



NASA STTR 2016 Phase I Solicitation

T12 Materials, Structures, Mechanical Systems and Manufacturing

Materials, Structures, Mechanical Systems, and Manufacturing This topic is extremely broad, covering five technology areas: materials, structures, mechanical systems, manufacturing, and cross-cutting technologies. The topic consists of enabling core disciplines and encompasses fundamental new capabilities that directly impact the increasingly stringent demands of NASA science and exploration missions.

Subtopics

T12.01 Advanced Structural Health Monitoring

Lead Center: LaRC

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

Future manned space missions will require spacecraft and launch vehicles that are capable of monitoring the structural health of the vehicle and diagnosing and reporting any degradation in vehicle capability. This subtopic seeks new and innovative technologies in structural health monitoring (SHM) and integrated vehicle health management (IVHM) automated systems and analysis tools. Techniques sought include modular/low mass-volume systems, low power, low maintenance systems, and complete systems that reduce or eliminate wiring, as well as smart-sensor systems that provide processed data as close to the sensor and systems that are flexible in their applicability. Examples of possible automated sensor systems are: Surface Acoustic Wave (SAW)-based sensors, passive wireless sensor-tags, flexible sensors for highly curved surfaces, flexible strain and load sensors for softgoods products (broadcloth, webbing or cordage), direct-write film sensors, and others. Damage detection modes include leak detection, ammonia detection, micrometeoroid impact and others. Reduction in the complexity of standard wires and connectors and enabling sensing functions in locations not normally accessible is also desirable. Proposed techniques should be capable of long term service with little or no intervention. Sensor systems should be capable of identifying material state awareness and distinguish aging related phenomena and damage conditions in complex composite and metallic materials. Techniques and analysis methods related to quantifying material properties, density, microcrack formation, fiber buckling and breakage, etc. in complex composite, metallic and softgoods material systems, adhesively bonded/built-up and/or polymer-matrix composite sandwich structures are of particular interest. Some consideration will be given to the IVHM /SHM ability to survive in on-orbit and deep space conditions, allow for changes late in the development process and enable on orbit modifications. System should allow NASA to gain insight into performance and safety of NASA vehicles as well as commercial launchers, vehicles, inflatable structures and payloads supporting NASA missions. Inclusion of a plan for detailed technical operation and deployment is highly favored.

State of the Art

Current tools for SHM are rudimentary and or need development for future space missions. Current data analysis methods are frequently non-ideal for the large scales of data needed for SHM analysis and/or require expert involvement in interpretation of data.

This technology enables:

- Monitoring of advanced structures/vehicles.
- Cost-effective methods for optimizing SHM techniques.
- Feasible methods for validating structural health monitoring systems.

Once developed this technology can be infused in any program requiring advanced structures/vehicles Aerospace companies are very interested in this enabling technology.

STMD/NASA/NARP/National - Directly aligns with NASA space technology roadmaps and Strategic Space Technology Investment plan.

T12.02 Technologies to Enable Novel Composite Repair Methods

Lead Center: KSC

Participating Center(s): JSC

As composite structures become more prevalent on launch vehicles, it will become necessary to have the capability to inspect and repair these structures during ground processing prior to launch. Current composite repair methods developed for the aviation industry are time consuming and require complex infrastructure in order to restore the structural strength. Aerospace structures have structural and thermal profiles which are different than aircraft and require different considerations; for example, unlike a commercial aircraft, a launch vehicle sees high loading but is only a one time use vehicle. Advancements are needed to repair materials and methods which allow for a structural repair to be performed in locations with minimal access and in a short time frame. Small damages may be accepted by analysis with no repair. Large damages may require extensive repair or component replacement. This subtopic focuses on developing novel composite repair methods for damages that fall in between these two categories. These novel materials and methods should consider the following:

- Use of out of autoclave composite materials and processes, which are being investigated for large launch vehicle components, such as fairings, skirts and tanks on the Space Launch System vehicle. Advancements in these material systems has begun to approach properties of autoclave materials but allow for larger structures to be fabricated.
- Simplified preparation of the damaged structure. Current methods require very precise methods, which is time consuming and can be a risk for further damage.
- Material systems and methods which reduce or eliminate the need for external heat and/or vacuum. These require complex infrastructure, which can be difficult to accommodate at the launch pad, and can be time consuming, which could cause a launch delay.
- Ability to acquire data on the state of the repair, during repair and/or during the launch. This may include data such as temperature at the bondline during cure, strain across the repair patch, etc.

