NASA REQUEST FOR INFORMATION

Request for Information on Topics Supporting Crew Health and Performance

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DESCRIPTION

NASA's Human Research Program (HRP) investigates and mitigates the highest risks to astronaut health and performance in exploration missions. The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration, and to ensure safe and productive human spaceflight. The scope of these goals includes both the successful completion of exploration missions and the preservation of astronaut health over the life of the astronaut.

HRP has developed an Integrated Research Plan (IRP) to describe the requirements and notional approach to understanding and reducing the human health and performance risks. The IRP describes the Program's research activities that are intended to address the needs of human space exploration and serve HRP customers. The IRP illustrates the HRP's research plan through the timescale of exploration missions of extended duration. The Human Research Roadmap (http://humanresearchroadmap.nasa.gov) is a web-based version of the IRP that allows users to search HRP risks, gaps, and tasks.

Access to NASA's human life sciences data can assist the research community in providing a better understanding of the appropriate strategies required to mitigate spaceflight-related health risks. If interested in learning about and accessing this data, please visit the Users' Guide for requesting data at: http://lsda.jsc.nasa.gov/common/dataRequestFAQ.aspx

To support formulation of a solicitation scheduled to be released in September 2016, NASA is seeking feedback regarding the set of Research Topics listed below. Specifically, NASA wishes to know:

1. Are the correct research questions being asked to meet the goals of the Program? --- based on the research plan associated with each of the major risks addressed by the Program, as embodied in the gaps and tasks planned to carry out that plan (http://humanresearchroadmap.nasa.gov).
2. Is each topic sufficiently well-defined, clear and unambiguous?

This RFI is open to responses from all parties including commercial entities, international organizations, academia, NASA Centers, and other government agencies. Appendices referenced in this RFI will be posted alongside this document on the NSPIRES (http://nspires.nasaprs.com) web site. Ideas are sought to help refine the following research topics:

RESEARCH TOPICS

1. Biological, Physiological, and Behavioral Functions of Mice during Partial (0 – 1) G-Exposures Provided by Centrifugation on the International Space Station

Primary Risk or Research Area	Relevant Gap
Artificial Gravity	*N/A*
Risk of Bone Fracture	**Fracture 2:** We need to characterize the loads applied to bone for standard in-mission activities.
Risk of Early Onset Osteoporosis Due to Spaceflight	**Osteo 4:** We don't know the contribution of each risk factor on bone loss and recovery of bone strength, and which factors are the best targets for countermeasure application.
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance	**M2:** Characterize in-flight and post-flight muscle performance. **M24:** Characterize the time course of changes in muscle protein turnover, muscle mass, and function during long duration space flight.
Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations	**VIIP1:** We do not know the etiological mechanisms and contributing risk factors for ocular structural and functional changes seen in-flight and post flight. **VIIP13:** We need to identify preventive and treatment countermeasures (CMs) to mitigate changes in ocular structure and function and intracranial pressure during spaceflight.
Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight	**SM26:** Determine if exposure to long-duration spaceflight leads to neural structural alterations and if this remodeling impacts cognitive and functional performance.
Risk of Cardiac Rhythm Problems	**CV1:** What are the in-flight alterations in cardiac structure and function? **CV7:** How are fluids redistributed in flight?

Secondary Risk	Relevant Gap
Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload	**Sleep Gap 10:** We need to identify the spaceflight environmental and mission factors that contribute to sleep decrements and circadian misalignment, and their acceptable levels of risk.
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed3:** We need to identify and quantify the key threats to, and promoters of, mission relevant behavioral health and performance during autonomous, long duration and/or long distance exploration missions.

Background

During long-duration exposure to microgravity astronauts undergo cardiovascular deconditioning, bone and muscle loss, immune system changes, metabolic alterations, and visual and ophthalmologic changes. Also seen are a decrease in post-flight tolerance to orthostatic challenges, and sensorimotor disturbances with G-transitions. It is not known if artificial gravity

(AG) exposure via centripetal acceleration is an effective countermeasure for these deleterious physiological changes (Clement et al. 2015). One constraint of ground-based studies using centrifugation on Earth is that the centripetal acceleration combines with the gravitational acceleration (g) to create a net resultant vector, which has an amplitude larger than 1 G. In the absence of gravity in orbit centripetal acceleration is the sole force acting on the subject. Therefore, flight studies allow a direct comparison of the potential differences between the effects of centrifugation in ground-based and space conditions. Such comparisons can potentially reveal the confounding effects of Earth's gravity. These confounding effects could then be used to calibrate and adjust the artificial gravity prescription in the crew that will be determined from ground-based studies in humans

Aims

Research is hereby being solicited for proposals that will quantify the effects of varying G-levels (between 0 and 1 G, levels to be suggested by the proposers) on biological, physiological, and behavioral responses in mice centrifuged using the Japan Aerospace Exploration Agency (JAXA) Mouse Habitat Unit onboard the International Space Station's Kibo module. The centrifuge in the Mouse Habitat Unit can spin 6 cages, each containing an individual mouse, at a distance of 15 cm from the axis of rotation, for a period ranging from 30 days up to 6 months (preferred study duration to be suggested by the proposers). The Mouse Habitat Unit also contains a 0 G counterpart, housing an additional 6 individually-caged mice (Morita et al. 2015). It is anticipated that the funded experiment/s will include several flights of 12 mice each, so that different G levels may be investigated. To maximize science return from each set of flown mice, NASA may choose to execute multiple experiments in a single payload, including sharing tissues (Biospecimen Sharing Program) among multiple investigators.

In-flight, non-invasive measurements of interest would include food and water intake, body mass, posture and orientation, activity, and sleep/wakefulness parameters. After retrieval of the animals, measurements of interest would include bone size, mineral mass, and mechanical properties; muscle fiber size and type content; retinal and cardiovascular properties; functional and structural changes in otolith structures; expression of bone, muscle, immune, cartilage, and inner ear alteration markers; and proteomics analysis of tissues.

In-flight centrifugation of mice will provide valuable data on how mammalian health and behavior is affected by an imparted partial gravity, focusing on bone loss, muscle atrophy, changes in intracranial pressure, cardiovascular flow, immunity, and inner ear function. It will also provide information indicating whether partial gravity as found on the Moon or Mars is sufficiently protective or whether additional countermeasures are required while on these planetary bodies.

Specifically, proposals should address the following topic:

- Characterize the effects of G-levels ranging from 0 to 1 provided by centripetal acceleration in orbit on biological, physiological, and behavioral functions in mice.
- Establish a dose response curve between physiological variables and G-effects between 0 and 1 in mice for determination of physiological G-thresholds in developing an in-flight centrifugation prescription to mitigate the negative health effects of weightlessness.

A summary of prior animal research in spaceflight supported by NASA over the past decades is available at https://www.nasa.gov/ames/research/space-biosciences/nasa-special-publication-on-translational-cell-and-animal-research

Research Environment: ISS

References

Clement GR, Bukley AP, Paloski WH (2015) Artificial gravity as a countermeasure for mitigating physiological deconditioning during long-duration space missions. Front Syst Neurosci 9: 92. doi: 10.3389/fnsys.2015.00092

Morita H, Obata K, Abe C, Shiba D, Shirakawa M, Kudo T, et al. (2015) Feasibility of a short-arm centrifuge for mouse hypergravity experiments. PLoS ONE 10(7): e0133981. doi:10.1371/journal.pone.0133981.

