NASA Human Research Program

Protecting Human Health and Performance to Enable Deep Space Exploration

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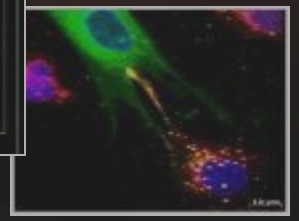
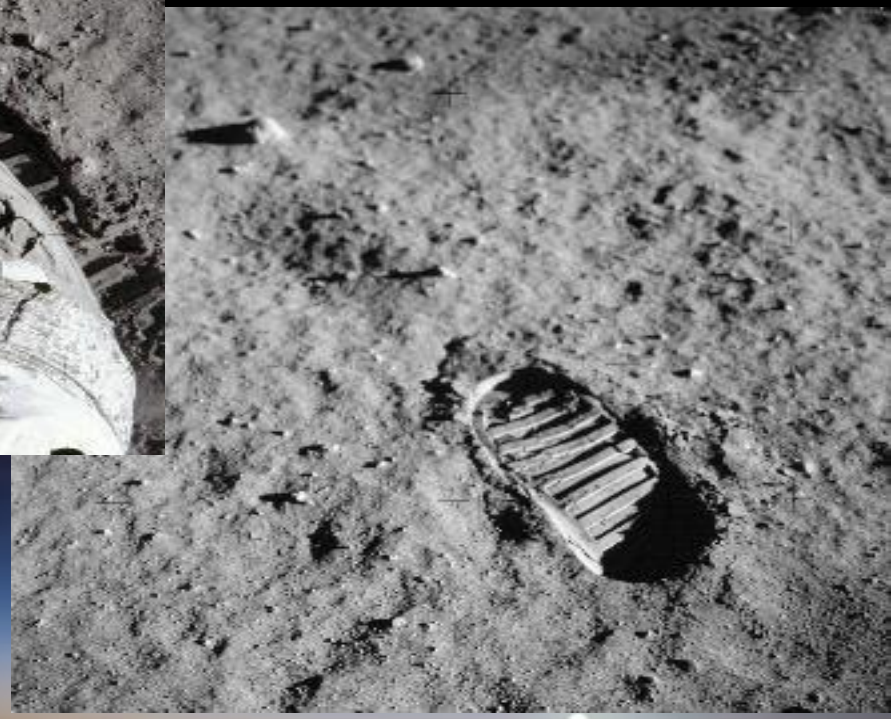
Text



Human travelers to Mars will experience unprecedented biological, physiological, and psychosocial challenges that could lead to significant health & performance decrements during and after the mission

NASA's Human Research Program is responsible for

Characterizing the effects of spaceflight and developing mitigation strategies



Human Research Program Mission

To enable space exploration beyond Low Earth Orbit by reducing the risks to human health & performance through a focused program of:

- **Basic, applied, and operational research**

leading to the development and delivery of:

- **Human health, performance, and habitability standards**
- **Countermeasures and other risk mitigation solutions**
- **Advanced habitability and medical support technologies**

The Human Research Program (HRP) was established in 2007. It resides in the Human Exploration Operations Mission Directorate (HEOMD).

Human Research Program

Program Science Management Office

- Peer Review, Task/Risk Management, Data Archive
- Program planning, integration & control

Elements

Space Radiation

- Radiation exposure limits and health effects

Human Health and Countermeasures

- Physiology, nutrition, immunology, pharmacology, ocular impairment

Human Factors and Behavioral Performance

- Individual, interpersonal interactions, sleep, stress
- Interfaces between humans and vehicles/habitats

Exploration Medical Capability

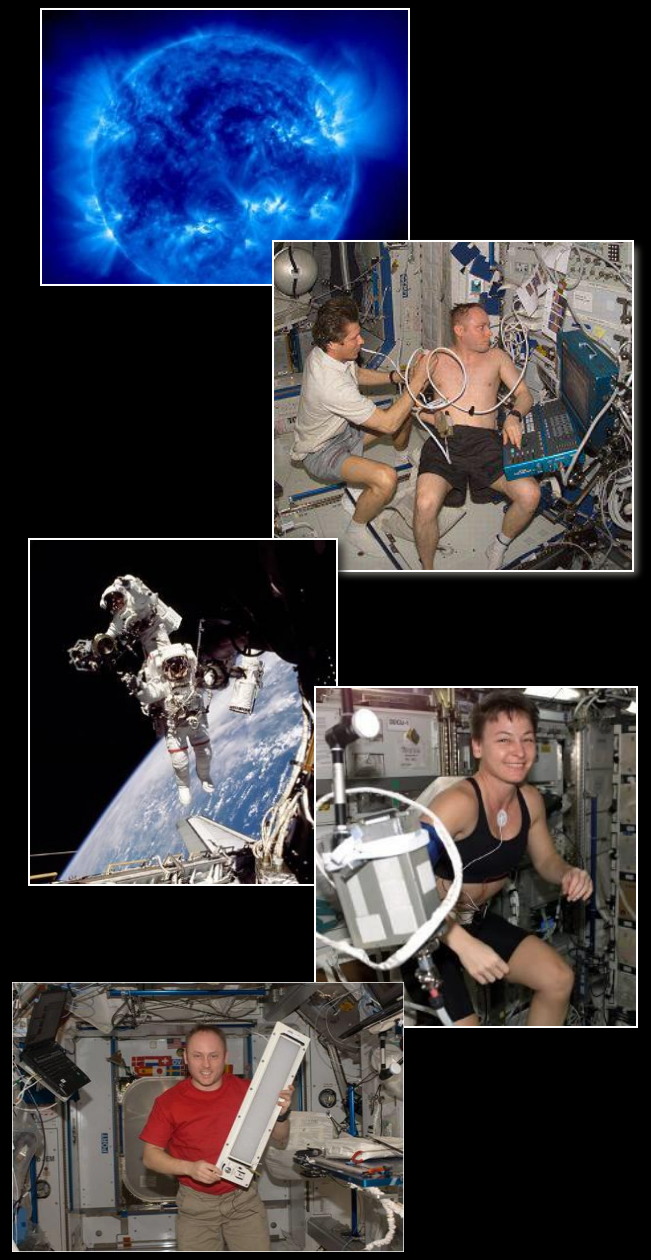
- Medical care for missions beyond low Earth orbit

