Environmental Control and Life Support (ECLS) encompasses the process technologies and equipment necessary to provide, monitor, and control a livable environment within a crewed spacecraft or surface habitat cabin. Functional areas of interest to this solicitation include atmospheric management; atmosphere revitalization and water recovery systems; waste management; habitation systems including crew accommodations; fire protection systems; and environmental monitoring. Technologies are needed for crewed space exploration missions supporting the Vision for Space Exploration with emphasis on missions to the lunar surface, including short duration lunar sortie missions and long duration lunar outpost. Vehicles of interest include the Lunar Surface Access Module (LSAM) and Lunar Outpost (LO). Special emphasis is placed on development of technologies that will fill existing gaps, have a significant impact on reduction of mass, power, volume and crew time, and increase safety and reliability.

Subtopics

X3.01 Spacecraft Cabin Atmospheric Management and Habitation Systems

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

Atmospheric management and habitation systems supporting critical needs for lunar mission architectures are requested. Vehicles and habitats are expected to be significantly restricted with respect to habitable volume and may operate at reduced atmospheric pressure with elevated oxygen concentrations. Improved non-regenerative and regenerative processes technologies for atmospheric quality control must be developed. The ability to economically supply atmospheric gases and refill storage tanks in flight will be needed. Isolating habitable volumes from surface dust and disposing of accumulated particulate matter will be challenges. Habitation systems must be innovative, extremely space efficient, and re-configurable (dual or multi-use).

Atmospheric Management

Atmospheric management encompasses the range of process technologies and equipment to remove impurities and condition crewed spacecraft and habitat cabin atmospheres, supply and store atmospheric gases, and achieve mass closure by recycling resources and using in situ resources. Process technologies typically involve separations and reactions. Separations-based processes include physical adsorption, absorption, and mechanical filtration processes. Reaction based processes include chemical adsorption, oxidation, and reduction. Techniques for enhancing NASA's present capabilities are sought. Areas of emphasis include:

- Atmospheric Purification and Conditioning: Process technologies for single and dual function atmospheric purification and conditioning based on novel embodiments of commercially available adsorbent,
chemisorbent, and catalyst media are required. Novel engineered media substrates to enhance durability, energy efficiency, and mass transfer leading to increased reliability, functional capacity, and smaller size relative to NASA's existing experience are sought. Specific challenges exist for efficiently removing ammonia, formaldehyde, and carbon monoxide from cabin atmospheric gases using process technologies that can be regenerated in place. Process technologies for removing and sequestering carbon dioxide from cabin atmospheric gases via means other than adsorption or chemisorption and conditioning carbon dioxide for use in reduction processes to facilitate cabin mass balance closure are also of interest.

- Supply and Store Atmospheric Gases: Novel means for supplying and storing oxygen and nitrogen under sub-critical conditions that lead to enhancements in energy efficiency, reduced mass and volume, and mission flexibility are sought.
- Recycle Resources and Use In Situ Resources: Novel means for supplying atmospheric gases using gas purification process waste products or means to more directly couple carbon dioxide and moisture removal to extract usable oxygen are sought.

Dust Control and Abatement
Dust and particulate matter contamination are challenges that must be overcome for lunar and Mars surface exploration. Particulate contamination originating from the external surface environment or from internal sources are both of concern. Development of regenerable process technologies and equipment to minimize the impacts of surface dust on crew health and life support equipment are sought. Novel approaches to isolate habitable volumes from surface dust and to remove dust from the spacecraft atmosphere, space suits and equipment are sought. Candidate technology solutions should provide high efficiency, long-lived removal capacity and be amenable to regeneration in place. Areas of emphasis include:

- Particulate Matter Removal and Disposal: Process technologies for removing and disposing of surface dust and particulate matter are sought. Salient features for this application include capability for regeneration in place, long-lived removal capacity and high efficiency.
- Isolation Technologies: Process technologies and design concepts to isolate habitable volumes from surface dust are sought. Such process technologies and design concepts may employ a variety of techniques to prevent surface dust from being transported through an airlock into the habitable part of the spacecraft or habitat cabin.

