Scope Title

Design Tools for Advanced Tailorable Composites

Scope Description

Affordable space exploration beyond the lower Earth orbit will require innovative lightweight structural concepts. Use of advanced tailorable composites or hybrid material systems can be one of the means of lightweighting exploration vehicles, space habitats, and other space hardware or to enable challenging performance characteristics such as near-zero thermal dimensional sensitivity of telescope structures while retaining required strength and stiffness. Lightweighting and/or reducing thermal sensitivity stemming from application of novel material systems oftentimes fails to be fully exploited due to the lack of engineering tools enabling structural and thermal-structural tailoring to yield optimal designs. Consequently, highly tailorable material systems are commonly used to produce quasi-isotropic (black aluminum) or otherwise off-optimal designs.

By recognizing that achieving certain performance requirements might entail using not just layups of similar reinforcing and matrix materials but also the option of integrating dissimilar reinforcement and/or matrix materials resulting in a hybrid material system. This solicitation seeks to advance the design capabilities not only for layered composites but also for hybrid systems. To exploit the full potential of novel structural concepts, applicable composite and hybrid material systems can leverage a broad variety of materials, including but not limited to metallic alloys, short and/or continuous fiber reinforcements, and a variety of matrices (thermoset, thermoplastic, ceramics, and others).

A design tool development for composite and/or a hybrid material system and its demonstration on a relevant structure is sought. The design tool shall be developed leveraging the broadly adopted and accessible engineering codes, including but not limited to MSC.Patran/Nastran, Abaqus, Hypersizer, Hyperworks, LSOPT, etc. Development in a form of a wrapper or plug-in codes is strongly preferred over re-developing functionalities that readily exist and can be incorporated within the design tool. Intuitive user-friendly code interfaces for the design definition setup are also highly desirable.

The ability to predict performance based on tailorable composite or a hybrid material system integrated in the most optimal way shall be demonstrated on a study case representative of a space exploration hardware, including but not limited to:

- Pressurized structures, e.g.,
- Crew modules and habitats (including features such as hatches, access, and windows cutouts).
- Cryogenic tanks.
- Dry and unpressurized structures, e.g.,
  - Thermally stable telescope arrays.
  - Truss structures, such as lander cages or landing gear struts.
  - Other smaller/discrete structural components or portions thereof, such as joints and mechanisms (e.g., brackets, hinges, clevises).

Examples of relevant applications and specific metrics sought include current vehicle architectures being considered for the return to the Moon missions. They are targeted to fit within a 15-ft-diameter shroud, thus tank and habitat maximum dimensions are likely on the order of this 15-ft-diameter constraint. For tanks, nominal operating pressures in the range of 40 to 65 psi are considered common. The internal pressures for habitats can be guided by the International Space Station's internal pressure of 14.7 psi. For thermally stable telescope array and similar applications, passive dimensional thermal stability is sought rather than a solution assisted by an active thermal control. A design based on the minimum 40 Msi elastic modulus in the principal direction and the coefficient of thermal expansion (CTE) of order of $0.01 \times 10^{-6}$ in./(in. °F) over a range of 10 °F is likely required. Tailored/optimized designs shall be manufacturable considering presently available fabrication techniques.

**Expected TRL or TRL Range at completion of the Project**

5 to 6

**Primary Technology Taxonomy**

**Level 1**

TX 12 Materials, Structures, Mechanical Systems, and Manufacturing

**Level 2**

TX 12.2 Structures

**Desired Deliverables of Phase I and Phase II**

- Analysis
- Software
- Research

**Desired Deliverables Description**

Phase I of the award shall deliver a proposed implementation of the design tool with a functioning code, however its capabilities can be truncated relative to the overall proposed development. The truncated code shall include enough capabilities to be able to produce a simplified demonstration case that would also constitute a part of the Phase I deliverable. Phase II deliverable shall include a releasable version of the design tool with the complete proposed functionality and a refined demonstration study case. For both Phase I and II developments, an open code architecture is of value such that the end users can gain insight into the implementation and possibly alter or add functionalities. From a practical standpoint, use of Python in conjunction with Abaqus implementation or PCL in conjunction with MSC.Patran/Nastran implementation might be considered examples of open architectures. Use of an existing design optimization tools, e.g., LSOPT, is also allowed and encouraged.

**State of the Art and Critical Gaps**

Present composite designs are typically limited to straight fiber arrangements and lamination stacking sequences resulting in quasi-isotropic material properties. No commercially available design tools exist to produce advanced highly tailorable designs with optimized load paths or minimized effective coefficient of thermal expansion.
Relevance / Science Traceability

Examples of potential uses include Space Technology Mission Directorate, Artemis/HLS programs, developers of air-launched systems (e.g., Generation Orbit Launch Services; Science Mission Directorate (SMD) and projects concerned with telescope structure development; Aeronautics Research Mission Directorate) Â next-generation airframe technology beyond “tube and wing” configurations (e.g., hybrid/blended wing body).

References


