The SBIR topic area of Lightweight Spacecraft Materials and Structures centers on developing lightweight expandable structures, advanced manufacturing technologies for metallic and composite materials, structural sensing techniques, in-situ non-destructive evaluation systems, and low-temperature mechanisms. Applications are expected to include space exploration vehicles including launch vehicles, crewed vehicles, and surface and habitat systems.

The area of expandable structures solicits innovative concepts to support the development of lightweight-structure technologies that would be viable solutions to high packaging efficiency and increasing the usable primary pressurized volume in habitats, airlocks, and other crewed vessels. Technologies are needed to minimize launch mass, size and costs, while maintaining the required structural performance for loads and environments.

Advanced fabrication and manufacturing of lightweight structures focuses on the development of metallic alloys and hybrid materials, processing and fabrication technologies related to near-net shape forming. The goal is to reduce structural weight, assembly steps, and minimize welds, resulting in increased reliability and reduced cost. Research should evaluate material compatibility with forming methods and establish fundamental microstructure/processing/property correlations to guide full-scale fabrication. Laboratory scale test methods are needed to accurately simulate the deformation modes experienced in large-scale manufacturing.

Polymer matrix composite (PMC) materials have been identified as a critical need for launch and in-space vehicles. The reduction of structural mass translates directly to additional performance, increased payload mass and reduced cost. PMC materials are also critical for other structures, such as cryogenic propellant tanks. Advances in PMC materials, automated manufacturing processes, non-autoclave curing methods, advances in damage-tolerant/repairable structures, and PMC materials with high resistance to microcracking at cryogenic temperatures are sought. The objective is to advance technology readiness levels of PMC materials and manufacturing for launch vehicle and in-space applications resulting in structures having affordable, reliable, and predictable performance.

Practical modular structural sensor systems and NDE technologies are sought for spaceflight missions. Smart, lightweight, low-volume, and stand-alone sensor systems should reduce the complexities of standard wires and connectors and enable sensing in locations not normally accessible. NDE sensor system technology should include
modular, low-volume systems and have the ability to perform inspections with minimal human interaction. Systems need to provide the location and extent of damage with the minimal data transfer between the flight system and Earth. Mission application areas include space transportation vehicles, pressure vessels, ISS modules, inflatable structures, EVA suits, MMOD shields, and thermal protection structures.

Low-temperature mechanism technology is being developed for reliable and efficient operation of mechanisms in low temperature environments at -230°C and sustained performance thru temperature cycles of -230°C to +120°C. The goal is to enhance operation of mechanized parts by lowering the operating temperature of the component, and by improving performance at cold conditions under vacuum over the life of the mechanism. The targeted application of the technology is to provide for operation of motors and drive systems, lubricated mechanisms, and actuators of rovers, mobility systems, and robotic mechanisms.

Research under this topic should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a full-scale demonstration unit for functional and environmental testing at the completion of the Phase II contract.

Subtopics

X5.01 Expandable Structures

Lead Center: LaRC

The Expandable Structures subtopic solicits innovative structural concepts that support the development of lightweight structures technologies for expandable exploration space modules and surface based habitats. The targeted structural concepts are desired for utilization in primary pressurized volumes and in secondary structures internal to the deployed primary volume. Innovations in expandable structures technology is desired to minimize launch mass, volume, and costs, while maximizing operational volume and structural performance of a crewed or material transfer pressure vessel.

Inflatable structures is a research area within expandable structures, which offers a viable solution for increasing the volume of habitats, airlocks, and other crewed vessels. Inflatable structure concerns, due to the low level of maturity include: consistent and reproducible mechanical behavior, durability in the presence of micrometeoroid impact, incorporation of material for radiation shielding, crew-induced damage, and repair techniques for long term survivability. Other areas of concern include, pre-integration solutions, storage of a pressurized volume within an expandable structure, and deployment techniques. Solicitations which address topics in these areas would be welcomed.

One remaining area of interest is the development of innovative deployable secondary structures that have minimal mass, high packaging efficiency, and multi-functional utilization. One simple example of a secondary structure could be a walkway internal to a lunar surface habitat, which could be reconfigured as a storage container or a radiation shield during a major solar flare event. These secondary multi-functional structures should provide highly robust, stiff and mass efficient surfaces that enable the useful outfitting and pre-integration of subsystems within the primary structural volume.

In general, development of structural concepts can include structural components, methods of validation, and/or predictive analysis capabilities. Analytical and numerical methods to analyze the behavior of soft-goods from a
global scale, down to the fabric and strap level are desired. Methods and designs for integrating instrumentation into soft-goods, including the ability to detect damage, creep (strains), loads in the primary restraint layers, and temperatures are also desired. Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

X5.02 Advanced Fabrication and Manufacturing of Metallic and Hybrid Materials for Lightweight Structures
Lead Center: LaRC
Participating Center(s): MSFC

X5.03 Manufacturing of Polymer Matrix Composite (PMC) Structures
Lead Center: MSFC
Participating Center(s): ARC, GRC, KSC, LaRC

X5.04 Spaceflight Structural Sensor Systems and NDE
Lead Center: LaRC
Participating Center(s): ARC, JSC, MSFC

Spaceflight Structural Sensor Systems
Technologies sought include: modular/low mass-volume systems, stand-alone smart sensor systems that provide answers as close to the sensor as practical, Surface Acoustic Wave (SAW)-based sensors, passive wireless sensor-tags, flexible sensors for highly curved surfaces and direct-write film sensors. These systems allow for additions or changes in instrumentation late in the design/development process and enable relocation or upgrade on orbit. They reduce the complexities of standard wires and connectors and enable sensing functions in locations not normally accessible with previous technologies. They allow NASA to gain insight into performance and safety of NASA vehicles as well as commercial launchers, vehicles and payloads supporting NASA missions.

Mission Application Areas (Interior or Exterior):

(1) Add-on in-space modular sensors for:

- Commercial human-rated transportation systems
- Composite Overwrapped Pressure Vessels (COPVs) and other pressure-vessels
- International Space Station (ISS) habitable modules and exterior structure
- Inflatable habitat modules

(2) Built-in flight monitoring systems for:

- New COPV and other pressure vessels
- New manned and unmanned spacecraft
- New propulsion system tankage and transfer systems
- New heavy-lift vehicles: fairings, transition sections, engines, Thermal Protection Systems (TPS), tanks
- New transformational habitats and structures like inflatables

(3) Mobile sensor interrogation systems - robotic, wireless network or interrogation which can:

- Program and download data from smart systems without wires
- Acquire active/passive sensor-tag data
- Determine real-time position/orientation for other sensors or tools

Performance Goals/Metrics:

Ability to establish new functionality in one of the 3 areas above, and:

- Increase number of sensor locations per pound of monitoring weight by 50%
- Decrease the system monitoring electronics weight by 50%
- Decrease total wiring required for monitoring by 50%
- Decrease the time to plan and install monitoring by 50%
- Decrease the overall life-cycle cost per sensor by 50%
- Decrease total data rate required from sensor data acquisition location by 50%
• Decrease the expected cost of instrumentation changes/upgrades by 50%

NDE Systems for use during Spaceflight

Technologies sought include: modular/low mass/volume smart NDE sensors systems and associated software that enable effective use with minimum crew training or re-familiarization after extended periods of no use. Systems should include ability to perform inspections with minimal human interaction. These systems need to provide reliable assessments of the location and extent of damage with the minimal data transfer between vehicle and Earth. Methods are desired to perform inspections in areas with difficult access in pressurized habitable compartments and external environments. Many applications require the ability to see through conductive and/or thermal insulating materials without contacting the surface. Sensors that can dynamically and accurately determine position and orientation of the NDE sensor are needed to automatically register NDE results to precise locations on the structure. Structural design and material configurations are sought that can enhance NDE and monitoring. Advanced processing and displays are needed to reduce the complexity of operations for astronaut crews who may only use the NDE tool infrequently, but need to make important assessments quickly. Micro-miniature, low power NDE inspection sensors are needed for potential use on free-flying inspection platforms. Integration of wireless systems with NDE may be of significant utility.

Mission Application Areas:

Enabling NDE (Interior and Exterior):

(1) On-orbit NDE sensor systems (e.g. Visual, Laser, Micro-wave, Terrahertz, Infra-red, X-ray backscatter, eddy current or other) that have high resolution and small form-factor to inspect:

• Thermal protection - Multi-Layer Insulation (MLI) and TPS) structures
• Inflatable habitats, Extra-Vehicular Activity (EVA) suits and visiting vehicles
• Electronic systems, environmental control systems, and other vehicle systems
• Conductive structures, Micro-Meteoroid and Orbital Debris (MMOD) shields, primary structure, pressure vessels
• Structures (COPV, module walls) under MLI/MMOD shielding
• Be deployed/used without the need for robotic manipulators or EVA crew

(2) On-orbit NDE sensor systems that can be used:

• In difficult access areas: flexible borescopes, micro-robots, smart sensors
• To identify, locate and quantify potential damage areas: MMOD damage, module and pressure vessel
leaks, corrosion, etc.

- On robotically operated platforms: free-flyers, micro-robots, dexterous robots, or remote manipulators

Performance Goals/Metrics:

Ability to establish new functionality in one of the 2 areas above, and:

- Decrease total data/rate required from the NDE sensor by 50%
- Decrease time to perform NDE inspections by 50%
- Decrease the size, weight and power of NDE systems by 50%

X5.05 Low Temperature Mechanisms

Lead Center: GSFC

Participating Center(s): GRC, JPL, JSC, LaRC