National Aeronautics and Space Administration

Pioneering Space

Human Exploration Vision

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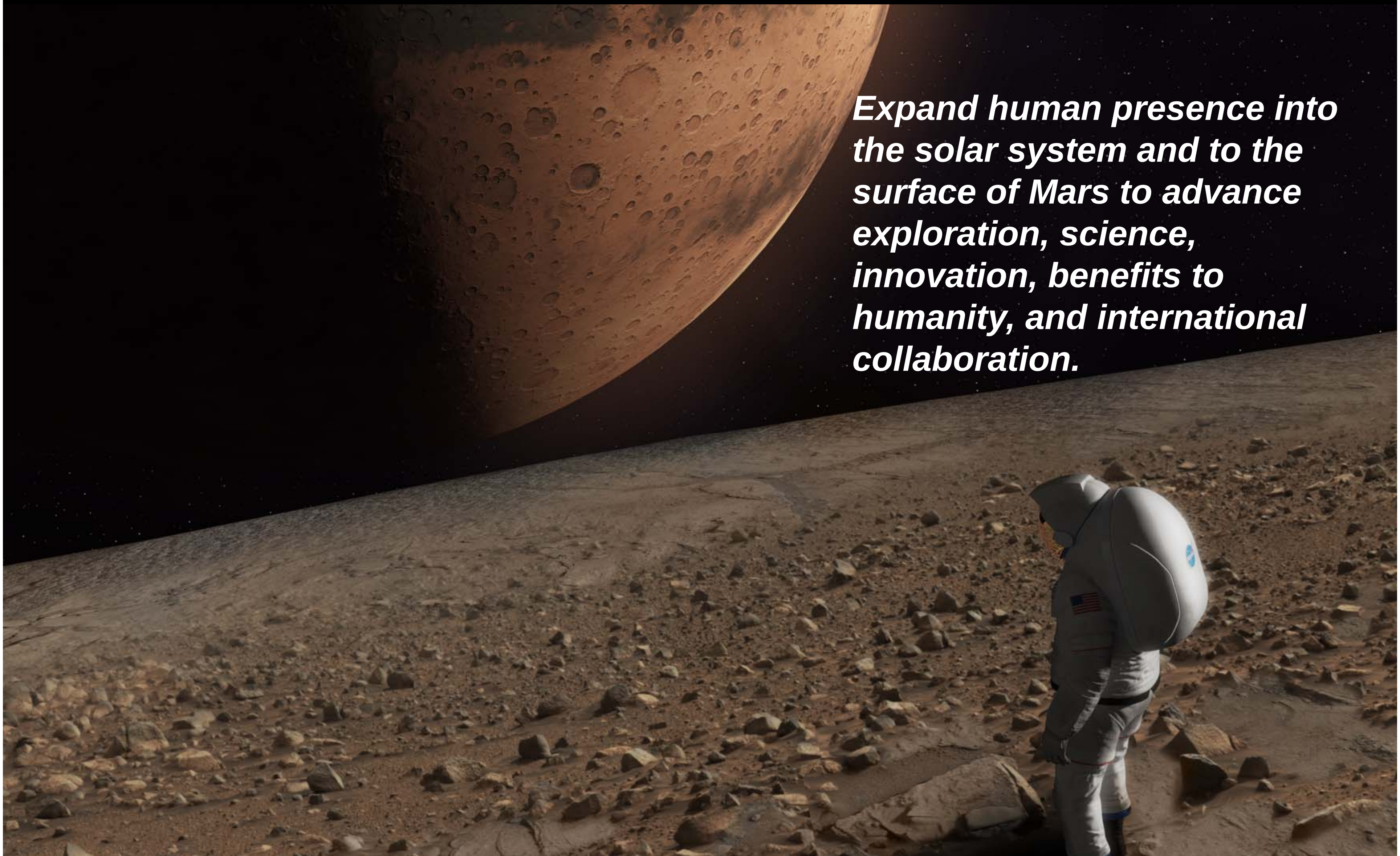
Pioneering Space - Goals

