

Moon2Mars: Enabling Human Exploration

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Indian Space Research Organisation
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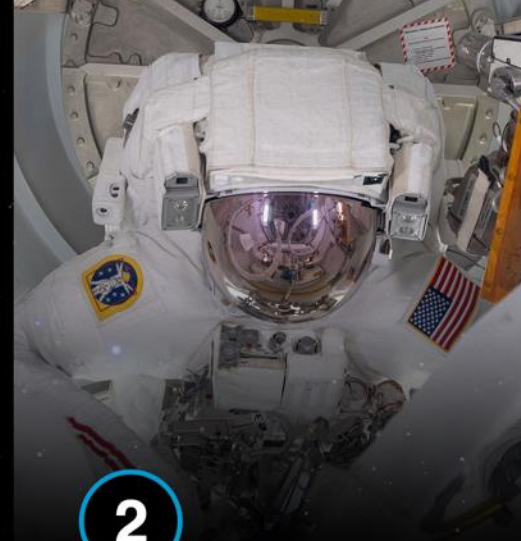
THE JOURNEY
CONTINUES





Space Radiation

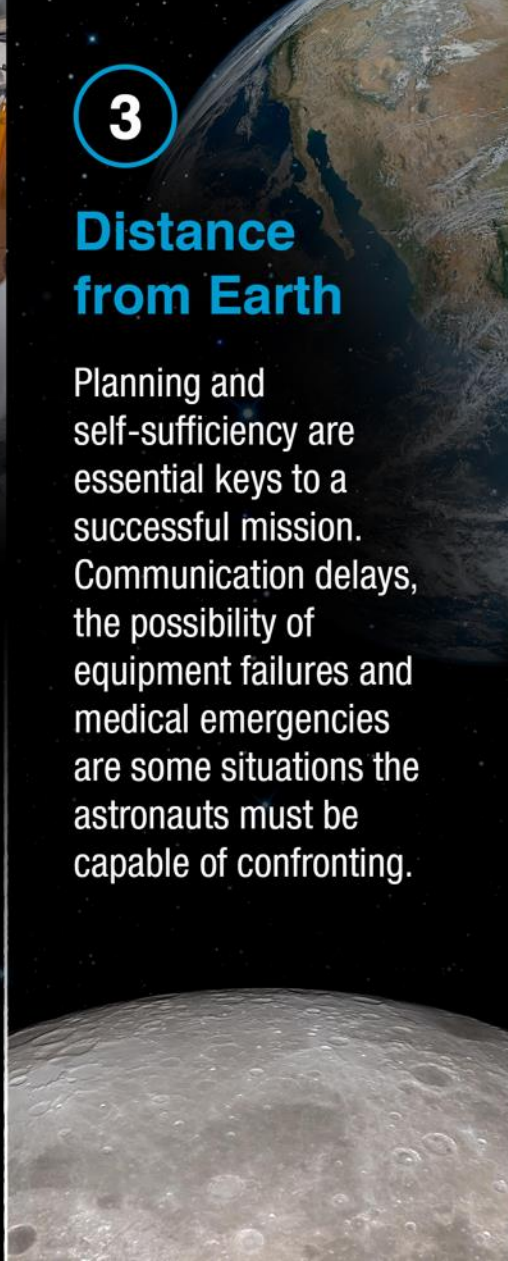
Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.



2

Isolation and Confinement

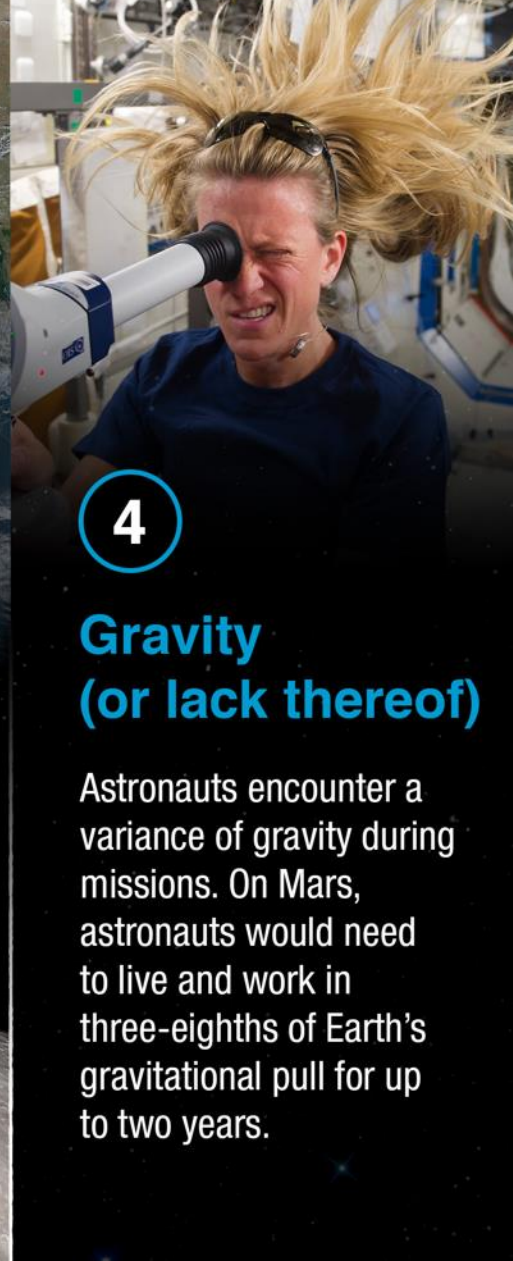
Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.



3

Distance from Earth

Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.



