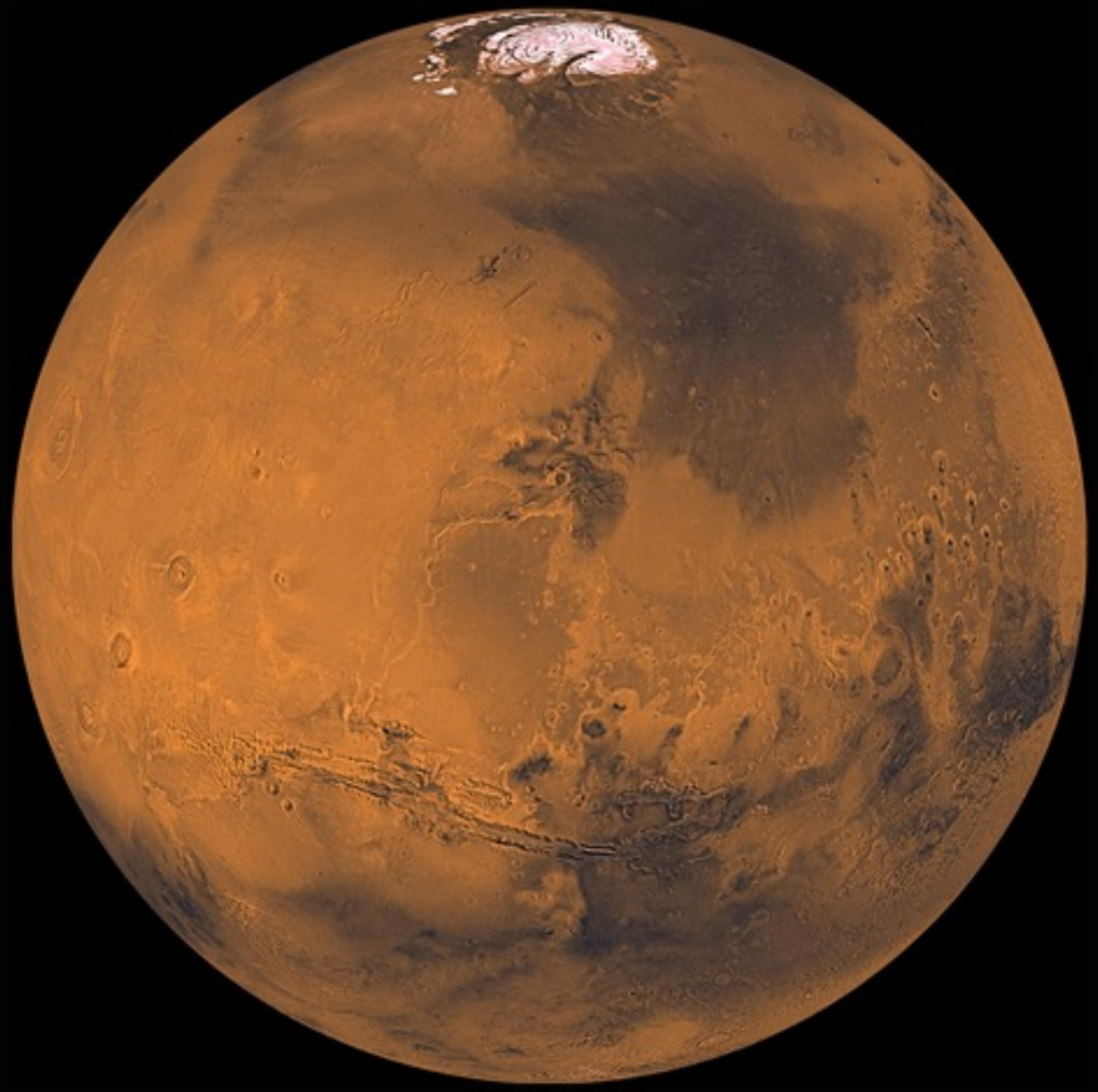
Human Research Program (HRP)
Presentation to NASA Advisory Council

David Baumann
Director, Human Research Program

May 16, 2023

HRP Presentation to the NAC – May 16, 2023

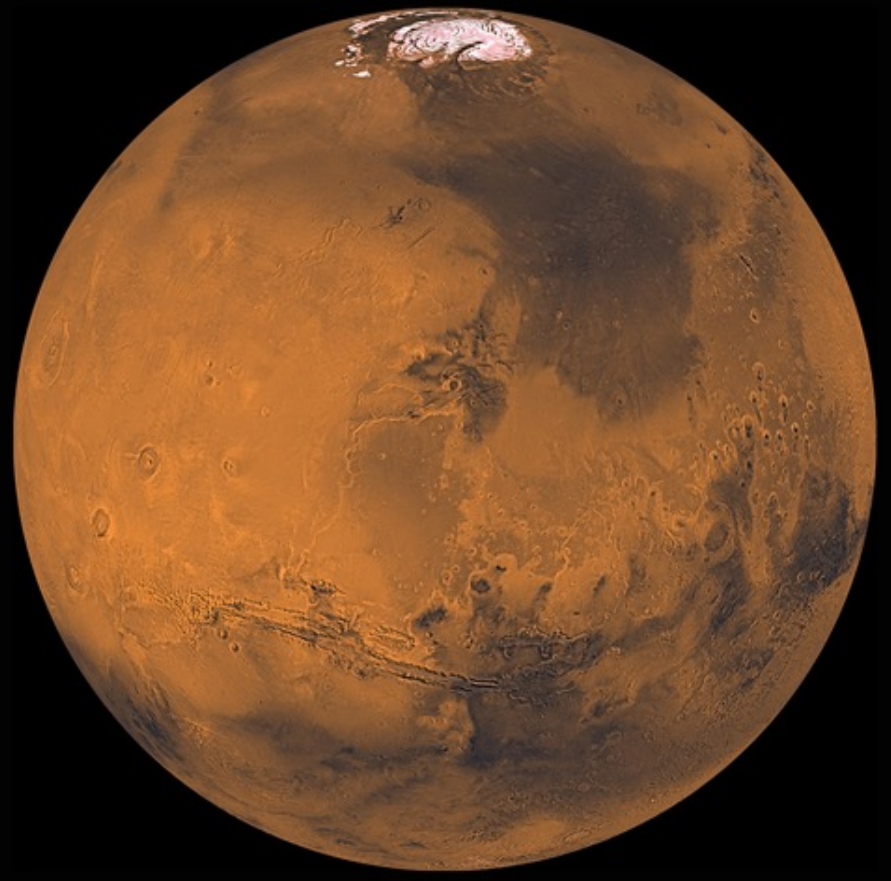


Topics

- 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

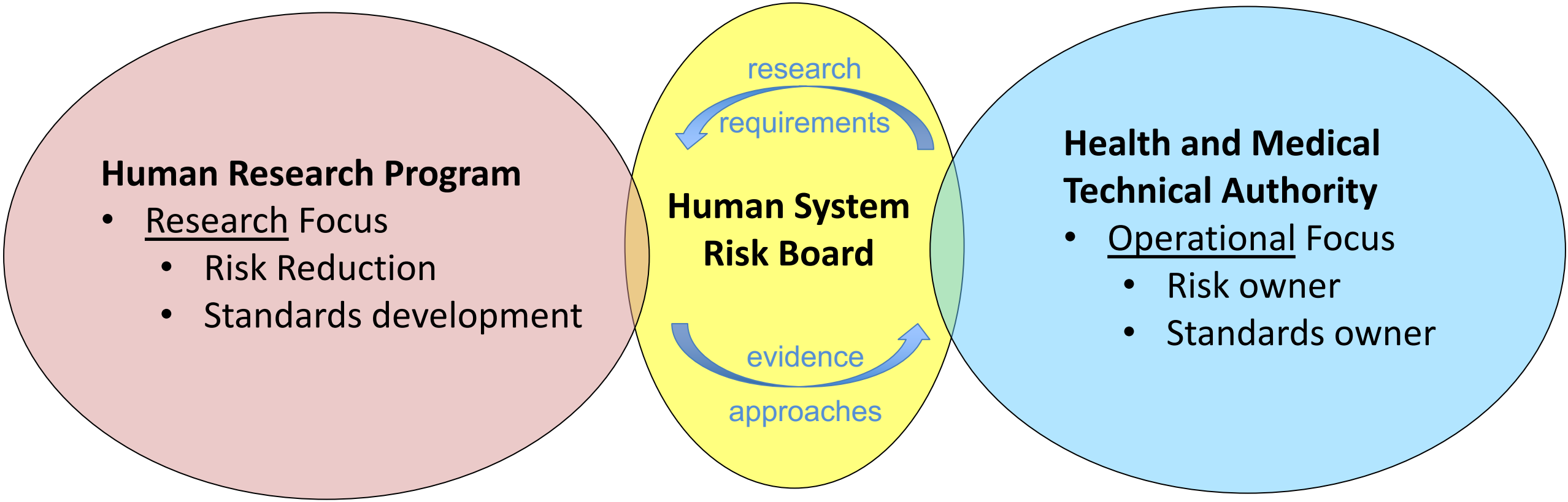
Human Research Program Mission Statement

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



Continuous Risk Management for the Human System

Human System Risk Board (HSRB)

