NASA SBIR 2021 Phase I Solicitation

A1.03 Propulsion Efficiency - Propulsion Materials and Structures

Lead Center: GRC

Scope Title:

Advanced Materials and Structures Technologies Enabling New Highly Efficient Propulsion Systems for Subsonic Transport Vehicles

Scope Description:

Materials and structures research and development (R&D) contributes to NASA’s ability to achieve its long-term aeronautics goals, including the development of advanced propulsion systems. Proposals are sought for advanced materials and structures technologies that will be enabling for new propulsion systems for subsonic transport vehicles with high levels of thermal, transmission, and propulsive efficiency. Integrated computational and experimental approaches are needed that can reduce the time necessary for development, testing, and validation of new materials systems and components.

Advanced high-pressure-ratio compact gas turbine engines will include components of sufficiently compact size that new approaches to processing and advanced manufacturing will be needed. Temperature capability, thermomechanical performance, environmental durability, reliability, and cost-effectiveness are important considerations.

The increased use of various types of modeling to improve R&D effectiveness and enable more rapid and revolutionary materials design has been identified as critical. NASA recently sponsored a study to define a potential 25-year goal for integrated, multiscale modeling of materials and systems to accelerate the pace and reduce the expense of innovation in future aeronautical systems. Through a series of surveys, workshops, and validation exercises, this study identified critical cultural changes and gaps facing the multiscale modeling community. The results of this study were published in a NASA report, "Vision 2040: A Roadmap for Integrated, Multiscale Modeling and Simulation of Materials and Systems" [Ref. 1]. Some of the critical gaps identified in this report are: (1) under-development of physics-based models that link length and time scales, (2) inability to conduct real-time characterization at appropriate length and time scales, (3) lack of optimization methods that bridge scales, (4) lack of models that compute input sensitivities and propagate uncertainties, and (5) lack of verification and validation methods and data.

Proposals emphasizing modeling can address topics which shall address gaps in that 2040 vision. The range of topics could include data management, data analytics, machine learning, linkage and integration across spatiotemporal scales, and characterization of materials over their lifecycle. Proposals may address any material class associated with aeronautics propulsion for subsonic transport vehicles, multiscale modeling and
measurements, multiscale optimization methods, and verification and validation of models and methods. However, approaches should rely on iterative, predictive methods that integrate experiments and simulations to describe the behavior and response of materials at various length and time scales.

Technology areas of interest this year include:

- Computational materials and multiscale modeling tools, including methods to predict properties, and/or durability of propulsion materials based upon chemistry and processing for conventional as well as functionally graded, nanostructured, multifunctional, and adaptive materials.
- Robust and efficient methods/tools to design and model advanced propulsion system materials and structures at all scale levels, including approaches that are adaptable for a multiscale framework.
- Multiscale design tools that integrate novel materials, mechanism design, and structural subcomponent design into system level designs.
- Advancing technology for ceramic matrix composites (CMCs) and their environmental barrier coatings (EBCs) for gas turbine engine components operating at 1,482 °C (2,700 °F) or higher. Focus areas include increased thermomechanical durability, increased resistance to environmental interactions, cost-effectiveness of processing and manufacturing, and improved approaches to component fabrication and integration. Computational tools and integrated experimental/computational methods are sought, including models/tools to predict degradation and failure mechanisms.
- Additive manufacturing and other advanced processing/manufacturing approaches for structural components or materials to enable improved engine efficiency through decreasing weight and/or improving component design, properties, and performance.
- In support of future aircraft with hybrid electric or all electric propulsion systems, advanced cross-cutting materials technologies are needed. For example: (1) soft magnetic material with high magnetic saturation and/or lower losses for 100 to 300 kHz operation, (2) hard magnetic materials with an energy product greater than neodymium iron boron, (3) conductors for power cables with a specific resistivity less than copper or aluminum, and (4) novel materials systems and structures to enable functionality, such as power harvesting, thermal management, self-sensing, and actuation.
- Design and development of unique materials such as shape memory alloys and high entropy alloys for subsonic transport vehicle propulsion system structures and components.
- Propulsion aeromechanics, damping devices, and analysis and mistuning analysis for turbomachinery rotating blades.

