



NASA SBIR 2014 Phase I Solicitation

H12 Human Research and Health Maintenance

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 addresses a subset of the risks, with ISS Medical Projects responsible for the implementation of the research on various space and ground analog platforms. With the exception of Space Radiation, HRP subtopics are aligned with the Elements and solicit technologies identified in their respective research plans.

Subtopics

H12.01 Next Generation Oxygen Concentrator for Medical Scenarios

Lead Center: GRC

Participating Center(s): JSC

For exploration missions, a contingency system which concentrates the oxygen within the cabin environment and provides the required concentration of oxygen to the crewmember for various medical scenarios will be necessary. Oxygen concentration technology is being pursued to concentrate oxygen from the ambient environment so that oxygen as a consumable resource and the fire hazard of an elevated cabin oxygen atmosphere can be reduced. The goal of this project is to develop an oxygen concentration module that minimizes the hardware mass, volume, and power footprint while still performing at the required clinical capabilities.

An Oxygen Concentrator Module (OCM) with an adjustable positive pressure output 2-15 lpm of O₂ at 50% to >90% oxygen concentrations by volume has been recommended by the flight medical team. The unit must be able to operate continuously in microgravity and partial gravity exploration atmospheres that include the atmospheres of 14.7 psia/21% oxygen, 10.2 psia/26.5% oxygen, and 8.2 psia/34% oxygen by volume. The unit must run continuously on available spacecraft power, and be switchable between 28 VDC and 120 VDC. It must have adequate heat rejection so as to not exceed a touch temperature of 45°C. It is also highly desirable to have a portable low output capability for use in EVA pre-breathing or patient transfer between vehicles. Usage scenarios for oxygen treatment of smoke inhalation or toxic spills also predicated the need for an inlet filter on the unit that removes (converts/absorbs/filters) toxic gases from the delivered gas stream to the patient.

The OCM system should be capable of regulating the oxygenation of the patient using a closed loop feedback system that senses the oxygenation level of the patient tissues and adjusts the oxygen flow rate and/or oxygen concentration according to treatment protocols for the illness being treated. The system shall also be able to operate open loop in the event of feedback signal failure. The control variable(s) are not specified (rate/concentration) here since the basic unit's topology may dictate how the regulation is best achieved. Because the system may be configured during times of duress, it shall be user friendly to the caretaker by adopting a "plug and play" philosophy.

This SBIR Phase I development is to determine the architecture of such a system exhibiting the characteristics (high capacity flow range, closed-loop tissue oxygen control, and operations in microgravity or partial gravity exploration atmospheres), a description of the basic unit as a sub-system component, method of optimizing power over the range of flows and oxygen levels, redundancy and sparing for a long duration missions, and the relationship of the OCM system to caretaker (what does the caretaker need to do to fulfill the medical need?).

Phase I Requirements - Phase I should concentrate on developing the scientific, technical, and commercial merit and feasibility of the proposed innovation resulting in a feasibility report and concept, complete with analyses that discuss functionality in microgravity and at the proposed exploration atmospheres, algorithms for closed-loop oxygenation protocols, and inlet filtering of smoke or toxic gases.

NASA Deliverables - A concept for a microgravity and partial gravity exploration atmospheres oxygen concentrator with a closed loop oxygenation flow rate system with inlet filtering of potential toxic ambient gases.

HRP IRP Risk - Risk of Unacceptable Health and Mission Outcomes Due to Limitations of In-flight Medical Capabilities.

H12.02 Inflight Calcium Isotope Measurement Device

Lead Center: JSC

Bone loss in crewmembers is a major concern for long duration space flight. The ability to rapidly detect changes in bone mineral balance (BMB) in crewmembers living on ISS would have great potential as a surveillance tool for future exploration missions. Calcium isotopes have been shown to detect changes in BMB on very short timescales (e.g., one week). In order to detect these important changes, a technological device could be used in-flight. Thus, we are seeking a device (portable to bench top size) with the same accuracy and precision as is currently available in the non-flyable Multiple Collector Inductively Coupled Plasma mass spectrophotometer.

