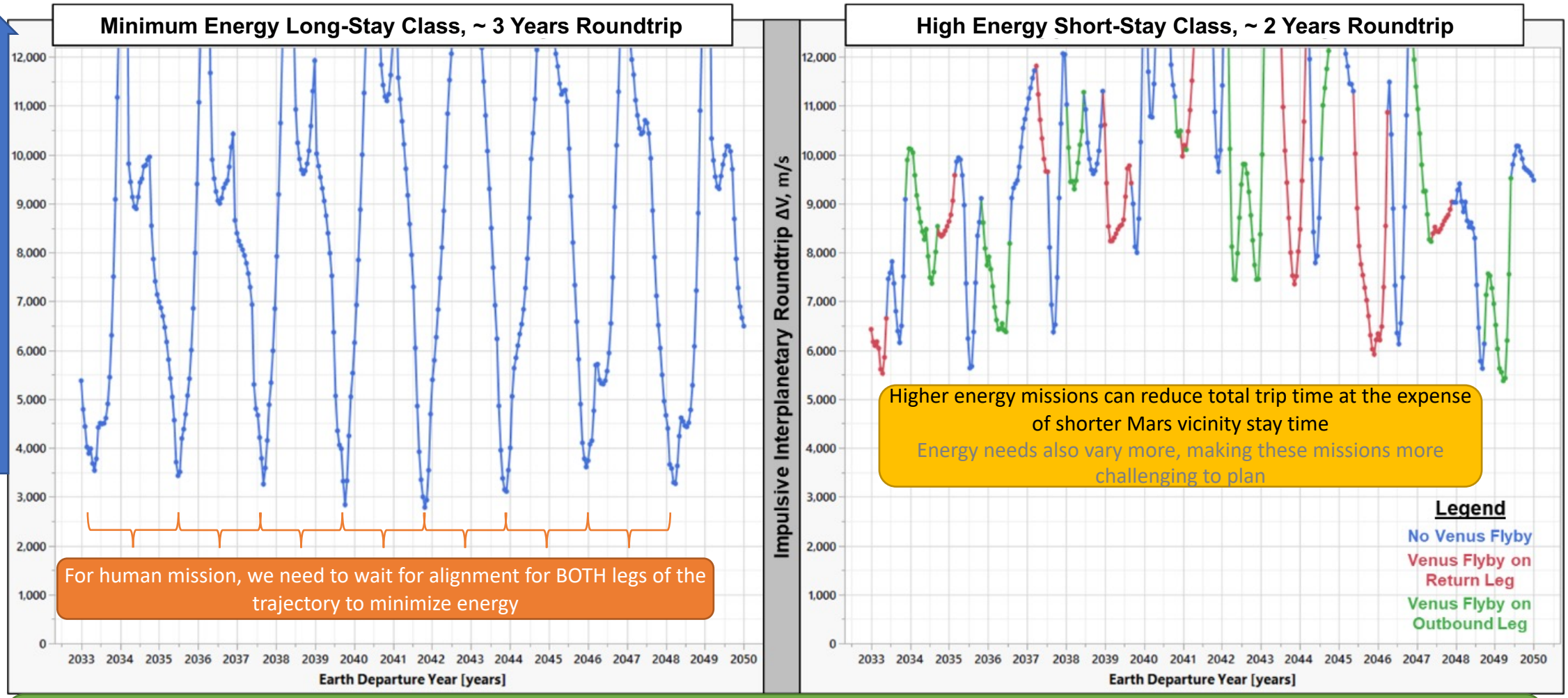
Optimum Departure Windows ~Every 2 Years

But we must also consider optimum <u>return</u> window

WHEN we will go

Increasing Energy = Exponential Increase in Vehicle Mass

Higher energy Mars missions require vehicles that are multiple ISS mass equivalents



"When" is a very complicated decision to address.

