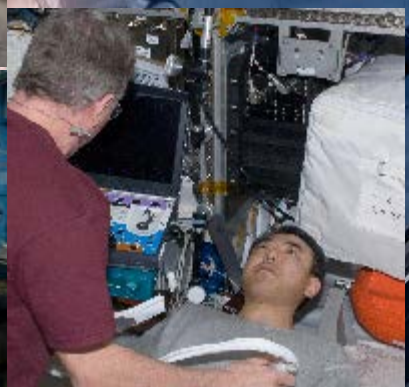
National Aeronautics and Space Administration

Human Research Program Status

WH Paloski, PhD
Director, HRP

October 31, 2017
National Academies of Sciences, Engineering, and Medicine
Committee on Biological and Physical Sciences in Space
Beckman Center, Irvine, CA



Human Research Program Mission

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**

Exploring Space In Partnership

Now

Using the International Space Station

2020s

Operating in the Lunar Vicinity

2030s

Leaving the Earth-Moon System and Reaching Mars Orbit

Advancing technologies, discovery and creating economic opportunities

Phase 0

Solve exploration mission challenges through research and systems testing on the ISS.

Phase 1

Conduct missions in cislunar space; assemble Deep Space Gateway and Deep Space Transport

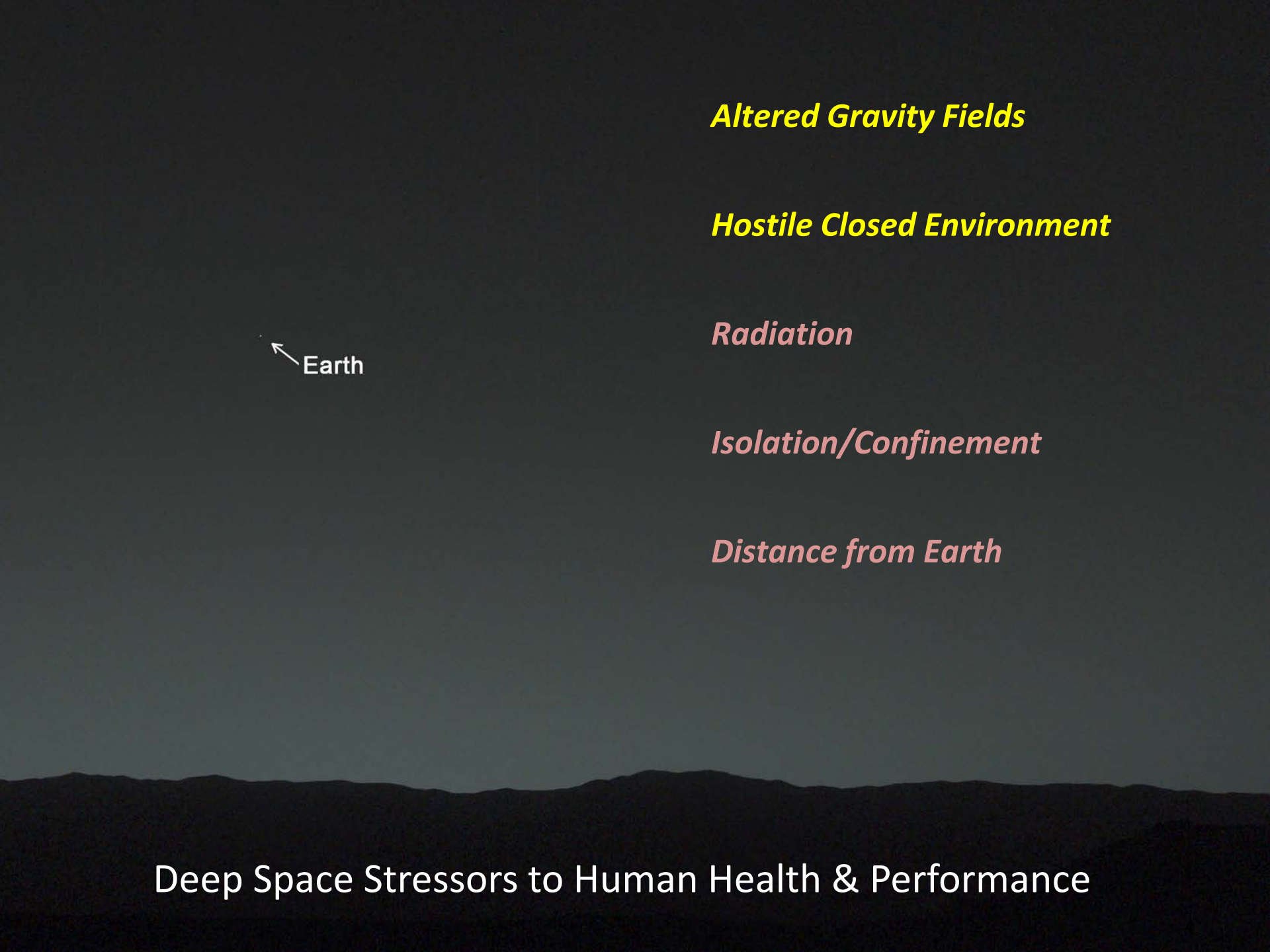
Phase 2

Complete Deep Space Transport and conduct Mars verification mission

(shakedown cruise)

Phases 3 and 4

Missions to the Mars system, the surface of Mars



Altered Gravity Fields

Hostile Closed Environment

Radiation

Isolation/Confinement

Distance from Earth

Deep Space Stressors to Human Health & Performance

Exploration Health & Performance 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

Concerns

1. Concern of Clinically Relevant Unpredicted Effects of Medication
2. Concern of Intervertebral Disc Damage upon and immediately after 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

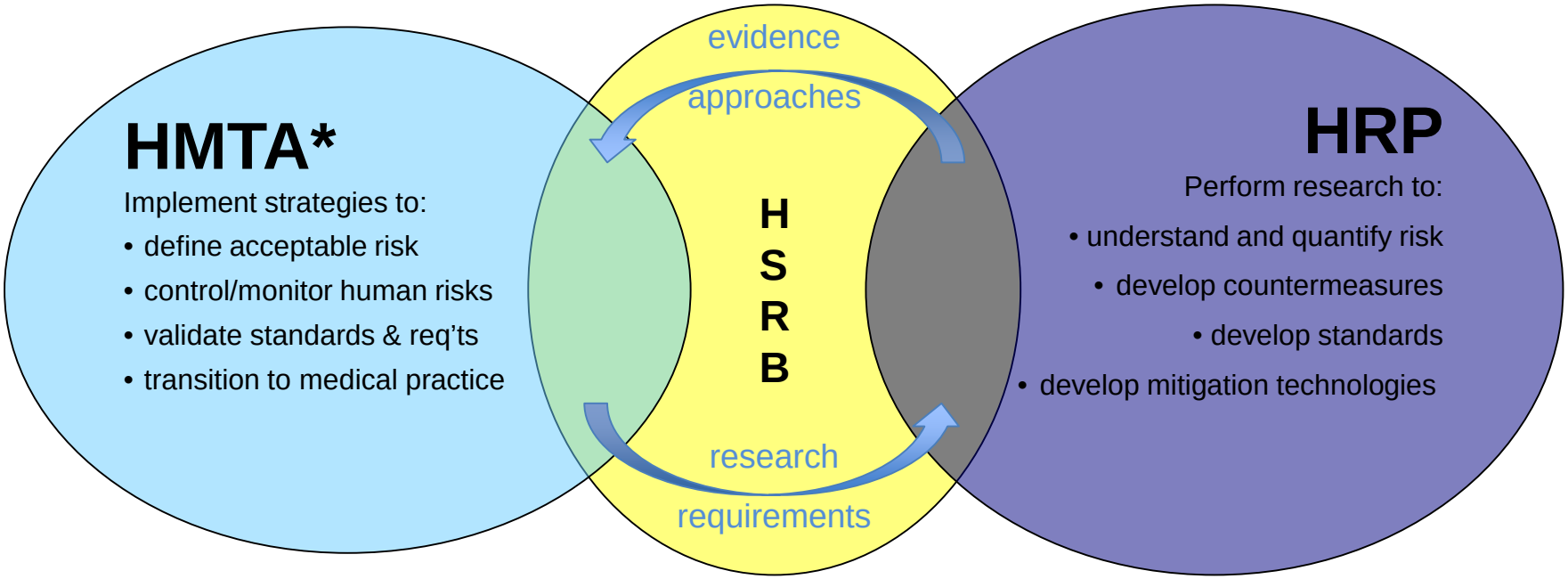
Isolation/Confinement

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

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 Medical Operations*
- *Crew Office*
- *Engineering TA*
- *Safety & Mission Assurance TA*

HSRB Risk Assessment Rubric

Consequence
Mission Health and Performance (OPS)

High	Death or permanently disabling injury to one or more crew (LOC) OR Severe reduction of performance that results in loss of most mission objectives (LOM)
Medium	Significant injury, illness, or incapacitation – may affect personal safety OR Significant reduction in performance results in the loss of some mission objectives
Low	Minor injury/illness that is self-limiting OR Minor impact to performance and operations- requires additional resources (time, consumables)
Very Low	Temporary discomfort OR Insignificant impact to performance and operations - no additional resources required

CM = Countermeasure
LOC = Loss of Crew
LOM = Loss of Mission

	Low	Medium	High
High	1 x 4	2 x 4	3 x 4
Medium	1 x 3	2 x 3	3 x 3
Low	1 x 2	2 x 2	3 x 2
Very Low	1 x 1	2 x 1	3 x 1
	≤0.1 %	<1 %	≥1.0%

Likelihood

Consequence
Long Term Health (post mission) (LTH)

High	• Unknown and improbable return to baseline (requires drastic intervention surgery & therapy) • Major impact on quality of life (permanent reduced function, premature death)
Medium	• Return to near baseline requires extended medical intervention w/ known clinical methods/technologies (pharmaceuticals, etc.) • Moderate impact on quality of life
Low	• Return to baseline values within 1 year with nominal intervention (time, exercise, nutrition, lenses) • Negligible effect on quality of life
Very Low	• Return to baseline values within 3 months with limited intervention • No effect on the quality of life

Quality of Life is defined as impact on day to day physical and mental functional capability and/or lifetime loss of years

Green	– mitigations validated	Yellow	– mitigations identified	Red	– mitigations sought

Exploration Health & Performance Risks

Altered Gravity Field

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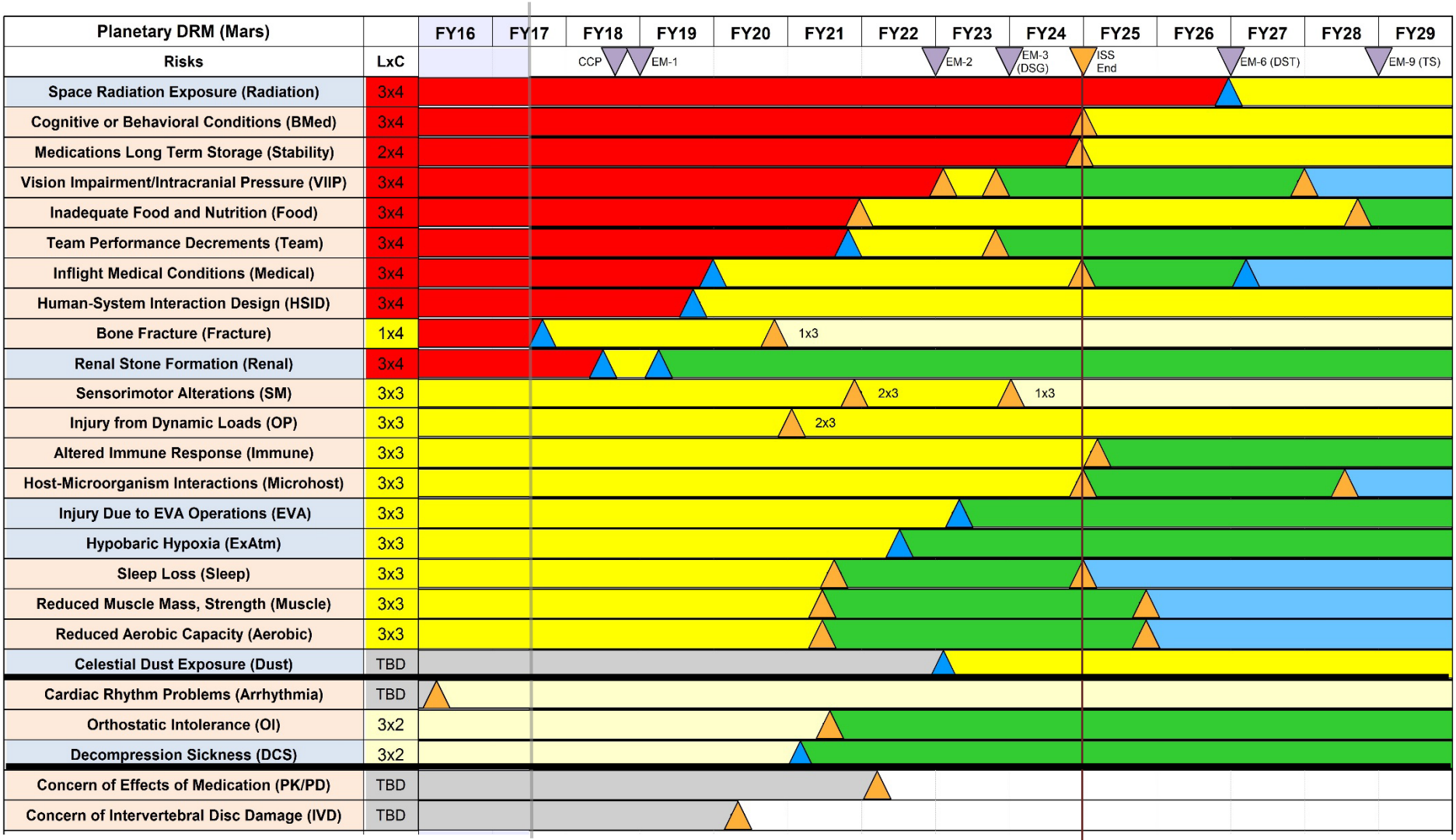
NASA Human Systems Risk Board: Red Risks for Mars DRMs

HRP Path to Risk Reduction (Mars Landing)



Strategy to Support Exploration Plan

Accelerate Research on risks having unknown/immature mitigation solutions**:**

- Radiation risks having potential in-mission consequences (CNS, Cardio Degen)
- VIIP/SANS
- Behavioral Health (BMED, Team)
- Food & Pharmaceutical Stability
- Autonomous medical operations (Inflight Medical Conditions)
- Integrated food/micro-host/immune system

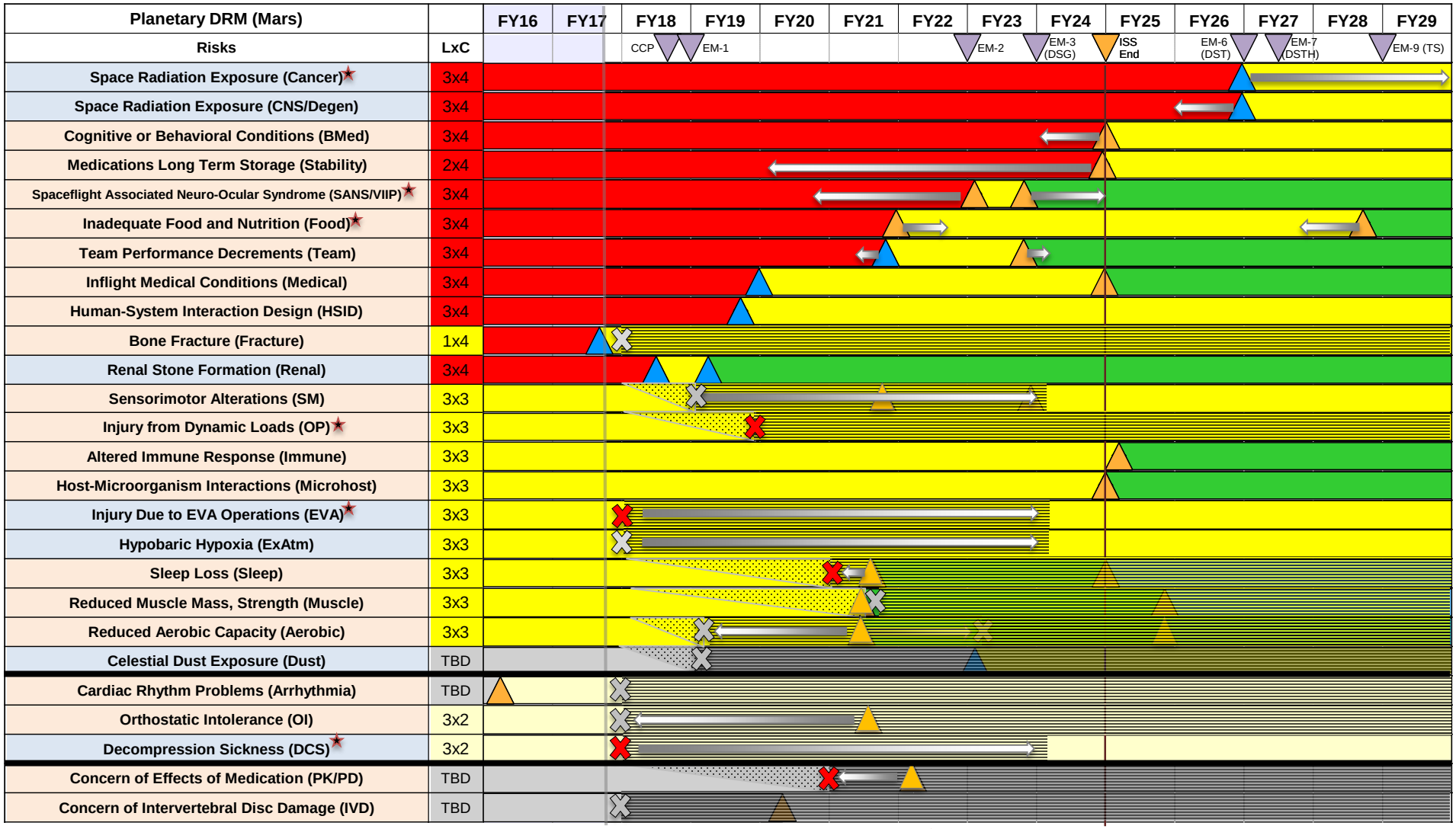
Delay Research on risks associated only with Mars surface operations or long term health:

- EVA
- DCS
- Hypobaric Hypoxia
- Sensorimotor
- Radiation-induced Cancer

Phase Out Research on concerns and risks having mature mitigation solutions:

- Bone
- Muscle
- Aerobic
- Orthostatic Intolerance
- Cardiac Rhythm
- Sleep Loss
- Concerns: Intervertebral Disk Damage, Effects of Medication

HRP Path to Risk Reduction (DST—Mars Flyby)



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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 Countermeasures
- Physiology, nutrition, immunology, pharmacology, ocular impairment

Human Factors and Behavioral Performance
- Individual, interpersonal interactions, sleep, stress
- Interfaces between humans and vehicles/habitats

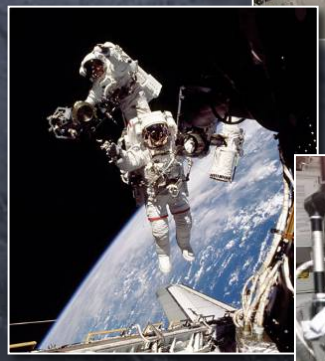
Exploration Medical Capability
- Medical care for missions beyond low Earth orbit

ISS Medical Project
- Infrastructure for flight and analog experiments

National Space Biomedical Research Institute (1997–2017)
- Cooperative agreement to pursue R&T that complements the HRP portfolio

Translational Research Institute (2016–tbd)
- Cooperative agreement to pursue R&T that disrupts the HRP portfolio





Translational Research Institute (TRI)

TRI 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.

Status:

7/20/16: Award Announced: Baylor College of Medicine/MIT/Caltech

9/30/16: Cooperative Agreement (NNX16AO69A) signed

10/1/16: TRI commenced operations @ TMCx+

10/1/17: Rebranded themselves as TRI for Space Health

Translational Scientist Program

10/2016: Hired first two Sr. Science Managers (BCM Faculty appointments)

09/2017: Hired new deputy element scientist for ExMC (starts 12/17)

10/2017: Seeking JSC Visiting Scientist in Omics

10/2017: Awarded initial Post-Doctoral Research Fellowships

Supporting Program

5/2016: Initiated 2017 NASA's Space Radiation Summer School

1/2017: First virtual conference: live streamed key sessions of the HRP Investigators Workshop.

Translational Research Program

Q1/FY17: Established geographically distributed Development Specialists Team and Scientific Advisory Board (academic and industrial)

3/2017: Released 1st research solicitation.

9/2017: Announced 1st ten research award recipients

The Ambidextrous Organization

CA O'Reilly III and ML Tushman; Harvard Business Review, April 2004

Successful ambidextrous organizations

- separate their new, exploratory units **(TRI)** from their traditional, exploitative ones **(HRP Research Elements)**,
- allowing them to have different processes, structures, and cultures;
- at the same time, they maintain tight links across units at the senior executive level.

Such organizations allow executives to pioneer radical or disruptive innovations while also pursuing incremental gains.

TRANSLATIONAL RESEARCH INSTITUTE FOR SPACE HEALTH™

space.health

HRP Research Acquisition Status

HERO	Appendix	Release Date	Step 1 Received	Step 2 Received	Peer Review Date	Selection Date	# Proposals Planned to be Awarded	# Proposals Actually Awarded	Notes
2016	A	7/28/2016	65	22	Feb and Mar-17	May-17	1	1	Limited Omnibus; BHP, HHC, and SR opted out due to budget cuts
	B	9/1/2016	60	46	Feb and Mar-17	May-17	6	6	HFBP and SR Flagship
	C	3/8/2017	129	98	Jul-17	Sep-17	10	10	First TRI Solicitation
	E	3/22/2017	79	47	Oct-17	Nov-17	6	TBD	HHC and SR Flagship; Collaboration with SB
2017	A	7/31/2017	18	TBD	Feb and Mar-18	Apr-18	3-4	TBD	Flagship; SR Tissue Sharing
	B	7/31/2017	166	TBD	Feb and Mar-18	Apr-18	4-5	TBD	Omnibus
	C	11/30/17	TBD	TBD	May and Jun-18	Aug-18	TBD	TBD	1YMP, mouse centrifuge, ground, and analog studies

data as of October 30, 2017

Awarded Solicitation

Released Solicitation — Acquisition in Progress

Planned Solicitation Milestone

2017 Translational Research Institute Awards

- 10 high risk projects CRL/TRL (2 to 4); potential for higher CRL/TRL (5 – 7)
- 2 studies funded for **flight** definition phase
- 80% of PI's are NEW to HRP funding
- 3 Program grants + 7 individual grants
- 10 projects from 9 institutions in 6 states

Charles Chiu, M.D., Ph.D. (flight definition & TCOR*)
Duration: 4 years
University of California, San Francisco
In-flight metagenomic monitoring of infections and associated host responses in astronauts

Lawrence David, Ph.D.
Duration: 2 years
Duke University
Personalizing prebiotic therapies for astronauts' gut microbiota

Donald Fox, Ph.D.
Duration: 3 years
Duke University
Mining biology's extremes for new space radiation resistance strategies

Dawn Kernagis, Ph.D.
Duration: 2 years
Institute for Human and Machine Cognition
Cervical lymphatic function quantification and associated molecular changes in response to simulated microgravity

Robert Langer, Sc.D.
Duration: 2 years
Massachusetts Institute of Technology
Gastrointestinal devices for long-term in situ delivery of therapeutic microbes

George Pantalos, Ph.D.
Duration: 2 years
University of Louisville
Creating surgical capabilities for exploration space flight

Christopher Porada, Ph.D. (TCOR*)
Duration: 4 years
Wake Forest Institute for Regenerative Medicine
Novel microfluidic biomarker detection platforms to monitor in vivo effects of solar particle events and galactic cosmic rays radiation, using mice with human hematopoietic systems

Susan Rosenberg, Ph.D.
Duration: 3 years
Baylor College of Medicine
Discovery of human radiation-protection genes and pathways

