NASA's Human Research Program (HRP) investigates and mitigates the highest risks to astronaut health and performance in exploration missions. The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration, and to ensure safe and productive human spaceflight. The scope of these goals includes both the successful completion of exploration missions and the preservation of astronaut health over the life of the astronaut. HRP 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 program's research plan through the timescale of early lunar missions of extended duration. The Human Research Roadmap (http://humanresearchroadmap.nasa.gov) is a web-based version of the IRP that allows users to search HRP risks, gaps, and tasks. The HRP is organized into Program Elements:

- Human Health Countermeasures.
- Behavioral Health & Performance.
- Exploration Medical Capability.
- Space Human Factors and Habitability.
- Space Radiation and ISS Medical Projects.

Each of the HRP Elements address a subset of the risks, with ISS Medical Projects responsible for the implementation of the research on various space and ground analog platforms. The overview and responsibilities of each of the Elements is described within the Human Research Roadmap (referenced above). With the exception of Space Radiation, the SBIR subtopics in this solicitation align with the HRP Program Elements:

- H12.02 Exploration Medical Capability - Medical Suction Capability addresses a specific Exploration Medical Capability technology gap.
• H12.03 Behavioral Health and Performance - Innovative Technologies for A Virtual Social Support System for Autonomous Exploration Missions helps address Behavioral Health and Space Human Factors and Habitability risks.

• H12.04 Advanced Food Systems Technology helps address the Space Human Factors and Habitability food system risks.

• H12.05 In-Flight Biological Sample Analysis helps address an ISS Medical Project technology need to allow on-orbit biological sample analysis, limiting the need for biological sample return.

Subtopics

H12.01 Exploration Countermeasure Capability - Portable Activity Monitoring System

Lead Center: JSC

Participating Center(s): GRC

Human space flight is associated with losses in muscle strength, bone mineral density and aerobic capacity. Crewmembers returning from the International Space Station (ISS) can lose as much as 10-20% of their strength in weight bearing and postural muscles. Likewise, bone mineral density is decreased at a rate of ~1% per month. During future exploration missions such physiologic decrements represent the potential for a significant loss of human performance which could lead to mission failure and/or a threat to crewmember health and safety. NASA is conducting research to enhance and optimize exercise countermeasure hardware and protocols for these missions. In this solicitation, we are seeking portable technologies to collect foot ground reaction force data from current exercise hardware deployed on the International Space Station to be analyzed by research teams on the ground.

NASA seeks a portable, force/load measurement system capable of being integrated into existing ISS exercise systems and suitable for use in future transfer and exploration vehicles. During long duration spaceflight, exercise is prescribed to mitigate bone and muscle loss. Advancement of these exercise prescriptions may require biomechanical analysis of exercise on orbit. Output parameters from the proposed device must be valid in the bandwidth from 0-100Hz and be able to be synchronized with existing analog data systems. 3-D force, torque, acceleration, and turn rates are required. Must include a portable data logging system or wireless interface compatible with the Windows platform or Apple iPad. On-board data processing, activity recognition and display is desirable. The portable system should be low-maintenance, durable, easy to set-up and calibrate, non-disruptive to exercise form or gait, accurate (NASA Deliverables) - Fully developed concept complete with feasibility and top-level drawings as well as computational methodology as applicable. A breadboard or prototype system is highly desired.

HRP IRP Risks - Risk of Impaired Performance Due to Reduced Muscle Mass, Strength, and Endurance; Risk Of Early Onset Osteoporosis Due To Spaceflight

Technology Readiness Levels (TRL) of 6 or higher are sought.

Potential NASA Customers include:
H12.02 Exploration Medical Capability - Medical Suction Capability

Lead Center: JSC
Participating Center(s): GRC

The existing in-space medical suction system (used on ISS) provides insufficient medical suction capability. Medical suction clears the airway, empties the stomach, decompresses the chest, and keeps the operative field clear. The existing design provides limited operational flexibility in providing airway management support, oropharyngeal suction, and chest tube drainage during an exploration mission due to limitations in suction performance, usability, patient interfaces, and reusability. It is restricted for use by a trained medical doctor and has several design limitations including:

- It can only be used to clear the airway. It would be insufficient/incapable to perform other types of medical suction.
- Device consists of several pieces that are only held together by a friction fit/seal and may come apart unless handled carefully.
- Device does not meet flow rate requirement since it is limited by operator speed.
- Device can only collect about 1 liter total volume. This volume includes volume of air since there is no gas separator.