ISS Medical Project

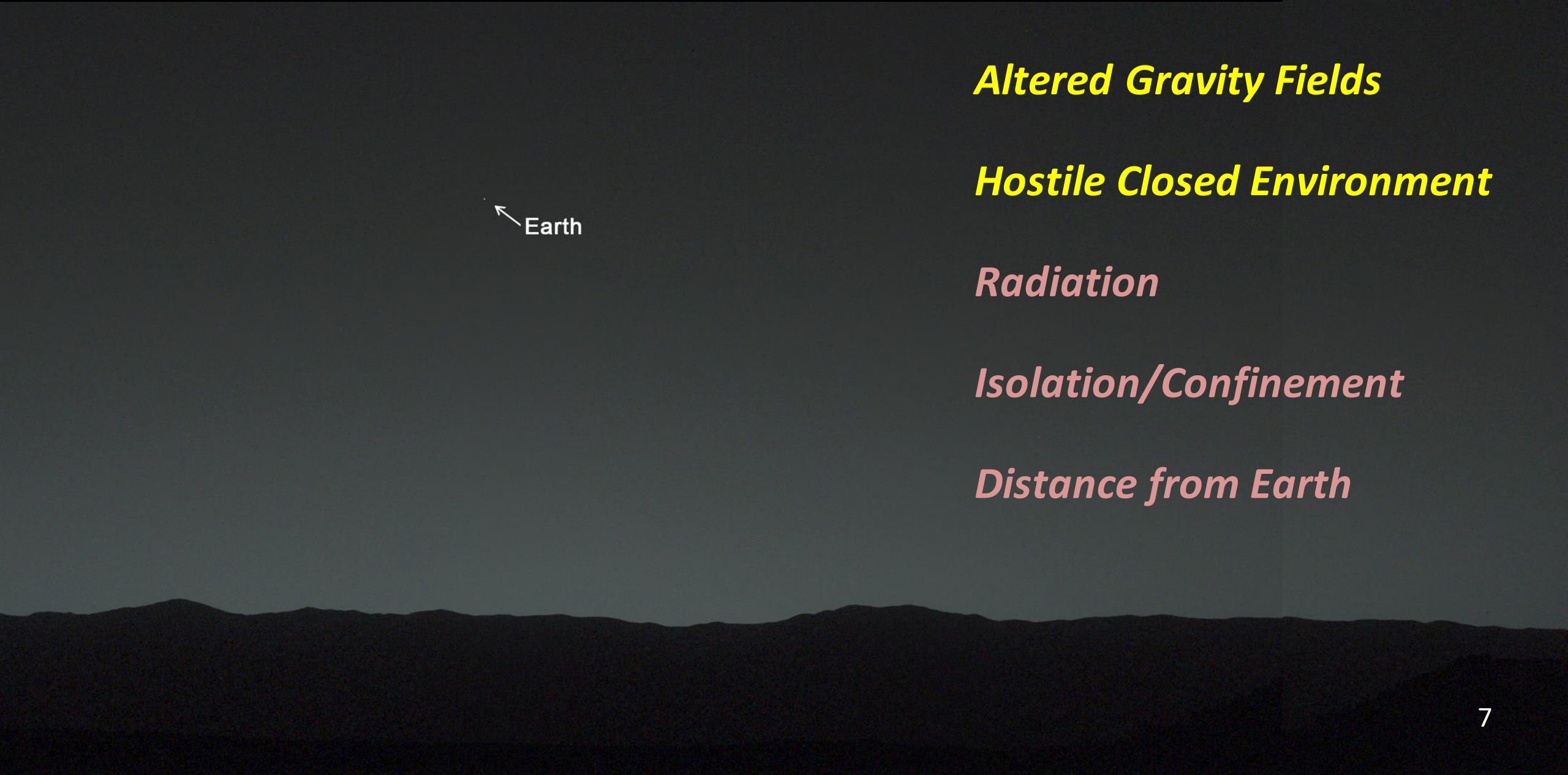
- Infrastructure for flight and analog experiments

Translational Research Institute for Space Health

Cooperative agreement to pursue R&T that disrupts the HRP portfolio



Deep Space Stressors to Human Health & Performance



Altered Gravity Fields

Hostile Closed Environment

Radiation

Isolation/Confinement

Distance from Earth

Altered Gravity Fields

Hostile Closed Environment

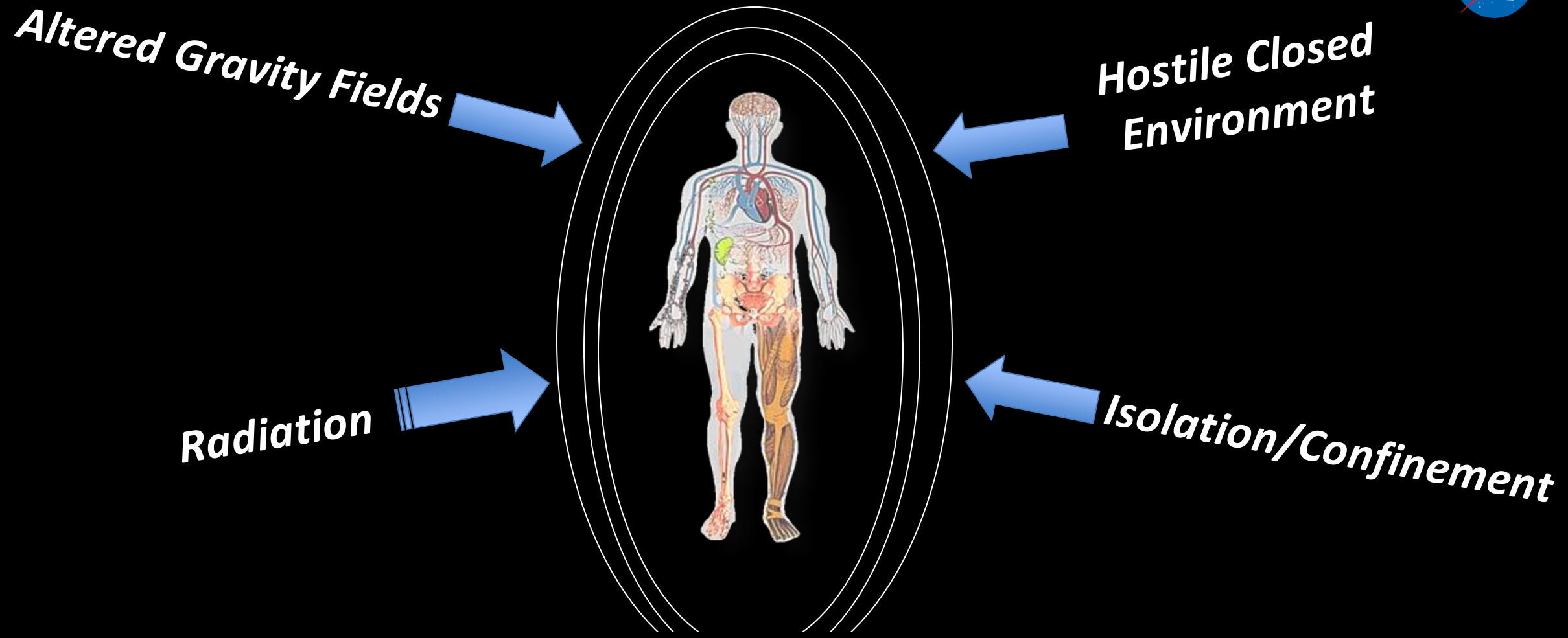
Radiation

Isolation/Confinement

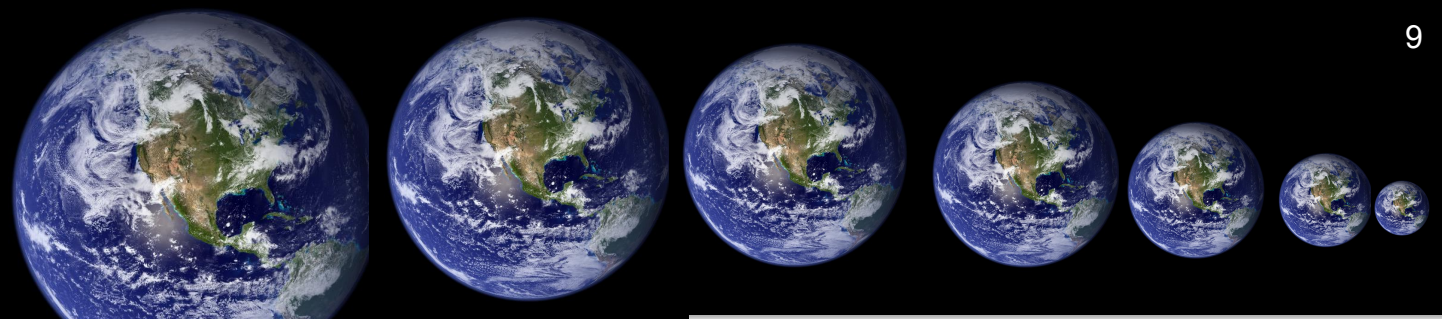
Distance from Earth

Apollo 17 (1972)

