NASA REQUEST FOR INFORMATION

Request for Information (RFI) on Topics in Human Health Countermeasures, Human Factors, and Behavioral Performance

Solicitation Number: 80JSC018L0002
Release Date: March 2, 2018
Response Date: March 16, 2018

DESCRIPTION

The 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 (HRR - 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 and performance risks. If interested in learning about and accessing this data, please visit the Users’ Guide for requesting data at: https://lsda.jsc.nasa.gov/Request/dataRequestFAQ

To support formulation of a solicitation scheduled to be released in March 2018, NASA is seeking feedback regarding the set of research topics listed below. Specifically, NASA wishes to know:

1. Is each topic sufficiently well-defined, clear and unambiguous? In particular, NASA is interested to know if the Background, Research Platform, and Deliverables are clearly articulated for each topic.
2. Are the risks and gaps listed for each topic appropriate to meet the goals of the Program? Respondents are encouraged to study the HRR and review the risks and gaps for each topic. Missing research questions, whether included in the HRR or not, that will aid in addressing each research topic should be identified.

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 NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) (http://nspires.nasaprs.com) website. Ideas are sought to help refine the following research topics:

RESEARCH TOPICS

Topic 1: Cerebrospinal Fluid Biomarkers for Physiological and Behavioral Effects of Spaceflight – an ISS Sample Sharing Opportunity
Background

A cerebrospinal fluid (CSF) sample sharing opportunity will occur with the implementation of an experiment entitled “Invasive and Noninvasive Intracranial Pressure (ICP) Monitoring and Vision Impairment Intracranial Pressure (VIIP) Biomarker Identification” (co-principal investigators M. A. Williams and S. Zanello) in astronauts before, during and after spaceflight of approximately six months duration on the International Space Station (ISS). The primary purpose of the study is to measure ICP by lumbar puncture (LP, spinal tap) six to nine months before flight and immediately thereafter on the first day of landing. Non-invasive estimations of ICP will be done in conjunction with the LPs as well as without LP on flight days 30 and 170, and 10 and 90 days after return to Earth, using the cerebral cochlear fluid pressure (CCFP) and distortion product otoacoustic emissions (DPOAE) techniques. A third non-invasive ICP estimation technique based on a combination of transcranial Doppler, electrocardiography signals and blood pressure waveforms will be conducted before and after flight. Other measures reflecting the fluid shift to the head induced by weightlessness will include internal jugular venous pressure by the VeinPress-technique. The details of the study can be found at this link: https://taskbook.nasaprs.com/publication/index.cfm?action=public_query_taskbook_content&TASK_KID=11543

As part of this study, blood, urine and CSF will be collected, for genomics via evaluation of exosomal ribonucleic acid (RNA), and for evaluation of folate and folate intermediaries. Of the CSF volume withdrawn, a total of one milliliter (ml) will be made available for additional analyses. If more than one proposal is selected, all proposers will have to share the one ml sample. Proposers should clearly indicate any specific preservation needs they have for the CSF sample, for example whether they require the CSF frozen or fresh, centrifuged or whole, or preserved with specific chemicals, as well as the type of tube required and any special processing or aliquoting that is needed.

The CSF samples will be collected from a total of 10 ISS crewmembers who sign up for Drs. Williams’ and Zanello’s study, which is anticipated to occur between the years 2019-2027. The current topic aims to understand omics and biochemical mechanisms reflected in the CSF that underlie the physiological and behavioral manifestations of long-duration spaceflight in humans, in particular for the following three risks: Risk of Spaceflight Associated Neuro-ocular Syndrome (SANS), Risk of Impaired Control of Spacecraft/Associated Systems and Decreased Mobility Due to Vestibular/Sensorimotor Alterations Associated with Spaceflight, and Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders. The goal of characterizing such mechanisms is to eventually enable development of more efficient countermeasures targeted towards individual susceptibilities to the spaceflight environment.

While specific emphasis is placed on proposals that focus on the three risks listed above, HRP will also consider proposals that address other physiological and behavioral mechanisms of relevance for the Path to Risk Reduction (PRR) in the HRR. Therefore, it is expected that the identified biomarkers in the CSF will be related to physiological variables and behavioral outcomes determined by NASA’s Standard Measures Project (project scientist: S. Zwart, list at https://tinyurl.com/2018-HHCHFBP-RFJ), which will be implemented on the International Space Station (ISS) in as many astronauts as possible starting in 2018, and which will be available for all selected ISS investigators. It is also possible and encouraged to establish data sharing agreements with other selected ISS-investigators.

