National Aeronautics and Space Administration

Cube Quest Challenge

How Cube Quest Relates to the Human Exploration and Operations Mission Directorate and NASA Goals

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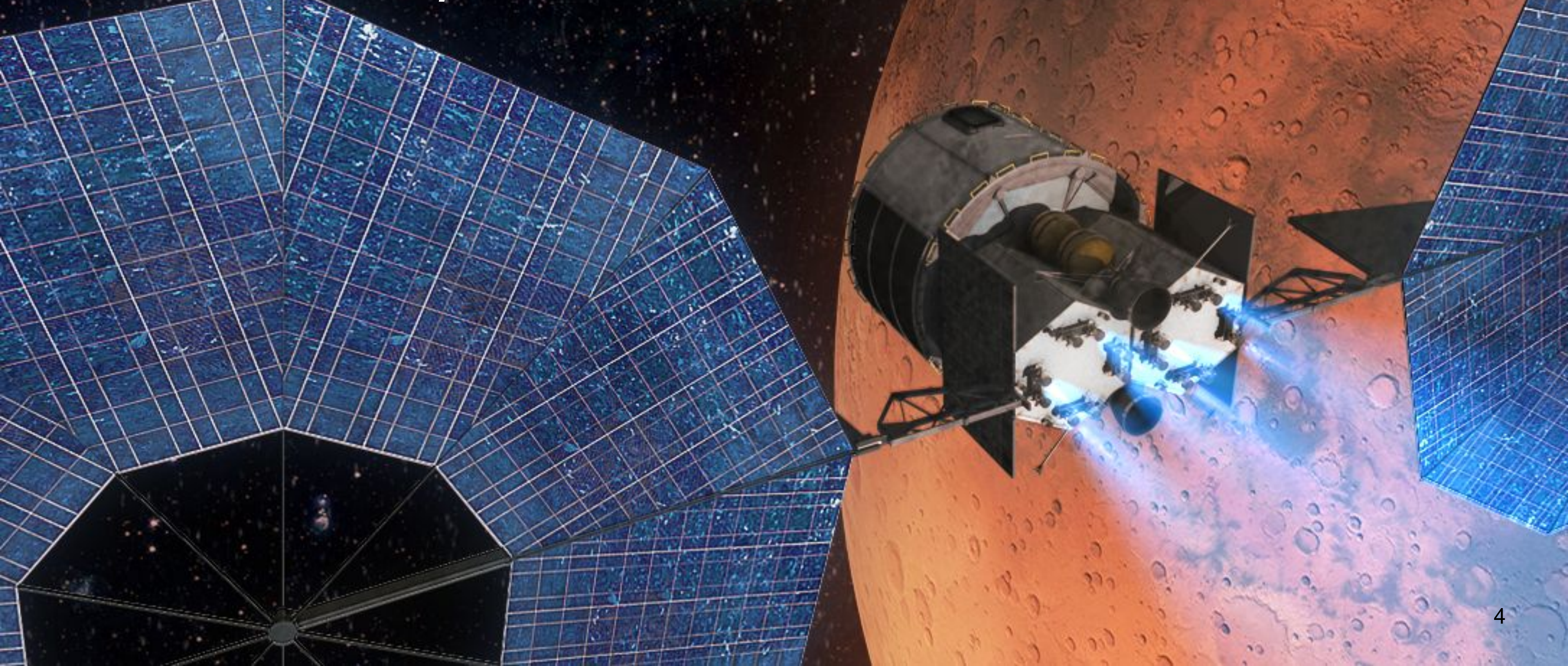
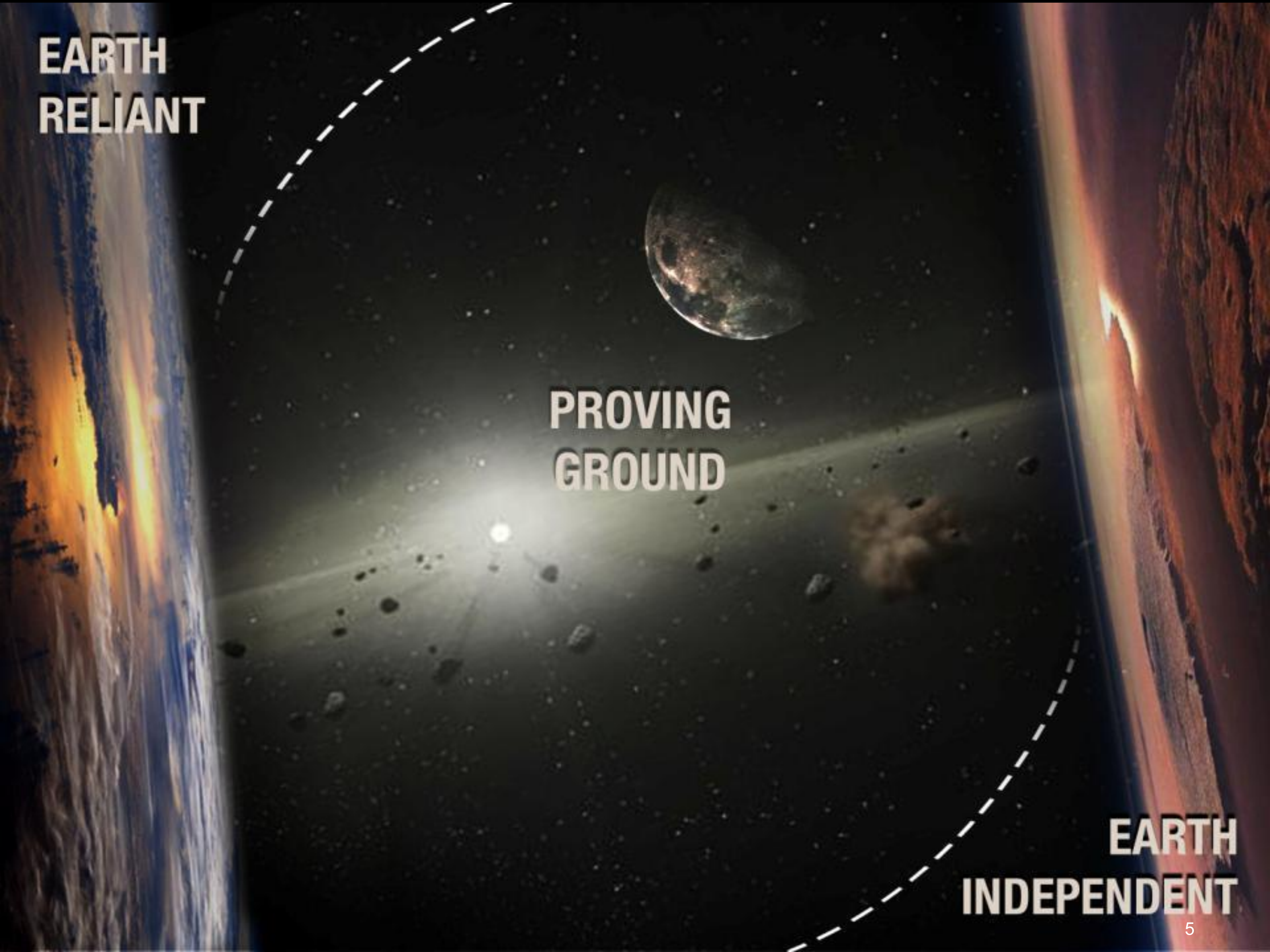
Human Exploration and Operations Mission Directorate

