Human Research Program

National Academies, Space Studies Board
Committee on a Midterm Assessment of Implementation of the Decadal Survey on Life and Physical Sciences Research

Steve Davison

7 February 2017

Human Research Program (HRP)

HRP mission is 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 the following:

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

ISS Research: Critical to Mitigating Mars Mission Human Health and Performance Risks

HRP is a high priority for NASA science payloads aboard ISS.

Each USOS crewmember participates in 10-15 separate experiments.

Compare Going to Mars to Where We Are Today with ISS

~ 1 – 2 days transit time

Communications (near real-time)

Crew exchanges

Crew supplies and logistics

Crew and atmosphere samples

Modified hardware

Emergency Crew Return

Trash

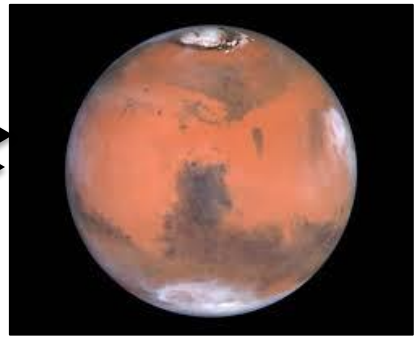
390 kilometers

“extreme car camping in space”

228,000,000 kilometers

~1 – 1.5 years transit time, ~2 – 3 years mission time

Communications (up to 42 minutes)



“ recreate living on Earth capability”

Crew Stressors in Deep Space Missions

Radiation

Altered Gravity Fields

Hostile Closed Environment

Isolation/Confinement

Distance from Earth

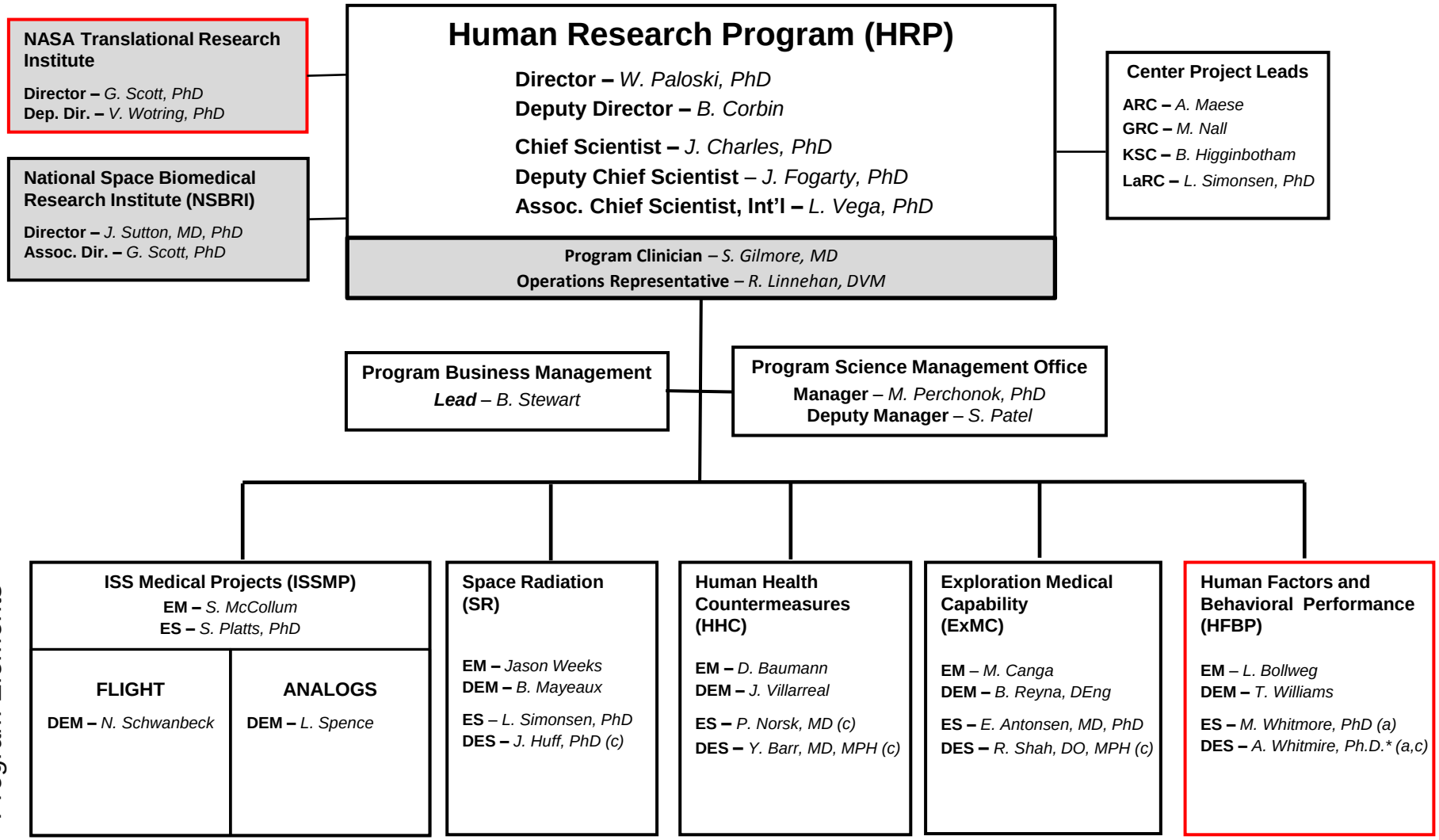
Astronauts on a Mars mission will experience unprecedented physiological, environmental, and psychosocial challenges that could lead to significant health and performance decrements in the absence of effective mitigation strategies.

HRP Research Elements: Align with Crew Stressors and Associated Human Risks

Human Health Countermeasures (HHC) →	**Altered Gravity Fields** *Balance Disorders, Visual Alterations, Immune Function, Muscle Atrophy, Bone Loss, Nutrition, Food, Cardiovascular, Microbiome, Countermeasures*
Behavioral Health & Performance (BHP) →	**Isolation/Confinement & Altered Light-Dark Cycles** Neurobehavioral and psychosocial *aspects, Sleep disorders, Monitoring/intervention tools*
Space Human Factors & Habitability (SHFH) →	**Hostile/Closed Environment** *Vehicle Design, Human system interface design (*lighting*, display/control, ergonomics, anthropometry, robotic interfaces), Occupant protection*
Space Radiation (SR) →	**Space Radiation** *Acute In-flight effects, Long-term cancer risk, CNS and Cardiovascular, Permissible exposure limits*
Exploration Medical Capabilities (ExMC) →	**Distance from Earth** *Autonomous medical care capability (monitoring, diagnostic, treatment), Medical data management, Probabilistic risk assessment*

**Note that effect severity generally increases with mission duration (i.e., time of exposure to stressor)*

HRP Organization



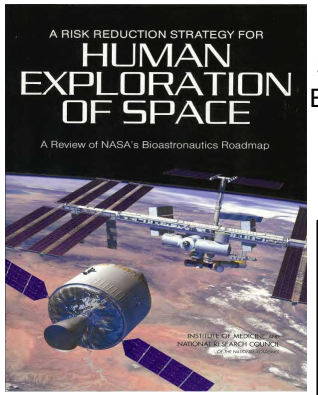
(c) = contractor

(a) = acting

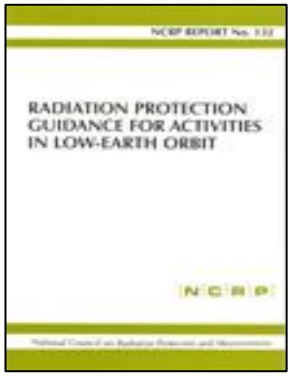
EM = Element Manager
DEM = Deputy Element Manager
ES = Element Scientist
DES = Deputy Element Scientist

External Research Community

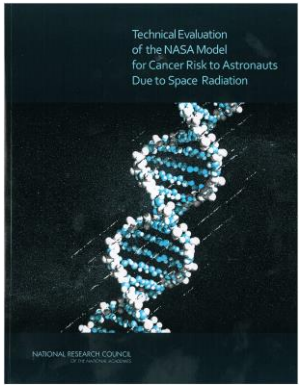
- **Strategic Planning**
  - National Academies (IOM, NRC)
    - Risk Reduction Strategy for Human Exploration of Space
    - Review of HRP Evidence Base and Merit Review Process
  - National Council on Radiation Protection (NCRP)
  - NASA Advisory Committee (NAC)
- **Science Planning**
  - Standing Review Panels (SRP)
  - Research and Clinical Advisory Panels for Visual Impairment, Space Radiation Health, Bone Health
  - Lunar Atmospheric Dust Toxicity Assessment Group
  - Decompression Risk Review, Dental Working Group
  - Habitable Volume Workshop
- **Research Implementation**
  - National Research Solicitations
    - Human Exploration Research Opportunities (HERO): Crew Health and Performance, Space Radiobiology
  - Graduate Student and Post-Doctoral Programs



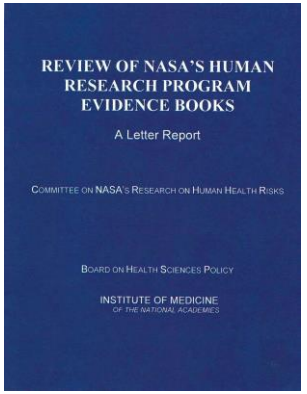
A Risk Reduction Strategy for Human Exploration of Space



