NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
Johnson Space Center
Space Operations Mission Directorate
Human Research Program
Houston, TX 77058

2024 Human Exploration Research Opportunities (HERO)

Appendix A

NASA Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions

ANNOUNCEMENT NUMBER: 80JSC024NA001-FLAGSHIP

ISSUED DATE: October 02, 2023

KEY DATES
Pre-Proposers Conference: October 16, 2023
Step-1 Proposals Due: November 01, 2023, 5 PM Eastern Time
Step-2 Proposals Due: January 30, 2024, 5 PM Eastern Time
Step-2 Selection Announcement: No earlier than July 2024

OMB Control Number: 2700-0092

You must read and understand this solicitation in its entirety to prepare a competitive proposal. Key requirements are identified here:

- **The information and specific submission instructions in this Appendix supersede those found in the HERO Overview document and NASA Guidebook for Proposers. Proposals that do not conform to the requirements in this Appendix may be declared noncompliant and declined without review.**
- **Information or instructions given in this Appendix which add to or modify the HERO Overview document are unique to this opportunity and should not be considered to apply to other HERO appendices unless noted in that appendix.**
- For Step-1 and Step-2 proposals: You and your organization must be registered with NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES). Your proposal must be submitted by an authorized representative of your organization. All team members listed on the proposal must be registered with NSPIRES.
- For Step-1 and invited Step-2 proposals: Your specific aims must address the research emphases in this solicitation, and must be clearly outlined in the project description of your proposal.
- **For Step-1 proposals: The length of the proposal cannot exceed 1 page using standard (12-point) type.**
- For Step-2 proposals: Proposers must identify the Human Research Roadmap (HRR) risks and gaps that are being addressed by their proposal (https://humanresearchroadmap.nasa.gov/).
- **For Step-2 proposals: The length of the project description of the proposal cannot exceed 10 pages using standard (12-point) type.**
- Investigators resubmitting a proposal in response to this solicitation may only submit a proposal with similar hypothesis(es) and aims a total of three times (original submission plus two resubmissions). Significant changes must be made to the proposal hypothesis(es) and specific aims for consideration after the third attempt or the proposal will be declined without further review.
- For Step-2 proposals: If you use vertebrate animals or higher-order cephalopods for your research, your proposal must meet requirements of the Vertebrate Animal and Higher-Order Cephalopod Section (VACS) section of the HERO Overview.
- For Step-2 proposals: A thorough statistical section must be included which includes a reproducible power analysis for the estimate of sample size and the comparison of males and females unless compelling evidence is provided that shows that no sex differences are expected. **Proposers should plan to consult with a statistician prior to proposal submission and finalizing the experimental design.**
- For Step-2 proposals: Include the Retrospective Data Request Form or Analog Study Resource Worksheet if applicable. For Step-2 proposals: Proposals with international participation that do not include an endorsement from a respective government agency or sponsoring institution in the foreign country may be declined without further review.
- Step-1 and Step-2 selection decision information can be accessed after the selection announcement date listed in this solicitation. After logging in, the PI selects the “Proposals/NOIs” link, the “Submitted” drop-down header, and then clicks on the proposal submitted to the solicitation identified above. The document(s) provided by NASA will be displayed under the heading “PI Selection Information Package” located at the bottom of the “View Proposal” page.

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Appendix A

NASA Human Research Opportunity

A. Funding Opportunity Description

1. Introduction

Note: All citations of the Human Exploration Research Opportunities (HERO) Overview document refer to the 2024 version available here.

To be responsive to this research solicitation, proposed studies should lead to specific products that address at least one of the three specific objectives outlined in the HERO Overview document, section A.2.b Goal and Specific Objectives. The proposed studies should lead to new knowledge within accepted scientific standards. Proposals should consider the impact of sex, age, nutrition, stress, genetic predisposition, or sensitivity on other factors of importance. A thorough statistical section must be included which includes a power analysis for the estimate of sample size. When archival samples are available, the comparison of males and females should be included in the statistical section unless compelling evidence is presented that shows that no sex differences are expected. Please see the Sample Size Specification Guidelines posted alongside the HERO Overview document for additional information concerning sample size calculations. Proposers that request NASA archived data should fill out the Retrospective Data Request Study Feasibility Assessment Form posted alongside the HERO Overview document.

Please note that this appendix will be using Dual-Anonymous Peer Review (DAPR), wherein the reviewers will be unknown to the proposers and the proposers will be unknown to the reviewers for the scientific and technical merit review. Proposers must adhere to the instructions in this document on how to prepare proposals that enable dual-anonymous peer review. Further instructions for the preparation of proposals are provided in the "Guidelines for Proposers to HRP Dual-Anonymous Peer Review (DAPR) Programs" document available alongside the HERO Overview document in NSPIRES.

Proposals must be responsive to the research emphases outlined below in order to be reviewed as significant to the goals of this solicitation. The proposed research approach must adhere to all constraints and guidelines outlined in this solicitation.

2. Research Emphases

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Research in the Human Research Program (HRP) is organized around 22 risks and one concern as outlined in the Human Research Roadmap. **In the current Appendix, HRP is soliciting research for the following topics:**

Topic 1: Sensory Augmentation to Enhance Sensorimotor Recovery

Primary Risk	**Relevant Gap**
Risk of Altered Sensorimotor/Vestibular Function Impacting Critical Mission Tasks	**SM-201:** SM-201: Develop and test postural control and locomotion countermeasures, including human factors aids.

Secondary Risk	**Relevant Gap**
Risk of Injury and Compromised Performance Due to EVA Operations	**EVA-101**: Characterize EVA preparedness shortly post-landing on a planetary surface. **EVA-301**: Identify and test countermeasures related to spatial disorientation and motion sickness to enable early EVA's post g-transition.