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

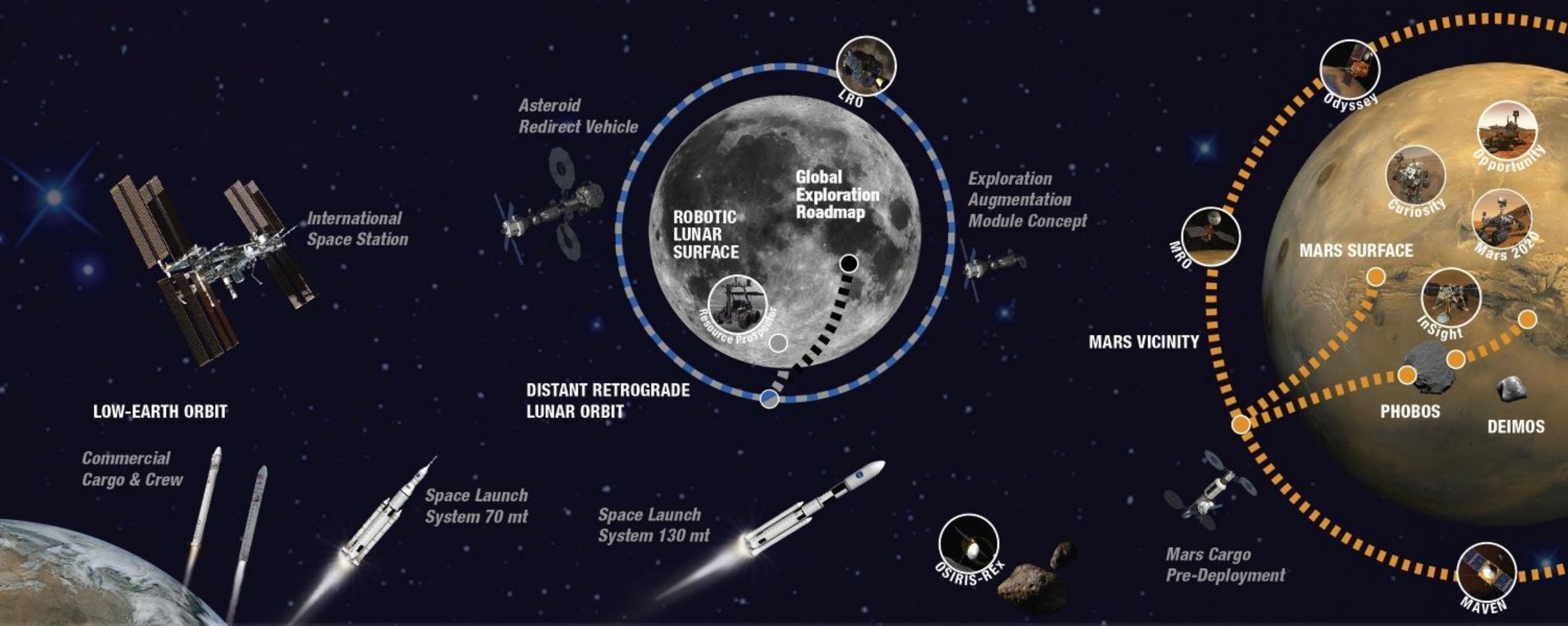
NASA Strategic Plan Objective 1.1

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

EVOLVABLE MARS CAMPAIGN

A Pioneering Approach to Exploration

EARTH RELIANT | **PROVING GROUND** | **EARTH INDEPENDENT**



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

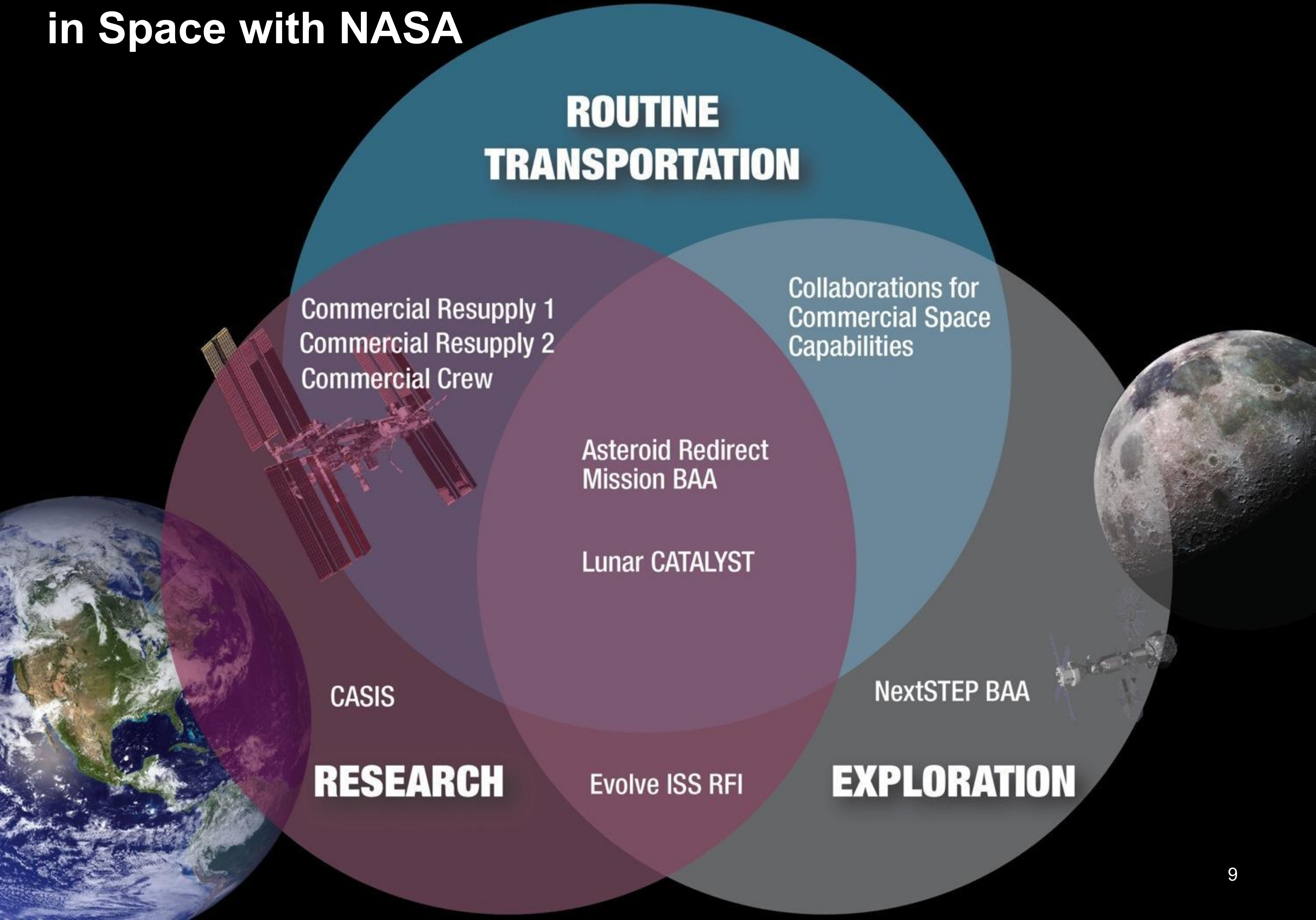
Cis-lunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