Research Platform

International Space Station

Required Deliverables

The deliverables will be information on the relationships between physiological and behavioral outcomes versus CSF biomarkers in astronauts exposed to ISS flights in support of understanding molecular mechanisms that could lead to development of personalized
countermeasure prescriptions to protect health and performance during future deep space exploration missions.

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<tr>
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**Topic 2: Promoting Stress Tolerance, Adaptability, and Behavioral Health via Enhancing Exercise Protocols for Long Duration Exploration Mission (LDEM) Crews**

**Background**

Spaceflight hazards, such as isolation and confinement, as well as acute, in-mission space radiation risks pose risks to the central nervous system (CNS) that could significantly increase cognitive and emotional effects of the stress for crewmembers on long-duration exploration missions (LDEM). Stressful environments, and even the perception of an increased stressful environment, to include increased schedule demands, circadian misalignment, and lack of sensory stimulation from a reduced volume habitat, might all contribute to experiencing higher stress on LDEMs. Since higher stress is associated with individuals becoming less motivated to exercise, with feeling less self-efficacious, and with feeling one’s exercise is less satisfying (i.e., doesn’t really help), we need to better understand the potential role of exercise in stress reduction and adaptability (Steptoe & et al., 1996; Stetson et al., 1997; Zuzanek et al., 1998). Although reactions to stress are moderated by individual differences (e.g., in personality, coping styles, and health promoting behaviors), there is also a risk posed by spaceflight hazards to both the immune system (Segerstrom & Miller, 2004) and to reduced caloric intake (Oliver & Wardle, 1999). Crewmembers onboard the ISS tend to reduce their caloric intake (Smith et al., 2009) and this caloric reduction has been attributed to a lack of variability in the types of food. In light of these various factors, we need to better characterize the complex interplay of stress, adaptability, and the potential for exercise programs to help mitigate these human system risk factors. We seek to determine if exercise, appropriately delivered—at the correct dose, can promote adaptability, wellness, and/or produce an effect as a countermeasure for stress associated with one or more spaceflight hazards.

The physiological and psychological adaptations associated with a regular exercise regimen are well-established. Exercise reduces the risk of diseases and the risk of incurring deleterious health outcomes, such as cardiovascular and metabolic disease. There is a positive relationship between cognitive functioning and exercise, with it promoting operationally-relevant
improvements in the areas of improved attention and processing speed, alertness, circadian shifting, a positive valence, and reduced physiological processes associated with premature 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. There are also recent findings (Demertz et al., 2016; Van Ombergen et al., 2017) that suggest reduced brain structure in altered gravity of space and with isolation and confinement in ground-based, long-duration analogs. Given these “adaptations” to spaceflight and isolation and confinement, it is interesting to note how exercise also has been associated with preserving and increasing brain volume in the hippocampus (Erickson et al., 2011), an area of the brain important for learning and memory—an area that is particularly vulnerable to acute effects of space radiation (Limoli et al., 2007).

On the ISS, the exercise system offers two options (an exercise cycle ergometer and treadmill) targeting aerobic activity, and a larger device the Advanced Resistive Exercise Device targeting resistance training. Recent research has demonstrated that the exercise 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 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 cycle ergometer or treadmill. It is envisioned that the system will involve a cable-based rowing exercise device. The device will enable a combination of resistance 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 Resistance Exercises** – The device shall allow for the proper execution of squats, dead lifts, and heel raises by all crew members.
2. **Types of Resistance Exercise** – The device should allow for the proper execution of resistance 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 Resistance Load** – The device shall provide a maximum total load of 600 lbf (2.67 kN) during resistance exercise.
4. **Minimum Resistance Load** – The device shall provide a minimum total load of 20 lbf (89 N) during resistance 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. An example of an optimal exercise protocol/prescription, titled the Integrated Resistance and Aerobic Training (SPRINT) protocol, has been developed and evaluated in a 14-day bed rest study (Ploutz-Snyder et al., 2014) and recently underwent validation in a flight study (Hackney et al.,
2015). The protocol consists of three days per week of short, high-intensity, interval-type aerobic exercises, alternating with three days of 30 minutes continuous aerobic exercise. Short periods of high-intensity resistance exercises are performed three days per week, on the same day as the continuous aerobic exercise, but separated from it by 4–8 hours of rest. Resistance exercise sessions generally consist of three sets of squats, deadlifts, and heel raises. Upper body exercises are also often included. The aerobic exercise intensities are prescribed as a percentage of each crewmember’s peak heart rate and maximal oxygen consumption (VO2max), with the continuous exercise intensity targeting a level of 75% or higher of VO2max. For the interval days, one of three interval protocols are performed: 1) six two-minute stages at target intensities of 70%, 80%, 90%, 100%, 90%, and 80% of VO2max with a two-minute rest; 2) eight 30-second intervals at maximal effort with a 15-seconds active rest; 3) four four-minute intervals at a target intensity of 85% VO2max with a three-minute active rest. Each interval is performed once per week.