Background

Sensorimotor alterations pose a significant risk for a deconditioned long-duration crew during landing, egress and subsequent recovery operations (Clément *et al.,* 2022). Alterations in vestibular sensory processing following gravity transitions lead to motion sickness and sensorimotor impairment upon return to Earth's gravity and may compromise performance during early surface operations. While there is a high degree of variability among crewmembers, most if not all long duration crewmembers experience decrements in postural control and locomotion that may take days to weeks to regain preflight performance levels depending on task difficulty (Wood *et al.,* 2015; Mulavara *et al.,* 2018). These decrements are seen despite a comprehensive system of in-flight exercise countermeasures, which helps maintain muscle strength and aerobic capacity. Interventions are necessary to optimize crew performance for success on upcoming exploration missions. Crews continue to be visually dependent during the early post-landing period as they recalibrate effective use of vestibular and somatosensory feedback systems (Hupfeld *et al.,* 2022). The use of sensory augmentation technologies has the potential to improve post-landing recovery through sensory reweighting or cognitive mechanisms (Sienko *et al.,* 2018). The purpose of this solicitation is to develop and validate sensory augmentation rehabilitation tools and balance aids to enhance recovery in the post-landing timeframe. Both the rehabilitation tool(s), and the associated assessment tasks needed to evaluate their efficacy, must demonstrate operational relevance and feasibility to transition towards self-administered autonomous use during space exploration following planetary landings.

Recent postflight results suggest that post-landing sensorimotor functional performance can take more than one week to recover, potentially impacting early extravehicular activities (EVAs) during exploration missions. The time course of recovery is impacted by flight duration, with most functional task performance returning to baseline within the first week following short-duration Shuttle missions compared to long duration crewmembers that continue to have significant decrements for at least one week (*e.g.*, Miller *et al.,* 2018). These decrements are more pronounced during functional tasks that required the greatest demand for dynamic control of postural equilibrium (Mulavara *et al.,* 2018), such as the time to complete a mobility task simulating a seat egress. Early interventions to drive adaptation may enhance recovery, as long as the movements are within an individual motion tolerance thresholds (Rosenberg *et al.,* 2022).

These decrements are seen after International Space Station (ISS) missions despite a comprehensive system of pre-, in- and postflight exercise countermeasures guided by the astronaut strength rehabilitation and conditioning (ASCR) specialists (Loehr *et al.,* 2015). While postflight postural recovery has been improved with the current ISS state of the art exercise devices (Wood *et al.,* 2015), future exploration exercise devices may have reduced capabilities due to mass and volume constraints. Preflight and inflight countermeasure approaches are the focus of current studies to minimize the initial decrement. This solicitation instead focuses on sensorimotor countermeasures that can be introduced in the post-landing timeframe to enhance recovery toward functional readiness.

Research has previously demonstrated that real-time multimodal sensory augmentation (SA) can improve balance and locomotion within laboratory environments (Sienko *et al.,* 2018). The main approach is to use measures of body motion obtained through instrumentation (*e.g.*, accelerometers, force plates) and provide feedback of that movement through natural senses (vision, auditory, touch) to reinforce / recalibrate one's expected sensory feedback during active movements (*e.g.*, Wall, 2010; Sienko *et al.,* 2017; Oddsson *et al.,* 2022). Other approaches to augment sensory information (*e.g.*, fingertip contact, Jeka and Lackner, 1994) may also improve recovery through use of balance and mobility aids. Further, motor learning tasks that incorporate incremental exposures can facilitate adaptation and be more effective in driving neural plasticity and learning (Lackner and Lobovits, 1978; Kagerer *et al.,* 1997; Cakit *et al.,* 2007; Schubert and Migliaccio, 2019; Rosenberg *et al.,* 2022).

Topic Description

The purpose of this solicitation topic is to develop and validate countermeasures that mitigate sensorimotor decrements in the post-landing timeframe to enable crewmembers to perform critical mission tasks, and/or to return crewmembers to preflight levels of functional fitness following return to Earth. For planetary landings, it is assumed these countermeasures will be implementable within the landing vehicle prior to egress (*i.e.*, not require implementation within a suited environment during extravehicular activities). Research is specifically solicited to apply field-type implementations of sensory augmentation rehabilitation tools (visual, vibrotactile, auditory, or multimodal) that can be self-administered using minimal equipment. This will require demonstration of the equipment and software to be used, as well as rehabilitation exercises that would be required of the crewmembers. It should be assumed that time required to deploy the equipment and perform the rehabilitation will be constrained by crew time, typically not to exceed 60 min/day.

Certain tasks performed shortly after landing, such as rapid head movements, have the potential to exacerbate symptoms and impair adaptation. Therefore, proposers should also define an incremental approach using their rehabilitation tools to facilitate adaptation. Complementary assessments of movement coordination with and without the sensory augmentation should be included as a guide for when to advance to progressively challenging movements. Rehabilitation and assessment tasks must also be functionally relevant to operational tasks utilized during exploration missions (*e.g.*, Mulavara *et al.,* 2018).

A summary of the current evidence for risks, and a reference list, is available here.

Research Platform
Proposers should also include a plan to validate the clinical performance of both rehabilitation and assessment tools using an appropriate spaceflight analog. While head down bed rest (HDBR) and dry immersion (DI) have been used to model sensorimotor deconditioning due to body-unloading (Tomilovskaya *et al.,* 2019; Macaulay *et al.,* 2021), these are beyond the scope of this solicitation timeframe. Other approaches have included the use of clinical populations, such as vestibular patients (Van Ombergen *et al.,* 2017), or vestibular disruption to healthy subjects using galvanic vestibular stimulation or motion environments (Wood *et al.,* 2009; Lawson *et al.,* 2016). Exposure to sustained Gx centrifugation (Sickness Induced by Centrifugation - SIC, Nooij *et al.,* 2007) provides an acute vestibular disruption analogous to that encountered following spaceflight g-transitions, *e.g.*, with increased sensitivity to head movements. HRP has developed the necessary arrangements to implement the Gx centrifuge analog using facilities located at domestic (USA) locations. The nominal profile includes continuous 2.5 to 3 Gx centrifugation (front-to-back) for 60 min. The budget to accommodate this analog testing will be covered by NASA external to this grant; however, investigator team travel and support should be factored in the final budget. While this is the preferred platform for this solicitation, other spaceflight analogs such as those described above will be considered. Note that successful validated rehabilitation tools and/or assessments from this solicitation will be considered for future flight study incorporating a sensorimotor countermeasure suite that incorporates other elements (*e.g.*, preflight and inflight conditioning).