Habitation Systems
Habitation systems include crew accommodations, provisions, housekeeping and crew interfaces with vehicle systems including life support. Products can include applied research, system analysis, mockup evaluation, functionality demonstrations/tests, and actual prototype hardware. Proposals may address the following considerations and themes: re-configurable crew volumes and work stations for multi-gravity environments (micro and reduced gravity), multi-use work stations, multi-gravity translation strategies, physically and psychologically ergonomic personal volumes, automated deployment, quiescent operations between missions, multi-purpose stowage systems, advanced hygiene systems, automated housekeeping, and commonality of hardware/systems. Specific areas in which advanced habitability system innovations are solicited include:

- Crew Hygiene Systems: Low maintenance/self-cleaning fecal, urine, menstrual, emesis, hand/body wash, and grooming systems. Specific areas include non-foaming separators and no-rinse/non-alcohol hygiene products. Toilet systems should consider air, liquid, vacuum, and low-gravity transport methods. Collected waste should be prepared for recovery or long-term stabilization. Integrated hygiene systems should provide acoustic and odor isolated private crew volumes compatible with multi-gravity interfaces.
- Crew Accommodation Systems: Reconfigurable, deployable, erectable, or inflatable integrated crew accommodations that support crew wardroom, dining, conference, sleeping, relaxation activities and or stowage. May include visual and acoustical isolation, illumination, quiet ventilation/thermal control, audiovisual communication/entertainment, and off-nominal uses (emergency medical or repair) while maintaining hygienic conditions. Stowage systems may include interior/exterior stowage systems for partial gravity environments that maximize usable volume and include contents identification and inventory control systems.
- Clothing Systems: Low mass reusable or long usage clothing options that meet flammability, out gassing, and crew comfort requirements. Cleaning and drying systems for re-use of clothing that have low-water usage, non-toxic cleaning agents compatible with physicochemical or biological water reclamation systems, or that do not require water.
Advanced life support systems will be essential to enable human planetary exploration as outlined in the Vision for Space Exploration. These future systems must provide additional mass balance closure to further reduce logistics requirements and to promote self-sufficiency. Requirements include safe operability in micro- and partial-gravity as well as ambient and reduced-pressure environments, high reliability, regeneration, minimal use of expendables, ease of maintenance, and low system volume, mass and power. Proposals should explicitly describe how the work is expected to improve power, volume, mass, logistics, crew time, safety and/or reliability, giving comparisons to existing state-of-the art technologies. Although this solicitation is directed at technologies for lunar missions, crosscutting technologies that are also applicable to human missions to Mars or that are compatible with both partial and microgravity environments may be of interest. Technologies that perform several functions or that eliminate the need for intermediate processing steps are also of interest. Additional documentation and information can be found at http://advlifesupport.jsc.nasa.gov, including the expected composition of solid wastes and wastewater which can be found within the "Baseline Values and Assumptions Document".

**Water Reclamation**

Efficient, direct treatment of wastewater and product water consisting of urine, wash water, humidity condensate, and/or product water derived from in situ planetary resources to produce potable and hygiene water supplies. Treatment methods for long duration lunar surface missions should seek higher levels of mass closure. Treatment methods for short-to-moderate duration lunar missions (several weeks to several months) may have lower recovery rates.

- Stowable small-scale gravity-independent water treatment units for contingency or back up use for treatment of condensate, contaminated potable water or wastewater, which may incorporate flow-through units such as ion exchange, adsorption, multi-filtration and/or osmotic filtration;
- Disinfection and residual disinfectant technologies for potable water storage and point-of-use that are compatible with wastewater processing systems including biological treatment;
- Techniques to minimize or eliminate biofilms, microbial contamination and/or solids precipitation from potable water, wastewater and water treatment system components such as pipes, tanks, flow meters, check valves, regulators, etc.;
- Physicochemical methods for primary wastewater treatment to reduce total organic carbon from 1000 mg/L to less than 50 mg/L and/or total dissolved solids from 1000 mg/L to less than 100 mg/L; and
- Post-treatment methods to reduce total organic carbon from 100 mg/L to less than 0.25 mg/L in the presence of 50 mg/L bicarbonate ions, 25 mg/L ammonium ions and 25 ppm other inorganic ions.

**Solid Waste Management**

Wastes (trash, food packaging, feces, paper, tape, filters, water brines, clothing, hygiene wipes, etc.) must be managed to protect crew health, safety, and quality of life, to avoid harmful contamination of planetary surfaces, and to recover useful resources. Areas of emphasis include:

- Volume reduction of wet and dry solid wastes;
- Small and compact fecal collection and/or treatment systems;
- Water recovery from wet wastes (including human fecal wastes, food packaging, brines, etc.);
- Stabilization, sterilization, and/or microbial control technologies to minimize or eliminate biological hazards associated with waste;
- Mineralization of wastes (especially fecal) to ash and simple volatile compounds (e.g. carbon dioxide and water);
- Containment of solid waste onboard spacecraft that incorporates odor abatement technology;
• Partial-gravity containment devices or systems with low volume and mass that can maintain isolation of disposed waste on planetary surfaces; and
• Microgravity-compatible technologies for the containment and jettison of solid wastes in space.

