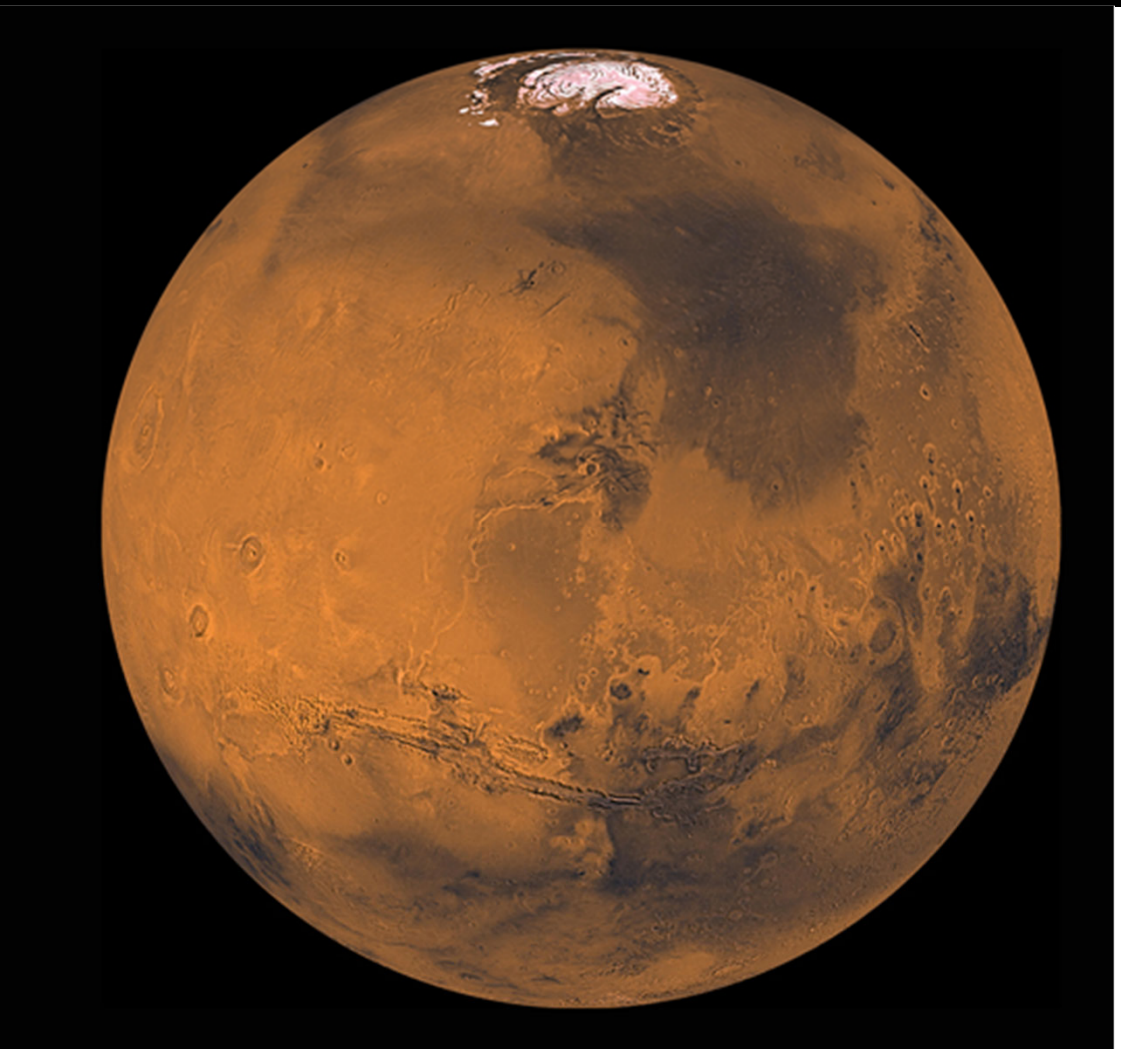
Human Research Program (HRP)
Presentation to NASA Advisory Council



David Baumann
Director, Human Research Program

May 16, 2023

HRP Presentation to the NAC – May 16, 2023

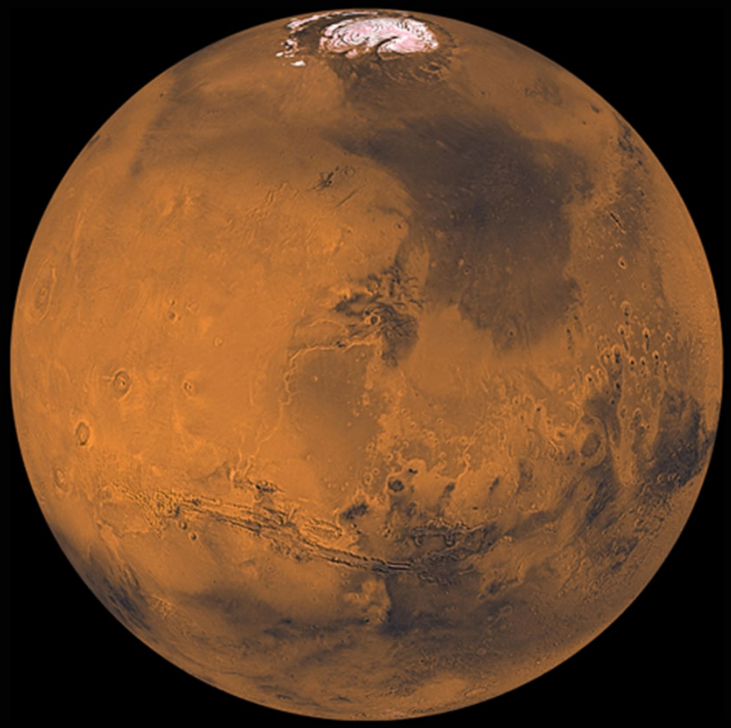


Topics

- HRP's Risk-Reduction Mission
- HRP Organization and Overview
- Risk-Reduction Progress and Research Highlights
- Support for Moon-to-Mars Objectives
- Collaborations and Commercial Spaceflight

Human Research Program Mission Statement

To enable space exploration beyond Low Earth Orbit by reducing the risks to human health & performance



THE HUMAN SYSTEM RISKS

Behavioral Conditions

Inflight Medical

Toxic Medications

Carcinogenesis

Bone Fracture

Reduced Muscle Size

Cardiac Rhythm Problems

Renal Stone Formation

Alterations

Orthostatic Intolerance

Spaceflight-Associated Neuro-ocular Syndrome (SANS)