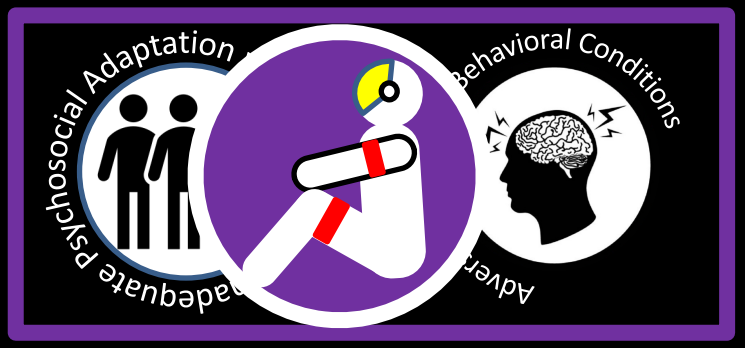


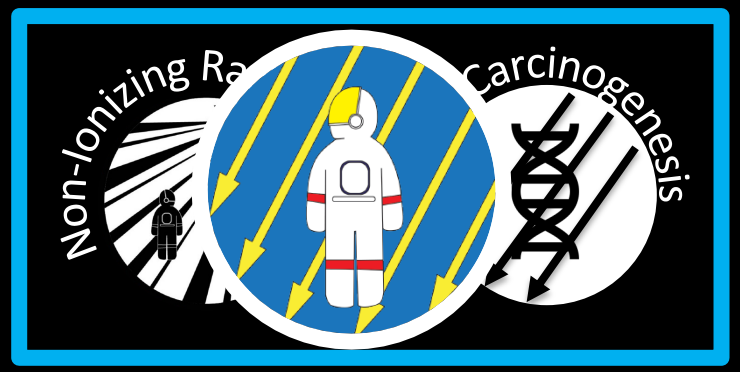
HSRB Risk Ratings (HRP "requirements")

