National Aeronautics and Space Administration

Evolvable Mars Campaign

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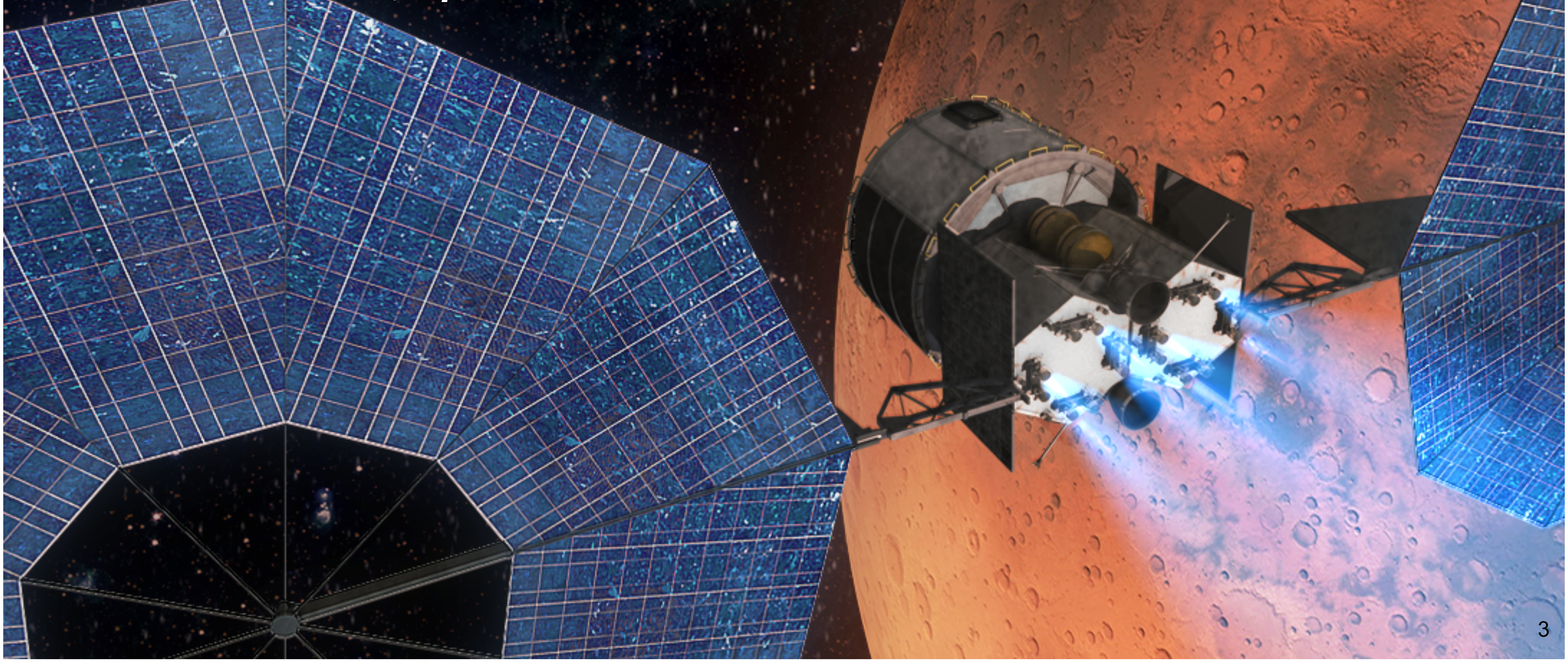
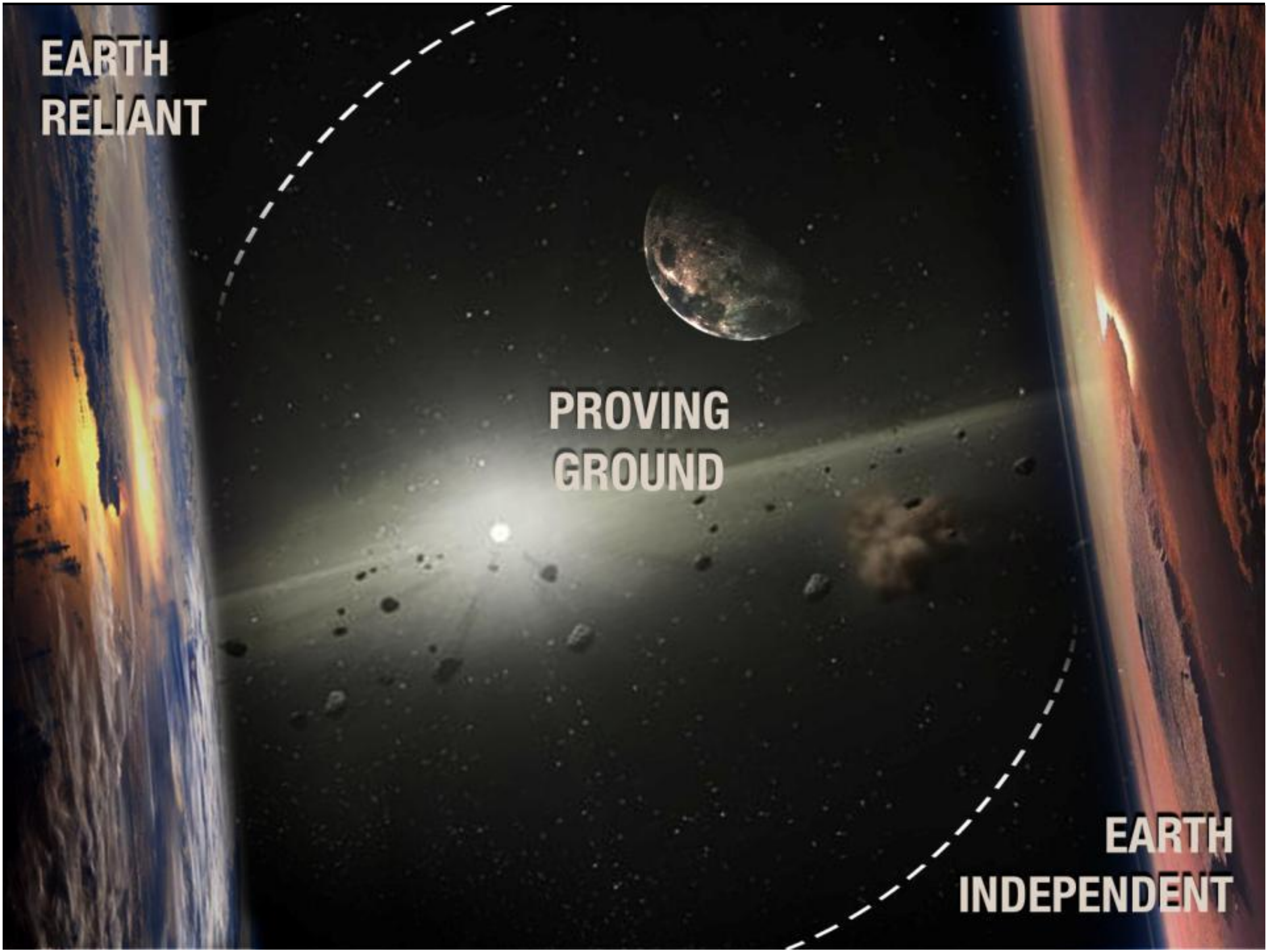
Pioneering Space - Goals