Expected TRL or TRL Range at completion of the Project: 2 to 4
Primary Technology Taxonomy:
Level 1: TX 12 Materials, Structures, Mechanical Systems, and Manufacturing
Level 2: TX 12.1 Materials
Desired Deliverables of Phase I and Phase II:
Desired Deliverables Description:

NASA’s intent is to select proposals that have the potential to move a critical technology beyond Phase II SBIR funding and transition it to Phase III, where NASA’s aeronautics programs, another Government agency, or a commercial entity in the aeronautics sector can fund further maturation as-needed, leading to actual usage in an enhanced propulsion system. The Phase I outcome should establish the scientific, technical, and commercial feasibility of the proposed innovation in fulfillment of NASA needs. Phase I should demonstrate advancement of a specific technology, supported by analytical and experimental studies that are documented in a final report. Phase IIs could yield: (1) models supported with experimental data, (2) software related to a model that was developed, (3) a material system or subcomponent that has been demonstrated to have better properties/performance (ability to operate at a higher temperature, carry more current, etc.), and (4) modeling tools for incorporation in software, etc. that can be infused into a NASA project or lead to commercialization of the technology. Consequently, Phase II efforts are strengthened when they include a partnership with a potential end-user of the technology.

State of the Art and Critical Gaps:

This subtopic would support R&D on advanced materials and structures technologies that will be enabling for new propulsion systems for subsonic transport vehicles with high levels of thermal, transmission, and propulsive efficiency. The needs are specified in the scope description. One of the major NASA Glenn Research Center core competencies is Materials and Structures for Extreme Environments. This subtopic supports that type of research—enabling materials and structures research that allows more efficient propulsion systems.

In general, integrated computational and experimental approaches are needed that can reduce the time necessary for development, testing, and validation of new materials systems and components. The increased use of various types of modeling to improve R&D effectiveness and enable more rapid and revolutionary materials design has been identified as critical. NASA recently conducted a study that identified critical cultural changes and gaps facing the multiscale modeling community.

For future aircraft with hybrid electric or all electric propulsion systems, advanced materials technology is needed for power components including electric machines and power cables.

Advanced high-pressure-ratio compact gas turbine engines will include components of sufficiently compact size that new approaches to processing and advanced manufacturing will be needed. Improvements in temperature capability, thermomechanical performance, environmental durability, reliability, and cost-effectiveness are important considerations.

Relevance / Science Traceability:

Aeronautics Research Mission Directorate (ARMD) projects that would/could support each of the specified areas of interest are listed below, along with advocates for the technologies. The technologies would lead to improved propulsion efficiencies (subsonic transport vehicles).

- Computational materials and multiscale modeling tools, including methods to predict properties, and/or durability of propulsion materials based upon chemistry and processing for conventional as well as functionally graded, nanostructured,
multifunctional, and adaptive materials. TTT (Transformational Tools and Technology) Project.

- Robust and efficient methods/tools to design and model advanced propulsion system materials and structures at all scale levels, including approaches that are adaptable for a multiscale framework. TTT Project.
- Multiscale design tools that integrate novel materials, mechanism design, and structural subcomponent design into system level designs. TTT Project.
- Advancing technology for CMCs and their EBCs for gas turbine engine components operating at 1,482 °C (2,700 °F) or higher. TTT and AATT (Advanced Air Transport Technology) Projects.
- Additive manufacturing and other advanced processing/manufacturing approaches for structural components or materials to enable improved engine efficiency through decreasing weight and/or improving component design, properties, and performance. TTT Project.
- Soft magnetic material with high magnetic saturation and/or lower losses for 100 to 300 kHz operation, hard magnetic materials with an energy product greater than neodymium iron boron, conductors with a specific resistivity less than copper or aluminum, and cable insulation materials with increased dielectric breakdown strength, and significantly higher thermal conductivity (?1 W/m·K) and resistance to ageing effects such as corona, ozone, humidity, and dust operating at greater than 3 kV. TTT, AATT, CAS (Convergent Aeronautics Solutions) Projects/HGEP (Hybrid Gas-Electric Propulsion) subproject.
- Novel materials systems and structures to enable functionality, such as power harvesting, thermal management, self-sensing, and actuation. Approaches may include use of nanotechnology and novel processing to tailor and control properties such as thermal conductivity, electrical conductivity, thermoelectric response, microstructure and porosity, and shape-memory behavior. TTT Project.
- Design and development of unique materials such as shape-memory alloys and high-entropy alloys for aeronautics structures and components. TTT and CAS Projects.
- Propulsion aeromechanics, damping devices, and analysis and mistuning analysis for turbomachinery rotating blades. TTT Project/AATT - UPAI (Unconventional Propulsion Airframe Integration)

References:


HGEP: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170004515.pdf

Hybrid Electric Propulsion: https://www1.grc.nasa.gov/aeronautics/hep/