Cardiovascular Adaptations

Reduced Aerobic Capacity

Urinary Retention

Crew Egress

Toxic Exposure

Celestial Dust Exposure

Hypoxia

Carbon Dioxide Exposure

Altered Immune Response

Performance

Electrical Shock

Sleep Loss

Hearing Loss

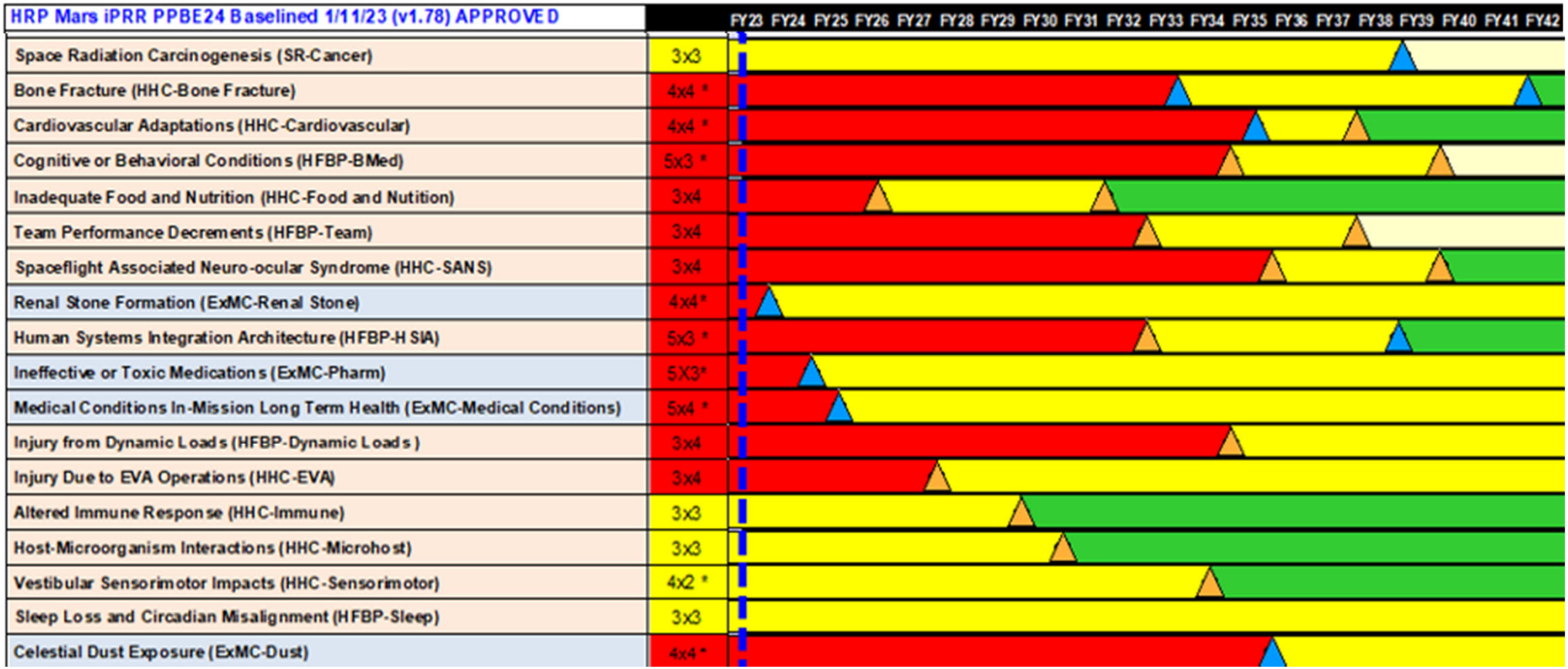
Injury from Dynamic Loads

Inadequate Human Systems Integration Architecture
Injury from Dynamic Loads
Carbon Dioxide Exposure
Reduced Muscle Size
Toxic Exposure
Celestial Dust Exposure
Hypoxia
Reduced EVA Performance
Sensorimotor Alterations
Decompression Sickness
P.S.I.
Renal Stone Formation
Cardiovascular Adaptations
Inadequate Food and Nutrition
Cardiac Rhythm Problems
Host-Microorganism Interactions
Sleep Loss
Altered Immune Response
Spaceflight-Associated Neuro-ocular Syndrome (SANS)
Ineffective or Toxic Medications
Reduced Aerobic Capacity
Electrical Shock
Adverse Cognitive or Behavioral Conditions
Orthostatic Intolerance
Bone Fracture
Inflight Medial Conditions
Crew Egress
Non-Ionizing Radiation
Urinary Retention
Inadequate psychosocial Adaptation within a Team
Hearing Loss
Radiation Carcinogenesis

Inadequate Human Systems Integration Architecture
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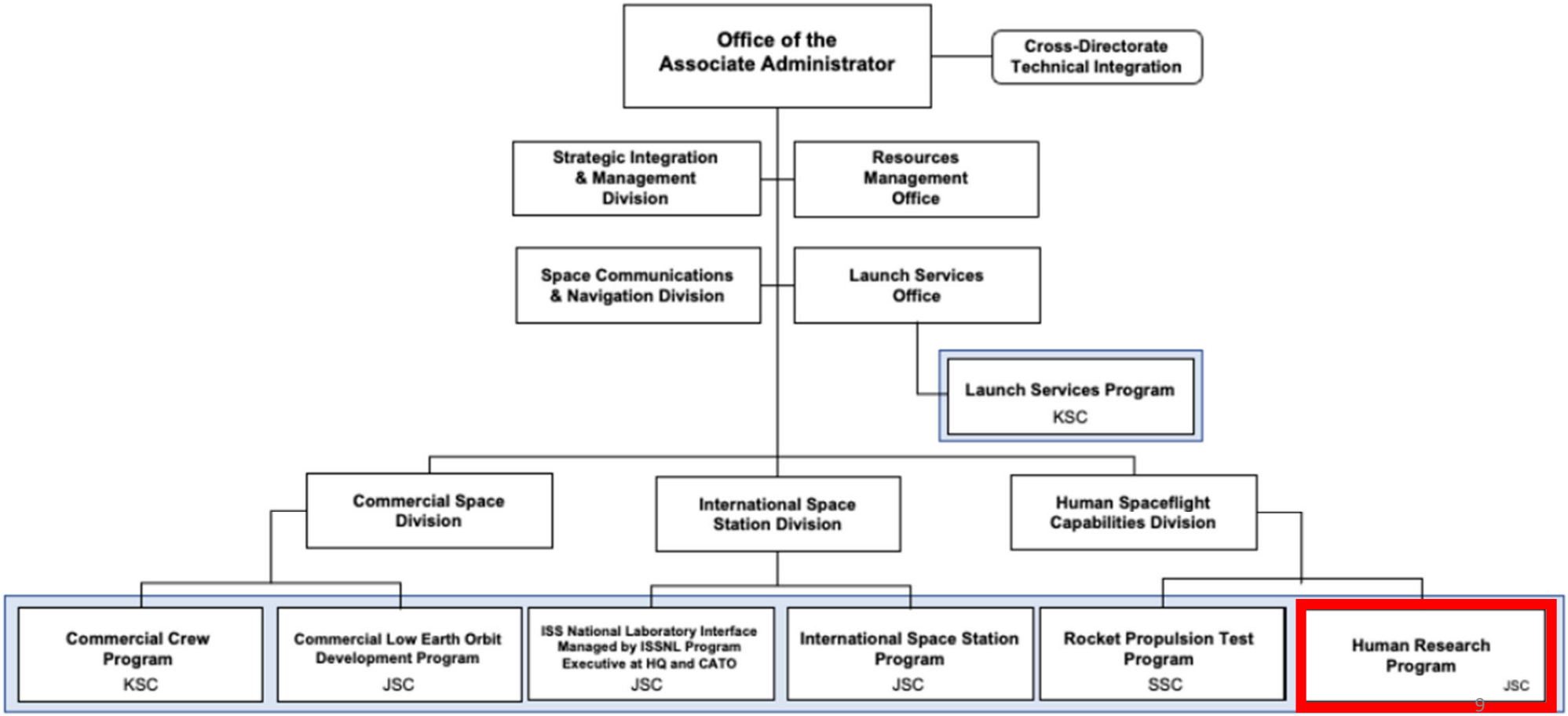
Path to Risk Reduction – Mars DRM