Integrated Human Health & Performance



Increasing Distance from Earth



Exploration Health & Performance Risks – Mars DRM

Altered Gravity Field

1. Spaceflight-Associated Neuro-ocular Syndrome (SANS)
2. Renal Stone Formation
3. Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
4. Bone Fracture due to spaceflight Induced changes to bone
5. Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance
6. Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity
7. Adverse Health Effects Due to Host-Microorganism Interactions
8. Urinary Retention
9. Orthostatic Intolerance During Re-Exposure to Gravity

Concerns

1. Concern of Clinically Relevant Unpredicted Effects of Medication
2. Concern of Intervertebral Disc Damage upon and immediately after re-exposure to Gravity

Radiation

1. Risk of Space Radiation Exposure on Human Health:
   - Acute solar events
   - Cancer
   - CNS impairment
   - Tissue degeneration (cardio)

Distance from Earth

1. Adverse Health Outcomes & Decrements in Performance due to inflight Medical Conditions
2. Ineffective or Toxic Medications due to Long Term Storage

Isolation/Confinement

1. Adverse Cognitive or Behavioral Conditions & Psychiatric Disorders
2. Performance & Behavioral health Decrements Due to Inadequate Cooperation, Coordination, Communication, & Psychosocial Adaptation within a Team

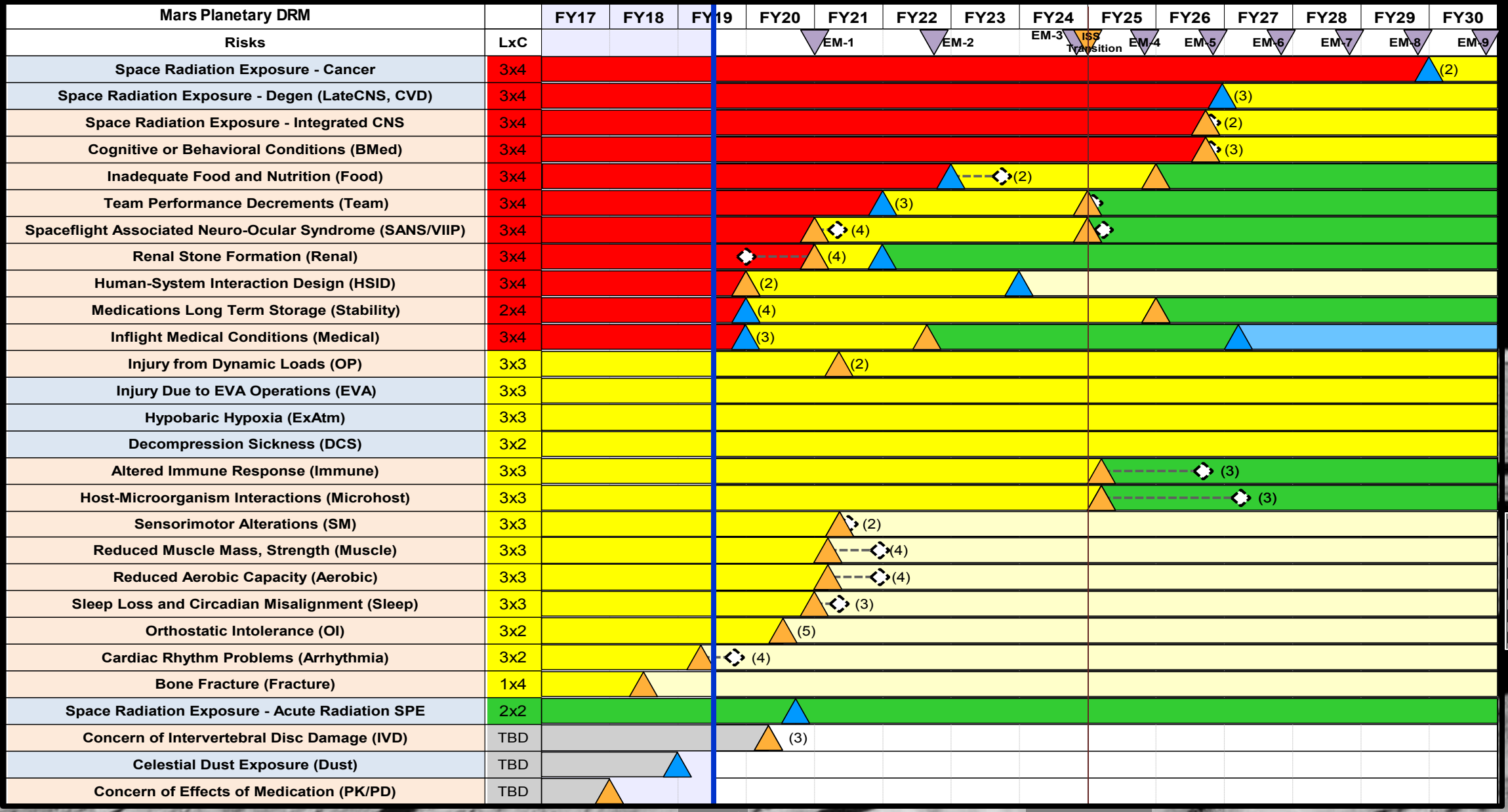
Hostile Closed Environment

1. Acute and Chronic Carbon Dioxide Exposure
2. Performance decrement and crew illness due to inadequate food and nutrition
3. Injury from Dynamic Loads
4. Injury and Compromised Performance due to EVA Operations
5. Adverse Health & Performance Effects of Celestial Dust Exposure
6. Adverse Health Event Due to Altered Immune Response
7. Reduced Crew Performance Due to Hypobaric Hypoxia
8. Performance Decrements & Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, & Work Overload
9. Reduced Crew Performance Due to Inadequate Human-System Interaction Design
10. Decompression Sickness
11. Toxic Exposure
12. Hearing Loss Related to Spaceflight

