NASA SBIR 2014 Phase I Solicitation

A3 Air Vehicle Technology

The Air Vehicle Technology topic solicits cutting-edge research in aeronautics to overcome technology barriers and challenges in developing highly efficient aircraft systems of the future, with reduced impact to the environment. The primary objective is the development of innovative design tools, capabilities and technologies that provide design and system solutions and capabilities to meet the national goals in cleaner environment, reduced noise and highly energy efficient and revolutionary aircraft for the next generation (NextGen) air transportation system.

This topic solicits tools, technologies, and concepts to enable revolutionary air vehicles of the future as well as having near-term application. Innovative ideas are sought in general areas of airframe structural efficiency, quiet performance, low emissions/clean power, aerodynamic efficiency, propulsion efficiency, rotorcraft, and physics-based conceptual design tools. Each of these general subtopic areas has a more specific focus that is detailed in the subtopic descriptions to follow. The research will contribute to enabling the best design solutions and technology innovations to meet performance and environmental requirements and challenges of future air vehicles that will operate in the NextGen air transportation system.

Beginning in FY14, this topic covers aircraft technologies covered by the Fundamental Aeronautics Program. This topic will emphasize development of tools, technologies, and knowledge to meet metrics derived from a definitive set of Technical Challenges responsive to the goals of the National Aeronautics Research and Development Plan (2010) and the NASA Strategic Plan (2011).

- *Fixed Wing Vehicles* - Technologies and concepts for subsonic transport aircraft, propulsion system energy efficiency and environmental compatibility supported by enabling tools and methods. Targeted challenges include drag and weight reduction for fuselages and high aspect ratio wings, quiet high performance high-lift and propulsion systems, high performance clean, alternative-fuel burning gas generators, paradigm-changing hybrid-electric propulsion systems, innovative propulsion-airframe integration concepts.
- *Rotary Wing Vehicles* - Advanced Efficient Propulsion (multi-speed lightweight rotorcraft drive trains and variable speed efficient engines), Advanced Concepts and Configurations (aerodynamically efficient rotorcraft, NextGen configurations, and multi-fidelity design and analysis tools), and Community and Passenger Acceptance (NextGen operations and standards, and comfort and safety).
- *High Speed* - Focused on supersonic research, design, and boom mitigation techniques to achieve low boom strength and other elements that will help enable a low-boom experimental aircraft; System Integration Assessment.
- *Supersonic Cruise Efficiency* - Propulsion; Supersonic Cruise Efficiency-Airframe; Sonic Boom Modeling; and Jet Noise Research.
- *Aeronautical Sciences* - Broad, cross-cutting discipline research (e.g., some CFD and structures & materials research) that is pervasive across flight regimes, helps develop some low-level concepts and ideas, and provides program-level systems analysis capability to assess balance and impact of program-wide investments.

Subtopics

A3.01 Structural Efficiency-Aeroservoelasticity

Lead Center: LaRC

Participating Center(s): AFRC

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for ensuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure and at times, active systems controlling the flight vehicle. The Fundamental Aeronautics Program's work on Structural Efficiency for the FY 2014 NASA SBIR solicitation is focused on aeroservoelasticity active structural control for lightweight flexible structures, specifically related to load redistribution, flutter prediction and suppression, and gust load prediction and alleviation. Of interest are:

- Aeroservoelastic analyses at the appropriate level of fidelity for the problem at hand.
- Aeroservoelastic experiments to validate methodologies and to gain valuable insights available only through testing.
- Development of computational-aeroservoelastic analysis tools that advance the state of the art in aeroelasticity through novel and creative application of aeroelastic knowledge.

Specific subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing aeroservoelastic studies. Example: CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, flight dynamics stability and control issues, and flutter.
- Development of aeroservoelasticity concepts and models, including unique control concepts and architectures that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Development of techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroservoelastic phenomena.

A3.02 Quiet Performance

Lead Center: GRC

Participating Center(s): LaRC

To reduce noise emissions from aircraft, tools and technologies are needed to design aircraft that are both efficient and low-noise. In support of several Aeronautics Research Mission Directorate projects, developments/ improvements in noise reduction technology, noise prediction tools, and flow & noise diagnostic methods are needed for subsonic and supersonic aircraft. In this call, innovations with an emphasis on aircraft propulsion are solicited in the following areas:

Noise Reduction

- Advanced liners including broadband liners (i.e., liners capable of appreciable sound absorption over at least two octaves), and low-frequency liners (i.e., liners with optimum absorption frequencies half of the current ones but without increasing the liner depth).

- Low-noise propulsor concepts that is quieter than current generation fans and open rotors.
- Concepts for active control of propulsion broadband noise sources including fan, open rotor, jet, compressor, combustor, and turbine.
- Adaptive flow and noise control technologies including smart structures for inlets, nozzles, and low-drag liners.
- Concepts to mitigate the effects of distorted inflow on fan noise.

Noise Prediction

- High-fidelity fan and turbine noise prediction models including Large Eddy Simulation of broadband noise, 3-D fan and turbine acoustic transmission models for tone and/or broadband noise.
- Accurate models for prediction of installed noise for jet surface interaction, fan inlet distortion, and open rotors.

Noise Diagnostics

- Tools/Techniques for quantitative characterization of fan in-duct broadband noise in terms of its spatial and temporal content.
- Phased array and acoustic holography techniques to measure source noise in low signal-to-noise ratio wind tunnel environments.
- Characterization of fundamental jet noise sources and structures.
- Innovative measurement of radiated acoustic fields from aeroacoustics sources.