"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

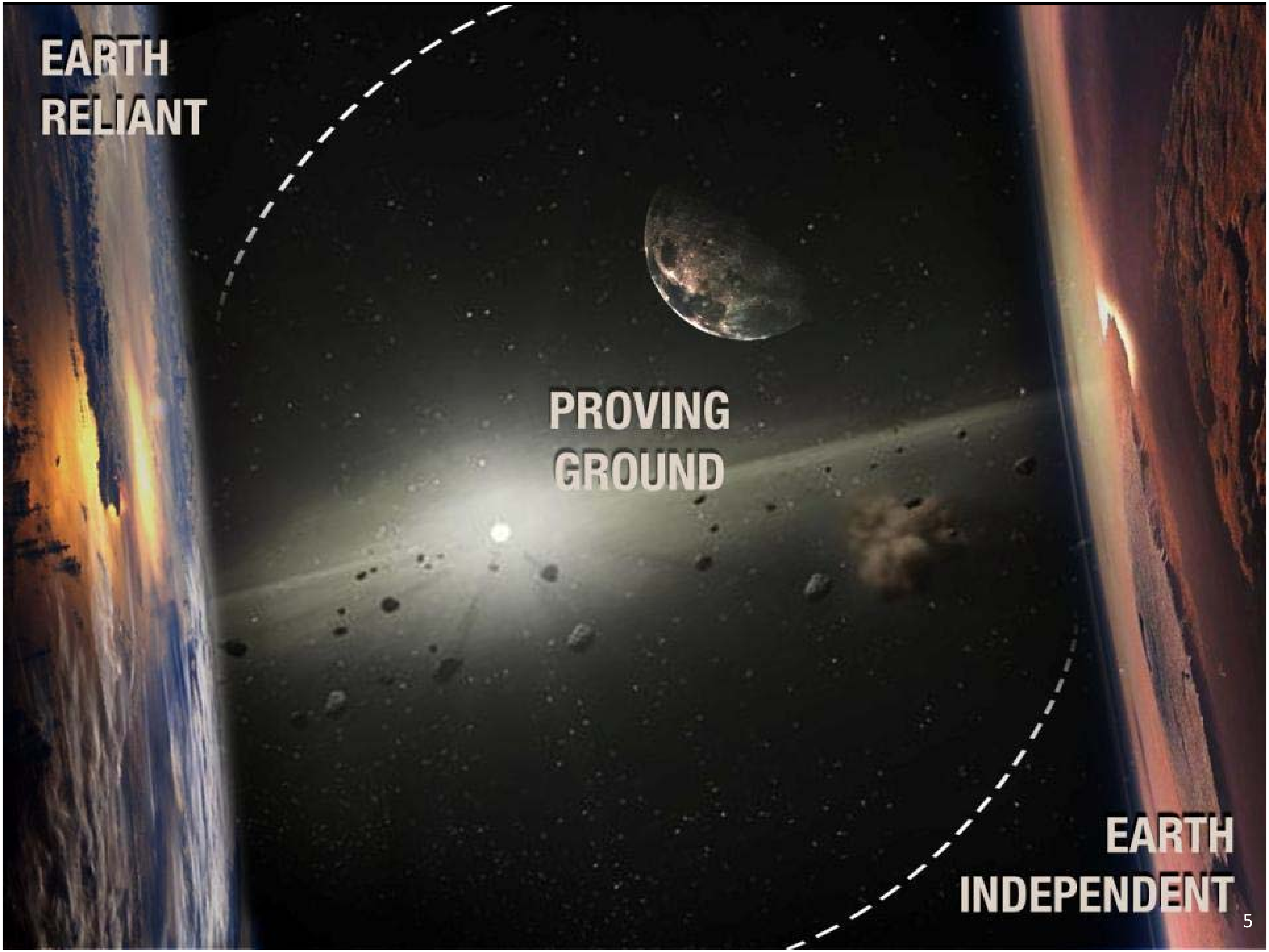
NASA Strategic Plan Objective 1.1