Human System Risks Requiring Research



HRP Organization and Overview

Space Operations Mission Directorate

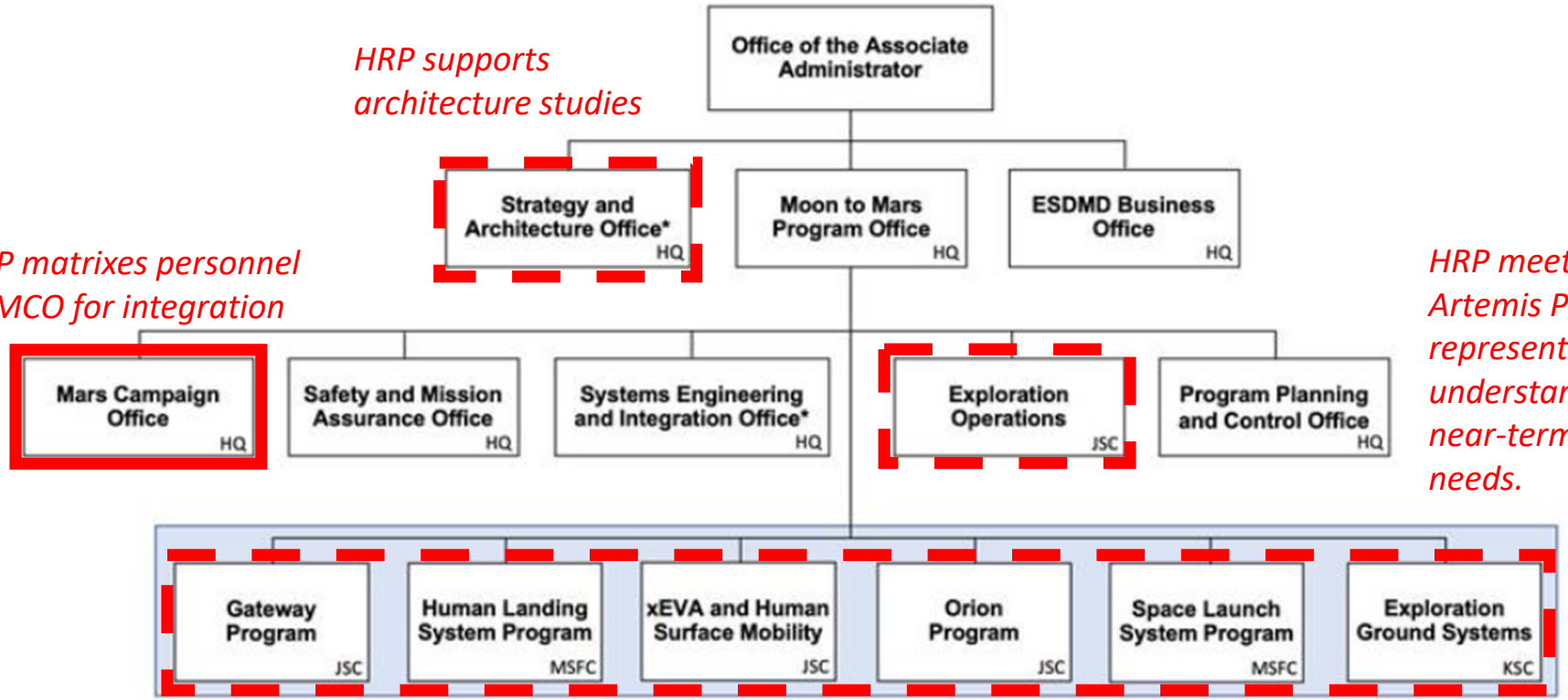


Exploration Systems Development Mission Directorate

HRP supports architecture studies

HRP matrixes personnel to MCO for integration

HRP meets regularly with Artemis Programs' representatives to understand areas of near-term risk reduction needs.



*Strategy and Architecture and SE&I have direct integration with SMD and STMD

National Aeronautics and Space Administration

NASA

Human Research Program

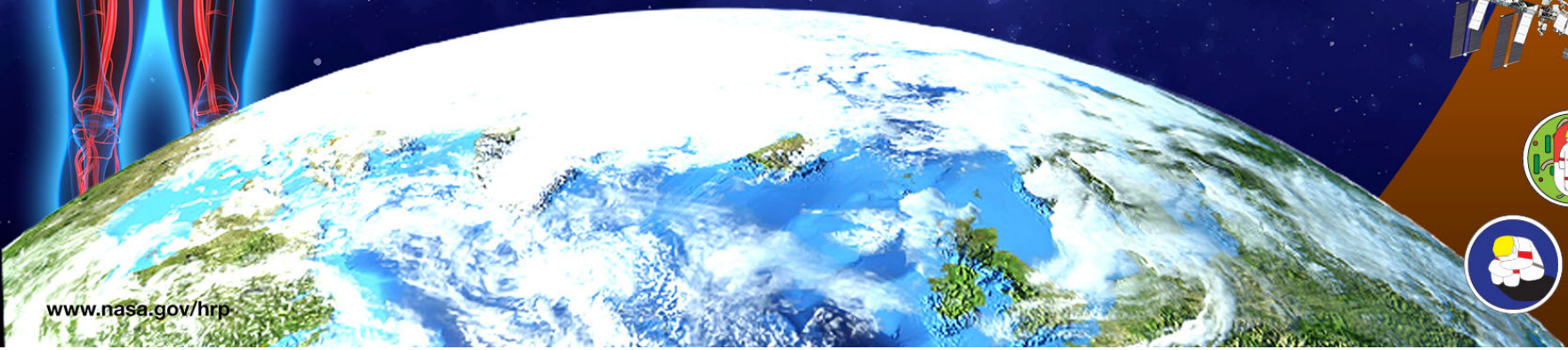
STEPS TO MARS



EARTH:
Simulated spaceflight hazards in Ground Analogs | :envihab | Antarctic Stations | NEK | HERA | Space Radiation Lab

LOW EARTH ORBIT:
International Space Station – A unique testbed to study micro-gravity and environment hazards, with varying mission durations

LUNAR MISSIONS:
Decreasing Earth-dependence around and on the lunar surface. Provides insight into deep space radiation, behavioral health, and gravity transitions

