Life Beyond LEO
New Science Campaign for NASA's Space Biology Program

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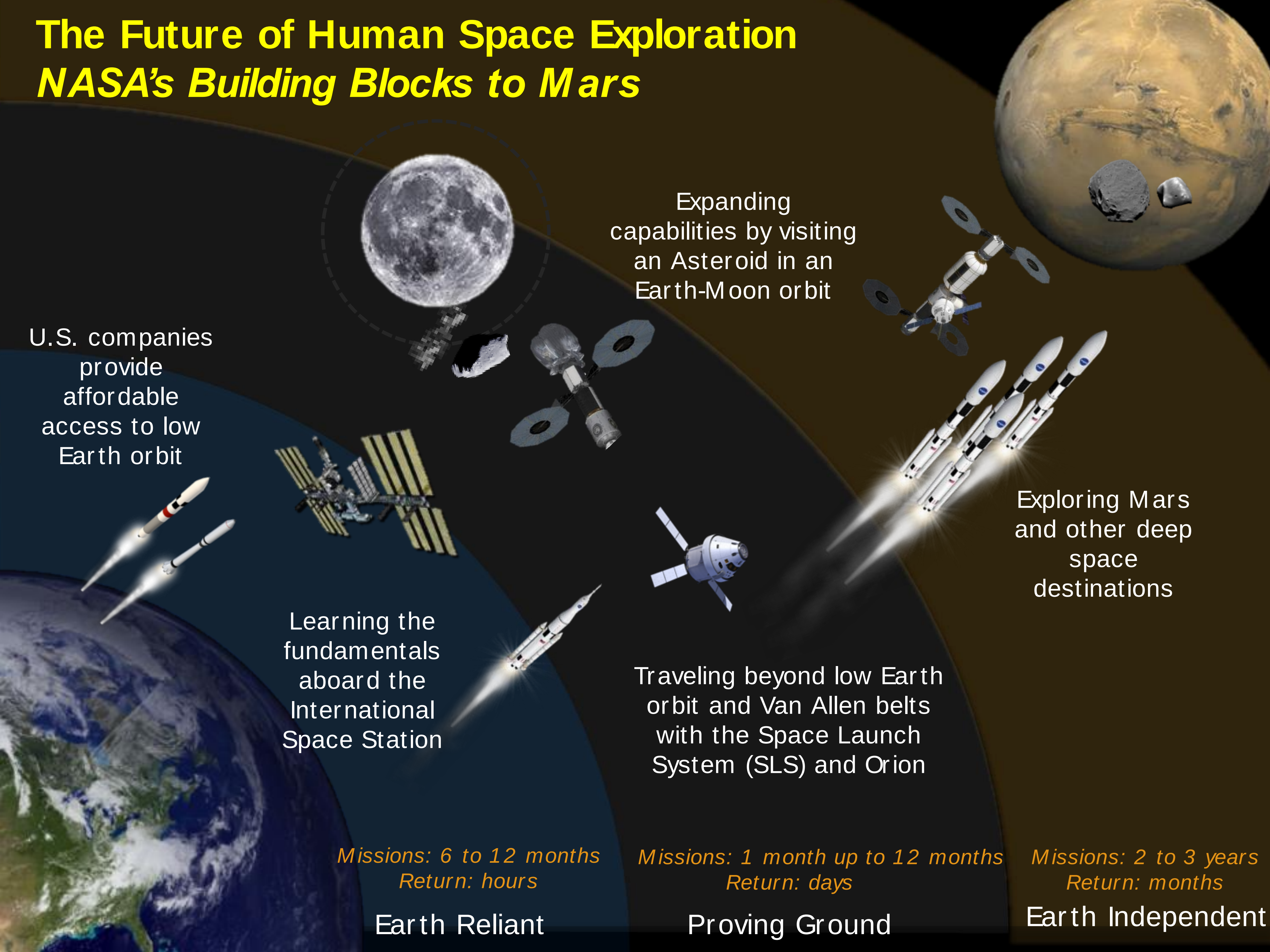
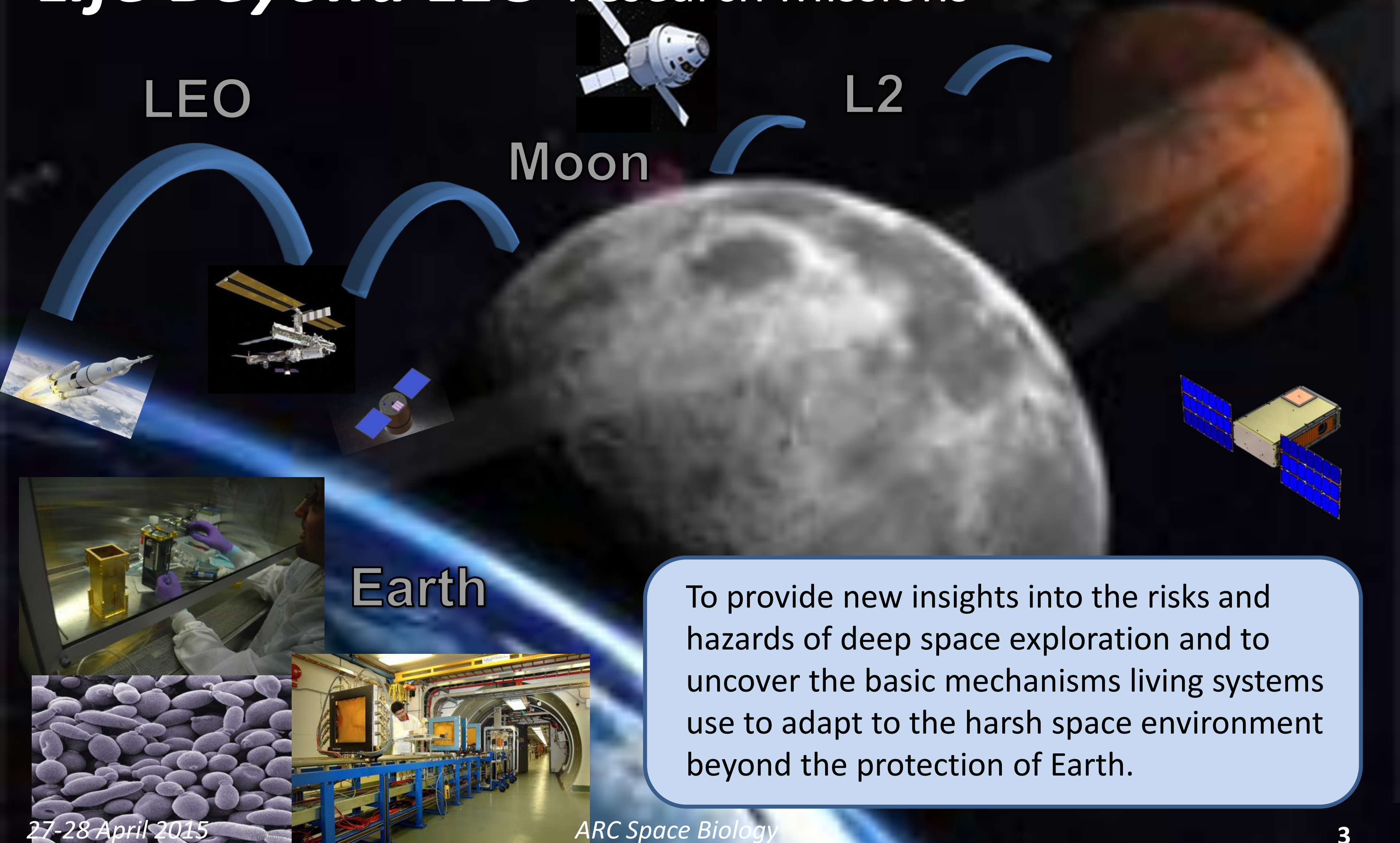

