NASA SBIR 2011 Phase I Solicitation

X3 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 thermal control and ventilation, atmosphere resource management and particulate control, water recovery systems, solid waste management, habitation systems, food production, environmental monitoring and fire protection systems. 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. Technology solutions involving both physicochemical and biological approaches are sought. 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

X3.01 Enabling Technologies for Biological Life Support

Lead Center: KSC

Participating Center(s): ARC, JSC, MSFC

Biochemical Systems for CO_2 Removal and Processing to Useful Products

NASA is interested in biochemical or biological systems and supporting hardware suitable for purifying the atmosphere in confined spaces such as crewed spacecraft or space habitat cabins. Of special interest is the removal and fixation of CO_2 from a cabin atmosphere via biochemical pathways or autotrophic organisms (plants, algae, cyanobacteria, etc) to produce oxygen and other useful products, including food. Processes considering photosynthesis must address how quantum and/or radiation use efficiency will be improved. Systems should consider minimizing power, mass, consumables and biologically produced waste, while maximizing reliability and efficiency.

Biochemical Systems for Wastewater Treatment

NASA is interested in biological or biochemical approaches to assist in purifying and recycling wastewater in confined spaces such as crewed spacecraft or space habitat cabins. Of special interest are novel approaches for removing carbon, nitrogen and phosphorus to potable or near potable concentrations, and reduction of biosolids. Systems should consider operating with low power, low consumables, low volume, high reliability and rapid deployment, as well as addressing multi-phase flow issues for reduced gravity.

X3.02 Crew Accommodations and Waste Processing for Long Duration Missions

Lead Center: ARC

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

Critical gaps exist with respect to interfaces between human accommodations and life support systems for long duration human missions beyond low Earth orbit. New technologies are needed for management and processing of human fecal waste and for clothing and laundry. Proposals should explicitly describe the weight, power, volume, and microgravity performance advantages.

Human Fecal Waste Management

Microgravity technology is needed to collect, stabilize, safen, recover useful materials, and store human feces or its processed residuals. Simple low energy systems that recover water and sterilize/sanitize feces or mineralize it to minimal residuals (and perhaps gases or fuels) are desired. Complete systems are desired that include consideration of preprocessing, processing, and venting or containment for storage of the resultant residuals and/or recovered materials.

Clothing and Laundry Systems

The requirements for crew clothing are balanced between appearance, comfort, wear, flammability and toxicity. Ideally, crew clothing should have durable flame resistance in a 34% O_2 (by volume) enriched environment. Fabrics must enable multiple crew wear cycles before cleaning/disposal.

The laundry system should remove or stabilize the combined contamination from perspiration salts, organics, dander and dust, preserve flame resistance properties, and use cleaning agents compatible with water recovery technologies, including both physiochemical and biological processes. Proposals using water for cleaning should use significantly less than 10 kg of water per kg of clothing cleaned.

X3.03 Environmental Monitoring and Fire Protection for Spacecraft Autonomy

Lead Center: JPL

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

Environmental Monitoring

Monitoring technologies to ensure that the chemical and 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 sought. Required technology characteristics: 2-year shelf-life; functionality in microgravity, low pressure and elevated oxygen cabin environments. Significant improvements in miniaturization, operational reliability, life-time, self-calibration, and reduction of expendables should be demonstrated. Proposals should focus on one of the following areas:

- Process control monitors for life support. Improved reliability for closed-loop feedback control system.
- Trace toxic metals, trace organics in water.
- Monitoring trace contaminants in both air and water with one instrument.
- Microbial monitoring for water and surfaces using minimal consumables.
- Optimal system control methods. Operate the life support system with optimal efficiency and reliability, using a carefully chose suite of feedback and health monitors, and the associated control system.
- Sensor suites. Determine, with robust technical analysis, the optimal number and location of sensors for the information that is needed, and efficient extraction of data from the suite of sensors.

Fire Protection

Spacecraft fire protection technologies to detect the overheating or combustion of spacecraft materials by their particulate and/or gaseous signatures are also sought. These must be of suitable size, mass, and volume for a distributed sensor array. Technologies that detect smoke particulates and identify characteristics (mean particulate sizes or distribution) would also be useful. Catalytic or sorbent technologies suitable for the rapid removal of gases, especially CO, and particulate during a contingency response are desired.