"Fifty years after the creation of NASA, our goal is no longer just a destination to reach. Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite. And in fulfilling this task, we will not only extend humanity's reach in space -- we will strengthen America's leadership here on Earth."

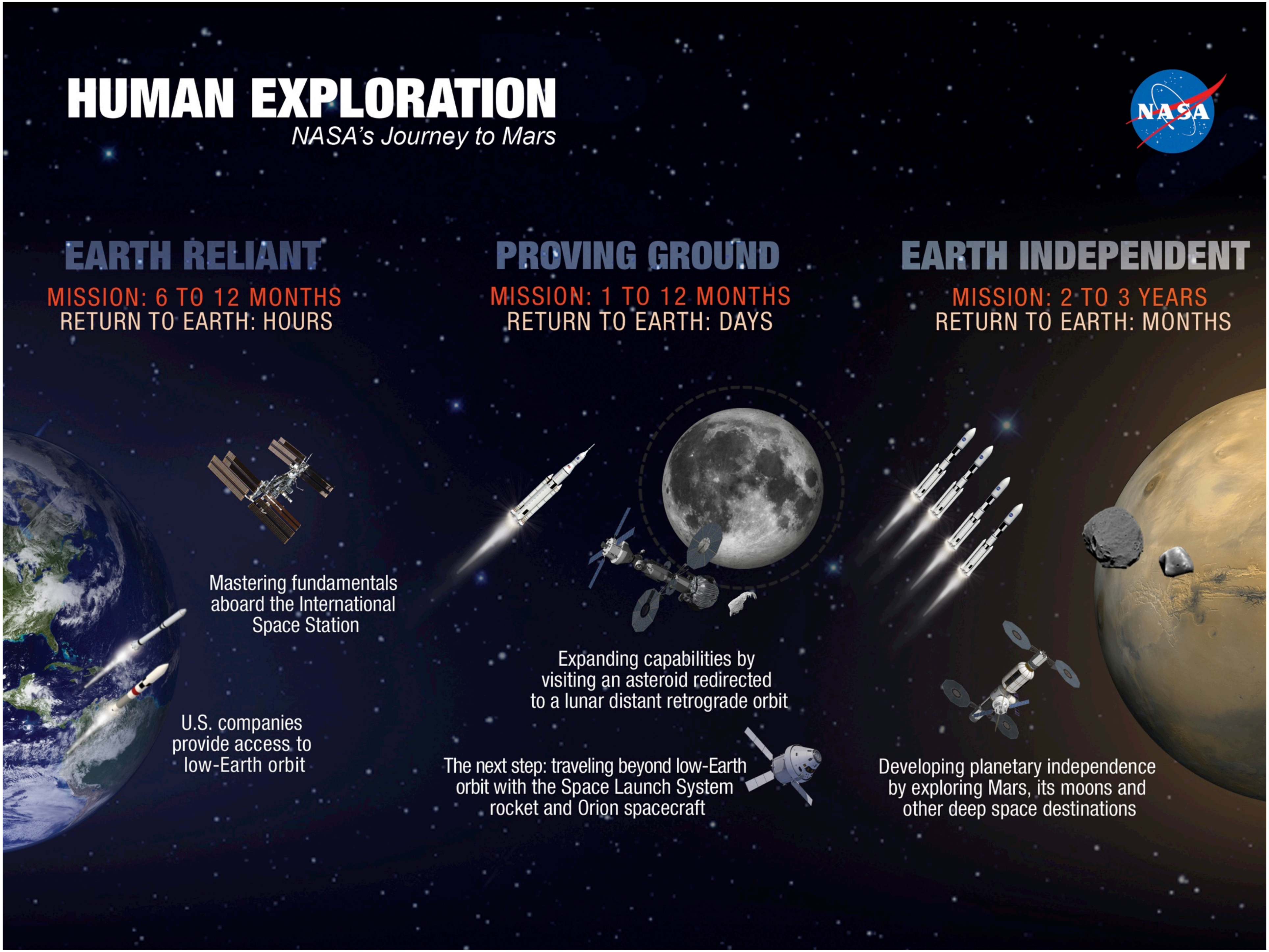
- President Obama, April 2010




EARTH
RELIANT
PROVING
GROUND
EARTH
INDEPENDENT

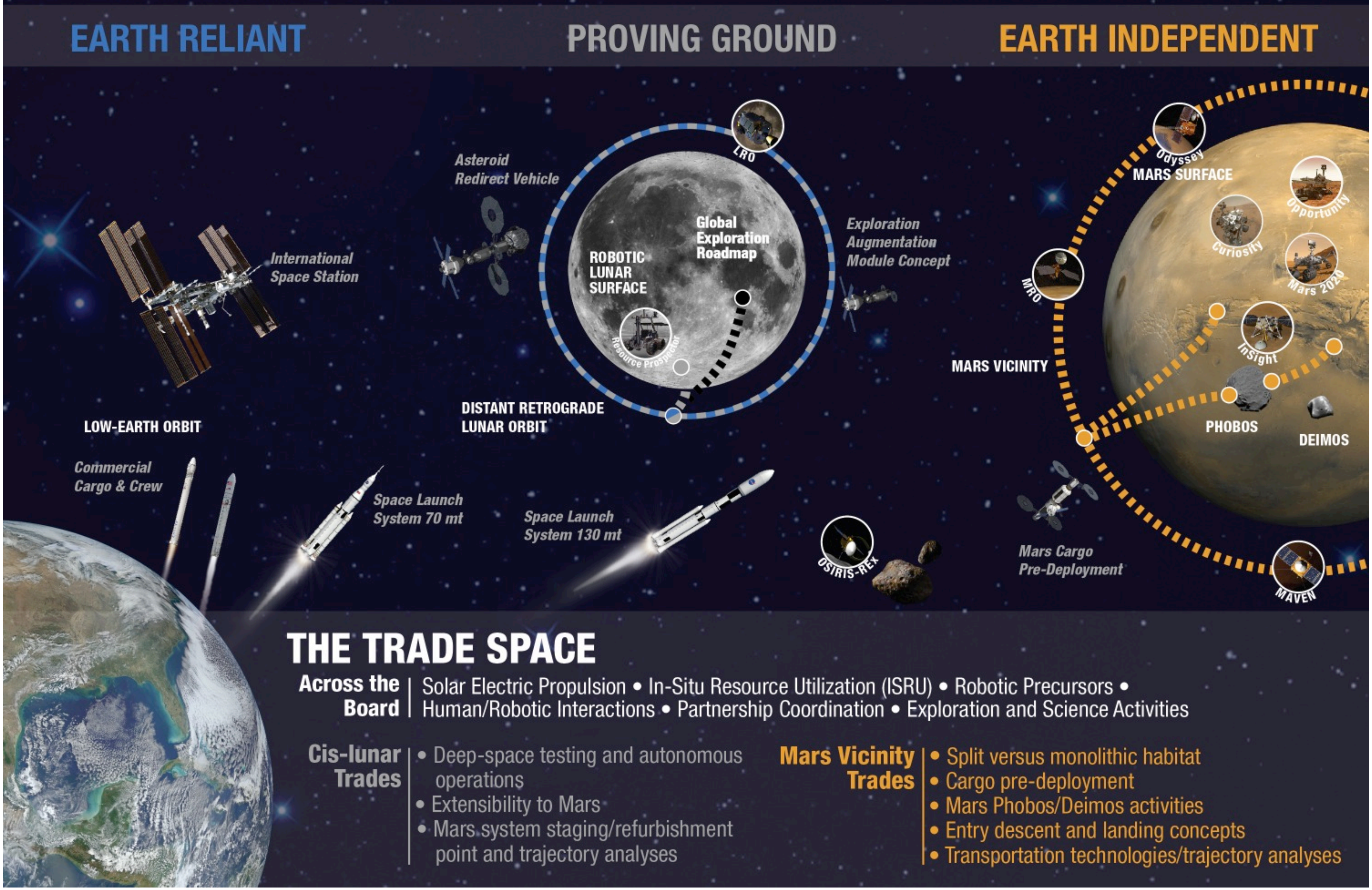
<u>*NASA Strategic Plan Objective 1.1*</u>

Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.


