NASA SBIR 2015 Phase I Solicitation

H5 Lightweight Spacecraft Materials and Structures

Lead Center: LaRC

The SBIR topic area of Lightweight Spacecraft Materials and Structures centers on developing lightweight structures and advanced materials technologies for space exploration vehicles including launch vehicles, crewed vehicles and habitat systems, and in-space transfer vehicles. Lightweight structures and advance 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 missions. The technology drivers for exploration missions are:Â

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- Lower mass.
- Improve efficient packaging of launch volume.
- Improve performance to reduce risk and extend life.
- Improve manufacturing and processing to reduce costs.

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Because this topic covers a broad area of interests, subtopics are chosen to enhance and or fill gaps in the exploration technology development programs. These subtopics can include but are not limited to:Â

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- Manufacturing processes for materials.
- Material improvements for metals, composites, ceramics, and fabrics.
- Innovative lightweight structures.
- Deployable structures.
- Extreme environment materials and structures.
- Multifunctional/multipurpose materials and structures.

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This year the lightweight spacecraft materials and structures topic is seeking innovative technology for multifunctional materials and structures, deployable structures, and extreme environment structures. The specific needs and metrics of each of the focus areas of technology chosen for development are described in the subtopic descriptions. Research awarded 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.Â Â Â

Subtopics

H5.01 Deployable Structures

Lead Center: LaRC

Participating Center(s): GRC, JSC

This subtopic seeks deployable structures innovations in two areas for proposed deep-space space exploration missions:Â

- Large deployable solar arrays for 50+ kW solar electric propulsion (SEP) missions.
- Lightweight deployable hatches for manned inflatable structures.

Design solutions must minimize mass and launch volume while meeting other mission requirements including deployed strength, stiffness, and durability.

Innovations are sought in the following areas for both capabilities (deployable solar arrays and deployable hatches):Â

- Novel design, packaging, deployment, and in-space manufacturing or assembly concepts.
- Lightweight, compact components including booms, ribs, substrates, and mechanisms.
- Validated modeling, analysis, and simulation techniques.
- Ground and in-space test methods.
- Load reduction, damping, and stiffening techniques.
- High-fidelity, functioning laboratory models.

Capability #1: Deployable Solar Arrays

NASA is currently developing solar array systems for solar electric propulsion in the 30-50 kW power range for near-term missions such as the Asteroid Redirect Mission (ARM). This subtopic seeks structures and materials innovations for the next generation of lightweight solar arrays beyond 50 kW. NASA has a vital interest in developing much larger arrays over the next 20 years with up to 1 MW of power (4000 m^2 total deployed area) for SEP-powered exploration missions. Scaling up solar array size by over an order-of-magnitude will require game changing innovations. In particular, novel flexible-substrate designs are needed that minimize structural mass and packaging volume while maximizing deployment reliability, deployed stiffness, deployed strength, and longevity.

Nominal solar array requirements for large-scale SEP applications are:Â

- Specific power > 120 W/kg at beginning of life (BOL).
- Packaging efficiency > 40 kW/m^3 BOL.
- Deployment reliability > 0.999.
- Deployed stiffness > 0.1 Hz.
- Deployed strength > 0.1 g (all directions).
- Lifetime > 5 yrs.

Variations of NASAâ€™s in-house large solar array concept referred to as the Compact Telescoping Array (CTA) could be used for design, analysis, and hardware studies. Improved packaging, joints, deployment methods, etc. to enable CTA-type solar arrays up to 4000 m^2 in size (1 MW) with up to 250 W/kg and 60 kW/m^3 BOL are of special interest. The CTA is described in Reference 1.