The Phase I technology developed under this SBIR should demonstrate proof of concept medical suction capability in a space operational environment and should focus on the following aspects:

- Phase separation.
- Range of flow rates.
- Range of applied vacuum pressure.
- Continuous and intermittent operation.
- Variety of operational conditions including micro, partial and normal gravity; and in-space and post-landing usage.
- Minimize mass, volume, and power usage.

Minimum specifications that should be in the design:
- Airway Management and Oropharyngeal Suction:
  - Suction pressure - at least 500 mmHg
  - Flow rate - at least 25 liters per minute
  - Duration - at least 30 minutes
- Chest tube drainage:
  - Suction pressure - between 150-180 mmHg
  - Duration - at least 24 hours
- Biological waste cleanup:
  - Suction pressure - at least 500 mmHg
  - Flow rate - at least 35 liters per minute
  - Duration - at least 30 minutes

**NASA Deliverable** - Prototype functional system in a proof of concept demonstration

**HRP IRP Risk** - Inability to Adequately Recognize or Treat an Ill or Injured Crew Member

Technology Readiness Levels (TRL) of 3 or higher are sought.

Potential NASA Customers include:

- Exploration Medical Capability Element in Human Research Program:

**H12.03 Behavioral Health and Performance - Innovative Technologies for A Virtual Social Support System for Autonomous Exploration Missions**

Lead Center: JSC

NASA wants to identify how virtual worlds (i.e., interactive games, avatars, social networks) could be used for long-
duration space exploration missions. This subtopic is aimed at developing a virtual social support system for crews of such missions.

During these missions, the crews, by virtue of their distance from Earth, are separated from their significant others and will no longer have access to social support currently provided to the ISS crews. They are living in a confined and isolated environment devoid of normal Earth settings as they venture to distant destinations. Long communication delays between Earth and vehicle are also anticipated. Expanding the crew's social connectivity to friends, family, and colleagues back home through a variety of virtual platforms will help mitigate the stressors inherent to living and working in such an isolated, confined, and extreme environment.

During the actual mission, the tool could provide a more homelike "virtual world" to augment the constrained physical habitat the crew lives and works. It could also help the crews maintain connections and provide the needed social support. As a design tool, the insight gained into the crew members' interaction with the outside world would be valuable for developing new mission training regimens and design concepts for future long-duration missions.

The proposal shall describe:

- The virtual environment to be developed.
- Plans to provide adaptive systems to deal with communication latencies.
- How the tool could enhance and measure behavioral health and performance, including perceived closeness to home.
- Ways to assess habitability issues.

*NASA Deliverables* - Phase I deliverable shall yield a proof of concept that includes both an evidence review that encompasses an assessment of current knowledge of virtual reality technologies and their use in supporting this topic.

In addition, the following deliverables shall be required:

- A requirements document for such a support system that fits the needs of a NASA exploration mission.
- A plan for evaluating the effectiveness of the tool as a behavioral health countermeasure, training, and habitability assessment.

The subsequent Phase II deliverable shall provide a prototype of specific modules that can demonstrate improved communication and perceived social support by utilizing these technologies.

*HRP IRP Risks* - Risk of Adverse Behavioral Conditions and Psychiatric Disorders; Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a
Team: Risk of an Incompatible Vehicle/Habitat Design

Technology Readiness Levels (TRL) of 4 or higher are sought.

Potential NASA Customers include:

- Behavior and Performance Element in Human Research Program:

### H12.04 Advanced Food Systems Technology

**Lead Center:** JSC

The purpose of the NASA Advanced Food Technology Project is to develop, evaluate and deliver food technologies for human centered spacecraft that will support crews on long duration missions beyond low-Earth orbit. Safe, nutritious, acceptable, and varied shelf-stable foods with a shelf life of 5 years will be required to support the crew during these exploration missions. Concurrently, the food system must efficiently balance appropriate vehicle resources such as mass, volume, water, air, waste, power, and crew time.

