The Human Research Program Suite of Integrated One-year Mission Experiments: Description and Integration

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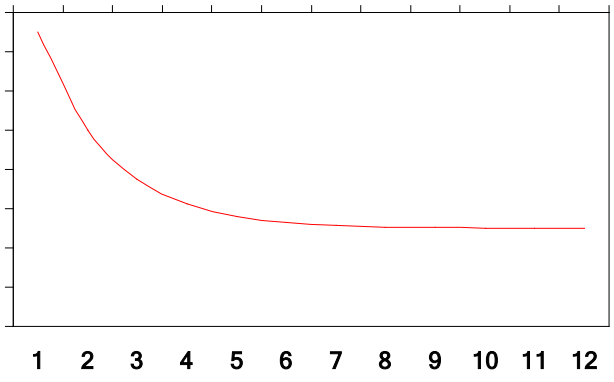
HRP IWS

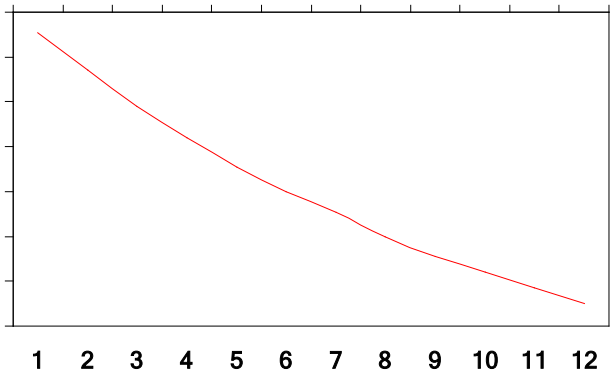
Why One-Year Missions?

- No number of six-month flights will tell us that we can send people to Mars with a reasonable expectation of maintaining health, safety, and performance.
- One-year ISS missions can reduce uncertainty.
- Identify and study aspects of human health and performance that can benefit from one-year missions.

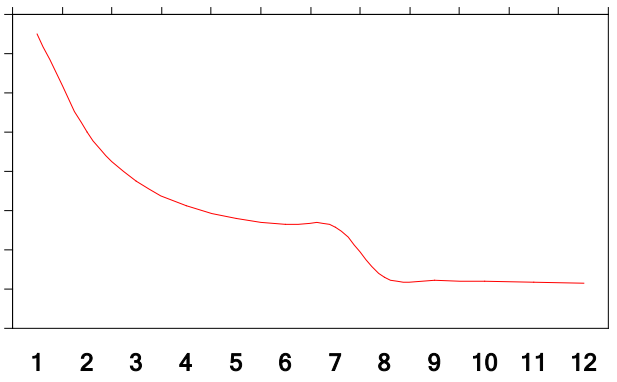
- Assumed (optimistic)



- Worse



- Worst-case



Integrated One-Year Mission (i1YM) Solicitation

NRA: HERO 80JSC017N0001-BPBA App C

Proposals submitted April 2018, selection October 31, 2018

Topic #1: Analyses of the Temporal Nature of Human Adaptation to Long-Duration Low-Earth Orbit Missions **Virtual NASA Specialized Center of Research (VNSCOR)**

Targeted crewmembers:

- One-year missions (n=10)
- Six-month missions (n=10) paralleling year-long expeditions
- Short-duration up to two-months (n=10) vehicle exchange expeditions

What does “integrated” mean:?

- Consistent set of measures across concurrent expeditions of three different durations on ISS (i.e., up to 2 months, six months and 1 year) to identify trends in adaptations to human health and performance and needs to be right sized so each crewmember can participate in all measures
- The short and six-month mission data will supplement the results for the one-year measures to develop the time course of the responses
- Individual proposals selected to become elements of integrated VNSCOR

Spaceflight Standard Measures (SSM)

- i1YMP proposers are encouraged to maximize use of the Spaceflight Standard Measures project as a fundamental resource when developing research methods
- Inflight times: $FD30^{SML}$, $FD150^{ML}$, $R\text{-}30^{L}$ (S=2mo, M=6mo, L=1yr)
- Includes:
  - Biochemical Measures: pre/in/post blood, pre/post urine
  - Cellular Profile: pre/in (mid/late)/post ambient blood & saliva
  - Microbiome: pre/in/post body/fecal/saliva
  - HFBP: pre/in/post cognition, surveys, actigraphy
  - Sensorimotor: pre/post Field Test subset
  - Cardiovascular: pre/post carotid Intima-Media Thickness (cIMT)