Required Deliverables

- A dose-response curve of G-level between 0 and 1 for various spaceflight-relevant biological and physiological variables
- Determination of G-thresholds for various physiological functions for developing in-flight AG countermeasures

2. Exploration Information System (EIS)

Primary Risk	Relevant Gap
Risk of Inadequate Human-Computer Interaction	**HCI-06**: We need guidelines to ensure crewmembers receive all of the information required to accomplish necessary tasks in a timely fashion, even when operating autonomously.

Secondary Risk	Relevant Gap
Risk of Performance Errors Due to Training Deficiencies	**TRAIN-03**: We need to develop guidelines for effective onboard training systems that provide training traditionally assumed for pre-flight.
Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions	**Med-07:** We do not have the capability to comprehensively process medically-relevant information to support medical operations during exploration missions.
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team Gap 3:** We need to identify a set of countermeasures to support team function for all phases of autonomous, long duration and/or distance exploration missions.
Risk of Injury and Compromised Performance Due to EVA Operations	**EVA 10:** Can knowledge and use of real-time physiological and system parameters during EVA operations improve crew health and performance?
Risk of Inadequate Mission, Process and Task Design	**MPTASK-01:** We need methods and tools to collect measures of missions, process, and task performance.
Risk of Inadequate Design of Human and Automation/Robotic Integration	**HARI-02:** We need to develop design guidelines for effective human-automation-robotic systems in operational environments that may include distributed, non-colocated adaptive mixed-agent teams with variable transmission latencies.
Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload	**Sleep Gap 8:** We need to develop individualized scheduling tools that predict the effects of sleep-wake cycles, light and other countermeasures on performance, and can be used to identify optimal (and vulnerable) performance periods during spaceflight.

Background

Long-duration missions will involve greater crew autonomy and increased dependence on computer-provided information needed to perform routine tasks, as well as time- and safety-critical tasks. The current approach of calling ground control for questions, workarounds, and forgotten procedural steps will no longer be feasible, and in certain circumstances may not be available at all. Crewmembers will have to rely solely on available electronic information for tasks such as vehicle/habitat operations, maintenance, and scientific exploration. There is an increased risk of human errors, frustration, and inefficiency when information is not available, is difficult to find, or is presented in the wrong format.

Current information systems (e.g., medical information, physiology, behavioral health, vehicle and habitat environment, training, and science payloads) are being developed independently of each other. These systems are envisioned to store, organize, manage, and process the large amount data that will be needed and collected during a long-duration mission.

Without an overarching information architecture framework, the result will be a system of information silos that are not well integrated with each other, making it difficult for crew to find, interpret, and use information. Integrating the information silos is especially important for long-duration exploration missions due to increased crew autonomy. An information architecture framework is needed that will support the seamless integration of these information systems by providing intuitive data organization, a common user interface, and efficient user interaction. For example, proper integration of information from the exercise, sleep, and medical silos could provide valuable information based on crewmember health and status on the timing of an EVA task.

The integrated information system will need to manage a vast amount of information necessary for long duration mission tasks, such as monitoring and operating systems, communicating, maintenance, and scientific studies. It will also need to provide assistance with behavioral and physiological health as well as individual and team psychological well-being.

The objective of this project is to design an Exploration Information System (EIS) framework based on laboratory studies of representative systems incorporating different candidate techniques for navigation, metadata, data categorization, search, and interaction design. Guidelines based on the research findings, along with a visual style guide, and templates should be provided to aid commonality. This system will ensure a common look-and-feel across all information systems, and an information architecture that is effective, efficient, and acceptable to crew.

There is a need to develop and compare information architecture approaches (e.g., techniques for navigation, metadata, data categorization, search, interaction, and visualization) for a large critical information system that is integrating data from many sub-systems. The resulting system should demonstrate the visual interface for major sub-systems, and should also demonstrate the integration of information from at least three sub-systems.

Aims

1) Design and develop candidate flexible and extensible interfaces using several information architecture strategies that meet the requirements stated above. Solutions may be based on successful information systems in industry or government agencies, or may be novel and innovative.
2) Experimentally compare candidate architectures to determine the best approach in terms of effectiveness, efficiency, and satisfaction. Develop a design guideline document to capture the key aspects of the recommended architecture.
3) Develop a medium fidelity interactive information system prototype demonstrating the selected information architecture strategy.
   The prototype should have, at minimum, the following characteristics:

- Designed based on current surface operations design reference missions (DRM) and concepts of operation (NASA will provide DRM and task analysis information).
- Represents most major space mission sub-systems and their information structure (but not fully developed)
- Includes sample of a dynamically integrated data visualization from at least three sub-systems (e.g., EVA readiness determined by a display of sleep quality, exercise history, and schedule)
- Provides smart search interface with guide through search results
- Easy to use by users with different skill levels and adaptable to user types and tasks

Research Environment: Ground-Based Laboratory

Required Deliverables
- Design guidelines document, visual style guide, templates for common look-and-feel
- Report of experimental data and findings
- Interactive prototype demonstrating visual interface

3. Unobtrusive Methods for Measuring Situation Awareness

Primary Risk	Relevant Gap
Risk of Inadequate Mission, Process and Task Design	**MPTASK-01**: We need methods and tools to collect measures of missions, process, and task performance.

Secondary Risk	Relevant Gap
Risk of Inadequate Design of Human and Automation/Robotic Integration	**HARI-03:** We do not know how to quantify overall human-automation-robotic system performance to inform and evaluate system designs to ensure safe and efficient space mission operations.
Risk of Inadequate Human-Computer Interaction	**HCI-06:** We need guidelines to ensure crewmembers receive all of the information required to accomplish necessary tasks in a timely fashion, even when operating autonomously.
Risk of Performance Errors Due to Training Deficiencies	**TRAIN-01:** We do not know which validated objective measures of operator proficiency and of training effectiveness should be used for future long-duration exploration missions.
Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload	**Sleep Gap1:** We need to identify a set of validated and minimally obtrusive tools to monitor and measure sleep-wake activity and associated performance changes for spaceflight. **Sleep Gap 2:** We need to understand the contribution of sleep loss, circadian desynchronization, extended wakefulness and work overload, on individual health (physical and behavioral), team functioning, and performance (including operational performance), for spaceflight.
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team Gap 2:** We need to identify a set of validated measures, based on the key indicators of team function, to effectively monitor and measure team health and performance fluctuations during autonomous, long duration and/or distance exploration missions.
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed3**: We need to identify and quantify the key threats to and promoters of mission relevant behavioral health and performance during autonomous, long duration and/or long distance exploration missions.

Background
Situation awareness (SA) is the perception of environmental elements with respect to time and/or space, the comprehension of their meaning, and the projection of their status after something has changed, such as time (Endsley, 1995). For example, a crewmember may be monitoring parameters on multiple displays. He/she must be able to perceive relevant changes in those displays (e.g., component temperature rising), comprehend what that means in context (e.g., component approaching upper temperature threshold/overheating), and be able to predict what may happen next (e.g., failure of the component, potentially leading to a caution message and other outages). During spaceflight, this type of situation awareness must be maintained for a multitude of variables across multiple displays. Design of the displays can significantly influence the crewmember's ability to do that well.

Several measures for assessing situation awareness in the form of post-simulation or post-task surveys exist, but there is a dearth of information regarding available real-time or near real-time metrics of SA that can be used unobtrusively mid-task.

While methods of measuring SA exist and have been used extensively in aviation, the methods are generally obtrusive and interrupt the task being measured. These methodological issues are less critical when designing an aircraft that will have many upgrades and modifications over its lifecycle. Much higher confidence in initial design is required when there are significantly fewer upgrade opportunities, such as with spacecraft and habitat design.