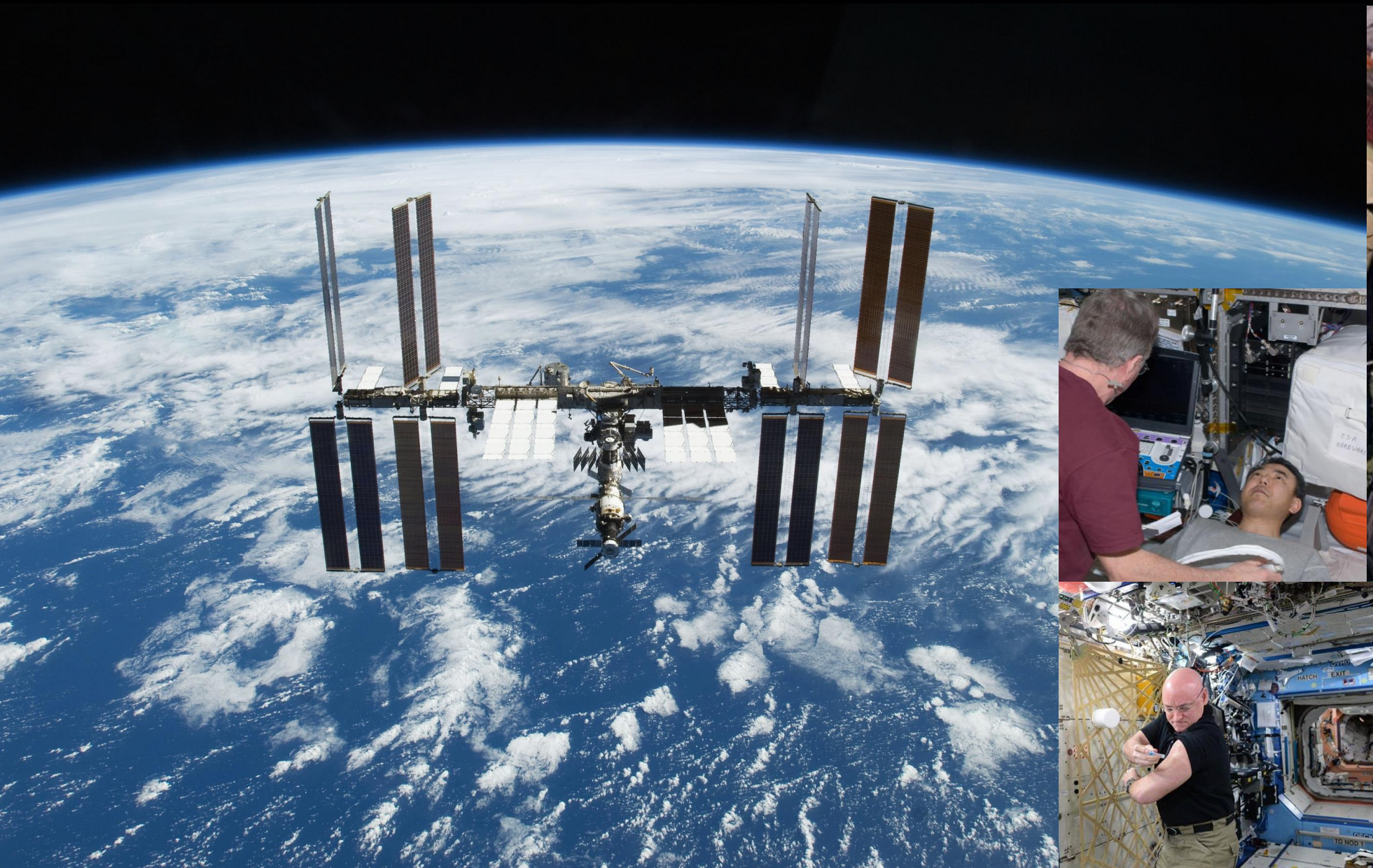
Key: High LxC Medium LxC Low LxC TBD LxC

Managed/configuration-controlled by NASA Human Systems Risk Board

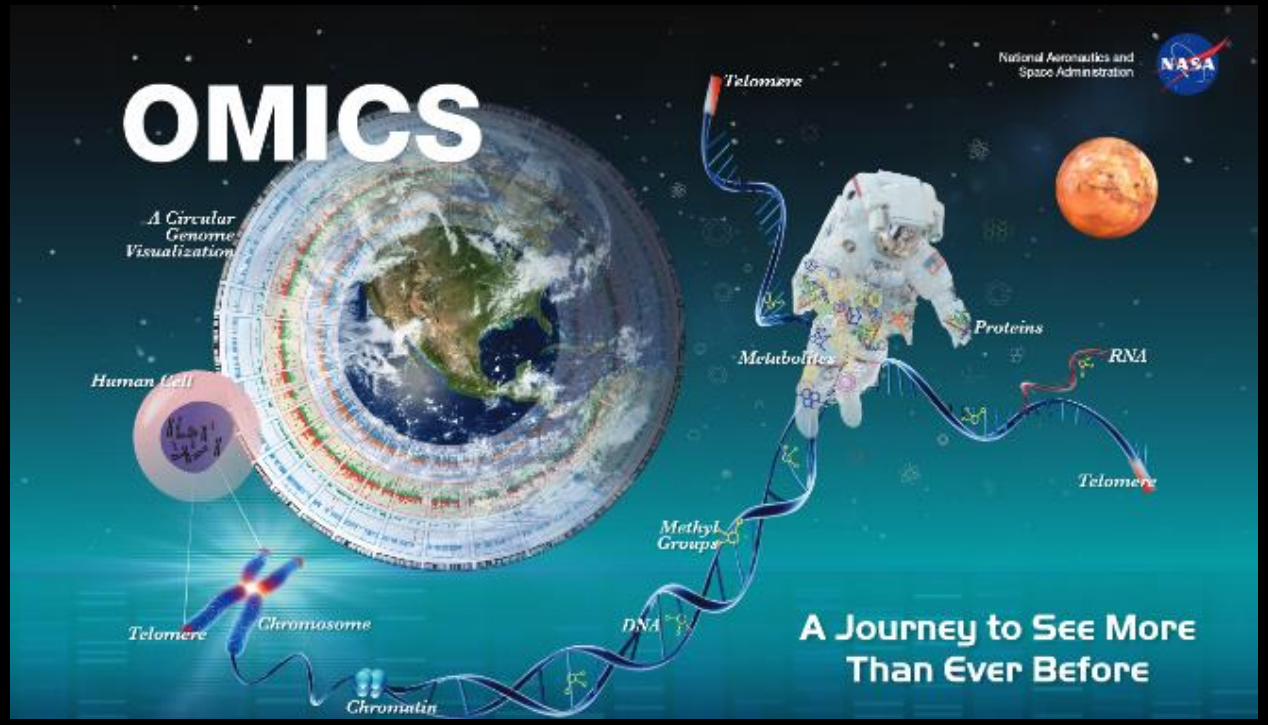
HRP Integrated Path to Risk Reduction



ISS: Space Platform for HRP Studies



ISS: Year in Space/Twins Study



Planning Exploration-Simulation Missions Aboard ISS

- **Extend Increments to 1 Year**
  - Validate effectiveness of microgravity countermeasures for longer missions
- **Enable More Crew Autonomy**
  - Limit interactions with ground control and family
  - Delay communications
  - Reduce the number of visiting vehicles and re-supply
  - Use hardware and procedures that do not rely on ground contro

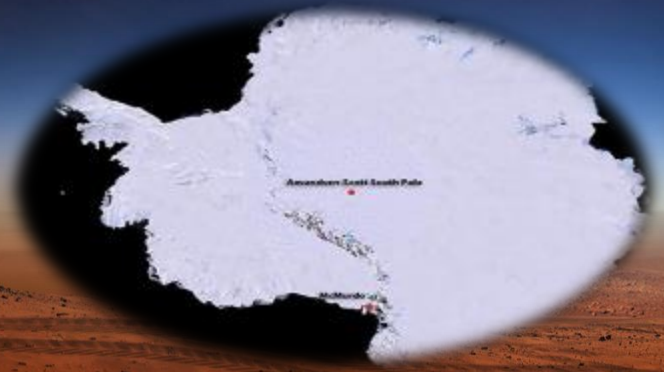
Simulating Exploration Stressors on Earth

