NASA SBIR 2008 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 EVA (Extra Vehicular Activity). Functional areas of interest to this solicitation include thermal control and ventilation, atmosphere resource management and particulate control, waste management and 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 micro- and partial- (1/6th) gravity and compatibility with cabin atmospheres of up to 34% O_2 by volume and pressures as low as 7.6 psia. Special emphasis is placed on developing technologies that will fill existing gaps; have a significant impact on reduction of mass, power, volume and crew time; and increased safety and reliability. Results of a Phase 1 contract should show feasibility of the technology and approach. A resulting Phase 2 contract should lead to development and evaluation of prototype hardware. Specific technologies of interest to this specific solicitation are addressed in each subtopic.

Subtopics

X2.01 Spacecraft Cabin Ventilation and Thermal Control

Lead Center: JSC

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

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Advanced technologies are sought for cabin ventilation and thermal management for next generation human spacecraft including lunar lander, lunar habitat, and pressurized rovers.

Spacecraft Ventilation

Controlling acoustic noise levels within spaceflight vehicles is needed to provide for adequate voice and ground communications, habitability, and alarm audibility. This will become very important with longer duration missions such as Lunar Habitat and Mars missions. Past experience has shown that controlling acoustic noise levels inside the spacecraft depend upon development of quiet ventilation system and environmental control system fans and pumps, as well as inclusion of effective noise controls to reduce the noise that is created (i.e., source and path technologies).

Advances are sought in the general areas of source noise-level reduction, vibration isolation, acoustic absorption, and sound blocking and sealing (i.e., source and packaging). Noise reduction technology should achieve significant noise reductions (> 5dB) with minimal impacts to performance characteristics (pressure rise and flow rate). Noise reductions and performance capabilities should be demonstrated. Materials should meet flight requirements for flammability, frangibility, and off-gassing. Ventilation fans and fluid pumps are the major source of interior spacecraft noise. Fan and pump technologies that prevent the generation of acoustic noise or limit its transmission to mounting structure or surrounding air are desired. Technologies achieving 5 dB or greater attenuation and accommodating variable equipment speeds, variable acoustic spectrums, and atmospheric pressures from 8 to 15 psia are required.

Thermal Control Systems

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 designs also must accommodate the harsh environments associated with these missions including dust and high sink temperatures. 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 Apollo program, landings were located and timed to occur early in the lunar day, resulting in a benign thermal environment. The long duration polar lunar bases that are foreseen in 15 years will see extremely cold thermal environments, as will the radiators for Martian transit spacecraft. Long sojourns remote from low-Earth orbit will require lightweight, but robust and reliable systems.

Innovative thermal management components and systems are needed to accomplish the rejection of heat from lunar bases. Advances are sought in the general areas of radiators, thermal control loops and equipment. Variable emissivity coatings, clever working fluid selection, or robust design could be used to prevent radiator damage from freezing at times of low heat load. Also, the dusty environment of an active lunar base may require dust mitigation and removal techniques to maintain radiator performance over the long term.

The lunar base may include high efficiency, long life mechanical pumps. Part of the thermal control system in the lunar base is likely to be a condensing heat exchanger, which should be designed to preclude microbial growth. Small heat pumps could be used to provide cold fluid to the heat exchanger, increasing the average heat rejection temperature and reducing the size of the radiators.

Thermal management of the lunar habitat, landers, and rovers may require mechanically pumped two-phase fluid loops. Innovative design of the loops and components is needed.

Future space systems may generate large amounts of waste heat which could either be rejected or redirected to areas which require it. Novel thermal bus systems which can obtain, transport, and reject heat between various components are sought. The system should be highly configurable and adaptable to changes in equipment locations. Large diurnal temperature changes in the environment are expected. Possible systems include single and two-phase pumped fluid loops, capillary-based loops, and heat pumps.

A scaling methodology is needed to allow long term 1-g testing of two-phase systems (including pumped two-phase loops, heat pumps, and condensing heat exchangers) representative of the $1/6^{th}$ Earth-normal gravity of the Moon.

X2.02 Spacecraft Cabin Atmospheric Resource Management and Particulate Matter Removal

Lead Center: MSFC

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

Particulate Matter Removal and Disposal

Particulate matter suspended in the habitable cabin atmosphere is a challenge for all phases of exploration missions. Removing and disposing of particulate matter originating from sources internal to the habitable cabin and from surface dust intrusion is of interest. Process technologies and equipment that efficiently remove the range of particulate matter sizes and morphologies encountered in a crewed spacecraft cabin from the atmosphere and surfaces are sought. Candidate technology solutions should provide high efficiency and long-lived removal capacity. Successful process technologies must be tolerant of the abrasive properties of lunar surface dust. Performance should be demonstrated with appropriate lunar dust analogs or simulants. Process technologies sought must be highly efficient and promote safe disposal of accumulated particulate matter. Areas of emphasis include:

- Removal and Disposal of Fine Particulate Matter Suspended in a Cabin Atmosphere: It is hypothesized that fine particulate matter introduced into the cabin will be detrimental to crew health. Filtration technologies are sought that will limit the levels of lunar dust contaminants of less than 10 micron size in the cabin atmosphere below 0.05 mg/m^3 while providing significantly improved capture efficiency with minimal pressure drop. These may include but are not limited to mechanical filtration, inertial separation and impingement, and electrostatic and/or electrically enhanced separation solid-gas processes that are light-weight, low power and operate at reduced atmospheric pressures. Process technologies that offer both improved efficiency and are suitable for in situ regeneration as described below are preferred. Novel techniques and materials are of interest.

- Regenerative Processes and Filters: Regenerable solid-gas separations techniques and process technologies are sought that effectively handle a broad size range from >100 microns in aerodynamic diameter to
- Vacuum Cleaner for Planetary Surface Vehicles and Habitats: Portable crew-operated devices for removing particulate matter from a wide range of surfaces (polymer, metallic, and fabric), operating at cabin atmospheric pressures ranging from 8 to 15 psia, and minimizing electrical power and acoustic noise generation are of interest. Successful devices may employ several of the above mentioned processes or filtration systems to remove a wide range of particulate matter sizes up to 2 mm in aerodynamic diameter without contaminating the air with ultrafine particulates. The ability for the portable device to be operated as a supplemental, portable cabin air filtration unit is a plus.

Atmospheric Resource Management

Atmospheric resource management encompasses process technologies and equipment to supply, store, and condition atmospheric gases; provide gaseous oxygen at pressures at or above 3,600 psia; and achieve mass closure by recycling resources and using in situ resources. Areas of emphasis include:

- Carbon Dioxide Reduction for Recovery of Oxygen: Process technologies for reducing carbon dioxide to a carbon product via high single-pass reaction efficiency with a product yield >90% are of interest. Successful process technologies and/or process technology unit operations combinations must demonstrate efficient power use and address safety issues associated with traditional reduction processes.

- High Pressure Oxygen Gas Supply: Process technologies leading to an on-demand, in-flight renewable source of oxygen at or above 3,600-psia are of interest. Process technologies employed for achieving these needs may include mechanical compressors, temperature or pressure-swing adsorption compressors, high pressure electrolytic oxygen production or other novel means.

X2.03 Spacecraft Habitation and Waste Management Systems

Lead Center: ARC

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

Waste management and habitation systems supporting critical needs for lunar mission architectures are requested. Improved technologies for recovery of water and other resources as well as safe long term stabilization and storage of residuals inside and outside the habitat are needed. Waste processes collect, process, recover resources, stabilize, and store residuals. Proposals should explicitly describe the weight, power, and volume advantages of the proposed technology.

Clothing/Laundry Systems

Clothing is a major consumable and trash source. Low mass reusable or long usage clothing options that meet flammability, out gassing, and crew comfort requirements are desired. Techniques, equipment, and clothing material that extend clothing life, facilitate clothing washing/drying, low consumable mass/volumes, low acoustic generation, and low water usage are desirable. Technologies must minimize crew time, be compatible with lunar gravity, atmospheric pressures from 8 to 15 psia, minimize electrical power, minimize acoustic noise generation, be flame resistant in 32% oxygen environments, have low outgassing, and have non-toxic cleaning agents waste products compatible with biological water processing and atmospheric trace contaminant control.

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:

- Solid waste stabilization including water removal and recovery of water from wet wastes (including human fecal wastes, food packaging, brines, etc.);
- Solid waste storage and odor control (e.g., catalytic and adsorptive systems);
- Energy efficient/internal heat recycling waste pyrolysis systems for mineralization of wastes and recovery of resources.

X2.04 Spacecraft Environmental Monitoring and Control

Lead Center: JPL

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

X2.05 Spacecraft Fire Protection

Lead Center: GRC

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

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 in all of these areas are applicable, they are particularly sought in the areas of nonflammable crew clothing and fire suppression technology.

The requirements for crew clothing are balanced between comfort, durability, and flammability. Non-flammable alternatives are requested for shirts, shorts, sweaters, jackets, etc. and, ideally, would be available in a variety of colors and weights. For exploration missions, clothing should be nonflammable up to 34% O_2 by volume without being stiff and uncomfortable. The flammability characteristics of the clothing must be maintained through the recommended cleaning process.

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% O_2 by volume and pressures as low as 7.6 psia;
- Be suitable for use in a portable fire extinguisher against fires behind panels and close-outs or the cabin open volume;
- Have minimal mass and volume requirements including consumables required for post-fire clean-up; 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 suppression system.