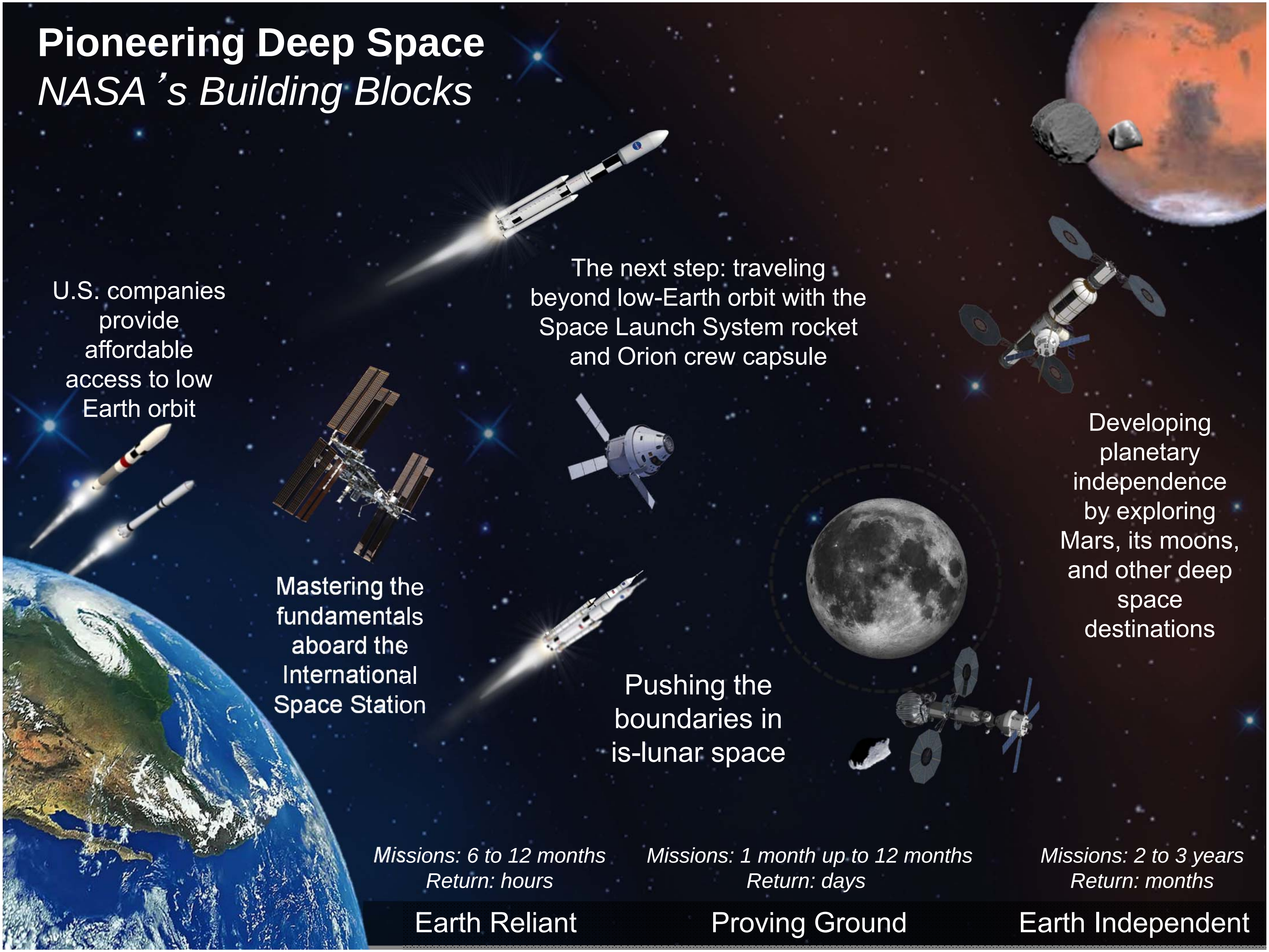


Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.