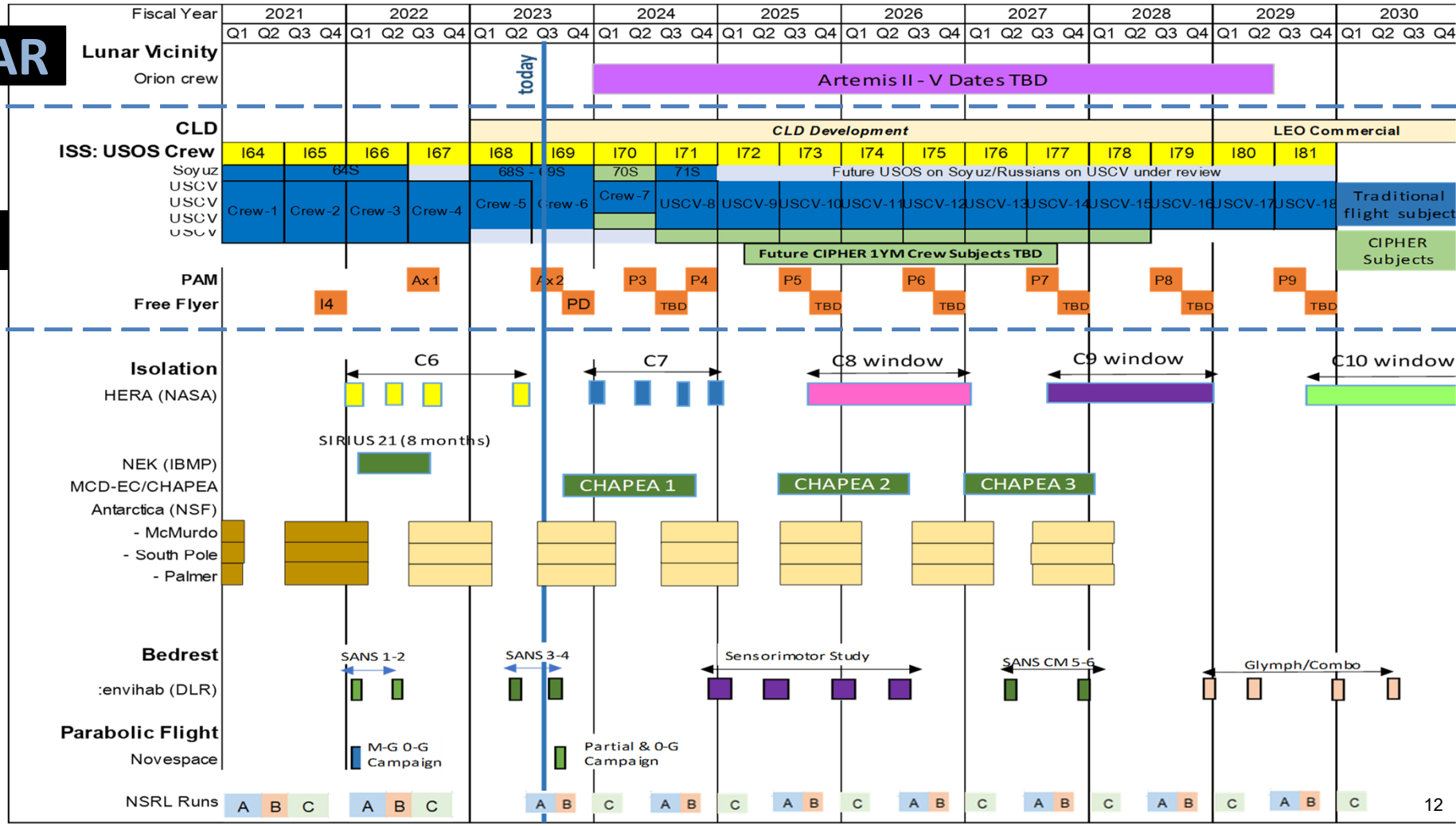




www.nasa.gov/hrp

NP-2020-11-020-JSC

HRP Research Platforms and Operations
Steps to Mars

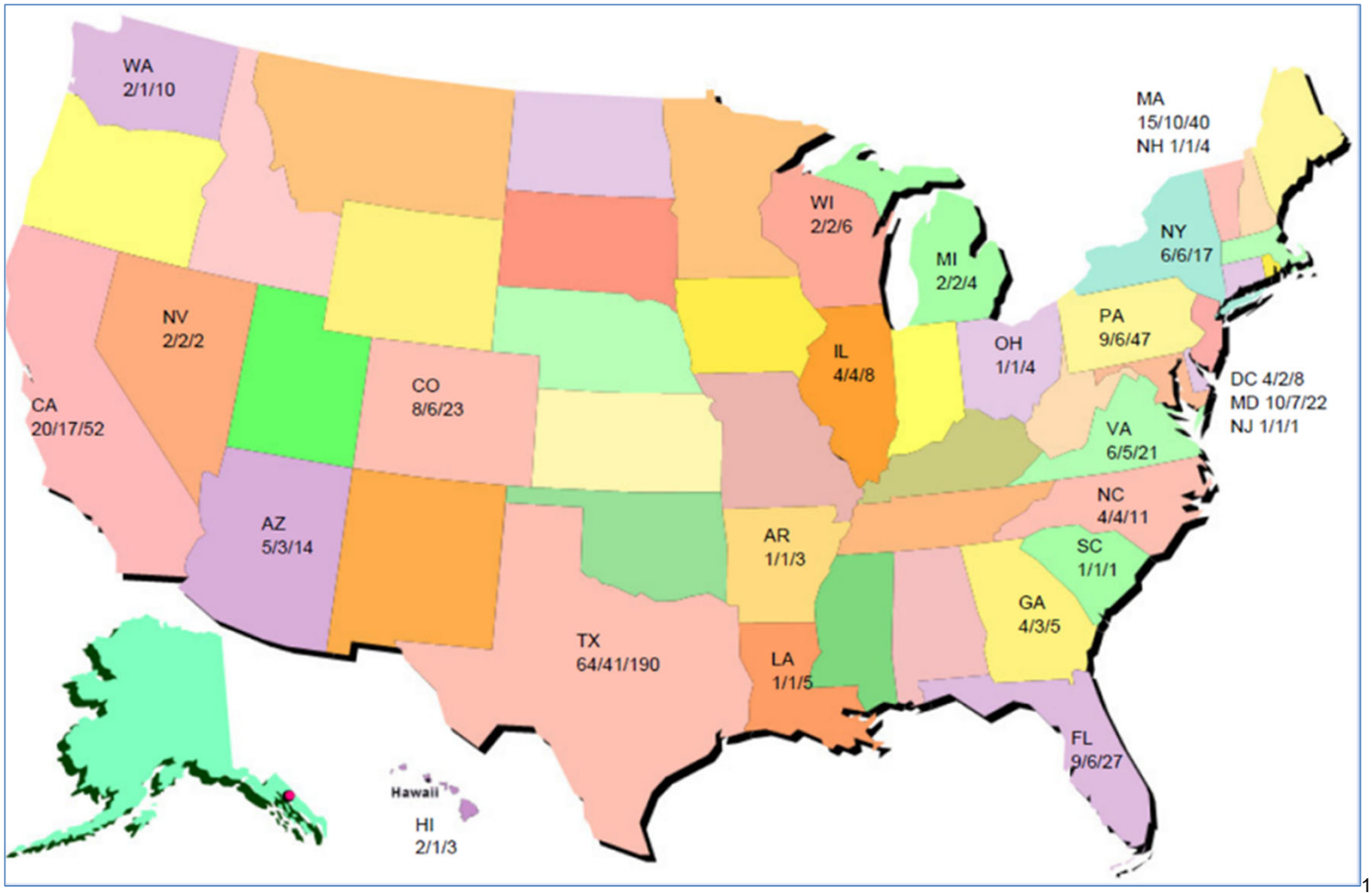


Nationwide Research Program

Projects/Principal Investigators/Co-Investigators by State

185 Research Projects
135 Principal Investigators
529 Co-Investigators

26 States



Translational Research Institute for Space Health (TRISH) Select Metrics FY17 - FY23



