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 composite material systems is one of the means of lightweighting exploration vehicles, space habitats, and other space hardware. Lightweighting potential stemming from application of composite materials oftentimes fails to fully exploit the potential for reducing mass due to the lack of design tools tailored to yield designs with optimal load paths. Consequently, highly tailorable material systems are commonly used to produce quasi-isotropic ("black aluminum") or otherwise off-optimal designs.

This solicitation seeks to advance the design capabilities for layered pre-impregnated composite materials reinforced with either continuous or short fibers and with a wide variety of ply thicknesses, from ultrathin (with the fiber areal weight in single digits when expressed in grams per square meter (gsm)), to standard (approx. in the 145- to 190-gsm range). A design tool development and its demonstration to 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 "wrapper" or "plug-in" codes is strongly preferred over redeveloping functionalities that readily exist and can be incorporated within the design tool. Intuitive user-friendly code interfaces for the design definition set up are also highly desirable.

Demonstration problems of interest include fiber-steered or otherwise highly tailored structural designs representative of cryogenic tanks, pressurized habitats, and other primary space structure components, including dry and unpressurized, such as lander truss cages or landing gears. Advantages of a new highly tailored composite design shall be demonstrated by its weight-saving potential over a legacy/conventional design while observing typical manufacturability constraints (determined, e.g., based on a literature survey). Other aspects, such as improved damage tolerance, extended service time, reusability, lower cost, or multifunctionality are also considered significant. Demonstration of improved performance of a highly tailored design relative to a conventional composite design (e.g., black aluminum approach) satisfies the requirements of this solicitation. However, comparisons to the metallic designs are also of interest as they ultimately can demonstrate the design goodness progression in the three-element series involving metallic, conventional composite, and highly tailored composite designs. Examples
of relevant applications include but are not limited to current vehicle architectures being constrained for the return to the Moon missions are 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.

While a global-local analysis might be beneficial and warranted in the overall design process, demonstration problems can include smaller structural components, such as hardpoint attachment brackets, fittings, clevises, etc. Ability of the proposed design approach and related code to tailor not only general sections/acreages but also highly discontinuous sections of primary structures, such as hatches, windows, or hardpoint attachments present within the thin-wall overall architecture are highly sought features of the proposed design tool.

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. The 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 tool, for example, 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.

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; Aeronautics Research Mission Directorate) next-generation airframe technology beyond "tube and wing" configurations (e.g., hybrid/blended wing body).

References:

- Guimaraes, T., Castro, S., Cesnik, C., Rade, D., Supersonic Flutter and Buckling