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 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 learned from the ISS logistics and crew market;
- ***Multi-use, evolvable*** space infrastructure;
- Substantial ***international and commercial participation***, leveraging current International Space Station partnerships.


EARTH
RELIANT
PROVING
GROUND
EARTH
INDEPENDENT



Pioneering Deep Space
NASA's Building Blocks
U.S. companies provide affordable access to low Earth orbit
Mastering the fundamentals aboard the International Space Station
The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion crew capsule
Pushing the boundaries in is-lunar space
Developing planetary independence by exploring Mars, its moons, and other deep space destinations
Missions: 6 to 12 months
Return: hours
Missions: 1 month up to 12 months
Return: days
Missions: 2 to 3 years
Return: months
Earth Reliant
Proving Ground
Earth Independent

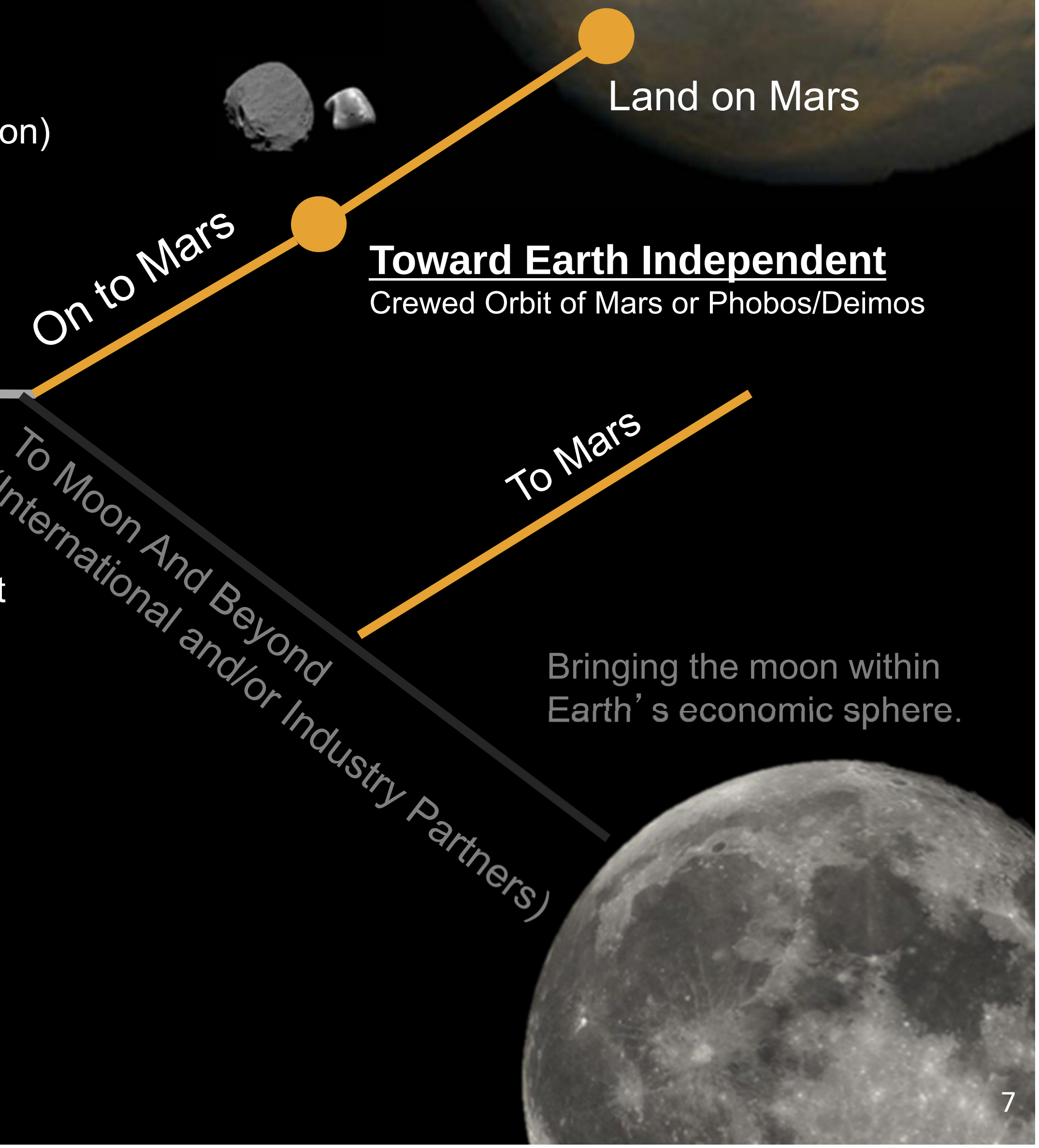
Human Exploration Pathways

Mastering the Fundamentals

- Extended Habitation Capability (ISS)
  - High Reliability Life Support
- Deep-space Transportation (SLS and Orion)
- Exploration EVA
- Automated Rendezvous & Docking
- Docking System

Pushing the Boundaries

- Deep Space Operations
  - Deep Space Trajectories
  - Deep Space Radiation Environment
  - Integrated Human/Robotic Vehicle
- Advanced In-Space Propulsion (SEP)
  - Moving Large Objects
- Exploration of Solar System Bodies



Key Thrusts for Advancement

Transportation

- The ability to launch a very powerful rocket
- High-reliability spacecraft systems
- Size requirements of crew capsule
- Validation of performance of SLS and Orion in the deep space environment *(hotter, colder, radiation)*
- Long duration and extended quiescent periods
- Deep space navigation
- Rendezvous and docking
- Life support systems
- High speed re-entry
- In space propulsion

Staying Healthy

- Air, water, food
- Waste containment
- Psychological impact
- Low- / no-gravity
- Medical emergencies
- Long duration and extended quiescent periods
- Bone loss
- Radiation
- Ocular degeneration
- Hygiene
- Using extant resources
- Logistics minimization

Working in Space

- Sample handling
- Microgravity operations
- Space suits
- Autonomous systems
- Advanced training & tools
- Robotic systems
- Mission planning w/Time Delay
- Situational awareness and decision making
- Crew relationships

EMC Expansion of Capabilities

Informed by NASA Technology Roadmaps, System Maturation Teams, Partners and External Experts

Earth Reliant

- International Space Station: **Can humans live & operate independently for ~1000 days in micro-G?**
  - Long-duration, Zero-g human factors research platform
  - Highly reliable life support, advanced logistics, low maintenance systems
  - Environmental monitoring
  - Supportability & maintenance concepts

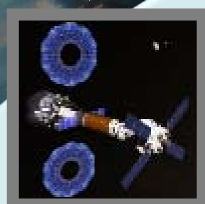
Earth Independent - Phobos/Deimos/Mars Orbit

- **"Can humans travel to Mars orbit and safely return to Earth?"**
- Deep Space Proving Ground plus:
  - High power SEP (150 kW)
  - ~1000 day deep space habitat(s)
  - Deep space countermeasures
  - Mars vicinity propulsion

Earth Independent – Mars Surface

- Phobos/Deimos plus:
  - Mars entry & landing systems
  - Partial-gravity countermeasures
  - Long duration surface Systems (ISRU, fission power)

Continued Leveraging of Commercial & International Partnerships



Deep Space Proving Ground

- **"Bridging from ISS, can human class systems operate in a deep space environment in a crew tended mode for long durations**
- Distant Retrograde Orbit:
  - Heavy lift launch (SLS), Orion
  - High-power In-Space Propulsion (40 kW SEP)
  - Exploration Augmentation Module - Crew support for increasing duration (habitat)
  - Advanced EVA (Suit, PLSS)
  - Deep space long duration systems and operations testing
  - Aggregation of Mars Mission Vehicles