HUMAN EXPLORATION
NASA's Journey to Mars
EARTH RELIANT
MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS
PROVING GROUND
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS
EARTH INDEPENDENT
MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS
Mastering fundamentals aboard the International Space Station
U.S. companies provide access to low-Earth orbit
Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft
Developing planetary independence by exploring Mars, its moons and other deep space destinations

EVOLVABLE MARS CAMPAIGN

A Pioneering Approach to Exploration



THE TRADE SPACE

Across the Board | Solar Electric Propulsion • In-Situ Resource Utilization (ISRU) • Robotic Precursors • Human/Robotic Interactions • Partnership Coordination • Exploration and Science Activities

Cis-lunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars Phobos/Deimos activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses

EARTH RELIANT

NEAR-TERM OBJECTIVES

DEVELOP AND VALIDATE EXPLORATION CAPABILITIES IN AN IN-SPACE ENVIRONMENT

- Long duration, deep space habitation systems
- Next generation space suit
- Autonomous operations
- Communications with increased delay
- Human and robotic mission operations
- Operations with reduced logistics capability
- Integrated exploration hardware testing

LONG-DURATION HUMAN HEALTH EVALUATION

- Evaluate mitigation techniques for crew health and performance in micro-g space environment
- Acclimation from zero-g to low-g

COMMERCIAL CREW TRANSPORTATION

- Acquire routine U.S. crew transportation to LEO

PROVING GROUND

NEAR-TERM OBJECTIVES

VALIDATE

- SLS and Orion in deep space
- Solar Electric Propulsion (SEP) systems
- Long duration, deep space habitation systems
- Mitigation techniques for crew health and performance in a deep space environment
- In-Situ Resource Utilization
- Operations with reduced logistics capability

CONDUCT

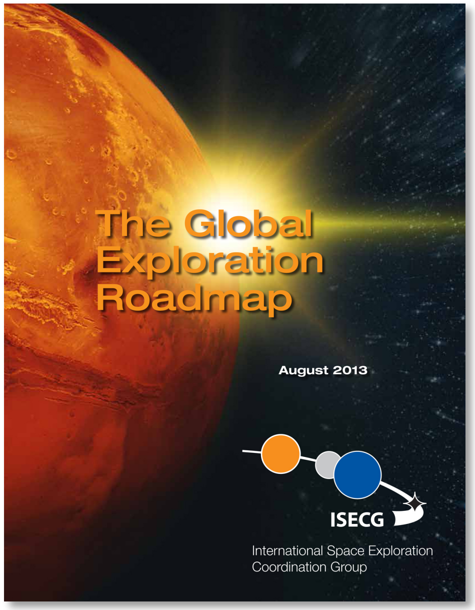
- EVAs in deep space, micro-g environments
- Human and robotic mission operations
- Capability Pathfinder and SKG missions

Strategic Principles for Sustainable Exploration

- Implementable in the ***near-term with the buying power of current budgets*** and in the longer term with budgets commensurate with economic growth*;*
- ***Exploration enables science*** **and science enables exploration**
- Application of ***high Technology Readiness Level*** (TRL) technologies for near term missions, while focusing sustained investments on ***technologies and capabilities*** to address challenges of future missions;
- ***Near-term mission opportunities*** with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- Opportunities for ***U.S. commercial business*** to further enhance the experience and business base;
- ***Multi-use, evolvable*** space infrastructure, minimizing unique major developments;
- Substantial ***international and commercial participation***, leveraging current International Space Station and other partnerships.

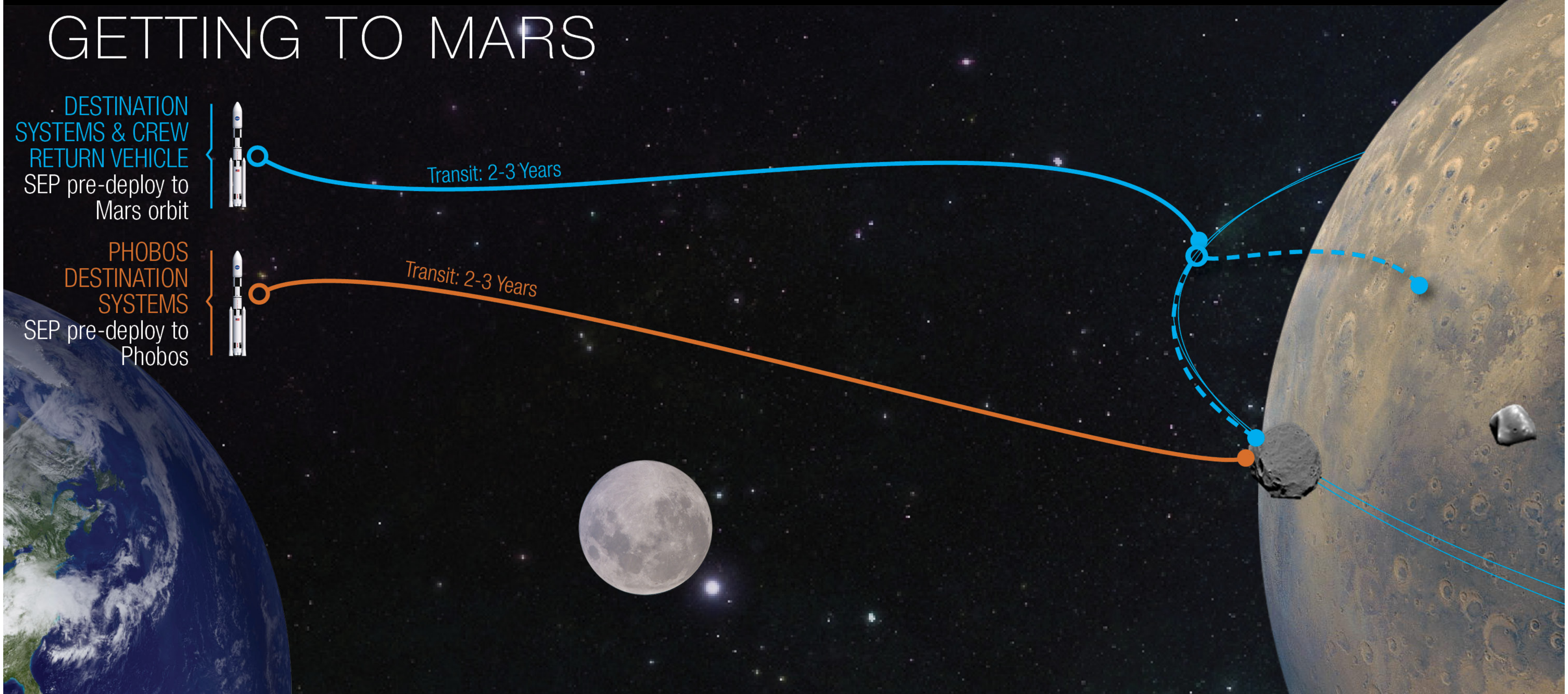
Global Exploration Roadmap:
Common Goals and Objectives