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 and adaptability) for performance of mission critical tasks beyond 30 days (e.g., for planned Cis-lunar missions of 42-45 days) is unproven.

This solicitation topic seeks to examine how the limited planned exercise 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?
- What are the types and dose-effects of exercise that are demonstrated 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 at the end of this topic, be modified? If so, how?
- Please note: NASA and the National Space Biomedical Research Institute (NSBRI) have previously supported behavioral studies that assessed exercise motivation, particularly using virtual reality. Proposers should not duplicate these efforts; proposals that are deemed too duplicative with existing or past research, may not be funded. Current and previous studies may be found at: https://humanresearchroadmap.nasa.gov/Tasks/
- Given the fact this topic will not be soliciting for spaceflight opportunities, proposals with strategies having limited, unproven, spaceflight feasibility (e.g., yoga in microgravity) require experimental conceptualizations that clearly reflect relevant application of the environmental constraints and challenges anticipated in spaceflight.

Integrative Approach
HRP is increasingly seeking integrative studies to address the primary research questions to accelerate the characterization of the multiple risks. This increased emphasis on an integrated approach is reflected in the proposed exercise regimens and types of equipment that will be implemented in the reduced volume vehicles planned for LDEMs that will potentially impact several human systems. The results from this research 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 at the end of this topic such as immune function, as well as identifying potential molecular and/or cellular biomarkers activated as a result of either positive or negative physiological “adaptations.”

Requirements

• The study shall examine the impact of NASA-defined exercise options in terms of exercise equipment that is planned and planned physiological protocols in the context of LDEMs—small volume, confined, isolated, and extreme environments—on individual adaptability, stress tolerance, self-care, motivation, valence, and cognitive performance.
• Research shall include a high fidelity, isolated, confined and controlled simulation or spaceflight 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 behavioral changes and adaptations that could combine with the cognitive and emotional effects of stressors to affect immune function, with consideration to using the National Institute of Mental Health’s (NIMH) Research Domain of Criteria (RDoC) heuristic to identify associated neurobiological changes at all levels, from molecules to networks—from genes, molecules, cells, circuits, physiology, behavior, and self-reports—relating them to the defined behavioral domains and neuronal networks underlying the basic behavioral domains.
• Not duplicative with existing or completed studies (https://humanresearchroadmap.nasa.gov/Tasks/).

Research Platform: Ground-Based Laboratory and Analog Definition

• Proposers should identify the characteristics they require in the analog environment(s) 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. If the analog(s) are known and secured, the proposal should include a full description of the analog(s) characteristics.
• Investigators proposing use of the Human Exploration Research Analog (HERA) should see the HERA description in the Human Exploration Research Opportunities (HERO) Overview document posted at https://nspires.nasaprs.com/external/solicitations/summaryinit.do?solId=%7B9B13E02D-9825-E9B8-3B5D-C132E46A519C%7D&path=open&redirectURL. 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). In addition, the Human Factors and Behavioral Performance (HFBP) Element will work with the principal investigator (PI) to determine the most applicable performance tasks available in the analog(s) secured for the study.

Descriptions of current, relevant research tasks may be found at: https://humanresearchroadmap.nasa.gov/tasks/task.aspx?i=1639
Required Deliverables
- A final 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, the final 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)
- Proposers must provide NASA with all methods, technologies, tools, software, software documentation (including start up directions), training and/or materials associated with the developed recommendations. The expectation is that the deliverables will transition to NASA operations at the end of this project. Upon completion of research, any software tools must be delivered to NASA using an architecture where data remains local or on NASA’s server. The Federal Government will retain license rights for all hardware and software created or modified during the project.

Multi-Cultural Requirements
Proposers should design study materials to address the potential 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).

References


Ploutz-Snyder, L. L., M. Downs, J. Ryder, K. Hackney, J. Scott, R. Buxton, E. Goetchius, and B.