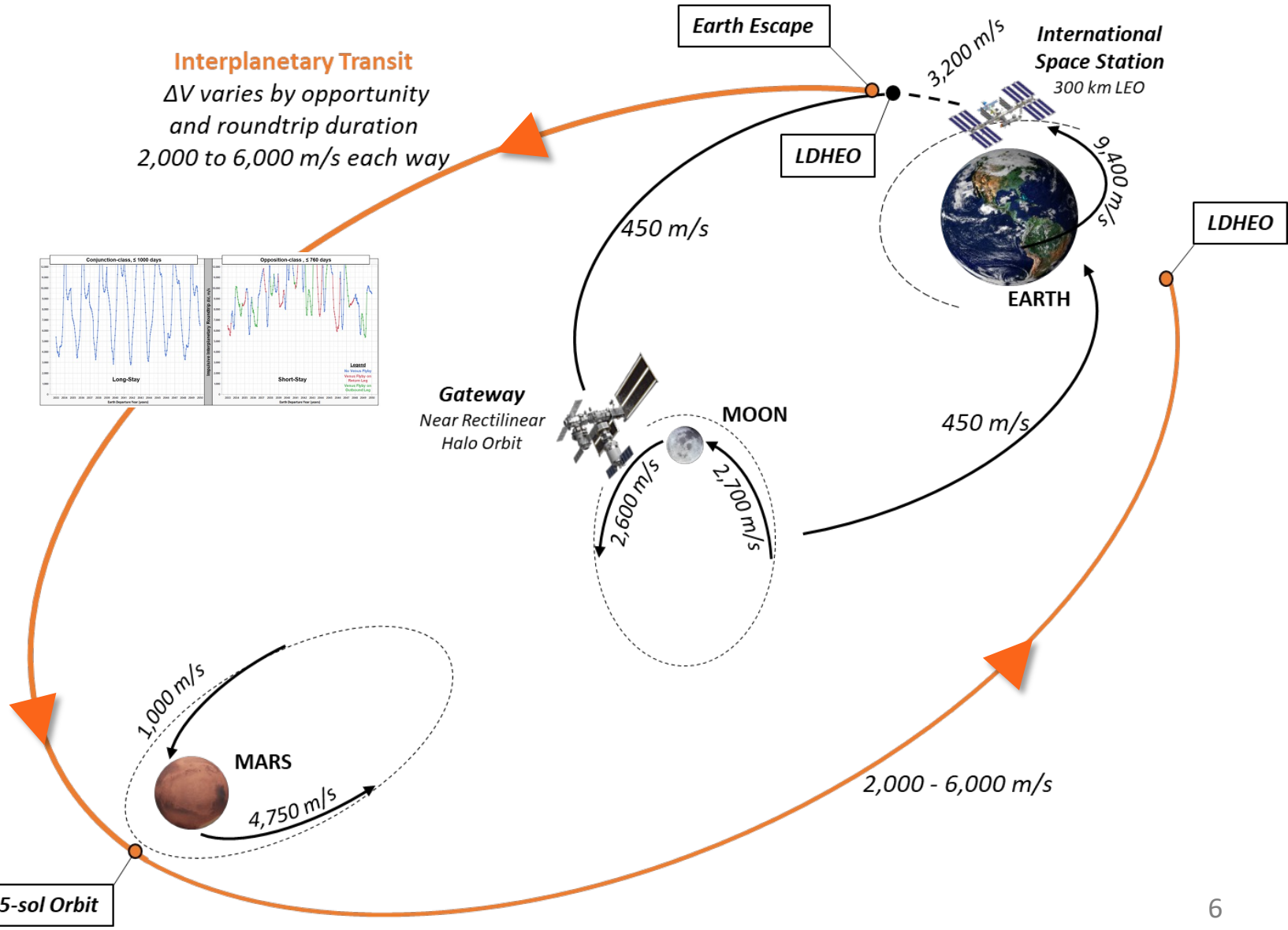
What is an acceptable roundtrip duration for humans?
How many rockets do we have and how often can we launch them?
What are the Surface Cargo pre-deployment needs?
What transportation system performance can we afford?

HOW
we will get there and back

Transportation Energy Needed

DRAFT

- **Always about the same amount of energy to get to the Moon and back**
- **But energy needed to get to Mars and back varies**
  - ✓ Some years require 20 – 60% more energy than other years
  - ✓ Transit propellant mass variations can be *equivalent to the assembled ISS mass*

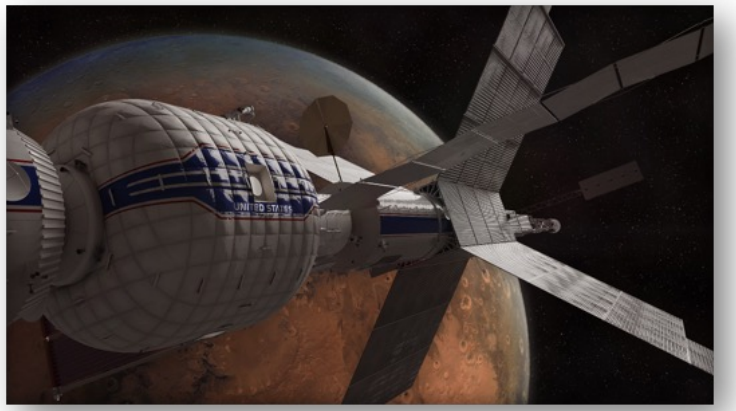


WHO will be involved

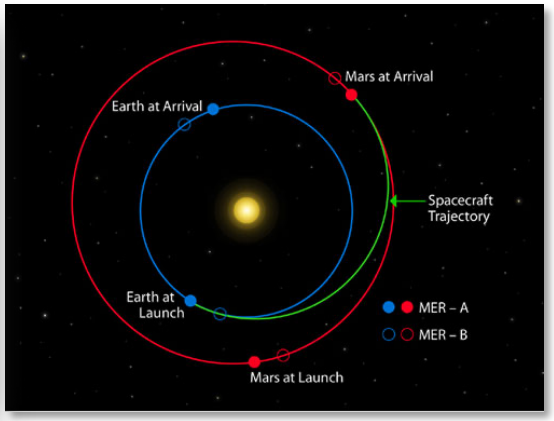
Mission Duration

Transitioning from months (ISS) to years (Mars)

