NASA SBIR 2007 Phase I Solicitation

X6  Structures, Materials and Mechanisms

The SBIR topic area of Structures, Materials and Mechanisms centers on (1) developing lightweight structures and advanced materials technologies to support Lunar Landers and Lunar Habitats and (2) low-temperature mechanisms to improve and/or allow for reliable and efficient mechanism operation for long duration in the cold polar and crater regions of the lunar surface. Lightweight structures and advanced materials have been identified as a critical need since the reduction of structural mass translates directly to additional up and down mass capability that would facilitate additional logistics capacity and increased science return for all mission phases. The structures and materials program utilizes and combines multi-center R&D teams into focused activities for developing lightweight structure technology for the primary load bearing structure of the pressurized elements of the Vision for Space Exploration (VSE) program. The major technology drivers of the lightweight structure technology development are to significantly enhance structural systems for man-rated pressurized structures by (1) lowering mass and/or improving efficient volume for reduced launch costs, (2) improving performance to reduce risk and extend life, and (3) improving manufacturing and processing to reduce costs. This topic area is responsible for mid-level technology research, development, and testing through experimental and/or analytical validation. Three subtopics represent the structures and materials area: (1) Lightweight Structures; (2) Low Temperature Mechanisms; and (3) Advanced Radiation Shielding Materials. In missions to the lunar surface, permanently shadowed regions of the Moon, e.g., the bottoms of craters in the Polar Regions, are high interest to science and exploration. These areas appear to remain at temperatures of 50 to 80K (-223°C to -193°C). Current surface exploration hardware has demonstrated capability to operate in the range of -115°C to 0°C on Mars. However, the technical challenges of developing and demonstrating hardware that can operate over 100°C colder than current capabilities are significant. The major technology drivers of the low temperature mechanism technology development are to significantly enhance operation of mechanized parts by (1) lowering the operating temperature for the life of the component and (2) improving mechanism performance (torque output, actuation performance, lubrication state) at the lunar environment conditions of cold and vacuum. The targeted application of the technology is to provide for operation of motors and drive systems, lubricated mechanisms, and actuators of lunar rovers and mobility systems, ISRU machinery, robotic systems mechanisms, and surface operations machinery (i.e., cranes, deployment systems, airlocks), for lunar surface operations. This topic area is responsible for mid-level technology research, development, and testing through experimental and/or analytical validation. There is one subtopic in this area, Low Temperature Mechanisms.

Subtopics

X6.01 Lightweight Structures

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

This subtopic solicits innovative structural concepts that support the development of lightweight structures technologies that could be applicable to lunar surface landers and habitats. The targeted innovative lightweight structures are for primary pressurized structures such as crewed vehicles (landers and habitats). Innovations in technology are needed to minimize launch mass and costs, and increase operational volume for minimal launch volumes while at the same time maintain required structural performance for loads and environments. Of particular interest are the following structural concepts:

- Lightweight multifunctional and/or integrated structural systems that include radiation shielding, impact shielding, thermal management, damage tolerance and durability, and/or integral diagnostics/health monitoring, and novel inspection/nondestructive evaluation capabilities are of interest if they can be developed to improve the efficiency (mass/performance) of the structural system over the parasitic systems used today.

- Inflatable structures are considered as viable technique to improve volume for crew in habitats and potentially other crewed vessels. However, areas of risk need to be mitigated to build confidence in the use of these structures. In particular, durability in the presence of micrometeoroid impact crew load induced damage, radiation-shielding protection, equipment placement and tie down concepts, and efficient packaging concepts are of interest.

Development of concepts can include structural components, improved low cost manufacturing processes, methods of validation, and/or predictive analysis capabilities. Technological improvements that focus on risk reduction/mitigation, and development of reliable yet robust designs are also being sought under this announcement. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

X6.02 Low Temperature Mechanisms

Lead Center: GSFC
Participating Center(s): GRC, JSC, LaRC, MSFC

This subtopic focuses on the development of selected hardware and support technologies for motors, drive systems and related mechanisms that will operate in cryogenic temperature environments such as permanently shaded craters on the Moon, and/or on the lunar surface exposed to the day/night cycle. In the former situation such mechanisms may be exposed to, and will need to operate in, sink temperatures as low as approximately 25K. In the latter situation they will need to operate over a temperature sink range of approximately 83K to 380K (-190°C to +107°C). The component technologies developed in this effort will be utilized for rovers, operational equipment, instruments, drills, crushers, and other such facilities. The nearer term focus for this effort is for lunar missions, but these technologies should ideally be translatable to applications on Mars. These components must operate in a hard vacuum and/or planetary environment, with partial gravity, and full solar radiation exposure. Additional requirements include high reliability, ease of maintenance, low-system volume, low mass, and minimal power requirements. Low out-gassing is desirable, as are modular design characteristics, fail-safe operation, and reliability for handling fluids, slurries, biomass, particulates, and solids. While dust mitigation is not specifically included in this subtopic, proposed concepts should be cognizant of the need for such technologies.
Specific areas of interest include gear boxes, suspension systems, material components (i.e., wiring, harnesses, insulating materials, and jackets/covers) that are flexible in cryogenic environments; advanced lubricants and lubrication technology; and an accelerated means of life testing for cold temperatures.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

X6.03 Advanced Radiation Shielding Materials

Lead Center: LaRC
Participating Center(s): ARC, MSFC

Revolutionary advances in radiation shielding materials and structures technologies are needed to protect humans from the hazards of space radiation during NASA missions. All particulate radiation species are considered, including electrons, protons, neutrons, alpha particles, light ions, heavy ions, etc. All space radiation environments in which humans may travel in the near future are considered, including low-Earth orbit, geosynchronous orbit, Moon, etc. The primary area of interest for this 2007 solicitation is radiation shielding materials systems for long duration lunar surface protection for humans. Lightweight radiation shielding materials systems for short-term in-space operations for humans are also of interest. The materials emphasis is on multifunctional materials, where two of the functions are, but not exclusively, radiation shielding efficiency and structural integrity. Radiation shielding design software to optimize multifunctional materials usage in specific designs is also of interest. Radiation shielding augmentation materials are part of this solicitation, along with associated software tools to minimize augmentation requirements. Research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path toward a Phase 2 technology demonstration. Specific areas in which SBIR-developed technologies can contribute to NASA's overall mission requirements for advanced radiation shielding materials and structures include, but are not limited to, the following:

- Innovative lightweight radiation shielding materials and structures to shield humans in crew exploration vehicles, large space structures such as space stations, orbiters, landers, rovers, rigid habitats, inflatable habitats, spacesuits, etc.;
- Radiation laboratory and spaceflight data to validate the shielding effectiveness of radiation shielding materials and structures;
- Physical, mechanical, structural, and other relevant characterization data to validate and qualify multifunctional radiation shielding materials and structures;
- Comprehensive radiation shielding databases to enable designers to incorporate and optimize radiation shielding structural materials into space systems during all phases of the design process;
- Radiation shielding software, compatible with Multi-Disciplinary Optimization (MDO) analysis, for optimization of specific vehicle designs;
• Innovative processing methods to produce quality-controlled advanced radiation shielding materials of all forms - resins, fibers, fabrics, foams, microcomposites and nanocomposites, fiber-reinforced composites, light alloys, and hybrid materials;

• Innovative fabrication techniques to fabricate advanced radiation shielding materials into useful products and structural components;

• Innovative manufacturing techniques to produce quality-controlled advanced radiation shielding products and structural components, including innovative scale-up methods for producing quality-controlled viable quantities of advanced radiation shielding materials and structures;

• Innovative commercialization strategies to introduce advanced radiation shielding materials and structures into the marketplace to enable availability of the technologies for use by NASA and the space exploration community;

• Innovative concepts to reuse, recycle, and reprocess materials and structures in space for use as radiation shielding materials and structures.

X6.04 Advanced Composite Materials

Lead Center: MSFC

Participating Center(s): GRC, LaRC

This subtopic solicits innovative research for advanced composite materials, processing and characterization concepts that support the development of lightweight structures technologies that should be applicable for space transportation vehicle systems, propulsion systems, and planetary access and operations. Reduction in structural mass translates directly to additional up-and-down mass capability that would facilitate logistics and increase science return for future missions. Advanced composites are targeted that could be implemented into vehicle and propulsion systems for launch vehicles, lunar landers, and habitats. Innovations in technology are needed to increase specific strength and stiffness, provide radiation shielding, enhance thermal management, reduce Micrometeoroid/Orbital Debris (MMOD) damage potential, and provide effective nondestructive verification and characterization, while maintaining safety, reliability, and reducing costs.

Advanced composite material systems and their corresponding manufacturing, processing and verification techniques are desired. Examples would include, but are not limited to, material systems and mature applications of nano-structured materials. Processing examples would include, but are not limited to, automated composite fiber/tape placement, non-autoclave curing, processing innovations for multifunctionality, ceramic processing, nano materials processing, freeform fabrication, and bonding of composites.

Development of concepts can include material system characterization, proof-of-concept demonstrations for integrated lightweight structures, innovative multifunctional concepts, enabling performance and affordability (including life cycle costs) enhancement, damage tolerance/control techniques, methods of validation, and/or predictive analysis methods that improve understanding of the technology to reduce risk and need for conservatism in design and demonstration of integrated system performance. Preferred processing and verification techniques would include non-contact, high-resolution nondestructive evaluation 2D and 3D imaging and characterization approaches using electromagnetic techniques such as Terahertz and millimeter waves with resolutions of 1-5 mm. Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a
Phase 2 prototype demonstration.