An unobtrusive method of measuring situation awareness is needed during development (for the purpose of redesigning/improving designs), and in-situ during a mission (for the purpose of adapting displays in real-time to make the task-relevant variables of interest more salient, thus improving situation awareness. In particular, we are seeking methods that would be appropriate to **reliably**, **affordably**, and **unobtrusively** measure SA during a short- or long-duration mission.

Aims
Develop and provide improved methods of **reliably**, **affordably**, and **unobtrusively** measuring situation awareness (SA) in real-time or near real-time contexts. Existing methods of measuring SA are inadequate for spaceflight operations due to their obtrusive, largely survey-based nature. Such methods should be sensitive enough to detect the loss of SA, which can be a predictor of errors and increased risk. Such a method would allow for real-time mitigation and modulation of human interactions with the system to reduce the likelihood of errors. The method should be developed and tested for future use in spaceflight system design and use in operational environments.

The proposal should include summarization of current methods, proposed development or maturation of either novel or existing methods for unobtrusive SA assessment, development of the method or tool itself, and ground-based preliminary testing. Validation is not required as part of this project, and may be done in the future as part of other integrated studies.

The proposed solution should build on existing methods, with a focus on enhancing the product to ensure spaceflight readiness. Proposers must also identify the NASA technology readiness level (TRL) of their research proposal. An initial TRL level of 3 at the start of the project is desired as a minimum to ensure that maturation of the concept to a usable level is realistic in the span of a 2-3 year funding period. Desired TRL at completion is a level of 6 or higher. If the solution is a non-technological one, then evidence of the method's maturity should be discussed instead, including relevant publications or implementations.

NASA is seeking innovative and novel methods. To this end, a variety of approaches are acceptable, including those using objective data as well as subjective or rater-based methods. Some potential examples of methods that may be applicable to this work include real-time vocalization of activities, intra-task survey methods, or use of eye tracking.

Research Environment: Ground-Based Laboratory

Reference

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. Human Factors, 37, 32–64.

Required Deliverable

- A method or tool that enables SA to be measured unobtrusively, and correlates with established measurement techniques

4. Tissue Sharing: Research Proposing the Use of Archived Tissue Samples or Samples from On-going Experiments

Primary Risk	Relevant Gap
Risk of Acute (in-flight) and Late Central Nervous System Effects from Radiation	All open Space Radiation research gaps listed in the Human Research Roadmap: https://humanresearchroadmap.nasa.gov/Risks/
Risk of Cardiovascular Disease and Other Degenerative Tissue Effects from Radiation Exposure	
Risk of Radiation Carcinogenesis	

Secondary Risk	Relevant Gap
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed3:** Need to identify and quantify the key threats to and promoters of mission relevant behavioral health and performance during autonomous, long duration and/or long distance exploration missions.
Risk of Cardiac Rhythm Problems	**CV8:** Can manifestations of sub-clinical or environmentally induced cardiovascular diseases during spaceflight be predicted?
Risk of Spaceflight-Induced Intracranial Hypertension/Vision Alterations	**VIIP1:** We do not know the etiological mechanisms and contributing risk factors for ocular structural and functional changes seen in-flight and postflight.
Risk of Adverse Health Event Due to Altered Immune Response	**IM1:** We do not know to what extent spaceflight alters various aspects of human immunity during spaceflight missions up to 6 months. **IM8:** We do not know the influence, direct, or synergistic, on the immune system of other physiological changes associated with spaceflight.
Risk Of Early Onset Osteoporosis Due To Spaceflight	**Osteo 7:** We need to identify options for mitigating early onset osteoporosis before, during and after spaceflight.
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength & Endurance	**M23**: Determine if factors other than unloading contribute to muscle atrophy during space flight.
Risk of Inadequate Nutrition	**N6:** What impact does the spaceflight environment have on oxidative damage? **N15**: Need to identify the most important nutritional factors for oxidative damage during spaceflight.

Background
The Space Radiation Element is interested in promoting tissue sharing of samples that have already been irradiated, collected, and stored at our various PIs' institutions. We are also interested in encouraging scientific collaborations between investigators and institutions for the sharing of tissue samples to be collected with arrangements planned before scheduled runs and/or sacrifices. New investigators are encouraged to apply for funds to expand research content in collaboration with the PI of an ongoing project or to propose hypothesis-driven research consistent with the relevant HRP gaps listed above.

A consolidated list of available samples and tissues available from upcoming sacrifices is provided in Table 1.

Aims

- Use existing tissue samples that have been irradiated, collected, and stored at the various Space Radiation Element PI institutions to address any open Space Radiation research gaps listed in the Human Research Roadmap (https://humanresearchroadmap.nasa.gov/Risks/). Of particular interest are the following studies:
    - Examination of available tissues for evidence of late neurological diseases across multiple animal species

    - Examination of available tissues for evidence of major markers related to radiation-induced late cardiovascular diseases such as fibrosis, atherosclerosis, and other vascular changes across multiple animal species
- Expand the research content in collaboration with the PI of an ongoing project or propose hypothesis-driven research consistent with the relevant HRP gaps listed in Table 1.

In order to be considered responsive to this special topic area, proposed studies must clearly identify and address one or more of the Space Radiation research gaps.

Research Environment: Ground-Based Laboratory

Table 1. Example listing of tissues available for sharing.

Animal strain	Gender	Age at exposure	Time point of sacrifice	Organ type	Particle type	Energy	Dose
CBA/CaJ	M	10-12 w	1 w, 1 mo, and 6 mo	Spleen	Titanium	1 GeV/n	0.1 to 0.5 Gy
C57Bl/6	F	6-8 w	5 d - 2 yr	Small intestine, Colon, Liver, Spleen, Kidney	Proton Iron Gamma	I GeV/n 1 GeV/n Cs 137	5 Gy 0.5-7 Gy 0.5-10 Gy
C57Bl6/J	M	6 mo	7 to 12 mo	Brain	Proton Iron Silicon	150 MeV 600 MeV 600 MeV	1 Gy 0.1-0.4 Gy 0.3-0.9 Gy
C57Bl6/FVB mix	M/F	4-8 w	up to 15 mo	Brain	Proton Carbon Silicon Iron	150 MeV/n 290 MeV/n 238 MeV/n 600 MeV/n	0.5 Gy
C57BL/6	M	2 mo	6 w	Brain	Proton	150 MeV/n	50-200 cGy
C57BL/6: strain Tg(Thy1-EGFP)MJrsJ	M	6 mo	6, 12 and 24 w	Brain	Oxygen Titanium	600 MeV	5, 30 cGy
C57Bl	M	10 w-7 mo	1, 7, 30, 120 d	Kidney, Spleen	Iron Silicon	600 MeV/n 350 MeV/n	10, 100 cGy 10, 30, 100 cGy
C3H/HeN	M	10 w-5 mo	1, 7, 30, 120 d	Kidney, Spleen	Iron Silicon	600 MeV/n 350 MeV/n	10, 30, 100 cGy
LA1.Kras. 129S2, LA1.Kras. B6.129S2	M/F	5-15 w	Survival, 4 h-100 d	Lung, Spleen, Liver, Heart, Kidney	Iron Proton Silicon	600 MeV/n-1 GeV/n 50-150 MeV/n 600 MeV/n	0.05-1 Gy 2 Gy 0.17-2 Gy
Rb FL/FL; p53 +/+, p53 FL/+, p53 FL/FL; LSL-YFP	M/F	42-98 d	Showing symptoms of lung tumor development	Lung, Spleen, Kidney, Liver, Proximal small intestine, Thymus, Heart, Brain	X-rays Iron	320 kVp 600 MeV/n	1.2-4 Gy 0.2-1 Gy
Kras-LA1 & Kras-LA1; Super p53	M/F	42-98 d	180 d or showing symptoms	Lung, Spleen, Kidney, Liver, Proximal small intestine, Thymus, Heart, Brain	X-rays Iron	320 kVp 600 MeV/n	1.2 Gy 0.2 Gy
APC1638	M/F	6-8 w	150 d	Intestine, Colon, Serum	Iron Silicon Oxygen	1 GeV/n 300 MeV/n 325 MeV/n	5, 50 cGy 5 cGy 5, 10 cGy

Required Deliverable

- Report of research results

5. Promoting Stress Tolerance, Adaptability and Behavioral Health via Enhancing Exercise Protocols for Long Duration Exploration Mission Crews

Primary Risk	Relevant Gap
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed 1:** We need to identify and validate countermeasures that promote individual behavioral health and performance during exploration class missions. **BMed7:** We need to identify and validate effective methods for modifying the habitat/vehicle environment to mitigate the negative psychological and behavioral effects of environmental stressors (e.g., isolation, confinement, reduced sensory stimulation) likely to be experienced in the long duration spaceflight environment.

Secondary Risk	Relevant Gap
Risk of Adverse Health Event Due to Altered Immune Response	**IM1:** We do not know to what extent spaceflight alters various aspects of human immunity during spaceflight missions up to 6 months. **IM6:** We do not know the cumulative effects of chronic immune dysfunction on missions greater than six months.
Risk of Inadequate Nutrition	**N4:** Does mission architecture and/or available countermeasures impact nutritional status of crewmembers during spaceflight? **N3.1:** Determine the macronutrient requirements for spaceflight.
Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance	**M14:** Identify adjuncts to exercise countermeasures that can be used to better mitigate muscle loss.
Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity	**A7:** Develop the most efficient and effective exercise program for the maintenance of VO2 standards.
Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight	**SM7.1:** Determine if there are decrements in performance on functional tasks after long-duration spaceflight. Determine how changes in physiological function, exercise activity, and/or clinical data account for these decrements. **SM28:** Develop a sensorimotor countermeasure system integrated with current exercise modalities to mitigate performance decrements during and after spaceflight.
Risk of an Incompatible Vehicle/Habitat Design	**HAB-05:** We need to identify technologies, tools, and methods for data collection, modeling, and analysis that are appropriate for design and assessment of vehicles/habitats (e.g., net habitable volume, layout, and usage) for predetermined mission attributes, and for refinement and validation of level of acceptable risk.

Background

Evidence supporting the beneficial role of exercise in our daily lives is undisputable. It promotes physical fitness and decreases our risk of incurring deleterious health outcomes, such as cardiovascular and metabolic disease. Additional studies have shown that exercise promotes acute alertness, circadian shifting, a positive valence, and improved aging. In isolated, confined, and extreme (ICE) environments, exercise can counteract the tendency of the human system to slow down, elicit less physical and social activity, and conserve energy. In the weightless ICE environment of spaceflight, without the right exercise protocol, the body responds with significant bone and muscle loss, as well as cardiovascular deconditioning.

On the ISS, the exercise system offers two options (an exercise bike and treadmill) targeting aerobic activity, and a larger device (the ARED) targeting resistance training. Recent research has demonstrated that the system on the ISS is effective at minimizing bone and muscle loss. Unfortunately, while robust and efficacious, these devices are physically too large for the planned vehicles of future long duration exploration missions (LDEMs). Such missions will involve a much smaller vehicle traveling far from Earth, with increased separation from home, danger from prolonged isolation and radiation exposure, and long communication delays with the ground. The small (4-6 individuals) and independent crew will be confined to living and working for prolonged periods in a small volume habitat.

The exercise system for proposed exploration mission starting with Cis-Lunar missions will have limited options and there will be no treadmill. It is envisioned that the system will involve a cable-based rowing exercise devise. Its associated protocol has been tested in a 14-day bed rest study (Ploutz-Snyder et al. 2014) and will be a combination of resistive exercise up to 600 pounds, aerobic exercise and combinations thereof, sufficient to protect astronaut physical health.
The specific requirements for the planned exercise device are planned as follows:

1. Required Resistive Exercises – The device shall allow for the proper execution of squats, dead lifts, and heel raises by all crew members.
2. Types of Resistive Exercise – The device should allow for the proper execution of resistive exercise the following movements patterns: triple extension, vertical pushing, vertical pulling, horizontal pushing and horizontal pulling, and any combination of the movement patterns
3. Maximum Resistive Load – The device shall provide a maximum total load of 600 lbf (2.67 kN) during resistive exercise.
4. Minimum Resistive Load – The device shall provide a minimum total load of 20 lbf (89 N) during resistive exercise.
5. Load profiles: The device shall be able to accommodate a variety of load profiles (e.g. inertial, flywheel, eccentric: concentric overload)
6. Aerobic exercises: The aerobic exercise modality shall be rowing.
7. Continuous Aerobic Work Rate: The device shall provide a minimum, continuous power load of 400 W for up to 30 min.
8. Peak Aerobic Work Rate – The device shall provide a peak power load of 750 W for up to 5 min.

In addition, the enhanced exercise protocols should be tested in a restricted, realistic exercise volume anticipated for future vehicles, estimated to be approximately 17 cubic meters.
While the planned system may be adequate for a crew of four for up to 14 days, or even 30 days, long term engagement and protection of behavioral health outcomes (e.g. stress tolerance) for performance of mission critical task is unproven.

This solicitation seeks to examine how the limited planned hardware and exercise protocols for physiological health (as described above) impact individual psychological well-being, including stress tolerance and adaptability, and to develop and test behavioral and environmental design strategies to augment the planned exercise protocols for exploration missions.

Primary Research Questions

- Will planned exercise regimens and proposed types of exercise and equipment be sufficient to maintain behavioral health of individuals during LDEMs?
- Given the limited exercise options for future spacecraft vehicles, what behavioral regimens, strategies, techniques (e.g. mindfulness training) are needed to augment exercise protocols to maintain the astronaut's motivation to exercise, promote behavioral adaptability and stress tolerance, and ensure continued self-care for crews during LDEMs?

Secondary Research Questions

- Given the restricted volume of future LDEM vehicles, what enhancements to the environment can support continued engagement and satisfaction for individual crewmembers who must comply with a limited exercise option?
- As a result of study findings, should existing protocols such as those that address secondary gaps noted above, be modified? If so, how?
- Please note: NASA and the NSBRI are currently supporting behavioral studies that assess exercise motivation, particularly using virtual reality. Proposers should seek to not duplicate these efforts; proposals that are deemed too duplicative with existing research, may not be funded.

Integrative Approach

An integrative study is needed to address the primary research questions given currently proposed exercise regimens and types of equipment that will be implemented in the reduced volume vehicles planned for LDEMs. Results may inform exercise performance feedback interfaces and volumes for LDEM vehicle habitat constraints, human factors considerations (functional volume and layout for exercise), as well as the interface display for monitoring performance. As a secondary focus, results should address how enhanced protocols may impact recommendations related to other physiological health outcomes, as noted in “Secondary Gaps" listed above such as immune function.

Requirements

- The study shall examine the impact of NASA-defined exercise options in terms of exercise equipment and planned physiological protocols in the context of long duration exploration missions—small volume, confined, isolated, and extreme environments—on individual adaptability, stress tolerance, self-care, motivation, valence, and cognitive performance
- Research shall be conducted in high fidelity, isolated, confined and controlled simulation or space analog
- Restricted volume, long duration mission-like crew, tasks, and schedule are required
- Ability to invoke spaceflight-like stressors is required to test efficacy
- Need to examine outcomes relevant to behavioral health and performance; proposers are urged to consider the National Institute of Mental Health’s (NIMH) Research Domain of Criteria (RDoC) when proposing their framework
- Not duplicative with existing or completed studies

Research Environment: Ground-Based Laboratory and Analog Definition

- Proposers should identify the characteristics they require in an analog environment for their scientific objectives. However, it is not necessary to propose a specific analog. NASA will work with the investigators to secure an analog(s) with the specified characteristics if funding is awarded. In addition, BHP will work with the principal investigator to determine the most applicable performance tasks available in the analog secured for the study.
- Investigators proposing use of the HERA should see the HERA description in the HERO Overview document. In previous HERA campaigns, both individual and team performance tasks have been included in the HERA mission operations. These tasks have included a two-person flight simulation program; a four-person rover assembly activity; a two-person virtual extravehicular activity (EVA) program and the Robotics OnBoard Trainer (ROBoT). ROBoT is used for training on the ISS, and provides a high-fidelity training simulation task that allows crewmembers to practice maneuvering the Canadarm2 (http://www.nasa.gov/mission_pages/station/structure/elements/mss.html) to grapple or capture an incoming resupply vehicle to the ISS. ROBoT is composed of a hand controller device and software, and, when available, can serve as an individual, operational performance task in HERA investigations (for additional information on

ROBoT, please
visit http://nix.nasa.gov/search.jsp?R=20130012667&qs=N%3D4294916663).

References

Ploutz-Snyder, L. L., M. Downs, J. Ryder, K. Hackney, J. Scott, R. Buxton, E. Goetchius, and B. Crowell. Integrated resistance and aerobic exercise protects fitness during bed rest. Med. Sci. Sports Exerc. 46:358-68, 2014.

Descriptions of current, relevant research tasks may be found at:
https://humanresearchroadmap.nasa.gov/tasks/task.aspx?i=1639
https://humanresearchroadmap.nasa.gov/tasks/task.aspx?i=709
http://nsbri.org/researches/virtual-reality-based-pre-flight-astronaut-3d-navigation-training-postdoctoral-fellowship/

Required Deliverables

- Report on study results that addresses primary research questions noted above, and includes evidence-based countermeasure recommendations for the following:
  - Specific types of behavioral health enhancements and protocols (e.g., mindfulness, breathing, postural poses, stretch/strengthen venues to improve exercise compliance and effectiveness, with an emphasis on wellbeing)
  - Protocols to enhance behavioral health outcomes needed to perform mission critical tasks
- Additionally, report should address evidence-based recommendations related to the following:
  - Vehicle design and/or interfaces to support continued engagement in exercise regimens, given limitations
  - Updates to current related to other physiological health outcomes (e.g. nutrition, immune function)
- Must provide NASA with all measures, methods, technologies, tools, and/or materials associated with the developed recommendations. The expectation is that the deliverables will transition to operations at the end of this task.

6. Coordination across the Spaceflight Multi-Team System for Long Duration Exploration Missions

Primary Risk	Relevant Gap
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team Gap 1:** We need to understand the key threats, indicators, and evolution of the team throughout its life cycle for autonomous, long duration and/or distance exploration missions.

Secondary Risk	Relevant Gap
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team Gap 5:** We need to identify validated ground-based training methods that can be both preparatory and continuing to maintain team function in autonomous, long duration, and/or distance exploration missions. **Team Gap 6:** We need to identify the best methods to support and enable multiple distributed teams to manage shifting levels of autonomy during long duration and/or distance exploration missions. **Team Gap 8:** We need to identify psychological and

	psychosocial factors, measures, and combinations thereof that can be used to compose highly effective crews for autonomous, long duration and/or distance exploration missions.
Risk of Inadequate Mission, Process and Task Design	**MPTASK-01:** We need methods and tools to collect measures of missions, process, and task performance. **MPTASK-02:** We need methods and tools to support mission, process, and task design.

Background

Current International Space Station (ISS) missions involve a strong command and control element via the Johnson Space Center Mission Control Center (MCC). In addition to the multi-team system (MTS) that is crew-to-ground (i.e., ISS to MCC), MCC is composed of many specialized discipline teams, that are coordinated through an interdisciplinary "front room" team. Each member of this front room team communicates virtually with members from his/her specialized discipline teams located in "back rooms" at MCC. Scientific payloads are managed through the MCC at Marshall Space Flight Center, which requires coordination with the Johnson Space Center MCC. Communication with the ISS crew from MCC is funneled through a capsule communicator (CapCom) or payload communicator (PayCom). Thus, a complex MTS exists on the ground and includes the spaceflight crew on ISS. Broadening the scope, a global MTS also exists between NASA and other space agencies from Japan, Canada, Europe and Russia. The international crewmembers answer to the various space agencies, but must also work together as an international team during some tasks. Members of the international MTS have differing cultural norms and goals as well as overlapping goals, particularly the shared goals of crew safety and mission success. While NASA has little direct control over the processes and norms of other space agencies, NASA research may provide evidence-based recommendations for training and composition of the NASA MTS to effectively interact within the international MTS.

For future long-duration exploration missions (LDEM), a crew of 4 will work with MCC on Earth while under a communication delay of up to 22 minutes each way, further complicating coordination across the MTS. A recent literature review of multi-team systems outlined key factors that may influence MTS functioning and performance during future missions (Shuffler et al., 2015). For example, diversity of knowledge and culture is inherent in a spaceflight MTS, but may impede the development and maintenance of shared mental models, reactions to leadership and communication behaviors, and a shared identity, causing decrements in team coordination. Preliminary unpublished results from a recent ISS study (Palinkas et al., 2016) instituting just a 50-second communication delay with MCC, found that crew well-being and communication quality were significantly reduced in communication-delayed tasks, when compared to real-time communication tasks. Communication delays were also associated with increased stress and frustration, and qualitative data suggested communication delays negatively affected task efficiency and teamwork processes. In HERA and NEEMO analog studies with communication delays of 5 to 10-minutes each way (Fischer et al., 2016), crews and habitat MCCs reported decreased effectiveness ratings on communication delayed days as compared to non-communication delayed days. Additionally, crews committed more errors and required time-consuming additional assistance from habitat MCC.

Given the strenuous conditions of future LDEMs, team processes such as coordination -- an essential component for productive teamwork, accomplishment of tasks, management of inter-relational conflicts, and ultimately, mission success -- may require new protocols for assessing the skill sets of mission controllers comprising MTS (e.g. selection), and different training paradigms aimed at the unique demands of exploration missions. NASA's selection and training protocols for these future missions should reflect evidence-based practices to ensure coordination among the MTS needed for successful execution of LDEMs. In addition to these needed countermeasures for MTS, improvements in vehicle and computer systems that interact with humans throughout the MTS are also needed. It has been noted by current MCC planners that information relayed via information technology (e.g. autonomous systems) should be

communicated to the crew in such a way as to ensure crewmembers maintain awareness of the progress and completion of automated and MCC-initiated system procedures.

Individuals who operate on multiple teams and coordinate between those teams (e.g. boundary spanners or gatekeepers) will require strategic composition and training of common skills to enhance coordination capabilities; such specific methods, tools, and roles related to MTSs have not been evaluated in the LDEM context, however. While MTS processes have been examined in the existing organizational literature, research in many areas is sparse, and there is a general lack of understanding related to MTS dynamics over time, and specifically how coordination aspects change. The projected 2.5 year duration of future exploration missions will naturally include rotating team membership of each MCC team during a 24-hour period, as well as more permanent changes from individuals hiring into and leaving the organization. The aforementioned literature review (Shuffler et al., 2015), in concert with other recent reviews examining team variables that may influence MTS functioning and performance (e.g., Bell et al., 2015, Fiore et al., 2015), have identified several recommendations for future research into this complex and dynamic multi-team system. Thus, research is needed to 1) examine MTS related to key factors (e.g., attitudes, diversity, culture) that support effective MTS coordination, 2) determine the degree to which the key identified factors influence MTS coordination functioning and performance, 3) identify when and how shifts in MTS interdependencies occur, especially how to recognize and/or implement such shifts based on triggers, 4) examine MTS dynamics in the context of a long-duration mission under communication delays, and 5) identify countermeasures such as MTS training protocols, and composition recommendations and methods, that support development and maintenance of coordination capabilities for effective MTS over time.

Results should inform existing NASA models of team skills training, and related selection and composition practices. Research proposals must include consideration of the MTS between the spaceflight crew and MCC, the MTS within each NASA MCC and between NASA MCCs. If possible, provide recommendations to inform effective coordination between NASA MCCs and international space agency spaceflight support teams. Validation evidence must include data from analog environments that mirror the specific challenges of LDEMs such as physical confinement for long durations, isolation, a small non-rotating crew, and communication delays. Where possible, this work should also make use of existing performance data from spaceflight and spaceflight analog environments such as the Human Exploration Research Analog (HERA), Antarctic research stations, and the Russian NEK chamber facility used in the Mars500 studies, as well as existing NASA multi-team systems in Mission Control. Access to spaceflight data may require significant collaboration with internal NASA subject matter experts. More information regarding Research Resources, including an overview of the BHP Laboratory, can be found in the HERA Overview document. In addition, proposers should design study materials to address the needs of a multicultural crew. Materials may include activity instructions, training materials, participant consent forms, measures and questionnaires, and research software programs. For example, design subject feedback with differing cultural orientations in mind; integrate both intellectual and experiential learning; consider cultural norms related to team processes (e.g., communication), team outcomes (e.g., performance, adaptation), and team emergent states (e.g., conflict); and cultural norms that may influence unobtrusive measures (e.g., interaction monitoring tools and cultural norms of personal space).

Research Questions

- What are the key MTS factors related to coordination (planning, execution and review) of teamwork tasks and management of interpersonal conflict, based on work by Shuffler et al. (2015)?
- What training countermeasure recommendations (e.g. method, content, implementation) and composition recommendations related to improving the coordination among MTS, will be needed to support LDEMs?
- What tools and technologies will assist in coordination and communication between the members of the MTS, and between members of the MTS and autonomous processes of the vehicle?

Research Environment: Ground-Based Laboratory and Analog Definition

- Proposers should identify the characteristics they require in an analog environment for their scientific objectives, taking into consideration the communication delay (including data delay) and multi-team systems components. However, it is not necessary to propose a specific analog. NASA will work with the investigators to secure an analog(s) with the specified characteristics if funding is awarded. In addition, BHP will work with the principal investigator to determine the most applicable performance tasks available in the analog secured for the study.
- Investigators proposing use of the HERA should see the HERA description in the *HERO Overview* document. In previous HERA campaigns, both individual and team performance tasks have been included in the HERA mission operations. These tasks have included a two-person flight simulation program; a four-person rover assembly activity; a two-person virtual extravehicular activity (EVA) program and the Robotics OnBoard Trainer (ROBoT). ROBoT is used for training on the ISS, and provides a high-fidelity training simulation task that allows crewmembers to practice maneuvering the Canadarm2 (http://www.nasa.gov/mission_pages/station/structure/elements/mss.html) to grapple or capture an incoming resupply vehicle to the ISS. ROBoT is composed of a hand controller device and software, and, when available, can serve as an individual, operational performance task in HERA investigations (for additional information on ROBoT, please visit http://nix.nasa.gov/search.jsp?R=20130012667&qs=N%3D4294916663).

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Bell, S. T., Brown, S. G., Outland, N. B., & Abben, D. R. (2015). Critical team composition issues for long-distance and long-duration space exploration: A literature review, an operational assessment, and recommendations for practice and research. NASA/TM-2015-218568.

Fiore, S. M., Wiltshire, T. J., Sanz, E. J., & Pajank, M. E. (2015). Critical team cognitive processes for long-duration exploration missions. NASA TM-2015-218583.

Fischer U, Mosier K. "Communication protocols to support collaboration in distributed teams under asynchronous conditions." 59th Annual Meeting of the Human Factors and Ergonomics Society, Los Angeles, CA, October 26–30, 2015.

Palinkas, L. and Kintz, N. (2016, April). *The impact of experimental delays in communication to-and-from the International Space Station on subjective assessments of performance and well-being*. Presentation given at the Aerospace Medical Association Annual Scientific Meeting, Atlantic City, New Jersey.

Shuffler, ML, Jimenez-Rodriguez, M, Kramer, WS. (2015). The science of multiteam systems: A review and future research agenda. *Small Group Research*, 1-41. DOI: 10.1177/1046496415603455

Required deliverables:

- Report on the study results that assesses and prioritizes the key multi-team system factors related to coordination aspects (planning, execution and review) of teamwork tasks and management of interpersonal conflict, as identified in a recent NASA literature review and operations assessment on multi-team systems by Shuffler et al. (2015).
- Evidence-based training countermeasure recommendations related to improving the coordination among MTS that will be needed to support LDEMs. Recommendations should address the method and content of training, as well as temporal aspects of when to implement during the flow of Astronaut training.
- Recommendations for tools and technologies to assist in coordination and communication between the members of the MTS, and between members of the MTS and autonomous processes of the vehicle.
- Evidence based MTS composition recommendations related to coordination skills and competencies for LDEMs.

- Must provide NASA with all methods, technologies, tools, and/or materials associated with the developed recommendations. The expectation is that the deliverables will transition to operations at the end of this task.

7. Behavioral Health and Performance NASA Specialized Center of Research (NSCOR) Risk Characterization

Primary Risk	Relevant Gap
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed3**: We need to identify and quantify the key threats to and promoters of mission relevant behavioral health and performance during autonomous, long duration and/or long distance exploration missions. **BMed5:** We need to identify and validate measures that can be used for the selection of individuals that are highly resilient to the key behavioral health and performance threats during autonomous, long duration and/or long distance exploration missions.
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team 1:** We need to understand the key threats, indicators, and evolution of the team throughout its life cycle for autonomous, long duration and/or distance exploration missions. **Team 4:** We need to identify psychological measures that can be used to select individuals most likely to maintain team function for autonomous, long duration and/or distance exploration missions.
Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload	**Sleep Gap 2:** We need to understand the contribution of sleep loss, circadian desynchronization, extended wakefulness and work overload, on individual health (physical and behavioral), team functioning, and performance (including operational performance), for spaceflight.

Secondary Risk	Relevant Gap
Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System	**Food-02:** We need to determine how the sensory and psychosocial acceptability of the food system changes due to microgravity, processing, storage, choice, and eating environment.
Risk of Performance Errors Due to Training Deficiencies	**TRAIN-02:** We need to identify effective methods and tools that can be used to train for long-duration, long-distance space missions.
Risk of Inadequate Mission, Process and Task Design	**MPTASK-02:** We need methods and tools to support mission, process, and task design.
Risk of an Incompatible Vehicle/Habitat Design	**HAB-01:** We need to understand how new aspects of the natural and induced environment (e.g., vehicle/habitat architecture, acoustics, vibration, lighting) may impact performance, and need to be accommodated in internal vehicle/habitat design.
Risk of Adverse Health Event Due to Altered Immune Response	**IM6:** We do not know the cumulative effects of chronic immune dysfunction on missions >6 months.
Risk of Inadequate Nutrition	**N7.4:** We need to identify the most important nutritional factors for behavior and performance.
Risk of Acute (In-flight) and Late Central Nervous System Effects from Radiation	**CNS-8**: Are there significant CNS risks from combined space radiation and other physiological or space flight factors, e.g., psychological (isolation and confinement), altered gravity

Exposure	(micro-gravity), stress, sleep deficiency, altered circadian rhythms, hypercapnea, altered immune, endocrine and metabolic function, or other?
Risk of Adverse Health Outcomes & Decrements in Performance due to Inflight Medical Conditions	**Med09**: We do not have the capability to predict estimated medical risk posture during exploration missions based on current crew health and resources.