4

Gravity (or lack thereof)

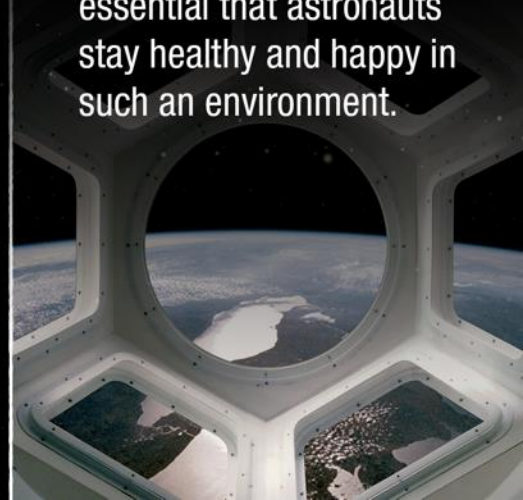
Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.



5

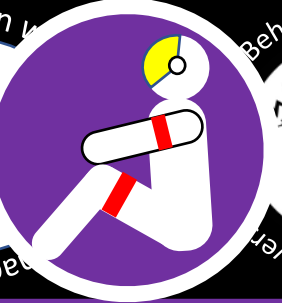
Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.



Psychosocial Adaptation

Inadequate Behavioral Conditions


Human Systems Integration Architecture

Inadequate Food and Nutrition

Inflight Medical Support

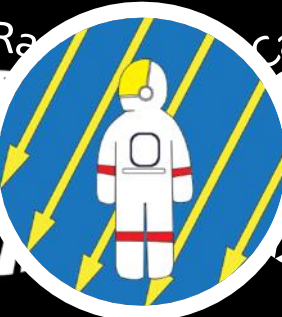
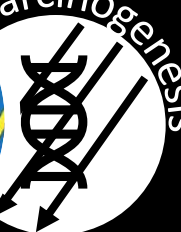
Ineffective Toxic Medications






Non-ionizing Radiation

Carcinogenesis

Bone Fracture

Reduced Muscle Size

Cardiac Rhythm Problems

Renal Stone Formation

Host-Microorganism Alterations









THE HUMAN SYSTEM RISKS

Orthostatic Intolerance

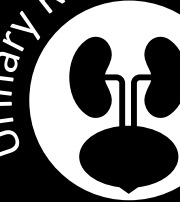
Spaceflight-Associated Neuro-ocular Syndrome (SANS)