Standard Measures mapped to HRP Risks

Altered Gravity Level

- Vision alterations
- Renal stone formation
- Sensorimotor alterations
- Bone fracture
- Reduced muscle mass, strength
- Reduced aerobic capacity
- Adverse host-microorganism interactions
- Urinary retention
- Orthostatic intolerance
- Back pain
- Cardiac rhythm problems

Radiation

- Exposure to space radiation

Distance from Earth

- Limited in-flight medical capabilities
- Toxic medications

Isolation

- Adverse cognitive or behavioral conditions
- Performance & behavioral health decrements

Environment–Spacecraft Design

- Inadequate food/nutrition
- Human-system interaction
- Injury from dynamic loads
- Injury during EVA
- Celestial dust exposure
- Altered immune response
- Hypobaric hypoxia
- Sleep loss & work overload
- Decompression sickness
- Toxic exposure
- Hearing loss
- Sunlight exposure

Risks addressed by the *Spaceflight Standard Measures* project

Integrated One-Year Mission Selected Studies

Human Performance Integration

Norcross - Validation of Fitness for Duty Standards Using Pre- and Post-Flight Capsule Egress and Suited Functional Performance Tasks in Simulated Reduced Gravity

Downs - Temporal changes in astronauts muscle and cardiorespiratory physiology pre, during, and post spaceflight (CM efficiency and subsystem interrogation)

Shelhamer - Assessment of Otolith Function and Asymmetry as a Corollary to Critical Sensorimotor Performance in Missions of Various Durations

Reschke - Neuro-Vestibular Examination During and After Spaceflight (Vestibular Health)

Bouxsein - Time Course of Spaceflight-Induced Adaptations in Bone Morphology, Bone Strength and Muscle Quality

Boyd - The effect of long-duration space flight on bone microarchitecture and strength using three-dimensional high-resolution imaging (CSA)

Romaniello - Evaluating Resistive Exercise as a Long-term Countermeasure for Spaceflight-induced Bone Loss Using Calcium Isotopes

Liphardt - Joint health during a 1-year mission to the ISS - an assessment of exploration relevance (DLR)

Hughson - Manifestations of spaceflight-induced sub-clinical cardiovascular disease as a long-term health risk (CSA Vascular)

Arbeille - Preventive Medical Ultrasound Investigation of Organs Potentially Affected by Prolongated Exposure to Microgravity (CNES)

Bailey - Telomeres and the One Year Mission Project

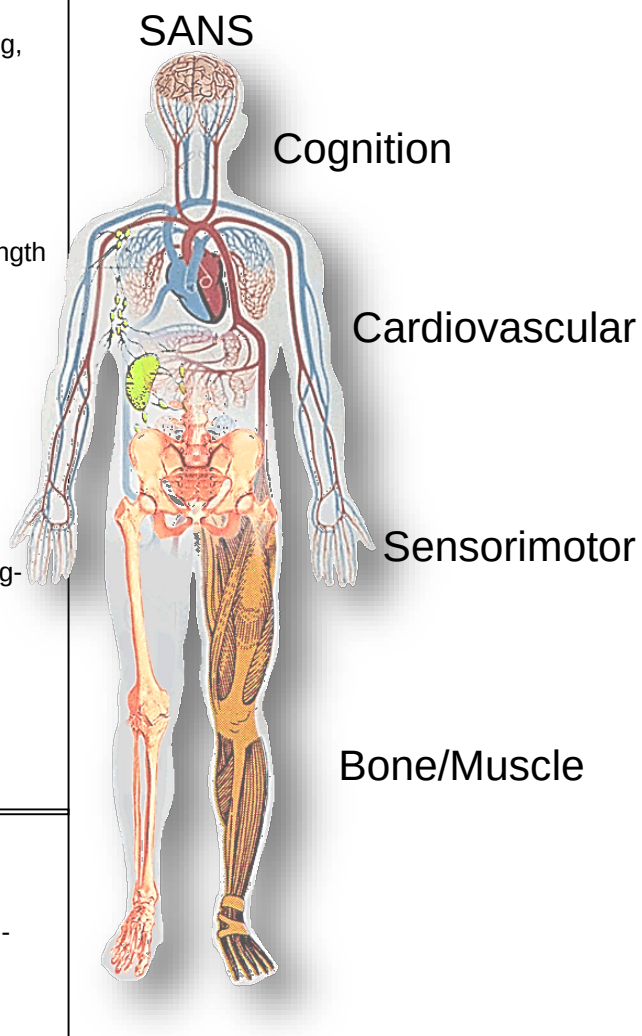
Levine - Coronary Anatomy and Physiology During 1 Year in Space

Cranial Optical Axis

Macias - Investigating Structure and Function of the Eye (SANS)

Basner - Temporal Nature of Cognitive and Visuospatial Brain Domain Changes during Long-Duration Low-Earth Orbit Missions

Zhang - Characterizing the Baselines of Sleep Quality, Cognitive / Operational Performance, Immune Function, and Intracranial Fluids for Deep Space Expeditions (SANS/Immune)



Why Integration?