National Council on Radiation Protection & Measurement

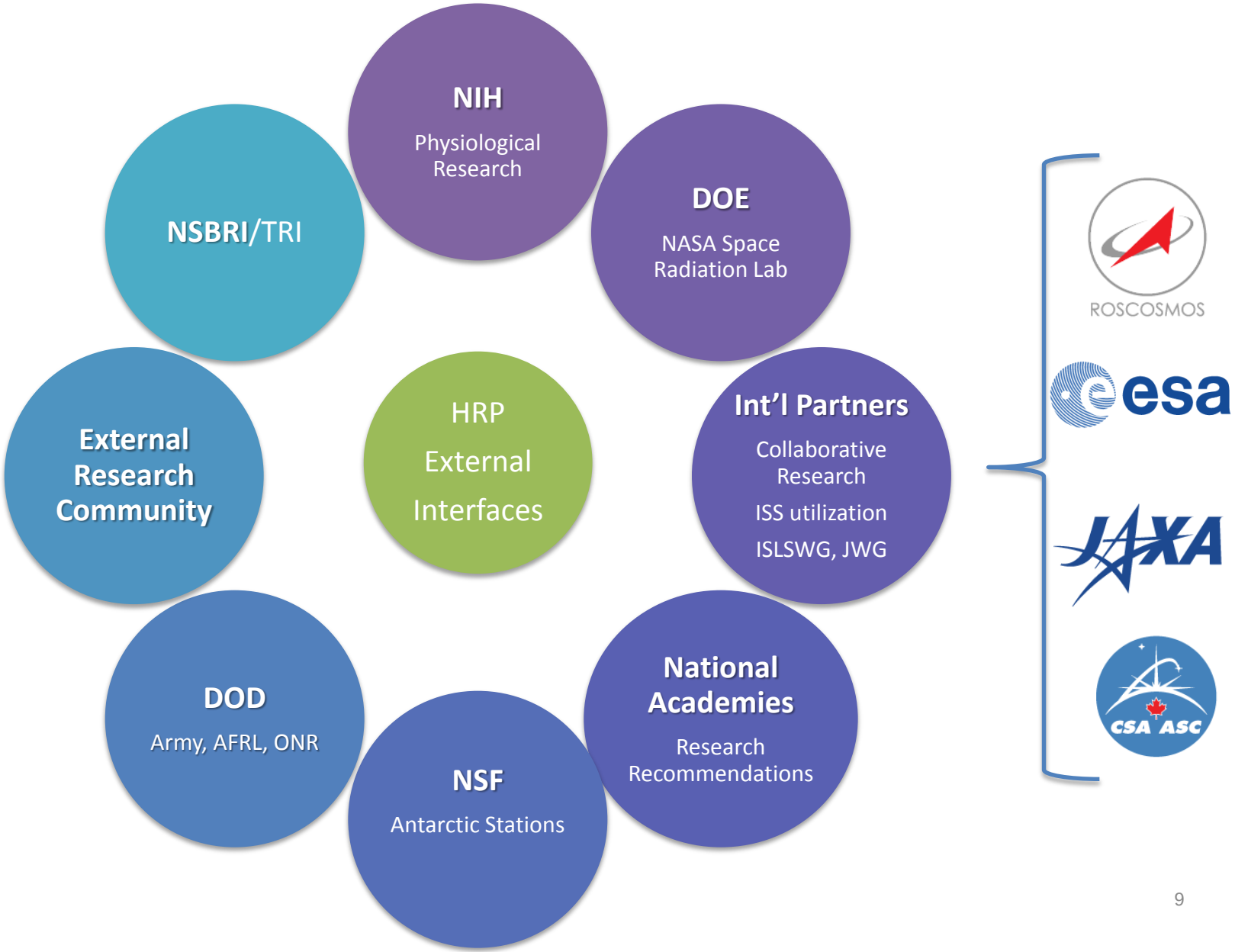


NRC Report on NASA Cancer Risk Models



IOM Review of NASA's Human Research Program Evidence Books

External Interfaces/Collaborations



International Research Coordination

- **International Space Life Sciences Working Group (ISLSWG)**
  - ❖ NASA, ESA, JAXA, CSA, DLR, CNES, ASI
  - ❖ International Life Science Research Announcement
- **US/Russian Joint Working Group (JWG) on Space Biomedical and Biological Sciences**
  - – Joint sub-groups: (i) Biomedical (ii) Crew Health and Medical Support (iii) Biological Sciences
- **Multilateral Human Research Panel for Exploration (MHRPE)**
  - – CSA, ESA, JAXA, NASA, Roscosmos
  - – ISS exploration fly-off plan for multilateral biomedical research
  - – ISS One-year missions

Inter-Agency Collaboration

- NASA/NIH Memorandum of Understanding (Recently Signed)
  - MOU sets forth a framework of cooperation between NIH/NASA on space and Earth related biomedical research that benefits health on Earth & enables space exploration
- NASA/Department of Energy (DOE) on NASA Space Radiation Laboratory (NSRL)
  - NSRL provides charged particles for space radiation research on carcinogenesis, CNS, and degenerative tissue effects; shielding materials, radiation sensitivity of electronics and nuclear physics
- NASA/National Science Foundation (NSF)on Polar Biomedical Research
  - Human performance research in Antarctic Polar Stations provides extreme environment operational experience and research data with stressors similar to those found in spaceflight
- NASA/Naval Submarine Medical Research (NSMRL) Laboratory Agreement
  - High performance operational teams, like those on U.S. submarines and NASA flight crews, face common issues including maintaining effective operational team performance during prolonged stressful missions.
- NASA/Department of Defense (DoD)-Natick on Advanced Food Technology
  - NASA and DOD (U.S. Army Soldier Systems Center- Natick) are working on a common goal to produce nutritionally balanced, high-calorie meal bars that reduces volume while providing longer shelf life
- NASA/DOD/VA Collaboration (In Development)
  - NASA, DoD, and the VA Medical S&T are discussing medical research, technologies and practices focused on deployable medical capabilities and behavioral research

Internal Integration and Coordination

OCHMO and OCS
- Medical and Science Policies

Advanced Exploration Systems
- Space Radiation Shielding/MSL RAD
- NASA Space Radiation Lab. Upgrade
- Crew Mobility Systems & EVA Surface Suit
- Habitat Testing: volume, Ops concepts, design
- Interface Display & Control Unit Studies
- HERA Mission Tasks/Fidelity: Flight Simulator

Crew Health & Safety (ISS Med Ops)
- VIIP, CO2 levels, Exercise Studies
- Astronaut Occupational Surveillance
- Crew Health Risk Assessment
- Cognitive Function and Measures
- Space Radiation Protection (SRAG)
- LSAH Database

Science Mission Directorate
- Solar System Explor. Rsrch. Virtual Inst. (SSERVI)
- Space Radiation Environment
  - LRO-CRaTER radiation measurements
  - SEP monitoring/characterization
  - MSL-RAD measurements of radiation during transit & on the surface of Mars

ISS Program
- MHRPE: ISS One-year Mission
- Russian collaborations (Field Test, Fluid Shifts)
- MARES Research (ESA/US/Roscosmos)
- Advanced Exercise Device
- ARED Platform
- Technology Demonstrations

Orion
- EM2 objectives in work
- Vibration validation assessments (EM1)
- E-Procedure Validation (EM2)
- Food System Mass Reduction
- Exercise hardware
- Human Testing using Orion seat and suit prototypes