- Cooperative Agreement with HRP
- Consortium led by Baylor College of Medicine
  - California Institute of Technology in Pasadena
  - Massachusetts Institute of Technology in Cambridge.
- The mission of the TRISH is to lead a national effort in translating cutting edge emerging terrestrial biomedical research and technology development into applied space flight human risk mitigation strategies for human exploration missions.

125
Innovative science projects funded in 94 organizations in 28 states

27
Trainee awards were made at 20 organizations in 13 states

210
Scientific publications including in Nature Medicine (impact factor: 53.44)

62
Science deliverables were formally presented to HRP with an estimated additional 5 to be presented by end of FY23

$17.1M
Institute Cost Sharing

Examples of HRP's Diversity, Equity, Inclusion and Accessibility Efforts

HRP's first Dual-Anonymous Peer Review Solicitation in progress

- Proposers unaware of the identity of the members on the review panel
- Reviewers are not told the identities of the proposers
- Objective is to minimize the impact of implicit or unconscious bias in the evaluation of the merit of a proposal

TRISH funding two diversity programs

- LBJ Space Health Inclusion Partnership (SHIP), PI: Dr. Kristina Collins
- Boosting Spaceflight Underrepresented Researcher Equity (B-SURE), PI: Dr. Rachael Seidler

HRP partnership with NASA's Minority University Research and Education Program (MUREP) to include HRP topics in its yearly solicitation

- Radiation and TRISH Topics
- https://www.herox.com/NASAMPLAN/faq



*Held "Foundations of Funding" workshop in October 2022 with **24 mentees and 11 mentors***



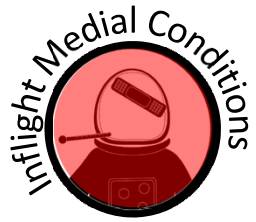
MUREP Partnership Learning Annual Notification (MPLAN)

Awards of up to $50,000 for Minority Serving Institutions (MSIs) to contribute to NASA Mission Directorate priorities.

Space

Risk Reduction Progress and Research Highlights

Agency Progress on Selected Risks



- 50+ years of spaceflight medical evidence integrated with resource requirements in a probable risk assessment decision support tool.
- HRP completing risk work in next 2 years





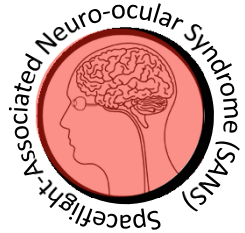
- Exercise standards validated for maintaining muscle and aerobic capacity
- HRP now focusing on exercise hardware



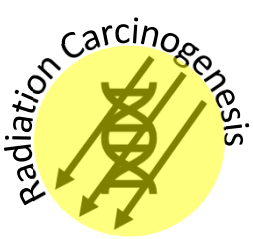
- Renal Stone mitigations (hydration, exercise, etc.) in place
- New detection/treatment technologies being demonstrated
- HRP completing risk work in next year



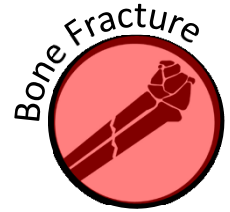
- Antarctica validated as a spaceflight analog.
- Ground countermeasure validation concluding soon.



- Strict head-down-tilt bedrest validated as a spaceflight analog
- Countermeasure concepts being tested now in analogs and in spaceflight



- New dose-based standard in place. Mitigations largely dependent on advances in terrestrial detection and treatment capabilities
- HRP working on characterizing unique GCR effects and individual susceptibility to provide informed consent and decision making



- New evidence indicates that Bone Density measurement not adequate to characterize fracture risk
- HRP working to develop bone microarchitecture scans as more predictive tool



- Compression suit and fluid loading countermeasures validated
- HRP risk work completed

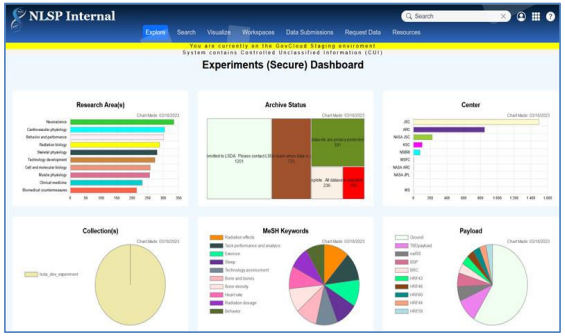
Research Highlights

Making Research Data More Accessible

Next Generation Life Science Data Archive
https://nlsp.nasa.gov/

Improved:

- Automations
- Visualizations
- Tools & Workspace

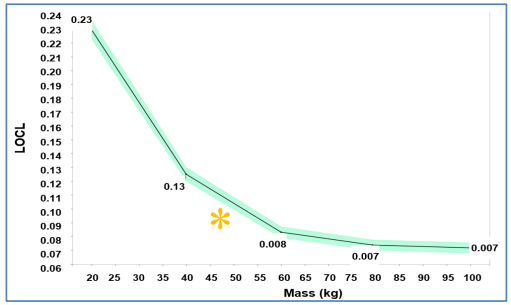


Making Research Data More Actionable

IMPACT Medical PRA and Resource Planning Tool
https://www.nasa.gov/hrp/elements/exmc

Integrates Data from Spaceflight and analog medical events with medical kit resources.

Informs medical system design



Using Data to Make Operational Decisions

Human – Suit – Seat – Vehicle Dynamic Load Models

HRP-funded model used to assess risk in re-locating ISS crewmember's Soyuz seat into a Dragon vehicle for a possible contingency scenario



Partnering with our Operational Stakeholders

Navy KRAKEN Collaboration

- HRP is investing in Sensorimotor Countermeasures for Manual Control of vehicles landing on the moon
- Experiment design and implementation has been closely coordinated with JSC's Flight Operations Directorate (FOD) and the Human Landing System (HLS) Program



KRAKEN facility at Wright-Patterson

Research Highlights: FY22 to FY23 Analog Missions

HERA Campaign 6 (Isolation & Confinement):
- Four 45-day missions: 15 HRP Studies
- **Primary research themes - Human Systems Integration Architecture (HSIA) & autonomy.**



HERA C6M4 Crew

:envihab (Bedrest) SANS Countermeasures:
- **6 HRP** and 6 DLR investigations
- **Campaigns 1-2 focus on Lower Body Negative Pressure**
- **Campaigns 3-4 focus on thigh cuff + exercise countermeasure**