Water Recovery from Byproducts of Water and Waste Processing - Brines and Slurries
Water recovery systems produce brines and slurries from water processing systems that use technologies such as reverse osmosis and distillation. Dissolved solids and organics can total about 3% to 20% by weight of the solution. Technologies for recovery of water from brines and slurries, which provide an increased level of mass closure of advanced life support systems, are of interest. The products of these systems may be dry solids and purified water low in total organic carbon.

X3.03 Crewed Spacecraft Environmental Monitoring and Control and Fire Protection Systems
Lead Center: JPL
Participating Center(s): GRC, JSC, KSC, MSFC

Environmental Monitoring and Control
Monitoring technologies are employed to assure that the chemical and microbial content of the air and water environment of the astronaut crew habitat falls within acceptable limits, and that the chemical or biological life support system is functioning properly. The sensors may also provide data to automated control systems.

Technologies should be appropriate for a small crewed mission to the Moon, of duration no more than a few weeks. Emphasis is on major constituents in the air and lunar dust. Extendibility to trace monitoring for longer missions is a plus. Significant improvements are sought in miniaturization, accuracy, precision, and operational reliability, as well as long life, real-time multiple measurement functions, in-line operation, self-calibration, reduction of expendables, low energy consumption, and minimal operator time/maintenance for monitoring and controlling the life-support processes. Proposals should be for either new technologies or combine existing technologies in a new way to simultaneously monitor several major constituents and dust, and/or trace constituents.

• Substances from an external environment such as lunar surface dust may be encountered during astronaut excursions and may be a mechanical or chemical threat both during the external encounter and if brought inside. Monitoring technologies are needed to assess and quantify these threats.
• For longer missions, water monitoring will be required. Needs will include sensitive, fast response, online analytical sensors to monitor suspended liquid droplets, dispersed gas bubbles, and water quality, particularly total organic carbon.
• Monitoring of other species of interest include dissolved gases and ions, and polar organic compounds such as methanol, ethanol, isopropanol, butanol, and acetone in water reclamation processes; and particulate matter, major constituents (such as oxygen, carbon dioxide, and water vapor) and trace gas contaminants (such as ammonia, formaldehyde, ethylene) in air revitalization processes. Both invasive and noninvasive techniques will be considered.
• Monitoring of microbial species, especially pathogens, primarily in water, will be important for longer missions. Enabling technologies may include proper sample preparation and handling, with minimal operator effort and minimal or no reagent usage.
• Crew members will employ software tools to help them interpret sensor data. Methods are sought which will assist the crew in using sensor data to detect and predict failures.

Results of a Phase 1 contract should show feasibility of the technology and approach. A resulting Phase 2 contract should produce at least a prototype demonstration and test of the environmental monitor.

Spacecraft Fire Protection Systems
The objective of fire protection strategies on exploration spacecraft is to quantitatively reduce the likelihood of a fire and reduce the impact to the mission should a fire occur. NASA's fire protection strategy includes: strict control of
ignition sources and flammable material, early detection and annunciation of fire signatures, and effective fire suppression and response procedures. While proposals describing innovations in all of these areas are applicable, they are particularly sought in the following areas:

- Advanced fire detection strategies are desired that respond uniquely to one or more fire or pre-fire characteristics such as thermal radiation, smoke, or gaseous product. These sensors should be appropriate for the unique fire behavior in low- and partial-gravity environments yet effectively discriminate between fire signatures and relevant spacecraft nuisance sources. Fire detection systems particularly attractive for long-duration exploration missions will have reduced mass, power, and volume requirements and exhibit high degrees of reliability, minimal maintenance, and self-calibration.
- Fire suppression technologies for exploration spacecraft and habitats must be applicable for use in a confined habitable volume having an atmosphere of up to 34% O₂ by volume and pressures as low as 7.6 psia. These systems would be effective in low- and partial-gravity environments and have minimal mass and volume requirements. Applicable technologies would be highly reliable with little or no maintenance, have multi-use capability and/or be replenishable during a mission, and be compatible with the spacecraft environmental control and life support system.

Results of a Phase 1 contract should show feasibility of the technology and approach. A plan for the demonstration of a prototype to be developed in Phase 2 should also be produced at the end of Phase 1. The Phase 2 contract should produce at least a prototype demonstration and test of the fire detection or suppression system.