Capability #2: Deployable Hatches

NASA is also seeking concepts for lightweight, deployable hatch systems for manned inflatable structures that require ingress/egress across a pressure differential. Designs should be efficient and tight-sealing and use softgoods materials in whole or in part. â€œSoftgoodsâ€ refers to advanced high-strength fabrics or woven materials. Applications of this technology include barometric chambers, airlocks and habitats, and large-scale space hangars for on-orbit assembly. The pressure vessel geometry could require hatches that conform to flat, singly-curved, or doubly-curved surfaces. Concepts will be evaluated on mass efficiency, minimal packaging volume for launch, operational reliability and simplicity, and strategy for integration into a soft-goods structure. Proposals should detail a concept of operations including packaged and deployed geometry, deployment approach, and operation of sealing/unsealing the hatch. Reference 2 provides additional information on deployable soft space structures.

Nominal hatch requirements are:Â

- 40-inch diameter clear opening for ingress/egress.
- Designed for a differential pressure of 15.2 psi.
- Hatch can be sealed and verified even when parent vessel is at vacuum.
- The hatch can be easily operated by a suited astronaut.

For both capabilities, contractors should prove the feasibility of proposed innovations using suitable analyses and tests in Phase I. In Phase II, significant hardware or software capabilities should be developed and demonstrated. A Technology Readiness Level (TRL) at the end of Phase II of 3-4 or higher is desired.

References:Â

- Mikulas, M. M. et al., â€œTelescoping Solar Array Concept for Achieving High Packaging Efficiency,â€ To be presented at the AIAA Spacecraft Structures Conference, January 2015.
- Bell L., â€œDeployable Soft Space Structures: Concepts and Application Requirements,â€ 50th AIAA Structures, Dynamics and Materials Conference, Paper 2009-2168, May 2009.Â

H5.02 Extreme Temperature Structures

Lead Center: MSFC

Participating Center(s): LaRC

This subtopic seeks to develop innovative low cost and lightweight structures for cryogenic and elevated temperature environments. The storage of cryogenic propellants and the high temperature environment during atmospheric entry require advanced materials to provide low mass, affordable, and reliable solutions. The development of durable and affordable material systems is critical to technology advances and to enabling future launch and atmospheric entry vehicles. The subtopic focuses on two main areas: highly damage-tolerant composite materials for use in cryogenic storage applications and high temperature composite materials for hot structures applications. Proposals to each area will be considered separately.Â

- *Cryogenic Storage Applications* - The focus of this area is to yield material systems and manufacturing processes which enable the capability to store and transfer cryogenic propellants (liquid oxygen & liquid hydrogen) to orbit. Operating temperature ranges for these fluids are -183Â°C to -253Â°C. Specific areas include:
  - Composite systems to be used in the construction of storage vessels or ductwork for cryogenic propellants. Performance metrics for cryogenic applications include: temperature dependent properties (facture toughness, strength, coefficient of thermal expansion), resistance to permeability and micro-cracking under cryogenic thermal and biaxial stress state cycling.
  - Reliable hatch or access door sealing technique/mechanism for cryogenic composite structures. Concepts must address seal systems for both composite to composite and composite to metal applications. Techniques must consider scale up and manufacturability factors.
- *Hot Structures* â€“ The focus of this area is the development of cost effective, environmentally

durable and manufacturable material systems capable of operating at temperatures from 1500Â°C to 3000Â°C, while maintaining structural integrity. Significant reductions in vehicle weight can be achieved with the application of hot structures, which do not require parasitic thermal protection systems. This area seeks innovative technologies in one or more of the following:

- Light-weight, low-cost, composite material systems that include continuous fibers.
- Significant improvements of in-plane and thru the thickness mechanical properties, compared to current high temperature laminated composites.
- Decreased processing time and increased consistency for high temperature materials.
- Improvement in potential reusability for multiple missions.
- Low conductivity, low thermal expansion, high impact resistance.

For all above technologies, research, testing, and analysis should be conducted to demonstrate technical feasibility during Phase I and show a path towards Phase II hardware demonstration. Emphasis should be on the delivery of a manufacturing demonstration unit for NASA testing at the completion of the Phase II contract.