Reduced Aerobic Capacity

Urinary Retention

Crew Egress




Toxic Exposure

Celestial Dust Exposure

Hypoxia

Carbon Dioxide Exposure

Altered Immune Response

Decompression

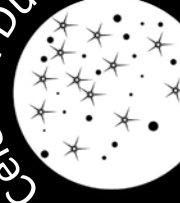
Performance

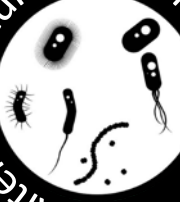
Electrical Shock

Sleep Loss

Hearing Loss

Injury from Dynamic Loads

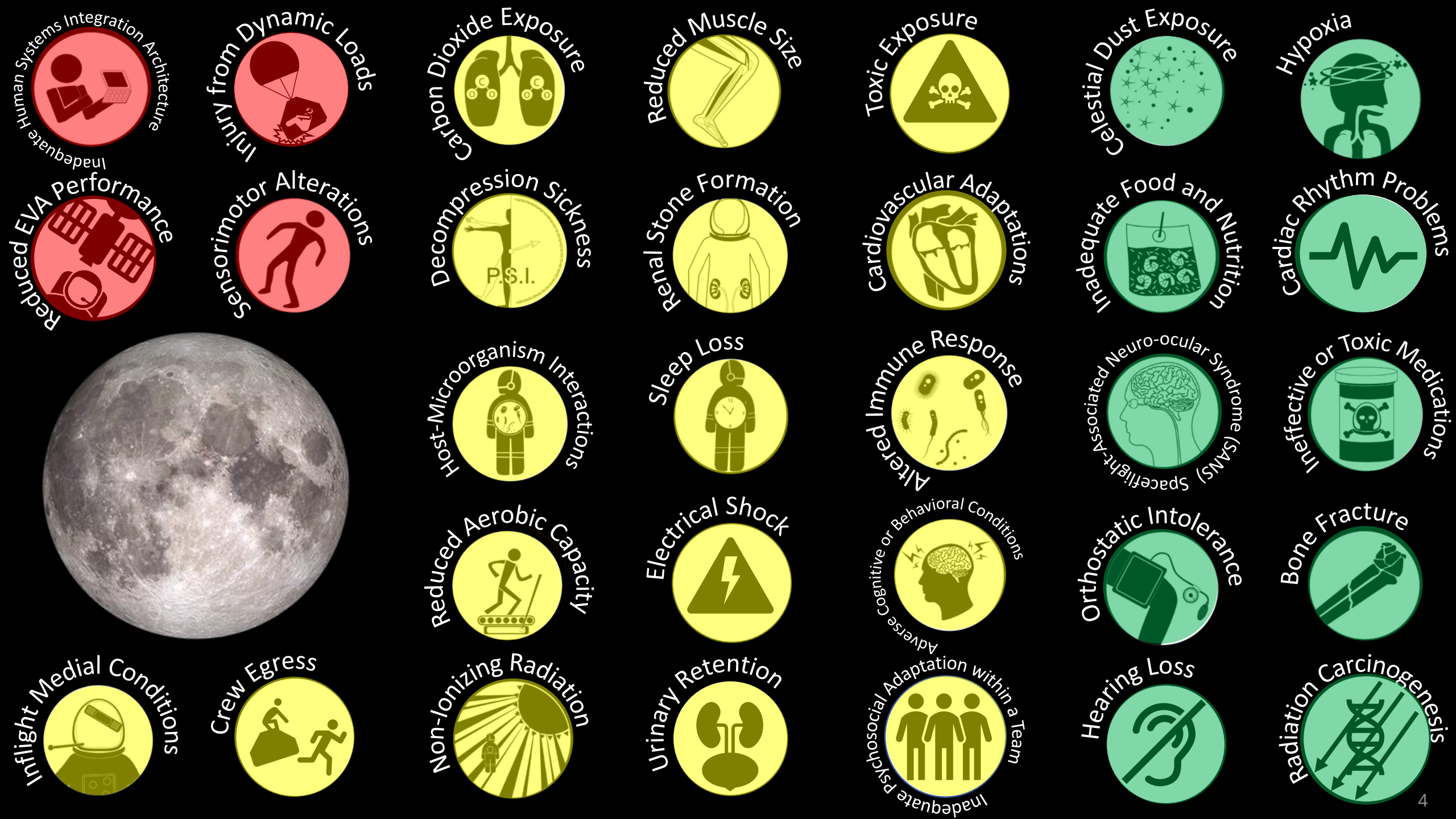



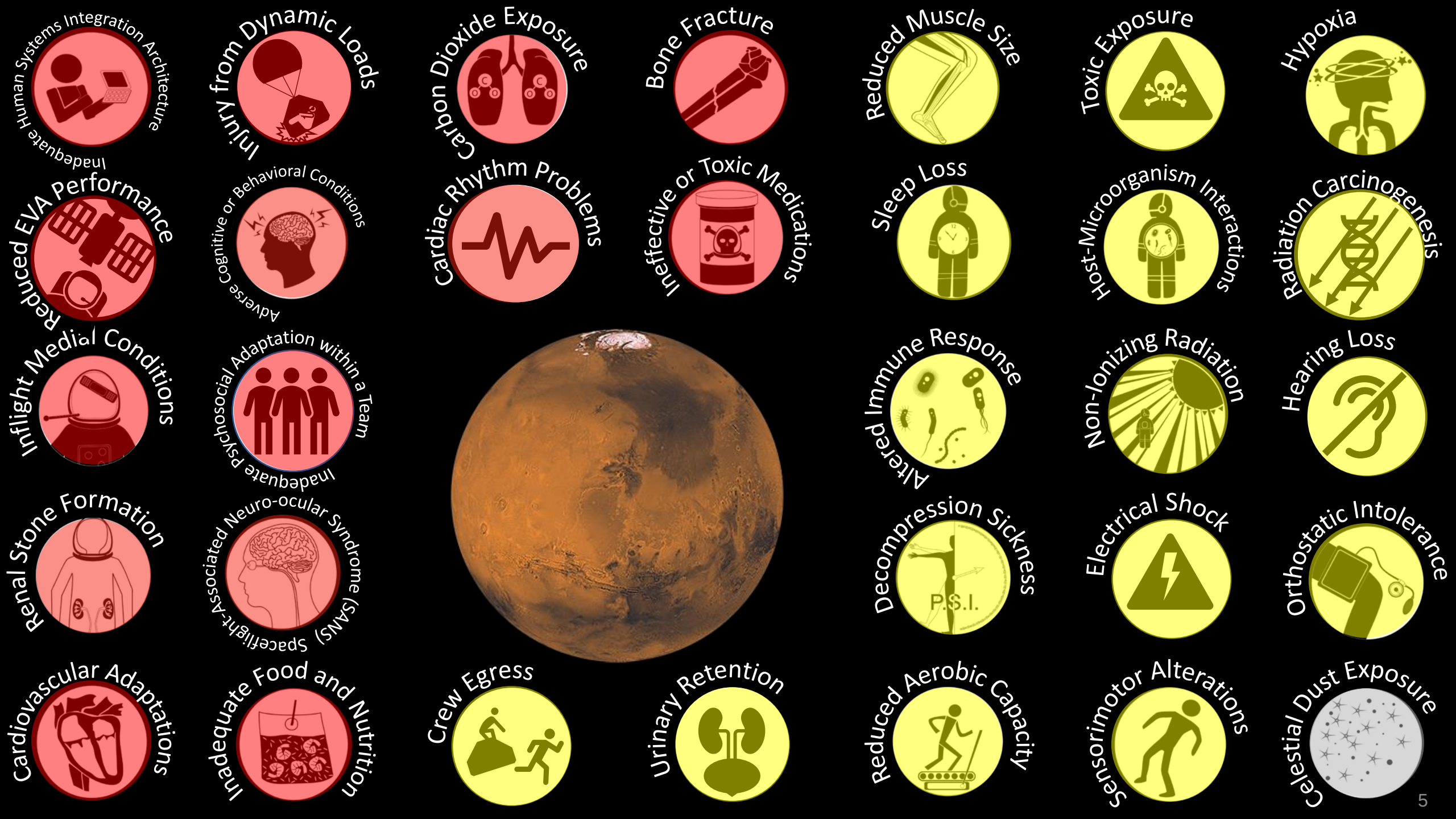













Artemis: Landing Humans On the Moon



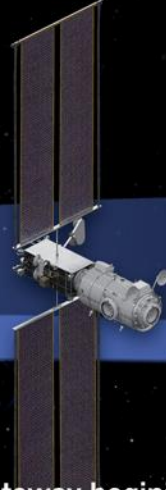
Lunar Reconnaissance Orbiter: Continued surface and landing site investigation



Artemis I: First human spacecraft to the Moon in the 21st century



Artemis II: First humans to orbit the Moon and rendezvous in deep space in the 21st Century



Gateway begins science operations with launch of Power and Propulsion Element and Habitation and Logistics Outpost



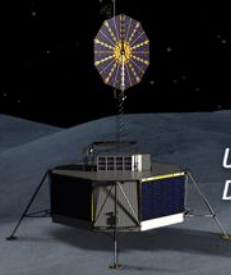
Artemis III-V: Deep space crew missions; cislunar buildup and initial crew demonstration landing with Human Landing System



Early South Pole Robotic Landings
Science and technology payloads delivered by Commercial Lunar Payload Services providers



Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey



Uncrewed HLS Demonstration



Humans on the Moon - 21st Century
First crew expedition to the lunar surface

LUNAR SOUTH POLE TARGET SITE

HRP Addressing Challenges to Enable Artemis and Mars Missions

HMTA* High Priority
Mitigation needed

Artemis

Medical Conditions

Likely medical conditions

Dynamic Loads

Integrated seat and EVA suit

Sensorimotor/Manual Control

Manual control option for landers

EVA

Improved performance and reduced injuries in EVA suits

HSI

Human System Integration across programs and vehicles

Mars

Pharm

Long-term medications storage

Medical Conditions

Likely medical conditions

EVA

Improved performance and reduced injuries in EVA suits

Dynamic Loads

Integrated seat and EVA suit

Food & Nutrition

Nutritious, desirable, sufficient food system

Team

Assured isolated Team performance

BMed

Assured psychological performance in isolated environment

HSI

Human System Integration across programs and vehicles

Cardiovascular (LTH)

Cardiovascular long-term health

SANS

Protection from Space flight-associated neuro-ocular syndrome (SANS)



*HMTA = Health and Medical Technical Authority



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



Earth Phase: Analogs



NEK



Antarctica



Parabolic Flight



HERA



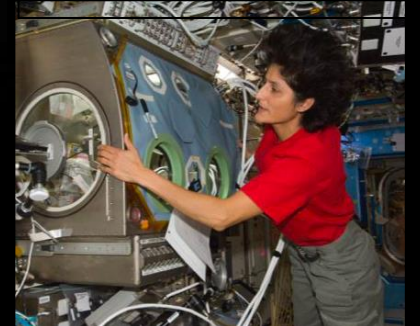
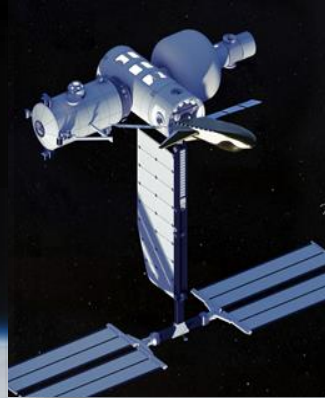
:enviLab



NSRL



Low Earth Orbit (LEO)



ISS Key Studies that Enable Artemis and Mars

Use Cases - ISS4Mars Analog Studies



Lower-body Negative Pressure (LBNP)
Countermeasure



Earth-independent Medical Operations



Post-landing Surface Fitness

Multiple and Integrated Studies



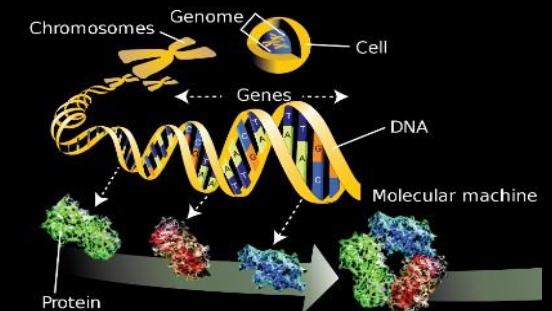
SANS (Vision changes)
Countermeasure Testing



Sensorimotor & manual
control countermeasures



CIPHER – Comprehensive
Human Physiology and
psychology (17 studies)



"Omics" Data Archive
Risk assessment and
Countermeasures

Sensorimotor Disturbances Caused by G-transitions



G-TRANSITIONS

Human Health Issues

- Postural and gait instability
- Visual performance changes
- Manual control disruptions
- Spatial disorientation
- Motion sickness

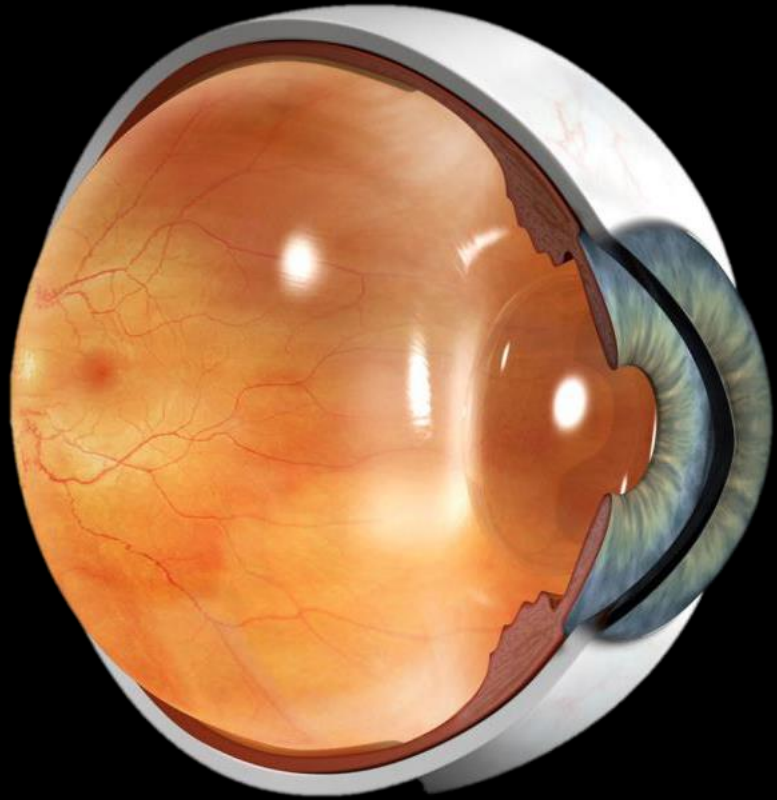
Operational Impact

- Vehicle control
- Vehicle egress
- Planetary EVAs



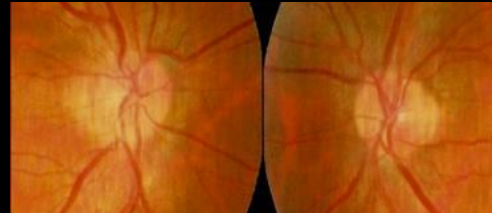
Postflight R+0 – Tandem Walk

Spaceflight Associated Neuro-ocular Syndrome (SANS)



Optic Disc Edema

Pre



Post



Right

Left



Space Radiation



Different Levels, Energy & Type

The visualization shows a complex, tangled web of glowing red and yellow lines against a dark background, representing the chaotic paths of high-energy cosmic particles.