Required Deliverables
Provide and verify operationally efficient post-landing sensory augmentation rehabilitation tools to enhance recovery.

Provide and verify operationally efficient assessment tasks to evaluate the efficacy of the sensory augmentation rehabilitation.

Award Information
This study will be executed with a Definition Phase, which includes planning and integration work needed to start the study, followed by an Implementation Phase. The milestone required to proceed from Definition to Implementation Phase is completion of the science integration.

After the Definition Phase, if this investigation is determined not feasible and/or NASA does not select for implementation, it will be cancelled.

Implementation phase will include the remainder of the full grant award amount.

Funding available is up to:

Year 1: $100,000 - This will be during the Definition Phase, in which IRB will be completed, feasibility assessment inputs are provided as required, science and planning meetings with various NASA personnel are completed, and a revised proposal is provided that takes into account science integration decisions.
Year 2: $350,000 - This will be during the Implementation Phase. Assume this is data collection year.
Year 3: $350,000 - This is continued Implementation Phase.
The total budget cannot exceed $800,000.

Topic Point of Contact:
Michael B. Stenger, Element Scientist, Human Health Countermeasures
E-mail: michael.b.stenger@nasa.gov

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Topic 2: Biomarker exploration system for measuring operationally meaningful performance in future exploration missions

Relevant Risk	**Relevant Gaps**
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed-102:** Given exposures to spaceflight hazards (space radiation, isolation), how do we identify individual susceptibility, monitor molecular/biomarkers and acceptable thresholds, and validate behavioral health and CNS/neurological/neuropsychological performance measures and domains of relevance to exploration class missions? **BMed-108:** Given each crewmember will experience multiple spaceflight hazards simultaneously, we need to identify and characterize the potential additive, antagonistic, or synergistic impacts of multiple stressors (*e.g.*, space radiation, altered gravity, isolation, altered immune, altered sleep) on crew health and/or CNS/ cognitive functioning to develop threshold limits and validate countermeasures for any identified adverse crew health and/or operationally relevant performance outcomes.

Background:
Future exploration crews will be exposed to multiple spaceflight hazards, including altered gravity, space radiation, isolation and confinement, distance from earth, and a hostile, closed environment. When paired with traditional life stressors, spaceflight stressors may have an exponential impact on behavioral health of long-duration fliers (Kanas & Manzey, 2008). It is further expected that the risk of a psychological event increases in direct proportion to the length of the mission (Ball & Evans, 2001; Slack *et al.*, 2016), elevating the risk of adverse behavioral health and performance outcomes in exploration scenarios such as extended missions to the moon and to Mars.

Current spaceflight missions in low earth orbit to the International Space Station (ISS) are built upon a foundation (primarily) of real-time communication, which facilitates ground control's partnership with inflight crews, as they work together to complete mission objectives, and collaboratively trouble-shoot off-nominal situations that may arise. The ISS's proximity to earth also enables regular delivery of crew care packages, real time communication with loved ones back home, and changing team composition with crew members coming and going to the ISS.

Research from the ISS reveals some behavioral and physiological changes can occur on orbit and in the current paradigm of spaceflight, however. As an example, an investigation by Agha and colleagues (2020) demonstrated an association between elevated stress biomarkers and immune system dysfunction on ISS, particularly with first-time flyers. Additionally, sleep loss and circadian misalignment have been shown to occur, especially during high tempo operations (Barger *et al.*, 2014; Flynn-Evans *et al.*, 2015). Recent advances in functional imaging have further identified brain structure changes in astronauts completing long-duration missions on the ISS, although only small to no changes are reported in cognitive assessment batteries conducted both inflight and post-landing (Garrett-Bakelman *et al.,* 2019; Roy-O'Reilly *et al.*, 2021; Tays *et al.,* 2021).

Concurrently, research from terrestrial analogs provides further insight into behavioral changes that could occur in extended duration stays in isolated, confined, and extreme (ICE) environments. Research in the Russian Mars Chamber has demonstrated one of six crew members reporting increasing depression symptoms over time (Basner *et al.*, 2014). Studies in other ICE environments have shown negative valence emotions associated with alterations of the hypothalamic-pituitary-adrenal (HPA) axis (Connors *et al.*, 1986; Palinkas, 1991; Palinkas *et al.*, 1989). Dampening of positive affect and other processes such as emotion regulation (Alfano *et al.*, 2019) has also been found. Furthermore, in studies evaluating animals irradiated with high-LET radiation at doses that astronauts could incur during an exploration mission, alterations in neural circuitry of the brain and cognitive function are found (for review see Desai *et al.,* 2022).

Notably, efforts are underway to help 'dissect' where discrepant findings may be at play. For example, while research reveals few decrements on cognitive tests, anecdotal reports from astronauts (Schroeder & Tuttle, 1992; Stuster, 2016) have suggested some difficulty attending to tasks, and there have been some complaints of cognitive slowing and memory problems during spaceflight (colloquially termed "space fog"). One explanation for the discrepancy between self-reported and measured cognitive deficits is "reserve capacity." High-functioning individuals are postulated to possess a reserve factor that moderates the expression of cognitive impairments when confronted with brain pathology or resource depletion (Jones *et al.*, 2011). Additionally, it is important to understand the fuller context surrounding challenges, such as whether these have occurred during an adaptation phase or period of high workload.