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

Strategic Knowledge Gaps

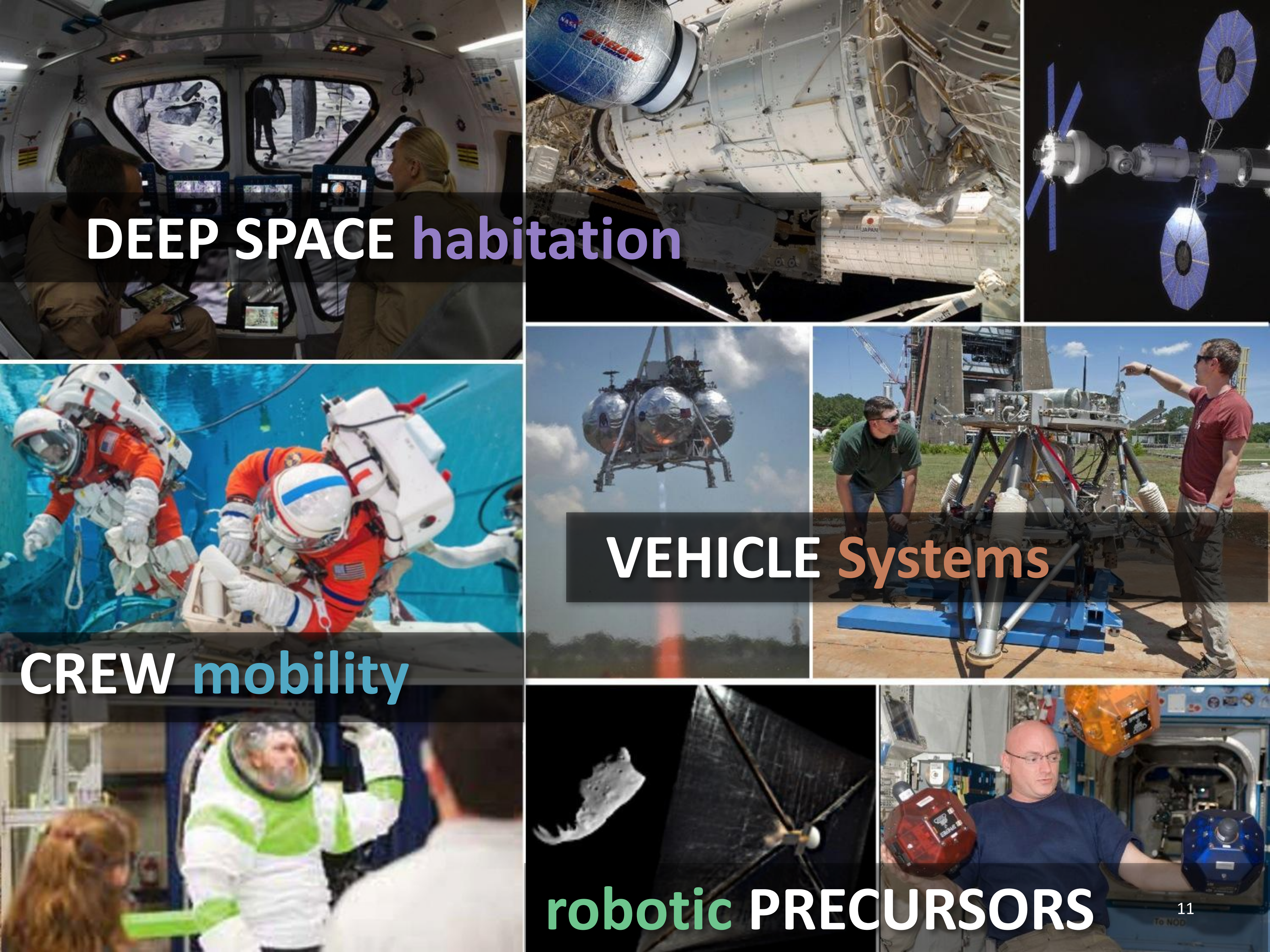
- **A Strategic Knowledge Gap (SKG) is an unknown or incomplete data set that contributes risk or cost to future human missions**
  - Apollo example: footpads oversized due to poor knowledge of lunar soil bearing strength
- **SKGs are not unique to human exploration; all NASA missions are designed based upon what is known and what is not.**
- **Science measurements are the greatest source of strategic Knowledge that has benefitted future human exploration.**

Commercial Opportunities in Space with NASA



Human Exploration and Operations
Advanced Exploration Systems

- Advanced development of exploration systems to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions beyond Earth orbit.
- Demonstrate prototype systems in ground test beds, field tests, underwater tests, and International Space Station flight experiments.
- Use and pioneer innovative approaches and public-private partnerships for affordable rapid systems development and provide hands-on experience for the NASA workforce.
- Maintain critical competencies at the NASA Centers and provide NASA personnel with opportunities to learn new and transform skills.
- Infuse new technologies developed by Space Technology Mission Directorate / Exploration Technology Development into exploration missions.
- Support robotic missions of opportunity to characterize potential destinations for human exploration.

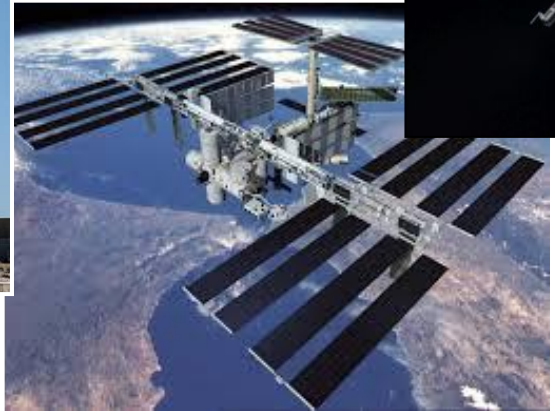

DEEP SPACE habitation
CREW mobility
VEHICLE Systems
robotic PRECURSORS

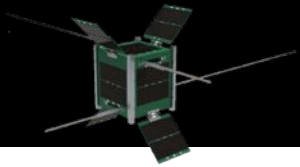
CubeSat Launch Initiative

NASA's CubeSat Launch Initiative (CSLI) provides opportunities to educational and non-profit organizations as well as NASA Centers to build small satellite payloads which will fly as auxiliary payloads on previously planned missions or as deployments from the International Space Station.

NASA
DoD
NRO

ISS





CSLI Benefits

Benefit to Educational Organizations and Non-profits:

- Enables students, teachers and faculty to obtain hands-on flight hardware development experience
- Advances the development of technologies
- Provides mechanism to conduct scientific research in the space environment
- Provides meaningful aerospace and Science, Technology, Engineering and Mathematics (STEM) educational experience

Benefit to NASA:

- Promotes and develops innovative public-private partnerships
- Provides a mechanism for low-cost technology development and scientific research
- Enables the acceleration of flight-qualified technology assisting NASA in raising the Technology Readiness Levels (TRLs)
- Strengthens NASA and the Nation’s future STEM workforce

2009-2014 CubeSats

114 Organizations – 29 States

CubeSat Focus Areas

Proposed CubeSats must align to NASA's Strategic Plan and, if appropriate, the Education Strategic Coordination Framework.