Refrigeration and freezing require significant vehicle resource utilization, so NASA provisions consist solely of shelf stable foods. Stability is achieved by thermal or irradiative processing to kill the microorganisms in the food, or drying to prevent viability of the microorganisms within the food substrate. Environmental factors (such as moisture ingress and oxidation) are also capable of compromising the nutrient content over the shelf life of the food. Since the food system is the sole source of nutrition to the crew, a significant loss in nutrient availability could significantly jeopardize the health and performance of the crew. Optimal nutritional content of the food for five years will ensure that the food can support crew performance and help protect their bodies from deficiencies that cause disease.

Vitamin content in NASA foods, such as vitamin C, vitamin A, thiamin, and folic acid, is degraded during processing and as the product ages in storage. The goal is to develop a system that either increases the bioavailability of the nutrients or protects the vitamins from this biological or chemical degradation at ambient temperatures over a five year duration. Possible technologies that could be investigated include novel food ingredients, protective or stabilizing technologies (e.g., encapsulation), biosensors, and controlled-release systems.

*Phase I Requirements* - Phase I should concentrate on the scientific, technical, and commercial merit and feasibility of the proposed innovation resulting in a feasibility report and concept, complete with analyses.
NASA Deliverables - A system which will result in higher nutrient content in shelf stable foods.

HRP IRP risk - Risk of Inadequate Food System

Technology Readiness Levels (TRL) of 4 to 5 or higher are sought.

Potential NASA Customers include:

- Space Human Factors and Habitability Element in Human Research Program:

H12.05 In-Flight Biological Sample Analysis

Lead Center: JSC

Participating Center(s): ARC

Although crewmembers undergo intensive medical screening, the possibility of crew injury or illness can never be completely eliminated. A mission could be jeopardized or compromised by reduction of able crewmembers, both directly and indirectly if an incapacitated crewmember requires nursing or care. Mission architecture limits the amount of equipment, consumables, and procedures that will be available to treat medical problems. Mission allocation and technology development must be performed to ensure that the limited mass, volume, power, and crew training time are used efficiently to provide the broadest possible treatment capability. There is also a gap in knowledge in how the spaceflight environment affects the effectiveness of drug therapies. This subtopic aims to mitigate those space mission constraints by means of innovative approaches for addressing the knowledge gap in the area of drug stability during long duration spaceflight.

This subtopic seeks proposals for novel approaches to develop an in-flight tool capable of monitoring stability of pharmaceuticals (ideally, solids, liquids and creams) under low gravity conditions. Such a device must be able to determine percentage of active ingredients with a preference to also characterize degradation of products while minimizing the amount of pharmaceutical sample consumed in the test. The technology will need to address approaches and methodologies for handling the different forms of pharmaceuticals (pills, liquids, creams) through the use of a flexible sample preparation front-end amenable to the space environment. The proposed technology should be low-resource, low-footprint, and should involve a low volume of supplies/consumables, which do not require refrigeration or freezing for storage. Also, the technological innovation should be user-friendly, requiring minimal training and operating via uncomplicated protocols.

The Phase I technology developed under this SBIR should investigate one or more one or more of the following drugs:
• Acetaminophen.
• Azithromycin.
• Injectable epinephrine.
• Lidocaine topical gel.

In the Phase I effort, the proof of concept analysis should be demonstrated by the innovative technology and provide comparable results to drug stability laboratory USP standards (i.e., high performance liquid chromatography, differential scanning calorimetry, UV/FTIR spectroscopy). Phase II will seek to optimize these results for additional drugs as well as sensitivity, compound identification, drug degradation products, analysis time and facilitated end-user protocols.

NASA Deliverables: Prototype functional system in a proof of concept analysis demonstrated by the innovative technology producing drug stability characterization including integrity and percentage of active ingredients and characterization/degradation of products (in Phase I). Drugs to be demonstrated in Phase I include: Acetaminophen, Azithromycin, Injectable epinephrine and Lidocaine topical gel.

**HRP IRP Risks** - Inability to Adequately Recognize or Treat an Ill or Injured Crew Member; Risk of Therapeutic Failure Due to Ineffectiveness of Medication

Technology Readiness Levels (TRL) of 5 or higher are sought.

Potential NASA Customers include:

• ISS Medical Project Element in Human Research Program: