NASA Human Research Program
Human Health and Performance for Space Exploration

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Chief Scientist
NASA Human Research Program

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UND Space Studies Colloquium
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).
Research to Enable Space Exploration

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

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
Human System Risks for Human Space Exploration

Altered Gravity - Physiological Changes
- Spaceflight Associated Neuro-ocular Syndrome
- Balance Disorders
- Fluid Shifts
- Cardiovascular Deconditioning
- Muscle Atrophy
- Bone Loss

Distance from earth
Drives the need for additional “self-reliant” medical care capacity – cannot come home for treatment

Hostile/Closed Environment
- Vehicle Design
- Environmental – CO₂ Levels, Toxic Exposures, Water, Nutrition/Food
- Decreased Immune Function, Microbiome Changes

Space Radiation
- Acute In-flight effects
  (controlled by vehicle design and operational constraints)
- Long term cancer risk

Isolation & Confinement
Behavioral aspect of isolation
- Sleep disorders

Integrated Human Performance

Drives the need for additional “self-reliant” medical care capacity – cannot come home for treatment
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/Sensorymotor 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

**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

#### Mars Flyby

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<thead>
<tr>
<th>Risks</th>
<th>FY17</th>
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<td>Injury from Dynamic Loads (OP)</td>
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<td>Host-Microorganism Interactions (Microhost)</td>
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<td>Bone Fracture (Fracture)</td>
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<td>Space Radiation Exposure - Acute Radiation SPE</td>
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<td>Concern of Intervertebral Disc Damage (IVD)</td>
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<td>Concern of Effects of Medication (PK/PD)</td>
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#### Milestone Requirements

- **ISS Mission Milestone**
- **Exploration Mission Milestone**
- **High LxC**
- **Mid LxC: Requires Mitigation**
- **Mid LxC: Accepted**
- **Optimized**
- **Insufficient Data**

**Milestone Requires ISS**

**Ground-based Milestone**

**ISS Not Required**

**ISS Required**

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**PPBE20 Baseline + FY18Q3**

8 Aug 2018

**End**

**ISS**

**EM-1**

**EM-2**

**EM-3**

**EM-4**

**EM-5**

**EM-6**

**EM-7**

**EM-8**

**EM-9**

**today**

**ISS End**
ISS: Space Platform for HRP Studies
ISS: Year in Space/Twins Study

**FUNCTIONAL INVESTIGATIONS**
- Fluid Shifts
- Ocular Health
- HBP
- Isometric Exercise
- Postural Instability
- Physical Performance
- Motor Skills
- Visual Acuity
- Visual Impairment
- Cardiac Function
- Metabolic Markers
- General Health
- Sleep

**OMICs**
- Proteins
- mRNAs
- microRNAs
- Chromatin
- Metabolomics
- Proteomics

**HUMAN FACTORS**
- Exercise
- Sleep
- Cardiac Function
- Metabolic Markers

**PHYSIOLOGICAL PERFORMANCE**
- Motor Skills
- Sleep
- Cardiac Function
- Metabolic Markers

**BEHAVIORAL HEALTH**
- Mood
- Cognitive Function
- Sleep

**MICROBIAL INVESTIGATIONS**
- Microbial Composition
- Microbial Function

**GREATNESS OF THE HUMAN EXPERIENCE**
- Exploration
- Collaboration

**ISS OPERATIONS**
- Spacewalks
- Space Station Operations
- Mission Planning

**ISS SCIENCE**
- Earth Observation
- Planetary Science
- Astrophysics

**ISS TECHNOLOGY**
- Spacecraft
- Launch Vehicles
- Ground Systems

**ISS RESOURCES**
- Power
- Water
- Oxygen

**ISS ARCHITECTURE**
- Module Configuration
- Space Station Architecture
- ISS Assembly

**ISS MANAGEMENT**
- Program Management
- Mission Planning
- Operations

**ISS IMPACT**
- Technology Transfer
- Education
- Public Outreach

**ISS PARTNERS**
- NASA
- International Partners
- Commercial Partners
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 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

Three multiweek research campaigns each calendar year

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
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)

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

Cosmonauts V.V. Polyakov and S.K. Krikalev
Altered Gravity Analogs

- Parabolic Flight
  (Fractional Gravity mission completed with DLR)

- :enviHab Facility (DLR, Cologne, Germany)
  (Artificial Gravity missions planned jointly with ESA)
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 CO₂)
- 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

- 11 volunteer test subjects (6 male, 5 female)
- 30-day strict HDT bed rest in 0.5% CO₂ (3.8 mmHg) environment
- Pre/post retinal thickness via Optical Coherence Tomography (OCT)
Next: cis-Lunar Space and Return to the Lunar Surface

THE JOURNEY CONTINUES
GATEWAY DEVELOPMENT
Establishing leadership in deep space and preparing for exploration into the solar system

FOUNDATIONAL GATEWAY CAPABILITIES

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<th>2022</th>
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<tr>
<td>50 kW-class Power &amp; Propulsion Element</td>
<td>Habitation and Utilization</td>
<td>Logistics and Robotic Arm</td>
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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

NRHO Near Rectilinear Halo Orbit

Orbit of the Moon

Orion

Bus shown for scale
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
Human Exploration Research Opportunity (HERO)

July – Annual Flagship and Omnibus Opportunity

November and March - Topic Specific Appendices

Working with HRP: https://www.nasa.gov/hrp/research

Current Research Announcements: https://www.nasa.gov/hrp/research/announcements
**Mission:** 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 exploration missions.

**TRISH: Funding human health research for space.**
Partnering with NASA through a cooperative agreement, the Translational Research Institute for Space Health (TRISH) funds transformative human health technologies to predict, protect, and preserve astronaut physical and mental wellness during deep space exploration missions. We fund high-risk, high-reward, human health and performance solutions that can be adapted for use in space. Focused on early stage (proof of concept) and late stage (market-ready) research, TRISH stands apart from other funding organizations due to our high-risk tolerance, our flexible grant mechanisms, and our ability to connect researchers with NASA scientists and space analogs.

https://www.bcm.edu/centers/space-medicine/translational-research-institute
Game-Changers: TRISH plus CIMIT Solicitation

CIMIT®
Consortia for Improving Medicine with Innovation & Technology

Accelerating Healthcare Innovation
CIMIT is a network of world-class academic and medical institutions partnering with industry and government. Our mission is to foster collaboration among clinicians, technologists, and entrepreneurs to accelerate innovation and catalyze the discovery, development, and implementation of innovative healthcare technologies.

POINT-OF-CARE DIAGNOSTICS FOR LONG-DURATION SPACE FLIGHTS

DEEP ARTIFICIAL INTELLIGENCE MEDICAL SUPPORT

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