Meeting the health-related challenges of human space exploration requires that one abandon any model of the human body that has the muscles, bones, heart and brain acting independently. Body parts will not travel on exploration missions. Instead, the individual space traveler's body must be viewed realistically, with all parts connected and fully interacting. (White & Averner (2001) Humans in space. *Nature* 409:1115-1118.)

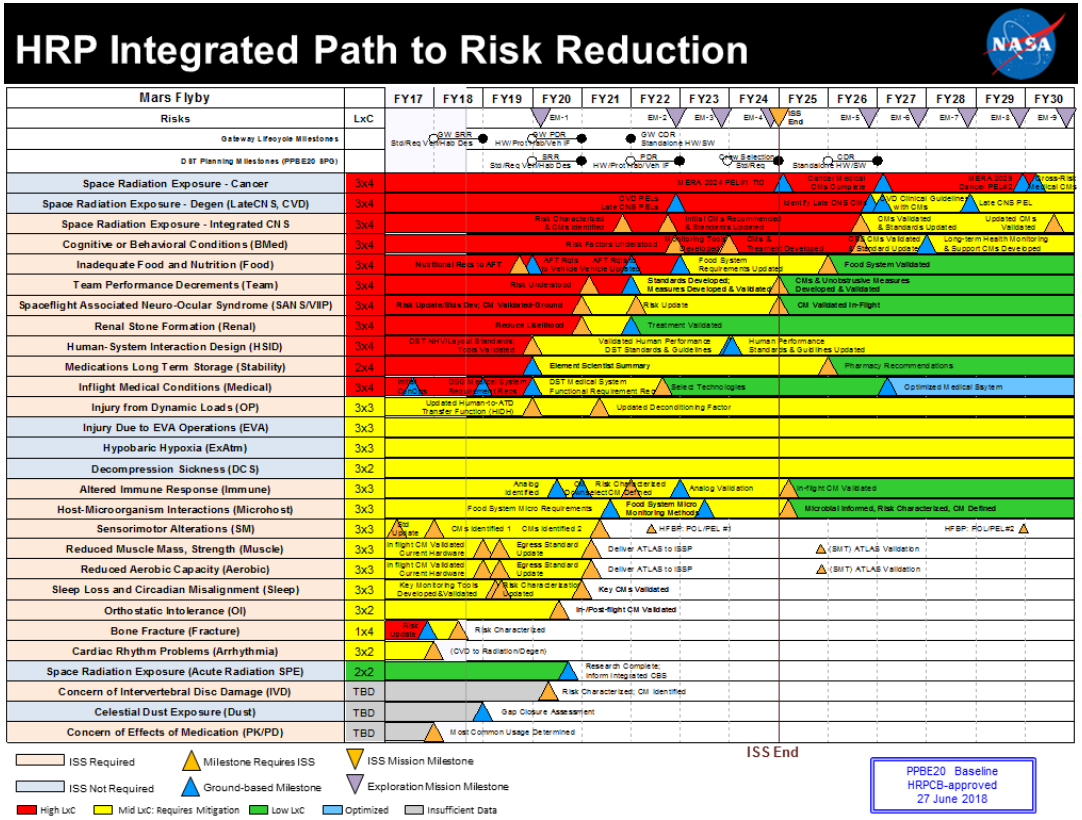
- Avoid conflicts between studies that might impact science
- Identify synergies between studies
  - increase science return
  - identify redundancies
  - share resources
  - find common contributing factors
  - find common countermeasures
- Ensure that associated data are made available to investigators
  - ISS Standard Measures
  - metadata (environmental, operational)
  - medical (if possible)
- Analyze combined data from all studies
  - check on data quality
  - cross-disciplinary results
  - identify outliers (→ examine related operational or environmental conditions)

Current and Forward Plans

- The Research Operations and Implementation (ROI) team is working the integration and implementation activities for the i1YM
- Currently, the first i1YM subject will launch No Earlier Than July 2021. Delays may be caused by commercial crew mission schedules and i1YM hardware development activities
- The launch/return of the first subject is planned on a commercial crew vehicle
- Focus areas for integration:
  - Crew time – need to be able to perform all testing within the crew time limits for pre, in, and post-flight
  - Blood limits – need to minimize blood requirements to stay with in blood volume limits
  - Potential conflicts with Med Ops/other experiments