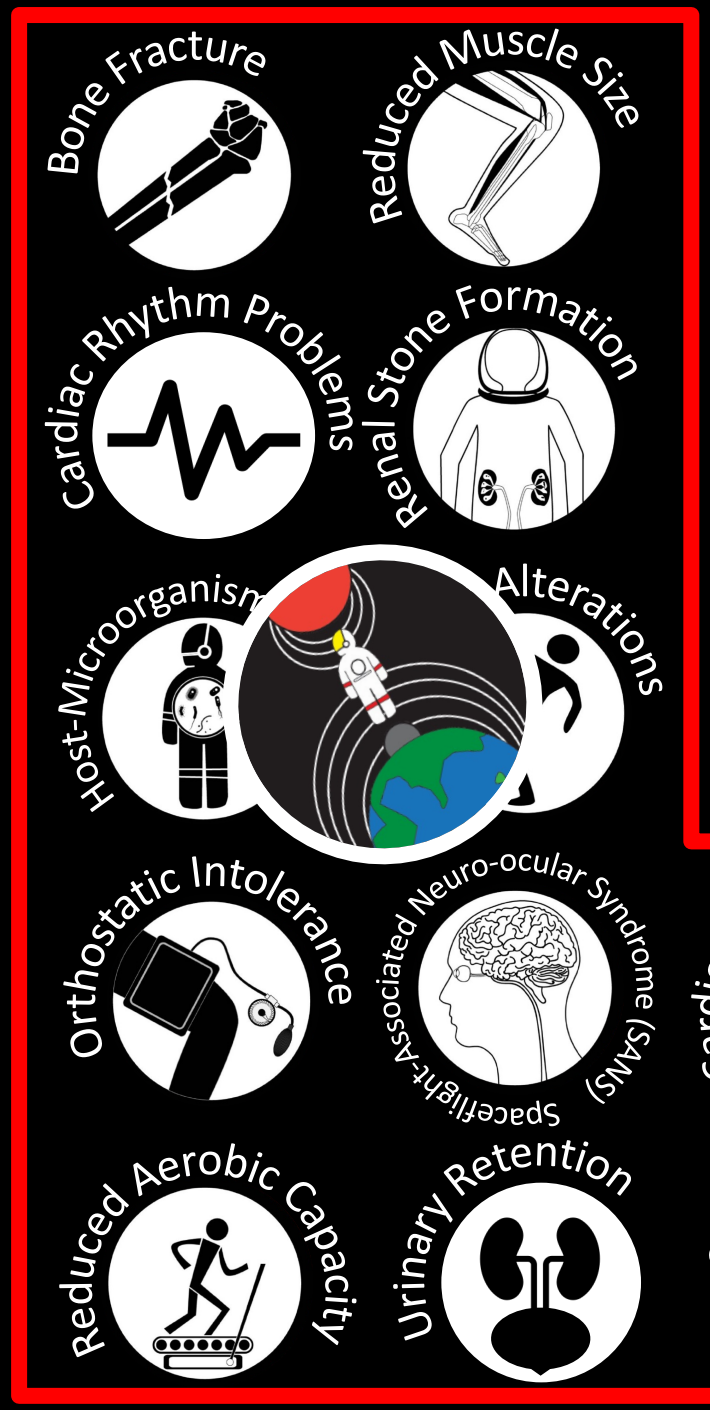
High Priority Mitigation target

Medium Priority Mitigation target

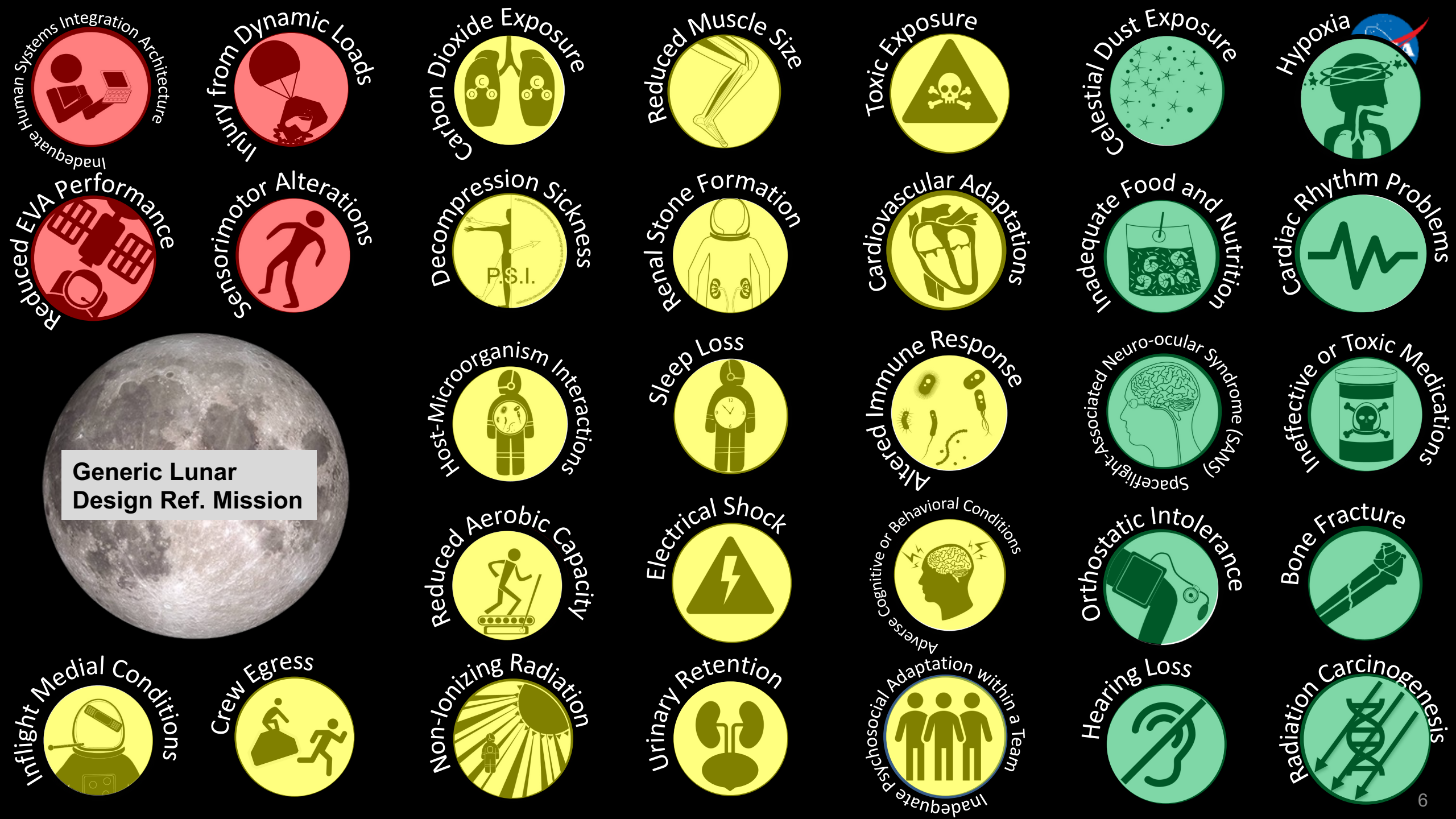
Low Priority Mitigation target

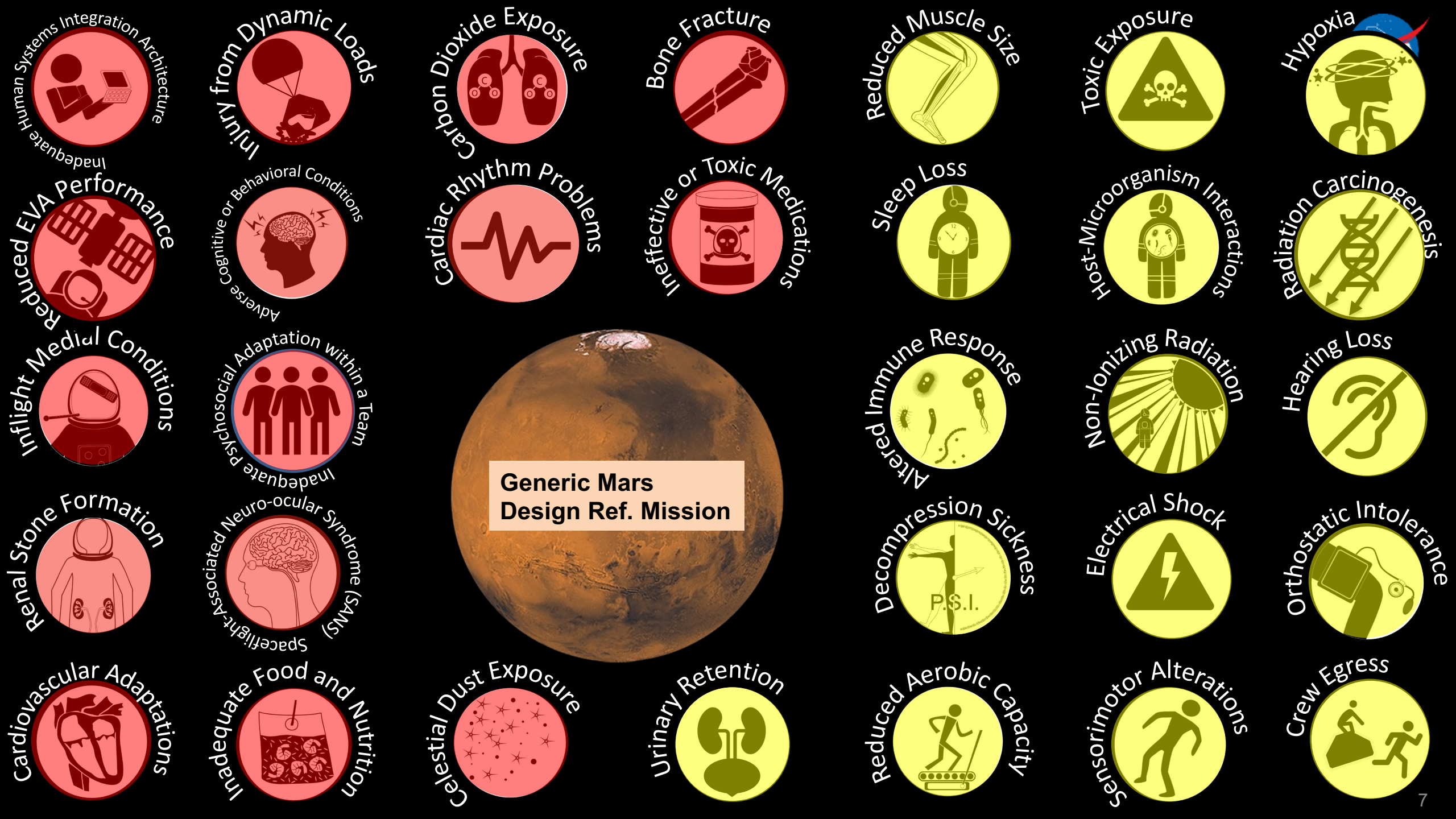






THE HUMAN SYSTEM RISKS


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
Generic Lunar
Design Ref. Mission
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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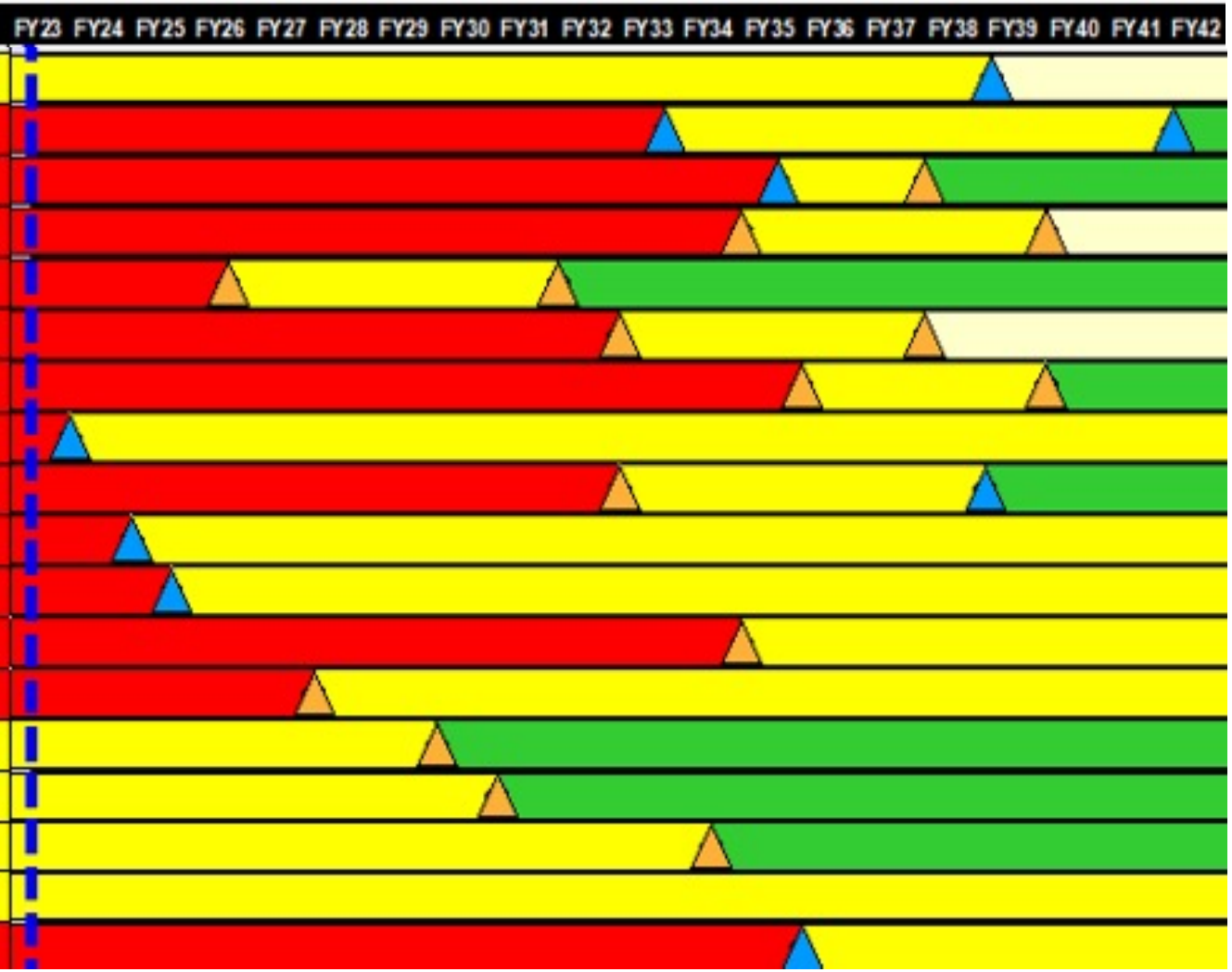
Reduced Aerobic Capacity
Sensorimotor Alterations
Crew Egress

Path to Risk Reduction – Mars

Human System Risks Requiring Research

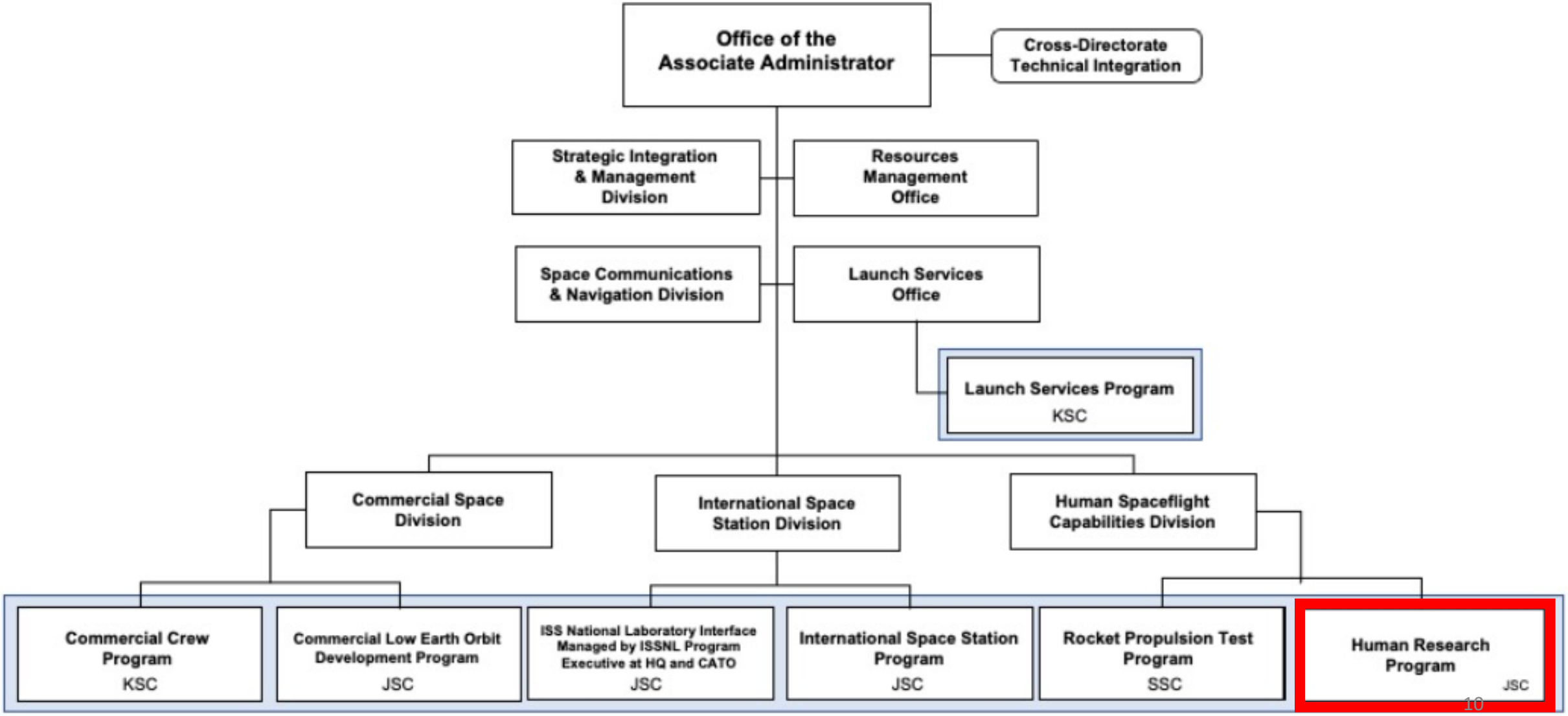
High Priority
Medium Priority
Low Priority