Recent advances in the field are moving toward a more comprehensive representation of markers which may dig deeper into drivers of such potential changes, while considering contextual factors. As an example, Tu *et al.* (2022) retrospectively evaluated psychomotor performance on the ISS, relative to time-varying and discordantly measured environmental, operational, and psychological covariates. Paromita and colleagues (2023) demonstrated computational models that can automatically detect micro-behaviors in real-time, evaluating the effectiveness of interpretable linguistic and acoustic features extracted at the conversation level, while integrating contextual information about the occurring task and the underlying sentiment of the conversation in the micro-behavior detection system (Paromita *et al.*, 2023).

Given the common overlap of both psychological and physiological symptoms that can present as behavioral and performance decrements, and the uncertainty as to whether major life events mediate or moderate such changes (Zhang *et al.*, 2007), we need to identify the appropriate combination of accessible, minimally obtrusive measures (subjective and/or objective) across multiple behavioral health domains, as part of a psychological support system for exploration mission so that effective countermeasures can be applied (Myasnikov *et al.*, 2000, as cited in Kanas *et al.*, 2001).

Topic Description

HRP's Risk Approach Plan for the Behavioral Medicine risk seeks to identify in-flight biomarkers that indicate changes in in-flight operationally relevant performance, due to exposures to relevant spaceflight hazards. The intent of monitoring biomarker changes is to understand how to best detect operationally meaningful changes, so that countermeasure support can be provided.

A biomarker is defined as a characteristic that is objectively measured and evaluated as an indicator

of normal biologic processes, pathogenic processes, or pharmacologic responses to a therapeutic intervention. Biomarkers can include behavioral as well as physiological and biological indicators (such as metabolites and cytokines) that indicate changes to relevant processes. It is likely that multi-modal approaches assessing longitudinal changes in accessible biomarkers derived from different techniques, including but not limited to behavioral, biochemical, electrophysiological, omics (genomics, proteomics, transcriptomics, metabolomics, neuroimaging), will be more reliable (and discriminating) than a single biomarker to predict risk of spaceflight-induced performance deficits.
Of additional consideration:

- Biomarkers should be accessible, minimally intrusive, informing changes in brain function linked with corresponding relevant changes in behavior and operational performance.
- Biomarkers must be useful for bi-directional translation of homologous human and animal measures

Proposal Topic Focus #A: This topic focus seeks proposals on the identification, development, and validation of a biomarker exploration system (BES) for humans. Outcomes of interest for space exploration missions should include multiple domains of behavioral health and could include, but are not limited to, cognitive systems (*e.g.*, executive function, working memory, arousal, attention, perception), emotional valence, arousal, reserve capacity, and neuroplasticity informing neuro-circuitry function needed to support operational task performance. Biomarkers should be validated in ground-based mission scenarios and with meaningful, mission-relevant content.

Proposal Topic Focus #B: Proposals for this topic focus should address items in Focus #A using animal models for ground-based studies using irradiators at home institutions and/or the NASA Space Radiation Laboratory analog facility at Brookhaven National Laboratory, in conjunction with other appropriate spaceflight stressor simulations of adaptations to gravity levels, isolation confinement, and other stressors relevant to spaceflight, such as sleep loss, and/or circadian misalignment. These biomarkers should be validated in ground-based mission scenarios and with meaningful, mission-relevant content.

Research Platform
This NRA is focused specifically on the identification of a validated set of accessible biomarkers, using ground-based studies for humans (Focus A) and in animal models (Focus B). Ground-based platforms should simulate hazards appropriate to the focus of the proposal, including but not limited to: varying gravity levels, isolation and confinement, irradiators at home institutions and/or the NASA Space Radiation Laboratory analog facility at Brookhaven National Laboratory. Utilization of historical data are encouraged to formulate initial sets of operationally relevant biomarkers with the addition of carefully selected, accessible biomarkers that have the potential to inform behavioral states given the context of measurement of complementary data.

Responses proposing flight-based studies will be considered non-responsive. Investigators interested in flight-based studies are encouraged to look for alternative funding opportunities from HRP or the Translational Research Institute for Space Health (TRISH).

Partnerships
NASA's Space Biology program plans to participate in the implementation of this research effort, by providing expertise and bridging to relevant Space Biology studies; in addition, later funding from

Space Biology may be offered for supplemental efforts. The Space Biology Program works across the spectrum of biological organization, from molecules to cells, from tissues and organs, and from systems to whole organisms. Space Biology initiates and supports experiments across multiple platforms, including ground platforms that mimic aspects of spaceflight, such as the National Space Radiation Laboratory (NSRL). More information about the Space Biology Program can be found at: https://science.nasa.gov/biological-physical/programs/space-biology

The Human Research Program (HRP) is focused on investigating and mitigating the highest known risks to human health and performance in support of NASA's exploration missions with the goal to develop and provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. Relative to this effort, NASA HRP supports research across internal and external laboratories as well as terrestrial analogs, such as the Human Exploration Research Analog and other environments that offer high fidelity to exploration missions.

Joint efforts between HRP and Space Biology therefore help facilitate understanding of the human system by ensuring various levels of measurement. Bridging changes from the cellular/molecular level, through tissues and organs, to clinically or operationally significant and health and performance changes, brings a comprehensive approach to characterizing and mitigating risk. Proposers should therefore anticipate interactions and potential opportunities with representatives from the Space Biology Program, in addition to those in HRP.

Required Deliverables

An approach fusing multimodal-biomarkers for an accurate, valid, reliable estimation of operationally relevant - behavior and/or operational task performance outcomes.

