NASA SBIR 2009 Phase I Solicitation

X2 Environmental Control and Life Support

Environmental Control and Life Support (ECLS) encompasses the process technologies and equipment necessary to provide and maintain a livable environment within the pressurized cabin of crewed spacecraft and to support associated human systems such as Extra Vehicular Activity (EVA). 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, environmental monitoring and fire protection systems. Technologies must be directed at Lunar transit and surface missions, including such vehicles as Lunar landers, surface habitats and pressurized rovers.

Requirements include operation in Lunar gravity and/or microgravity and compatibility with cabin atmospheres of up to 34% O_2 by volume and pressures ranging from 1 atmosphere to as low as 7.6 psia, or for EVA, as low as 3.2 psia and 100% O_2. Systems external to the spacecraft will be at vacuum. 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 dual application to Lunar and Mars missions. Results of a Phase 1 contract should show feasibility of the technology and approach. A resulting Phase 2 contract should lead to development, evaluation and delivery of prototype hardware. Specific technologies of interest to this Solicitation are addressed in each subtopic.

Additional information may be found at the following websites: http://els.jsc.nasa.gov and http://aemc.jpl.nasa.gov.

Subtopics

X2.01 Spacecraft Cabin Atmosphere Revitalization and Particulate Management

Lead Center: MSFC

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

Cabin Atmosphere Revitalization

Atmosphere revitalization developmental activities target process technologies and equipment to condition and supply gaseous oxygen at pressures at or above 3,600 psia and achieve mass closure by recycling resources. As well, portable means for atmosphere revitalization that have synergy with extravehicular activity (EVA) equipment pertaining to trace contaminant control, carbon dioxide removal, humidity control are target technology areas. Durable, dust-tolerant fluid connections support the EVA and life support system infrastructure. Details on areas of emphasis are the following:

High Pressure Oxygen Gas Supply and Conditioning: Process technologies leading to an on-demand, in-flight renewable 3,600-psia oxygen supply are of interest. Process technologies and techniques must be capable of conditioning oxygen for temperature, pressure, and water content using oxygen from several sources. Source oxygen may originate directly from the cabin atmosphere or from gaseous storage, cryogenic storage, and/or on-demand production from water electrolysis or in-situ resource utilization processes.

There is specific interest in process technologies to remove water from saturated oxygen to provide a product having a dewpoint below -62Â°C.

Atmospheric Resource Recycling Techniques: Process technologies suitable for conditioning and converting gaseous products produced by the Sabatier CO_2 reduction reaction to useful products are of interest. Of particular interest are process technologies to recover moisture from a saturated stream of methane that contains residual CO_2 and hydrogen reactants, to convert methane to products such as low molecular weight alcohols or other compounds suitable for use in power co-generation via fuel cells or other means, and to produce a solid carbon product via a regenerative process based on the Bosch reaction or a variant of the Bosch reaction.

Particulate Matter Management

Particulate matter suspended in the habitable cabin atmosphere is a challenge for all phases of crewed lunar surface exploration missions. Removing and disposing of particulate matter originating from sources internal to the habitable cabin and from lunar surface dust intrusion into the cabin environment is of interest. Staged techniques employing combinations of course media filtration (>50 micron size), inertial separation (2.5 micron size), and fine media filtration (

Atmosphere Revitalization for EVA

Synergy exists between cabin atmosphere revitalization and EVA suits. Common functions include trace contaminant control, CO_2 partial pressure control, and humidity control.

Trace Contaminant Control for EVA Suits: EVA suits designed for long durations with minimal maintenance will require new methods of trace contaminant control to maintain spacesuit environments below Spacecraft Maximum Allowable Concentrations for toxic or irritating chemicals. Historically this has used activated charcoal. In the case of ISS EVA, the charcoal is regenerable with heat. A need exists for a reduced power solution, such as vacuum regeneration of a sorbent, or another, innovative, low consumable solution. Consideration of on-back, real-time EVA regeneration as well as post EVA regeneration is acceptable.