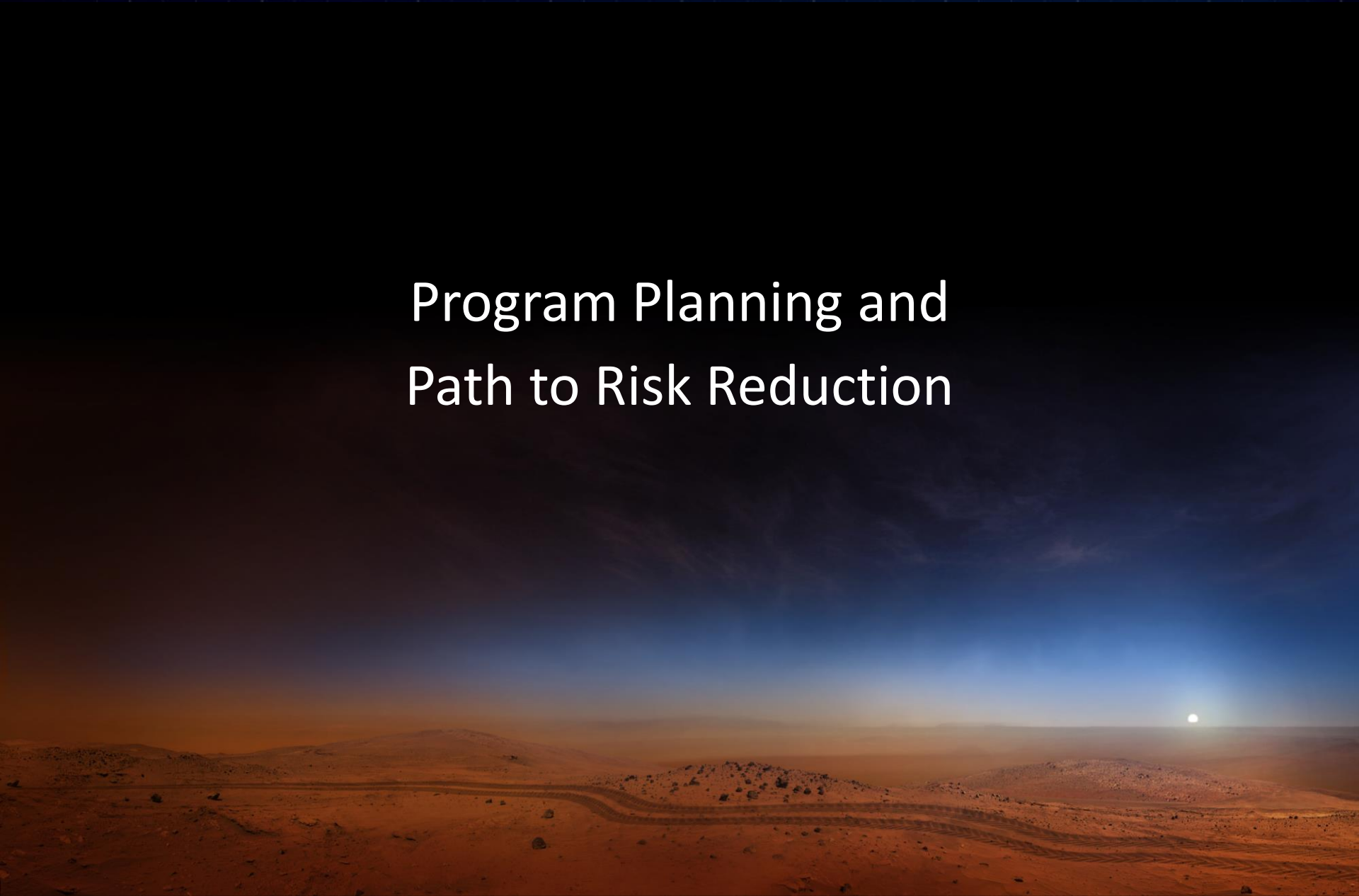
Space Technology Mission Directorate
- SBIR (Integral part of HRP's R&T Plan)
- Thick Radiation Shielding Project
- NASA Space Radiation Lab. Upgrade

Space Biology
- Advanced Food: Pick & Eat Veggies
- Microbial Assessment/Observatory
- Translational Research Roadmap
- Bioinformatics
- Artificial Gravity Studies
- LSDA Database

HRP Approach Summary

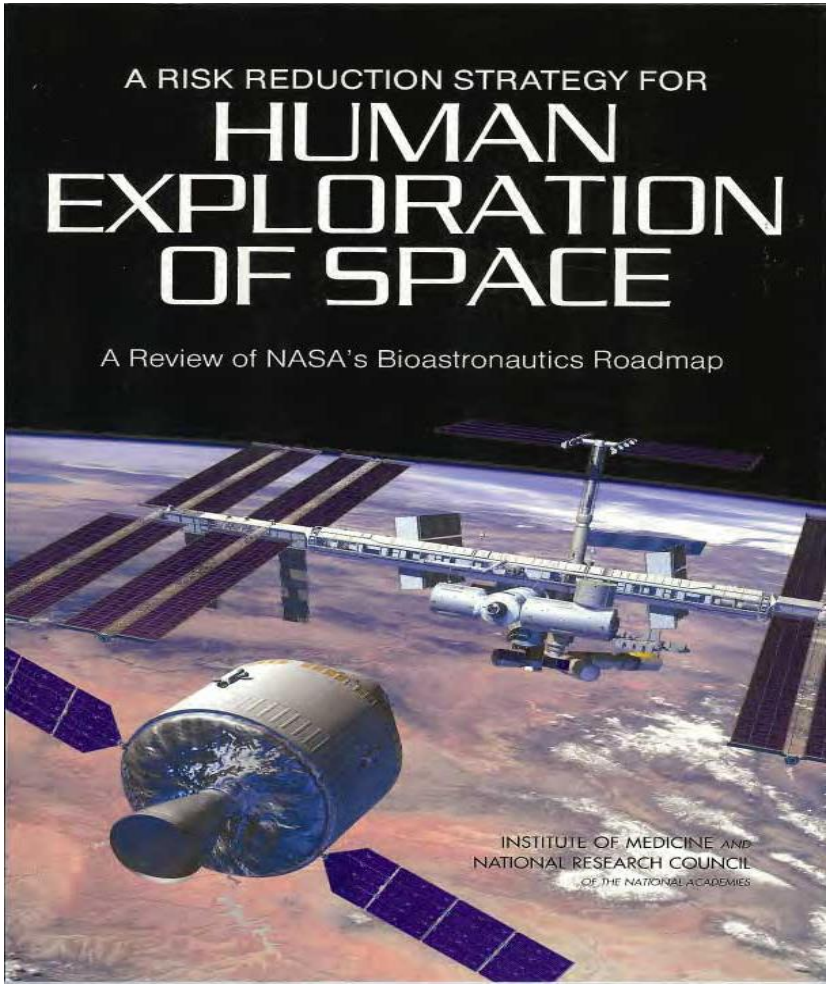
- Enable NASA human exploration goals by conducting flight and ground research to mitigate highest risks to human health and performance on current and future exploration missions
- Fully utilize ISS research and operational capabilities to mitigate human health space exploration risks to an acceptable level
- Establish research priorities consistent with guidance from the National Academies, other external independent reviews, and NASA Health and Medical Technical Authority (HMTA) assessments
- Implement an open competitive solicitation process and independent, external scientific peer review to ensure highest quality research
- Leverage resources and expertise through collaborative research with other NASA programs, international partners, and other US agencies
- Review portfolio regularly to rebalance work and ensure ISS research subjects are efficiently utilized to mitigate highest risks to human health

Program Planning and Path to Risk Reduction



Integrated Risk Planning Framework

"Human space flight remains an endeavor with substantial risks, and these risks must be identified, managed, and mitigated appropriately to achieve the nation's goals in space."



HRP works within an integrated framework to mitigate human health & performance risks

Human Risks of Spaceflight
Grouped by Hazards – 30 Risks

Altered Gravity Field

1. Spaceflight-Induced Intracranial Hypertension/Vision Alterations
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
10. Cardiac Rhythm Problems
11. Space Adaptation Back Pain

Concerns

1. Clinically Relevant Unpredicted Effects of Meds
2. Intervertebral Disc Damage upon re-exposure to μg
3. Health/Performance impacts of White Matter Hyperintensities

Radiation

1. Adverse Health Outcomes and Performance Decrements resulting from Space Radiation Exposure(cancer, cardio & CNS)

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

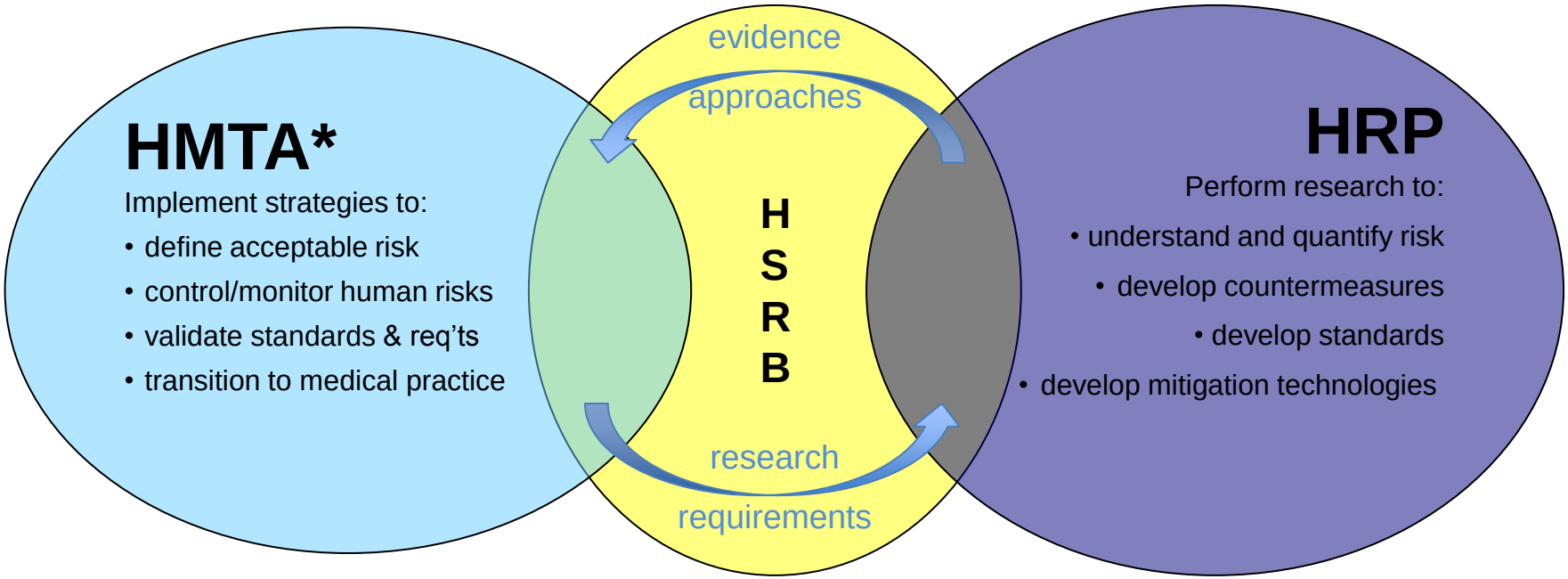
Isolation

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-Spacecraft Design

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

Human System Risk Board (HSRB)