DLR's :envihab Facility

Novespace Parabolic Flights:
- 0g **cardiovascular study** completed
- Upcoming **cardiovascular, sensorimotor and neurophysiological responses to 0-g & partial-g** in June



SIRIUS 21 (Isolation & Confinement):
- 8 month mission with 6 crew residing in the **NEK habitat in Moscow, Russia** completed July 2022
- Multinational crew – 3 Russian, 2 US, and 1 UAE
- HRP research themes – **Team functioning, stress and resilience, autonomy, food acceptability**
- 70 total studies participated, **8 HRP studies**
- **Numerous real-life challenges in mission**
  - Removal of Russian crewmember from mission due to exercise injury
  - Loss of key exercise devices for use, US ATLAS device used as alternative for remainder of mission
  - Numerous challenges caused by beginning of and ongoing Russia/Ukraine conflict



US SIRIUS 21 Crewmembers

Antarctic Stations (Isolation & Confinement):
- Palmer Station: **Immune Countermeasure study**
  - Data collection completed in 2022 winter-over and ongoing in 2023
- South Pole Stations: **VR Sensory Stimulation study**
  - Data collection began Aug. 2022 and continuing in 2023 winter-over.



Research Highlights: Upgraded Radiation Analog Capability
Electron Beam Ion Source (EBIS)





EBIS Containment vessels installed in their final location at Brookhaven National Laboratory.

EBIS provides capability of creating different ions – the highest fidelity simulation of Galactic Cosmic Radiation on Earth.

Research Highlights: FY22 to FY23 ISS Missions

ISS Crew Increment Support:

- **Increment 67: 194.67 hours crew time accomplished**
- **Increment 68: 309.43 hours crew time accomplished**
- **Increment 69: Ongoing, supporting 12 HRP studies**
- **68S anomaly resulted in significant re-planning of ops and manifests.**





HRP team on Crew-4 Landing Day

ISS Crew Post-flight Landing Science Support:

- **Crew-4 (Lindgren, Hines, Watkins, Cristoforetti) 10/14/22 landing**
- **Crew-5 (Mann, Cassada, Wakata, Kikina) 3/12/23 landing**

Total Samples Returned (SpaceX- 25, 26, 27, Crew-4, 5)

- 603 frozen samples (blood, urine, saliva, fecal, body)
- 22 ambient blood samples



Studies/operations completed:

- **rHealth One Technology Demonstration:**
  - Successful test of **Point-of-Care Laboratory Analysis** Capability



rHealth Tech Demo

- **Veggie Monitoring: Final samples returned on SpaceX-26.**
  - **Microbiology characterization** of ISS Veggie System to inform future plant system design.
- **Behavioral Core Measures: Final subject landed on Crew-5**
  - Tested **performance capabilities of deconditioned crew** which will inform performance requirements for exploration missions.
- **Rodent research investigation on SpX-27, joint with JAXA and Space Biology**
  - Data to develop dose response curves of **physiological responses to various G-levels**

New Studies:

- **Zero Treadmill Study**
  - Investigating effects of **not using Treadmill** on extended-duration spaceflight
- **ISAFE (Crew-6):**
  - Novel Hardware studying **ocular structure** and function alterations to inform the SANS risk.
- **Falcon Goggles:**
  - Tool for examining how an **astronaut's balance** adapts in space



ERG electrode placement for eye electrode



Falcon Goggles

Axiom-2 Mission:

- Negotiated **barter agreement** with Axiom to allow HRP access to pitch research to the Axiom-2 crew while providing access to HRP flight hardware and some consumables in return.
- HRP supported **Ax-2 mission experience in the HERA facility**



Examples of Artemis/Mars enabling work yet to be done on ISS





Sensorimotor/manual control countermeasures

Medical autonomy and technology demonstrations

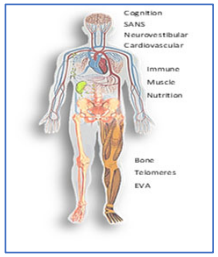




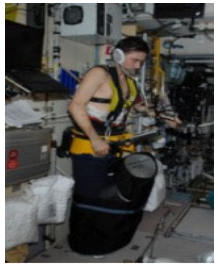


Landing egress and EVA functional testing

CIPHER – The most complex, integrated study ever of human physiology and psychology in space



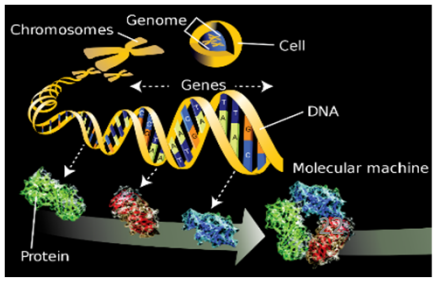






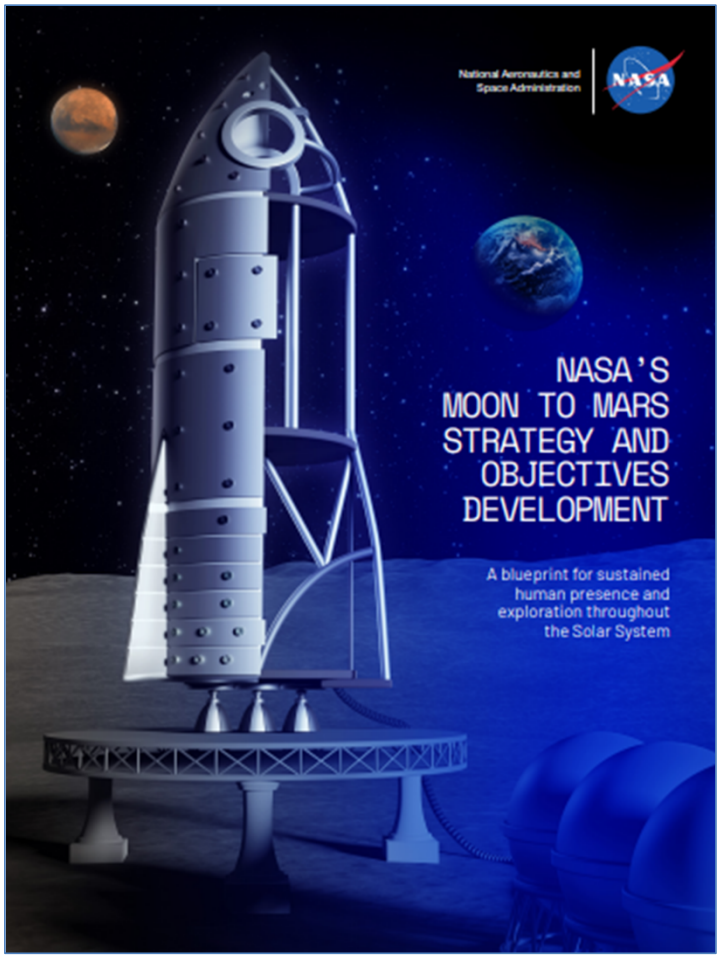
SANS Countermeasure Testing

-omics Data Archive For risk assessment and personalized countermeasures development



HRP Support for Moon-to-Mars Objectives

M2M strategy: HRP-Specific Objectives





Human and Biological Science (HBS)

Goal: Advance understanding of how biology responds to the environments of the Moon, Mars, and deep space to advance fundamental knowledge, to support safe, productive human space missions, and to reduce risks for future exploration.