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<thead>
<tr>
<th>Primary IRP Risk</th>
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<tbody>
<tr>
<td>Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders</td>
<td><strong>BMed 1:</strong> We need to identify and validate countermeasures that promote individual behavioral health and performance during exploration class missions. <strong>BMed 7:</strong> 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.</td>
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<td>Risk of Adverse Health Event Due to Altered Immune Response</td>
<td><strong>IM 1:</strong> We do not know to what extent spaceflight alters various aspects of human immunity during spaceflight missions up to 6 months. <strong>IM 6:</strong> We do not know the cumulative effects of chronic immune dysfunction on missions greater than six months.</td>
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<td>Risk of Inadequate Nutrition</td>
<td><strong>N 4:</strong> Does mission architecture and/or available countermeasures impact nutritional status of crewmembers during spaceflight? <strong>N 3.1:</strong> Determine the macronutrient requirements for spaceflight.</td>
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<td>Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance</td>
<td><strong>M 14:</strong> Identify adjuncts to exercise countermeasures that can be used to better mitigate muscle loss.</td>
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<td>Risk of Reduced Physical Performance Capabilities Due to Reduced Aerobic Capacity</td>
<td><strong>A 7:</strong> Develop the most efficient and effective exercise program for the maintenance of VO2 standards.</td>
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<td>Risk of Acute (In-flight) and Late Central Nervous</td>
<td><strong>CNS 3:</strong> How does individual susceptibility including hereditary pre-disposition (e.g. Alzheimer’s, Parkinson’s, apoE allele) and prior CNS injury (e.g. concussion, chronic inflammation or other)</td>
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### System Effects from Radiation Exposure

| 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. |

### Topic 3: Individual and Team Problem-Solving Skills Training for Exploration Missions

#### Background

NASA's "mission teams" are composed of astronauts and Earth-based support staff (flight crews, Mission Control Center (MCC), flight controllers, flight control teams, etc.) who work closely together to ensure both individual and crew performance. Future LDEMs, potentially including planetary surface missions on Mars, will demand the support and ability of these teams to manage shifting levels of autonomy when crew health, performance and/or mission success is threatened by unanticipated problems. As distance from Earth and communication delays increase, crew will necessarily become more dependent on their own ability to problem-solve, with reduced ability for Mission Control to assist them during an emergency. The emergency experienced by the Apollo 13 crew offers a relevant example. Mission Control greatly facilitated and helped the Apollo 13 crewmembers engage in the problem-solving that resulted in the creation of a carbon dioxide scrubber that helped save the crew’s lives. What happens if a problem arises and the distance from Earth creates either communications delays or even periods of no communications that preclude a similar level of support to crew from Mission Control? HRP needs to assess the crew as autonomous mission, team problem-solvers, and identify what types of on-board systems can offer them problem-solving support.

Team autonomy is not always desired. For example, resolving a problem in a risk-laden environment using remotely located experts may offer the greatest likelihood of resolving the problem safely. However, some problems require fast action with distance from Earth compounding (e.g., communication delay) the availability of those remote experts to provide assistance. There, greater autonomy during spaceflight will require astronauts who possess both the individual and team cognitive problem-solving abilities when facing unique and unpredictable events which may occur during LDEM (Fiore et al., 2015; Orasanu 2005). They must anticipate and plan for the communication delays that may interfere with the problem-solving process and inhibit coordination with MCC. The ability to maintain a collective orientation, which can affect team processes and emergent states such as backup behaviors and trust, may be decreased by the physical separation and communication delays (Smith-Jentsch et al., 2015). Research on submariners and Antarctic analogs found that problem-solving coping strategies are predictive of team success when used by achievement oriented individuals (Sandal et al., 2003; Leon et al., 2003). However, when problems are encountered, autonomous teams may also need to quickly switch from independent individual tasks to interdependent team tasks; and, depending on the international composition of the LDEM, even language. Similarly, Mendenhall et al. (2004)
reviewed problem-solving ability, ability to deal with misunderstandings, display of cultural sensitivity, and cultural competence within cross-cultural groups.

If the team onboard the spacecraft needs to be prepared to problem-solve, they may have to adapt to confusing procedures, inadequate equipment, or excessive workload. During an autonomous mission, effective coordination and problem-solving will depend on the identified information gaps of the team’s understanding of the anomaly and the ability to quickly resolve potential hidden disagreements between individuals on the team about the approach to problem-solving. Team task switching also may occur during the LDEM, with an autonomous team problem-solving with issues that previously required cooperation with MCC (for example, see Smith-Jentsch et al., 2015).

Teams will need each member to possess a shared team mental model of problem-solving in unfamiliar or unexpected situations in which shared mental models facilitate team problem-solving. When creative problem-solving is called for, divergent thinking is particularly helpful in generating solutions and for evaluating the potential solutions (da Costa et al., 2015). The challenge is allowing individuals to engage in divergent thinking to foster a shared mental model of how to structure and communicate their ideas to facilitate more creative and efficient problem solving.