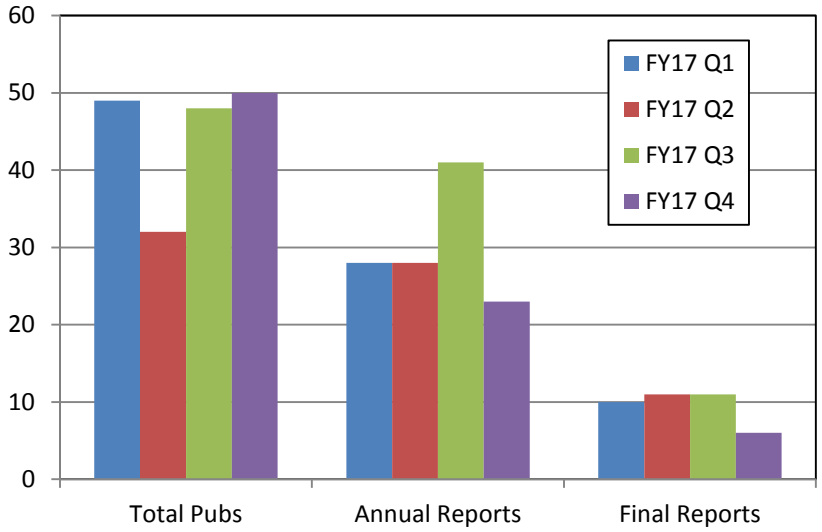
Kasthuri Venkateswaran, Ph.D. (flight definition & TCOR*)
Duration: 4 years
NASA Jet Propulsion Laboratory
Omics in space: Technology development for omics instrumentations and biomolecule measurements

Lihong Wang, Ph.D.
Duration: 2 years
California Institute of Technology
Label-free photoacoustic lymphatic flowgraphy in simulated microgravity

**Translational Research Institute for Space Health Core of Research (TCOR) = program grant*

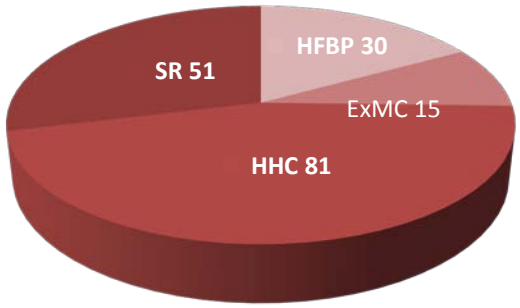
HRP Publication Metrics – FY17

Number of Publications



Number of book chapters for FY17 = 9

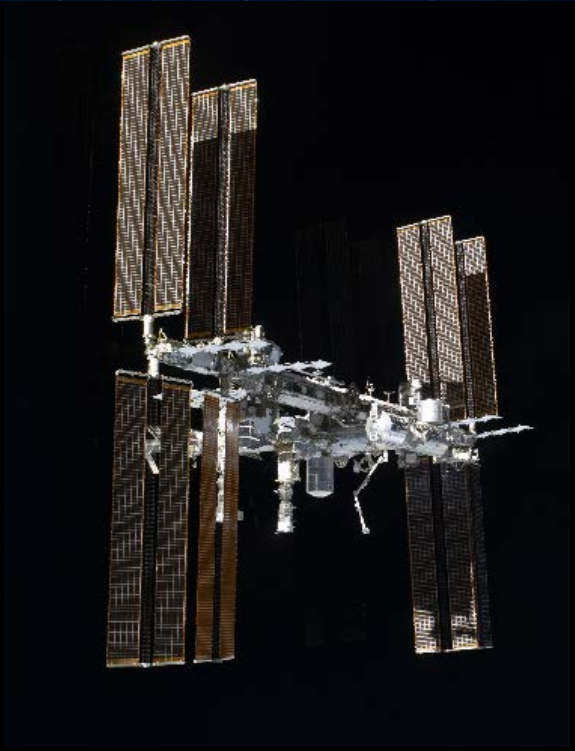
Publications by Element



Top 10 High-Impact Factor Publications (JIF > 5)

1. Yun S, Reynolds RP, Masiulis I, Eisch AJ. Re-evaluating the link between neuropsychiatric disorders and dysregulated adult neurogenesis. **Nat Med**. 2016 Nov;22(11):1239–47.
2. de Lemos JA, Ayers CR, Levine B, deFilippi CR, Wang TJ, Hundley WG, et al. Multimodality Strategy for Cardiovascular Risk Assessment: Performance in 2 Population-Based Cohorts. **Circulation**. 2017 May;135(22):2119–32.
3. Guo G, Gong K, Ali S, Ali N, Shallwani S, Hatanpaa KJ, et al. A TNF-JNK-Axl-ERK signaling axis mediates primary resistance to EGFR inhibition in glioblastoma. **Nat Neurosci**. 2017 Aug;20(8):1074–84.
4. Belcik JT, Davidson BP, Xie A, Wu MD, Yadava M, Qi Y, et al. Augmentation of Muscle Blood Flow by Ultrasound Cavitation Is Mediated by ATP and Purinergic SignalingClinical Perspective. **Circulation**. 2017 Mar 28;135(13):1240–52.
5. Gokhale NS, McIntyre ABR, McFadden MJ, Roder AE, Kennedy EM, Gandara JA, et al. N6-Methyladenosine in Flaviviridae Viral RNA Genomes Regulates Infection. **Cell Host & Microbe.** 2016 Nov 9;20(5):654–65.
6. Rodman C, Almeida-Porada G, George SK, Moon J, Soker S, Pardee T, et al. In vitro and in vivo assessment of direct effects of simulated solar and galactic cosmic radiation on human hematopoietic stem/progenitor cells. **Leukemia**. 2017 Jun;31(6):1398–407.
7. McIntyre ABR, Ounit R, Afshinnekoo E, Prill RJ, Hénaff E, Alexander N, et al. Comprehensive benchmarking and ensemble approaches for metagenomic classifiers. **Genome Biol.** 2017 Sep;18(1):182.
8. Wu MD, Atkinson TM, Lindner JR. Platelets and von Willebrand factor in atherogenesis. **Blood**. 2017 Mar 16;129(11):1415–9.
9. Zhang SL, Bai L, Goel N, Bailey A, Jang CJ, Bushman FD, et al. Human and rat gut microbiome composition is maintained following sleep restriction. **PNAS**. 2017 Feb 21;114(8):E1564–71.
10. Nandi S, Chandramohan D, Fioriti L, Melnick AM, Hébert JM, Mason CE, et al. Roles for small noncoding RNAs in silencing of retrotransposons in the mammalian brain. **PNAS**. 2016 Nov;113(45):12697–702.

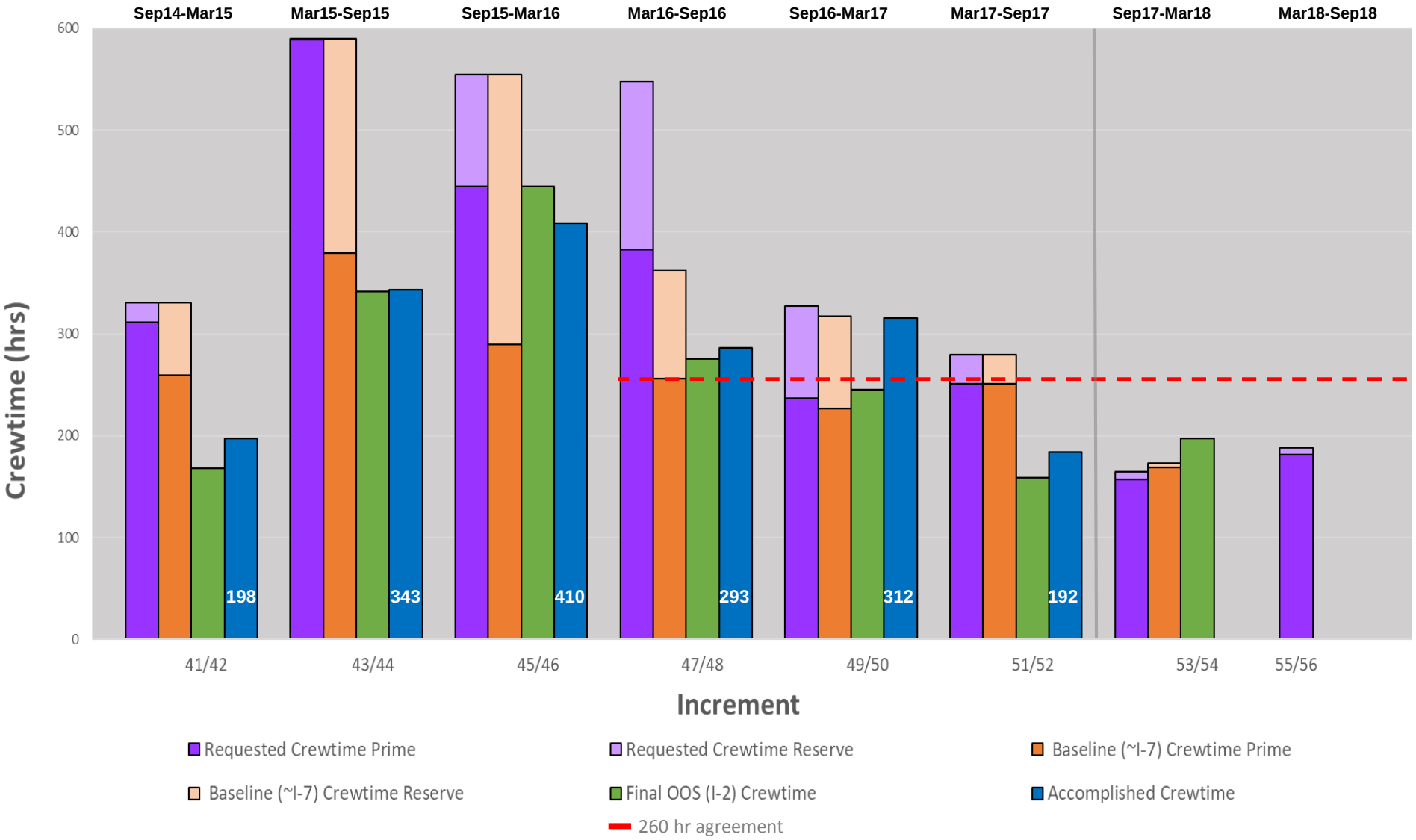
ISS: Space Platform for HRP Studies



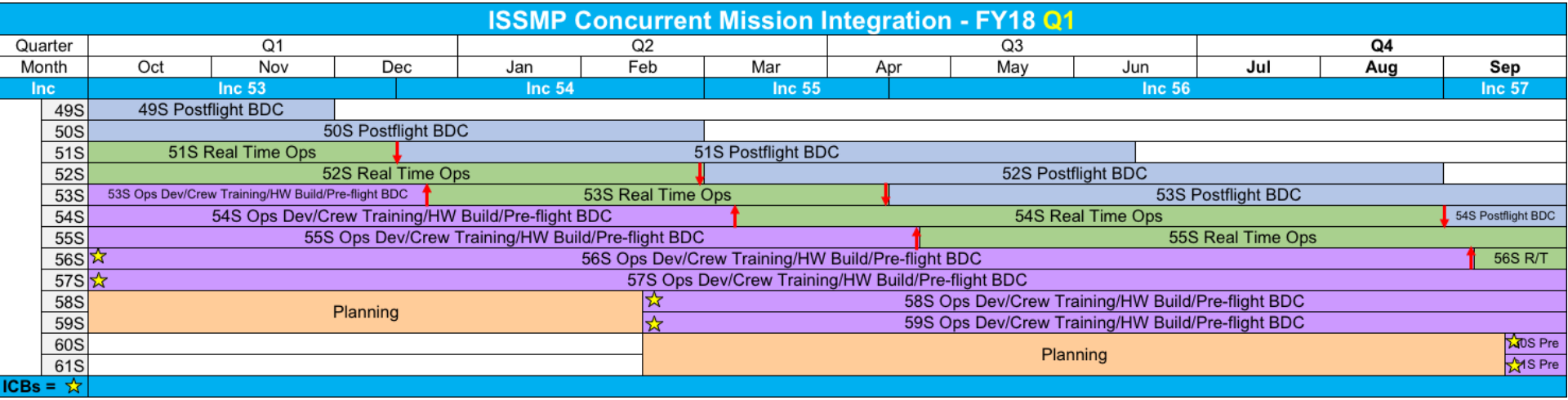
HRP studies receive highest priority for NASA science payloads aboard ISS.

Each USOS crewmember participates in 10-15 separate HRP experiments.