The Future of Human Space Exploration
NASA's Building Blocks to Mars
U.S. companies provide affordable access to low Earth orbit
Learning the fundamentals aboard the International Space Station
Expanding capabilities by visiting an Asteroid in an Earth-Moon orbit
Traveling beyond low Earth orbit and Van Allen belts with the Space Launch System (SLS) and Orion
Exploring Mars and other deep space destinations
Missions: 6 to 12 months
Return: hours
Earth Reliant
Missions: 1 month up to 12 months
Return: days
Proving Ground
Missions: 2 to 3 years
Return: months
Earth Independent

The Path to Human Exploration of Mars will Take

Life Beyond LEO Research Missions



To provide new insights into the risks and hazards of deep space exploration and to uncover the basic mechanisms living systems use to adapt to the harsh space environment beyond the protection of Earth.

Life Beyond LEO Science Campaign

ARC Space Biology
Life Beyond LEO Science
Campaign Proposal

Goals: Life Beyond LEO Science Campaign

Goal 1: Perform high-quality research in space, to provide new insights into the risks and hazards of deep space exploration and to uncover the basic mechanisms living systems use to adapt to the harsh space environment beyond the protection of Earth

Goal 2: Utilize the unique capabilities and opportunities offered by missions beyond LEO to perform biological research that addresses NRC Decadal Study High Priority Recommendations and Objective 1.1 of the NASA Strategic Plan:

NRC Recommendation: "Free-flying spacecraft may be used when extremely low-noise and low stray-acceleration environments are required, or when specific orbits are required to obtain the necessary science return." Highest priority recommendations, have components that require studies using free flyers.

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.

Implementation Plan: Solicit for PI research grants; leverage existing and emerging NASA capabilities and programs, Industry, Academia, and International Partners for flight studies.

Science: Life Beyond LEO Science Campaign

Understanding the Combined Effects of the Deep Space Environment: Radiation and Reduced Gravity

Stress Responses and Survival in Space

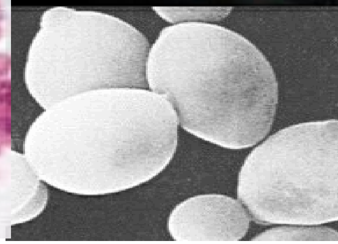
- *Determine the response in model organisms to reduced gravity and space radiation, e.g., viability and survival as a function of environment & organism type*
  - *Example: for **microbial biofilms**, determine growth rates, film formation & morphology, metabolic activity, and community interactions in heterocultures (mixed species)*

Adaptation and Evolution in Space

- *Track changes in: metabolism, viability, reproduction & development, aging and longevity*
- *Identify time course and process (mechanisms) of adaptation and evolution of model organisms over many generations at the organismal and genetic levels*
- *Understand how life adapts to gravity transitions from deep space to planetary surfaces*

Technology: Life Beyond LEO Science Campaign






- **Technology Development and Implementation for studies of Life Beyond LEO**
  - **Biosentinels and Biosensors** *(Strategic Knowledge Gaps from multiple Analysis/Assessment Groups)*
    - *Space environment effects: Contribute to the assessment of how the space environment impacts human health & performance thru studies with model organisms, biosentinel &, biosensors*
    - *Radiation-tolerant or radiation-responsive (bioengineered) model organisms:*
      - *determine thresholds of resistance & responses to radiation by type/dose/energy*
      - *validate models, develop "transfer standards" for terrestrial experiments*
  - **In-Situ Resource Utilization**
    - *Plant growth and multiple generations, food production*
    - *Organism growth, food production, monitoring of bioreactors & production*

Partners: Life Beyond LEO Science Campaign

Space Life and Physical Sciences

- ✓ Flight Project Development
- ✓ Science leadership
- ✓ Science development and grants for spaceflight experiments
- ✓ Workshops

Commercial

- ✓ Launch Vehicle Providers
- ✓ Lunar X Prize
- ✓ Lunar CATALYST
- ✓ Spaceflight Services SHERPA
- ✓ Tech Development Partnerships
- ✓ Emerging Deep Space Transport and Payload Providers