Major Risk Focus:

Carcinogenesis
Cardiovascular
CNS



Galactic Cosmic Radiation

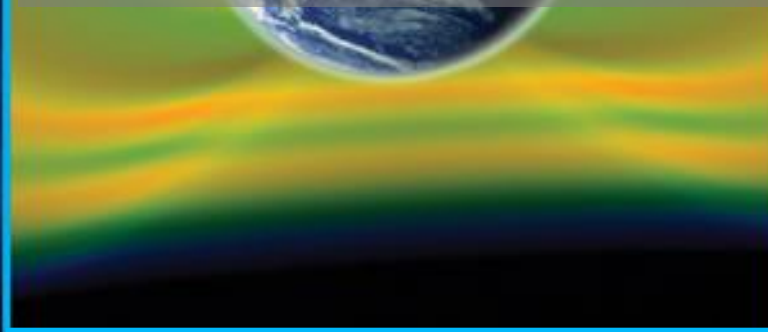
The visualization shows a bright, intense white and yellow light source surrounded by a dense, swirling cloud of red and orange particles, representing the high-energy environment of galactic cosmic radiation.

Protections Fall Short in Space

The visualization shows a cross-section of Earth's magnetic field with colorful bands of radiation (green, yellow, orange, red) trapped within it, illustrating the Van Allen belts.

Time

✖ Distance
✖ Shielding



Trapped Radiation

The visualization shows a bright, intense white and yellow light source surrounded by a dense, swirling cloud of red and orange particles, representing the high-energy environment of trapped radiation.

Countermeasure Strategies of
Surveillance & Early Detection

The visualization shows a bright, intense white and yellow light source surrounded by a dense, swirling cloud of red and orange particles, representing the high-energy environment of solar energetic particles.

Compound countermeasures: NERCI
Cross-risk Approach
Accelerate Candidates



Solar Energetic Particles

The visualization shows a bright, intense white and yellow light source surrounded by a dense, swirling cloud of red and orange particles, representing the high-energy environment of solar energetic particles.

Behavioral Health & Team Dynamics



Length: 45 day to 8-month missions

Simulate: isolation, confinement and autonomy, with transit and exploration activities

Focus: psychology, physiology, and team dynamics in a diverse crew

Standard Measures

Biomarkers Stress & Resilience

Team Task Switching

Components of Successful Autonomy

Crew Member Entrainment

Cultural Training

Food Acceptability



SIRIUS 19 Crew



Countermeasures Development



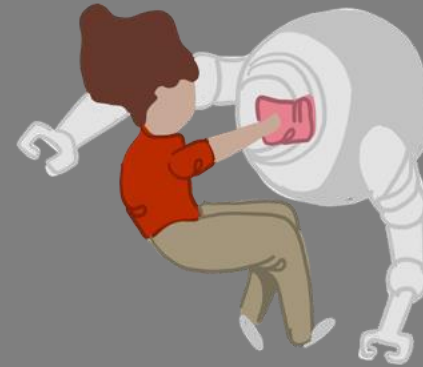
Greater Crew Autonomy



Current Operations



Future Operations



Toward Greater Human-systems Integration Architecture

Earth Independence: Medical Systems

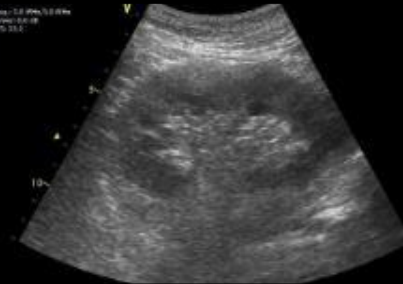


- | | | |
|---|--|---|
| • Real Time Communications | • Near Real Time Communications | • No Real Time Communications |
| • Strong Consumables Resupply & sample return | • Limited Consumables Resupply & sample return | • No Consumables Resupply & sample return |
| • Evacuation 1.5 –36 hours | • Evacuation 72 –144 hours | • No Evacuation Capability |