Mars EVA CO_2 and Humidity Control: ISS EVA suits utilize heat regenerable CO_2 removal systems. These systems are heavy and require significant power for regeneration. Lunar EVA suits are planned to use a lightweight, vacuum regenerable amine system to remove CO_2 and humidity from the suit. It is envisioned this concept could be extensible to Mars suits with the addition of sweep gas to prevent intrusion of the Martian atmosphere. An innovative CO_2 and humidity removal system that could remove CO_2 and humidity while eliminating gas losses to the Martian atmosphere, remain lightweight, and utilize minimal power is desired. Consideration of on-back, real-time EVA regeneration as well as post EVA regeneration is acceptable.

Dust Tolerant Quick Disconnects for High and Low Pressure Fluids

Connections will need to be made between the EVA suits and lunar and Martian vehicles in environments where dust will be present. A lightweight QD that excludes dust during connections and disconnections is required.

X2.02 Spacecraft Habitation Systems, Water Recovery and Waste Management

Lead Center: ARC

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

Habitation, water recovery and waste management systems supporting critical needs for lunar mission architectures are requested. Improved technologies are needed for clothing/laundry, recovery of water, recovery of other resources, stabilization of wastes and safe long term storage of waste residuals. Proposals should explicitly describe the weight, power, and volume advantages of the proposed technology and be compatible with the lunar and microgravity environments described in the overall X2 topic description.

Clothing/Laundry Systems

Clothing and towels are a major consumable and trash source. Advanced durable fabrics to enable multiple crew wear cycles before cleaning/disposal are required. The laundry system should remove/stabilize combined perspiration salt/organic/dander and lunar dust contaminants, preserve flame resistance properties and use cleaning agents compatible with biological water recovery technologies. Proposals using water for cleaning should use significantly less than 10 kg of water per kg of clothing cleaned.

Waste Management

Wastes (trash, food scraps, feces, water brines, clothing) must be managed to protect crew health, safety and quality of life, to avoid harm of planetary surfaces, and to recover useful resources. Areas of emphasis include: stabilization (particularly water removal and recovery) and solid waste storage and odor control (e.g., catalytic and adsorptive systems). Preferred stabilization methods will dry solids to less than 60% water activity and sterilize and/or prevent microbial growth. Waste compactors must reduce trash to less than 10% of hand compacted volume after any spring-back. Odor control technologies should reduce gaseous contaminants in air to below NASA's Space Maximum Allowable Concentration levels and below the human odor threshold. Lunar-Martian storage containers are desired that are lightweight, low in resupply stowage volume, easily deployable and capable of containing space mission wastes and residuals on Lunar or Martian surfaces without rupture for 400 years.

Water Recovery

Efficient technologies are desired for treatment to potability of wastewater including urine, brines, humidity condensate, hygiene water, and in situ lunar water. Areas of emphasis include: primary treatment reducing 1000 mg/L TOC to less than 100mg/L, post-treatment reducing 100 mg/L TOC to

X2.03 Spacecraft Environmental Monitoring and Control

Lead Center: JPL

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

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 life support system is functioning properly. The sensors may also provide data to automated control systems. All proposed technologies should have a 2 year shelf-life, including any calibration materials (liquid or gas). The technologies will need to function in low pressure environments (~8 psi) and may see unpressurized storage. Significant improvements are sought in miniaturization, accuracy, precision, and operational reliability, as well as long life, in-line operation, self-calibration, reduction of expendables, low energy consumption, and minimal operator time/maintenance for monitoring and controlling the life-support processes.