Background

NASA's future long duration exploration missions (LDEMs) will involve four to six individuals living and working in the environment of deep space for an unprecedented duration, and at an unprecedented distance from Earth. Such missions will pose strikingly different and novel challenges than current low Earth orbit (LEO) missions to the International Space Station (ISS). LDEMs will possess a higher degree of inherent dangerousness due to no vehicle evacuation methods, a more limited (and possibly no) re-supply option, and a greater radiation threat that could have effects on the central nervous system. The vehicle habitat will be restricted in volume, thus limiting private, social, and functional space. Physical and social stimulation will be reduced with the "Earth out of view," and the crew will have to endure confinement and separation for up to 30 months. Significant communication delays of up to 22 minutes each way, will result in greater autonomy from ground operations—establishing a new paradigm for human spaceflight. It is therefore expected that living and working for an extended period of time, in this isolated, confined, and extreme (ICE) environment, will impact the performance and well-being of the crew. In preparation for LDEMs, the Behavioral Health and Performance Element (BHP) in the NASA Human Research Program (HRP) solicits and manages research to mitigate three human health and performance risks: *Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders* (BMed), *Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team* ("Team"), and *Risk of Performance Decrements and Adverse Health Outcomes Resulting from Sleep Loss, Circadian Desynchronization, and Work Overload* ("Sleep and Circadian"). Research in the BHP portfolio addresses gaps in knowledge and mitigation, and provides deliverables from these efforts that *characterize* the likelihood and consequences of these risks; further the refinement and validation of *technologies and tools to detect and assess changes* in behavior and performance; or enable the development *of countermeasures to prevent and/or treat adverse outcomes*.

Areas of Focus

This topic primarily addresses characterization of the BMed Risk, a risk that is considered "Red", or highest priority, for HRP. Notably, certain aspects of the BHP portfolio and the BMed Risk, have been addressed more fully than others. As an example, several investigations have focused on technologies and tools to detect and assess changes in *cognitive function;* these include a series of studies towards the development and validation of a sensitive, reliable measure for evaluating cognitive changes (as caused by spaceflight relevant stressors, such as sleep restriction, circadian misalignment, and carbon dioxide). Additional investigations are characterizing cognitive function and potentially associated neurostructural and functional changes (via *f*MRI for example), sensorimotor performance, and operational task performance, across various analog platforms (e.g. Antarctic winter-over stations, HERA). Planned studies may continue to explore neurocognitive and neurobehavioral function in artificial gravity simulations. Hence, relative to cognitive function, BHP is building a comprehensive risk reduction strategy—quantifying the effects of threats and promoters to cognition in relevant environments, assessing the relationship between changes in cognitive performance to changes in operational performance outcomes, understanding the underlying mechanisms in the brain that may precede such changes, and the validation of a sensitive, acceptable measure for assessing cognitive performance.

Other areas that BHP has more thoroughly assessed include sleep and circadian rhythms, with several investigations having quantified sleep duration in analogs and in spaceflight, and a

current investigation evaluating sleep, circadian phase, and alertness on the ISS. Furthermore, two BHP-sponsored laboratory and analog efforts under way are honing in on specific biomarkers (genetic, metabolomics, physiological) to build towards an individualized countermeasure approach. Evidence-based mitigations such as a flexible lighting system to facilitate circadian entrainment, and individualized protocols for ground testing hypnotic medications, are currently operational in spaceflight.

Given the increased BMed risk aspects of LDEMs, it is essential to characterize and mitigate anticipated high priority stressors. As noted by Alfano and colleagues (in press), it is widely believed that maladaptive *emotional* responses pose as great a risk for LDEMs as other aspects of neurobehavioral functioning, yet despite empirical evidence on emotional outcomes less effort has been directed at evaluating and understanding such responses (positive and negative valence), as compared to the cognitive and sleep/circadian behavioral, alterations that occur in space. As such, emotional constructs (e.g. management of positive and negative emotions, such as patience, tolerance, irritability, anger) remain to be 'unpacked' to the same extent as other neurobehavioral variables including attention, concentration, and reaction speed. Additionally, while a key component of BHP's research portfolio focuses on *teams*—the evolution of teams in long duration isolation and confinement, the monitoring of team processes and performance outcomes, and the countermeasures needed to mitigate risk to teams—individual sociability, or engaging positively in social interactions with tolerance and awareness (e.g. affiliation, attachment, sensitivity to other teammates and to self) – is another aspect that has not yet been systematically or thoroughly assessed.

Proposed Framework

While BHP has adopted a medical model of prevention, detection, and mitigation, Slack et al. (2016) notes recent efforts by the National Institutes of Mental Health (NIMH) to "develop, for research purposes, new ways of classifying mental disorders based on dimensions of observable behavior and neurobiological measures," offering intriguing research possibilities for translational research that links basic research to more specific problematic and possible etiological variables, biomarkers, and effective psychosocial treatments. The NIMH Research Domain Criteria (RDoC) (Insel et al. 2010, as noted by Slack et al., 2016) offers a framework that integrates five major domains of behavior: positive valence system, negative valence system, cognitive system, social processes, and arousal/regulatory systems (Cuthbert & Kozak 2013, as noted by Slack et al., 2016). It proposes to consider mental disorders as falling along dimensions (e.g., cognitive, mood, social interactions) with traits arrayed along a continuum ranging from normal to extreme. The translational research approach of RDoC, its emphasis on the "individual risk factors" and biomarkers, the linkage of regulatory and arousal systems (e.g. sleep and circadian), cognitive, valence, and social behavior to an individual's risk and opportunities, combine to make this a relevant framework for identifying and quantifying individual variability and vulnerability with regard to individual adaptation, resilience and performance in the exploration spaceflight ICE environment. The units of analysis (e.g. genes, molecules, physiology, self-report) incorporated within the RDoC framework further informs an integrative, multidisciplinary approach to BMed risk assessment, measurement, and mitigation.

Topic

The purpose of this solicitation is to assemble a multi-disciplinary team to characterize the three, less-understood NIMH RDOC's-- positive valence (e.g. patience, tolerance), negative valence (e.g. irritability, anger), and social processes (e.g. affiliation, attachment, sensitivity to self and other teammates)--as they relate to performance, adaptation, and resilience of individuals living and working in an extended duration, isolated, confined, extreme (ICE) environment. While these dimensions are difficult to separate from cognitive, arousal & regulatory systems, the purpose of this topic is to further our understanding of valence and social processes in extended isolation utilizing the different units of analysis identified in the RDOC. Additionally, another purpose of the solicitation is to validate and/or refine measures, feasible in the spaceflight environment, for assessing the key constructs within these RDOCs, for astronaut selection, crew composition (where applicable), and/or in-flight assessment purposes.