- 70% conducting Technology Demonstrations
- 50% conducting Scientific Research
- 50% supporting Education

Scientific Research

- Biological Science
- Earth Science
  - Snow/Ice Coverage
- Near Earth Objects
- Orbital Debris Tracking
- Space Based Astronomy
- Space Weather

Technology Demonstrations

- In-Space Propulsion
- Space Power
- Radiation Testing
- Tether Deployment
- Solar sails
- Material Degradation
- Solar Cells
- Additive Manufacturing

EM-1 CubeSats

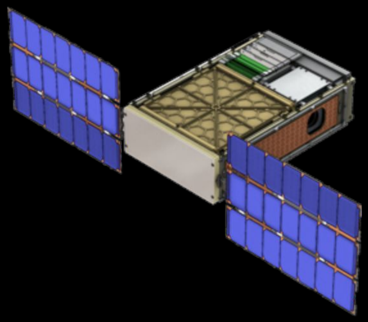
Common Drivers

- 6U CubeSat Form Factor
- SLS Integration
- Radiation tolerance & reliability
- Deep Space Navigation & Ops
- ADCS (3-Axis using SRU, IMU, RWA, RCS)
- Similar power demands

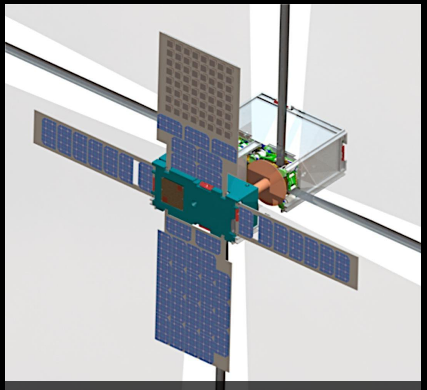
Unique Drivers

- Payloads (Biology/Imager/Spectrometer)
- SKG Objectives/Science Teams
- Trajectories/Propulsion
- Thermal constraints/environments

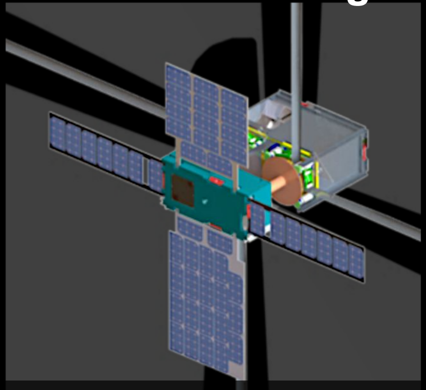
BioSentinel



NEA Scout



Lunar Flashlight



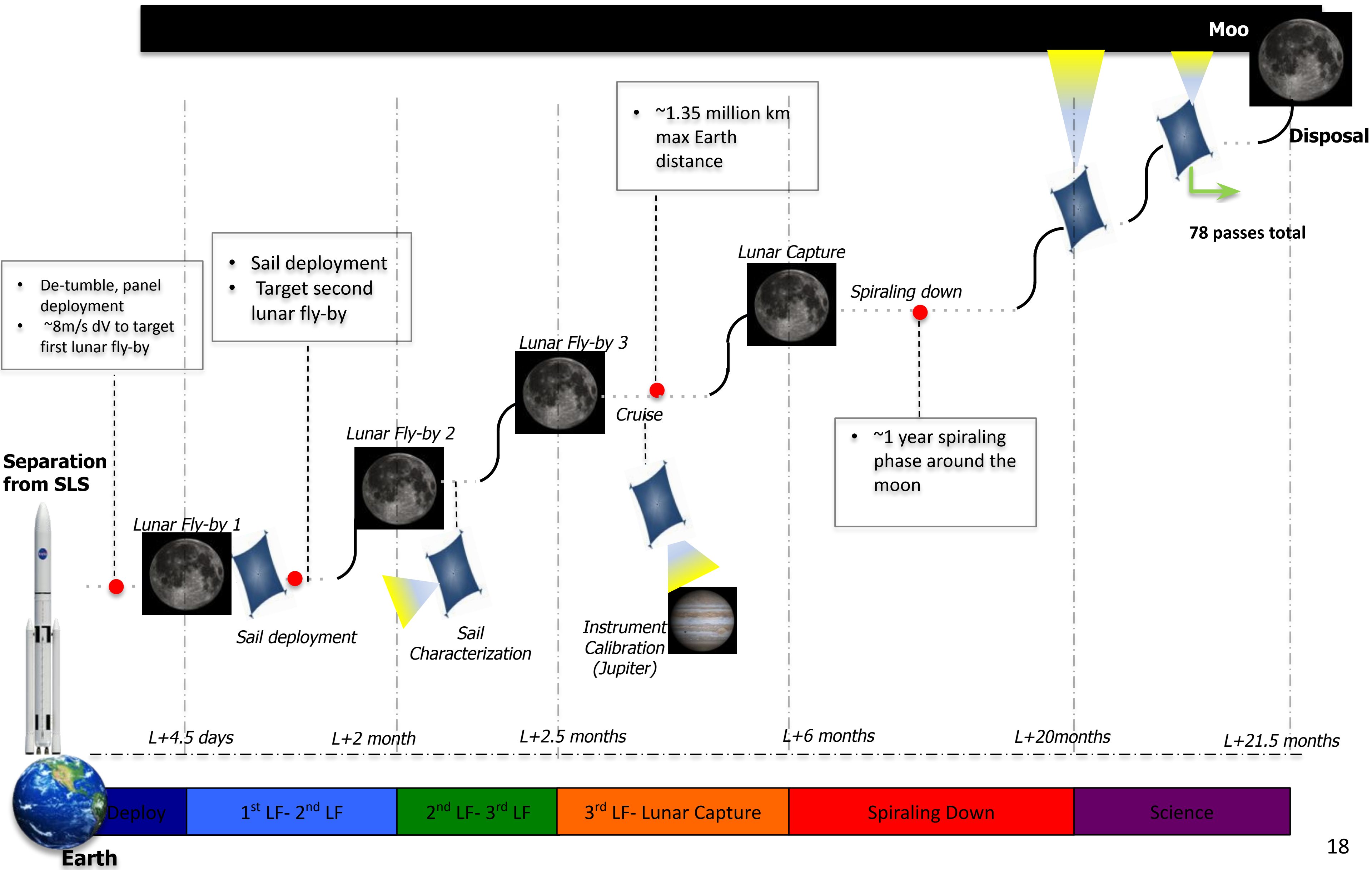
- Lunar Flashlight and NEA Scout are nearly identical, but all missions share common "DNA" on the subsystem level, even if not externally apparent
- Commonality is partially a result of relatively small pool of options for CubeSat components deemed suitable for long-term operations in deep space – but this is an emerging market!
- Even with common hardware, projects will require different modeling and analysis, to assess performance against unique mission profiles and requirements

Lunar Flashlight Objectives

- **SKG Addressed**: Understand the quantity and distribution of water and other volatiles in lunar cold traps
- Look for surface ice deposits and identify favorable locations for in-situ utilization
- Recent robotic mission data (Mini RF, LCROSS) strongly suggest the presence of ice deposits in permanently shadowed craters.
- Locations where Diviner measures the coldest year-round temperatures also have anomalous reflectivity in LOLA and LAMP data, suggesting water frost

Sunlight is specularly reflected off the sail down to the lunar surface in a 3 deg beam. Light diffusely reflected off the lunar surface enters the spectrometer to distinguish water ices from regolith.

Lunar Flashlight - Concept of Operations



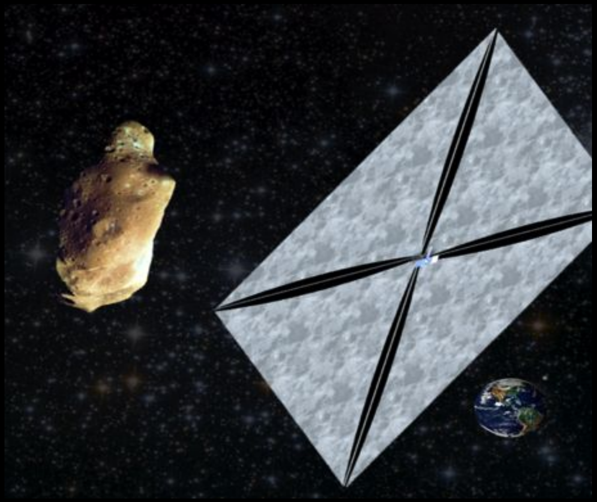
NEA Scout

Why NEA Scout?

- Characterize a NEA with an imager to address key Strategic Knowledge Gaps (SKGs)
- Demonstrates low cost reconnaissance capability for HEOMD (6U CubeSat)

Leverages:

- Solar sail development expertise (NanoSail-D, Solar Sail Demonstration Project, LightSail-1, etc.)
- CubeSat developments and standards (INSPIRE, University & Industry experience)
- Synergies with Lunar Flashlight (Cubesat bus, solar sail, communication system, integration & test, operations)