X3.04 Spacecraft Cabin Ventilation and Thermal Control

Lead Center: JSC

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

Future spacecraft will require quieter fans, better cabin air filtration, and advanced active thermal control systems.

Small Fan Aero-Acoustics

Procedures and non-intrusive apparatus to measure the sound pressure levels in the inlet and exhaust duct of a candidate spacecraft ventilation fan are requested. Details of the aerodynamic design and the predicted aerodynamic performance of the candidate spacecraft cabin ventilation fan are reported in NASA CR-2010-216329, "Aerodynamic Design and Computational Analysis of a Spacecraft Cabin Ventilation Fan". The duct diameter for this fan (89 mm) falls below the minimum diameter required (150 mm) by ASHRAE Standard 68. The pressure rise at design point for this fan (925 Pa) exceeds the maximum recommended (750 Pa) in ISO 10302. The procedure that is requested to be developed should apply to fans of similar size and capacity (or greater) as the identified candidate spacecraft ventilation fan. The procedure developed should overcome the deficiencies in the standards by providing plots of overall sound power levels as a function of fan flow rate (from full flow to fully throttled conditions) along lines of constant fan rotational speed in the inlet and exhaust ducts. Values of the radial and circumferential duct mode sound power levels calculated from the pressure measurement should be recorded and made available for subsequent examination at all tested conditions. It also must be shown that the flow-induced microphone self-noise, if any, does not contribute significantly to the measured fan sound pressure levels or sound power levels. Validation of the measured fan sound power levels must be shown for a sub-set of the performance range using an alternate technique.

Methods of Particulate Separation and Filtration from Air

Methods of particulate air filtration and/or separation targeting a range of particle sizes from tens of micron down to submicron in conjunction with efficient methods of regeneration are sought. The proposed technical solutions should reduce crew maintenance time and eliminate the need for consumable filter elements. These units should be able to handle large surges of particles and operate over very long periods. They should also be self-cleaning in-place (preferable) or off-line. Targeted technologies should be compact and lightweight, easily integrated with the spacecraft life support system, and provide viable methods for disposing of collected particulate matter while minimizing or eliminating direct contact by the crew.

Active Thermal Control Systems

Thermal control systems will be required that can dissipate a wide range of heat loads with widely varying environments while using fewer of the limited spacecraft mass, volume and power resources. The thermal control system designs must accommodate high input heat fluxes at the heat acquisition source and harsh thermal environments at the heat rejection sink. Advances are sought for microgravity thermal control in the areas of:

- Innovative Thermal Components and System Architectures that are capable of operating over a wide range of heat loads in varying environments (for example, a 10:1 heat load range in environments ranging from 0 to 275K).
- Two-phase Heat Transfer Components and System Architectures for nuclear propulsion that will allow the acquisition, transport, and rejection of waste heat on the order of megawatts,.
- Heat rejection hardware for transient, cyclical applications using either phase change material heat exchangers or efficient evaporative heat sinks.
- Smaller, lighter high performance heat exchangers and coldplates.
- Low temperature external working fluids (a temperature limit of less than 150K with favorable thermophysical properties - e. g., viscosity and specific heat).
- Internal working fluids that are non-toxic, have favorable thermophysical properties, and are compatible with aluminum tubing (i.e., no corrosion for up to 10 years).
- Low mass, high conductance ratio thermal switches.
- Long-life, lightweight, efficient single-phase thermal control loop pumps capable of producing relatively high-pressure head (~4 atm).
- Dust tolerant long-life radiators.

- Variable area radiators (e. g., variable capacity heat pipe radiators or drainable radiators).
- Radiators compatible with inflatable volumes.
- Thermal systems and/or components to extend operational times for spacecraft under the extreme planetary environments, for example: the Venusian surface at approximately 460C and 98 atm.
- Flexible heat pipes.
- Methods to predict the performance of cryogenic multi-layer insulation blankets at 1 atmosphere and during ascent venting.
- Advanced thermal analysis tools that utilize stream processing to improve computational speed over conventional approaches. Possible candidates are: view factor calculation via ray tracing, orbital heating rate calculations, and thermal environment modeling.
- Inflatable/deployable shades to enhance reduce boiloff of cryogenic propellants in long-term storage in low earth orbit.