Autonomous Medical Systems

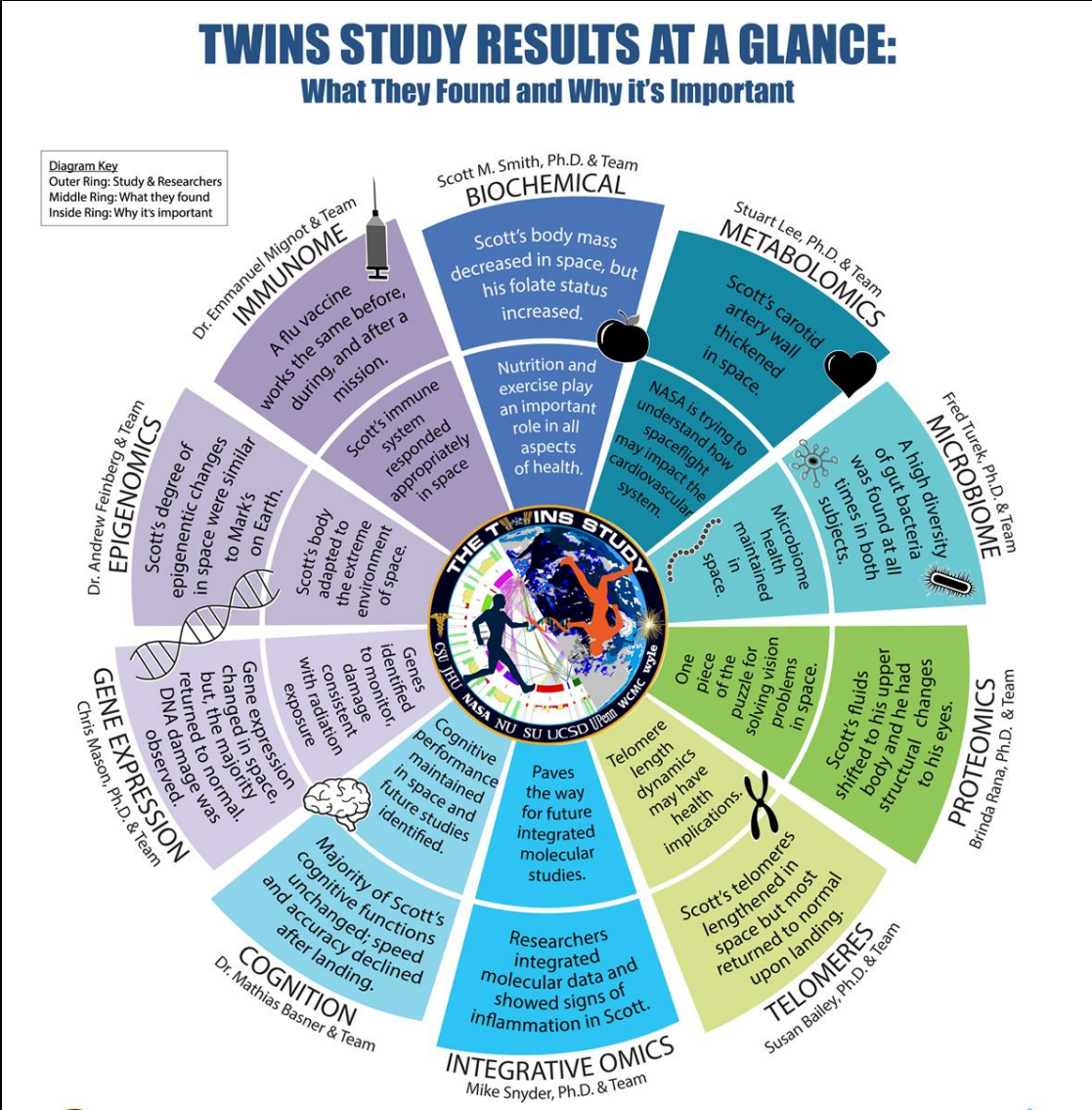


rHealthOne



Autonomous Medical Officer Support (Amos)

Whole Body, Long-Term, Integrated & Personalized Health





Moon2Mars: HRP PARTNERSHIPS



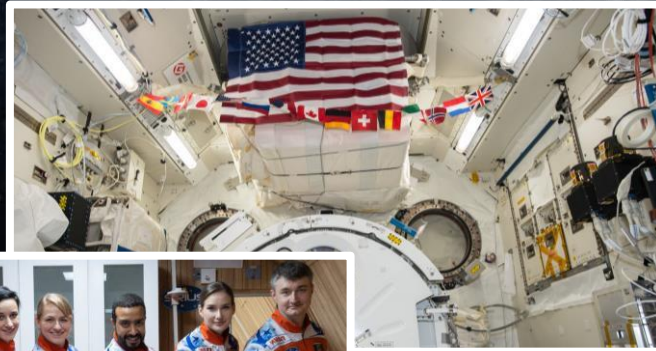
Educational & Other U.S. Gov't

- Research Grants
- Outreach
- Working Groups



International

- Space Agencies
- Government Agreements

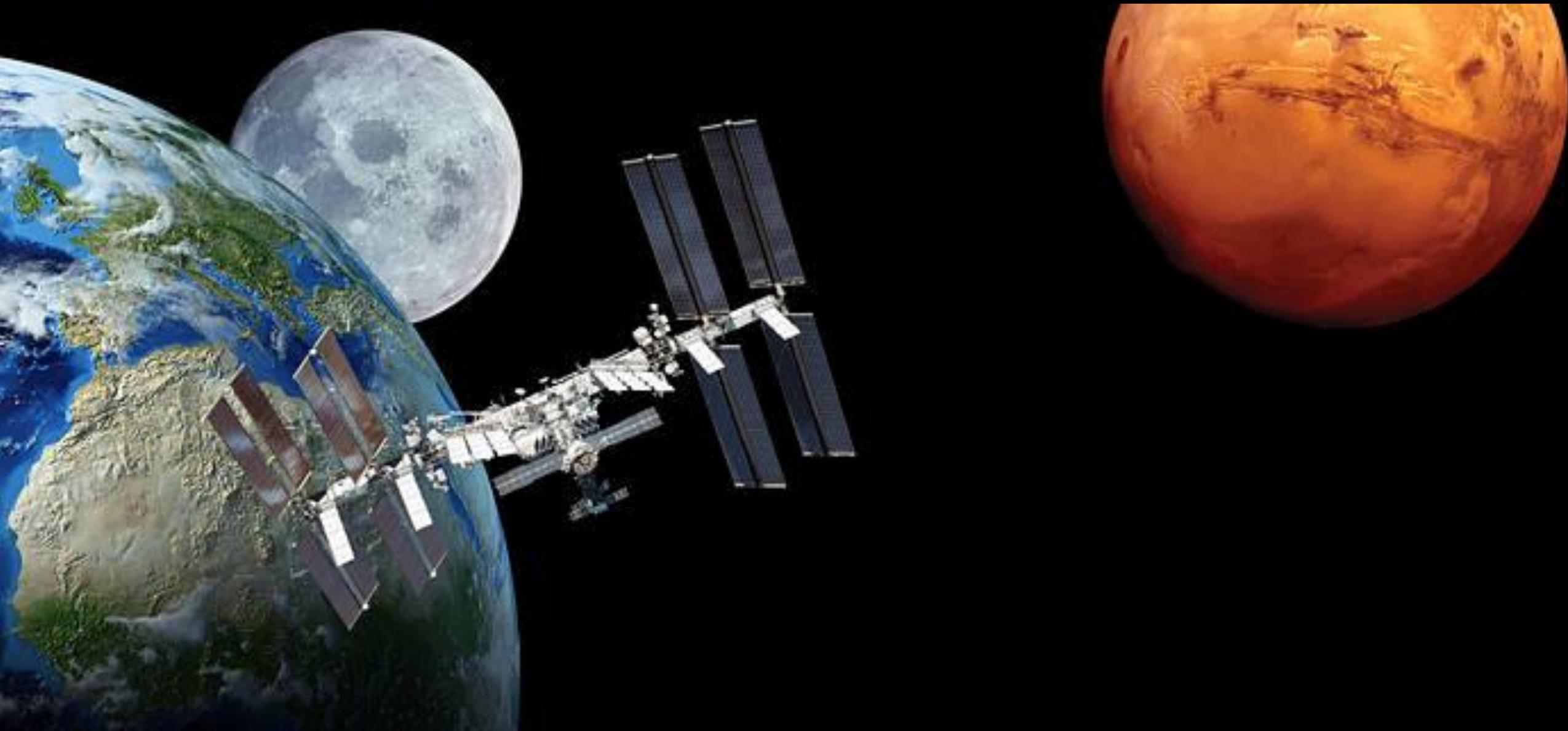


Commercial

- Commercial Crew Program
- Commercial Free-Flyers
- Low-Earth Orbit Destinations