Award Information

A maximum of $400,000/year for three years (total = $1,200,000) is available for this topic.

Topic Point of Contact

Alexandra Whitmire, Ph.D.; Element Scientist, Human Factors and Behavioral Performance
E-mail: alexandra.m.whitmire@nasa.gov

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Topic 3: Countermeasures for Inconsistency in Crew-Systems Integration

Relevant Risk – External Deliverable	**Relevant Gaps**
Risk of Inadequate Human Systems Integration Architecture (HSIA) - Validated ground countermeasures for HSIA	**HSIA-301:** Develop and test complex procedure execution and oversight countermeasures **HSIA-101:** Characterize risk and define solution space formulation (simulation, scenarios, architecture, integration) **HSIA-201:** Cross-cutting Human Factors tools, metrics, and solutions. Requirement for measuring consistency and countermeasures for working with diverse designs.

Background

NASA's Artemis program will lead humanity forward to the Moon and prepare us for the next giant leap, the exploration of Mars. It has been over 50 years since astronauts last walked on the lunar surface during the Apollo program, and since then, the robotic exploration of deep space has seen decades of technological advancement and scientific discoveries. NASA's return to the moon offers architectural and hardware solutions to leverage the core deep space transportation systems—the Space Launch System (SLS) rocket, the Orion spacecraft, and the supporting Exploration Ground Systems (EGS)—to return humans to the Moon for the first time in more than 50 years (NASA, 2022). Through partnerships with U.S. industry, NASA is developing 21st century deep space habitation capabilities and investing in lunar lander technologies. A cross-agency architecture team also has been formulating plans for a Gateway orbiting the Moon. While extension collaborations across government, commercial entities and international partners are needed to move the Artemis program forward, these do increase the need for integration and the risk of inconsistency across vehicle and mission design.

Topic Description

The Human Systems Integration Architecture (HSIA)

NASA's mission-operations paradigm, which originated with Project Mercury and endured with minimum evolution through the Apollo Program, Space Shuttle Program, and ISS missions, has been one of near-complete real-time dependence on a ground team of experts to manage the combined state of the mission, vehicle, and crew. This ground team has served as the safety net for crewed spaceflight missions over the past 60 years, and hence this paradigm will be significantly challenged by long duration exploration missions beyond low Earth orbit: deep-space crewed missions with infrequent resupply, inability to evacuate or be rescued, and high-latency communications that prohibit real-time operational and medical support.

Future deep space missions will present unique challenges for crews and increased risks to their performance due to the stress, fatigue, radiation exposure, and isolation that characterizes these missions. With crews less able to depend on real-time support from Mission Control Center (MCC), they will have to work increasingly autonomously (NASA, 2021). Success in this more autonomous environment will depend in part on advanced, onboard automated systems, and on new approaches for training. Additionally, it will also depend on effectively integrating intelligent vehicle capabilities with crew capabilities. It is therefore critical that *capabilities be wrapped around the human(s) for* *safety critical issues to be addressable.*

Artemis is comprised of numerous programs and vehicle developers/vendors, which may have different crew interface designs that are inconsistent with one another. This may result in training inefficiencies for the crew, as well as increased likelihood of human error during the mission. We need to determine how diverse designs may impact crew performance and develop countermeasures to mitigate human interface consistency for Artemis programs.

Previous and Ongoing Human Factors Behavioral Performance Research
Investigators are encouraged to review the research currently being conducted by HFBP to avoid duplicative studies. Information on these studies can be found in the NASA Task Book (http://taskbook.nasaprs.com/Publication/welcome.cfm). From the Task Book home page, click the "Search Task Book" button, and then select the Human Research Program Element: Human Factors and Behavioral Performance (HFBP) check box for a list of active studies.

Research Platform
We need to determine which of the most urgent issues related to HSIA interface inconsistencies are most effectively mitigated by training, and which require vehicle or system-based countermeasures to prevent/reduce errors in those cases. The proposed work should focus on human in the loop laboratory testing and associated simulations, in or out of a spaceflight analog, to develop, test, and refine countermeasures (*e.g.* vehicle-based, system-based, or training-based) that will mitigate potential errors caused by inconsistent interfaces, for future spaceflight.

Required Deliverables
Proposers should assume vehicle interfaces will be designed for increasing autonomy (*e.g.*, automation), and should consider countermeasures that are feasible in the future spaceflight environment (*e.g.* low volume and time burden). Deliverables will serve to inform Artemis program documents and NASA Habitability Standards and/or the NASA Human Integration Design Handbook (HIDH). These resulting countermeasures and evidence to inform standards and requirements, will help enable critical procedures in Earth-independent environments—operations that have reduced ground support due to communication delays.

Award Information
Please note that a maximum of $400,000/year for three years (total = $1,200,000) is available for this topic.

Topic Point of contact
Alexandra Whitmire, Ph.D.; Element Scientist, Human Factors and Behavioral Performance
E-mail: alexandra.m.whitmire@nasa.gov

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Topic 4: Mitigating Behavioral Health and Performance Risks for Lunar Missions

Primary Risks	Relevant Gap
Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team	**Team-105:** We need to identify a set of countermeasures to support team function and enable multiple distributed teams to manage shifting levels of autonomy for all phases of increasingly earth independent, long duration exploration missions.
Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders	**BMed-106:** Given increasing Earth independent long-duration missions with resulting communications delays, how do we maintain personal relations/interactions (family, friends and colleagues) and mitigate effects on astronauts' behavioral health and performance during exploration class missions?
Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture	**HSIA-301:** We need to determine the on-board, intelligent systems that will support crew health and performance, and we need to establish the thresholds that will define how these systems should be implemented (including in-mission and at landing).