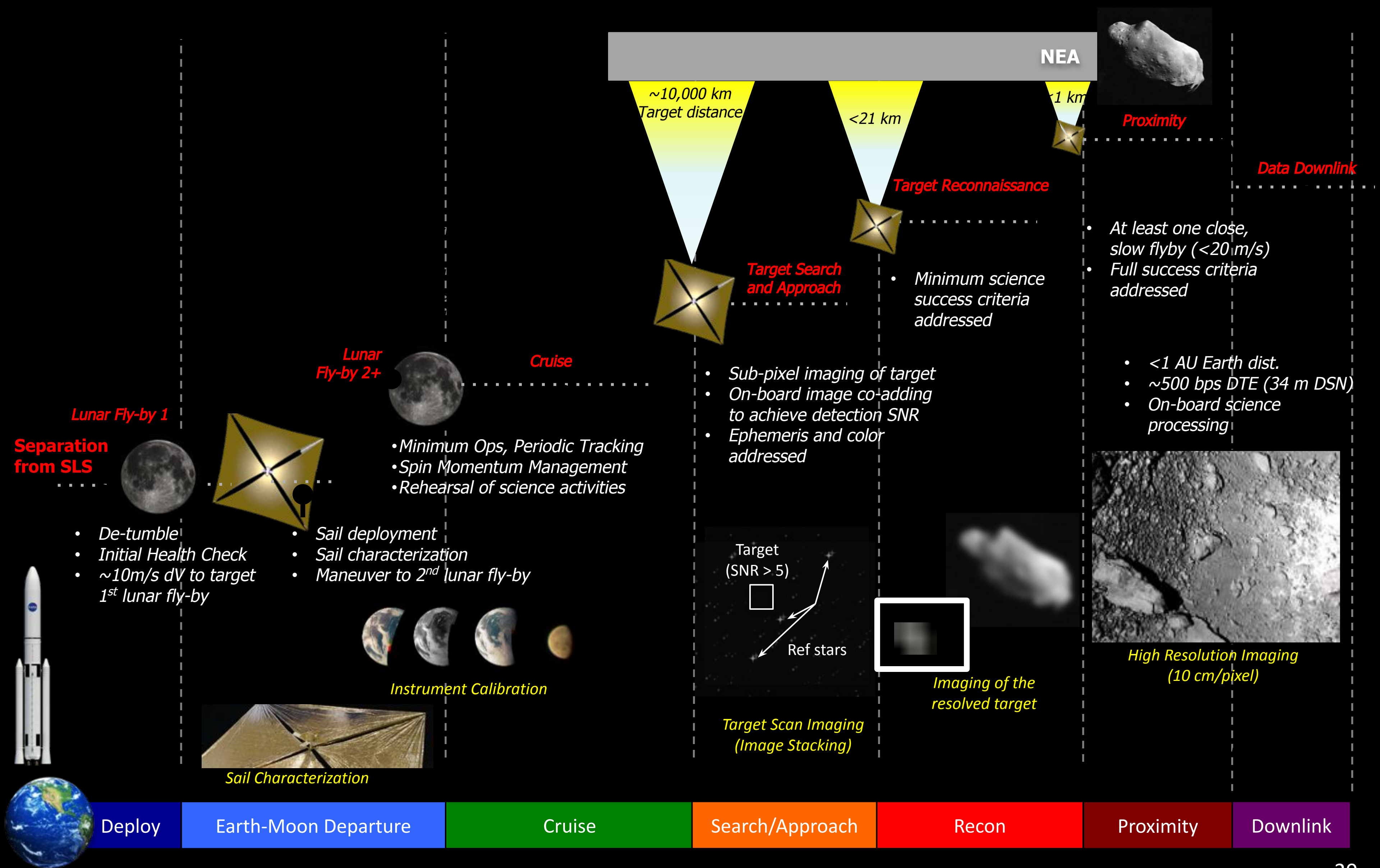
Measurements: NEA volume, spectral type, spin mode and orbital properties, address key physical and regolith mechanical SKG

- ≥80% surface coverage imaging at ≤50 cm/px
- Spectral range: 400-900 nm (incl. 4 color channels)
- ≥30% surface coverage imaging at ≤10 cm/px

Key Technical Constraints:

- 6U Cubesat and ~85 m^2 sail to leverage commonalities with Lunar Flashlight, expected dispenser compatibility and optimize cost
- Target must be within ~1 AU distance from Earth due to telecom limitations
- Slow flyby with target-relative navigation on close approach

NEA Scout



NEA
~10,000 km
Target distance
<21 km
<1 km
Proximity
Data Downlink
Target Reconnaissance
Target Search
and Approach
Separation
from SLS
Lunar Fly-by 1
Lunar
Fly-by 2+
Cruise
• De-tumble
• Initial Health Check
• ~10m/s dV to target 1st lunar fly-by
• Sail deployment
• Sail characterization
• Maneuver to 2nd lunar fly-by
• Minimum Ops, Periodic Tracking
• Spin Momentum Management
• Rehearsal of science activities