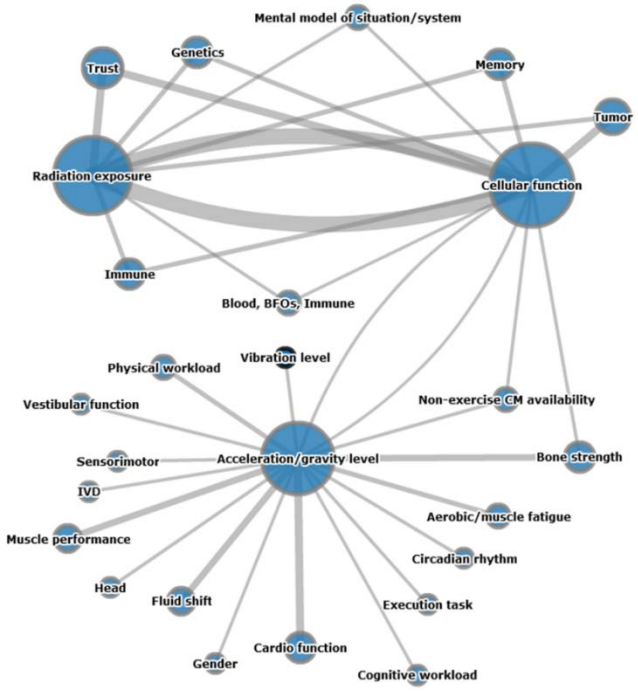
Obstacles to Integration

- Silos, Stovepipes
  - Scientific, Institutional
  - iPRR →
- Problem is not unique to HRP or NASA
- It is changing
  - CBS portfolio
  - Standard measures
  - IMPALA
- Need to be systematic in identifying interactions
- Opportunity with i1YM to start in the planning stages



Integration in the Planning Stage

- (ROI does *logistical* integration [excellently])
- Enable communication and file sharing
  - OneDrive
  - Slack
- Help arrange data sharing (including IRBs)
- Identify cross-disciplinary synergies (and conflicts)
- Identify relevant metadata and standard-measures data
- Initial approach
  - Text analytics on proposals (or reference lists) for common cited studies, common keywords and phrases, and common concepts
  - Network formulation to identify connections and critical hubs (highly interconnected ideas)
  - Incorporate metadata and standard measures



Integration in the Analysis Stage

- Obtain data across all studies
  - Arrange data sharing to avoid preemptive publication or release
  - May have opportunities for internal NASA briefings on interim findings
- Goals
  - Find possible redundant measures or synergies
  - Look for outliers that might indicate the need to examine a related operational or environmental condition
    - Close the loop from HRP measures back to mission impacts
    - Allow early identification of measures with operational impact that might help in rapid design of countermeasures
- Analysis procedures
  - Cross-correlations between measures
  - Factor analysis to identify measures related by a common underlying factor
  - Principal component analysis to identify minimal sets of measures that span the physiological space
  - Cluster analysis and network analysis to visualize relationships
  - Supervised machine learning to predict future time course

Spares

Spaceflight Standard Measures
ISS – 12-month mission

Pre-flight	In-flight	Post-flight
Actigraphy w/ sleep logs (2 weeks each) (L-180, L-90)	Actigraphy (continuous)	Actigraphy w/ sleep logs (2 weeks) (R+0-14)
Personality Survey (anytime preflight)	Sleep Quality/Team Questionnaire (monthly)	Cellular Profile Survey (R+15)
Cognition (L-120 fam, L-90)	Cognition (FD30, FD150 & R-30)	Cognition (R+10, R+30)
Cellular Profile (ambient blood, saliva) (L-180, L-90)	Cellular Profile (ambient blood, saliva) (Early mission vehicle return, R-0)	Cellular Profile (ambient blood, saliva) (R+30)
Biochemical Markers (blood, urine) (L-180)	Biochemical Markers (blood only) (FD30, FD150, R-30)	Biochemical Markers (blood, urine) (R+30)
Microbiome (body, saliva, fecal) (L-90)	Microbiome (body, saliva, fecal) (FD30, FD150, R-30)	Microbiome (body, saliva, fecal) (R+30)
Carotid Intima-Media Thickness (cIMT) (L-180)	N/A	Carotid Intima-Media Thickness (cIMT) (R+5, R+30)
Sensorimotor Measures (L-180 , L-90)	N/A	Sensorimotor Measures (R+0 at landing site, R+0 at JSC, R+9)
Crew time: 6.83 hrs	Crew time: 24.33 hrs	Crew time: 5.25 hrs