- **Develop Exploration Technologies and Capabilities**
  Develop the knowledge, capabilities, and infrastructure required to live and work at destinations beyond low-Earth orbit through development and testing of advanced technologies, reliable systems, and efficient operations concepts in an off-Earth environment.
- **Engage the Public in Exploration**
  Provide opportunities for the public to engage interactively in space exploration.
- **Enhance Earth Safety**
  Enhance the safety of planet Earth by contributing to collaborative pursuit of planetary defense and orbital debris management mechanisms.
- **Extend Human Presence**
  Explore a variety of destinations beyond low-Earth orbit with a focus on continually increasing the number of individuals that can be supported at these destinations, the duration of time that individuals can remain at these destinations, and the level of self-sufficiency.
- **Perform Science to Enable Human Exploration**
  Reduce the risks and increase the productivity of future missions in our solar system, characterizing the effect of the space environment on human health and exploration systems.
- **Perform Space, Earth, and Applied Science**
  Engage in science investigations of, and from, solar system destinations and conduct applied research in the unique environment at solar system destinations.
- **Search for Life**
  Determine if life is or was present outside of Earth and understand the environments that support or supported it.



- **Stimulate Economic Expansion**
  Support or encourage provision of technology, systems, hardware, and services from commercial entities and create new markets based on space activities that will return economic, technological, and quality-of-life benefits to all humankind.