HRP Mars iPRR PPBE24 Baselined 1/11/23 (v1.78) APPROVED	
Space Radiation Carcinogenesis (SR-Cancer)	3x3
Bone Fracture (HHC-Bone Fracture)	4x4 *
Cardiovascular Adaptations (HHC-Cardiovascular)	4x4 *
Cognitive or Behavioral Conditions (HFBP-BMed)	5x3 *
Inadequate Food and Nutrition (HHC-Food and Nutition)	3x4
Team Performance Decrements (HFBP-Team)	3x4
Spaceflight Associated Neuro-ocular Syndrome (HHC-SANS)	3x4
Renal Stone Formation (ExMC-Renal Stone)	4x4*
Human Systems Integration Architecture (HFBP-HSIA)	5x3 *
Ineffective or Toxic Medications (ExMC-Pharm)	5X3*
Medical Conditions In-Mission Long Term Health (ExMC-Medical Conditions)	5x4 *
Injury from Dynamic Loads (HFBP-Dynamic Loads)	3x4
Injury Due to EVA Operations (HHC-EVA)	3x4
Altered Immune Response (HHC-Immune)	3x3
Host-Microorganism Interactions (HHC-Microhost)	3x3
Vestibular Sensorimotor Impacts (HHC-Sensorimotor)	4x2 *
Sleep Loss and Circadian Misalignment (HFBP-Sleep)	3x3
Celestial Dust Exposure (ExMC-Dust)	4x4 *



HRP Organization and Overview

Space Operations Mission Directorate

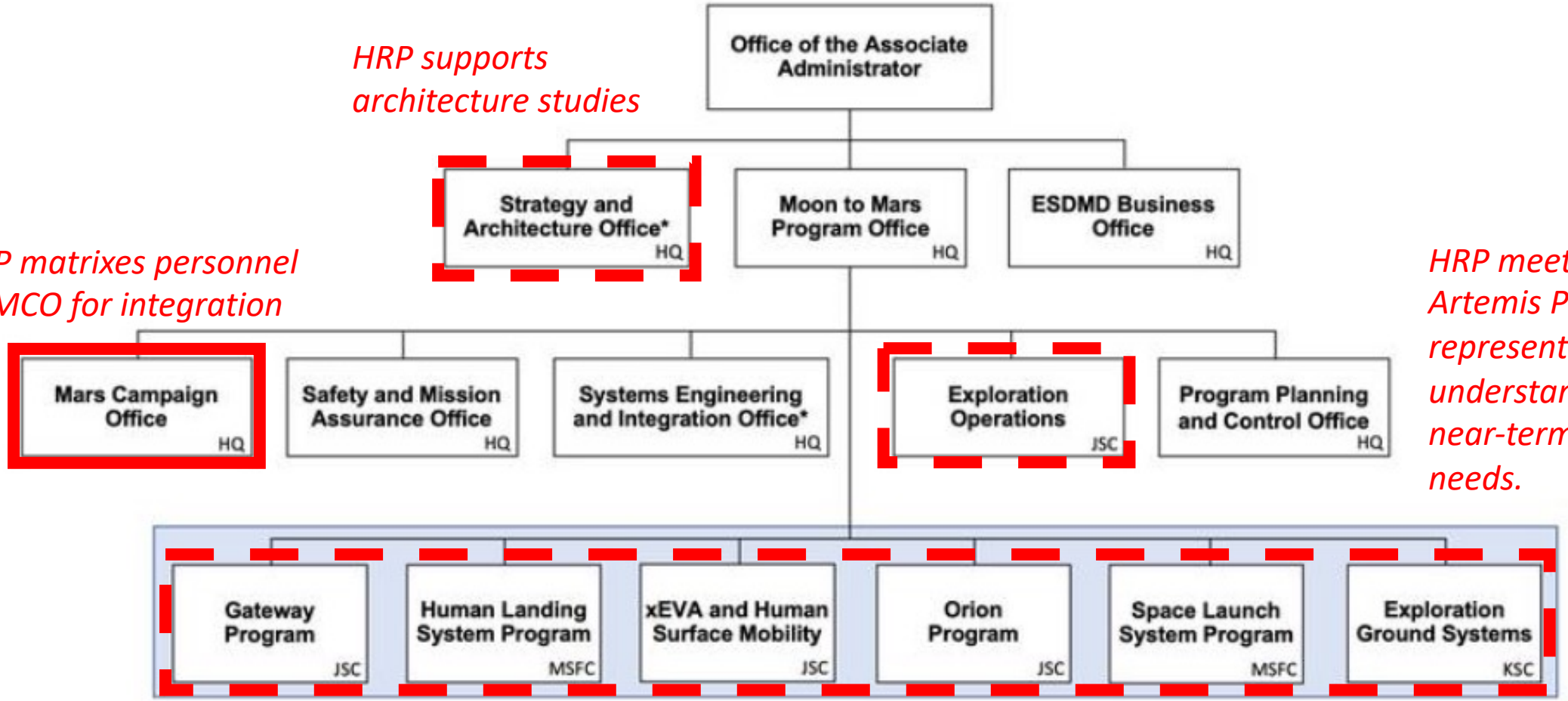


Exploration Systems Development Mission Directorate

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

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

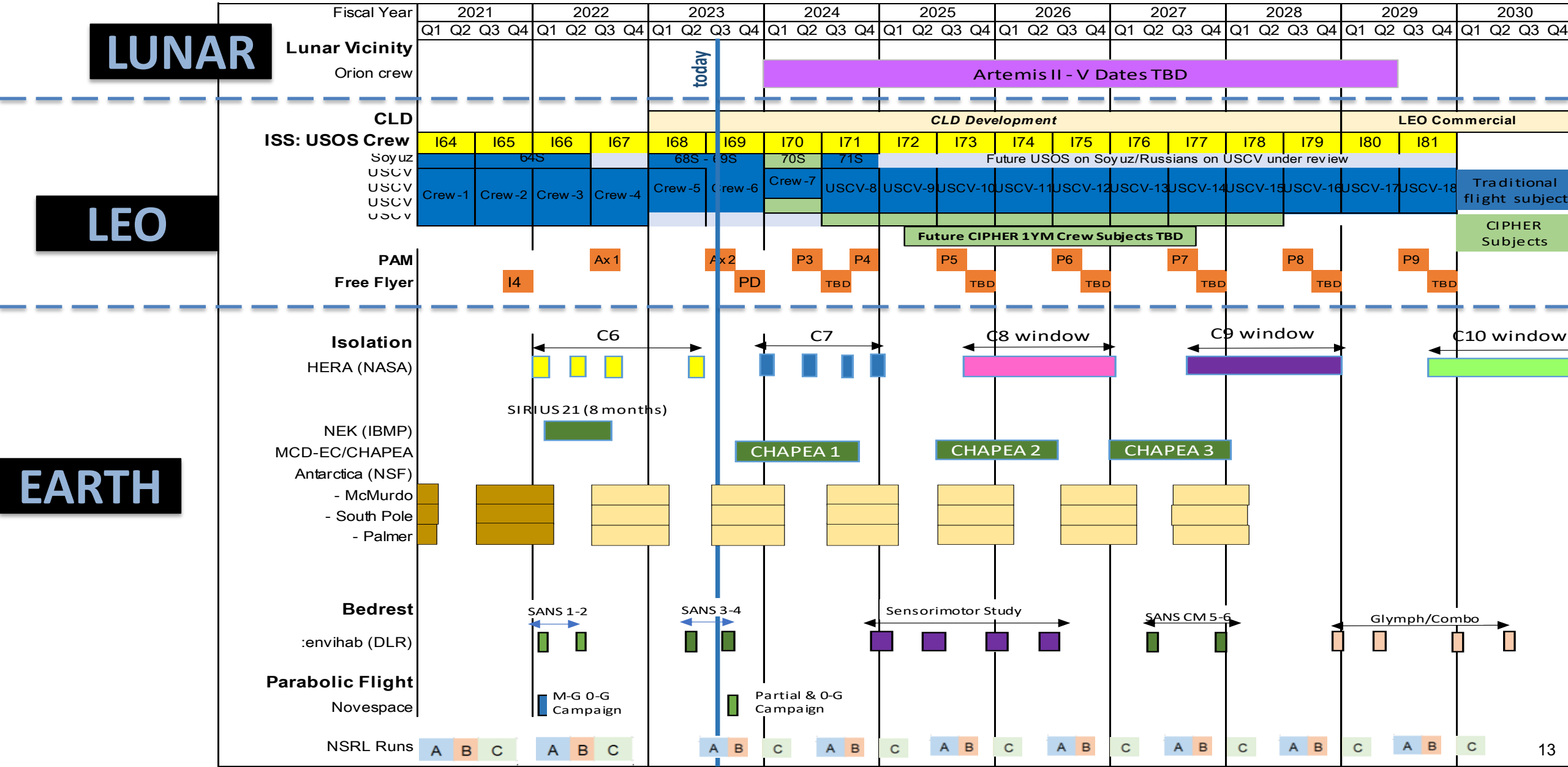
LUNAR MISSIONS:

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

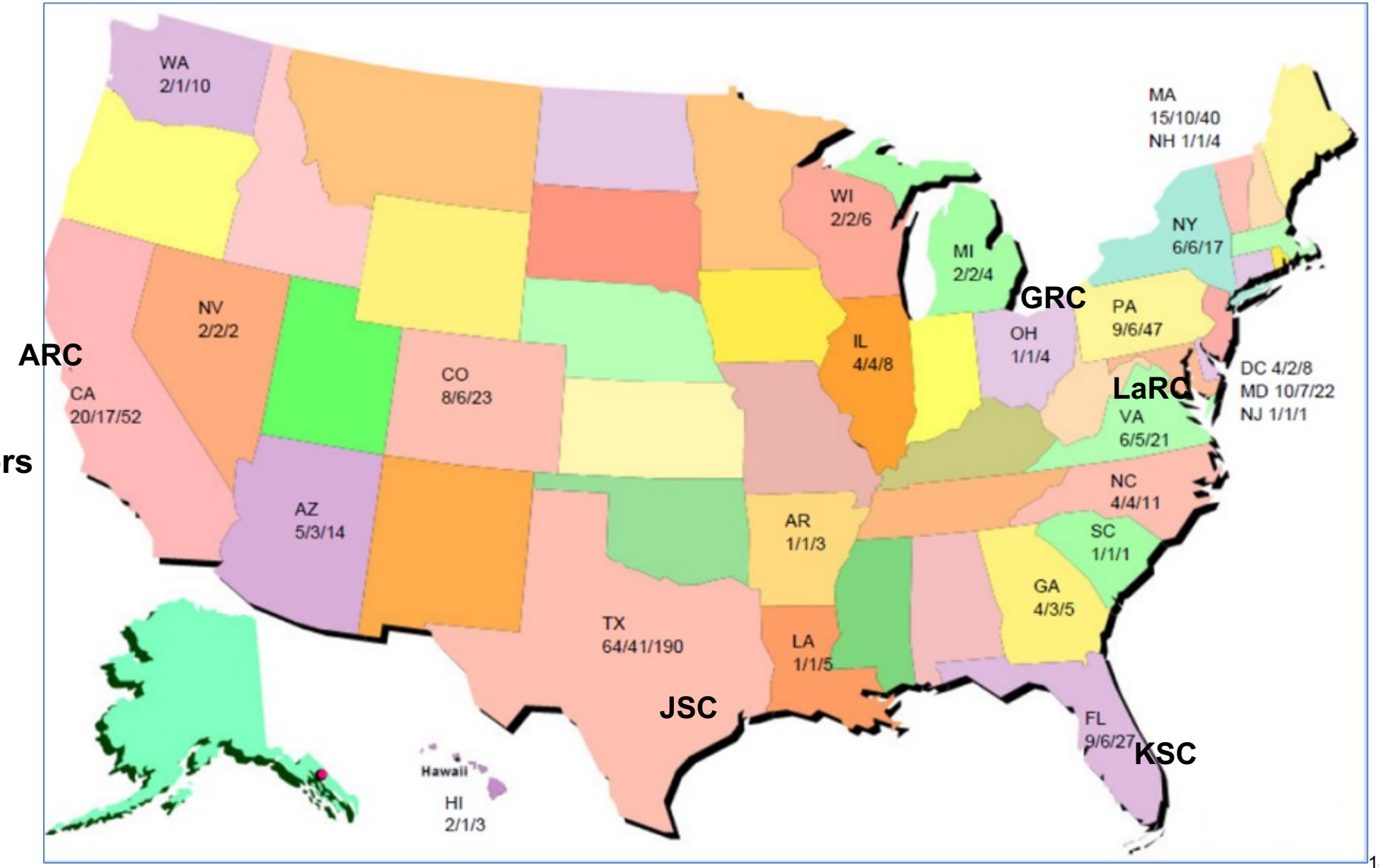
Projects/Principal Investigators/Co-Investigators by State

5 NASA Field Centers

- **JSC**
- **KSC**
- **GRC**
- **LaRC**
- **ARC**

185 Research Projects
135 Principal Investigators
529 Co-Investigators

26 States



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

TRANSLATIONAL RESEARCH INSTITUTE FOR SPACE HEALTH

- 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

- Reviewers are not told the identities of the proposers to minimize the impact of implicit or unconscious bias in the evaluation of the merit of a proposal

Student Awards

- Early Career Awards and New Investigator Awards
- Grant Augmentation Awards, Conference Poster Competition Awards

TRISH funding two diversity programs

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

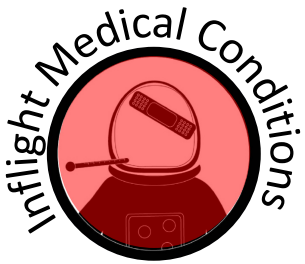
HRP partnership with NASA's Minority University Research and Education Program (MUREP)

- Radiation and TRISH Topics, Future conference travel awards
- https://www.herox.com/NASAMPLAN/faq

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

Risk Reduction Progress and Research Highlights

Agency Progress on Selected Risks

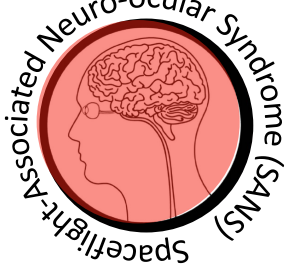


- 50+ years of **spaceflight medical evidence** integrated with resource requirements in a **probable risk assessment** decision support tool.
- HRP recommending moving risk to "**yellow**" in next 2 years

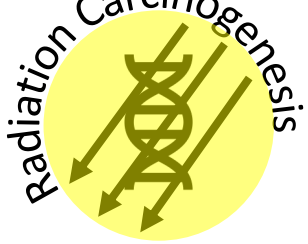
- **Exercise standards validated** for maintaining muscle and aerobic capacity
- HRP now focusing on **exercise hardware**

- Renal Stone mitigations (hydration, exercise, etc.) in place
- HRP recommending moving risk to "**yellow**" in next year

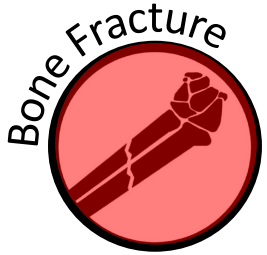
- **Antarctica validated** as a spaceflight analog.
- Ground **countermeasure** validation concluding soon.



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



- 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
- Detail on next page



- New evidence indicates that **DXA 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**

What are we doing to protect crews from radiation?
ALARA – As Low as Reasonably Achievable (GCR and SPEs)

Institutionalizing knowledge: NASA-STD-3001 standards and recent updates

1. [In review] **Galactic Cosmic Ray (GCR)** Shielding
2. [In review] Personal radiation exposure monitoring
3. Lifetime space radiation exposure limits (600mSv)
4. Design standards for **Solar Particle Events (SPE)** impacts and "storm shelters"
5. Real-Time Radiation Monitoring for Protection

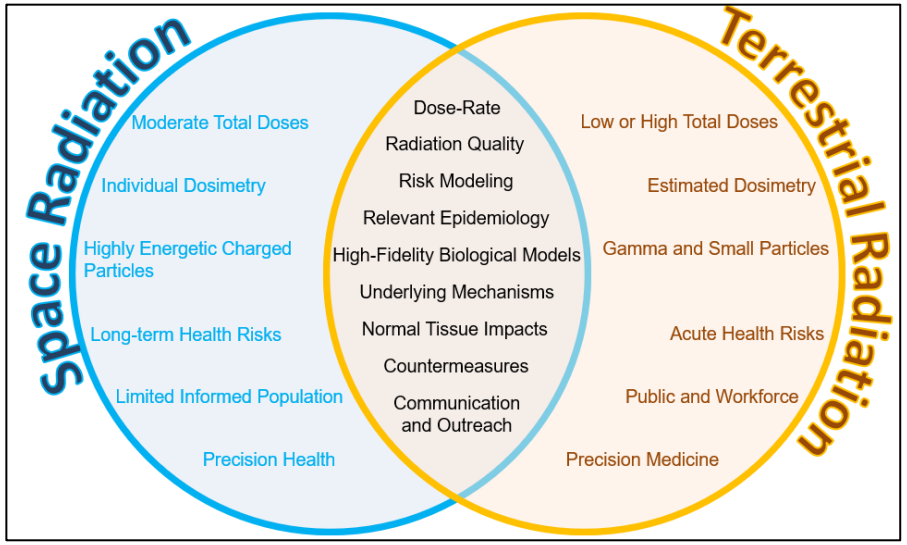
Continue mitigation strategies: Space Radiation Research

1. Characterize space environment on biology with GCR simulator
   - Dose Quality (Mixed Field GCR vs. Gamma)
   - Dose Rate (Dose provided over weeks vs. single exposure)
   - GCR Simulation in use since 2018 – first suite of studies starting to report results.
2. Leverages significant investment in **terrestrial radiation research** for **prevention, detection, treatment and personalized assessments**
3. Tools for **informed consent** for crews and agency decision makers
4. Improve SPE forecasting tools and technologies to minimize crew exposure levels

Providing recommendations to Agency: Mission Architecture Planning

1. Fly during Solar Maximum
2. Fly shorter Missions

NASA's Space Radiation Laboratory (NSRL) provides the highest fidelity simulation of Galactic Cosmic Radiation (GCR) on Earth



