



NASA SBIR 2016 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 environmental monitoring, solid waste management, crew accommodations, and water recovery systems. Technologies must be directed at long duration human missions, in microgravity, including Earth orbit and planetary transit, and planetary surfaces, including Mars. 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.

NASA is investing in technologies and techniques geared towards advancing the state of the art of spacecraft systems through the utilization of the ISS as a technology test bed. For technologies that could benefit from demonstration on the ISS, proposals should be written to indicate the intent to utilize the ISS. 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 at the completion of the Phase II contract that could be turned into a proof-of-concept system which can be demonstrated in flight.

Subtopics

H3.01 Environmental Monitoring

Lead Center: JPL

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

Environmental Monitoring is comprised of the following four monitoring disciplines: Air, Water, Microbial and acoustics. ISS has employed a wide variety of analytical instruments to deal with critical items. These functional needs are required to address identified risks to crew health during Exploration-class missions. The current approach onboard ISS, if any, will serve as the logical starting point to meeting the functional needs. However, the following limitations were found common to all the current approaches on-board ISS for any missions beyond low-Earth orbit (LEO): reliance on return sample and ground analysis, require too much crew time, constraints on size, mass, and power, lack of portability, and insufficient calibration life.

Hence a concerted effort is underway to address these gaps, determine the most promising solutions, and mature those solutions to ground and flight technology demonstrations. Technologies that show improvements in miniaturization, reliability, life-time, self-calibration, and reduction of expendables are of interest.

Methods for collection and concentration for microbial surface monitoring

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, systematic microbial monitoring of ISS is carried out for water and not for environmental surfaces or air. The sample collection and subsequent processing for either culturing or molecular methods require sample concentration. Presently, swabs are used to collect 25 cm² area before processing and often times this outdated technique is fraught with decreased sensitivity in removing biological materials from the surface. NASA is interested in an integrated sample collection/concentration/extraction system that could feed samples to conventional or molecular microbial monitoring techniques. Furthermore, integration of these steps and a sample delivery to the molecular instruments (such as PCR) as a single module is solicited. Required technology characteristics include a 2 year shelf-life and functionality in microgravity and low pressure environment (~8 psi). The proposed integrated sample collection/concentration/extraction delivery system for molecular microbial monitoring detection should be capable of collecting and concentrating all kinds of microorganisms including "problematic" microbial species on-board ISS (ISS MORD: SSP 50260; (<http://emits.sso.esa.int/emits-doc/ESTEC/AO6216-SoW-RD9.pdf>)).

Ethylene analyzer

Ethylene gas is a natural metabolite in plants and acts as a plant hormone. In closed settings, such as plant (food) production chambers, ethylene can build up to deleterious levels for the plants. NASA needs innovative concepts for monitoring ethylene on a real time or near real time basis. Detection limits should ideally be near 25 ppb to insure effective management of plant growth systems, both for fundamental space research and for using plants in bioregenerative life support applications.

Calcium, conductivity and pH monitors for urine and wastewater

A rugged calcium sensor is needed to optimize the percentage of the recovery from brine. The calcium sensor would allow engineers to process a urine batch by knowing precisely the actual calcium concentration, enabling the urine processor to approach the solubility limit of calcium species. The calcium sensor would need to be able to measure calcium at levels of 50-400 mg/L in urine that has been pretreated to a pH of 0.5-3.0. The sensor should be rugged and not require frequent calibration or replacement and should be accurate to within 10%. Rugged conductivity and pH sensors that monitor the conductivity and pH in the brine loop would allow brine to be processed more thoroughly to recover more water. As the brine becomes more concentrated during urine processing, the measurement of conductivity and pH would allow the processor to recover water just to the point of solids precipitation. The conductivity sensor should be able to measure conductivity from 10-250 mS/cm in a urine brine that has a pH of 0.5-5.0. Likewise the pH sensor should be able to measure pH from 0.5-5.0 in a urine brine that has the conductivity of 10-250 mS/cm. The sensor should not require frequent calibration or replacement and be accurate to within 15%.

H3.02 Environmental Control and Life Support for Spacecraft and Habitats

Lead Center: ARC

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

Solutions and innovations are needed for technology that supports the mass- and energy-efficient maintenance of closed air, water, and waste systems in spacecraft habitats that operate on planetary surfaces such as Mars and that operate in the microgravity environment of space. Three specific focus areas have been identified:

New Applications of the Heat Melt Compactor for Contaminant Control and Waste Management

NASA is seeking new uses for the Heat Melt Compactor (HMC) to extend its capabilities as a multipurpose/multiuse platform with a focus on addressing the needs for Mars surface and planetary

protection. These may include:

- Membrane bags and/or liner inserts to initially contain unprocessed trash and other wastes within the compactor chamber but that will allow water and gas to pass through during processing. The bags/liners can melt at process temperatures $>120^{\circ}\text{C}$ but upon cooling must encapsulate the solid dry trash and waste for long-term stable storage. The encapsulation of the processed final product should prevent inoculation by external microorganisms.
- Methods and supporting hardware, including consumables such as membrane bags and/or liner inserts, for safe drying, sterilization and compaction of feces, which allow for water to pass through during processing.
- Methods and supporting hardware, including consumables such as membrane bags and/or liner inserts, for safely recovering water from urine and wastewater brines.
- Design and demonstration of a modular subsystem that uses the existing functional capabilities of the HMC as an autoclave.