MISSION CONSTRAINTS



Lengthy Isolation/Confinement



Communication Delays

Extravehicular Activities

Resource Restrictions

HUMAN CHALLENGES

Health and Well-Being

Physical Performance

Cognitive Performance

HOW we will get there and back

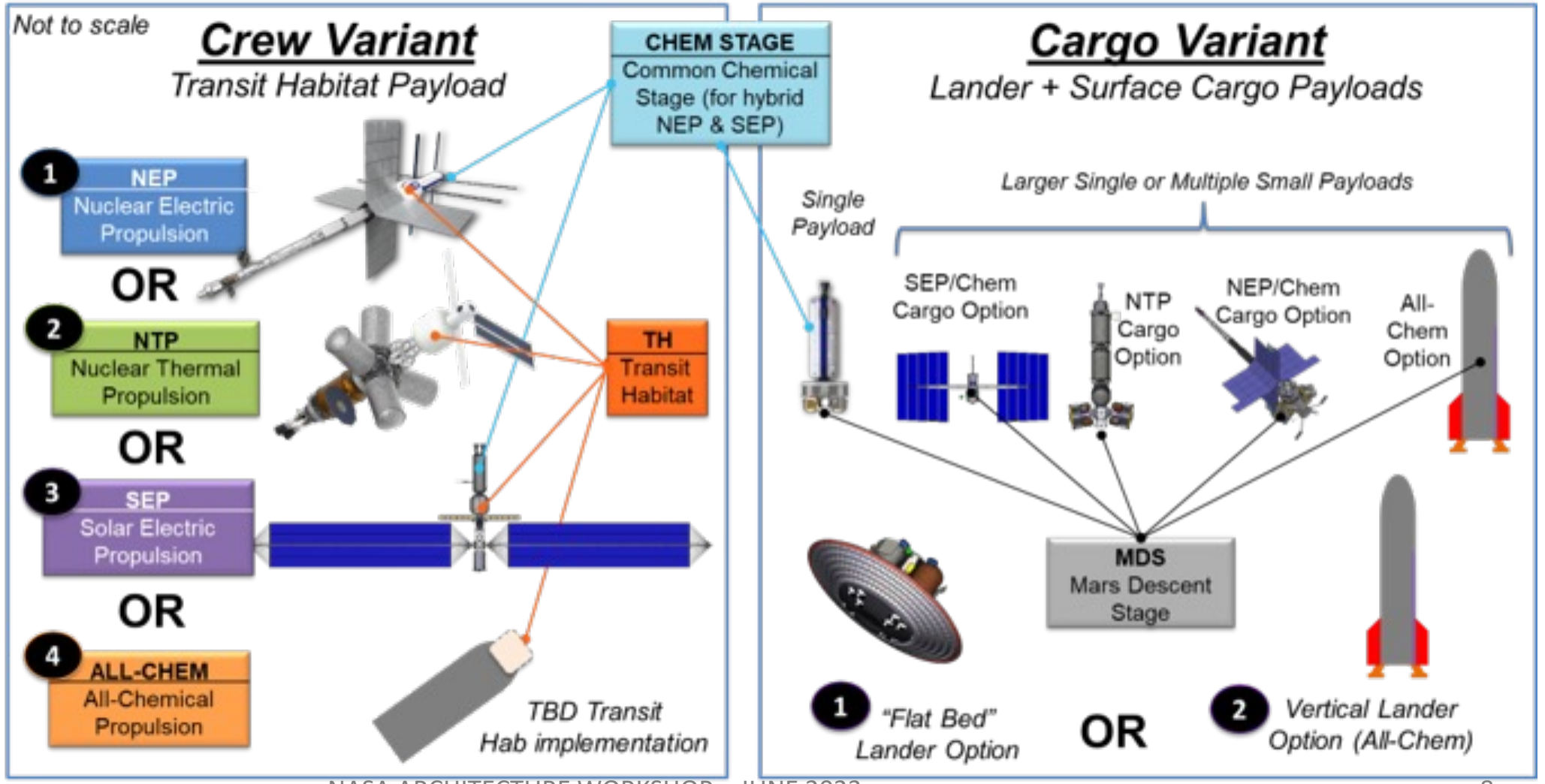
Mars Transportation Option Trade Space

4 transportation options, 2 lander options, and a range of surface systems

Refer to

[ESDMD-001, Moon to Mars Architecture Definition Document]

for more information



Summary

Mars missions will require significantly more energy and much longer system service life, with more constrained departure windows, than lunar missions

Shorter total roundtrip duration missions could reduce crew health and performance concerns

Four In-Space Transportation propulsion technologies are currently under consideration

Artemis transportation system developments and lessons learned can feed forward to Mars

Access the white paper with this QR code or at www.nasa.gov/MoonToMarsArchitecture