• Sub-pixel imaging of target
• On-board image co-adding to achieve detection SNR
• Ephemeris and color addressed
• Minimum science success criteria addressed
• At least one close, slow flyby (<20 m/s)
• Full success criteria addressed
• <1 AU Earth dist.
• ~500 bps DTE (34 m DSN)
• On-board science processing
Target
(SNR > 5)
Ref stars
Sail Characterization
Instrument Calibration
Target Scan Imaging
(Image Stacking)
Imaging of the
resolved target
High Resolution Imaging
(10 cm/pixel)
Deploy
Earth-Moon Departure
Cruise
Search/Approach
Recon
Proximity
Downlink

BioSentinel: A Biosensor in Space

<u>Objective</u>: A yeast radiation biosensor that will measure the DNA damage caused by space radiation, specifically double strand breaks (DSBs).

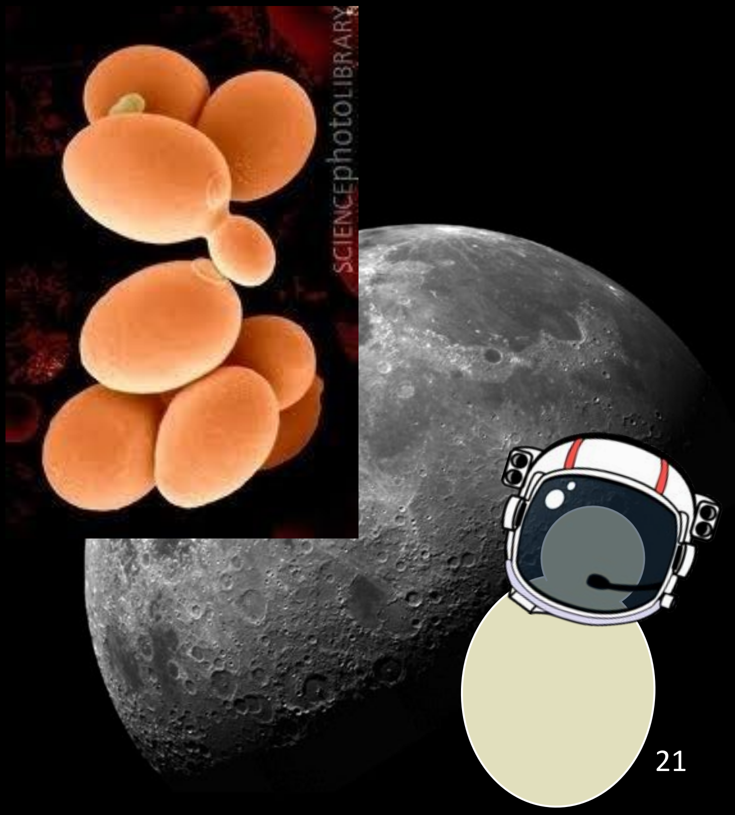
<u>Why</u>: Space radiation environment's unique spectrum cannot be duplicated on Earth. It includes high-energy particles, is omnidirectional, continuous, and of low flux. During solar particle events (SPEs), radiation flux can spike to a thousand times nominal levels.