A concern, based in part on observations in analog studies, is that the shared collective orientation needed for team problem-solving may decrease in long-duration missions, with in-groups and out-groups forming between the crew and MCC. This may also set the conditions for the crew to “prematurely” exercise their autonomy, reducing their coordination with MCC and thereby increasing risk to the mission. This could result in reduced levels of trust toward MCC with misaligned mental models about priorities and leadership which could lead to loss of efficiency and effectiveness of overall team efforts to solve problems.

Thus, in the spaceflight context, as problems arise, shared leadership is more likely to prompt more problem-solving and social support sensemaking and structuring/planning and action phase. Teams improve their performance when they possess and share an accurate mental model. Previous research has demonstrated that when unfamiliar or unexpected situations arise, teams with shared mental models are more creative problem-solvers, engage in more divergent thinking, and facilitate team problem-solving with more effective generation of solutions and evaluation of those solutions (da Costa et al., 2015). In addition, meta-analyses have found that information sharing positively predicts team performance, and that cooperation enhanced this relationship (Mesmer-Magnus et al., 2009).

**Research Emphases**

This research topic is designed to provide standards and guidelines for training individual and team problem-solving skills across all team, medical, and technical domains for both work and non-work situations throughout an LDEM. Standards and guidelines may impact documents such as NASA-STD-3001 Rev. A Vol. 2 ([https://www.nasa.gov/sites/default/files/atoms/files/nasa-std-3001-vol-1a-chg1_0.pdf](https://www.nasa.gov/sites/default/files/atoms/files/nasa-std-3001-vol-1a-chg1_0.pdf)) and the Human Integration Design Handbook ([https://www.nasa.gov/feature/human-integration-design](https://www.nasa.gov/feature/human-integration-design)).

The results of this research are intended to provide a cross-cutting, integrative contribution to both decision- and execution-support systems being considered for human capabilities interfaces with intelligent systems. These cross-cutting tasks may include intelligent support systems or medical systems in order to provide guidelines for vehicle capabilities that support crew task execution and decision-making for the technical and medical domains. While this research is intended to provide the problem-solving skills training necessary to perform tasks with those systems, it also must be adaptive and responsive to providing training for individual and team problem-solving for situations outside the scope of those systems.

Specifically, proposals must clearly address ALL of the following research aims:
• Determine how problem-solving skills are developed and used in operational settings such that there is generalization across many tasks and situations.
• Identify which individual and team skills are most important to performing tasks in normal conditions and surviving in emergency conditions for an LDEM.
• Determine the relationship of individual cognitive processes/skills (e.g., attention, reasoning) to team cognitive processes/skills (e.g., collaborative problem solving, decision making).
• Describe how these skills change over time and what may trigger these shifts.
• Validate measurement, particularly unobtrusive measurement, of these skills for both individuals and teams.
• Develop validated training guidelines and recommendations to develop and maintain individual and team cognitive skills throughout an LDEM, and allow them to be trained efficiently to maintain performance across tasks and situations in mission.

Research Platform
Ground Analog

Required Deliverables
• Risk characterization of individual and team cognitive problem-solving skills needed for LDEMs, and of best methods to support generalization of skills, taking cross-cultural and mixed gender considerations into account.
• Training guidelines/recommendations and other countermeasures to develop and maintain individual and team cognitive skills in LDEM.
• Deliverables will be used to inform specific NASA Standards and Guidelines. Measures will be used to assess individual and team processes/skills in LDEM.
• Research is preferred in a long-duration (i.e., greater than 30 days) Isolated, Confined, and Controlled (ICC) analog. Research may also be available in a high-fidelity long-duration spaceflight analog. Proposers should identify the characteristics that they require in an analogous 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 with the specified characteristics once funding has been awarded.

Each of the Required Deliverables must include all three of the following:
• Risk characterization describing which individual and team skills are most important in both nominal and off-nominal tasks/situation, how skills may generalize across tasks/situations, and how these skills change over time and what may trigger these shifts;
• Standards and Guidelines recommendations related to training and other countermeasures to develop and maintain individual and team problem-solving skills;
• Corresponding countermeasure prototypes and training protocols supporting the recommended Standards and Guidelines.

Deliverables may include relevant and feasible computer-based training and countermeasure recommendations for pre-mission, but in-flight training and countermeasures should not be solely computer-based. These deliverables and skills need to apply to non-work situations and influence team functioning for both operational and mission control personnel as well. For teams, countermeasures would likely include training to be adaptable in creative problem-solving, decision-making and prioritization, and maintaining a shared mental model such that team members are able to adapt smoothly under changing and unexpected conditions.