Background

There is a need to characterize and mitigate risks associated with Human Factors and Behavioral Performance, for future long duration (*i.e.*, 30-60 day) Artemis missions. Recent HFBP research in analogs has primarily focused on mitigating risk relative to Mars, and/or relative to a mix of varying Design-Reference Mission spaceflight stressors (*e.g.* HERA campaigns which have included Mars-like com delay during a simulated mission to an asteroid or moons of Mars). The focus of this topic is to conduct two targeted campaigns in an increasingly Artemis-like HERA environment, to characterize and mitigate stressors unique to future *lunar* missions.

This call addresses several HFBP-related topics, including: *In-Mission Problem Solving for Lunar Missions; Distributed Teams Under Conditions of Lunar Communication Delay; and Family and Social Support for Lunar Missions*. Each proposal is encouraged to address one of these topics in the context of an anticipated Artemis mission.

- Assumptions about targeted Artemis missions are provided below for the purpose of proposal writing, however, these assumptions may change once a study is selected and integration into the HERA campaign begins.
- HFBP may select more than one proposal and combine them into an integrated Virtual NASA Center of Excellence (VNSCOR), with multiple investigators working closely together in HERA

Campaign 8. Some studies could be extended for a second campaign in HERA Campaign 9.
- The currently anticipated start date for HERA C8 is October 2025, with integration efforts starting shortly after proposal selection.

With the completion of the unmanned Artemis I mission in late 2022, and the announcement of the four astronauts selected for the upcoming Artemis II mission, astronauts living and working on the lunar surface is on the horizon. Research evaluating the effects of prolonged isolation and confinement, distance from Earth, etc., has been conducted in various analogs, however there is a need to characterize the effects of Artemis-like stressors on behavioral health and performance, and to establish relevant, feasible, acceptable mitigations for these stressors.
Artemis-like stressors which may be present in the HERA analog for Campaign 8:

- A communication delay of (one-way) 5 to 14 seconds between the HERA crew and mission control, and family, friends, and colleagues back home
    - Concurrently, the potential for real-time communication and/or a smaller delay of (one-way) 1-4 seconds between the split crew (*i.e.* portions of the mission where half the crew may be on a ‘remote excursion’)
- Crew likely to function with a level of higher autonomy in comparison to current spaceflight operations, but given proximity to earth, mission control will still work closely with the crew (*i.e.*, not analogous to Mars ‘high autonomy’ scenarios with very little to no mission control involvement in time critical scenarios)
- EVA capabilities, including both a virtual simulation EVA and crews physically splitting into smaller teams to complete specialized rover and habitat activities
- Coordination between split teams (habitat, EVA/rover, possible ‘gateway mission control’, earth mission control)
- Computer/technology interfaces should include some level of higher fidelity to systems anticipated in Artemis missions, such as increased automation
- Exercise capabilities could be limited to devices that require more limited volume, *e.g.* bands and harnesses
- Food system may be further constrained, with limited variety and heating options
- High tempo mission with ambitious work schedules and limited time for exercise, food, and other non-work-related activities
- Intensive pre-mission training activities which may include virtual simulations
- Proposers can assume four, 45-day HERA missions within a campaign, with a team of four crew members that include two crew on workday ‘excursions’ (*i.e.* working in a smaller platform outside of the HERA habitat)

Topic Description
Based on the background information and assumptions provided, interested parties should submit a proposal to address one of the following sub-topics:

- *In-Mission Problem Solving for Lunar Missions*

  - Problem-solving in current spaceflight involves a collaborative relationship between an extensive team on the ground, and the spaceflight crew. When an unanticipated anomaly needs to be resolved (or contingency planning takes place, etc.) a large team, including Front Room, Back Room, and Mission Evaluation Room Controllers (up to about 40 people) respond immediately (Gore *et al.*, 2021). Given the anticipated communication delays during Artemis missions, crews on the lunar surface will rely increasingly on onboard problem-solving abilities as well as tools to support them (Wu and Vera, 2020). Research is needed to develop and validate countermeasures to support in-mission problem solving in context of lunar missions.
- *Distributed Teams Under Conditions of Lunar Communication Delay*
  - The multi-team system could take on new meaning in context of future missions (Landon *et al.*, 2015; Marquez *et al.*, 2022). As noted above, future Artemis missions will include times of split crew on the lunar surface, and/or with a (two to four person) team on the Gateway as well as with mission control back on earth. We need to understand the impact of the anticipated 5-14 second lunar delays for team performance and functioning, as well as space-to-ground coordination, and test and validate countermeasures for these impacts, in an Artemis-like environment.
- *Family and Social Support for Lunar Missions*
  - When considering future Artemis crews and the extensive pre-mission training and high tempo, in-mission workload (and other lunar mission stressors such as communication delays), it will be important to consider how to implement a robust behavioral health and performance support system (Picano *et al.*, 2022). The impacts to crews' family and the need for in-mission social support in exploration, needs to be further characterized (Slack *et al.*, 2016). As an example, what will be the most effective modes of communication (*e.g.*, email, asynchronous video message, text) for providing different types of emotional support between exploration crewmembers and their family, friends, and colleagues? Family and social support countermeasures should be tested and validated in an Artemis-like environment, especially in preparation for future extended exploration missions.

A summary of the current evidence for risks, and a reference list, is available here.

Research Platform
The intent of this topic is to solicit research for HERA Campaign 8 and Campaign 9, which will be focused on addressing research questions for Artemis.

Required Deliverables

- A comprehensive final report which describes the impacts of the Artemis-like environment on behavioral health and performance outcomes
- Ground validated recommendations for in-mission (and pre and post flight, if appropriate) countermeasure implementation
  - Development of evidence-based protocols feasible in the spaceflight environment

Award Information
Please note that a maximum of $300,000/year for five years (total = $1,500,000) is available for this topic.

