



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

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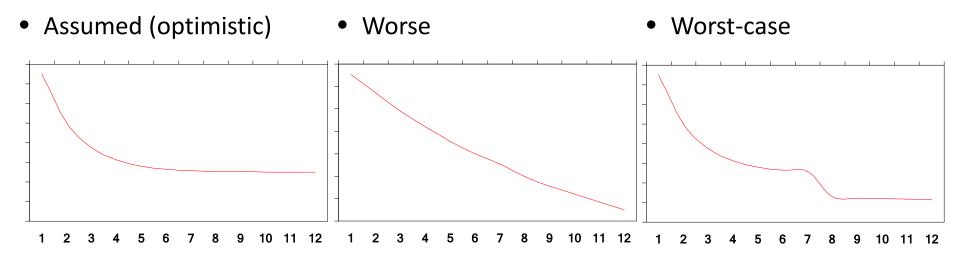
NASA Johnson Space Center, Houston TX

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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.



## 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<sup>SML</sup>, FD150<sup>ML</sup>, R-30<sup>L</sup> (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

<ul> <li>Altered Gravity Level</li> <li>Vision alterations</li> <li>Renal stone formation</li> </ul>	Radiation <ul> <li>Exposure to space radiation</li> </ul>	<ul> <li>Environment–Spacecraft Design</li> <li>Inadequate food/nutrition</li> <li>Human-system interaction</li> <li>Injury from dynamic loads</li> <li>Injury during EVA</li> <li>Celestial dust exposure</li> <li>Altered immune response</li> <li>Hypobaric hypoxia</li> <li>Sleep loss &amp; work overload</li> <li>Decompression sickness</li> <li>Toxic exposure</li> <li>Hearing loss</li> <li>Sunlight exposure</li> </ul>
<ul> <li>Sensorimotor alterations</li> <li>Bone fracture</li> <li>Reduced muscle mass, strength</li> <li>Reduced aerobic capacity</li> </ul>	<ul> <li>Distance from Earth</li> <li>Limited in-flight medical capabilities</li> <li>Toxic medications</li> </ul>	
<ul> <li>Adverse host- microorganism interactions</li> <li>Urinary retention</li> <li>Orthostatic intolerance</li> <li>Back pain</li> <li>Cardiac rhythm problems</li> </ul>	<ul> <li>Isolation</li> <li>Adverse cognitive or behavioral conditions</li> <li>Performance &amp; behavioral health decrements</li> </ul>	

**Risks** the Spaceflight Standard Weasures project

### **Integrated One-Year Mission Selected Studies**

#### **Human Performance Integration**

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

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

<u>Shelhamer</u> - 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)

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

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

<u>Romaniello</u> - Evaluating Resistive Exercise as a Long-term Countermeasure for Spaceflightinduced Bone Loss Using Calcium Isotopes

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

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

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

Bailey - Telomeres and the One Year Mission Project

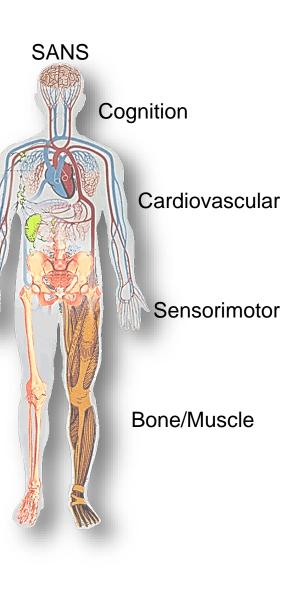
Levine - Coronary Anatomy and Physiology During 1 Year in Space

#### **Cranial Optical Axis**

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

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

<u>Zhang</u> - 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 <u>all parts connected and</u> <u>fully interacting</u>. (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



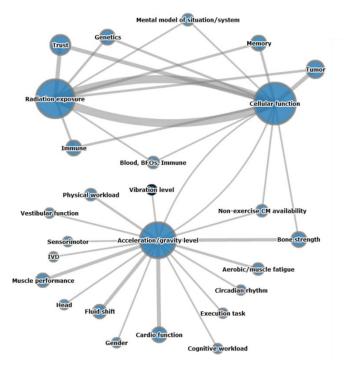
#### **Obstacles to Integration**

- 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

Mars Flyby		FY17 FY18 FY19 FY20 FY21 FY22 FY23 FY24 F	Y25 FY26 FY27 FY28 FY29
Risks	LxC		BS EM-5 EM-6 EM-7 EM-8
Gateway Lifeoyole Millestones		StorReg VerHab Des HW/ProtHab/Veh IF Standalone HW/SW	
D ST Planning Milesiones (PPBE20 SPG)			
Space Radiation Exposure - Cancer	3x4	M ERA 2024 PEL#1 TO	Oancer Miedical MERA 2029 Offis Complete Oancer PELE2
Space Radiation Exposure - Degen (LateCN S, CVD)	3x4	OVD PELS	entry Late ONS GM
Space Radiation Exposure - Integrated CN S	3x4	Risk Characterized Initial Oli's Recommended	Citis Validated Updated Citi & Standardis Updated Validated
Cognitive or Behavioral Conditions (BMed)	3x4	Risk Factors Understood Multipling Tools Olis &	CMs Validated Long-term Health Monity
Inadequate Food and Nutrition (Food)	3x4	Nutritional Ress to AFT AFT Rols AFT RO	Food System Validated
Team Performance Decrements (Team)	3x4	Risk Understo od Astronomick Dipotets Standards Developed; Misk Understo od Astronomick Developed; Misk at or	CMs & Unobstrusive Measures Developed & Validated
paceflight Associated Neuro-Ocular Syndrome (SAN S/VIIP)	3x4	Risk Update/Skis Dev; ON Validated-Ground Risk Update	CM Validated In-Flight
Renal Stone Formation (Renal)	3x4	Reduce Likelihood Treatment Validated	
Human-System Interaction Design (HSID)	3x4	DST NH VILsyout Standards; Validated Human Performance Human Perf DST Standards & Guide Ines Standards & Guide Ines Standards &	ormance & Guid lines Updated
Medications Long Term Storage (Stability)	2x4	Element Scientist Summary	Pharmacy Recommendations
Inflight Medical Conditions (Medical)	3x4	DEG M encal Bystem DST M edical System Drops Beautyment Bers Experience Beautyment Bea	Optimized M edical Skytem
Injury from Dynamic Loads (OP)	3x3	Updated Human-to-ATD Transfer Function (HIDH) Updated Deconditioning Factor	
Injury Due to EVA Operations (EVA)	3x3		
Hypobaric Hypoxia (ExAtm)	3x3		
Decompression Sickness (DC S)	3x2		
Altered Immune Response (Immune)	3x3	Analog CA Risk Characterized Analog Validation	In-flight CM Valid ated
Host-Microorganism Interactions (Microhost)	3x3	Food System Micro Requirements Food System Micro	Microbial Informed, Risk Characterized, CM Defined
Sensorimotor Alterations (SM)	3x3	Upg ste CN s Identified 1 CMs Identified 2	
Reduced Muscle Mass, Strength (Muscle)	3x3	In flight CM Validated Epress Standard Deliver ATLAS to ISSP	(SIIT) ATLAS Validation
Reduced Aerobic Capacity (Aerobic)	3x3	In flight OM Validated Egress Standard Deliver ATLAS to ISSP	(SMT) ATLAS Validation
Sleep Loss and Circadian Misalignment (Sleep)	3x3	Key Montoring Tools Res Characterization Key CM s Validated	
Ortho static Intolerance (OI)	3x2	Ir-/Post-flight ÇM Validated	
Bone Fracture (Fracture)	1x4	Risk Characterized	
Cardiac Rhythm Problems (Arrhythmia)	3x2	(CVp to Radiation/Degen)	
Space Radiation Exposure (Acute Radiation SPE)	2x2	Research Complete; inform Integrated CBS	
Concern of Intervertebral Disc Damage (IVD)	TBD	Risk Characterized: CM Identified	
Celestial Dust Exposure (Dust)	TBD	Gap Closure Assessment	
Concern of Effects of Medication (PK/PD)	TBD	Most Common Usage Determined	

#### Integration in the Planning Stage

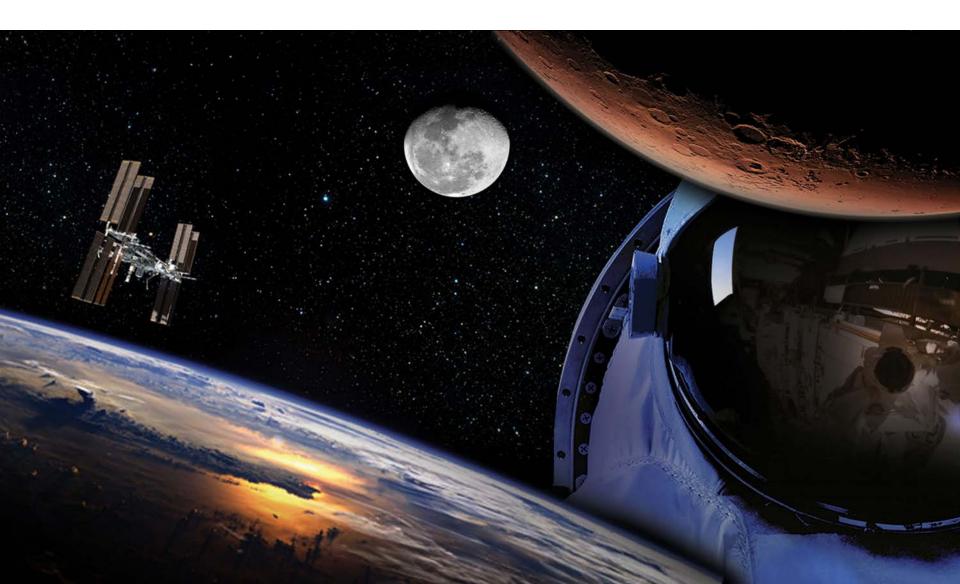
- (ROI does *logistical* integration [excellently])
- Enable communication and file sharing
  - OneDrive
  - Slack
- Help arrange data sharing (including IRBs)
- Identify cross-disciplinary synergies (and conflicts)
- Identify relevant metadata and standardmeasures data
- Initial approach
  - Text analytics 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)