HBS-1^{LM}:	Understand the effects of short- and long-duration exposure to the environments of the Moon, Mars, and deep space on biological systems and health, using humans, model organisms, systems of human physiology, and plants.
HBS-2^{LM}:	Evaluate and validate progressively Earth-independent crew health and performance systems and operations with mission durations representative of Mars-class missions.
HBS-3^{LM}:	Characterize and evaluate how the interaction of exploration systems and the deep space environment affect human health, performance, and space human factors to inform future exploration-class missions.

https://www.nasa.gov/sites/default/files/atoms/files/m2m_strategy_and_objectives_development.pdf

HRP working to enable near-term Artemis Missions



- Cabin imagery system
- Flywheel exercise device collaborations



- Integrated Medical Data Architecture Demonstration
- Exercise Time Efficiencies



- Autonomy Standards
- Acceleration requirements
- Motion Sickness Countermeasures
- Manual Control Countermeasure



- Emergency CO_2 limits
- In-suit Nutrition Requirements
- Acceleration/Vibration/Autonomy Requirements

Top Crew Health and Performance System Capability Challenges for Mars v1.0



Earth-Independent Human Operations



Mars Duration Food System



Mars Duration Effects on Human Physiology



Risk Mitigations for Vehicle Atmospheres



Computational Injury & Anthropometric Models



Exploration Exercise Countermeasures



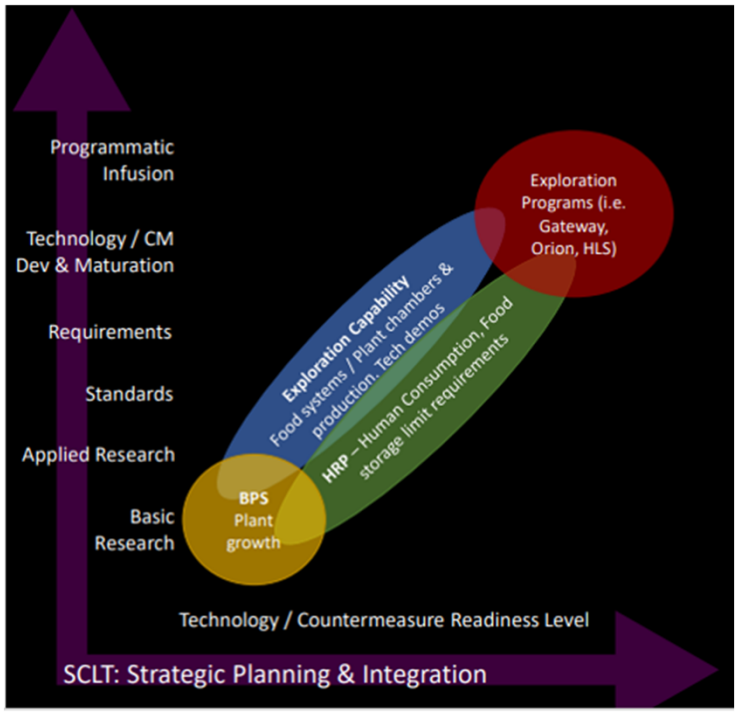
Understanding Individual Variability in Spaceflight

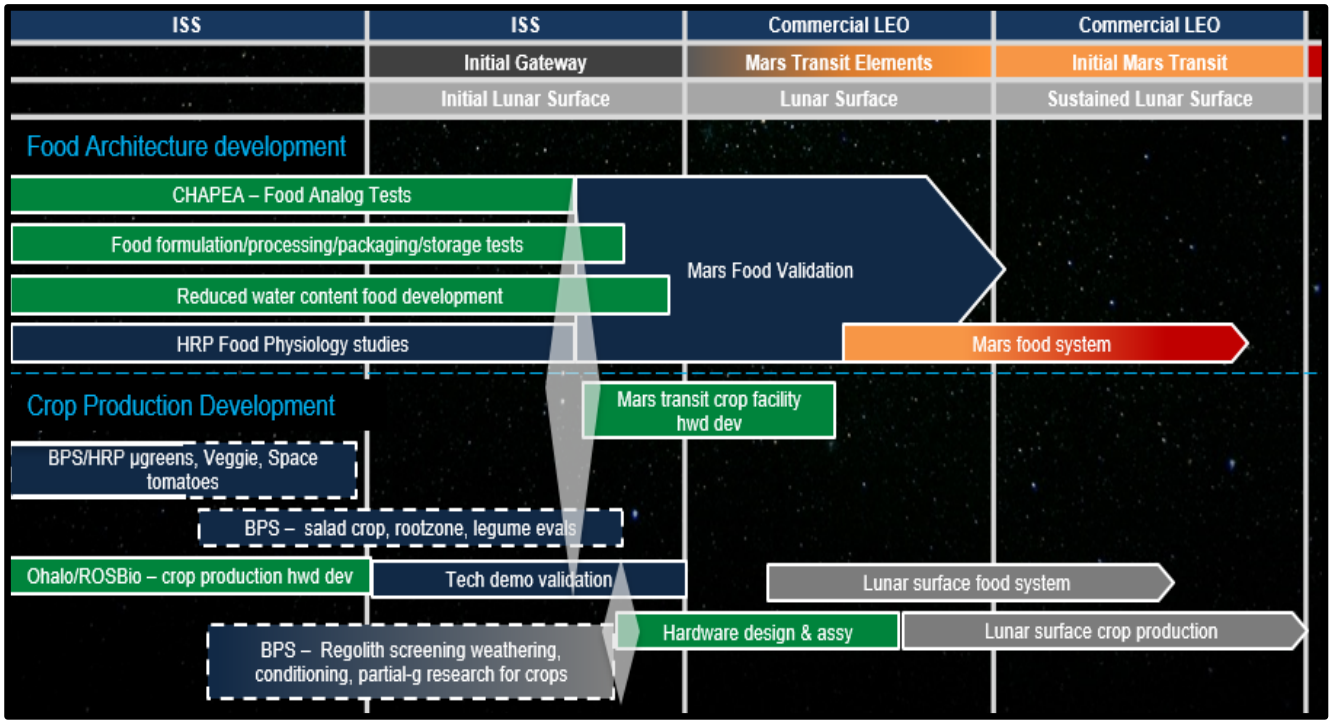


Sensorimotor Countermeasures

HRP Integration Across NASA Mission Directorates for Capability Gap Closure

Food System Coordination Example





Agreement on Responsibilities across NASA Mission Directorates and Programs

Detailed Capability Roadmaps that Integrate investments and highlight funding gaps

Collaborations and Commercial Spaceflight

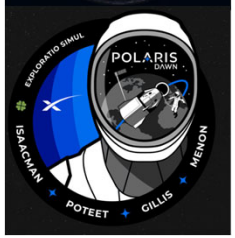
Use of Collaborations and Partnerships to Multiply Resources