Research Highlights

Data Availability
Operational Focus

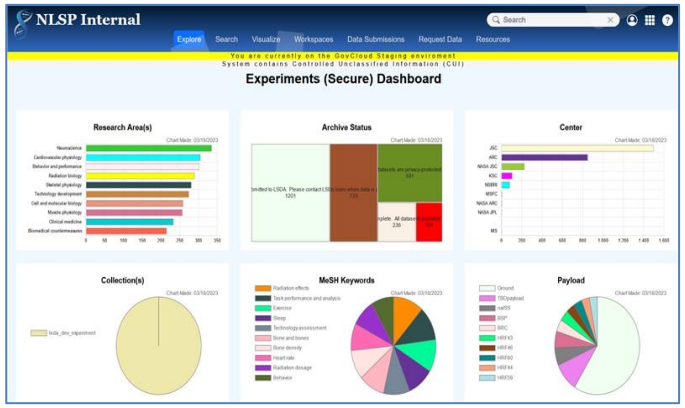
Making Research Data More Accessible

Next Generation Life Science Data Archive

https://nlsp.nasa.gov/

Improved:

- Automated tools
- Visualizations
- Tools & Workspace

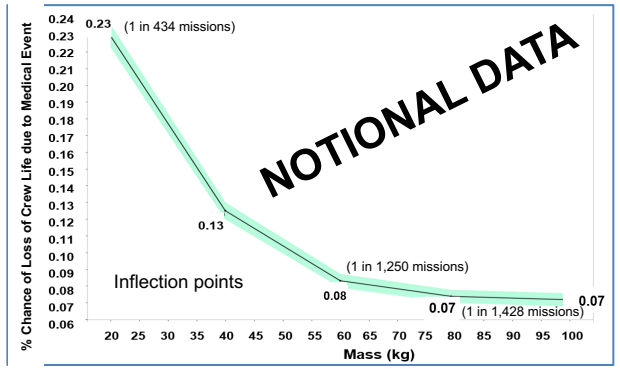


Making Research Data More Actionable

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: 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

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

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**

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**

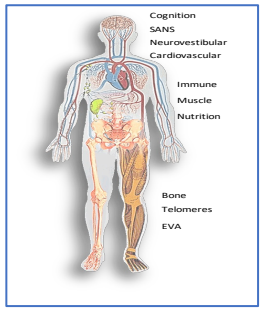
Examples of Artemis/Mars enabling work yet to be done on ISS

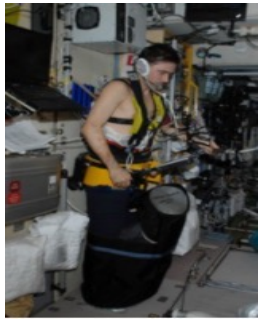
Sensorimotor/manual control countermeasures

Medical autonomy and technology demonstrations

Landing egress and EVA functional testing

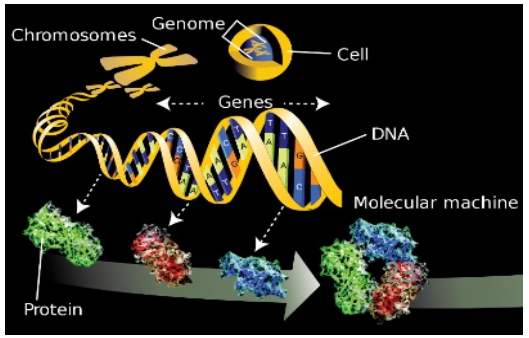
CIPHER – The most complex, integrated study ever of human physiology and psychology in space





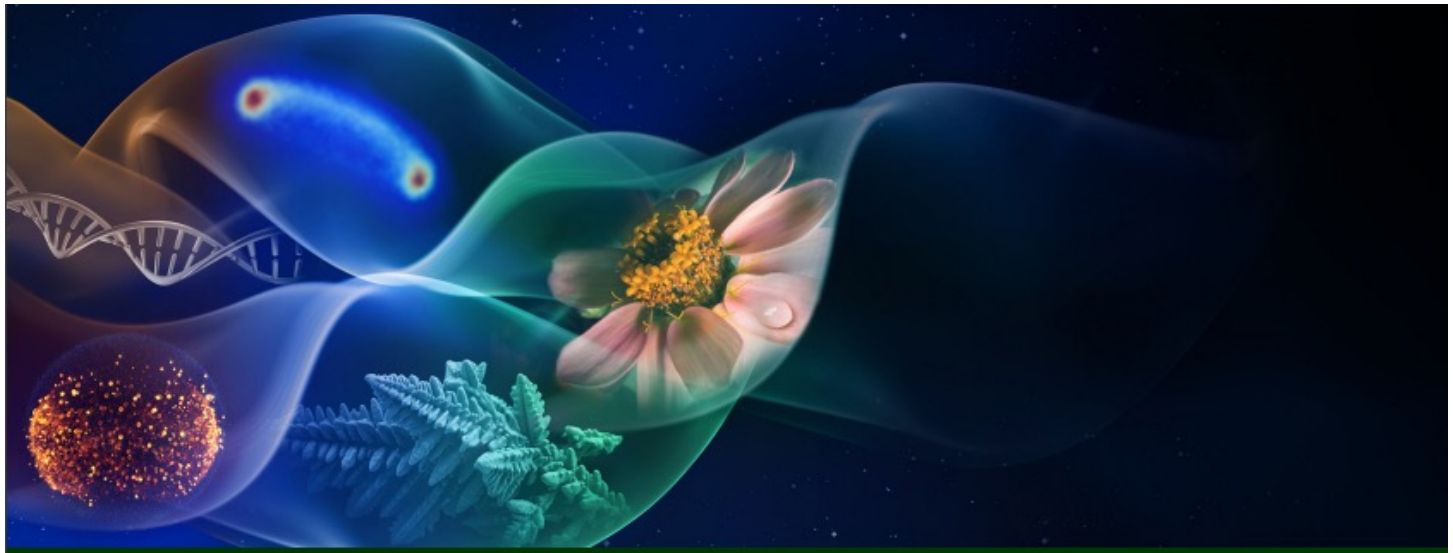
SANS Countermeasure Testing

-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

- Acceleration requirements
- Motion Sickness Countermeasures
- Manual Control Countermeasure

- Exercise Time Efficiencies

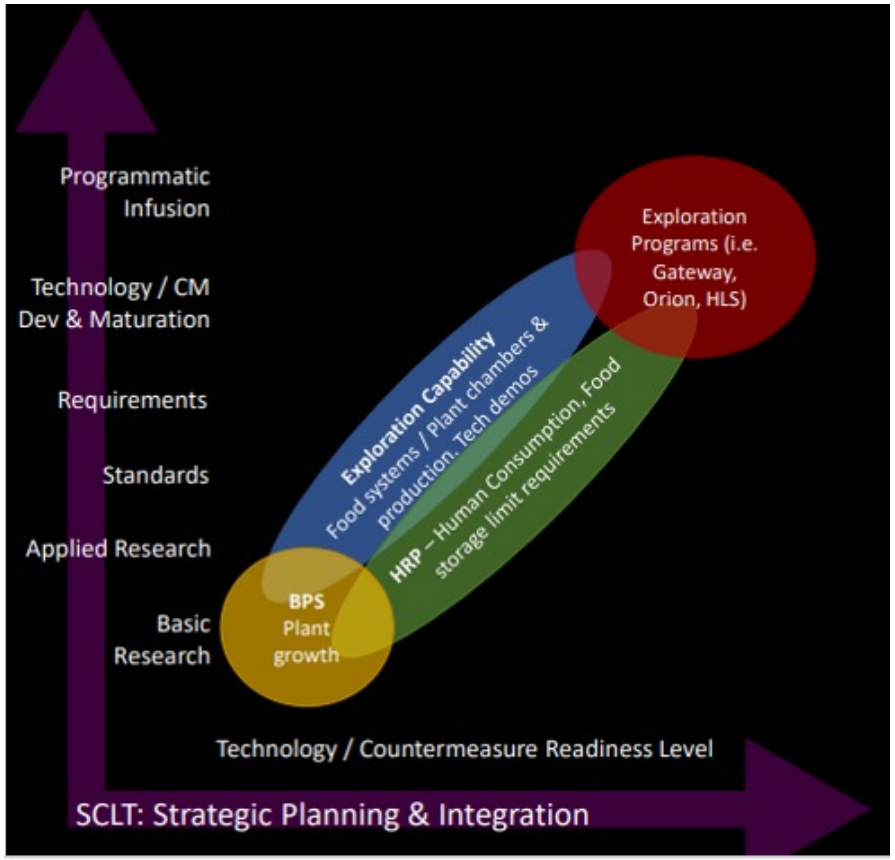
- Emergency CO_2 limits
- In-suit Nutrition Trade Study