<u>How</u>: Laboratory-engineered *S. cerevisiae* cells will sense and repair direct damage to their DNA (DSBs).

Yeast cells will remain dormant until activated by a DSB; gene repair will initiate yeast growth in microwells.

Multiple microwells will be in active mode during the mission.

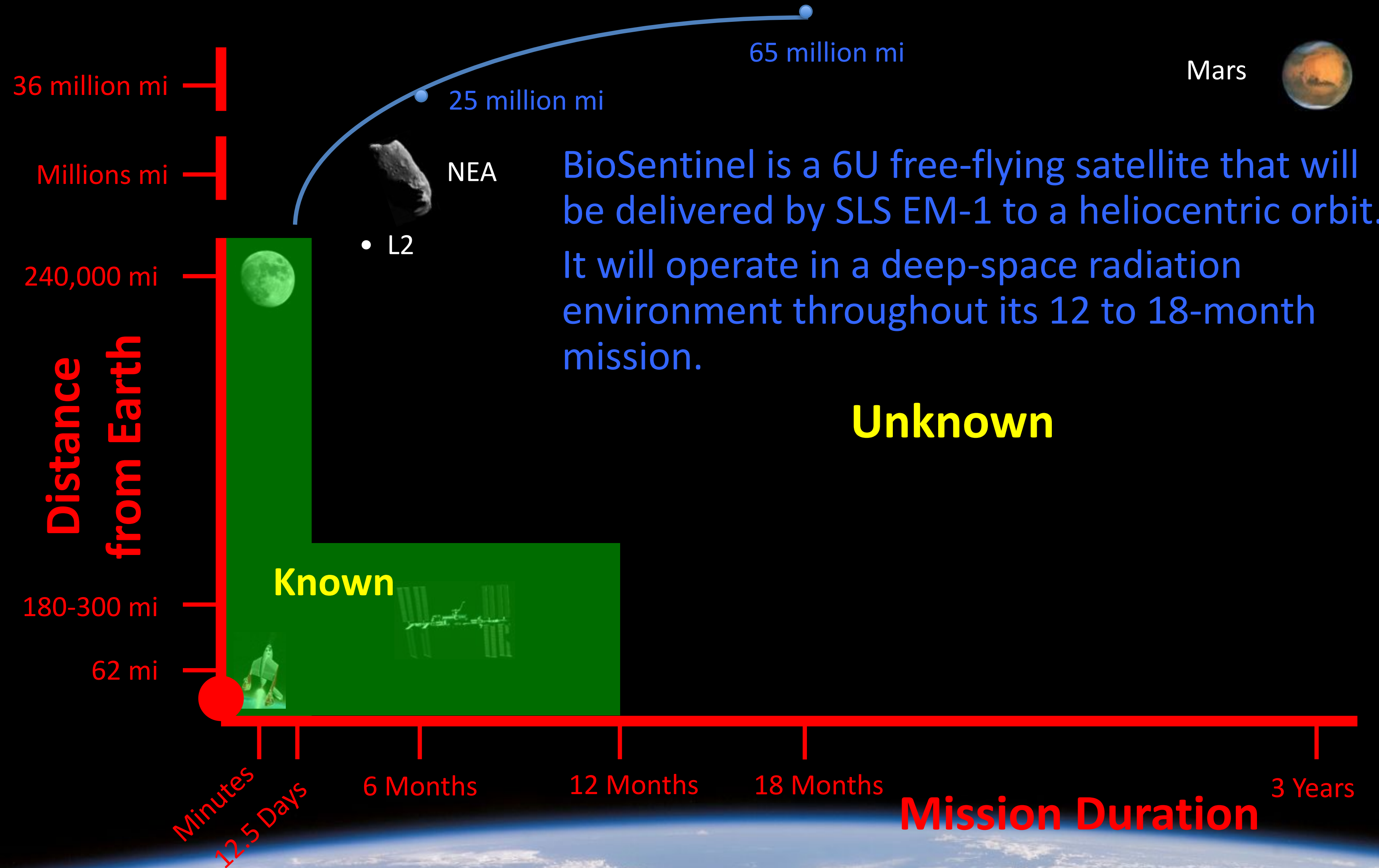
Extra wells will be activated in the event of an SPE.



The 1st Biology Experiment beyond LEO since Apollo

The limits of life in space, as we know it, is 12.5 days on a lunar round trip or 1 year in LEO. As we send people further into space, we can use model organisms to understand the biological risks and how they can be addressed.

Beyond



NASA