- Microbial monitoring in water
    - 2 year shelf-life; this requirement precludes the usual antibody techniques which have lifetime limitations. Sufficient precision to resolve the following: 50 CFU/ml bacteria; coliform and fungi are required to be zero per 100 ml; zero counts of parasitic protozoa
- Microbial control of surfaces, typically done by chemically treated wipes or ultraviolet
    - Microbial Controls should be recyclable w/reduced consumables
- Improved Oxygen Monitor for breathing air
    - +/- 0.05%, must operate in variable pressure 8-14.7 psia and survive exposure to vacuum
- Broad spectrum Trace Contaminant Monitor, for air, with 2 year shelf life

X2.04 Spacecraft Fire Protection

Lead Center: GRC

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

NASA's fire protection strategy consists of strict control of ignition sources and flammable materials, early detection and annunciation of fires, and effective fire suppression and response procedures. Providing effective and efficient means for conducting and monitoring post-fire cleanup and restoration of the cabin atmosphere to a habitable environment are also major concerns. While proposals for novel technologies in all of these areas are applicable, they are particularly sought in the areas of nonflammable crew clothing and advanced carbon monoxide sensors for fire detection and monitoring the progress of post-fire cleanup.

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 through all end-use conditions including cleaning methods and frequency.

Fire detection strategies are being developed that combine advanced particulate detection technology with sensors that detect gaseous combustion products. Monitoring of carbon monoxide is being targeted both for fire detection and to monitor the progress of post-fire cleanup. A robust optical method is desired that has the dynamic range required to detect and monitor CO from approximately 1 to 500 ppm with resolution to 1 ppm CO. In addition to being sufficiently rugged, this sensor must have minimal mass, power, and volume requirements and exhibit high degrees of reliability, minimal maintenance, and self-calibration under varying humidity and ambient pressures.

X2.05 Spacecraft Thermal Control Systems

Lead Center: JSC

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

Future spacecraft will require more sophisticated thermal control systems that can dissipate or reject greater heat loads at higher input heat fluxes while using fewer of the limited spacecraft mass, volume and power resources. The thermal control system designs also must accommodate the harsh thermal environments associated with these missions. Modular, reconfigurable designs could limit the number of required spares.

The lunar environment presents several challenges to the design and operation of active thermal control systems. During the approximately 2 hour lunar orbit, the environment can range from extremely cold to near room temperature. Polar lunar bases will see unrelenting cold thermal environments, as will the radiators for Martian transit spacecraft. In both cases the effective sink temperature will approach absolute zero.

Innovative thermal management components and systems are needed to accomplish the rejection of waste heat during these future missions. Advances are sought in the general areas of radiators, thermal control loops, thermal system equipment, and EVA thermal control.

Systems with enhanced thermal mass may be required to deal with the lunar orbital environment. Variable emissivity coatings (near unity emissivity with the ability to reduce emissivity by at least a factor of ten), clever working fluid selection (a freezing point approaching 150K), or robust design could be used to prevent radiator damage from freezing in cold environments at times of low heat load.

Part of the thermal control system in a habitable volume is likely to be a condensing heat exchanger, which should be designed to preclude microbial growth. Small, highly reliable, heat pumps could be used to provide 278 K cold fluid to the heat exchanger, allowing the loop temperatures to approach 300 K, thus reducing the size of the radiators.

Future space systems may generate waste heat in excess of 10 kW which could either be rejected or redirected to areas which require it. Novel thermal bus systems which can collect, transport (over a distance of ~30 meters), and provide heat for components are sought. The system should be highly flexible and adaptable to changes in equipment locations. Possible systems include single and two-phase pumped fluid loops, capillary-based loops, and heat pumps. Innovative design of the loops and components is needed.

Historically spacesuits have used water sublimators to provide heat rejection. Development of a low-venting or non-venting regenerable individual life support subsystem(s) concept for crewmember cooling and heat rejection is desired. Systems that integrate spacesuit thermal control systems with other life support tasks, such as removal of expired water vapor and CO_2 are highly desirable. Interests include low cost lightweight spacesuit compatible freezable radiators for thermal control and variable conductance flexible EVA spacesuit garments that can function as a radiator or as an insulator as required. Sensible heat loads average 300 W and peak at 800 W. Spacesuit cooling garments have water flow rates of approximately 100 kg/hr.