Mars Challenges

Technology Focus for Staying Healthy

Life Support

- High reliability systems
- O_2 recovery and reducing logistics
- Water recovery loop closure
- Processing of solid waste to recover water
- Store nutritionally-adequate food for years

Space Suits

- Low mass suit and power pack
- Lower torso mobility
- Enhanced dexterity
- Compatible with Mars environment
- Increase information system capabilities
- In-situ suit repair

Microgravity Countermeasures

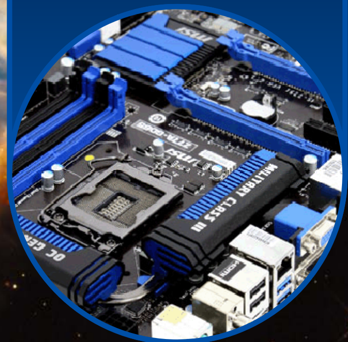
- Exercise equipment for muscle and cardiovascular atrophy, and bone loss
- Low-mass, rapid deploy, low-maintenance systems

Autonomous Medicine

- Advanced medical diagnosis, prognosis and treatment capabilities
- In-situ analysis of biomedical samples

Environmental Control

- In-flight analysis capabilities
- Rapid detection and mitigation of environmental hazards
- Detect contaminants introduced via surface activities
- Automated recovery
- Fire suppression



Mars Challenges

Technology Focus for Transportation

Access to Space

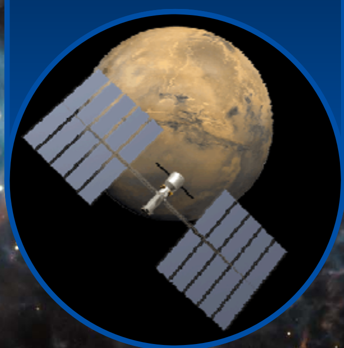
- Space Launch System heavy lift for large mass and volume
- Orion crew vehicle for crew delivery to and return from deep space

Chemical Propulsion

- O_2/Hydrocarbon (CH_4) propulsion for in-space, landing and ascent
- Integrated main and reaction control propulsion systems
- Ability to maintain cryogenic fluids for long durations

Advanced Propulsion

- Advanced capabilities to improve mass delivery and trip time
- Under investigation
  - Solar Electric
  - Advanced Chemical
  - Nuclear Thermal
  - Nuclear Electric



In-Situ Resource Utilization

- Production of O_2 from the atmosphere for Mars ascent
- Production of life-support consumables
- Construction of surface infrastructure from local resources

Entry, Descent, Landing & Ascent

- Hypersonic inflatable or deployable decelerators
- Supersonic retro-propulsion
- Precision landing
- Plume blast mitigation
- High-speed Earth re-entry
- Occupant protection

Mars Challenges

Technology Focus for Working in Space

Humans & Robots Working Together

- Human/machine coordination to improve productivity & reduce risk
- Robots performing routine tasks (inspection, logistics)
- Robotic Explorers (reconnoissance and risk reduction)

Autonomous Operations

- Independent, self-reliant crew can operate with up to 40 minute time delay
- Highly automated vehicle operable by minimal crew
- MCC automation (strategic/analysis role)
- Automated rendezvous & docking

In-Flight Maintenance

- Component-based design for maintainability & reliability
- Vehicle-wide diagnostics, prognostics & recovery
- In-space repair & manufacturing

Exploration Mobility

- Routine surface exploration
- Maximize time spent and distance traveled
- Minimize "time to get out the door"
- Environmental protection including dust abatement

Power Generation

- Production of high, continuous, latitude independent power for crew operations
- Mobile power systems for robust exploration