ISS Utilization Status



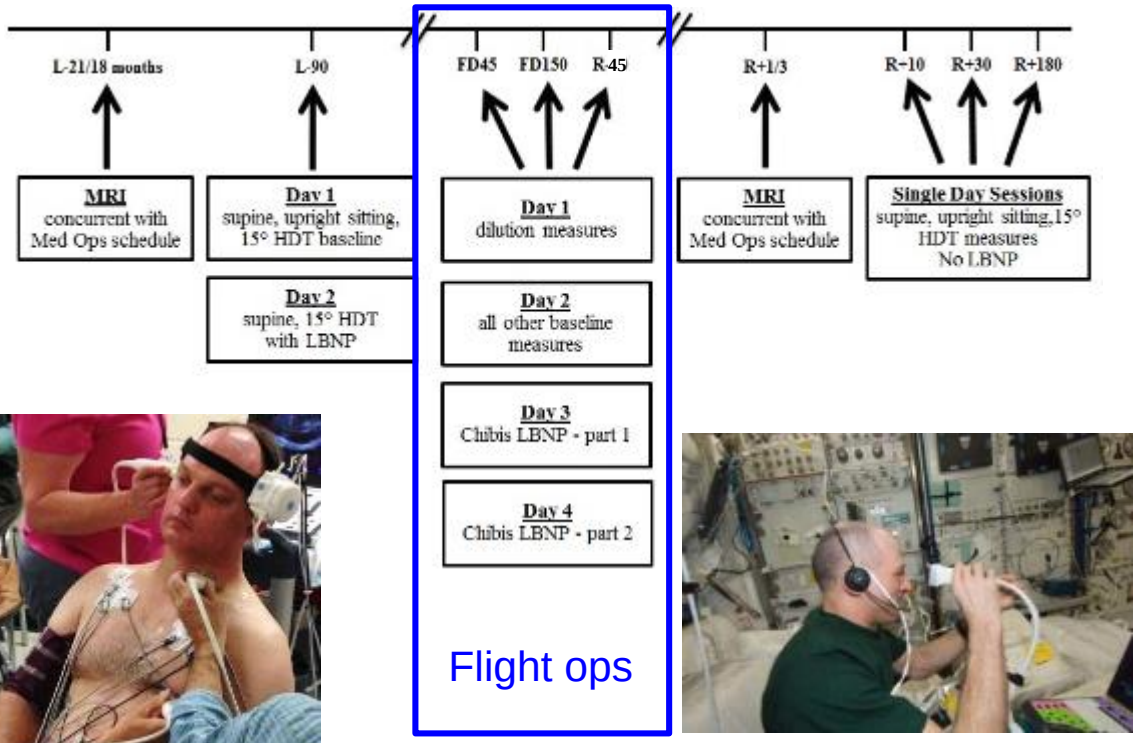
ISS Utilization Status

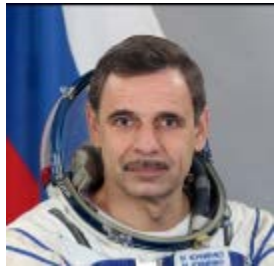


Forward ISS Utilization Plans

- Targeted “R01” studies in high risk areas (e.g., VIIP/SANS)
- Joint HRP/SB studies in focused areas (e.g., gravitational thresholds, food/plants, microhost/immune)
- Monitoring crew health and CM efficacy via Standard Measures + Occupational Surveillance
- Simulating Deep Space Missions via Follow-on 1-year Missions and (tbd) revised ISS ops strategies
- Technology Demonstrations for promising new devices (e.g., Butterfly IQ)
- Transitioning-to-Ops via MED TEDs (e.g. FUS, Compression garment
- Validating mature mitigation approaches via SMT/iSMT CTOs (e.g., ATLAS)

Visual Impairment–Fluid Shifts Experiment





Challenge: Russian Segment Ops

- Obtaining Agency-level Int'l Agreements
- Coordinating activities across NASA/Roscosmos
  - Hardware certification and testing activities
  - Simulation development planning
  - Real-time crew scheduling of US and Russian crew
- Consenting and training Russian crewmembers for NASA-sponsored science activities
- Procedure/Remote Guidance translation capability an unknown commodity

U.S./Russian Field Test Studies

Field Test Findings

1. Every returning crewmember exhibits Vestibular/Cerebellar and Sensorimotor symptoms.
2. Every crewmember experiences some degree of postflight Motion Sickness.
3. Considerable variance exists across crewmembers' functional performance.
4. Multiple test sessions on R+0 appear to be beneficial in enhancing readaptation.

Omics/Personalized CMs–Twins Study

Twins Study (Scott and Mark Kelly)

- ISS Sample Collection Completed
- Post Flight Sample Collection Completed

Objective

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

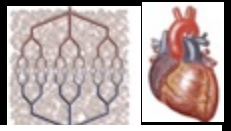
Twins Study National Research Team Examined

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

Significant Privacy and Ethics Issues

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

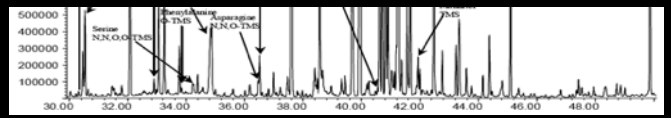
First Publications Expected January 2018



Vasculature
Lee

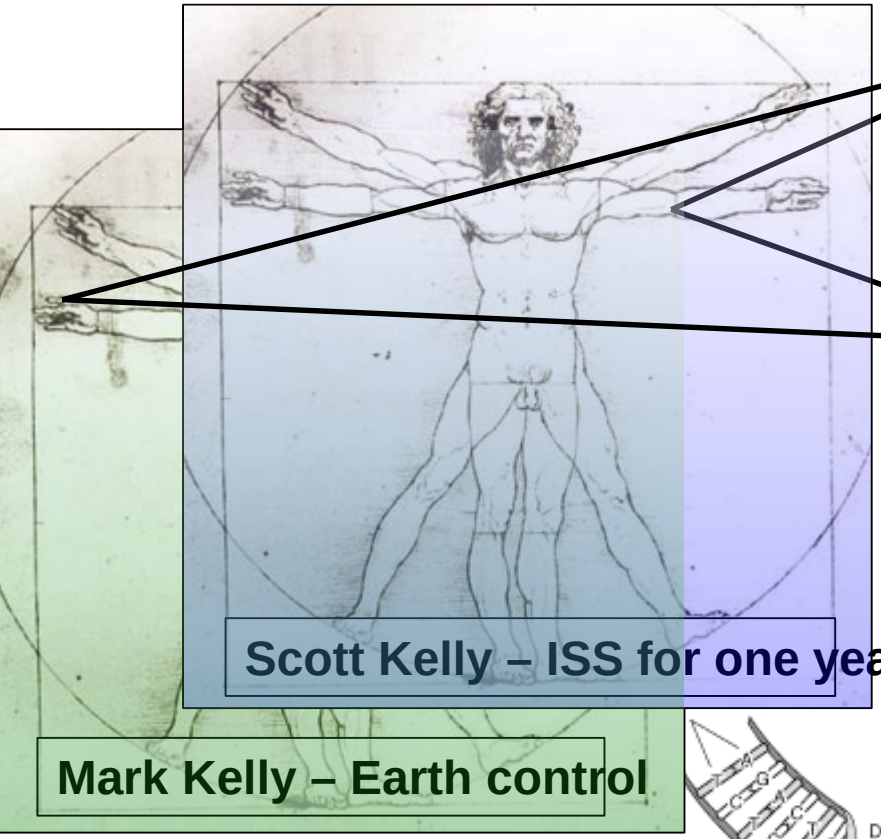
Cognition
Basner

Microbiome
Turek



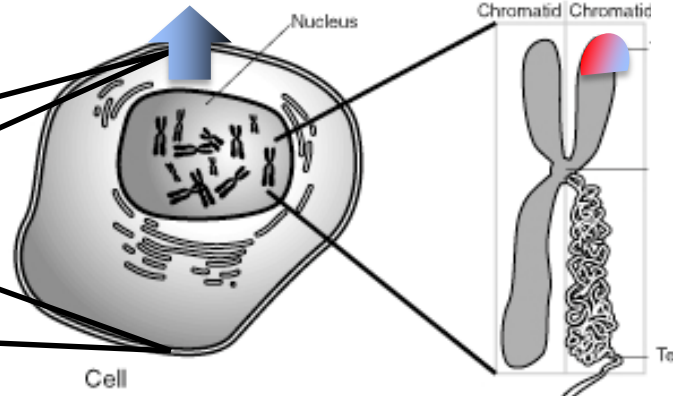
Targeted and Global Metabolomics
Lee/Rana, Mignot/Snyder & Smith

Cytokines
Mignot



Scott Kelly – ISS for one year

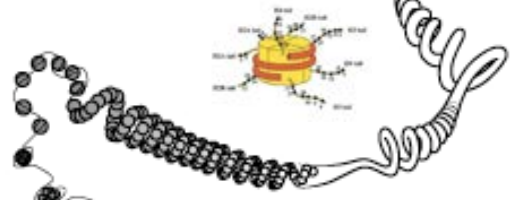
Mark Kelly – Earth control



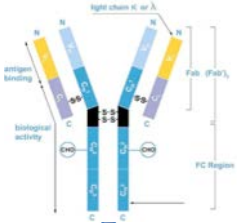
Telomere Length
Bailey

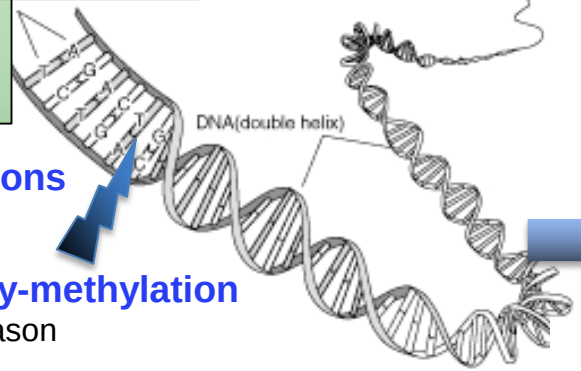
B-cells / T-cells
Mignot

Antibodies
Mignot/Snyder



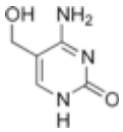
Chromatin
Feinberg

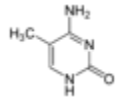




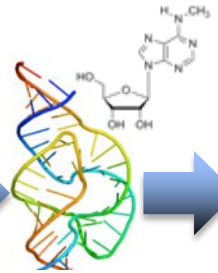
DNA Mutations
Feinberg

DNA Hydroxy-methylation
Mason

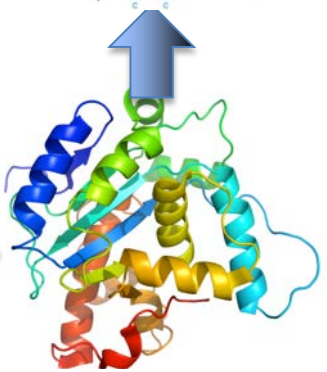




DNA Methylation
Feinberg & Mason



large/small RNA & RNA Methylation
Mason



Proteomics
Lee/Rana

Sequencing in Space

Aug. 29, 2016

First DNA Sequencing in Space a Game Changer

For the first time ever, DNA was successfully sequenced in microgravity as part of the Biomolecule Sequencer experiment performed by NASA astronaut Kate Rubins this weekend aboard the International Space Station. The ability to sequence the DNA of living organisms in space opens a whole new world of scientific and medical possibilities. Scientists consider it a game changer.

The Biomolecule Sequencer investigation sent samples of mouse, virus and bacteria DNA to the space station to test a commercially available DNA sequencing device called MinION, developed by Oxford Nanopore Technologies. The MinION works by sending a positive current through pores embedded in membranes inside the device, called nanopores. At the same time, fluid containing a DNA sample passes through the device. Individual DNA molecules partially block the nanopores and change the current in a way that is unique to that particular DNA sequence. By looking at these changes, researchers can identify the specific DNA sequence.

Remote Medical Care: Flexible Ultrasound System

- **Integrates imaging and therapeutics in a single integrated system.**
  - portable
  - low power consumption
  - minimal training w/remote guidance

NASA astronaut Chris Cassidy performs an ultrasound exam on ESA astronaut Luca Parmitano aboard the ISS. ISS scientists and clinicians have carried out more than 1,000 exams to date.

Next Generation?
Butterfly IQ: $2K, iPhone, FDA-cleared

Renal Stone Formation Risk Mitigation

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

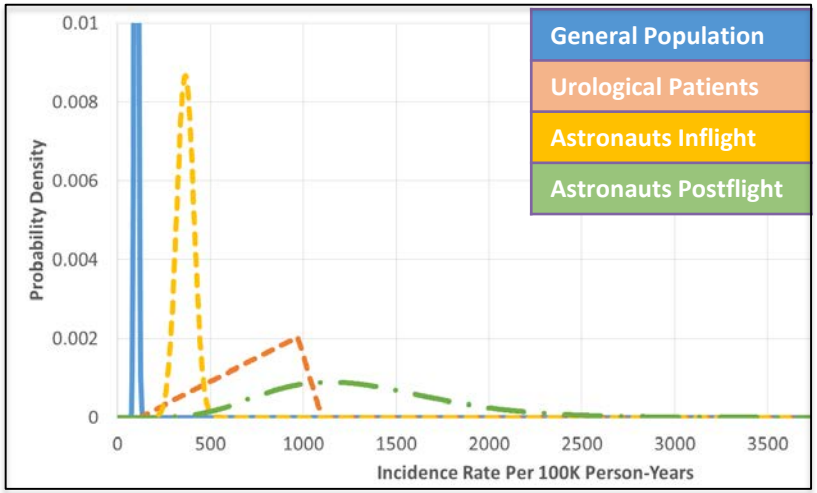
- Fluid redistribution, bone loss, muscle atrophy, diet

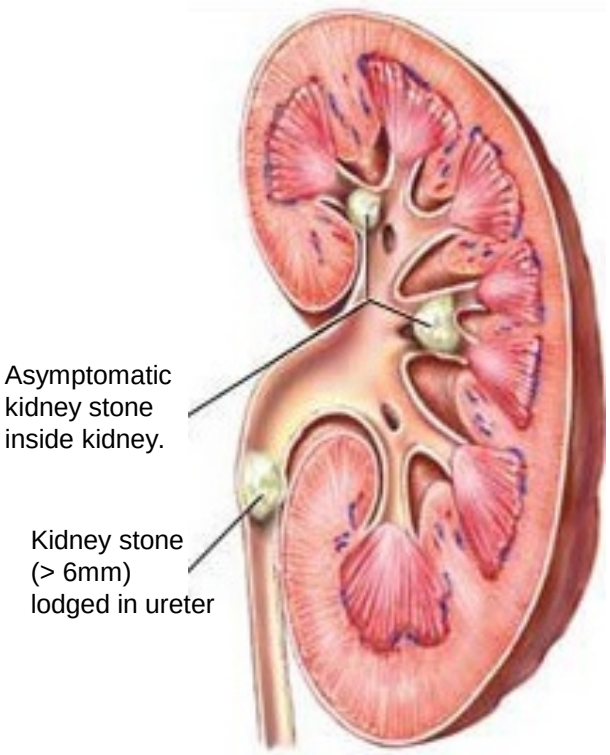
Current Risk Mitigation Strategy:

- Preflight ultrasound screening
- In-flight prevention: resistive exercise, increased fluid intake, appropriate 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.

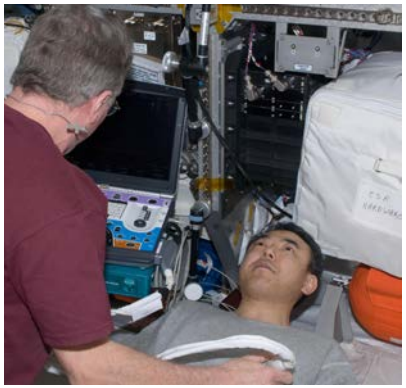





Misery


Agony

FUS moving stone in ER patient.



FUS testing aboard ISS

Deep Space Exercise Device (ATLAS*) Status

Objectives:

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

Development Approach:

- Leverage the MPCV/ROCKY, MMED2, and SBIR efforts
- Demonstrate/validate on ISS asap (NET 2019)
- TTO to 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

note: HULK and/or NGRED to be made available for BAA habitat testing.

NGRED Prototype

HULK Prototype

ATLAS Flight Concept

*Advanced Twin Lifting and Aerobic System

Spaceflight Analog Facilities


NSRL Beam Line

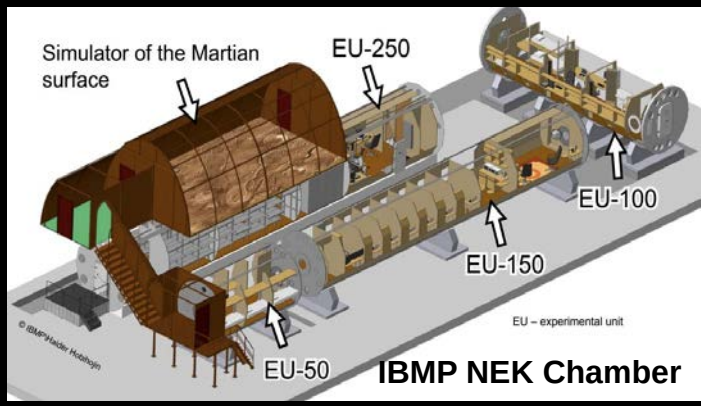

Parabolic Flight

NSF/ South Pole Station


6° HDT Bedrest


DLR :enviHab Facility

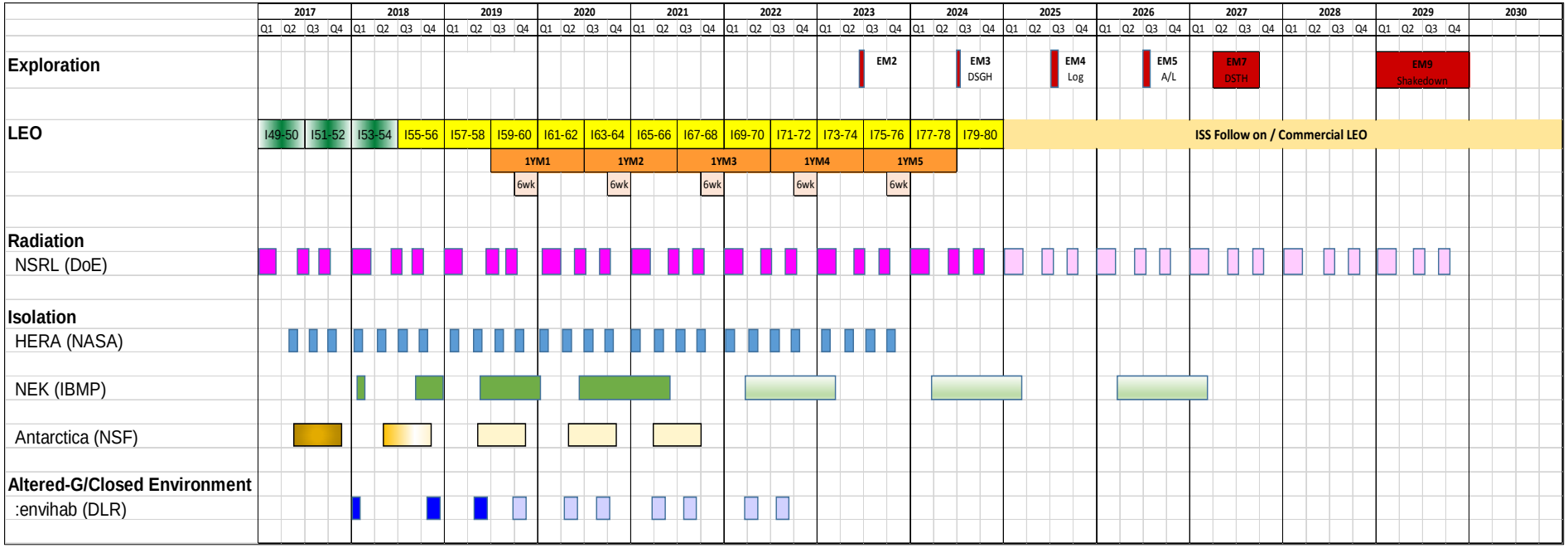
JSC HERA Facility



IBMP NEK Chamber

Flight & Flight Analog Research Facilities/Plans

Planned opportunities for using currently available research venues:



Note that translucent rectangles represent opportunities that are not yet fully required.

Joint studies with domestic and international partners is critical to our success.

NASA Space Radiation Lab (NSRL) DOE/BNL

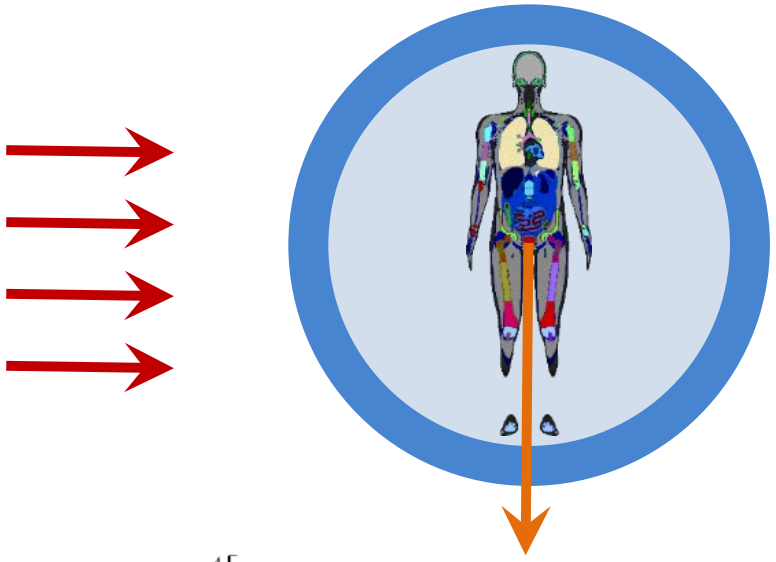
- ✓ altered gravity fields (n/a)
- ✓ isolation/confinement (n/a) & altered light-dark cycles (n/a)
- ✓ hostile/closed environment (n/a)
- ✓ increased radiation (+)
- ✓ distance from Earth (n/a)

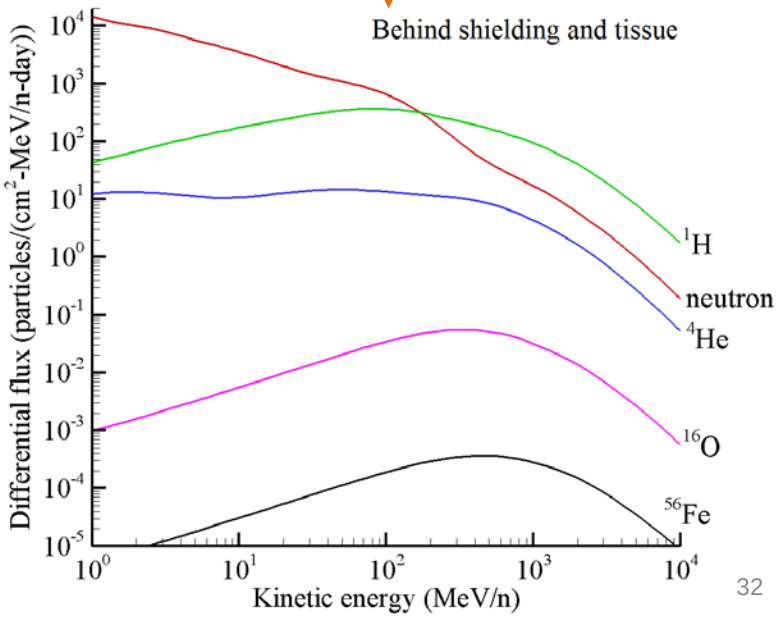
- Simulates the space radiation environment- high energy ion beams (H^+, Fe, Si, C, O, Cl, Ti, etc.)
- Beam line, target area, dosimetry, biology labs, animal care, scientific, logistic and administrative support
- 3 experimental campaigns per year
- Space Radiation Summer School

NSRL Beam Line

Images Courtesy of Brookhaven National Laboratory (BNL)

External and Internal Fields





The external field is modified as it passes through shielding and tissue

- Slowing down due to atomic processes
- Attenuation and breakup of heavy ions due to nuclear collisions
- Secondary particle production (especially neutrons)