Phase I Requirements - The sensitivity required to make the Calcium isotope measurements would need to be approximately 10^{12} - 10^{16} (i.e., this is how sensitive the machine should be for finding the Calcium isotope; it should be able to pick up one "atom" or unit in a pool of 10^{16} other things). Systems that measure elemental composition typically have sensitivities around 10^6 - 10^9 for some elements. The absolute concentrations of the isotopes are not required. We are looking for an instrument that can measure the variations in the ratio of any two Calcium isotopes on the order of 0.1-0.5 parts per 10,000 (44Ca/42Ca) but could vary depending on the isotopes used. A successful proposal will include the technologies being considered and detailed test plan for evaluating them during Phase I.

Phase I deliverables - Test results and plan for developing a low volume, low mass, easy-to-operate prototype. TRL of 3 desired.

Phase II deliverables - Prototype in year 1 with sample testing against industry standard in year 2.

HRP IRP Risk - Risk of Early Onset Osteoporosis Due to Spaceflight

Technology Readiness Levels (TRL) of 4 to 5 or higher are sought upon completion of the project.

H12.03 Objective Sleep Measures for Spaceflight Operations

Lead Center: JSC

Currently in spaceflight, crewmembers report their sleep duration as requested by their crew surgeon. This approach has several limitations, including the burden it places on the crew and the tendency for subjective over-reporting of sleep (Lauderdale et al., 2008; Van Den Berg et al., 2008; Silva et al., 2007). Given evidence that demonstrates the relationship between sleep and circadian phase and performance, sleep-activity data should be collected as unobtrusively possible during long duration spaceflight. Wrist-worn actigraphy has been implemented as a successful, validated research tool in spaceflight but lacks features to render it a useful tool operationally, such as real-time feedback and minimal crew time requirements. Hence, there is a need for a minimally obtrusive or unobtrusive measure that evaluates sleep-wake activity plus light exposure; is acceptable for continuous wear; minimizes crew time by allowing for automatic downloads; provides immediate feedback to the user; incorporates the constraints of spaceflight hardware, such as extended battery life; and potentially incorporates other features, including other physiological sensors. The proposed technology should build on existing technologies with a focus on enhancing the product to ensure spaceflight readiness.

Requirements - Phase I should concentrate on the enhancement of a prototype device providing minimally obtrusive data collection that objectively measures sleep duration and other relevant characteristics in the spaceflight environment. Phase II should also yield a plan for continued development (if needed) and for validation of the device prior to spaceflight implementation.

NASA Deliverables - An objective, validated measure of sleep that is feasible and acceptable in the spaceflight environment.

HRP IRP Risk - Risk of Performance Errors Due to Fatigue Resulting from Sleep Loss, Circadian Desynchronization, Extended Wakefulness and Work Overload.

A TRL Start of 3-4 with a TRL End of 7-8 (at the end of Phase II) is desired for this project.

H12.04 Advanced Food 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 foods with a shelf life of five years will be required to support the crew. Concurrently, the food system requirements must efficiently balance with their use of vehicle resources such as mass, volume, water, air, waste, power, and crew time.

NASA provisions currently consist solely of shelf stable foods due to vehicle resource limitations preventing food refrigeration or freezing. Stability is achieved by thermal, irradiative processing, or drying to kill or prevent microorganism growth in the food. These methods coupled with environmental factors (such as moisture ingress and oxidation) impact the micronutrients within the food. Since the food system is the sole source of nutrition to the crew, a significant loss in nutrient availability could jeopardize the health and performance of the crew.

This subtopic requests methods or technologies that enable development of an acceptable and safe food system to deliver appropriate amounts of bioavailable nutrients to crewmembers throughout a five year mission with no resupply. Vitamin content in NASA foods, such as vitamin C, vitamin K, thiamin, and folic acid, are key nutrients

degraded during processing and storage. NASA is seeking novel food ingredients, protective or stabilizing technologies (e.g., encapsulation), controlled-release systems, or novel processing technologies that allow the delivery of key nutrients at the time of consumption. Consideration must be given to food safety as well as acceptability, as under-consumption will similarly lead to nutritional deficiencies.

Deliverables - Feasibility demonstration of a novel food system approach with the potential to enable vitamin stability in an acceptable and safe food system for extended duration missions. Phase I should include a comprehensive report detailing the system feasibility, and show a clear path to Phase II development and analyses, with the expectation that Phase II will demonstrate that the food system will retain 70% of original content of vitamin C, vitamin K, thiamin, or folic acid over five years of ambient temperature storage. Phase II should deliver the innovation in a form that can be tested in NASA's food system.

HRP IRP Risk - Risk of Inadequate Food System.

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