Partnering to Overcome the Challenges of Future Space Exploration





Back Up

ISLSWG SLIDE EXAMPLES

Human Research Program



HRP Organization



Program and Science Management Offices

Director – David K. Baumann

***Deputy Director* – Nancy Fleming (Acting)**

Associate Director – Charles Lloyd, Pharm. D.

Chief Scientist – Steven H. Platts, Ph.D.

Deputy Chief Scientist – Kirsten Fabre, Ph.D.

Associate Chief Scientist – Jancy C. McPhee, Ph.D.

International Integration Science Manager – Igor Kofman

Translational Research Institute for Space Health (TRISH)

Director – Dorit Donoviel, Ph.D.

Deputy Director – James Hury

Maturation & Integration

Manager – Baraquiel Reyna, D.Eng.

Supporting Center Leads

ARC – Laura Lewis

GRC – Kelly Gilkey

JSC – Darby Magruder

KSC – Ralph Fritsche

LaRC – Ryan Norman, Ph.D.

Program Planning & Control

Manager – Macresia Alibaruho



Space Radiation (SR)

Manager – Jason Weeks

Scientist – Robin Elgart, Ph.D.

Human Health Countermeasures (HHC)

Manager – Laura Bollweg

Scientist – Michael Stenger, Ph.D.

Human Factors & Behavioral Performance (HFBP)

Manager – Aaron Allcorn

Scientist – Sandra Whitmire, Ph.D.

Exploration Medical Capability (ExMC)

***Manager* – Kevin MacNeil (Acting)**

Scientist – Kris Lehnhardt, M.D.

Research Operations & Integration (ROI)

Manager – Suzanne McCollum

Scientist – Brandon Vessey, Ph.D.

HRP Flight & Ground Analogs Facility Status



ISS Operations & Research

- **Completed Studies:** rHEALTH Tech Demo
- **New studies:** Zero T2 (controls)
- **CIPHER** – Accelerated first subject to 69S.
- **Axiom Research Planning** – HRP Spaceflight Standard Measures and Dynamic Loads planned for Ax-2 along with TRISH complement.



HERA Campaign 6

- Four 45-day missions: 15 HRP Studies (7 returning, 8 new)
- **Primary campaign research themes** - Human Systems Integration Architecture (HSIA) & autonomy.
- Mission 3 schedule delay of 1 month due to crewmember availability. Mission 4 postponed to Jan. 2023 due to COVID-19

Current planning dates for crew ingress:

- **Mission 1:** Oct 1 – Nov 15, 2021 - COMPLETE
- **Mission 2:** Jan 28 – Mar 14, 2022 - COMPLETE
- **Mission 3:** May 27- July 11, 2022 - COMPLETE
- **Mission 4:** Jan. 27 – March 13, 2023



enviHab | DLR SANS Countermeasure Bed Rest Study

- **6 HRP and 6 DLR investigations**
- Campaigns 1-2 focus on Lower Body Negative Pressure and Seated Upright countermeasures; Campaigns 3-4 focus on exercise countermeasure
- Campaign 1: Oct 12 – Nov 16, 2021 Campaign 2: Feb 8 – Mar 15, 2022
- Campaign 3: Jan 2023 Campaign 4: April 2023



NSF Antarctica Stations (ICE) Winter-over 2022 & 2023

- Human Health Countermeasures (HHC) Palmer Immune Countermeasure study (PI: Crucian) data collection ongoing in 2022 winter-over at Palmer Station
- Human Factors & Behavioral Performance (HFBP) VR Sensory Stimulation study (PI: Stankovic) data collection began Aug. 2022 at South Pole station
- Planning in work for 2023 winter-over studies: Palmer Immune Countermeasure study and Team Problem Solving study



NEK (IBMP) SIRIUS 21 Nov 2021 – July 2022

- **8- month International/Multicultural Isolation Mission**
- 7 HRP studies from SIRIUS 19 and one new HRP study included in SIRIUS 21.
- 2 US crew, 3 Russian crew and 1 Emirati crew
- Ingress occurred on November 4, 2021, egress occurred July 3, 2022.



Novespace (ESA) Parabolic Flight

- 0g cardiovascular study October 2021 – COMPLETE
- 5 HHC studies in planning with ESA focused on cardiovascular, sensorimotor and neurophysiological responses to 0 & partial-g targeted for June 2023.