GCR Simulator: A Beam Specification Strategy

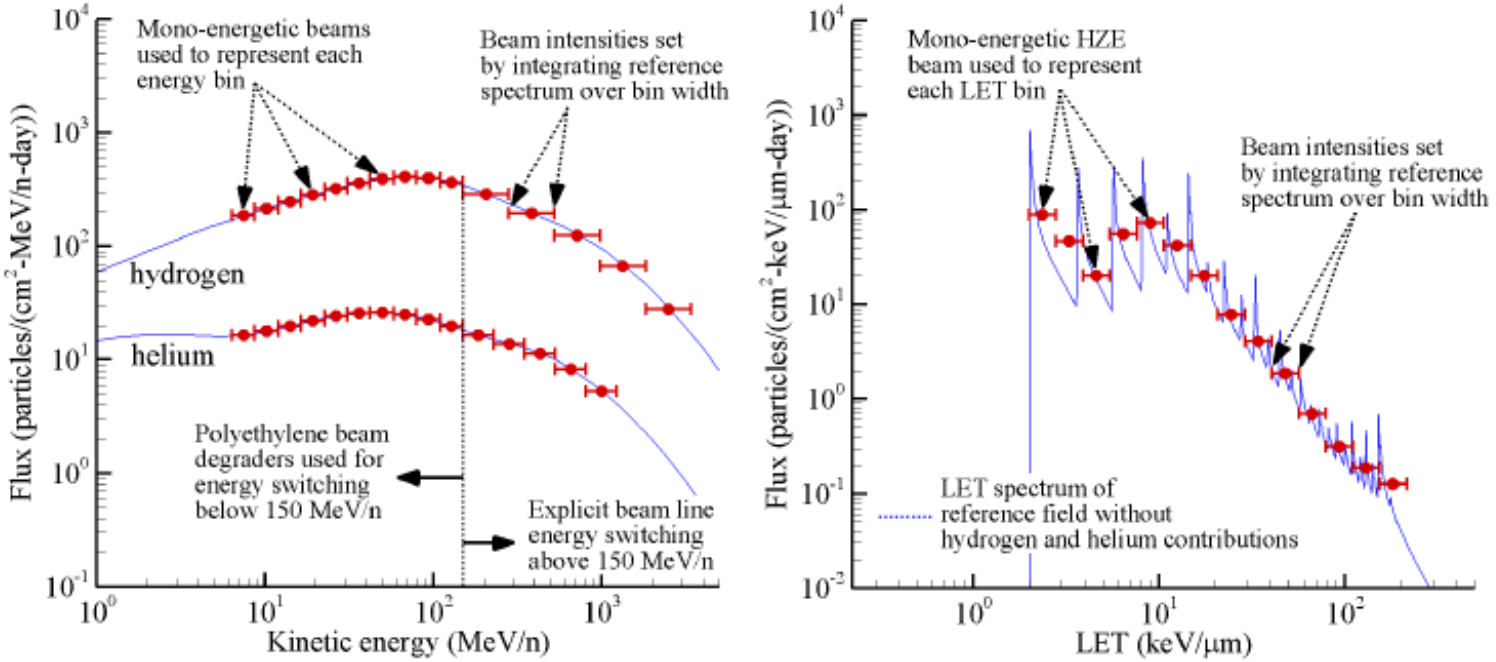


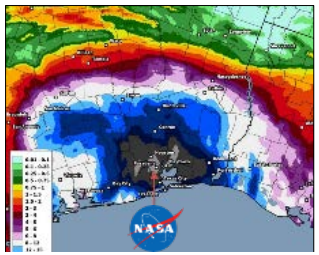
Figure 13. General strategy for representing the reference field with discrete mono-energetic beams. The hydrogen and helium energy spectra are considered directly (left pane), while HZE ions are represented within the LET spectrum (right pane). Solid blue lines are the reference spectra from Figure 10.

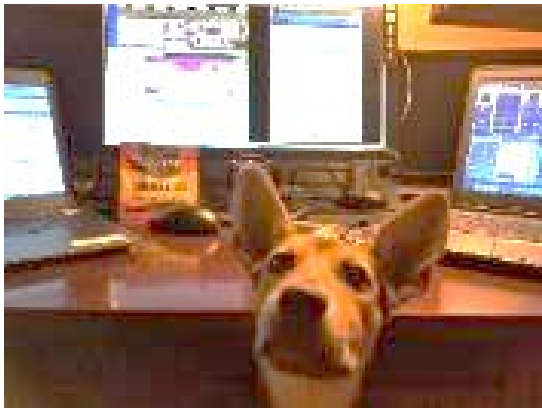
Human Exploration Research Analog (HERA)

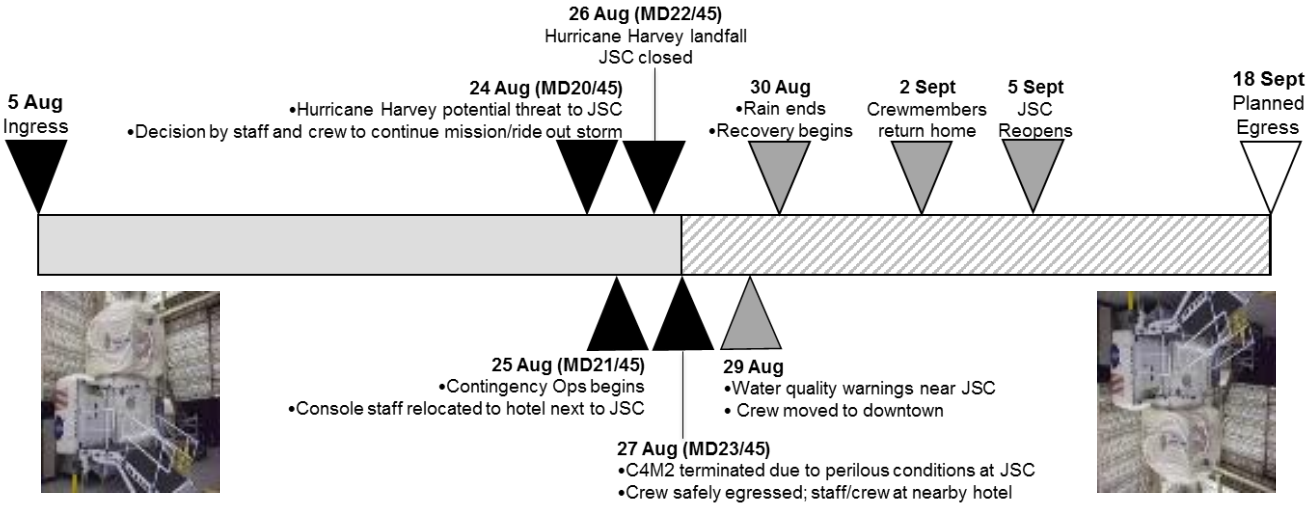
HERA Isolation Analog Status

Campaign 4: Four 45-day missions (18 studies: 15 HRP + 3 DLR)

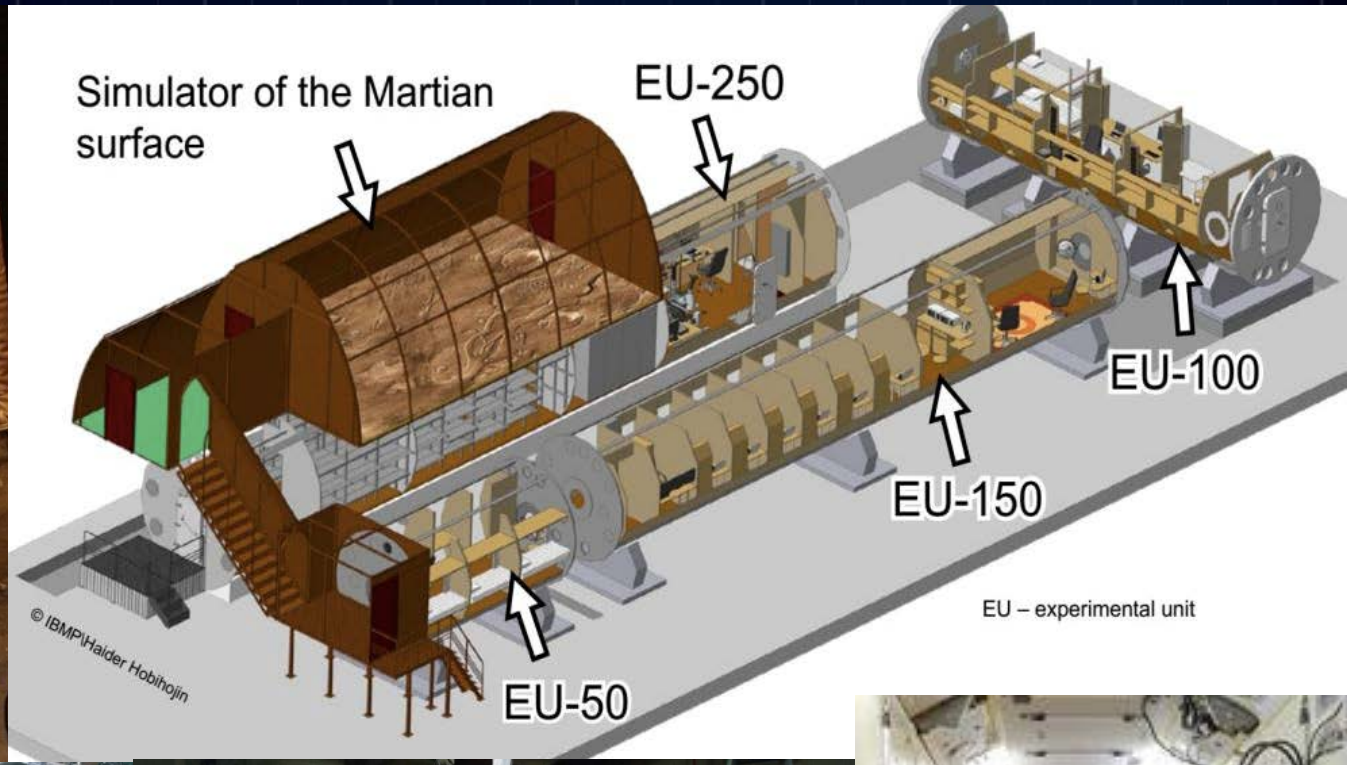
- Mission 2 began on 5 Aug and ran successfully until 27 Aug
- C4M2 terminated due to Harvey
- C4M3 mission was slipped out one week due to lack of available subjects
  - Crew selection complete; training and pre-mission BDC began 12 Oct
  - Ingress: 28 Oct; Egress: 11 Dec
  - post-mission BDC ending on 18 Dec
- Mission 2 repeat: Earliest opportunity Spring 2018
- Estimated cost to repeat C4M2 is **$1M**







NEK (RAS/IMBP, Moscow, Russia)



Cosmonauts V.V. Polyakov and S.K. Krikalev

Cosmonaut S.N. Ryazanskiy

NEK (IBMP) Isolation Analog Status

Scientific International Research in Unique Terrestrial Station (SIRIUS)

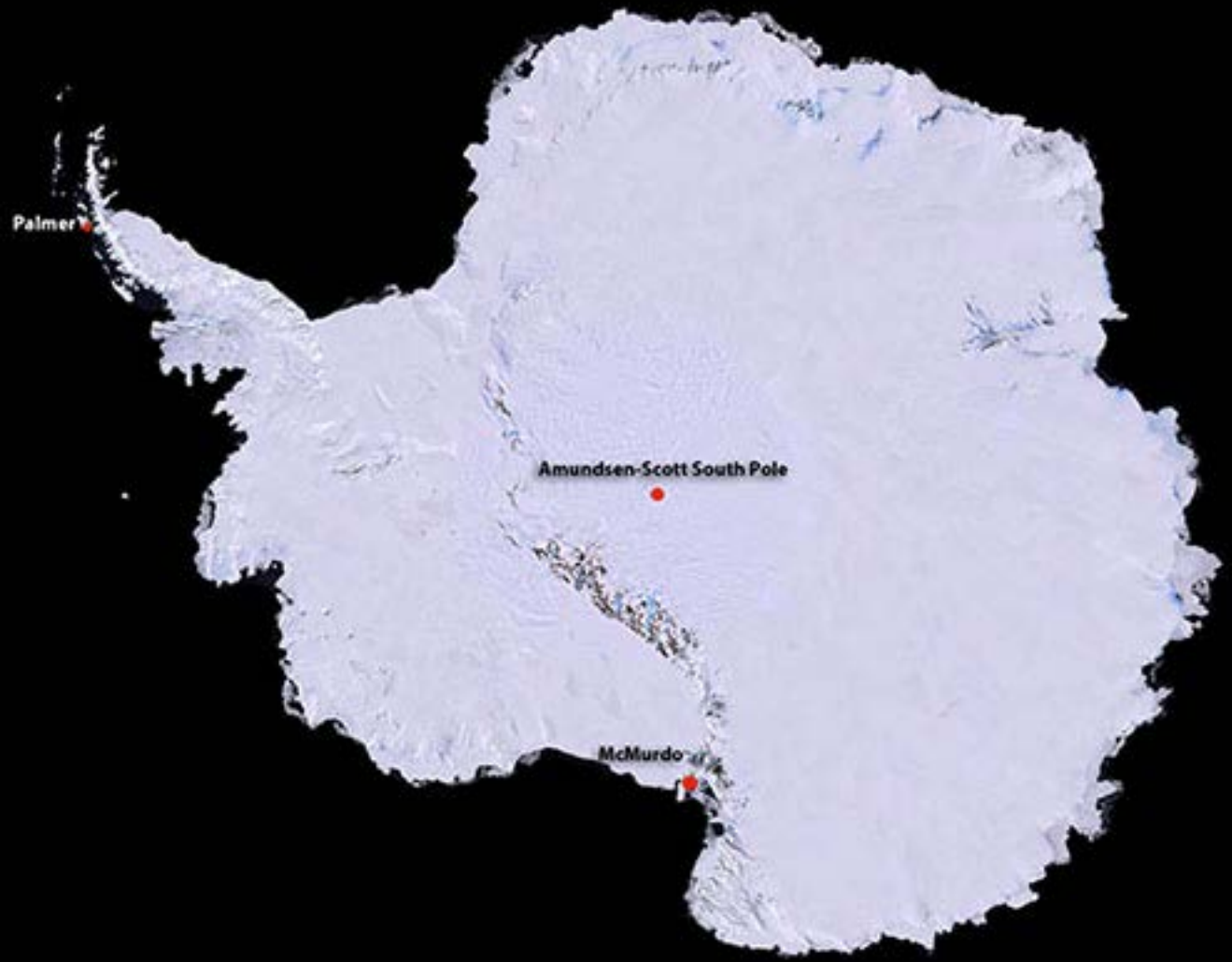
SIRIUS-17 feasibility study:

- ‘shakeout’ for future 4-, 8- and 12-month missions
- 40+ international studies (4 from HRP)
- 6 primary and 3 back-up crew selected

Schedule

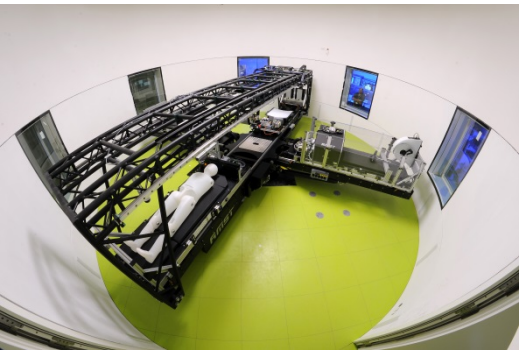
- 23 October: Crew training began
- 7 November: Crew ingress/hatch-closing
- 24 November: Crew egress

Antarctic Stations NSF+



NSF/ South Pole Station

:enviHab (DLR/IAM, Cologne, Germany)



:envihab (DLR) Altered Gravity Analog Status

VaPER (VIIP and Psychological :envihab Research) Study

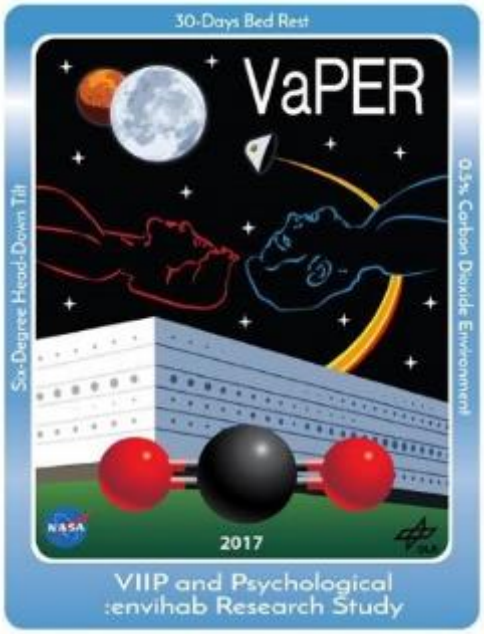
(5 HRP investigations)

Study design:

- 12 astronaut-surrogate volunteers (both sexes)
- 30 days duration
  - o simulated microgravity (6° head-down tilt bed rest)
  - o hostile, closed environment (elevated CO_2)
- 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)

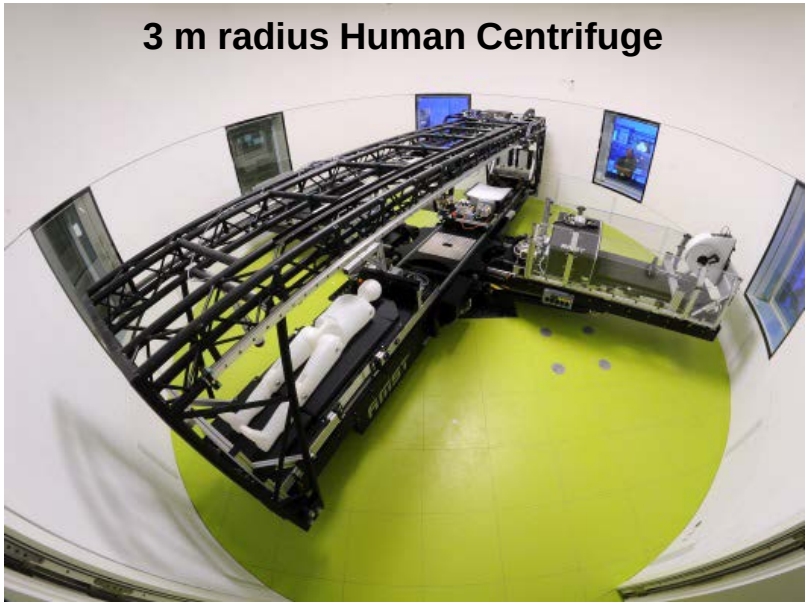


Joint NASA/ESA AG-Bedrest Study Status

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

Research to be carried out during two 12-subject, 60-day bedrest campaigns at the DLR's :enviHab facility in Cologne, Germany (2018, 2019).

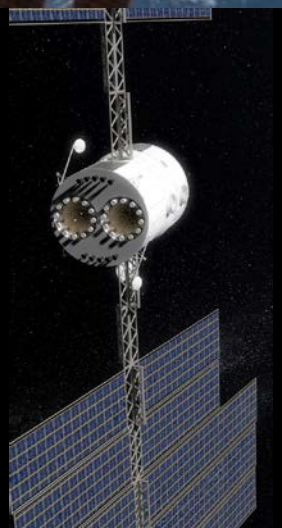
- Coordinated solicitations
- Common peer review (NRESS)
- Coordinated selections to maximize scientific gain
- Shared facility costs
- International Investigator Working Group: data sharing and coordinated publications



	SM1	CV3	VIIP1	M23	Osteo4	AG Gap 1	AG Gap 3	AG Gap 4
NASA AGBR 0009	X	X	X			X	X	X
NASA AGBR 0020	X	X				X	X	X
NASA AGBR 0011	X					X	X	X
NASA AGBR 0013					X	X	X	X
ESA AGBR 0014	X					X	X	X
ESA AGBR 0031		X				X	X	X
ESA AGBR 0013	X			X		X	X	X
ESA AGBR 0017						X	X	X
ESA AGBR 0018				X		X	X	X
ESA AGBR 0018					X	X	X	X
ESA AGBR 0005						X	X	X
Standard Measures	X	X	X	X	X	X	X	X

Hermes Vehicle, *The Martian* (2015)

Deep Space Transport



Crew Health and Performance System Must…

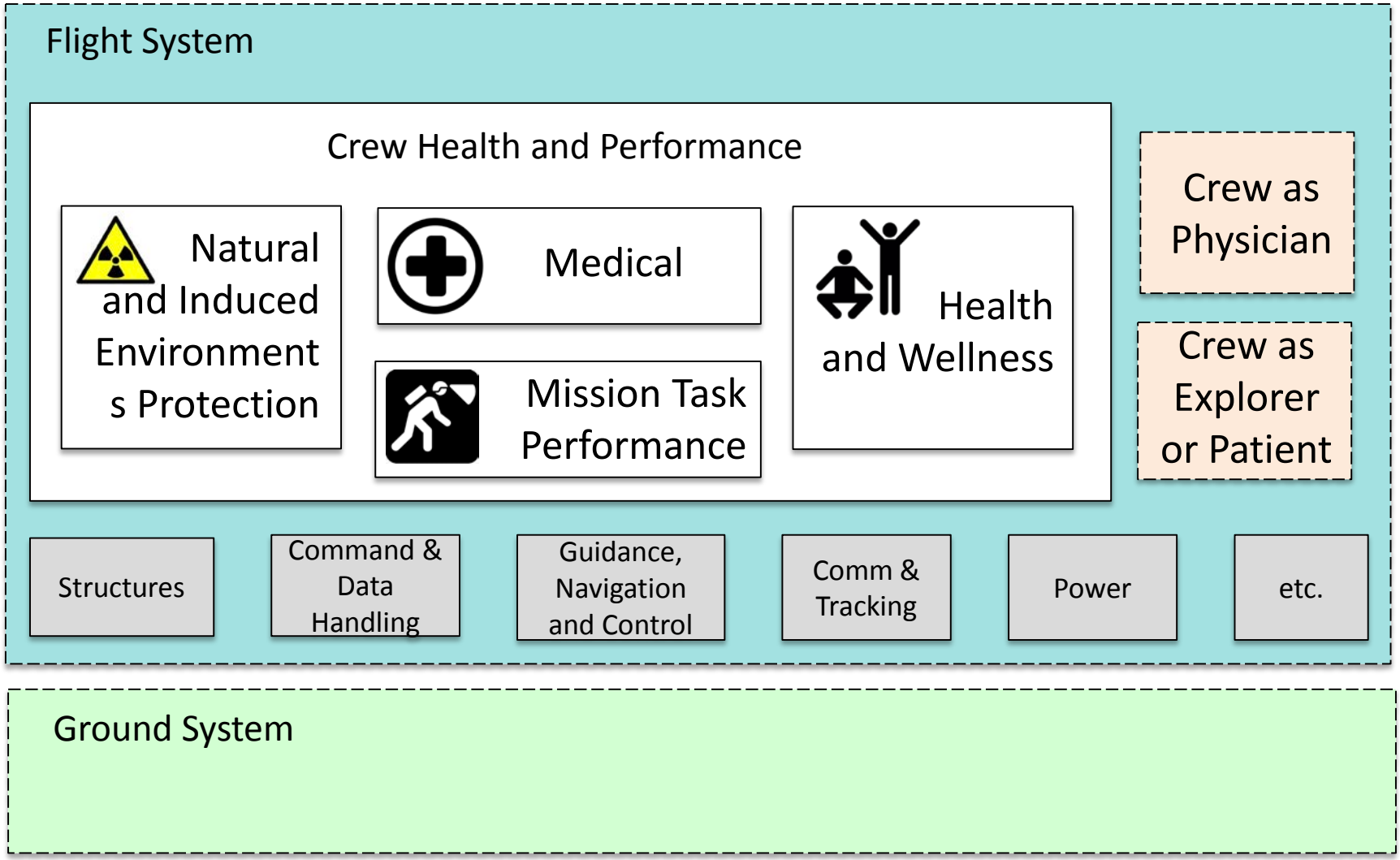
- **Protect crew from environmental hazards**
  - Radiation (SPE, GCR)
  - Noise, vibration, CO_2, etc.
  - Microbiome of the built environment

- **Keep healthy crew well**
  - Exercise
  - Other physiological countermeasures
  - Food
  - Behavioral health