Development of a material system and repair method which increases the performance of the repair and reduces the complexity and time required to perform a repair increases the launch capability and success rate. Improvements or modifications to current materials and processes can be made to meet NASA requirements. This technology can also be expanded to develop methods for in-situ repairs to spacecraft on long missions.

T12.03 Increasing Predictability of Softgoods Material Behavior for Inflatable Space Structures

Lead Center: LaRC

Participating Center(s): JSC

This subtopic is seeking innovative design and fabrication methodologies that increase the predictability and repeatability of the mechanical behavior of softgoods material architectures, including broadcloth, webbing and cordage that are used in expandable space habitats. To date, high-strength softgoods materials used in deployable habitats have been manufactured to industrial or Mil-Spec standards that only require meeting a minimum strength requirement for acceptance. NASA is seeking high-strength softgoods material architectures and processes that significantly improve pristine repeatability on strength and stiffness, and provide improved predictability of mechanical properties when loaded over time. In addition, these materials may be packaged in an unloaded state for long periods of time prior to deployment, thus methods for maintaining predictability after a period of relaxation are being sought.

Integration of indicator fibers or yarns into these materials during manufacture is also of interest, to identify damaged or stressed areas of the softgoods during and after fabrication, and to provide a measure of the softgoods structural integrity over time. Post-fabrication integration of advanced health monitoring sensors, such as for strain and load, are covered under a separate subtopic.

NASA is also interested in modeling and simulation approaches that can model the effects and impact of the space environment (thermal, radiation, vacuum) on these materials over time to maintain structural margins. These modeling techniques in combination with materials built for higher predictability and integrated health monitoring should allow prediction of residual strength and remaining safe life for missions of several years.

In summary NASA seeks innovations in:

- Designing and fabricating high-strength softgoods material architectures with highly predictable strength and stiffness in the pristine state, with improved predictability of long-term behavior after extended packaged or inflated conditions in a space environment.
- Integrating specialized indicator fibers or yarns into these materials during fabrication, to enable evaluation of structural integrity.
- Advanced modeling and simulation methodologies to predict mechanical behavior of these materials after long-term exposure to the space environment.

Contractors should prove the feasibility of proposed innovations using suitable analyses and small scale tests in Phase I. In Phase II, significant testing / fabrication or software capabilities should be developed and demonstrated. A Technology Readiness Level (TRL) at the end of Phase II of 4 is desired.

T12.04 Experimental and Analytical Technologies for Additive Manufacturing

Lead Center: MSFC

Participating Center(s): GSFC

Additive manufacturing is becoming a leading method for reducing costs, increasing quality, and shortening schedules for production of innovative parts and component that were previously not possible using more traditional methods of manufacturing. In the past decade, methods such as selective laser melting (SLM) have emerged as the leading paradigm for additive manufacturing (AM) of metallic components, promising very rapid, cost-effective, and on-demand production of monolithic, lightweight, and arbitrarily intricate parts directly from a CAD file. In the push to commercialize the SLM technology, however, the modeling of the AM process and physical properties of the resulting artifact were paid little attention. As a result, commercially available systems are based largely on hand-tuned parameters determined by trial and error for a limited set of metal powders. The system operation is far from optimal or efficient, and the uncertainty in the performance of the produced component is too large. This, in turn, necessitates a long and costly certification process, especially in a highly risk-aware community such as aerospace. Modeling and real time process control of selective laser melting is needed coupled with statistically significant correlations and understanding of the important process parameters and the resultant microstructural and mechanical properties, validated with detailed metallurgical investigations of the as-fabricated structures.

State of the Art

This topic seeks technologies that close critical gaps between SOA and needed technology in both experimental and analytical areas in materials design, process modeling and material behavior prediction to reduce time and cost for materials development and process qualification for SLM.

Technological advancements are needed in the areas of:

- Real-time additive manufacturing process monitoring for real-time material quality assurance prediction.
- Reduced-order physics models for individual phases of additive manufacturing technique.
- Analytical tools to understand effects of process variables on materials evolution.
- Digital models to standardize the use of structured light scanning or equivalent within manufacturing processes.
- Software for high-fidelity simulation of various SLM phases for guiding the development, and enabling the subsequent verification.