Topic Point of Contact
Alexandra Whitmire, Ph.D.; Element Scientist, Human Factors and Behavioral Performance
E-mail: alexandra.m.whitmire@nasa.gov

References
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B. Award Information

The selected proposals are expected to be funded as research grants, cooperative agreements, or contracts in one-year increments with funding allocations to participating investigators based on the submitted budget, available funds, and project review. The funding duration will depend on proposal requirements, peer review panel recommendations, and continuing progress of the activity. Proposals will be evaluated as described in section D of this document.

NASA does not provide separate funding for direct and indirect costs; thus, the amount of the award requested is the total of all costs submitted in the proposed budget. It is estimated that the initial selections will be announced by May 2024, and the grants will be awarded in a reasonable timeframe thereafter.

C. Proposal and Submission Information

1. Source of Application Materials
All information needed to submit an electronic proposal in response to this Appendix is contained in this document, the HERO Overview document, and the NASA Guidebook for Proposers. Please see the HERO Overview document, section D, for additional details on application materials.

The information in this Appendix **supersedes** and provides additional direction to that found in the HERO Overview document and the NASA Guidebook for Proposers and provides additional direction consistent with the NASA Federal Acquisition Regulations (FAR) Supplement. Proposals that do not conform to the standards outlined in this solicitation may be declared noncompliant and will be handled in accordance with the NASA FAR Supplement in the best interest of the Government.

Proposal submission questions received will be answered and published in a Frequently Asked Questions (FAQ) document. This FAQ will be posted on the NSPIRES solicitation download site alongside this Appendix and will be updated periodically between submission release and the Step-2 proposal due date. Any supplemental information will also be posted alongside this Appendix or the HERO Overview document.

2. Content and Form of Proposal Submission

a. Registration in NASA Proposal Data System
Please see section D.1.b of the HERO Overview document for details on NSPIRES registration.

b. Electronic Submission
Please see section D.3.a of the HERO Overview document for details on electronic submission.

3. Instructions for Preparation of Step-1 Proposals for DAPR
Proposals solicited through this NRA will use a two-step proposal process with mandatory Step-1 and invited Step-2 proposals. Please see the HERO Overview document, section D.3, for specific instructions on submitting a Step-1 proposal to this NRA. **Please note that there is a <u>one-page limit</u> for the Step-1 pdf attachment in response to this NRA. Required elements that are present in the Summary section of the NSPIRES cover pages need not be repeated in the Step-1 attachment.** Step-1 proposals shall be electronically submitted by the due date and time listed in section E. Electronic submission of Step-1 proposals will be open during the period listed in section E.

Additional instructions are given below for preparation of the Step-1 proposal. Instructions given in this NRA supersede instructions in the HERO Overview document. All Step-1 proposals must be prepared in an anonymized fashion, as described in the HERO Overview document and the accompanying "Guidelines for Proposers to HRP Dual-Anonymous Peer Review (DAPR) Programs".

Required elements of the Step-1 application must be addressed in either the NSPIRES cover pages/summary or the PDF (need not be repeated in both areas) and include:

(1) Title
(2) Background
(3) Hypothesis
(4) Aims
(5) Methods
(6) Deliverables
(7) Significance
(8) HRR Gaps addressed

The PDF is considered an addendum to information already given in the abstract, and proposers must address all of the items listed above between those two sections.

4. Instructions for Preparation of Invited Step-2 Proposals for DAPR
Please see the HERO Overview document, section D.3, for specific instructions on Step-2 preparation. Step-2 proposals are due by the due date and time listed in section E. **Step-2 proposals will be accepted from invited proposers only.** Invited Step-2 proposals must be submitted through the NSPIRES system. The scope and content of invited Step-2 proposals shall be limited and complementary to Step-1 proposals.

To ensure proper Step-2 proposal transmission, please upload only **two** PDF attachments ordered as below. **Specific instructions for proposal sections are given in the HERO Overview document (see section D.3). Instructions in the** HERO Overview document **supersede those found in the** NASA Guidebook for Proposers**. Instructions given in this NRA supersede instructions in the HERO Overview document.**

Proposals that do not conform to these requirements may be declared noncompliant and declined without review.

The following is a checklist of components for submitting a Step-2 proposal document in response to this solicitation. Details on these components may be found in the HERO Overview document (see section D.3). Additional details on specific or unique sections or constraints for this appendix are given beneath the checklist and supersede direction given in the HERO Overview document where the two contradict. Note that excess information exceeding page limits or that is inappropriate for a given section may be redacted and the PI notified. Before uploading to NSPIRES, please check your proposal document against the following list to ensure you have included all components:

General Requirements:

Topic	Location
NSPIRES Cover Pages	HERO Overview document, Table 2
Formatting	HERO Overview document, Table 3
PDF Requirements	HERO Overview document, Table 3

PDF Upload 1: Proposal Document PDF (Anonymized)

Section	Required?	Page Limit	Location (in this appendix unless otherwise specified)
1. Table of Contents	Yes	As needed	HERO Overview document, Table 4
2. Map to Human Research Roadmap (HRR)	Yes	2	HERO Overview document, Table 4
3. Project Description	Yes	10	HERO Overview document, Table 4; see also C.4.b below
4. Statistical Approach	Yes	1	HERO Overview document, Table 4
5. References and Citations	Yes	As needed	HERO Overview document, Table 4
6. Management Approach	Yes	As needed	HERO Overview document, Table 4
7. Vertebrate Animal and Higher Order Cephalopod Section (VACS)	Yes, if experiment involves non-human vertebrates or higher order cephalopods	2	HERO Overview document, Table 4
8. Data Management Plan (including Software Sharing Plan, if appropriate)	Yes. The provided template must be used for this section.	2	HERO Overview document, Table 4
9. Proposal Budget with Budget Narrative and Budget Details	Yes	As needed	HERO Overview document, Table 4

PDF Upload 2: Expertise and Resources PDF (Not Anonymized)