Radiation

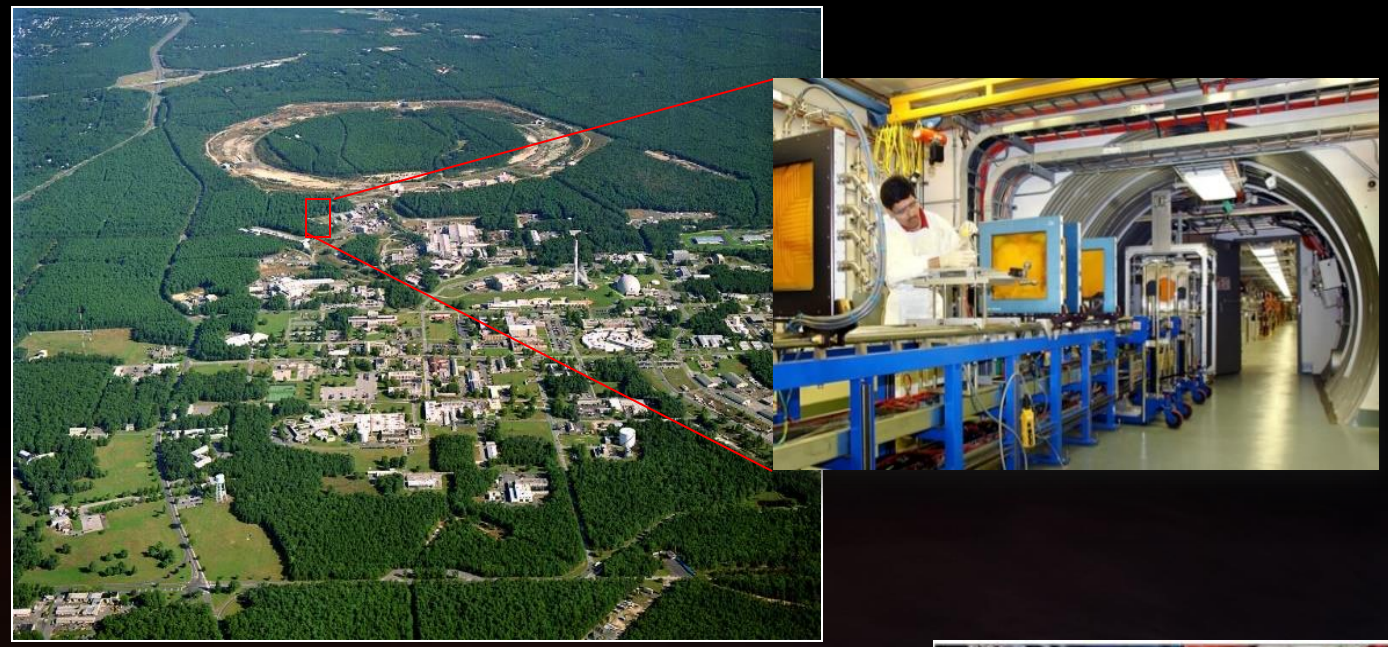
Isolation & Confinement

Altered Gravity

Hostile Environment

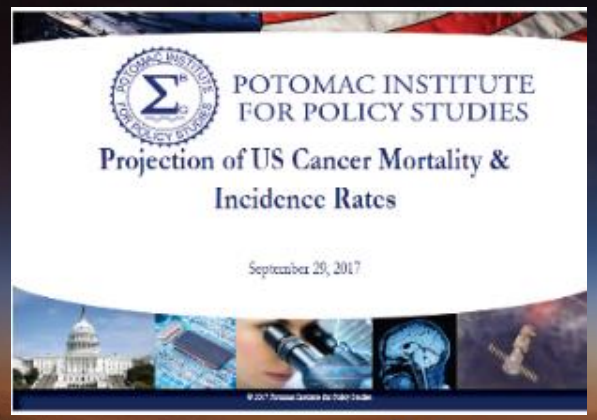


NASA Space Radiation Laboratory (NSRL)



NASA Space Radiation Lab (NSRL) DOE/BNL

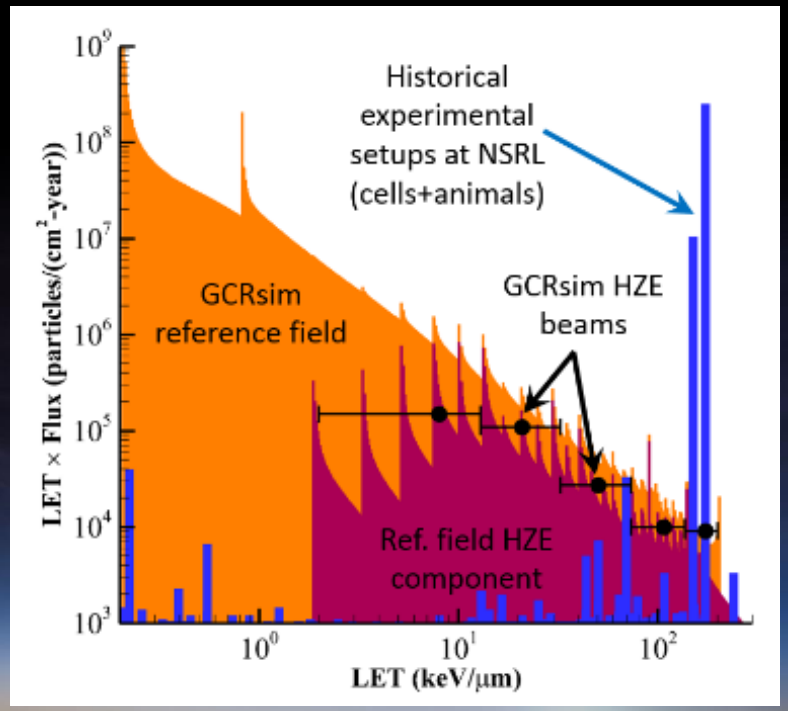
- Simulates the space radiation environment- high energy ion beams (H^+, Fe, Si, C, O, Cl, Ti, etc.)
- Beam line, target area, dosimetry, biology labs, animal care, scientific, logistic and administrative support



Standardized GCR Simulation at NSRL

GCR Simulation Beam consists of

- *5 proton energies plus degrader*
- *5 helium energies plus degrader*
- *5 Heavy ions: C, O, Si, Ti, Fe*



Chronic exposure over 2-6 weeks:

- Full GCRsim 15 ion beam delivered daily
- Beam delivered 6 days per week to allow for contingencies