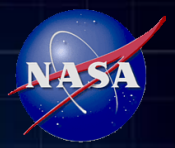


**NASA Health & Medical Technical Authority*

Human System Risk Board

- *HMTA/Space Medicine (chair)*
- *HRP/Human Research*
- *Environmental Science*
- *Human Factors Engineering*
- *Space Flight Operations*
- *Crew Office*

Human Risks Disposition for all Design Reference Missions



	In Mission Risk - Operations						Post Mission Risk - Long Term Health					
Human System Risks 07/01/15	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/Habitation	Planetary	Low Earth Orbit	Low Earth Orbit	Deep Space Sortie	Lunar Visit/Habitation	Deep Space Journey/ Habitation	Planetary
	6 Months	12 Months	30 Days	1 year	1 Year	3 years	6 Months	12 Months	30 Days	1 year	1 Year	3 years
VIIP	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Renal Stone Formation	A	A	A	A	RM	RM	RM	RM	RM	RM	RM	RM
Inadequate Food and Nutrition	A	A	A	A	A	RM	A	A	A	A	A	RM
Space Radiation Exposure	A	A	A	A	A	TBD*	A	A	A	RM	RM	RM
Medications Long Term Storage	A	A	A	A	A	RM	A	A	A	A	A	RM
Acute and Chronic Carbon Dioxide	A	A	A	A	RM	RM	A	A	A	A	A	A
Inflight Medical Conditions	A	A	A	RM	RM	RM	A	A	A	RM	RM	RM
Cognitive or Behavioral Conditions	A	RM	A	RM	RM	RM	A	A	A	A	A	RM
Bone Fracture	A	A	A	A	A	RM	A	A	A	A	A	A
Human-System Interaction Design	A	A	A	RM	RM	RM	A	A	A	A	A	A
Team Performance Decrements	A	A	A	A	RM	RM	A	A	A	A	A	A
Cardiac Rhythm Problems- Under Review	A	A	A	A	RM	RM	A	A	A	A	A	A
Reduced Muscle Mass, Strength	A	A	A	A	A	RM	A	A	A	A	A	RM
Reduced Aerobic Capacity	A	A	A	A	A	RM	A	A	A	A	A	RM
Sensorimotor Alterations	A	A	A	RM	RM	RM	A	A	A	A	A	RM
Injury from Dynamic Loads	A	A	RM	RM	RM	RM	A	A	RM	RM	RM	RM
Sleep Loss	A	A	A	A	RM	RM	A	A	A	A	RM	RM
Altered Immune Response	A	A	A	A	A	RM	A	A	A	A	A	RM
Celestial Dust Exposure	N/A	N/A	TBD	A	TBD	TBD	N/A	N/A	TBD	A	TBD	TBD
Host-Microorganism Interactions	A	A	A	A	A	RM	A	A	A	A	A	RM
Injury due to EVA Operations	A	A	A	RM	A	RM	A	A	A	RM	A	RM
Decompression Sickness	A	A	RM	A	RM	A	A	A	A	RM	A	RM
Toxic Exposure	A	A	A	A	A	A	A	A	A	A	A	A
Hypobaric Hypoxia	RM	RM	A	RM	RM	RM	RM	RM	A	RM	RM	RM
Space Adaptation Back Pain	A	A	A	A	A	A	N/A	N/A	N/A	N/A	N/A	N/A
Urinary Retention	A	A	A	A	A	A	A	A	A	A	A	A
Hearing Loss Related to Spaceflight	A	A	A	A	A	A	A	A	A	A	A	A
Orthostatic Intolerance	A	A	A	A	A	A	A	A	A	A	A	A
Injury from Sunlight Exposure	A	A	A	A	A	A	A	A	A	A	A	A
Electrical shock	A	A	A	A	A	A	A	A	A	A	A	A

A – Accepted RM- Requires Mitigation

Green – low/very low consequence Yellow – low to medium consequence Red – high consequence

Research Planning Cycle

Evidence Base – Flight and Ground
- Research
- Clinical
- Operational experience

Reviewed by IOM

Human Health & Performance Risks

HSRB Dispositioned Risks

Exploration Missions & Architectures

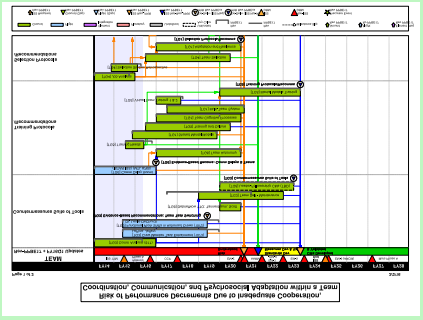
NASA Spaceflight Human System Standards

Reviewed by Standing Review Panels

Research Gaps

Prioritization/Implementation Constrained by
- Customer need dates
- Budgets
- Research platform availability

Integrated Research Plan



Solicitations & Directed Research

Peer Review

Results and Deliverables
- Mitigate Risks
- Inform Standards
- Countermeasures
- Medical Technologies

Customer Review

HRP Solicitations, Tasks, and Publications

National Aeronautics and Space Administration
Johnson Space Center
Human Exploration and Operations Mission Directorate
Human Research Program
Houston, TX 77058

Human Exploration Research Opportunities (HERO)

NNJ16ZSA001N-FLAGSHIP1

Appendix B

NASA Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions

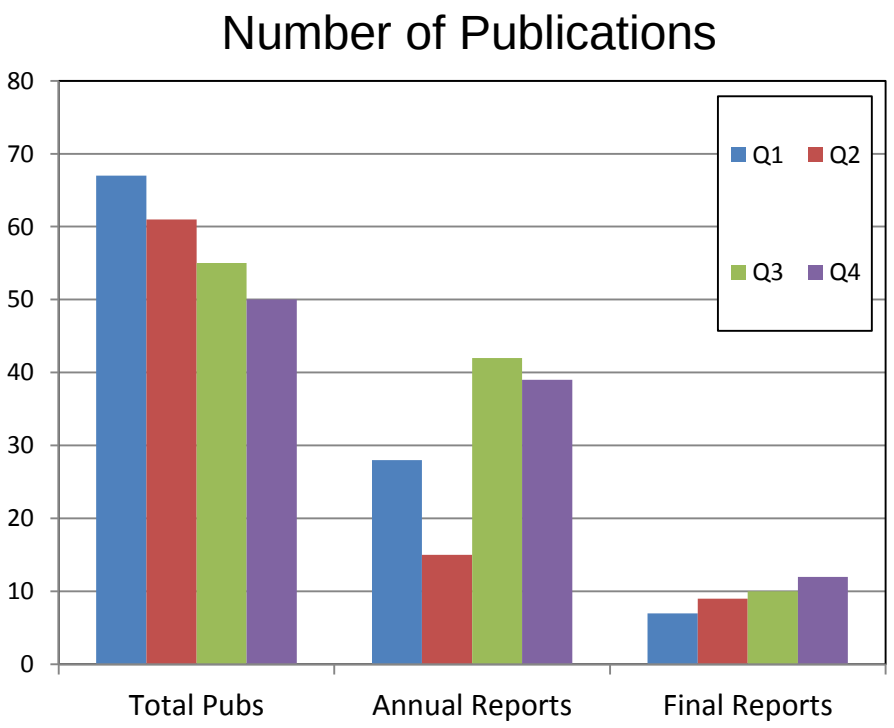
Step-1 Response Period: September 1, 2016 – October 3, 2016
Step-1 Proposals Due: October 3, 2016, 5 PM Eastern Time
Step-2 Response Period: October 17, 2016 – December 16, 2016
Step-2 Proposals Due: December 16, 2016, 5 PM Eastern Time
Estimated Step-2 Selection Announcement: April 2017