NASA Programs

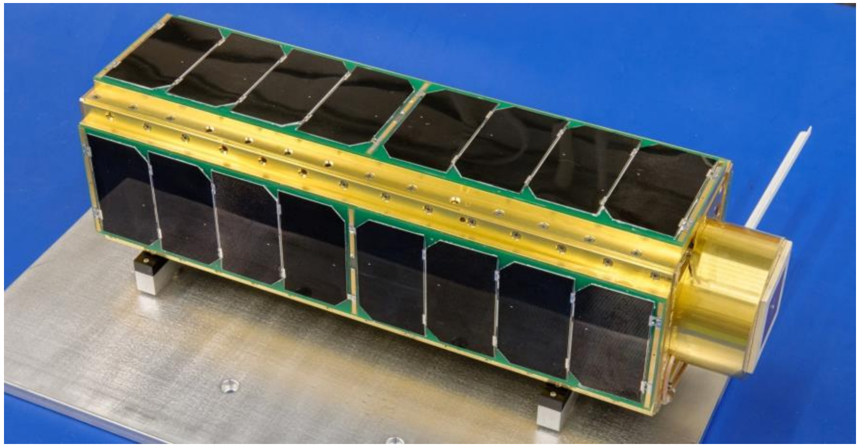
- ✓ Advanced Exploration Systems (AES)
- ✓ Exploration Missions (EM)
- ✓ Space Technology Mission Directorate (STMD)
- ✓ Science Mission Directorate (SMD)
- ✓ Human Research Program (HRP)
- ✓ Astrobiology
- ✓ Synthetic Biology

International

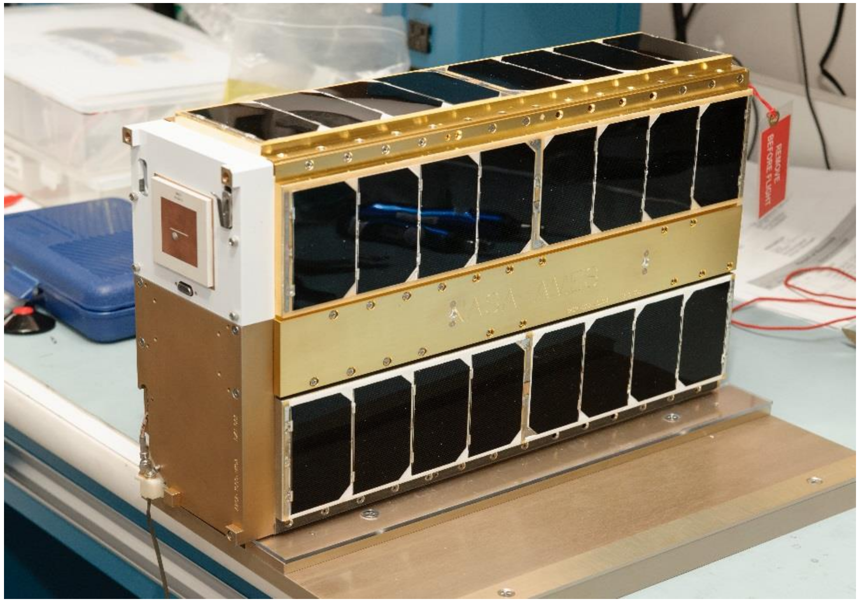
- ✓ CSA
- ✓ ESA, DLR (Example: EuCROPIS)
- ✓ JAXA
- ✓ RSA (Example: Bion)

Biology Cubesat Missions in LEO:

- GeneSat, PharmaSat, O/OREOS
- SporeSat
  - Ames 3U Bus
  - Investigating mechanisms of plant gravity sensing using a “lab-on-a-chip” approach
  - Launched in April of 2014



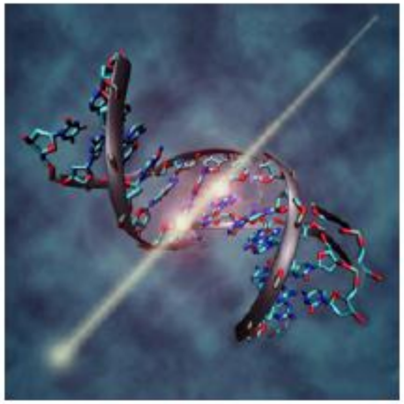
- EcAMSat
  - Ames 6U Bus based on 3U heritage
  - Investigating space microgravity affects on the antibiotic resistance of E. coli
  - Launch targeted for late 2015 or early 2016.



BioSentinel Mission on SLS EM-1

Advance Exploration System (AES) Program Office selected BioSentinel to fly on Space Launch System (SLS) Exploration Mission (EM-1) as a secondary payload

- Payload selected to help fill HEOMD **Strategic Knowledge Gaps in Radiation effects on Biology**
- Development schedule based on July 2018 Launch



Key BioSentinel Project Objectives

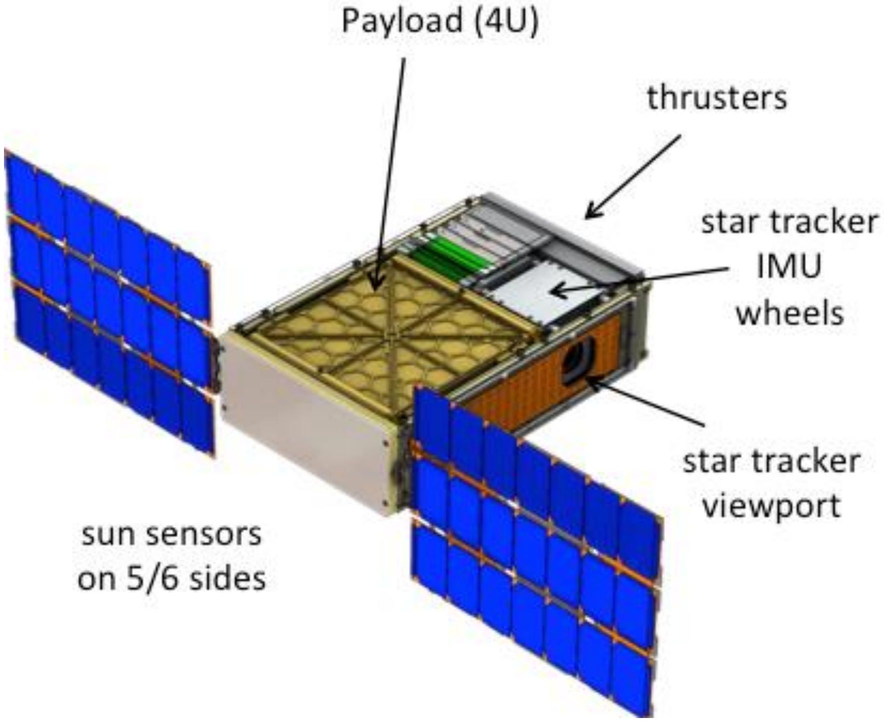
- Develop a **deep space Nanosat** capability
- Develop a **radiation biosensor** useful for other missions
- Define / validate **SLS Secondary Payload Interfaces**
- Compare life science results across **multiple space environments** relevant to human exploration

Proposed BioSentinel/Mars 2020 Objectives

- Measure radiation effects on biology over the Earth-to-Mars voyage
- Provide life science results across **multiple space environments**
- Fly on cruise state using power and data resources; mission ends on approach to Mars

BioSentinel Mission Overview

- 1st NASA biology studies beyond LEO in 4 decades
  - Enabling comparison across multiple radiation & gravitation environments
- 1st 6U CubeSat to fly beyond LEO
  - Challenges for communications and attitude control
- 1st CubeSat to combine a biology science payload with capable C&DH and FSW
  - Payload includes autonomous measurement response to SPEs



Affiliations : NASA ARC, NASA JSC, NASA GRC, LLUMC, Univ. Saskatchewan

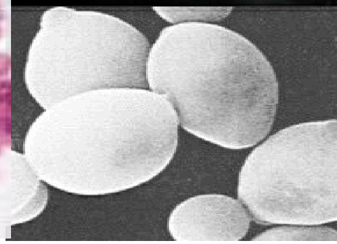
Support : NASA Human Exploration and Operations Mission Directorate (HEOMD) Advanced Exploration Systems Division

- **Potential Technology Needs**
  - Modular, adaptable, multi-Platform Bioreactors to support organism growth
    - Controlled thermal environment for specimen incubation
    - Species-specific Biological Sample Management and Handling Systems
  - Miniature, in-situ Biological Sensors, Arrays, Signal Processors
  - Advanced, miniature Microscopy and Imaging Systems
  - Technologies for in-situ Molecular Biology Research
  - Miniaturized, Fluorescent Activated Cell Sorters/Cytometers
  - Autonomous, robotic, life support technologies, sample collection and preservation
  - Radiation shielding for electronics/optics and science goals as needed

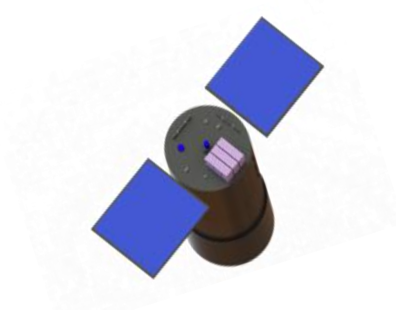
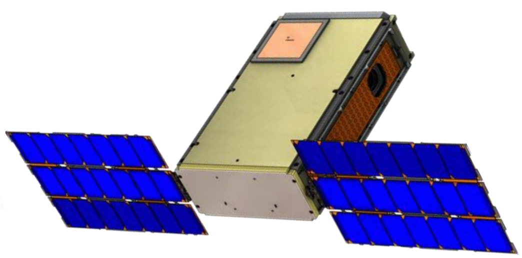
- **Capability Needs**
  - Payload accommodation on small satellites for missions beyond LEO
    - Available mass, volume, power, thermal management, data storage and downlink
    - From HEO to Lunar orbit and surface missions to long duration deep space and on to Mars orbit and surface missions
  - Late load integration capability with the launch vehicle
    - L-48 hours is ideal for biological payloads
    - Up to L-4 weeks can be worked out depending on biology
  - Sample return capabilities
    - Orion Exploration missions – Lunar, Asteroid, Mars
    - Free flyer missions to deep space with Earth return and payload return/entry capabilities
      - Example: Lunar Flyby or Cis-Lunar with sample return capability
  - Sub-orbital and LEO platforms for technology maturation

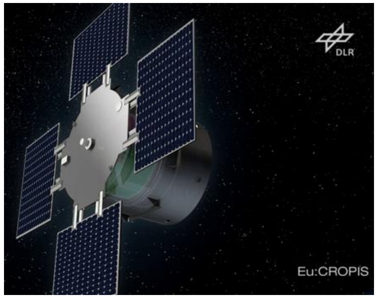
Impact: Life Beyond LEO Science Campaign