Three multiweek research campaigns each calendar year

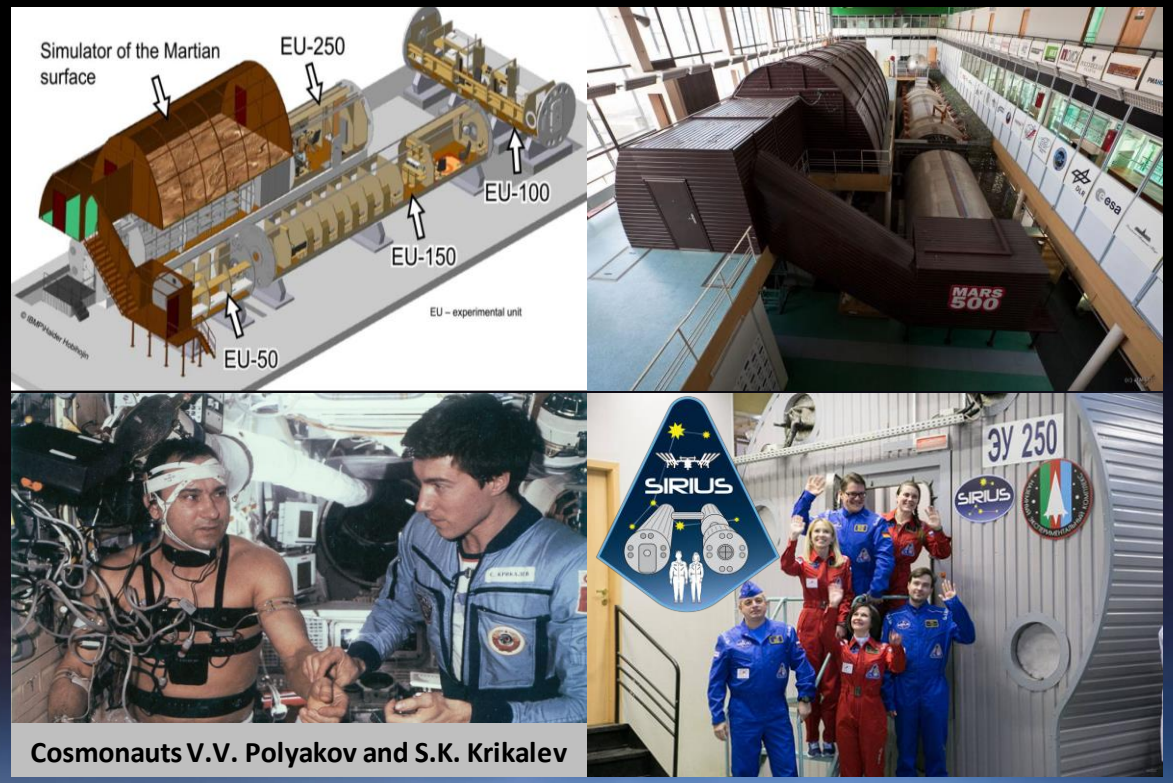
Isolated/Confined/Extreme (ICE) Environments

- **Partnership between NASA and the US National Science Foundation (NSF)**
  - Data collection at both McMurdo (88 subjects) & Admunsen-Scott South Pole (21 subjects) Stations complete. Analysis underway.
  - New Team study at McMurdo Station underway (April 2018)
  - More studies planned for future winter-overs
- **Partnership between NASA and ESA**
  - Immune study complete at Concordia
- **Partnership with DLR**
  - Cognitive function study at Neumayer Station

At least one study manifested each winter-over season.

Isolated/Confined/Controlled (ICC) Environments

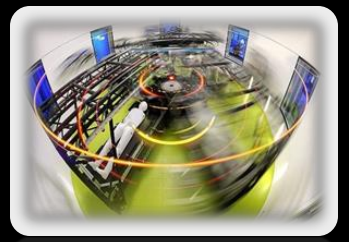
Human Exploration Research Analog (HERA)
(4 x 45 days missions per year)



Cosmonauts V.V. Polyakov and S.K. Krikalev

NEK Facility (RAS/IMBP, Moscow, Russia)
(SIRIUS: 4, 8, 12 month missions planned)

Altered Gravity Analogs



Parabolic Flight
(Fractional Gravity mission completed with DLR)

:enviHab Facility (DLR, Cologne, Germany)
(Artificial Gravity missions planned jointly with ESA)

:envihab (DLR) Altered Gravity Analog Status

VaPER (VIIP and Psychological :envihab Research) Study

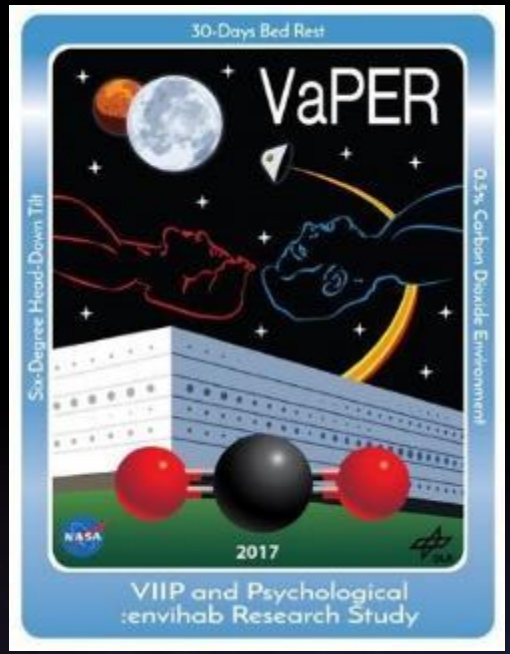
(5 HRP studies)

Study design:

- 11 astronaut-surrogate volunteers (both sexes)
- 30 days duration
  - simulated microgravity (6° head-down tilt bed rest)
  - hostile, closed environment (elevated CO_2)
- physiological and psychological outcome measures (pre/in/post)

Schedule:

- 2 October: Subjects began 2-week pre-bed rest BDC studies
- **17 October: Mission ingress began (staggered)**
- 4 December: Mission egress ends

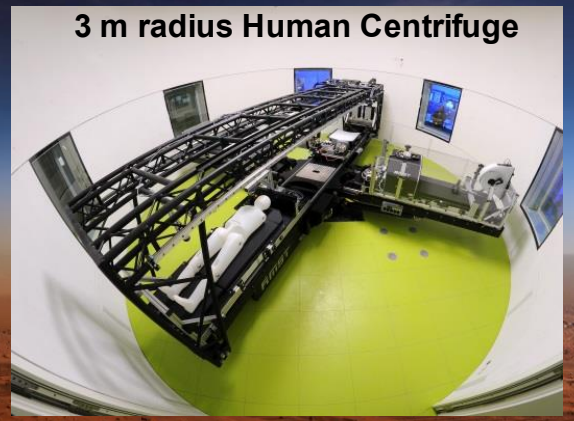


Artificial Gravity Bed-Rest study (2018-2019)

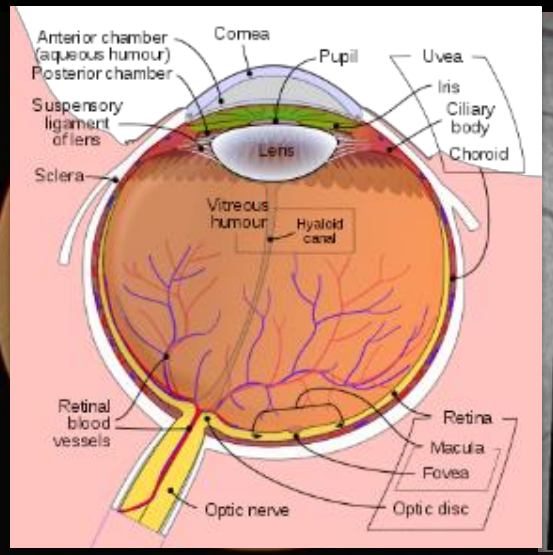
(4 HRP studies, 7 ESA studies + BR standard measures)