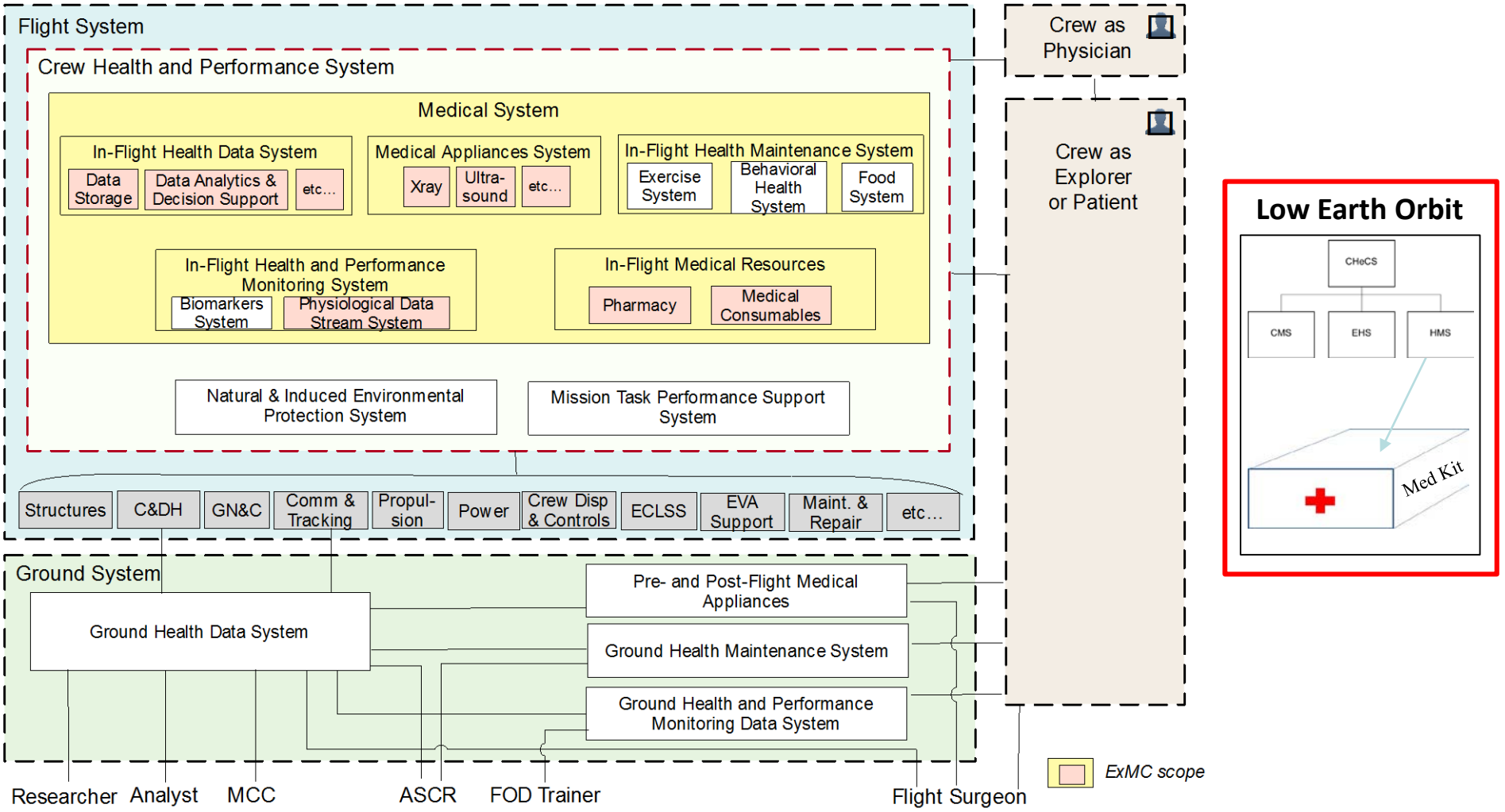
- **Prevent, diagnose, treat, manage long-term health care**
  - Data system
  - Medical devices
  - Medical supplies

- **Support crew to accomplish mission tasks**
  - Procedures
  - Training
  - User interfaces

Applying Systems Engineering to Integrate



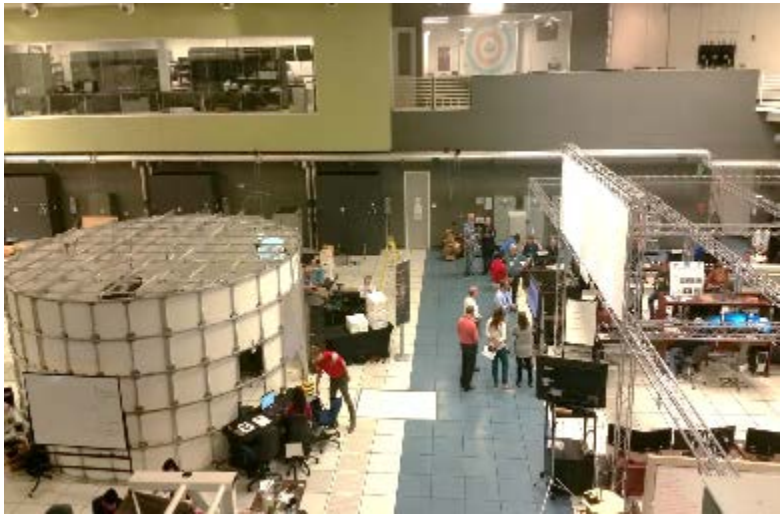
Exploration Medical Care Concept



Integrated Power, Avionics and Software (iPAS)

Deep Space Gateway - Ground Prototype Testing

- The NextSTEP Ground Test team successfully executed the first demonstration of a Deep Space Gateway (DSG) habitat mockup in the iPAS Habitat Test Bed at JSC.
- The iPAS environment integrates the Avionics & Software architecture with modular power systems developed by AES.
- A crew of four performed a representative activity timeline over eight hours, including exercise, medical procedures, lunar rover operations, and habitat logistics.



iPAS Mockup Habitat Test Bed

iPAS Habitat Mockup and Mission Control Workstation

DSG Integrated Test: Exercise, MDA, and Biosensor

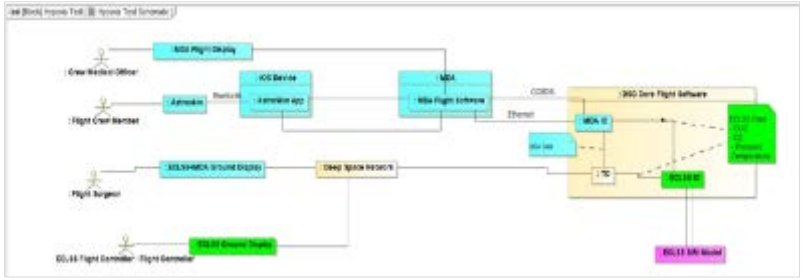
Purpose: Integration and Simulation for DSG Habitat evaluation and technology integration

Use-case Simulation: Detect Hypoxia

- Crew exercise using HULK2 device evaluates habitat architecture accommodation
- Canadian-provided Astroskin collects real-time biometric data is transferred to Medical Data Architecture (MDA)
- Concurrently, iPAS simulates Environmental Control and Life Support System (ECLSS) response of crew exercise
- MDA stores and transfers biometric and ECLSS information to on-board displays and Mission Control via flight-like Core Flight Software and CCSDS telemetry
- On-board crew medical officer or ground medical doctor evaluate information to detect hypoxia condition

Crew wearing Astroskin exercises on HULK device in habitat mockup

Mission Control displays show crew biometric and ECLSS information



Medical Data Architecture, ECLSS, and iPAS Block Diagram

Habitat crew displays show crew biometric and ECLSS information

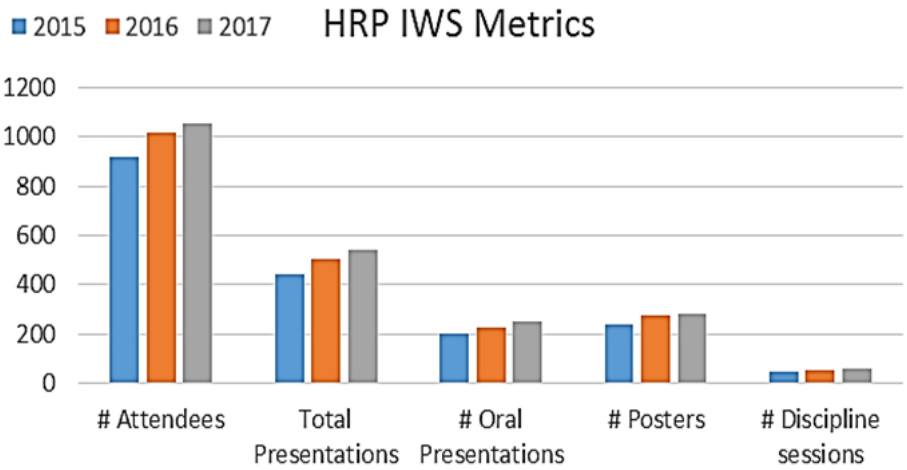
HRP Investigators' Workshops

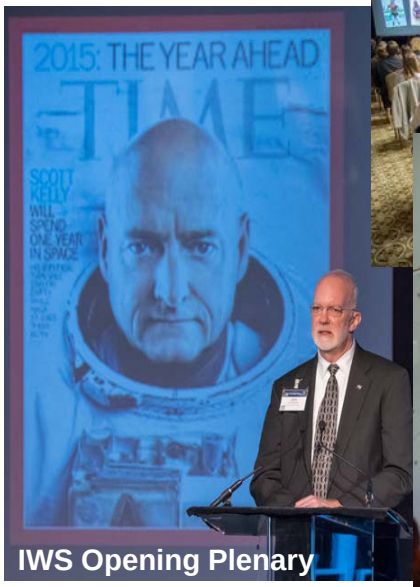
HRP IWS - A New Dawn: Enabling Human Space Exploration

- Held 23-26 January, 2017
- 1,057 participants; 538 presentations; 60 discipline-specific sessions
- Preliminary results from Twins and 1YM studies
- First IP Plenary session

Twins Investigator Working Group

- Held 27 January, 2017
- Early findings presented; data integration, sharing and analysis plans discussed

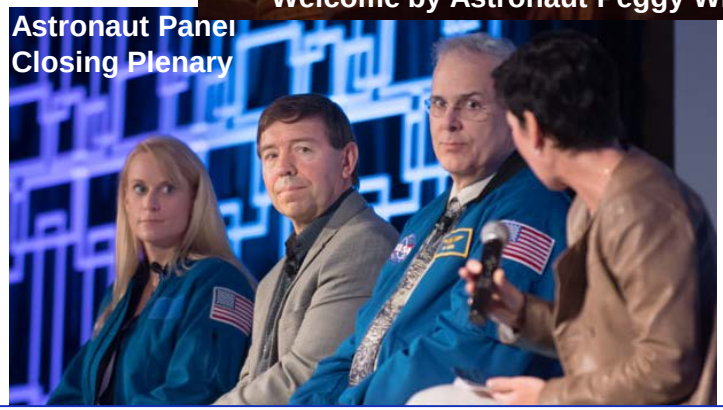




IWS Opening Plenary

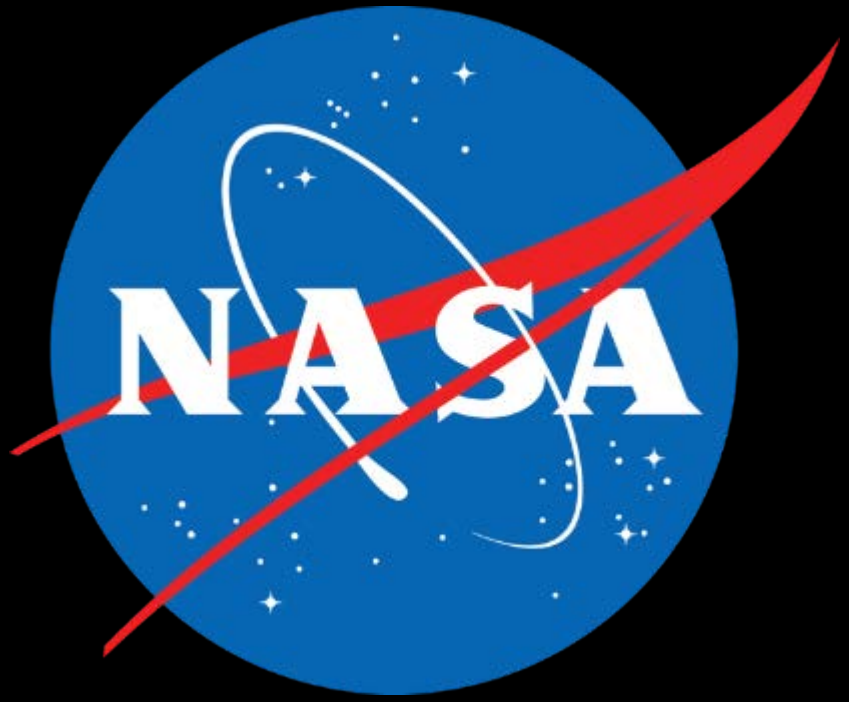

Twins IWG


Welcome by Astronaut Peggy Whitson


Astronaut Panel Closing Plenary

HRP Research: The Gateway to Mars

2018 NASA Human Research Program Investigators' Workshop
January 22-25, 2018
Galveston Island Convention Center, Galveston, TX


NASA