Appendix B - 1

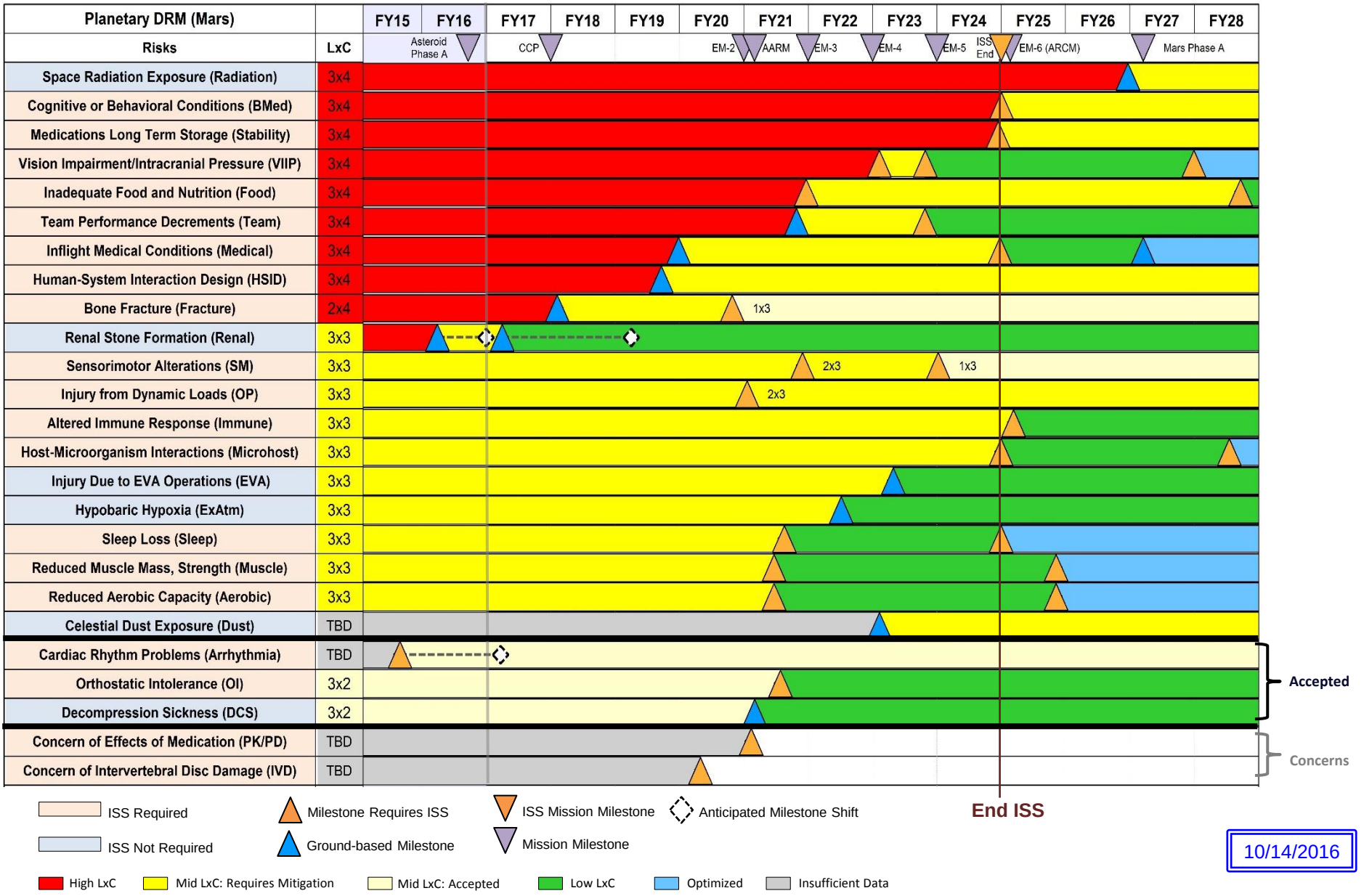
Human Exploration Research Opportunities (HERO) Solicitation

FY 2016

307 Tasks, 255 PIs, 118 Institutions

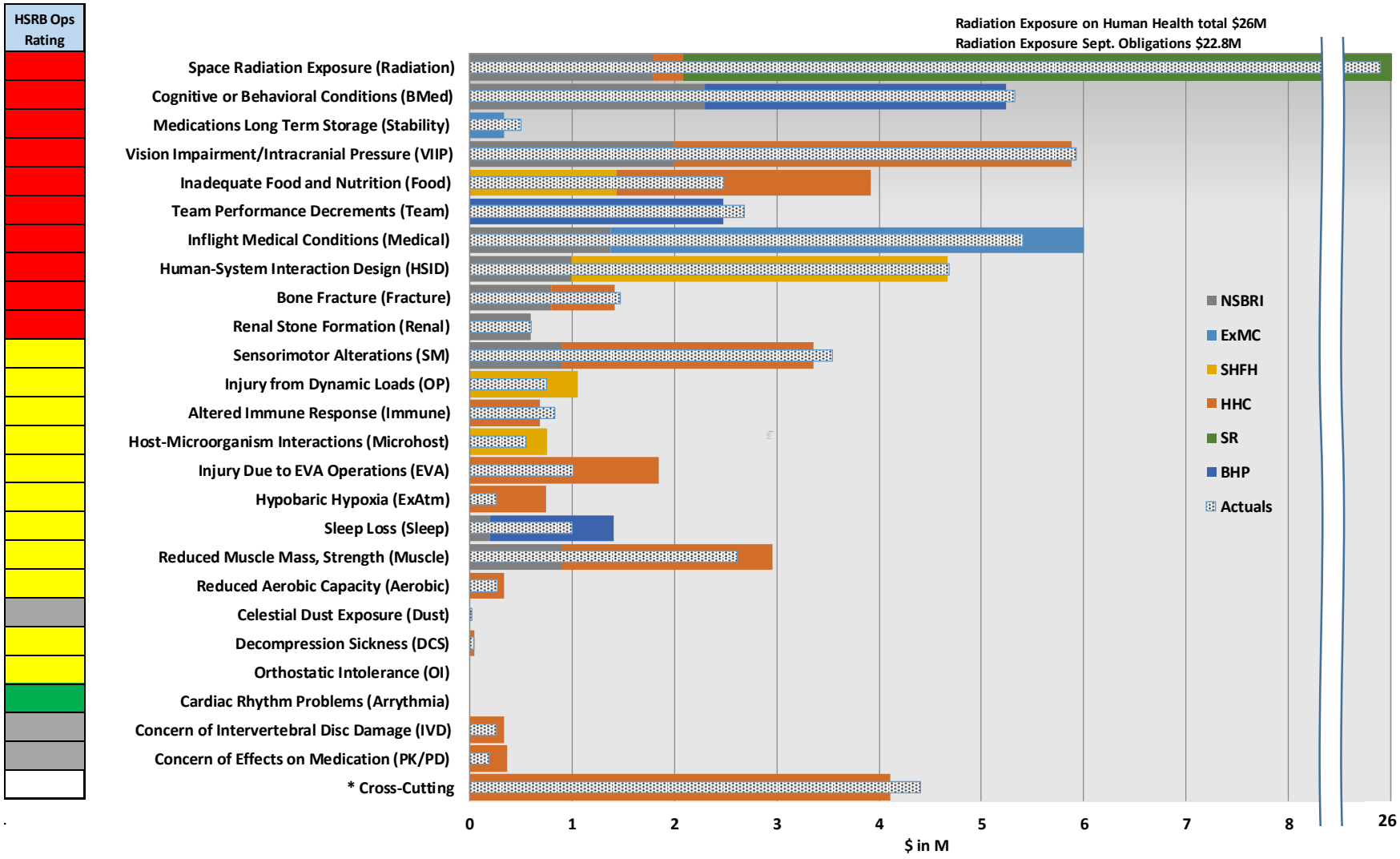


HRP Integrated Path to Risk Reduction (Mars)



10/14/2016

HRP R&D Investment by Risk



HRP Risk Mitigation Maturation Plan

~2035–20nn

Fine-tune mitigation approaches

- Exploration vehicles
- Planetary surfaces

~2021–2030

Validate mitigation approaches

- Orion
- Deep-space hab
- Lunar surface (?)

