NASA SBIR 2015 Phase I Solicitation

H3 Life Support and Habitation Systems

Lead Center: JSC

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.Â

Subtopics

H3.01 Environmental Monitoring for Spacecraft Cabins

Lead Center: JPL

Participating Center(s): GRC, JSC, KSC

Measurement of Inorganic Species in Water

There is limited capability for water quality analysis onboard current spacecraft. Several hardware failures have occurred onboard ISS which demonstrate the need for measurement of inorganic contaminants. Monitoring capability is of interest for identification and quantification of inorganic species in potable water, thermal control system cooling water, and human wastewater. Examples of inorganic species of interest and their levels in potable water are specified in Spacecraft Water Exposure Guidelines (SWEGs), released as JSC 63414 (Last revised - November 2008). Target compounds identified in the SWEGs that will be needed for exploration missions include ammonium, antimony, barium, cadmium, manganese, nickel, silver, and zinc. But there is also interest in measurement of other cations and anions including iron, copper, aluminum, chromium, calcium, magnesium, sodium, potassium, arsenic, lead, molybdenum, fluoride, bromide, boron, silicon, lithium, phosphates, sulfates, chloride, iodine, nitrate and nitrite. Detection limits should be below 0.5 mg/L where possible. The proposed analytical instrument should be compact, microgravity compatible, and have limited power and consumable requirements. Sample volumes should be minimized.

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Particulate Monitor for Air

Instruments that measure indoor aerosols in spacecraft cabins to monitor air quality and for characterizing the background particle environment and major particle sources are desired. Real-time measurement instruments must be compact and low power, without volatile working fluids, intuitive for crew to operate, requiring minimal maintenance, and able to maintain calibration for years. A large measurement range is necessary in low gravity due to the absence of gravitational settling, and it is expected that more than one instrument, or a multi-sensor unit, will be required to cover the desired range from nanometer (ultrafine) to 50 microns in diameter. A major portion of aerosols on the International Space Station (ISS) are from lint and fibers, so instruments must not rely on spherical morphology for accurate measurements. High accuracy should be quantitatively demonstrated for the range of interest. Development of an instrument that covers a sub-range, as broad as possible, that optimizes the performance within that range and that can subsequently be easily expanded, or integrated with other instrumentation, to cover the full range and requirements will also be of interest. Ideally, the instrument would be portable, with a graphical user interface for crew to read directly and also with the ability to log data and offer standard data transfer interfaces for longer-term indoor air quality surveys.

Microbial Monitor

NASA continues to invest in the near- and mid-term development of highly-desirable systems and technologies that provide innovative ways to monitor microbial burden and enable to meet required cleanliness level of the closed habitat. To date, every attempt to monitor microbial communities on-board the ISS has relied on traditional, culture-based approaches. Such techniques are laborious (7 days), require a considerable amount of crew time (up to 5 hrs), sample return, and ground based analysis (1 month after sample return), and are fraught with difficulty, as different microbial species require various media or cultural conditions to grow. In current microbial quality verification protocols, which use a single medium and a single culture condition, many types of cells will go undetected.

Molecular detection of biological agents offers increased sensitivity and specificity, such that lower levels of contaminating material can be detected and unambiguous identification can be achieved. NASA is interested in an integrated molecular system that could combine all required steps such as:Â

- Sample collection/concentration/extraction.
- Amplification/enrichment.
- Detection.

The scope this solicitation is the first item, i.e., sample collection, concentration, and extraction. However, integration of any two of the above mentioned steps as a single module with a capability to develop the interface of the third step can also be proposed. Technologies that determine microbial content of the air and water environment of the crew habitat falls within acceptable limits and life support system is functioning properly and efficiently are solicited. Required technology characteristics include:Â

- 2 year shelf-life.
- Functionality in microgravity and low pressure environment (~8 psi).

Technologies that show improvements in miniaturization, reliability, life-time, self-calibration, and reduction of expendables are also of interest. The proposed integrated molecular microbial monitoring/detection system should be capable of measuring total microbial burden as well as identifying â€œproblematicâ€ microbial species on-board ISS (ISS MORD: SSP 50260; http://emits.sso.esa.int/emits-doc/ESTEC/AO6216-SoW-RD9.pdf).

For the above, research should be conducted to demonstrate technical feasibility and prototype hardware development during Phase I and show a path toward Phase II hardware and software demonstration and delivering an engineering development unit for NASA testing.Â

H3.02 Bioregenerative Technologies for Life Support

Lead Center: KSC

Participating Center(s): ARC, JSC

Food Production Technologies for Space Exploration

NASA is interested in food production and related food safety technologies for ISS, transit missions, and eventual surface missions (fractional gravity). Of special interest is the use of photosynthetic organisms such as plants to produce food, and contribute to cabin O_2 production and CO_2 removal. Food production technologies should address how light use efficiency will be improved to reduce energy costs, including advanced electric and solar lighting concepts. Electric light sources should achieve at least 1.5 Âµmol photosynthetically active radiation per Joule of electrical energy, and solar collection systems should achieve at least a 40% delivery efficiency of solar light. Innovative concepts for gravity independent watering and nutrient delivery techniques are also needed. Technical approaches could include selecting or adapting the plants for optimal performance in smaller growing volumes common to space. All systems should consider minimizing power, mass, consumables, and biologically produced waste, while maximizing reliability and efficiency. Consumables and waste products that allow their residual water to be recovered or are easily refurbished are desirable. System TRLs should be 2-4 for Phase I. Phase II projects that evolve from the call are expected to deliver a working prototype to NASA.