While a review of literature is a necessary component of research, proposers should note that a literature review is not expected to constitute a significant portion of the funding for this research. To that end, NASA has funded a literature review that has been published as a NASA Technical Memo: [https://ston.jsc.nasa.gov/collections/trs/_techrep/TM-2015-218583.pdf](https://ston.jsc.nasa.gov/collections/trs/_techrep/TM-2015-218583.pdf).
As stated above, NASA will work with the investigators to secure an analog(s) with the specified characteristics if funding is awarded for the long duration analog. If the analog is known and secured, the proposer should include a full description of the analog(s) characteristics. In addition, the Human Factors and Behavioral Performance (HFBP) Element will work with the PI to determine the most applicable performance tasks available in the analog(s) secured for the study.

Proposers should provide estimated costs per year for each of their planned analog usage to achieve study objectives (e.g., HERA for shorter and a polar ICE environment or simulated ICC chamber for longer duration).

Data Sharing Requirements
In order to maximize resources, all investigators funded by NASA for this particular topic will be required to share data within the team for the duration of the project to include raw, analyzed and meta-data. The investigator team, together, will enter into a Data Sharing Agreement (DSA) that contains non-negotiable NASA requirements.

To optimize resources, NASA pursues the intentional formation of investigator partnerships between individual investigators whose experiments will leverage resources by addressing different facets of the same questions. NASA anticipates that such intentional teaming arrangements will result in better utilization of available resources to resolve specific critical questions. NASA strongly encourages investigators submitting applications in response to this NASA Research Announcement (NRA) to consider identifying collaborations between individual investigators as part of the development of their individual proposals and to identify this pre-coordination in their management plan. Finally, NASA may integrate proposals if, in their judgments, the goals, objectives or products of the proposals are similar.

Software Development Requirements
If any software is developed in the course of this NASA funded research for this particular topic, the team must be willing to provide the source code, short training on how to use the software, and enable NASA to make the software available as an open source product. The team must provide NASA with all methods, technologies, tools, software, software documentation (including start up directions), training or materials associated with the developed recommendations. The expectation is that the deliverables will transition to operations at the end of this task. Upon completion of research, any software tools must be delivered to NASA using an architecture where data remains local or on NASA’s server. The Federal Government will retain license rights for all hardware and software created or modified during the project. The proposer shall output data in a non-proprietary data format that is clearly described by either a publicly available standard or in a proposer-provided data specification.

References


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<tr>
<th>Primary IRP Risk</th>
<th>Relevant IRP Gap</th>
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| 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.  
**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.  
**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. |
| 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.  
**TRAIN-04**: We do not know the types of skills and knowledge that can be retained and generalized across tasks for a given mission to maximize crew performance. |

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<th>Secondary IRP Risk</th>
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| Risk of Adverse Cognitive and Behavioral Conditions and Psychiatric Disorders | **BMed1**: We need to identify and validate countermeasures that promote individual behavioral health and performance during exploration class missions.  
**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. |
| Risk of Inadequate Mission, Process and Task Design | **MPTASK-01**: We need methods and tools to collect measures of missions, process, and task performance. |

**Topic 4: Sensory Stimulation for Cognitive and Behavioral Health**

**Background and Approach**
Spaceflight missions of long duration (i.e., greater than 30 days) pose medical and psychological risks for astronauts (Davis, 1999; Williams and Davis, 2005). An exploration class mission will involve extended periods in an ICE, with some Design Reference Missions for Mars potentially lasting several years. As one of the five spaceflight hazards identified by NASA that pose risks to humans, the risk associated with being in ICE environments needs to be mitigated to reduce both the likelihood and consequences of cognitive and behavioral conditions and psychiatric disorders.
The likelihood of the risk is increased by a number of stressors that are associated with long-duration space exploration missions and include the following: small teams of four to six individuals living and working in extreme conditions for prolonged periods separated from family and friends; loss of the natural 24-hour day/light cycle; reduced gravity; threat of space radiation (e.g., galactic cosmic radiation (GCR) exposure); delayed or limited communication coupled with distance from Earth (i.e., out of view); and limited habitat space, privacy, medical capabilities, food selection, and sensory stimulation. How important is meaningful and stimulating sensory input at the right level as an important promoter of cognitive and behavioral health? What is that “right level” to promote and sustain good mental health in crewmembers during isolated and confined long-duration spaceflight?