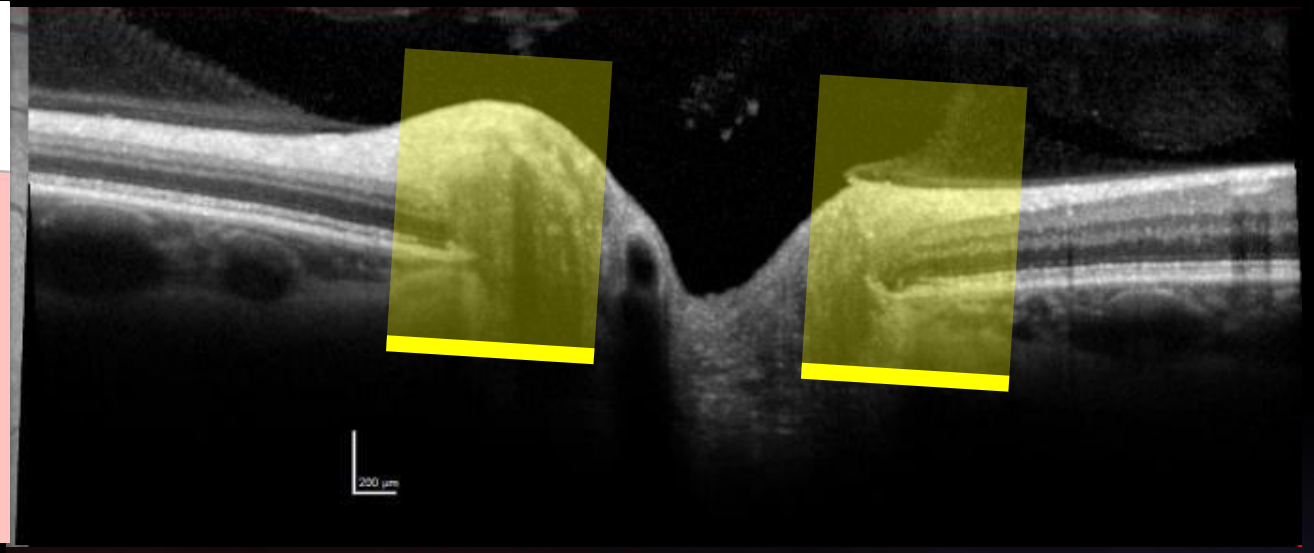
Study design:

- 2 x 12 astronaut-surrogate volunteers (both sexes)
- 2 x 60 days duration
  - simulated microgravity (6° head-down tilt bed rest)
  - short-duration continuous and intermittent centrifugation as a countermeasure
- physiological, neurological, and behavioral outcome measures (pre/in/post)



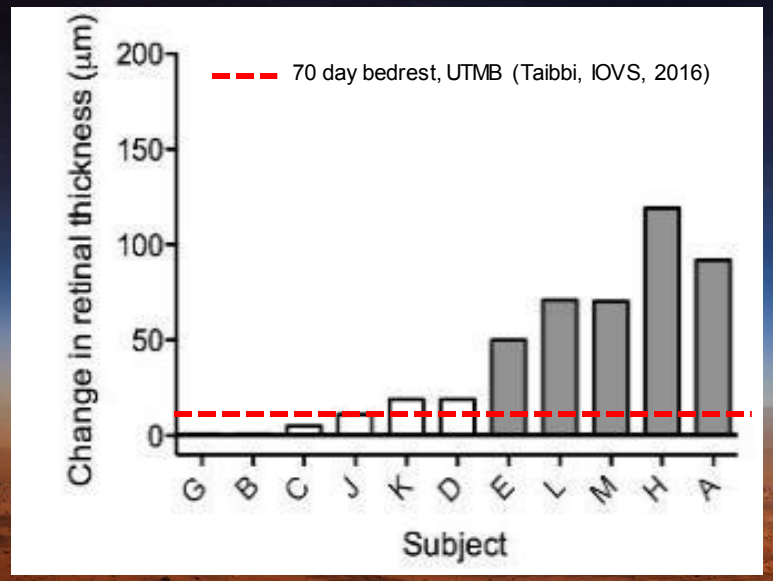
:enviHab VaPER Study: 1st Ground-based SANS Model





PI: S Laurie (NASA/JSC/KBRWyle)

- 11 volunteer test subjects (6 male, 5 female)
- 30-day strict HDT bed rest in 0.5% CO_2 (3.8 mmHg) environment
- Pre/post retinal thickness via Optical Coherence Tomography (OCT)



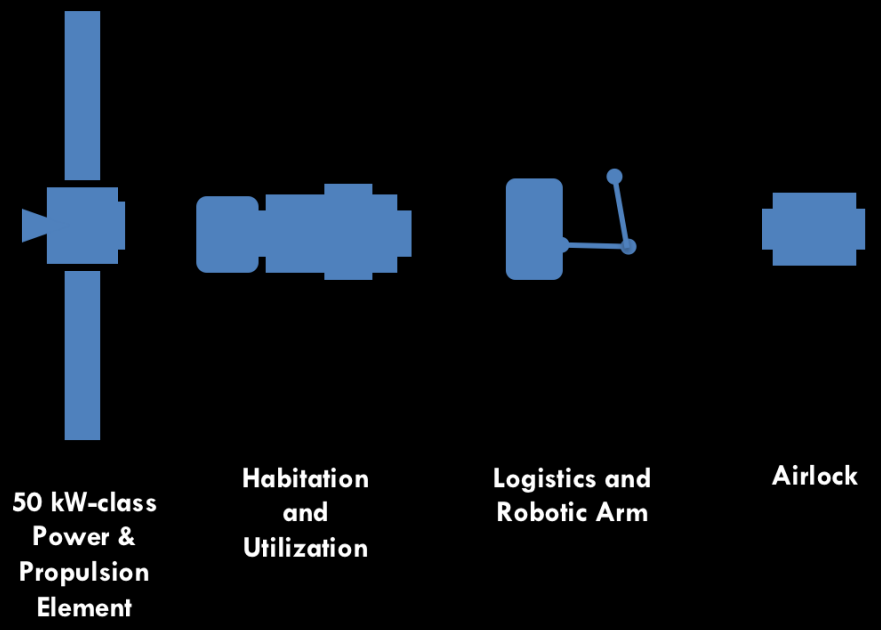
Next: cis-Lunar Space and Return to the Lunar Surface

GATEWAY DEVELOPMENT

Establishing leadership in deep space and preparing for exploration into the solar system

FOUNDATIONAL GATEWAY CAPABILITIES

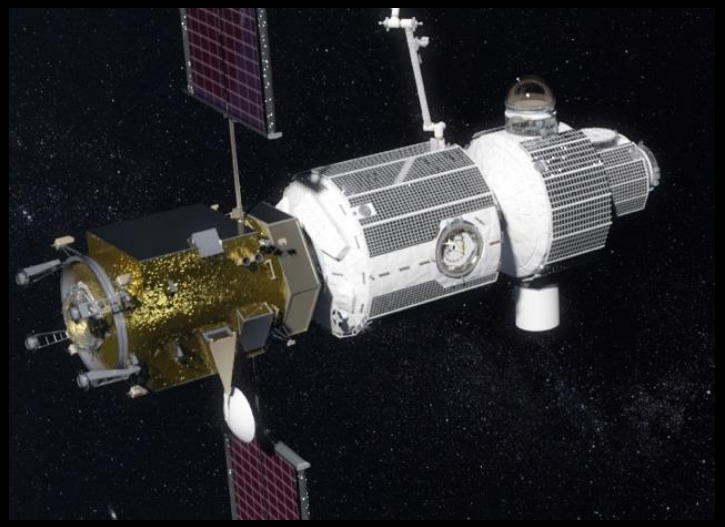
2022	2023	2024+



These foundational gateway capabilities can support multiple U.S. and international partner objectives in cislunar space and beyond.