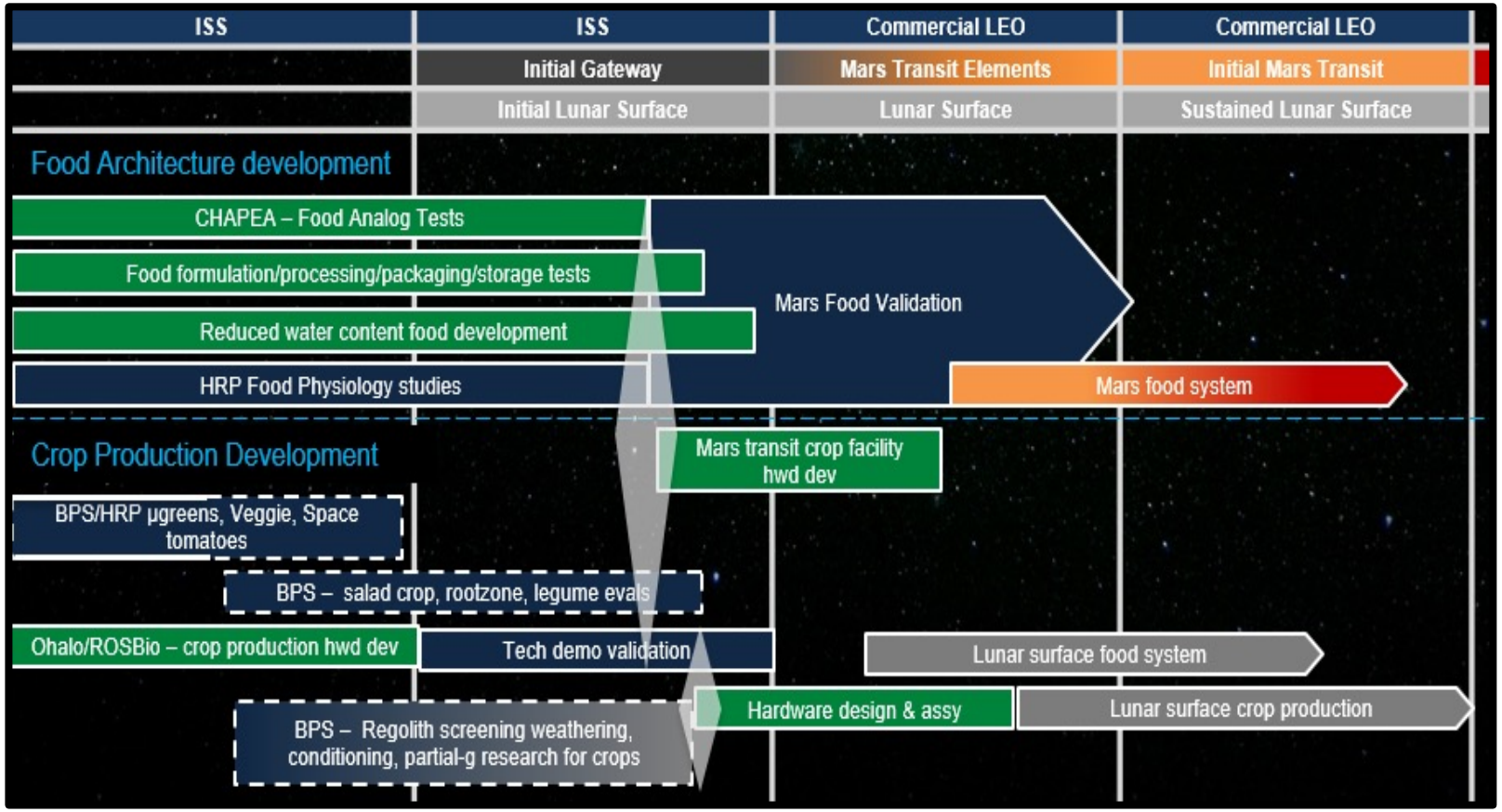
Top Crew Health and Performance System Capability Challenges for Mars v1.0

- 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

NASA Programs and Affiliates

- Biological & Physical Sciences (BPS)
- Health & Medical Technical Authority (HMTA)

yet2

NASA EPSCoR

SBIR-STTR

MUREP

Center of Excellence for Collaborative Innovation

TRANSLATIONAL RESEARCH INSTITUTE FOR SPACE HEALTH

International

DLR

CSA ASC

ИМБП

esa

cnes

ASI

ICRP

مركز محمد بن راشد للفضاء

MOHAMMED BIN RASHID SPACE CENTRE

इसरो isro

Domestic OGA

- NSRL Outside Users

NSF

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

BIOMEDICAL ADVANCED RESEARCH AND DEVELOPMENT AUTHORITY BARDA

NIH NATIONAL CANCER INSTITUTE

NIH National Institute of Allergy and Infectious Diseases

NIH National Center for Advancing Translational Sciences

Industry / External

- Commercial Space Providers
- TRISH industry partners
- Others

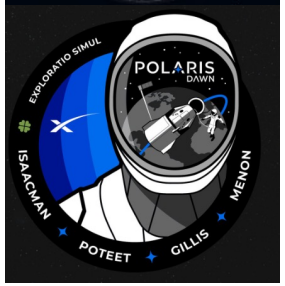
SCIENTIFIC AUTHORITY SINCE 1928 · CONGRESSIONALLY CHARTERED · NCRP

National Council on Radiation Protection and Measurements

CURRENT PARTNERSHIPS

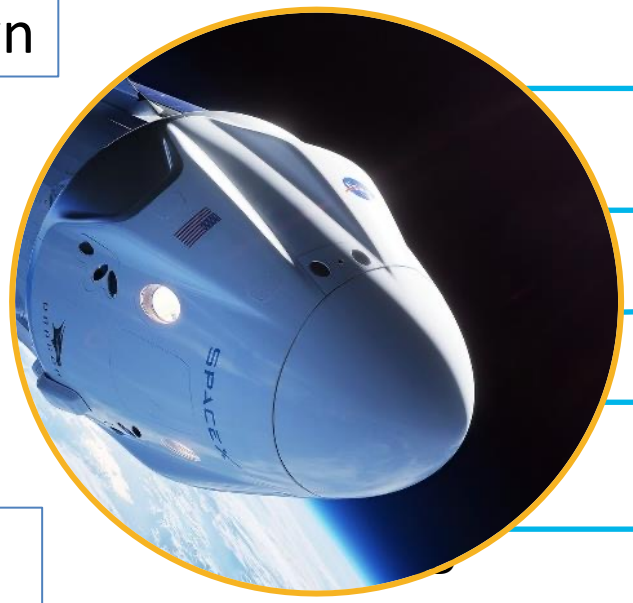
Commercial Space Human Research

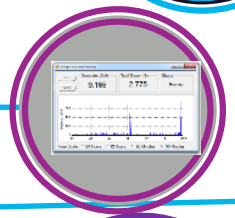
Establishing relationships to accelerate HRP's risk reduction mission.