Koppelmans et al. (2016) found evidence for a dose-response effect in gray matter decreases due to spaceflight. They note that it is unclear whether these brain structural changes reflect intensive training associated with mission preparation. Previous findings have linked sensory input, including motor input and tactile input, directly to brain physiology and neural plasticity, with a connection to the cortical volumes in the somatosensory system (Zentall et al., 1983; Korman et al., 2017; Wu et al., 2017). These findings provide evidence that when organisms are exposed to unusually high or low sensory input, they moderate the incoming sensory stimulation in an effort to approach more optimal levels of arousal. This suggests the importance of tactile stimulation for sensory stimulation, a finding that has been reinforced by a number of classical studies demonstrating that neural plasticity in sensory systems is modulated by motor input (Korman et al., 2017). Of particular interest to this specific research topic, brain imaging studies have demonstrated the important role of sensory stimulation when tactile stimulations are present versus absent. For example, Wu et al. (2017) found that white matter bundles encode neural activity related to their functional roles by connecting cortical volumes in the somatosensory system, exhibiting significantly greater temporal correlations with the primary sensory cortex and signal power during tactile stimulations when compared to a resting state. This suggests that sensory stimulation may contribute to the functional connectivity between the primary sensory processing and motor planning regions, which not only impact on sensorimotor systems, but also have important implications for behavioral and psychiatric problems. For example, Kilgore et al. (2013) provide evidence for how increased cognitive and physiological arousal that is caused by acute stressors can lead to a perpetual cycle of hyperarousal and increased sensitivity to sensory stimulation, resulting in insomnia. They found sleep initiation problems were associated with the increased functional connectivity between the primary visual cortex and other sensory regions (e.g., primary auditory cortex, olfactory cortex, and the supplementary motor cortex). This poses an intriguing question regarding behavioral health and performance among current astronauts on the ISS: What risks are posed by over, or under, sensory stimulation? Is there a dose-response relationship associated with sensory stimulation, brain structure, and behavioral health?

There are also several important findings suggesting that reduced sensory stimulation associated with isolation and confinement may be associated with a loss of pleasure, satisfaction, engagement and risk of behavioral health difficulties which can impact mission safety and success. Some have offered that the failure to address the monotony and boredom aspects of an ICE environment can lead to risk taking behaviors in some individuals that could in turn endanger the mission (Suedfeld et al., 2000). It is also of concern that sensory input can easily become monotonous and drop below the level needed to promote and maintain astronaut health. That is, research has demonstrated that ICE environments can dampen affect and interpersonal engagement (Otto, 2010); and increase sedentariness, fatigue, and other adverse behavioral states (Basner et al., 2013; Basner et al., 2014).

The promotion and maintenance of behavioral health among astronauts is essential for the success of long-duration spaceflight missions. The approach adopted by the HFBP Element and Behavioral Health and Performance Operations is to prevent and mitigate behavioral health problems with early detection and intervention at the first signs or symptoms of adverse behavioral events. However, if and when adverse cognitive or behavioral conditions and psychiatric disorders do arise, effective interventions or treatment must be provided to ensure astronaut health and mission success.
We need to better understand the mechanisms of behavioral health problems and whether certain forms of sensory stimulation can also function as coping mechanisms for dealing with stress, adversity, and directed attention; particularly when these are restorative. As such, we seek to reduce both the likelihood and consequence of the impact of sensory stimulation related to isolation and confinement within environmental settings similar to spaceflight habitats by developing countermeasures that maintain and augment the sensory needs of astronaut crewmembers living and working in the ICE environment of deep space. Current work underway in support of NASA includes virtual reality environments focused on restorative aspects of behavioral health related to social connectedness, mental well-being, and exercise (i.e., depression, conflict, and stress). Proposals should not replicate on-going efforts (https://taskbook.nasaprs.com/publication/index.cfm?action=public_query_taskbook_content&TASKID=9989; http://www.sbir.gov/sbirsearch/detail/411888; https://taskbook.nasaprs.com/publication/index.cfm?action=public_query_taskbook_content&TASKID=9787).

A recent review of the literature on sensory stimulation has identified a framework of four major areas of sensory stimulation considered important for ICE settings:

**Information foraging:** pleasure of learning new things by engaging the human information foraging drive, which is related to brain systems that mediate understanding (sense-making), learning, exploration and sensation seeking (cf., Ludwig and Evens, 2017; Pirolli and Card, 1999). Adequate stimulation of a high degree of novelty and interpretability prevents boredom and subsequent stress.

**Relaxation and restoration:** closely aligned with the safety of obtaining satisfaction from things we have previously learned to like; familiar surroundings (habitat); providing a form of sensory stimulation that allows for recovery from stress and restoration of mental resources.

**Therapeutic release:** sensory stimulation that allows for an individual to engage in active processing techniques to “work through” an emotional response to an event, with the goal of regulating the emotional response and modifying future behavior (see e.g., Dong and Jacob, 2016).

**Homeostatic maintenance:** protecting those sensory systems where long-term sensory or perceptual deprivation may lead to a loss of sensitivity or specificity.