Section	Required?	Page Limit	Location (in this appendix unless otherwise specified)
1. Table of Contents	Yes	As needed	HERO Overview document, Table 5
2. List of Team Members and Organizations	Yes	As needed	HERO Overview document, Table 5
3. Team Expertise	Yes	1	
4. Biographical Sketches/Curriculum Vitae	Yes	As needed (1-2 pages each are preferred)	HERO Overview document, Table 5
5. Current and Pending Support	Yes	As needed	HERO Overview document, Table 5
6. Bibliography of Current and Past HRP Funded	Yes, if PI or Co-Is are previous HRP	As needed	HERO Overview document, Table 5

Projects	awardees		
7. Statements of Commitment and Letters of support, feasibility, and endorsement	Yes, if lacking full access to a necessary resource or for foreign team members; use NSPIRES for commitment	As needed	HERO Overview document, Table 5
8. Assurance of Compliance	Yes, if involving human or animal subjects. Must be addressed as pending or approved.	As needed	HERO Overview document, Table 5
9. Facilities and Equipment	Yes	As needed	HERO Overview document, Table 5
10a. Flight Experiment Resource Worksheet	**Not Allowed**, Flight experiments are not allowed for this opportunity.	N/A	HERO Overview document, Table 5
10b. Analog Study Resource Worksheet	Yes, if analog experiment proposed.	As needed	HERO Overview document, Table 5
10c. Retrospective Data Request Study Feasibility Assessment Form	Yes, if experiment requires previous NASA data/samples.	As needed	HERO Overview document, Table 5
11. Grant Compliance Waiver	Only for PIs not in compliance with current/past HRP grant agreements	As needed	HERO Overview document, Table 5

a. Project Description
In addition to the guidance given in the HERO Overview document, the project description section for responses to this appendix is limited to ten pages and should be complementary to the submitted Step-1 proposal. Please see the HERO Overview document, Table 4, for descriptions of what is and is not included in the project description page limit.

D. Proposal Evaluation Process

1. Step-1 Proposal Relevancy Review

NASA will review the submitted Step-1 proposals and assess relevance to the solicitation (see HERO Overview, section E.2). Step-1 proposals that are not in alignment with the research emphases may be declined. Investigators of Step-1 proposals submitted in response to one opportunity described in this solicitation may be invited to submit a Step-2 proposal to a different active HERO opportunity. Additionally, before review, each Step-1 Flagship proposal submitted to this solicitation will undergo a compliance check for formatting, page count, and DAPR compliance. At NASA's discretion, noncompliant proposals may be withdrawn from the review process and declined without further review.

2. Step-2 Proposal Scientific and Programmatic Reviews

a. Compliance Matrix

All proposals must comply with the general requirements of the NRA as described in this solicitation, the HERO Overview document, the NASA Guidebook for Proposers, and the NASA FAR Supplement. Upon receipt, proposals will be reviewed for compliance with these requirements as described in the HERO Overview document, section E.2.b. ***Note: At NASA's discretion, noncompliant proposals may be withdrawn from the review process and declined without further review.***

b. Scientific and Programmatic Reviews

The overall evaluation process for proposals submitted in response to this NRA will include a First-Tier Merit Review and a Second-Tier Program Alignment Review as described in section E.2.d of the HERO Overview document.

The criteria listed in section E.2 of the HERO Overview document will be used for the purposes of this appendix.

c. Selection

Selections will be handled according to the details given in sections E.2 and E.3 of the HERO Overview document.

E. Submission Dates

Solicitation Announcement Identifier: 80JSC024NA001-FLAGSHIP
NRA Release: October 02, 2023
Pre-Proposers Conference: October 16, 2023
Step-1 Proposals Due: November 01, 2023, 5 PM Eastern Time
Step-2 Proposals Due: January 30, 2024, 5 PM Eastern Time
Step-2 Selection Announcement: No earlier than July 2024
Selected awards are expected to begin no earlier than August 2024

F. NASA Contacts

NASA Selecting Official: HRP Director or their designee

Additional technical information for the NASA programs is available from:

Steven H. Platts, Ph.D.

Chief Scientist, Human Research Program
NASA Johnson Space Center (Mail Code SA2)
Houston, TX 77058
Telephone: 281-483-8177
Fax: 281-483-6089
Email: js-hrp-chief-science-office@mail.nasa.gov

Additional information on the proposal submission process is available from NSPIRES:
Telephone: 202-479-9376, Monday through Friday, 8 a.m. to 6 p.m. Eastern Time.
Email: nspires-help@nasaprs.com

Frequently Asked Questions and User Guides: Available through the Proposal Online Help site at https://nspires.nasaprs.com/external/onlineHelp/index.htm.

G. Summary of Key Information

Number of new awards pending adequate proposals of merit	1-5 per topic
Maximum duration of awards	3-5 years (depending on topic)
Page limit for the central Project Description section of Step-1 proposal	1 page
Page limit for the central Project Description Section (Project Description) of Step-2 proposal	10 pages
Relevance to NASA	This appendix is relevant to the human health and performance strategic goals and subgoals in NASA's *Strategic Plan*; Proposals that are relevant to this appendix are, by definition, relevant to NASA.
General information and overview of this solicitation	See Human Exploration Research Opportunities (HERO) Overview posted https://nspires.nasaprs.com
Detailed instructions for the preparation and submission of proposals	See NASA Guidebook for Proposers at NASA Guidebook for Proposers
Submission medium	Electronic proposal submission is required; no hardcopy is required. See also HERO Overview and Chapter 2 of the *NASA Guidebook for Proposers*.
Web site for submission of proposal via NSPIRES	https://nspires.nasaprs.com (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
NASA point of contact	Steven H. Platts, Ph.D.

concerning the Human Research Program	js-hrp-chief-science-office@mail.nasa.gov