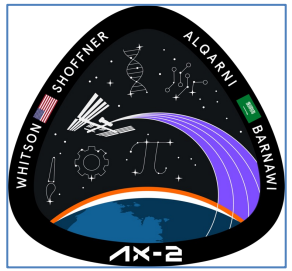


SpaceX

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

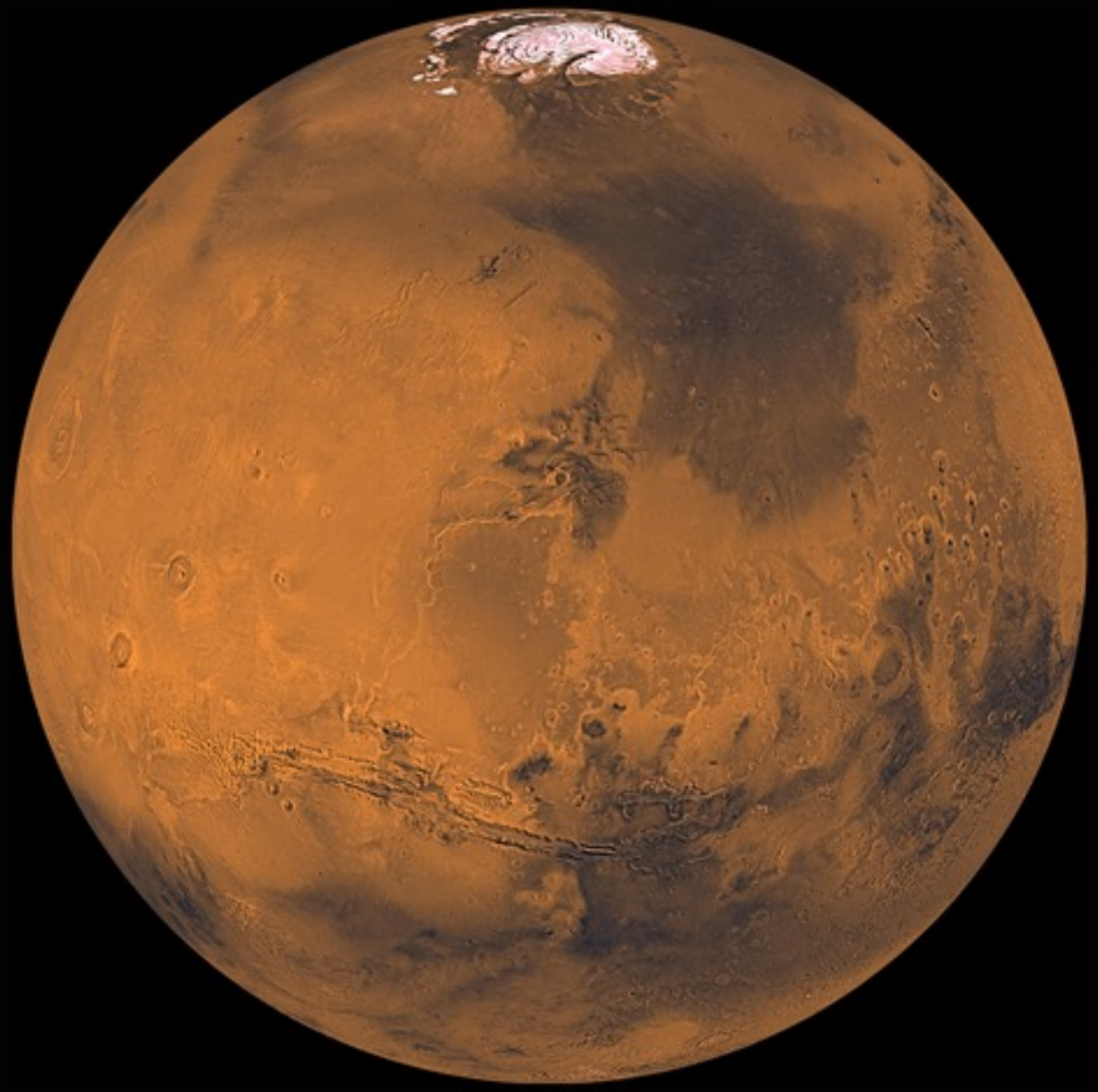
Axiom

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



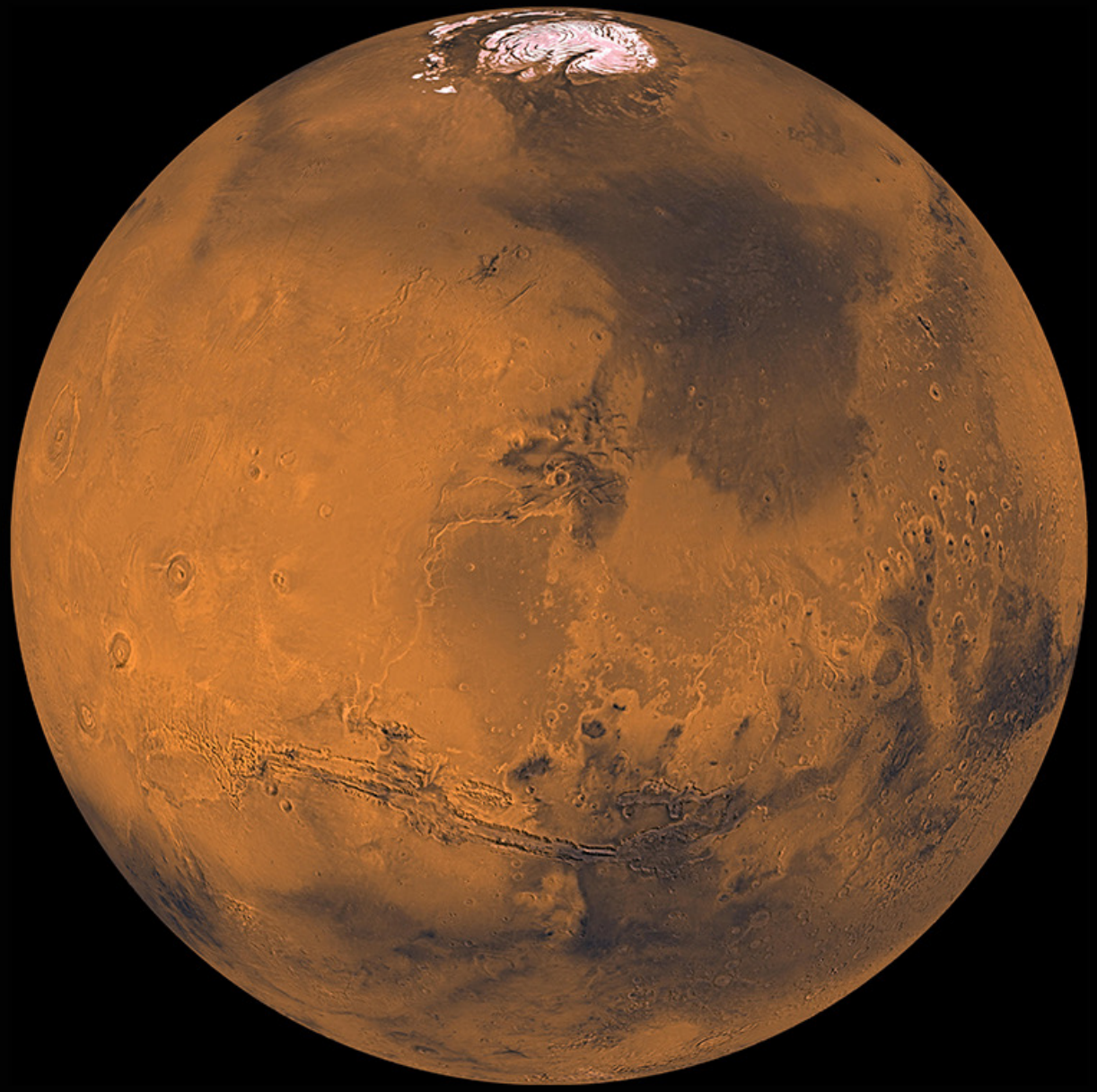
HRP remains a key component of the Agency's Moon-to-Mars Strategy

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

Questions?



Design Reference Missions

DRM Categories	Mission Type and Duration	Gravity Environment	Radiation Environment	Vehicle/Habitat Design	Distance from Earth		EVA
					Evacuation	Communication	Frequency
Low Earth Orbit	Short (<30 days)	Microgravity	LEO-Van Allen (<5-15 mGy)	Mid-sized volume, resupply	1 day or less	Real time	1-4 EVAs
	Long (30 days-1 year)	Microgravity	LEO-Van Allen (5-150 mGy)	Mid-large optimized volume, resupply	1 day or less	Real time	1-10 EVAs
Lunar Orbital	Short (<30 days)	Microgravity	Deep Space-Van Allen (15-20 mGy)	Small volume, self contained, resupply	3 – 11 days	Real time	Contingency EVA only or very few EVA
	Long (30 days-1 year)	Microgravity	Deep Space (175-220 mGy)	Mid-sized volume, self contained, limited resupply	3 – 11 days	Real time	Contingency EVA only or very few EVA
Lunar Orbital + Surface	Short (<30 days)	Microgravity & 1/6g	Deep Space-Van Allen (15-20 mGy)	Small volume, resupply	3 – 11 days	Real time	5 EVAs, some back to back
	Long (30 days-1 year)	Microgravity & 1/6g	Deep Space (100-120 mGy)	Mid-large sized optimized volume, limited resupply	3 – 11 days	Real time	3-4 EVA per week, 20-24 EVA hrs. per week
Mars	Preparatory (<1year)	Microgravity	Deep Space (175-220 mGy)	Midsized optimal volume, limited resupply, closed loop environment	Days – weeks	Controlled - Delayed	Contingency EVA only or very few EVA
	Mars Planetary* (730-1224 days)	Microgravity & 3/8g	Deep Space – Planetary (300-450 mGy)	Midsized optimal volume, no resupply, closed loop environment	Mission duration	No real time	2 crew x 8-hour EVA x 20 EVA days

Backup – Risks by DRM

Human System Risks	Low Earth Orbit (Short)	Low Earth Orbit (Long)	Lunar Orbital (Short)	Lunar Orbital (Long)	Lunar Orbital + Surface (Short)	Lunar Orbital + Surface (Long)	Mars (Preparatory)	Mars (Planetary)
	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 30 D	30 D - 1 Y	< 1 Y	730-1224D
Distance from Earth								
* Human Systems Integration Architecture (HSIA) Risk [5x5]	A	A	RM/SR	RM/SR	RM	RM	RM	RM
* Medical Conditions Risk [5x5]	A	A	A	RM	RC	RM	RM	RM
* Food and Nutrition Risk	AO	A	A	RM	A	RM	RM	RM
* Pharm Risk	AM	A	A	A	A	A	A	RM
Isolation and Confinement								
* Behavioral Risk [5x5]	AM	RM	AM	RM	RC	RM	RM	RM
* Team Risk	AM	AM	AM	RM	AM	AM	RM	RM
Altered Gravity								
* Sensorimotor Risk [5x5]	A	RM/SR	AM	RM/SR	RM/SR	RM/SR	RM/SR	RM/SR
* Bone Fracture Risk [5x5]	A	A	A	RC	A	RC	RC	RC
* Cardiovascular Risk [5x5]	A	AM	AM	AM	AO	AO	AM	RM/SR
* Renal Stone Risk	A	A	A	A	A	A	RM	RM
* SANS Risk	A	A	A	A	A	A	A	RM
Crew Egress Risk [5x5]	AM	AM	RC	RC	RC	RC	RC	RC
* Microhost Risk	AM	AM	AM	AM	AM	AM	AM	RM
Urinary Retention Risk	A	A	A	A	A	A	A	A
* Aerobic Risk	A	AM	AO	AO	AO	AO	AO	AO
* Muscle Risk	A	AM	AO	AM	AO	AO	AO	AO
Venous Thromboembolism (VTE) Concern	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hostile Closed Environment								
* EVA Risk	A	A	AO	AO	RM	RM	AO	RM
* Dynamic Loads Risk	AM	AM	AM	AM	RM	RM	AM	RM
Carbon Dioxide (CO2) Risk [5x5]	AM	AM	AM	AM	AM	AM	AM	AM
Toxic Exposure Risk [5x5]	AM	AM	AM	AM	AM	AM	AM	AM
* Immune Risk	AM	AM	AM	AM	AM	RM	RM	RM
* Sleep Risk	A	AO	AO	AO	AO	RM	RM	RM
Decompression Sickness (DCS) Risk	A	A	RM	RM	RM	RM	RM	RM
Hypoxia Risk (LTH)	A	RM	A	RM	A	RM	RM	RM
* Dust Risk	N/A	N/A	A	A	A	RM	N/A	TBD
Electric Shock [5x5]	A	A	A	A	RC	RC	RC	RC
Hearing Loss (LTH)	AM	AM	AM	RC	AM	AM	RC	RC
Radiation								
* Radiation Carcinogenesis Risk (LTH)	A	RC	A	RC	A	RC	RM	RM
Non-Ionizing Radiation Risk	A	A	A	A	A	A	AO	AO

Risk colors:
- High LxC
- Mid LxC
- Low LxC

Risk dispositions:
- **A** Accepted
- **AM** Accepted with monitoring
- **AO** Accepted with optimization
- **RC** Requires characterization
- **RM** Requires mitigation
- **RM/SR** Requires Mitigation/ Standards refinement