Specifically, proposals must address all of the following:

- Address conceptual context for sensory stimulation: Compare, differentiate and provide the basis for the understanding of the impact of the presence or impoverished sensory stimulation due to isolation, confinement and extreme conditions associated with spaceflight habitat and environment.
- Identify and develop methods and tools to measure and monitor sensory stimulation needs within ICE environments and evaluate potential countermeasures to augment sensory stimulation (see countermeasures below).

**Countermeasures:**
- Provide recommendations for the thresholds for meeting sensory stimulation needs (e.g., within habitat, augmented reality) and composition of an appropriate set of countermeasures for sensory stimulation using existing tools and technologies, or spaceflight habitat, based on the concepts in the framework above. Well validated tools and technologies are preferred. Countermeasures must be feasible for a long-duration space exploration mission (e.g., low mass, power, and volume).

**Testing:**
- Testing must include the acceptance, effectiveness and operational feasibility of this set of countermeasures for meeting the crew’s sensory stimulation needs.
- Testing must be done in the high-fidelity spaceflight analog called HERA. HERA details are provided in the HERO Overview document posted on NSPIRES at https://nspires.nasaprs.com/external/. Both individual and team performance tasks are
included in the HERA mission operations. These tasks include a two-person flight simulation program; a four-person rover assembly activity; a two-person virtual 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](http://www.nasa.gov/mission_pages/station/structure/elements/mss.html)) to grapple or capture an incoming resupply vehicle to the ISS. ROBoT is comprised of a hand controller device and software, and 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](http://nix.nasa.gov/search.jsp?R=20130012667&qs=N%3D4294916663)).

- Testing must also be done in a high-fidelity long-duration spaceflight analog. Proposers should identify the characteristics that they require in an analogous 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 with the specified characteristics once funding has been awarded.

- Subjective and objective evaluation criteria are required and should include, but are not limited to: mood, morale, affect, cognitive function, and other well-being aspects (e.g., hedonic, eudaimonic) and how these are influenced by habitat.

- Work should address the adequacy of the set of countermeasures at various phases of the mission (early, mid, and late), and address individual differences such as personality, culture, age, genetics, sex, and gender.

Research Platform

Ground Analog

Required Deliverables

1. Applied, time-dependent evidence of neurophysiological or brain structure progression of an individual's response to sensory stimulation at varying levels in the framework as outlined above (Information foraging, Relaxation and restoration, Therapeutic release, Homeostatic maintenance) along with recommended countermeasure and habitat modifications/supplementations and guidelines for implementation in future long-duration exploration-type space missions.

2. An assessment of recommended countermeasures' effectiveness at different mission stages (e.g., pre, early, mid, late and post-mission) with a goal of dose-response determinations for sensory stimulation as a countermeasure. This assessment should also address individual differences related to responsiveness to sensory stimulation; such as personality, culture, age, genetics, sex, and gender.

3. An operational protocol for understanding the neurophysiological processes related to sensory stimulation and human performance. These processes may help identify individual differences approaches that can lead to new insights into human sensorimotor performance.

4. A delivery plan for the set of sensory stimulation countermeasures.

The expectation is that the deliverables will transition to operations at the end of this project. The deliverable must provide NASA with all methods, technologies, tools, software, software documentation, training or materials. To avoid the transition costs associated with a server transition, software deliverables should be local whenever feasible.

The proposer shall output data in a non-proprietary data format that is clearly described by either a publicly available standard or in a proposer-provided data specification.

References


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<tr>
<td>(BMed)</td>
<td><strong>BMed7</strong>: 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.</td>
</tr>
<tr>
<td>Risk of Incompatible Vehicle/Habitat Design (HAB)</td>
<td><strong>HAB-01</strong>: 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.</td>
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<td><strong>HAB-03</strong>: We need design guidelines for acceptable net habitable volume and internal vehicle/habitat design configurations for predetermined mission attributes.</td>
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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 Federal Acquisition Regulation (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. 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. 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 EST on March 16, 2018. 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 for Information (RFI) on Topics in Human Health Countermeasures, Human Factors, and Behavioral Performance" (80JSC018L0002).
- Follow the step-by-step instructions provided in NSPIRES to complete your RFI. The following two elements are mandatory for this RFI submission:
  - Utilize the "Summary" element of the RFI to provide a concise response limited to 4000 characters
  - Utilize the "Program Specific Data" element to identify the topic area to which you are responding

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

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**
Name: Dr. Jennifer Fogarty  
Title: Chief Scientist, Human Research Program  
Email: jennifer.fogarty-1@nasa.gov