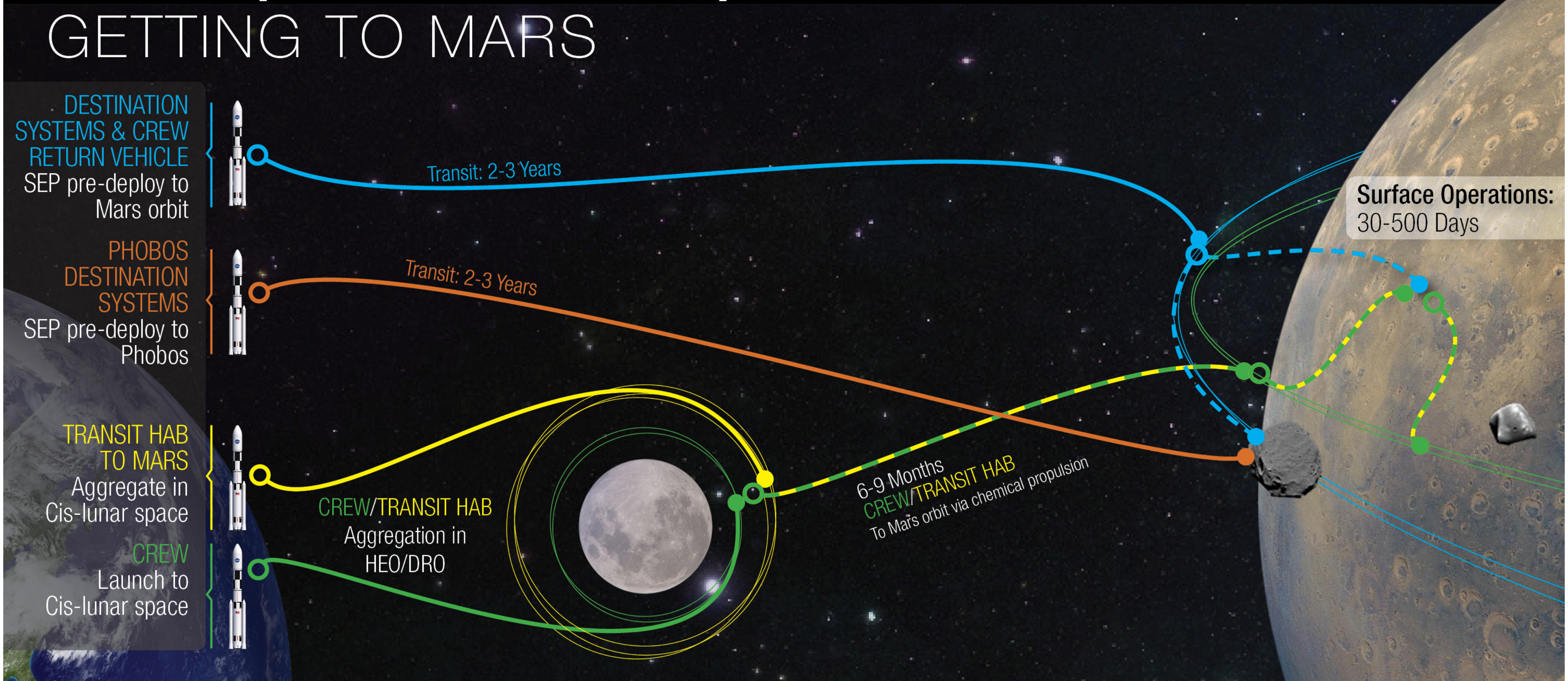
Mars Split Mission Concept



Using SEP for pre-emplacement of cargo and destination systems enables sustainable Mars campaign

- Minimizes the cargo needed to be transported with the crew on future launches
- Enables a more sustainable launch cadence
- Pre-positions assets for crew missions allows for system checkout in the Mars vicinity prior to committing to crew portion of mission