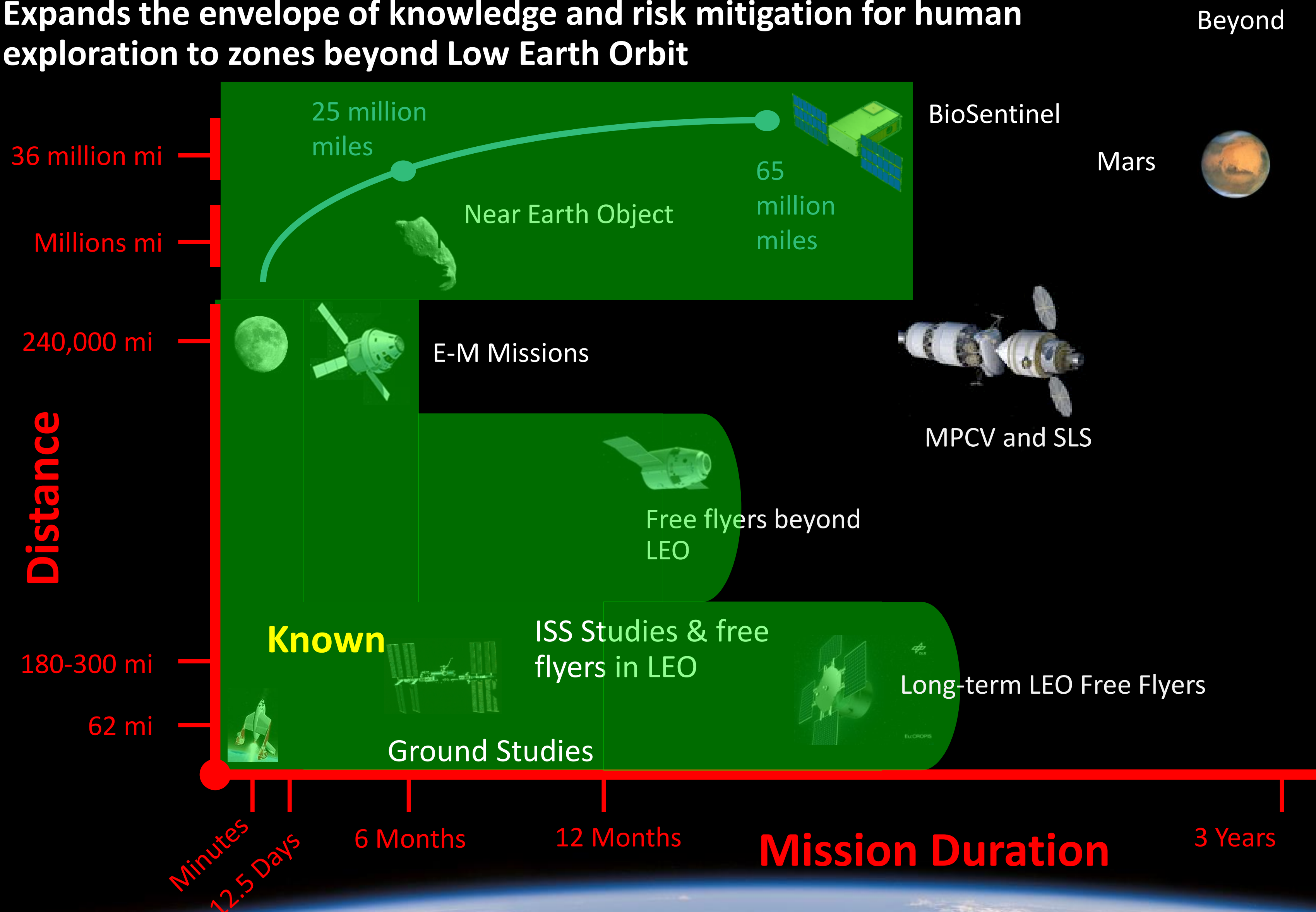

Characterizing the effects of the space environment beyond LEO will provide new insights into the risks and hazards of exploration beyond LEO. Results will support and guide new risk reduction approaches, new potential therapies for biomedical problems, new materials and technologies to protect life, and new information on basic mechanisms living systems use to adapt to the harsh space environment beyond LEO.



Life Beyond LEO Science Campaign

Expands the envelope of knowledge and risk mitigation for human exploration to zones beyond Low Earth Orbit



Summary

- NASA's roadmap to Mars and exploration of the Solar System involves human and other biological systems.
- Extended human presence in deep space as well as the Moon and Mars will require understanding of the effects of reduced gravity, radiation, transit and destination specific variables from cellular to the whole organism level.
- Emerging capabilities to travel beyond LEO will provide great opportunity to conduct biological research and human exploration precursor missions to understand these effects and reduce risks to future exploration missions.
  - Concepts to allow more frequent access to deep space
  - Biological payload accommodations
  - Advances in autonomous, in-situ, sample handling and management
  - Sample return capabilities