CAPABILITIES

- Supports exploration, science, and commercial activities in cislunar space and beyond
- Includes international and U.S. commercial development of elements and systems
- Provides options to transfer between cislunar orbits when uncrewed
- External robotic arm for berthing, science, exterior payloads, and inspections

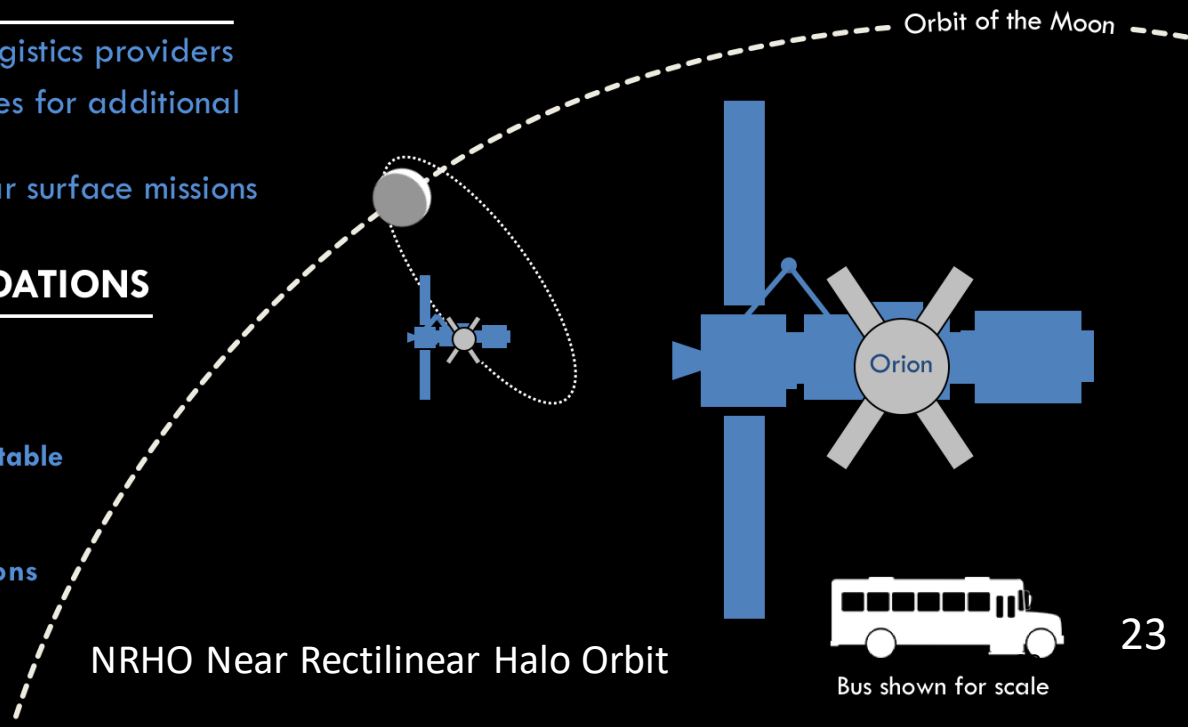


OPPORTUNITIES

- Logistics flights and logistics providers
- Use of logistics modules for additional available volume
- Ability to support lunar surface missions

INITIAL ACCOMMODATIONS

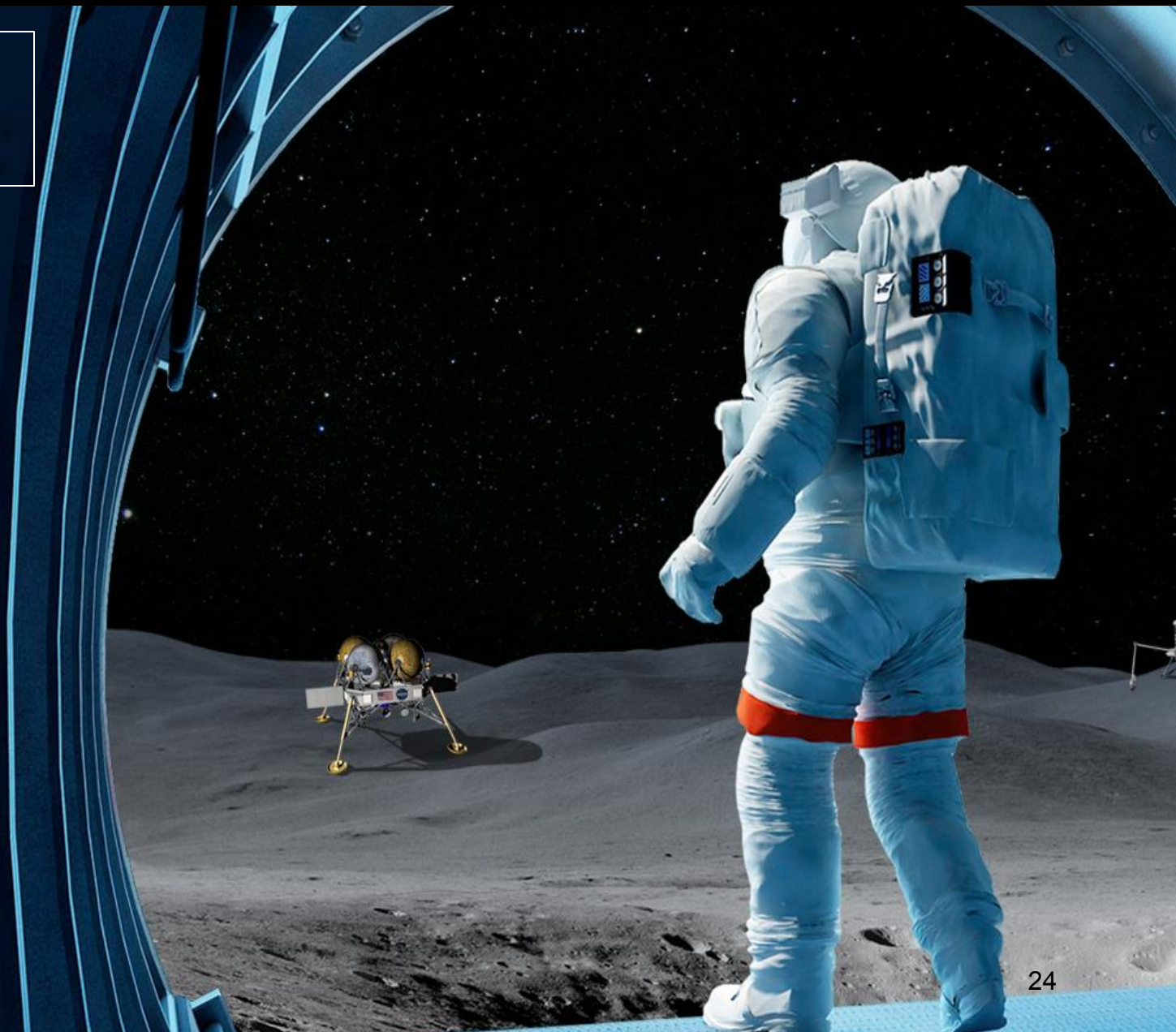
- 4 Crew Members
- At least 55 m³ Habitable Volume
- 30 Day Crew Missions



Lunar Surface Research Operations

Depending on mission design and duration, Lunar Surface Operations Missions could add significantly to our understanding/mitigation/validation of human health and performance risks during future Mars surface missions.

- **Autonomous egress/ post-landing operations:**
  - sensorimotor, orthostatic intolerance
  - occupant protection
  - team performance
  - human-systems interaction design
  - EVA, DCS, exploration atmospheres
- **Long-term habitation/exploration:**
  - bone, muscle, aerobic, sensorimotor, orthostatic intolerance
  - medical system
  - team performance, bmed
  - human-systems interaction design
  - EVA, DCS, exploration atmospheres
  - radiation: acute, degen, CNS
  - dust, immune, microhost



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