New applications of the HMC are not to be limited to the above aforementioned areas, as new and innovative uses for the HMC are welcome. Other considerations are the benefits that can arise from recycling and reutilization of materials from the trash and waste, and the recovery of useful resources such as water and oxygen. The system must work in the Mars gravity environment with micro-gravity operation highly desirable.

A detailed description of the HMC can be found in technical paper number ICES-2014-24, entitled "Generation 2 Heat Melt Compactor Development," authored by Mark Turner, John Fisher and Greg Pace, 44th International Conference on Environmental Systems, 13-17 July 2014, Tucson, Arizona. The paper is available at the following link: (<http://repositories.tdl.org/ttu-ir/handle/2346/59662>). The HMC was primarily designed to compact and sterilize bulk trash and waste into a reduced volume, stable and sterile hard tile that is impregnated and encapsulated with plastics from the trash. The HMC consists of a nine inch wide cubic chamber (729 cu in) which can be heated to 180 C. Gas pressure in the chamber is controllable between 3 and 14 psia. A ram at one end of the chamber can create compression loads on materials within the chamber from 2000 to 4000 lb force. The downstream effluent processing system can collect approximately 200 ml of water per hour and oxidize noxious/toxic gases that evolve from processed materials.

Cleaning Agents and Physicochemical Treatments for Habitat Housekeeping and Laundering Clothes

Crew contact surfaces (hand rails, Velcro, acoustic blankets, racks) and food contact surfaces (utensils, table surfaces) are currently cleaned with pre-moistened wipes that are consumable intensive. A mechanism for the in-situ generation of cleaning/sanitizing solutions is needed that will enable these solutions to be applied to reusable fiber based wipes to remove particulate, food, and body oil soiling of surfaces. Solutions must be effective against a range of microbial organisms; their effectiveness against representative organisms must include, but is not limited to, food based bacteria, iodine resistant bacteria, and fecal coliform bacteria. Specific challenges include direct crew contact with cleaning/sanitizing solutions and direct off-gassing and accumulation of solutions in cabin atmosphere. Technologies that can reliably generate, provide short term storage, and dispense cleaning solutions are desired. Prepackaged cleaning solution wipe technologies are not requested.

There is currently no space based laundry technology. Traditional laundry surfactants combined with water and substantial agitation can return clothing to near original condition. However, used surfactants result in a substantial organic contaminant burden on downstream wastewater processors. Future space laundry or refreshing systems will not be required to fully restore clothing to its original condition but should enable clothing to be reused a number of times. Current clothing materials include cotton, poly blends, wool, modacrylic, elastic bands, metallic zippers, metallic snaps, Velcro®, Nomex®, Gore-Tex®, and will likely expand to include fabrics present in many current athletic garments. Generation of cleaning solutions or gases for refreshing/sanitizing clothing are needed that address particulate/dander, salts, body oils (such as squalene or other representative compound), and bacteria that cause odors (including *Staphylococcus epidermidis* and *Pseudomonas aeruginosa*). Specific challenges include capability to adequately disperse cleansing solutions through a wide range of fibers and materials, minimize mineral and organic load to wastewater processors, and minimal foam generation. Processes are desired that can recover unused cleaning solution or regenerate $>70\%$ of consumables. This request is not specifically for the laundry/sanitation device that interacts with the garments. The capabilities of the future laundry device would provide ability to agitate, partially remove liquids, and garment drying. Use of fabric brighteners, fragrances, pearlizers, and other aesthetic compounds are undesirable.

Surface treatments that limit biofilm and scaling within water processing system plumbing lines

NASA is seeking technologies or surface treatments that limit biofilm and scaling within water processing system plumbing lines. Both laboratory and flight systems have shown a strong tendency towards biofilm formation and occlusion in wastewater collection systems, particularly small diameter plumbing (3-13 mm internal diameter). Accumulation and sloughing of biofilm increases pressure drop, reduces flow rate, and can cause blockage or premature component change out within wastewater piping. Prevention technologies are sought that will limit microbial growth in piping and water recovery system components for up five years but short timeframes are also useful. Periodic inactivation or remediation technologies that use introduced compounds should be capable of being generated in-situ or recovered after use to minimize consumables. Specific challenges include high microbial and total organic carbon loads. Technologies should be effective for wastewater typical of the International Space Station (urine and humidity condensate) as well as exploration ersatz body hygiene wastewater (see "Advanced Life Support Baseline Values and Assumptions Document", NASA/CR-2004-208941, available at the following link: (<http://ston.jsc.nasa.gov/collections/TRS/techrep/CR-2004-208941.pdf>)). Proposed solutions should demonstrate compatibility with ISS type water processors, an ability to protect the wastewater system for a long quiescent period in a clean state, and the ability to withstand intermittent exposure to wastewater followed by additional quiescent periods.

Additional information on NASA needs can be found in draft 2015 NASA Technology Roadmaps including but not limited to sections TA06 6.1.4.1, TA06 6.1.3.3, TA06 6.1.4.6, TA06 6.1.4.8, and TA07 7.5.2.3. These roadmaps are available at the following link: (<http://www.nasa.gov/offices/oct/home/roadmaps/index.html>).