Commercial Space Human Research

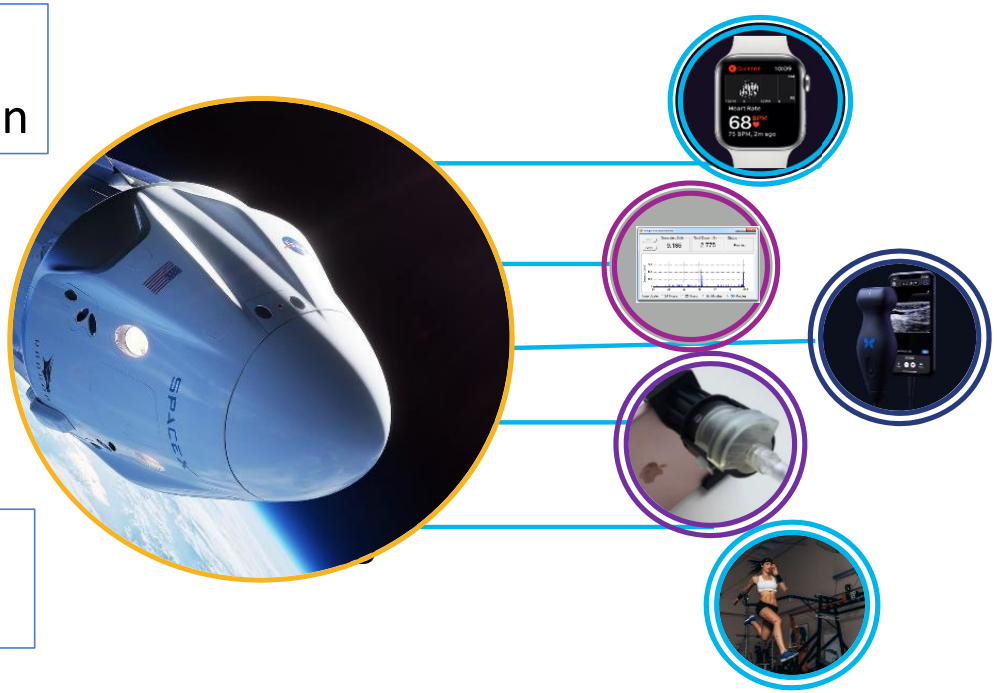
Establishing relationships to accelerate HRP's risk reduction mission.





SpaceX

Inspiration4, Polaris Dawn





Axiom

Ax-1, Ax-2



HRP and TRISH are partnering with commercial space companies to set the precedent that human research will be offered to all LEO commercial spaceflight participants

Commercial LEO Destinations (CLD)

Ensuring requirements meet future HRP and Agency needs.



Blue Origin | Northrop Grumman | Nanoracks | Axiom

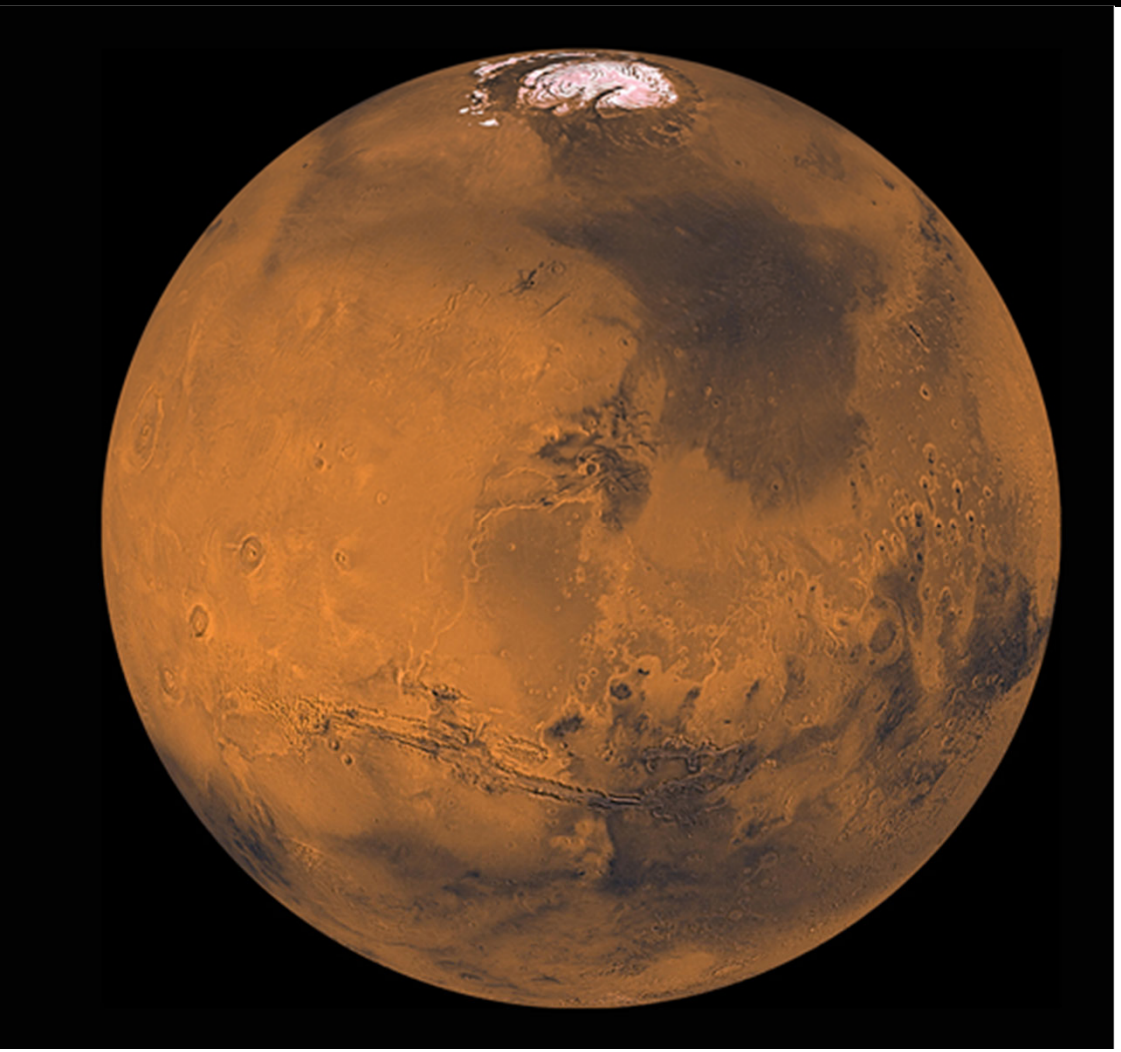
Commercial LEO Platforms in Development



HRP developing requirements for research on CLDs

HRP capabilities included in recent CLDP Request for Information that went out to Industry
https://sam.gov/opp/cc3aaa40bd0a46d68c3c4f4245493684/view

Summary



HRP remains a key component of the Agency's Moon-to-Mars Strategy

HRP has plans in place to help enable and utilize Artemis Missions

Progress is being made on reducing human health and performance risks for the Moon and Mars.

HRP is exploring ways to utilize Commercial Space opportunities for its risk-reduction Mission