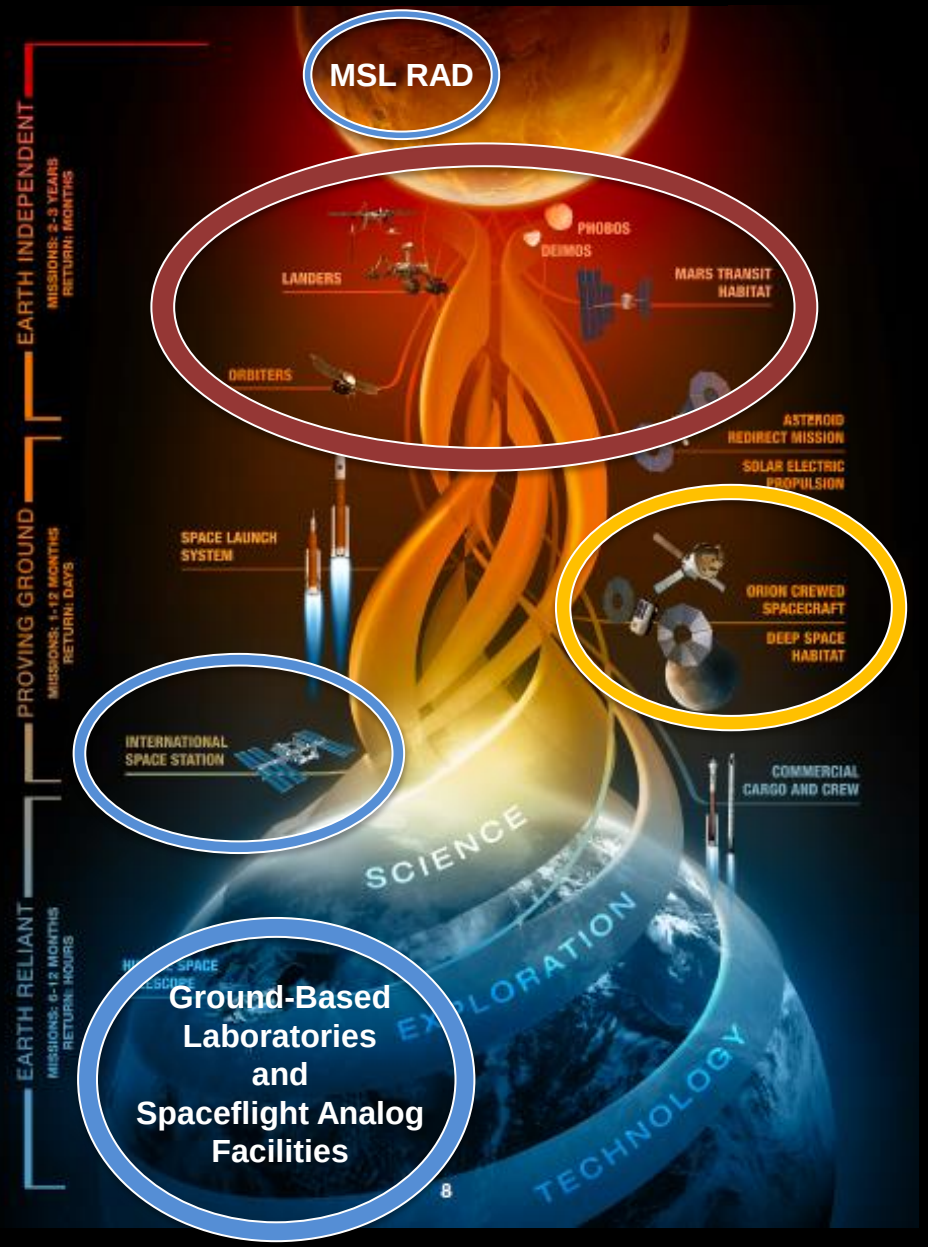
Inform exploration system designs

Now–2024 (+/-)

Develop/test mitigation approaches

- ISS
- Spaceflight analog facilities
- Ground-based laboratories

Inform deep-space hab designs

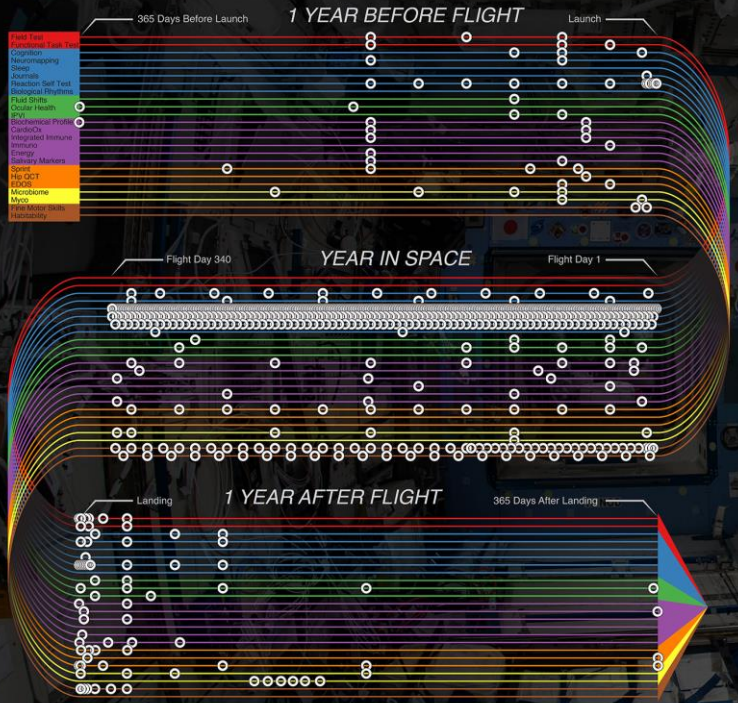


Research Activities

National Aeronautics and Space Administration

ONE YEAR in SPACE
THREE YEARS of SCIENCE

Through research on astronaut Scott Kelly in seven major areas, we will improve our understanding of how the human body reacts to long-duration spaceflight. Testing began one year before his launch, intensified during his 340 days in space, and will continue for a year — or longer — after his return to Earth. Each line below represents one of the investigations for the Year in Space, and the circles indicate data collection points such as blood draws, ultrasound scans and cognition tests. The results of this research will help prepare us for future voyages beyond low-Earth orbit.



FUNCTIONAL INVESTIGATIONS *(Field Test, Functional Task Test)*: Can Scott perform tasks such as walking or opening a spacecraft hatch after landing? It's a lot harder after a year in microgravity!

BEHAVIORAL HEALTH *(Cognition, Neuromapping, Sleep, Journals, Reaction Self Test, Biological Rhythms)*: Has living in space affected Scott's psychological health? Stressful environments can impair cognitive performance.

VISUAL IMPAIRMENT *(Fluid Shifts, Ocular Health, IPVI)*: Has Scott's vision been impaired? Fluid shifts in microgravity can put pressure on the optical nerves.

METABOLIC INVESTIGATIONS *(Biochemical Profile, CardioOx, Integrated Immune, Immuno, Energy, Salivary Markers)*: How is Scott's immune system? He even got a flu shot while he was in space!

PHYSICAL PERFORMANCE *(Sprint Study, Hip QCT, EDOS)*: How strong are Scott's bones, muscles and cardiovascular system? The body deconditions in microgravity, so astronauts exercise two hours each day.

MICROBIAL INVESTIGATIONS *(Microbiome, Myco)*: Will Scott's microbiome change in space? Environmental changes affect Earth's organisms and ours, too.

HUMAN FACTORS *(Fine Motor Skills, Habitability)*: Will Scott's fine motor control diminish? Fine motor skills are important for controlling spacecraft.

Some investigations may collect data beyond the one-year post-flight mark. Learn more about each investigation represented above at: www.nasa.gov/1ym/research

INTERNATIONAL SPACE STATION
OFF THE EARTH, FOR THE EARTH

U.S./Russian Field Test Studies

Twins Study (Scott and Mark Kelly)

Begin to examine next generation genomics solutions to mitigating crew health and performance risks: Personalized countermeasures

National Research Team

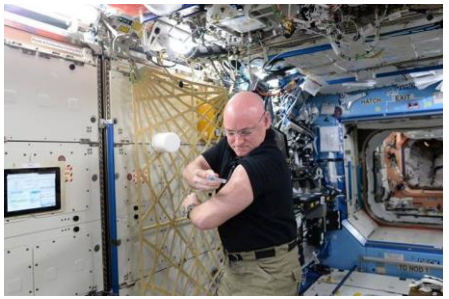
- Genome, telomeres, epigenome, transcriptome, epitranscriptome
- Proteome, Metabolome, Microbiome
- Physiology and Cognition

Significant Privacy and Ethics Issues

NASA developed a new genomics policy (modeled after NIH policy) that addresses informed consent, data privacy approaches, and genetic counseling on consequences of discovery (individual, family)

Preliminary Results Presented at HRP IWS (January 2017)

- RNA sequencing showed more than 200,000 RNA molecules that were expressed differently between the twins
- Scott's telomeres on the ends of chromosomes in his white blood cells increased in length while in space (shortened again on return)
- Microbiome shift in microbial species included a change in ratio of two dominant bacterial groups (i.e., Firmicutes/Bacteroidetes) present in Scott's GI tract
- Flu vaccines: T cell receptors were created and increased in both twins which was the expected immune response



Circadian Regulation via Lighting

- Astronaut Kate Rubins recently installed new lighting in the ISS that emits light in wavelengths that can be tuned to help astronauts get a better night's sleep
- Solid-state lighting assembly (SSLA) is an example of the ISS testing underway to prepare for eventual human travel to Mars.

Michael Fincke holding a General Luminaire Assembly (GLA) in Node 2.

Solid State Lighting Assembly (SSLA)

- Energy efficient, longer life span, no toxic mercury vapor.
- Excellent, bright light for visual performance and color discrimination
- Suppresses melatonin to better manage circadian rhythms.
- Provides spectral adjustments to aid sleep and circadian disruption
  - Blue shifts for the morning
  - Red shifts for the evening

Flight unit Solid State Lighting Module (SSLM)

Delivery and Testing Aboard ISS

- 7/16: 1st 4 SSLAs launched on SpX-9
- 10/16: Kate Rubins installed 3 SSLAs in Crew Quarters
- 11/16 Lighting Effects Flight Study begins on 49S
- 12/16: Next 11 SSLAs launch on HTV6

NASA Space Radiation Lab (NSRL) DOE/BNL

Began testing GCR simulator during Fall 2016 run.