Biological Systems for Wastewater Treatment

NASA is interested in efficient biological or biochemical approaches to assist in purifying and recycling wastewater in confined spaces such as crewed spacecraft or space habitats. Of special interest are biological approaches and bioreactors for removing carbon, nitrogen and phosphorus, and reduction of biosolids. Specific technologies or approaches are sought for:Â

- Development of long term stable inocula.
- Inoculation and start-up of bioreactors in flight, including remote operations.

Systems should consider operating with low power, low consumables, small volumes, high reliability and rapid deployment, as well as addressing multi-phase flow issues for reduced gravity. Consumables that allow their residual water to be recovered or be easily refurbished are desirable. Proposed systems shall be capable of treating combined waste waters from hygiene activities (containing surfactants/dander/body oil), human urine (with minimal flush water and a bio compatible preservative), and humidity condensate (containing VOCs). Proposed systems should also be capable of maintaining viability during long periods of quiescent operations (90-365 days) when no human generate waste water is available. Proposed systems should use fewer consumables than the current ISS physico-chemical system. System TRLs should be 2-4 for Phase I. Phase II projects that evolve from the call are expected to deliver a working prototype to NASA.Â

H3.03 Spacecraft Cabin Atmosphere Quality and Thermal Management

Lead Center: MSFC

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

Advances in spacecraft atmospheric quality management are sought to address cabin ventilation and flow delivery to air scrubbing equipment, suspended particulate matter removal and disposal, and volatile trace chemical contaminant removal. Methods to separate particulate matter from both the cabin atmosphere and from Environmental Control and Life Support (ECLS) system process gas streams are sought. Interest in humidity control and separation processes within life support system processes are of interest. Specifics regarding areas of interest in spacecraft atmospheric quality management are the following.

Multifunctional Filtration Techniques

Techniques and methods are sought leading to compact, low power, autonomous, regenerable bulk particulate matter separation and collection techniques suitable for general cabin air purification. The particulate matter removal techniques and methods must accommodate high volumetric flow rates up to 11.3 m^3/minute, yet possess pressure drop <125 Pa. Filtration performance equivalent to HEPA rating is desired. Configurations incorporating multi-stage filtration that separate and optimize regeneration and capturing efficiency functionalities may be considered. The particulate matter separation and collection technique must be suitable for seamless integration into a spacecraft cabin ventilation system from a volumetric perspective. The techniques and methods must safely store and enable easy disposal of collected particulate matter by the crew while minimizing exposure during the disposal operation.

Combination of the particulate matter separation and collection technique with techniques possessing high removal capacity for volatile chemical contaminants, with a focus on light polar organic compounds (e.g., ethanol and acetone) and linear and cyclic siloxanes, is of interest. The volatile chemical contaminant removal techniques must accommodate high volumetric flow rates up to 11.3 m^3/minute and possess pressure drop <125 Pa. The technique must provide for a minimum 1 year service life and a goal of 3 years.

ECLS System Process Gas Filtration Techniques

Techniques and methods leading to compact, regenerable methods for removing particulate matter generated in ECLS system process equipment such as carbon formation reactors and methane plasma pyrolysis reactors. Filtration performance approaching HEPA rating is desired for ultrafine particulate matter with minimal pressure drop. The gas filter should be capable of operating for hours at high particle loading rates and then employ techniques and methods to restore its capacity back to nearly 100% of its original clean state through in-place and autonomous regeneration or self-cleaning operation. Compact storage of the particulate matter after it is collected is as important as the effective collection. The device must minimize crew exposure to accumulated particulate matter and enable easy particulate matter disposal.

Process Gas Phase Moisture Removal and Collection

Innovative technologies are sought to dehumidify a hot, humid airstream and remove and collect the product as condensate for further processing. The airstream pressure is between 0.2 and 1.0 atmospheres, its temperature is 150Â°C and it is saturated with water vapor. The dewpoint of the airstream must be reduced to 10Â°C and the condensed liquid that results must be completely removed. Cooling at ambient temperature and electrical power and are available. Both the electric power and liquid carryover must be minimized.

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 of the limited spacecraft mass, volume and power resources. Advances are sought for microgravity thermal control in the following areas:Â

- 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. Room temperature thermal control systems are sought that are sized for full sun yet are able to maintain setpoint control and operate stably at 25% of their design heat load in a deep space (0 K) environment. 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.
- Non-toxic 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 moving on to a 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.Â