NASA SBIR 2014 Phase I Solicitation

H3 Life Support and Habitation Systems

Life support and habitation encompasses the process technologies and equipment necessary to provide and maintain a livable environment within the pressurized cabin of crewed spacecraft. Functional areas of interest to this solicitation include atmosphere revitalization, environmental monitoring and fire protection systems, crew accommodations, water recovery systems and thermal control. Technologies must be directed at long duration missions in microgravity, including Earth orbit and planetary transit. Requirements include operation in microgravity and compatibility with cabin atmospheres of up to 34% oxygen by volume and pressures ranging from 1 atmosphere to as low as 7.6 psi (52.4 kPa). Special emphasis is placed on developing technologies that will fill existing gaps, reduce requirements for consumables and other resources including mass, power, volume and crew time, and which will increase safety and reliability with respect to the state-of-the-art. Non-venting processes may be of interest for technologies that have future applicability to planetary protection. Results of a Phase I contract should demonstrate proof of concept and feasibility of the technical approach. A resulting Phase II contract should lead to development, evaluation and delivery of prototype hardware. Specific technologies of interest to this solicitation are addressed in each subtopic.

Subtopics

H3.01 Thermal Control for Future Human Exploration Vehicles

Lead Center: JSC

Participating Center(s): GRC, GSFC, JPL, KSC, LaRC, MSFC

Future human spacecraft will require more sophisticated thermal control systems that can operate in severe environments ranging from full sun to deep space and can dissipate a wide range of heat loads. The systems must perform their function while using fewer spacecraft resources, including mass, volume and power. Advances are sought for microgravity thermal control in the following areas:

- Heat rejection systems and/or radiators that can operate at low fractions of their design heat load in the cold environments that are required for deep space missions. Systems that can maintain setpoint control and operate stably at 25% of their design heat load in a deep space (0 K) environment are sought. Innovative components, working fluids, and systems may be needed to achieve this goal.
- Lightweight non-venting phase change heat exchangers are sought to ameliorate the environmental transients that would be seen in planetary (or lunar) orbit. Heat exchangers that have minimal structural mass and good thermal performance are sought. The goal is a ratio exceeding 2/3 phase change material mass and 1/3 structural mass.
- Two-phase heat transfer components and system architectures that will allow the acquisition, transport, and rejection of waste heat loads in the range of 100 kW to 10 megawatts are sought.

- Nontoxic working fluids are needed that are compatible with aluminum components and combine low operating temperature limits (<250K) and favorable thermophysical properties - e.g., viscosity and specific heat.

Technologies are expected to be raised from TRL2 to TRL 3/4 during Phase I. Minimum deliverables at the end of Phase I are analysis/test reports, but delivery of development hardware for further testing is desirable. In addition, the necessity and usefulness of a follow-on Phase II should be demonstrated.

Technologies would be expected to be matured from TRL 3/4 to TRL 5 during a potential Phase II effort. Expected deliverables for a Phase II effort are analysis/test reports and prototypic hardware.

For more detailed relevant information:
(http://www.nasa.gov/pdf/501320main_TA14-Thermal-DRAFT-Nov2010-A.pdf).

H3.02 Atmosphere Revitalization and Fire Recovery for Future Exploration Missions

Lead Center: MSFC

Participating Center(s): ARC, GRC, JSC, KSC

This topic seeks to develop targeted process technologies and equipment to advance the operability and reliability of atmosphere revitalization (AR) subsystems that enable crewed deep space exploration objectives.

Highly reliable AR subsystem equipment and process technologies, supplemented by atmosphere decontamination equipment and methods, are necessary components to crewed deep space exploration mission success. While the International Space Station (ISS) AR subsystem equipment approaches many of the functional goals necessary for deep space exploration mission success, flight operational experience has identified areas for improvement in resource recovery and rapid atmosphere decontamination capabilities. Technologies related to resource recovery include gas compression and management as well as gas separations. Rapid atmosphere decontamination capabilities are needed to remove the functional burden for recovering from a contamination event, such as a fire or chemical spill, from the primary AR subsystem equipment. Details in each functional area of interest are provided by the following:

- *Gas Compression and Management* - NASA is seeking safe, compact, quiet, long-lived, and efficient ways to compress, store, and deliver gaseous oxygen and carbon dioxide within an AR subsystem. Also, methods to store, condition, and deliver reactant gases, primarily carbon dioxide, to carbon dioxide reduction process equipment are sought. Present AR equipment aboard ISS consists of power-intensive, noisy compressors that have service lives less than 2 years. Significant acoustic treatment is necessary to achieve NC-40 criteria. Applications for deep space exploration missions include but are not limited to production of high pressure oxygen for EVA use, and compression and storage of carbon dioxide for use in carbon dioxide reduction systems. Improvements in service life, reliability, and mechanical compression for atmospheric gas recharge to pressures up to 3,600 psia, including long life and reliability, and novel methods to increase tank storage capacity at lower pressures are of particular interest.
- *Hydrogen Purification for Resource Recovery* - Resource recovery and recycling is an enabling functional area for the AR subsystems needed for long-duration missions. For this purpose, NASA is interested in a regenerative separation technology to enable maximum hydrogen recovery from a stream containing water vapor (saturated), carbon monoxide (CO), and hydrocarbons including methane, acetylene, ethane, and ethylene, among others. While a high quantity of methane in the hydrogen product stream is acceptable, and even desirable, the presence of CO, water, and other hydrocarbons is highly undesirable. Final gas composition must be >99% hydrogen with some allowable methane and the dewpoint must be less than -60 °C. System concepts must strive to minimize power, mass, and consumable requirements while maximizing efficiency, operational life, and reliability.
- *Post-Fire Cabin Atmosphere Cleanup* - A portable, self-contained fire and toxic atmosphere cleanup system is desired that can rapidly remove contaminants from a spacecraft volume, to quickly and effectively decontaminate cabin atmosphere after a fire. The capability to reduce starting concentrations by >80% within 15 minutes for a 100-m^3 volume is desired. Methods have involved either deploying a filter assembly to the commode after a fire and using the commode fan as the source of airflow or attaching a series of

filters to a portable fan using an adapter kit. Both methods result in low atmospheric scrubbing flow rates and significant time for deployment as well as limited capacity and non-specific scrubbing. Russian-provided portable equipment aboard the ISS provides 65 m^3 /h flow through a replaceable cartridge. The equipment's mass is 17 kg and the power consumption is 150 W. Filter service life is 7.5 hours. The dimensions are approximately 33 cm diameter and 35 cm tall. Future equipment must provide the rapid contamination reduction within the characteristic size and performance envelope of the Russian-developed portable scrubbing device.

For each technical area, projects are sought to research and demonstrate technical feasibility during Phase I that will develop a clear technical maturation path towards Phase II hardware development and demonstration. Phase II products must include a demonstration unit suitable for testing by NASA.

Phase I Deliverables - Documentation, data, and feasibility assessment proving the proposed approach is suitable to develop the proposed product (at least TRL 3 at completion according to NPR 7123.1 TRL definition). A breadboard developmental unit is desirable.

Phase II Deliverables - Functional engineering development unit at a minimum high fidelity breadboard (brassboard fidelity preferred), defined by NPR 7120.8, and technical maturity level 4 (TRL 4 defined by NPR 7123.1) of the proposed product, along with a full report of developmental and performance results, including drawings, analyses, and models as applicable. Opportunities and plans should also be identified and summarized for potential commercialization.

H3.03 Human Accommodations and Habitation Systems for Future Exploration Missions

Lead Center: JSC

Participating Center(s): ARC, KSC, MSFC

Habitation systems that are dispersed throughout a spacecraft volume need to be investigated as a system to improve future human accommodations. Current spacecraft interiors exceed acoustic limits from a wide range of equipment; have manual inventory tracking and no capability for assistance of lost items; and require substantial crew time and wipes for cleaning common crew surfaces (hand rails and panels) and water/solids hygiene surfaces. Future spacecraft interiors will need to be reconfigurable to meet changing crew needs as a mission moves from launch, transit, and exploration-destination phases. Adaptable distributed habitation technologies are needed in the following areas.