The NSCOR should address the following five risk-reduction research topics:

- Individual Differences in Adaptation and Resilience
- Emotional Regulation
- Biological Basis of Social Support
- Meaningful Work
- Effects of Well-Being on Performance

Individual Differences in Adaptation and Resilience is the umbrella topic; all listed topics are important for understanding how the individual responds, adapts to, and performs in the ICE environment of a future Mars mission. BHP is seeking to look across individual risk factors and utilize components of the RDoC framework as they relate to performance, adaptation, and resilience in the space exploration ICE environment.

When considering future LDEMs, NASA's outcomes of interest do vary from that of the NIMH, which focuses on mental disorders. Within the realm of future exploration missions, the focus of the BHP element has been on, not surprisingly, risk factors as they tie to *behavioral health (i.e. "well-being")*, and risk factors as they tie to *performance.*
Proposers should consider:

- Relative to performance, outcomes beyond standard methods; for instance, "performance" in context of fatigue research, is often defined by vigilance using a traditional measure such as the Psychomotor Vigilance Task (PVT). Relative to future missions however, the concept of performance for this solicitation should be further expanded to consider operationally-relevant or mission-relevant performance metrics.
- When considering outcomes specific to behavioral health, there is general agreement that *adaptation* – the process of adjusting or conforming to new conditions (Slack et al., 2016) – is key. As noted by Bartone et al. (2016), much of the existing research blurs the distinction between *adaptability*, which is a person's relatively enduring capacity to adapt, and *adaptation or adaptive performance*, which is the result, or outcome of an adaptive process. A focus of this effort is primarily to understand adaptation as an outcome, however this does not preclude proposers from considering the propensity to adapt as a predictive factor as well. While resilience is often used synonymously with performance, as noted by Slack et al. 2016), resilience represents the 'bouncing back' from adversity.
- Proposed efforts should build on gaps in the BHP portfolio. As previously mentioned, cognitive, arousal and regulatory systems (specific to sleep and circadian rhythms) are not intended to be the focus of this effort. Proposals emphasizing these areas may not be considered for funding.

Research Environment: Analog Definition

- An Isolated Confined Extreme (ICE) required with a mission lasting no less than 9 months; proposals may also include an additional aspect taking place in an Isolated Confined and Controlled Environment (ICC)
    - Proposers should identify the characteristics they require in an analog environment for their scientific objectives. However, it is not necessary to propose a specific analog. NASA will work with the investigators to secure an analog(s) with the specified characteristics if funding is awarded. In addition, BHP will work with the principal investigator to determine the most applicable performance tasks available in the analog secured for the study.

Specific Research Questions to Consider

- What individual risk factors are most related to positive valence, negative valence, and social process domains?
- How do these risk factors within the domains, relate to the outcomes (performance, adaptation, and resilience)?

- How do fluctuations in work (in terms of meaningfulness) or sociability, mediate the relationship between risk factors and outcomes?
- In considering future LDEMs, what are the best tools, technologies, and measures – as in sensitive, reliable and valid, but also feasible in the context of spaceflight-- for measuring relevant variables/constructs (e.g. emotional regulation, sociability, motivation)

References

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Bartone, P. et al. (NASA TM in press). Individual Differences in Adaptability for Long Duration Space Exploration Missions.

Slack, K., Williams, T., Schneiderman, J., Whitmire, A., and Picano, J. (2016). Evidence Report: Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders. Retrieved from https://owl.english.purdue.edu/owl/resource/560/10/

Stuster, J. (2010). Behavioral Issues Associated with Long Duration Space Expeditions: Review and Analysis of Astronaut Journals. NASA TM- 2010-216130.

Vanhove, A. (2015). Examining Psychosocial Well-being and Performance in Isolated, Confined, and Extreme Environments. NASA TM-2015-218565.

Whitaker-Azmitia, P. (2016). Biological Basis of Social Support. NASA-TM-2016-218598.

Required Deliverables

- BMed risk characterization via a report that provides a set of individual risk factors, and the relationship to the research domains (valence systems and social processes) and the specified outcomes over an extended duration mission in ICE environment.
- Recommended measures, tools, or technologies for astronaut selection, crew composition and assignment, and in-flight assessment and monitoring, particularly in the research domain areas of valence systems (positive and negative) and social processes.
- Must provide NASA with all methods, technologies, tools, software, software documentation, training and/or materials associated with the developed recommendations. The expectation is that the deliverables will transition to operations at the end of this task.

8. General Research Topics

Research Emphasis

- Investigators working in human research-related fields are encouraged to review the Human Research Roadmap risks and gaps and identify potential research topics for NASA HRP solicitations. Applicants to this RFI should list any areas of focus that may be of interest to NASA HRP.

PURPOSE OF RFI

The information obtained will be used by NASA for planning and acquisition strategy development. NASA will use the information obtained as a result of this RFI on a non-attribution basis. Providing data and information that is limited or restricted for use by NASA for that purpose would be of very little value and such restricted/limited data/information is not solicited. No information or questions received will be posted to any website or public access location. NASA does not plan to respond to the individual responses.

The Government does not intend to award an award on the basis of this RFI or to otherwise pay for the information solicited. As stipulated in FAR 15.201(e), responses to this notice are not considered offers, shall not be used as a proposal, and cannot be accepted by the Government to form a binding contract. Inputs shall be compliant with all legal and regulatory requirements concerning limitations on export controlled items. To the full extent that it is protected pursuant to the Freedom of Information Act and other laws and regulations, information identified by a respondent as "Proprietary or Confidential" will be kept confidential.

RESPONSE INSTRUCTIONS

Responses must be submitted electronically. Responses must be submitted electronically using the NSPIRES (http://nspires.nasaprs.com) web site. It is important to note that some of the functionality of the NSPIRES system uses terminology that does not exactly track to the collection of RFI data. For instance, when submitting responses to this RFI, use of the term “proposals” or “NOIs” in these instructions does not mean that NASA is inviting proposals or offers in response to this RFI.

All respondents are required to register with NSPIRES first, and are urged to access this site well in advance of the RFI due date to familiarize themselves with its structure and enter the requested identifier information. This data site is secure and all information entered is strictly for NASA use only.

Only one topic area can be addressed per response. Multiple RFI responses must be submitted if responding to multiple topic areas. Responses to this RFI shall be submitted no later than 5:00 PM EDT on August 1, 2016. Responses must be submitted using the “Notice of Intent (NOI)” module within the NSPIRES system.

To initiate an RFI Response:

- Log in using your NSPIRES user name and password. Access Proposals/NOIs in the NSPIRES Options Page.
- Click on the “Create NOI” button on the right hand corner of the screen. Select the “NASA Request of Information (RFI) on Topics Supporting Crew Health and Performance” (NNH16ZSA001L).
- Follow the step-by-step instructions provided in NSPIRES to complete your RFI. The following two elements are mandatory for this RFI submission:
- characters
    - Utilize the “Program Specific Data” element to identify the topic area to which you are responding
    - Utilize the “Summary” element of the RFI to provide a concise response limited to 4000

Requests for assistance in accessing and/or using the NSPIRES website should be submitted by E-mail to nspires-help@nasaprs.com or by telephone to (202) 479-9376 Monday through Friday, 8:00 AM – 6:00 PM Eastern Time. FAQs on NSPIRES may be accessed through the Proposal Online Help site at http://nspires.nasaprs.com/external/help.do. Tutorials of NSPIRES are available at http://nspires.nasaprs.com/tutorials/index.html.

No solicitation exists; therefore, do not request a copy of the solicitation. When a solicitation is released, it will be synopsized in FedBizOpps and on the NASA Acquisition Internet Service. The solicitation will be posted on the same site where you accessed this RFI.

POINT OF CONTACT

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