- Simulates the space radiation environment- high energy ion beams (H^+, Fe, Si, C, O, Cl, Ti, etc.) individually or together.
- Beam line, target area, dosimetry, biology labs, animal care, scientific, logistic and administrative support
- 3 experimental campaigns per year
- Space Radiation Summer School

NSRL Beam Line

Images Courtesy of Brookhaven National Laboratory (BNL)

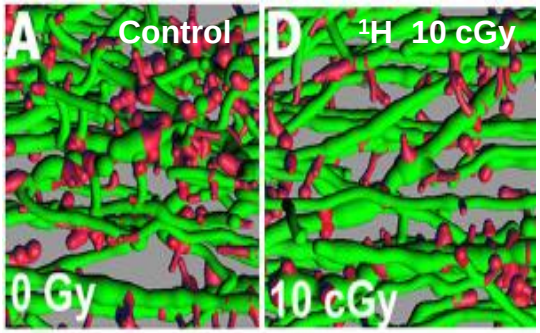
Space Radiation Health Risks

Health Risk Areas	Status
Carcinogenesis Space radiation exposure may cause increased cancer morbidity or mortality risk in astronauts	➢ Cancer risk model developed for mission risk assessment ➢ Model is being refined through research at NASA Space Radiation Laboratory (NSRL) ➢ Health standard established
Acute Radiation Syndromes from SPEs Acute (in-flight) radiation syndromes, which may be clinically severe, may occur due to occupational radiation exposure	➢ Acute radiation health model has been developed and is mature ➢ Health standards established ➢ Risk area is controlled with operational space radiation monitoring & shielding mitigations
Degenerative Tissue Effects Radiation exposure may result in effects to cardiovascular system, as well as cataracts **Central Nervous System Risks (CNS)** Acute and late radiation damage to the central CNS may lead to changes in cognition or neurological disorders	➢ Non-cancer risks (**Cardiovascular and CNS**) are currently being defined ➢ Research is underway at NSRL and on ISS to address these areas ➢ Appropriate animal models needed to assess clinical significance

NASA Space Radiation Laboratory (NSRL) Research

Central Nervous System (CNS) Effects from Space Radiation

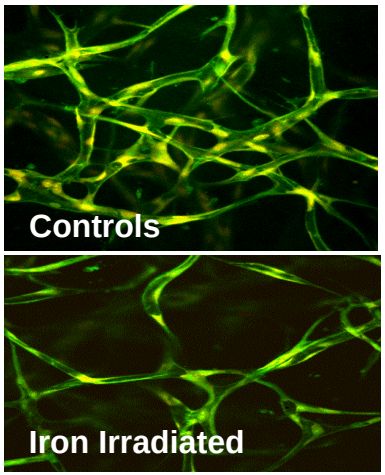
- Research with animal models shows changes to the CNS at exposure levels in range of concern to NASA
- Current research is focused on establishing significance, mechanistic basis, and of dose thresholds for these effects
- Major uncertainty in how to extrapolate results from animals to humans
- NCRP Committee (Radiation Exposures in Space and the Potential of Central Nervous System Effects) will provide guidance on future research



Structural Changes in Neurons: Dendritic spines (red) are lost after 10 cGy of protons

Cardiovascular Effects from Space Radiation

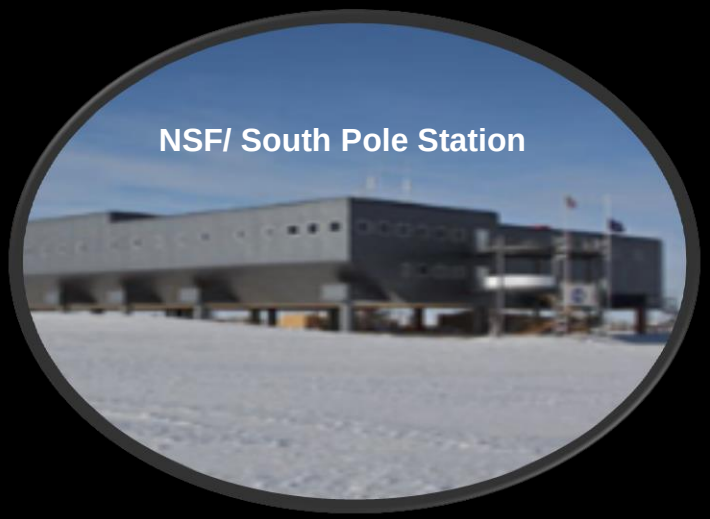
- Current research is focused on understanding and quantifying the risk of cardiovascular effects at space-relevant exposures
- Establish whether a dose threshold exists, influence of dose-rate, and establish individual sensitivity
- Necessity for life span studies in appropriate animal models



Vasculature damage: μm of vessel per cell after protons or Fe (C. Geard Columbia U)

Isolation and Confinement Analogs

NASA HERA:
3-4 Missions/yr
4 Crew
14, 30, 45 d



NASA/NSF:
Multiple Stations winter overs+

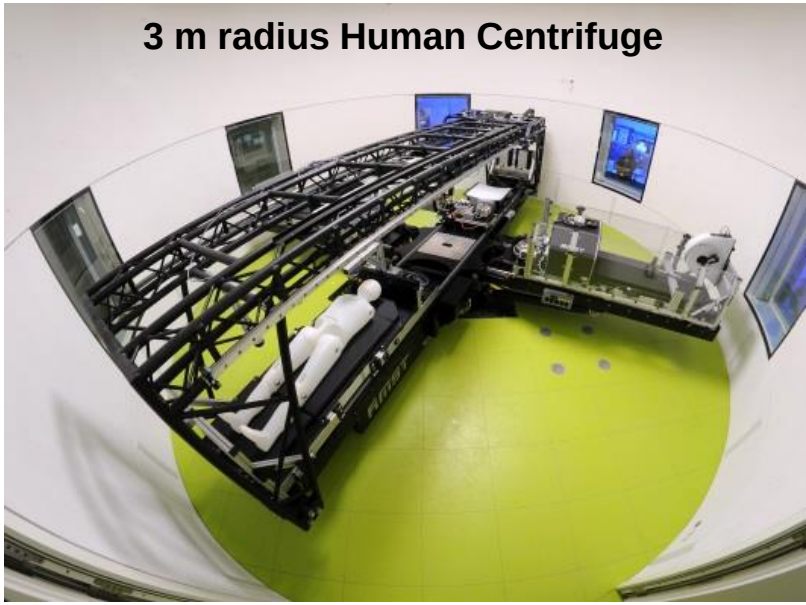
US/Russian (IMBP/NEK):
4 (2018), 8, 12 month

Joint NASA/ESA AG-Bedrest Solicitation

Physiological and Behavioral Responses in Humans to Intermittent Artificial Gravity during Bed Rest

Research to be carried out during two 60-day bedrest campaigns at the DLR's :enviHab facility in Cologne, Germany (2017, 2018).

- Coordinated solicitations
- Common peer review (NRESS)
- Coordinated selections to maximize scientific gain
- Shared facility costs
- International Investigator Working Group: data sharing and coordinated publications

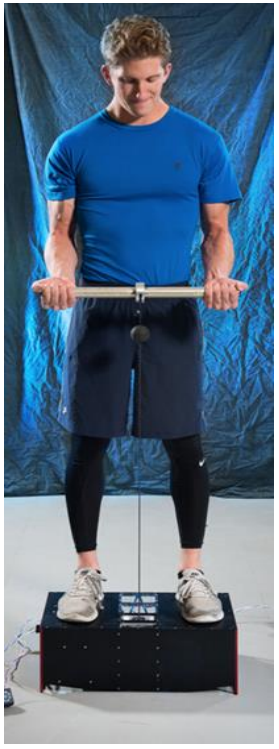


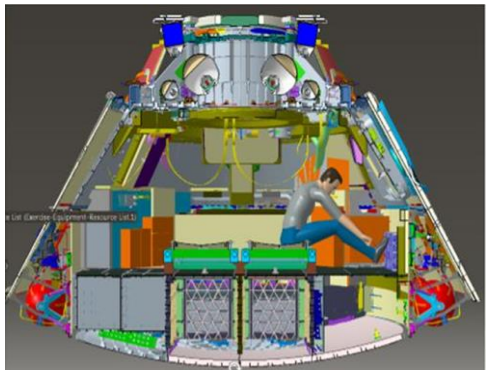
	SM1	CV3	VIIP1	M23	Osteo4	AGEGap1	AGEGap3	AGEGap4
NASAEAGBRED009E	X	X	X			X	X	X
NASAEAGBRED020	X	X				X	X	X
NASAEAGBRED011	X					X	X	X
NASAEAGBRED013					X	X	X	X
ESAEAGBRED014	X					X	X	X
ESAEAGBRED031		X				X	X	X
ESAEAGBRED013	X			X		X	X	X
ESAEAGBRED017						X	X	X
ESAEAGBRED018				X		X	X	X
ESAEAGBRED018					X	X	X	X
ESAEAGBRED005						X	X	X
StandardEMeasures	X	X	X	X	X	X	X	X