- *Quiet Crew Cabin Environments* - Smaller future vehicles will unlikely have dedicated quiet volumes for crew rest so maintaining a quiet cabin is required. Crew cabin acoustic noise mitigation needs to control noise levels to enable improved voice communication, alarm signal to noise ratio, and reduce crew fatigue from long duration noise exposure. There is need for non-wearable active and passive noise cancellation/reduction strategies for open crew cabin environment that do not impede voice or alarms. Need for adaptive broad coverage area to accommodate changing crew cabin layout and volume.
- *Crew Item Location Capability* - Significant crew time is lost in tracking or locating items at the piece part level in space habitat environment that serves both as living quarters and laboratory. Items are sometimes misplaced or simply float away in the microgravity environment. Innovative approaches are sought for automatic location and tracking of a large number of individual crew items as they move from their original launch configuration to any area in the crew cabin. Crew items range in size from pill size, hand tools, clothing, and spare equipment and vary in material composition from non-metallic, metallic, to fluid containing. There is a need for low-power, and miniature Radio Frequency Identification (RFID) readers for dense storage and sparse tag environments. Flexible reader deployment that allows individual item autonomous logistics management tracking and precise 3-D locating are desired. Solutions providing enhanced localization utilizing the EPCglobal UHF reader-tag protocols (Class 1 Gen2 or advanced classes) are of high interest. Similar types of reader-tag communication protocols at higher frequencies that enable more accurate spatial localization are also of interest. Innovative algorithmic solutions for finding lost items, based on RFID or similar sensory information, are also of interest. All solutions must accommodate a highly reflective and complex scattering environment such as a conductive habitat cylindrical volume of ~ 3.5 m diameter ~6 m in length.

- *Crew Cabin Surfaces* - Crew activity and surface contact of fabric and solid surfaces result in generation and accumulation of particulate, moisture, organic, and salt. Surface treatments for fabrics and solid surfaces to prevent this accumulation of contaminants are needed to reduce crew time and the large number of wipes used for cleaning. Innovative low out gassing, super hydrophobic, super hydrophilic, antistatic, and antimicrobial treatments are needed for crew hygiene areas and waste collection hardware is needed. Non-mechanical fastener/non-particle generating removable physical connections are needed for repeated reconfiguring of interior volumes on longer missions. Examples of the types of temporary and reversible physical connections include crew restraints (e.g., hand rails), close out panels, and the hook-and-loop type fasteners present on most crew items.

Phase I Deliverables - Detailed analysis, proof of concept test data, material test coupons, key algorithms/ subroutines, and predicted performance comparison to industry state of the art.

Phase II Deliverables - Comparison of analysis to prototype test data in representative environment, sufficient material samples/components for independent evaluation, functional software, functional breadboard component hardware and/or system, and operations documentation.

H3.04 Development of Treatment Technologies and Process Monitoring for Water Recovery

Lead Center: JSC

Participating Center(s): ARC, JPL, KSC, MSFC

The capability to recover potable water from wastewater is critical to enable space exploration missions beyond low Earth orbit. A major focus of technology development is to increase reliability of water recovery systems, so these systems require less crew intervention and a lower risk of failure with longer operational lifetimes. With these goals in mind, two areas of interest have been identified for further focus:

- *Water Recovery Post-Processing Systems* - Technologies are needed to increase the reliability of systems for polishing of partially-treated wastewater. The current state of the art uses catalytic oxidation to remove dissolved organic carbon contaminants. Technologies that operate below 100 °C or ambient pressure are desirable. Examples of these technologies include low-temperature catalytic oxidation, photolysis, or photocatalysis.
- *Monitoring Systems for Mineral Species in Water & Wastewater* - A capability is needed to measure dissolved mineral ions in water and wastewater, including polyatomic ions (could encompass organic ions) and the alkaline, alkaline-earth and transition metals. Multi-analyte capability is needed, such as that available from ion chromatography and plasma spectroscopy. Potential applications include measurement of typical ionic species in humidity condensate, potable water, wastewater, byproducts of water treatment such as brines, and biomedical and science samples. Desirable attributes should include minimal sample preparation, minimal consumables, in situ calibration, and operation in microgravity and partial gravity.

At the completion of Phase I, the technology should be TRL 3. The expected deliverable for Phase I is a detailed report describing experimental methods and results, with a clear feasibility demonstration of critical technology components. The equivalent system mass, including consumables, power, volume and mass, should be estimated for the technology and be included in the report. Phase II deliverables should have completed TRL 4 and be approaching TRL 5. The Phase II deliverable should include a prototype system suitable for additional testing at a NASA center as well as a detailed report of testing and development demonstrating TRL 4.