Phase I Deliverables - Test coupons and characterization samples for demonstrating the proposed material product. Matrix of verification/characterization testing to be performed at the end of Phase II.

Phase II Deliverables - Test coupons and manufacturing demonstration unit for proposed material product. A full report of the material development process will be provided along with the results of the conducted verification matrix from Phase I. Opportunities and plans should also be identified and summarized for potential commercialization.

References:Â

- Anon, â€œFinal Report of the X-33 Liquid Hydrogen Tank Test Investigation Team,â€ National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama 35812, May 2000.
- Glass, D. E. â€œCeramic Matrix Composites (CMC) Thermal Protection Systems (TPS) and Hot Structures for Hypersonic Vehicles,â€ 15th AIAA International Space Planes and Hypersonic Systems and Technologies Conference, Dayton, Ohio, AIAA-2008-2682, April 2008. (http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080017096.pdf)Â

H5.03 Multifunctional Materials and Structures

Lead Center: LaRC

Participating Center(s): GRC, JSC, MSFC

Multifunctional and lightweight are critical attributes and technology themes required by deep space mission architectures. Multifunctional materials and structural systems will provide reductions in mass and volume for next generation vehicles. The NASA Technology Roadmap TA12, â€œMaterials, Structures, Mechanical Systems, and Manufacturingâ€ (http://www.nasa.gov/sites/default/files/501625main_TA12-ID_rev6_NRC-wTASR.pdf), proposed Multifunctional Structures as one of their top 5 technical challenges, and the NRC review of the roadmap recommended it as the top priority in this area stating: â€œâ€¦ To the extent that a structure can simultaneously perform additional functions, mission capability can be increased with decreased mass. Such multifunctional materials and structures will require new design analysis tools and might exhibit new failure modes; these should be understood for use in systems design and space systems operations.â€

Some functional capabilities beyond structural that are in this multifunctional theme are: insulating (thermal, acoustic), inflatable, protective (radiation and micrometeoroids and orbital debris), sensing, healing, in-situ inspectable (e.g., IVHM), actuating, integral cooling/heating, and power generating (thermal-electric, photovoltaic â€¦), and so on. Because of the broad scope possible in this SBIR subtopic, the intent is to vary its focus each year to address specific areas of multi-functionality:Â

- That have high payoff for a specific mission.

- That are broadly applicable to many missions.
- That could find broader applications outside of NASA which would allow for partnerships to leverage the development of these technologies. For FY15, this SBIR subtopic seeks innovative structures and materials technologies and capabilities for three principle areas:
    - Integration of acoustic metamaterial concepts into the primary structure to reduce interior acoustic and vibration environments. Specifically, innovations are solicited which maintain the load bearing capability of the primary structure while simultaneously reducing interior noise and vibration levels below 400 Hz. Successful innovations are anticipated to enable the design of lighter and cheaper spacecraft and launch vehicle structures, as well as lower costs associated with ruggedizing and qualifying spacecraft and launch vehicle secondary structures.
    - Sensory materials incorporated into a primary structure to provide health monitoring data, and low-mass/wireless methods of transmitting localized structural responses to diagnostic models for material and structural state. Manufacturing technologies capable of producing structural components with embedded capability for sensing strain, damage initiation and propagation, and temperature are of particular interest. Ideally, the sensing technology should also augment the load carrying capability or some other structural design requirement. Technologies should enable weight reduction with similar or better structural performance when compared to traditional approaches.
    - Thin film conformal layers on structures or integrated in structures with different functional capabilities. Examples include conformal solar cells, conformal antennas, conformal energy storage, and conformal energy harvesting. The conformal layer should provide additional functionality to the structure without adversely affecting the load bearing capability. The conformal functional layer offers the potential for significant weight reduction and reduced complexity for spacecraft, rovers, and habitats. For example, conformal photovoltaic layer on spacecraft, rover, or habitat can eliminate the need for separate solar array panels."