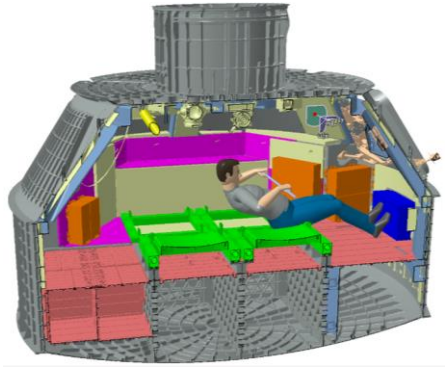
MPCV Exercise Device (ROCKY*) Status

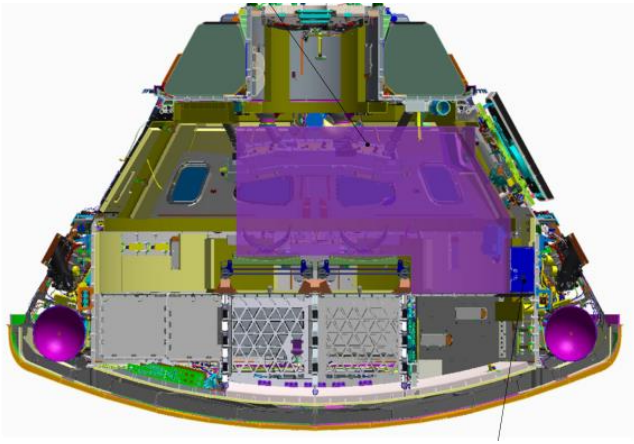
Design/Capabilities

- Servo-motor controlled, single cable exercise system
- Provides resistive loads up to 400 lbf at velocities up to 2 m/s
- Software-modifiable exercise loading profiles
  - Inertial characteristics of free weights for resistive training
  - Oar/boat loading dynamics for aerobic (rowing) training
  - Custom profiles for eccentric overloading, weight racks, etc.
- Capacitor bank allows unpowered operation in rowing mode









Status

- 10/18/16: SRR held at GRC
- 11/22/16: RID Review Board

**Resistive Overload Combined with Kinetic Yo-yo*

Deep Space Exercise Device (ATLAS*) Status

Objectives:

- Develop exercise hardware for exploration
- Base on ISS exercise CM hardware suite
- Minimize mass, power, volume and highly
- Maximize reliability, versatility, effectiveness

Development Approach:

- Leverage the MPCV/ROCKY efforts
- Demonstrate/validate on ISS (NET 2019)
- Augment/replace ARED after initial valid

Design Goal: ATLAS will exceed ARED capabilities at 1/10 of its mass and volume

Design Specification Goals:

Accommodation (carrier)	ISS
Up-mass (lbm)	200 lbm target
Stowed Volume (ft^3)	3.0 ft^3 target
Peak Power (W)	480 W target
Life Cycle Count	750,000 cycles / year
Launch / Increment	Year 2019

*Advanced Twin Lifting and Aerobic System

Prototype

Prototype

ATLAS Flight Concept

Renal Stone Formation Risk Mitigation

Risk of renal stone formation/development is elevated during and early after flight

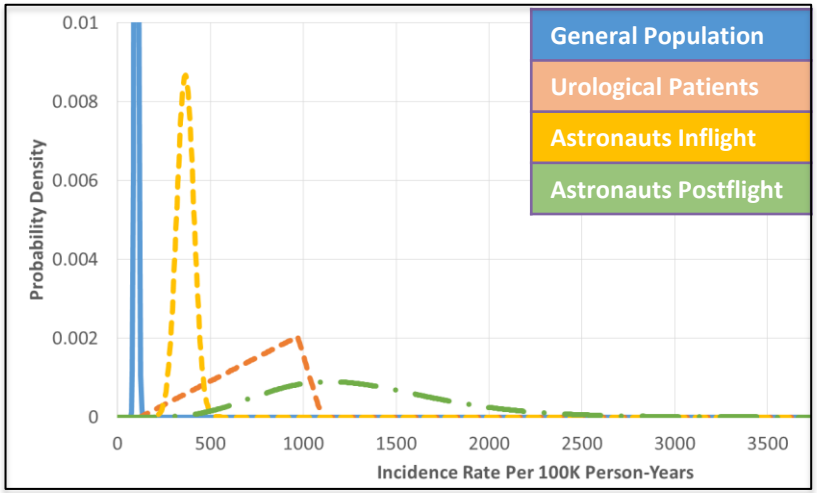
- Fluid redistribution, bone loss, muscle atrophy, diet

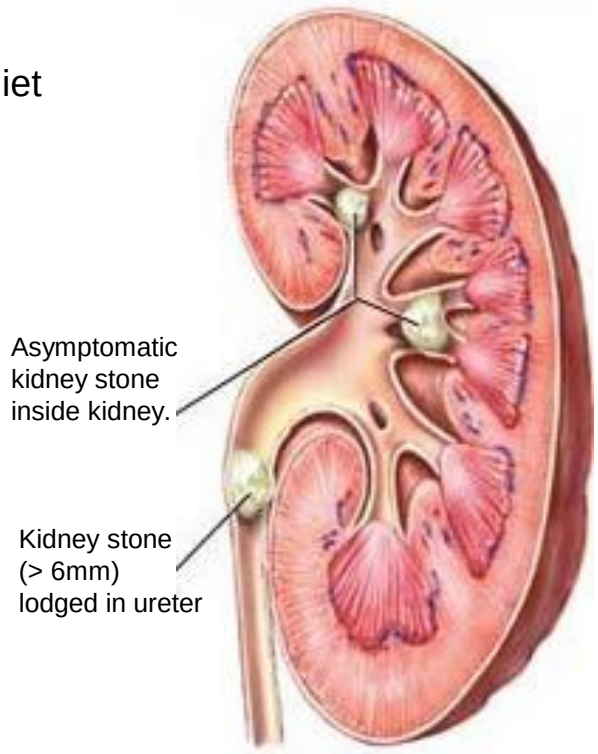
Current Risk Mitigation Strategy:

- Preflight ultrasound screening
- In-flight prevention: increased fluid intake, diet
- Oral Calcium citrate

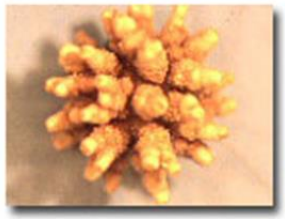
Future Risk Mitigation Research Goals:

- Flexible Ultrasound System (FUS) to provide clinical grade imaging of asymptomatic stones.
- FUS to provide therapeutic modalities:
  - Moving a kidney stone away from the ureters
  - Moving a kidney stone lodged in the ureter
  - Non-invasively breaking-up a kidney stone.






Misery


Agony

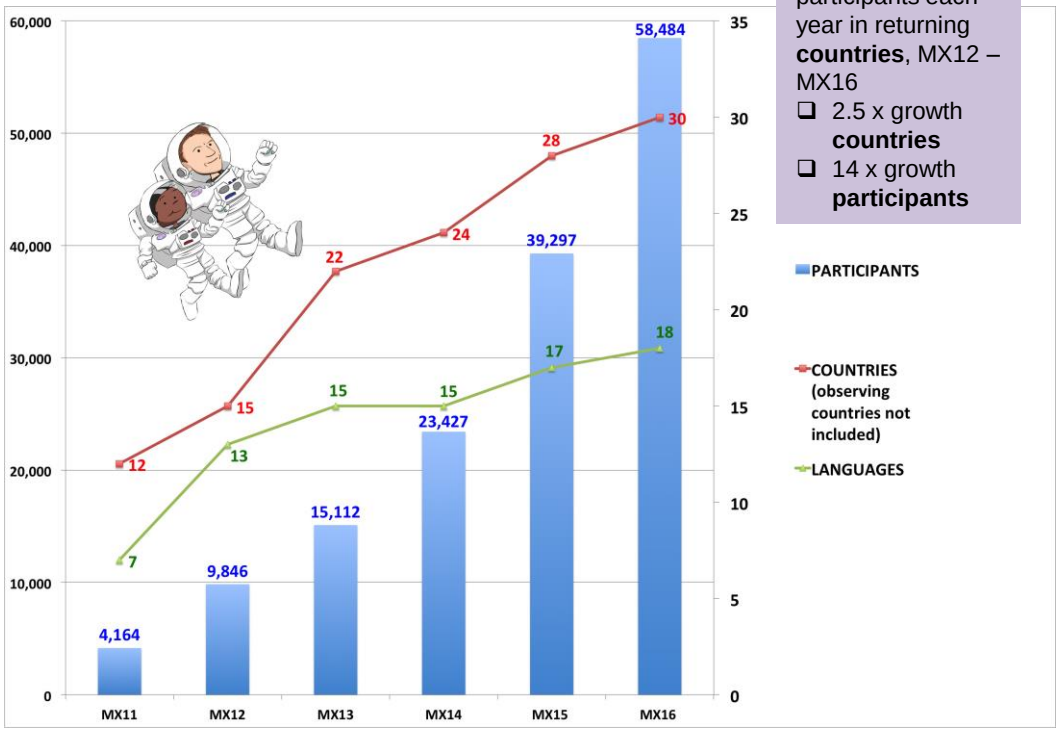
FUS moving stone in ER patient.


Ultrasound testing aboard ISS

Engagement and Communications

Train Like an Astronaut /Mission X

- **Mission X 2016 (MX16) International Fitness Challenge**
  - MX16 Walk To The Moon Challenge closed with 30 countries, four observing countries, and nearly 60K participants



Growth of participants each year in returning **countries**, MX12 – MX16

- ❑ 2.5 x growth **countries**
- ❑ 14 x growth **participants**

research to outreach

- **ISS Twins Study: Omics Exploring Space Through You Series**
  - Conclusion video 8 of 8 in the series were posted in conjunction with Twins Day, Aug 5. http://www.nasa.gov/content/exploring-space-through-you-omics

Human Research Roadmap:

A Risk Reduction Strategy for Human Space Exploration

- HRP uses an Integrated Research Plan to identify the approach and research activities planned to address these risks
- http://humanresearchroadmap.nasa.gov/