Human System Risk Posture Summary – Risks by Hazard



Human Spaceflight 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 ^{5x5}	A	A	A	A	A	AO	RC	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 ^{5x5}	N/A	N/A	A	A	RM	RM	N/A	RC
Electric Shock ^{5x5}	A	A	A	A	RC	RC	RC	RC
Hearing Loss Risk (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 text color:

- Current risk ratings
- Risk posture under HSRB review
- Risk posture pending approval via CR process or concurrence from OCHMO

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

HRP Science Highlights

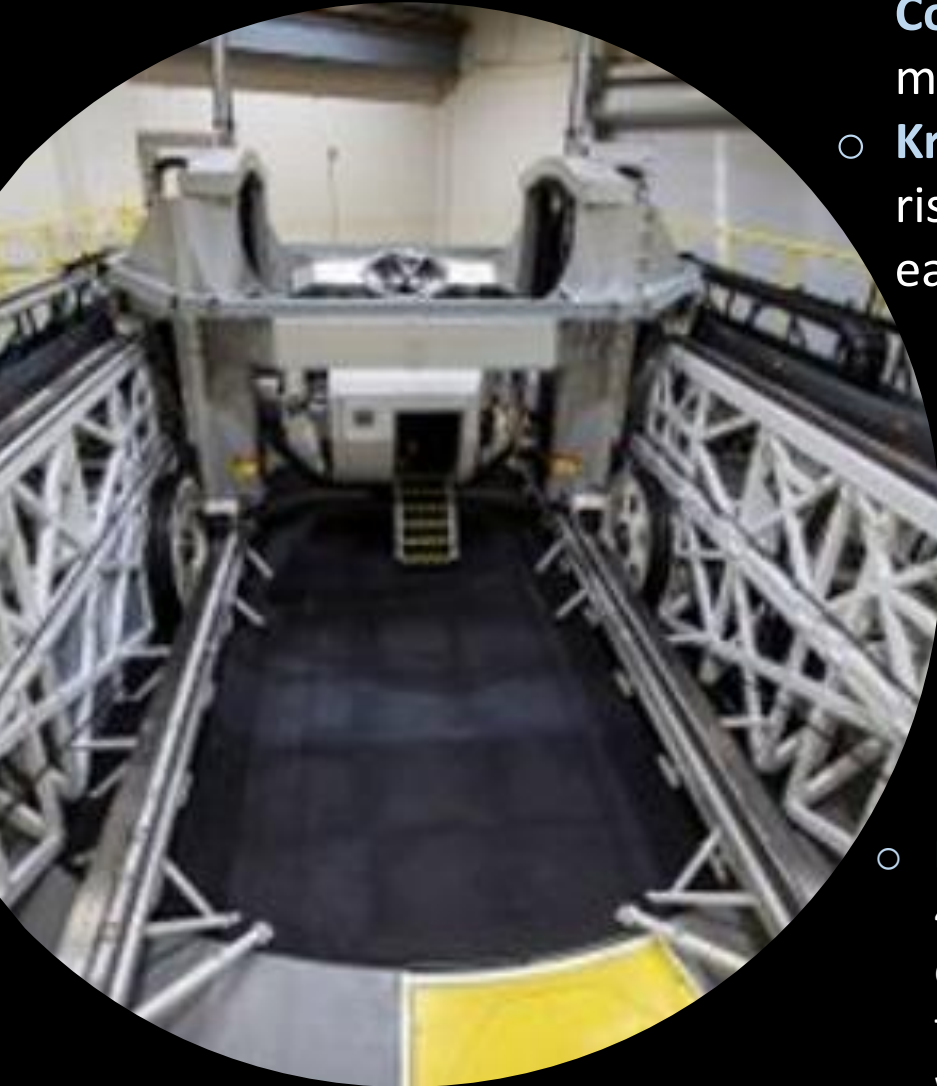


- **rHEALTH TECH DEMO PERFORMED ON ISS MAY 13 AND 16 – SAMPLES RETURNED SPACEX-25.**



rHEALTH (or reusable Handheld Electrolyte and Lab Technology for Humans) is a miniature flow cytometer for biomarker identification to assess biological changes in space and a medical analyzer designed for diagnosing and monitoring spaceflight medical conditions such as blood clots, kidney stones, radiation exposure, and other illnesses and injuries.

- **Human Exploration Research Analog (HERA) INTERNATIONAL HIGHLIGHTS**
 - **ROI hosted representatives from Mohammed Bin Rashid Space Center (MBRSC)** during pre-mission training and BDC activities for HERA C6M4 who shadowed ROI personnel. MBRSC personnel will return for in-mission observations in 2023.
 - **ROI is assessing MBRSC and ESA science proposals** for inclusion in HERA C7. Additionally, MBRSC will provide crewmembers for C7 and participate in C7 integration activities to help inform the development of their own isolation and confinement analog.



- **Artemis Prep: Microgravity Validation of Dry Saliva, Dry Blood Collection Protocols (Immune Biomarkers Study, PI: Crucian)** – New methodology validated in parabolic flight
- **Kraken** - Navy motion simulator to explore and mitigate HLS landing risks and test sensorimotor countermeasures for landing, egress and early EVA's.
- **HSIA Usability Scale** – Crew feedback used to improve usability scale for evaluating interfaces. Required by Gateway and HLS programs to aid provider development testing. (Holden)
- **Lighting for Spaceflight** – Updated NASA Standards document to reflect expert lighting recommendation to support circadian health and well-being (Brown et al., 2022)
- **Extended Mission Duration in HERA** – Publication highlights results from either, 45-day HERA Missions with 32 subjects. Mission duration had significant effect on spaceflight operational performance. Accuracy peaks mid-late quartiles, then degrades to baseline; however, workload decreased linearly, consistent with task learning over a campaign. (Duda, Draper))

HRP Science Highlights (Other)

- **SMALL BUSINESS INNOVATIVE RESEARCH (SBIR) SELECTIONS**
 - Space Radiation Element Countermeasures
 - Sensory Motor Device for Characterizing, Training, & Countermeasures
- **ARTEMIS / GATEWAY**
 - Artemis II - Flying two studies
 - Internal NASA Artemis Research & [Medical] Operations Working Group – formed to identify synergistic capabilities
 - Artemis III – identified payloads for lunar surface and orbit
 - Gateway Utilization Planning - Working with international partners
- **INTERNATIONAL AGREEMENTS**
 - CSA- PowerBlade/MicroPREP Technology Biological Sample Preparation
 - NASA and MBRSC (Mohammed Bin Rashid Space Centre) – Analogs
- **HRP IWS FEBRUARY 7-9, 2023 – In Person, Galveston, TX**
 - Abstracts due September 30, 2022
 - Initial Selections, October 2022