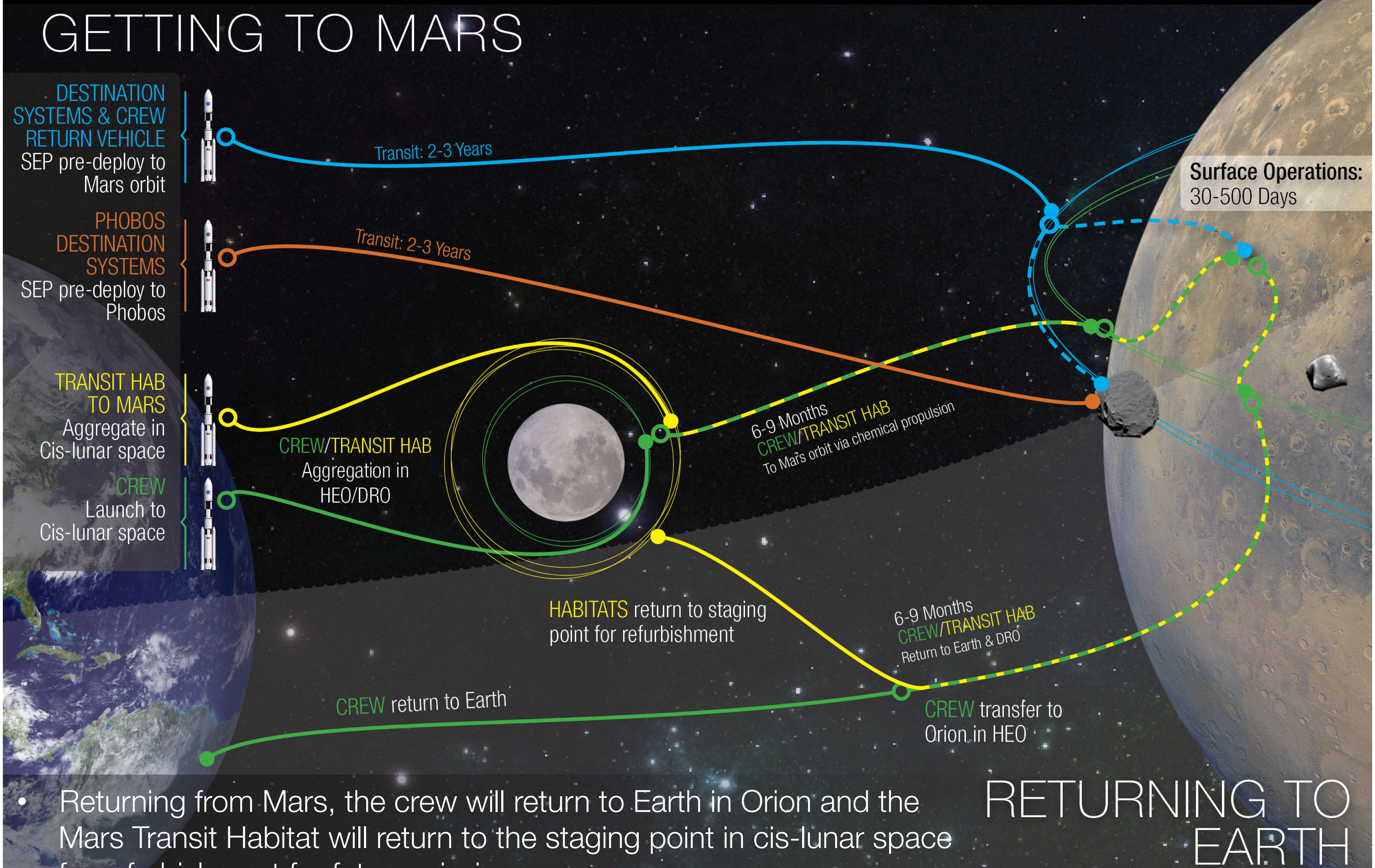
Mars Split Mission Concept



DRO as an aggregation point for Mars habitation systems

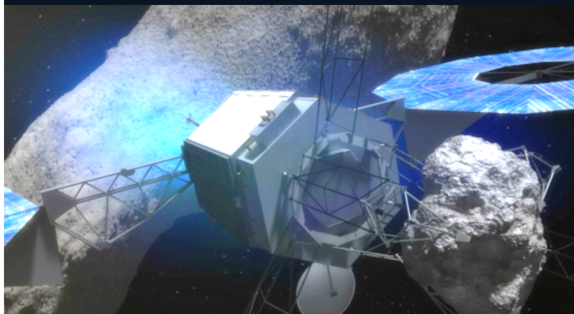
- Provides a stable environment and ease of access for testing Proving Ground capabilities
- Allows for Mars transit vehicle build-up and checkout in the deep-space environment prior to crew departure
- Able to transfer Mars Transit Vehicle from DRO to High Earth Orbit with small amount of propellant to rendezvous with crew in Orion – HEO is more efficient location to leave Earth-moon system for Mars vicinity

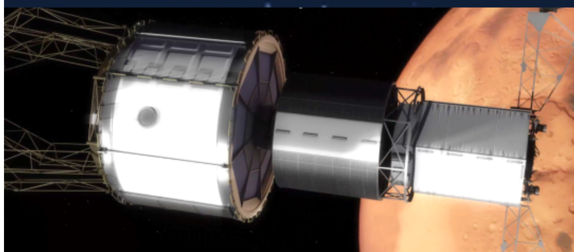
Mars Split Mission Concept



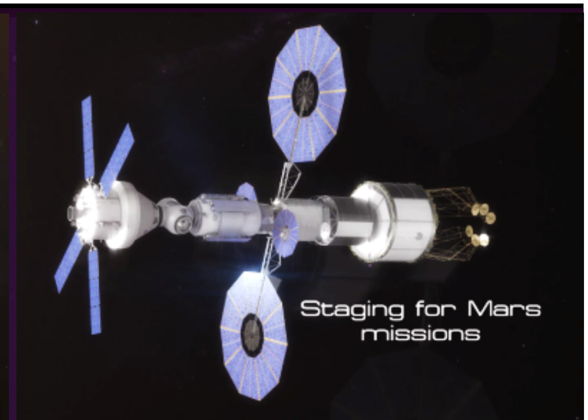
- Returning from Mars, the crew will return to Earth in Orion and the Mars Transit Habitat will return to the staging point in cis-lunar space for refurbishment for future missions

ARM Risk Reduction for Future Mars & Deep Space Missions

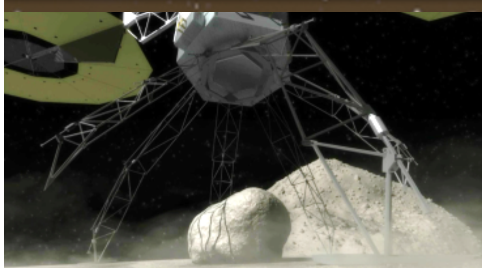




Long duration **human-scale systems operating in deep space**. Pre-deployment of crewed mission elements via solar electric propulsion with long quiescent periods.

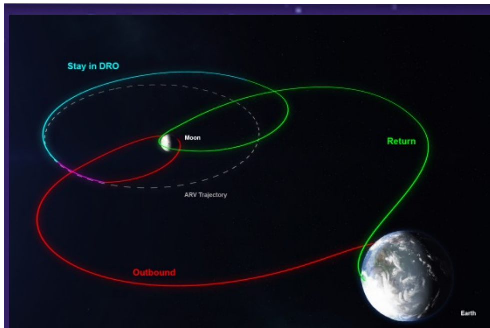


Sensor suites and proximity operations required for aggregating Mars mission vehicle stacks, deep space rendezvous and docking with Orion.



Enhanced interaction with **uncooperative, low-G targets** as will be experienced with Mars Moons.

In-space EVA ops and on micro-g body (Phobos), sample handling, and ISRU.



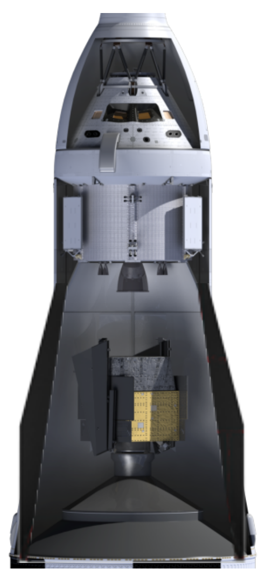
Mission Operations: Deep space trajectories, rendezvous and docking, pre-deployment of systems.

Long duration, high-power **Solar Electric Propulsion:** Solar arrays, thrusters, PMAD, Xenon storage.

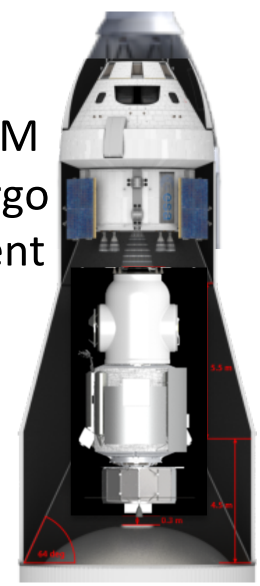
Notional Proving Ground Vehicle Capability

Concept trade for co-Manifest large payloads with Orion on early Exploration Missions

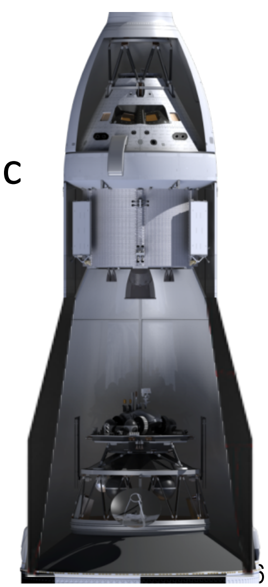
- **Co-manifesting large payloads enables significant opportunities**
- **Proving ground vehicle is SLS with Exploration Upper Stage (EUS) – Block 1B**
  - Volume between EUS and Orion for large payloads
  - Approximately 10mt capability, subject to analysis
  - Flight rate is one/year beginning with EM-2
- **Supports development of Mars capabilities and enhances value of Proving Ground missions**



Orion w/ARV or Science Payload

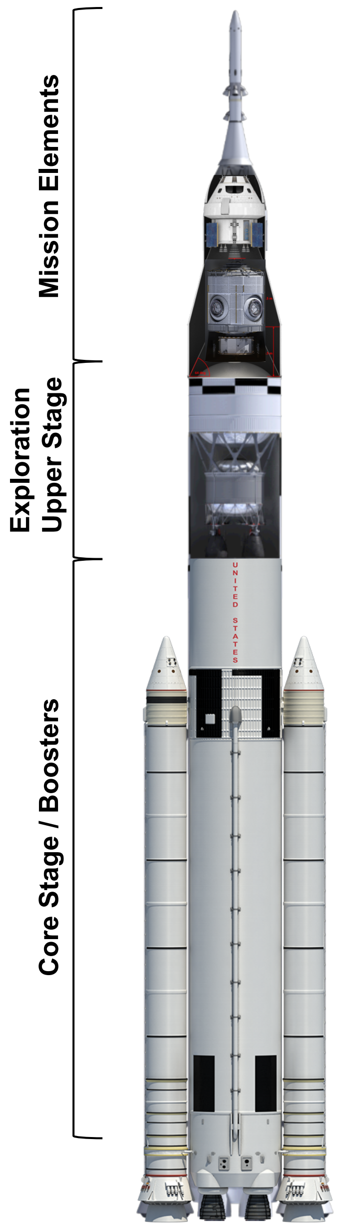


Orion w/ EAM or Cargo Element



Orion w/Robotic Landers

Block 1B Configuration



Mission concepts with Universal Stage Adaptor (includes additional payload capability)

Orion with EAM

total mission volume = ~ 400m3

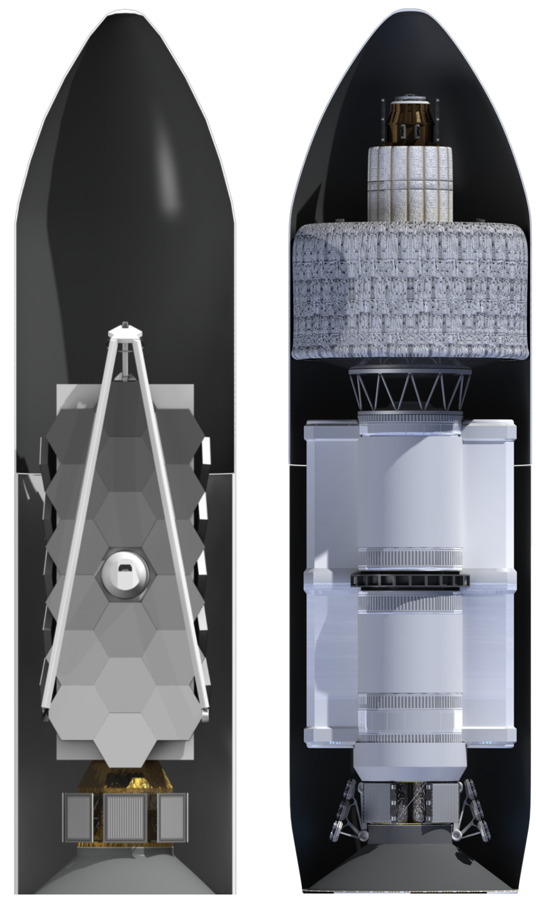
Orion with ARV

total mission volume = ~ 400m3

5m fairing w/Robotic Lunar Lander & EAM

total mission volume = ~ 600m3

Mission concepts with 8m and 10m fairings



8m fairing with ATLAST

total mission volume = ~ 1200m3

10m fairing w/notional Mars payload

total mission volume = ~ 1800m3