A3.03 Low Emissions/Clean Power

Lead Center: GRC

Participating Center(s): LaRC

Achieving low emissions and finding new pathways to cleaner power are critical for the development of future air vehicles. Vehicles for subsonic and supersonic flight regimes will be required to operate on a variety of certified aircraft fuels and emit extremely low amounts of gaseous and particulate emissions to satisfy increasingly stringent emissions regulations. Future vehicles will be more fuel-efficient which will result in smaller engine cores operating at higher pressures. Fundamental combustion research coupled with associated physics based model development of combustion processes will provide the foundation for technology development critical for these vehicles. Combustion involves multi-phase, multi-component fuel, turbulent, unsteady, 3-D, reacting flows where much of the physics of the processes are not completely understood. CFD codes used for combustion do not currently have the predictive capability that is typically found for non-reacting flows. Low emissions combustion concepts require very rapid mixing of the fuel and air with a minimum pressure loss to achieve complete combustion in the smallest volume. Areas of specific interest where research is solicited include:

- Development of laser-based diagnostics for quantitative spatially and temporally resolved measurements of fuel/air ratio in reacting flows at elevated pressure.
- Development of ultra-sensitive instruments for determining the size-dependent mass of combustion generated particle emissions.
- Low emissions combustor concepts for small high pressure engine cores.
- Chemical kinetics mechanisms with approximately 20 species for Jet-A fuel suitable for use with 3-D Combustion CFD Codes.

A3.04 Aerodynamic Efficiency

Lead Center: ARC

Participating Center(s): AFRC, LaRC

NASA is conducting fundamental aeronautics research to develop innovative ideas that can lead to next generation aircraft design concepts with improved aerodynamic efficiency. Innovative vehicle concepts are being studied with emphasis on MDAO methods that can simultaneously address complex interactions among aerodynamics, aeroelasticity, propulsion, dynamics, and controls. Modern aircraft development is a tightly coupled multi-disciplinary process designed to achieve as much efficiency as possible. There is an increasing interest in flight control technologies that can improve aerodynamic efficiency. Concepts such as performance adaptive aeroelastic wing shape control for drag reduction and circulation control for lift augmentation are potential aviation technologies that can contribute to the goal of aerodynamic efficiency. To realize the full potential of these technologies, tight coupling with vehicle dynamics and control should be emphasized. The vehicle-centric flight control perspective will enable an integrated approach that ensures complex vehicle interactions with new technologies are addressed. Areas of interest are performance adaptive aeroelastic wing shape control concepts that can:

- Tailor the spanwise lift distribution for optimal L/D throughout the flight envelope.
- Enable high-aspect ratio wing design with relaxed stiffness to reduce weight and drag penalties of non-lifting structures.
- Improve aerodynamic performance by enabling more efficient designs.

Specific subjects to be considered include but are not limited to:

- Novel control systems that can potentially reduce size, weight, and drag relative to the existing state-of-the-art, including concepts that can improve aerodynamic performance by exploring design options with relaxed static stability.
- Control laws and associated architectures that blend wing shape control for optimal L/D with performance, command tracking, and suitable handling and ride quality in all flight phases, taking into account aeroelasticity and flow physics as necessary.
- Measurement and instrumentation required to enable the control laws and architectures.
- Measurement, instrumentation, and/or estimation techniques for real-time identification of vehicle drag or L/D.
- Techniques to ensure robustness relative to measurement, estimation, and control uncertainty.

A3.05 Physics-Based Conceptual Design Tools

Lead Center: LaRC

Participating Center(s): GRC

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the subsonic and supersonic flight regimes. Conceptual design and analysis of unconventional vehicle concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. The agency’s systems analysts need to have the best conceptual design/analysis tools possible to support these efforts. Substantial progress has been recently made in incorporating more physics-based analysis tools in the conceptual design process and NASA has developed a capability that integrates several analysis tools and models in engineering frameworks, such as ModelCenter and OpenMDAO. The current focus is instead on filling remaining capability gaps in specific design disciplines. As such, the purpose of this subtopic is to solicit proposals for innovative solutions which address the problem of rapidly obtaining reasonably accurate airframe weight and center of gravity estimates during the conceptual design of unconventional configurations.

Historically, empirical and semi-empirical weight estimation methods have been utilized during the conceptual design phase. These methods work well for the conceptual design of conventional vehicles with parameters that reside within the historical databases used to develop the methodologies. These methods are not well suited, however, for unconventional vehicle concepts, or even conventional concepts which reside outside of the database (for example, very high aspect ratio swept wings). Developing higher order, more accurate tools suitable for conceptual design is a difficult challenge. The first issue is analysis turnaround time. To perform the configuration trades and optimization typical of conceptual design, runtimes measured in seconds or minutes, instead of hours or days, are required. However, rapid analysis turnaround time alone is insufficient. To be suitable for conceptual design, tools and methods are needed which accurately predict the "as-built" characteristics. Because it is not possible to model every detail of the design and account for all the underlying physics in the problem formulation, it is difficult to predict the "as-built" characteristics with physics-based methods alone. What is usually required is a combination of these methods with some semi-empirical corrections. A final challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods often require only gross design parameters as inputs. High-order, physics-based methods currently require detailed design knowledge to be useful. For example, whereas semi-empirical weight prediction tools provide estimates for wing weight without needing a structural layout, such detail is necessary to successfully utilize finite-element analysis tools. This gap between the analysis capability and the maturity of the design being analyzed currently limits the usefulness of high order analysis in conceptual design. Physics-based tools for conceptual design are needed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

Specifically for FY 2014, desired capabilities include the following:

- New weight estimation relationships valid for wing and/or fuselage geometries outside of current historical databases.
- Increased fidelity loads generation.
- Engineering based weight estimation techniques for systems, equipment, and operational items.

A3.06 Rotorcraft

Lead Center: ARC

Participating Center(s): GRC, LaRC

The challenge of the Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles. Technologies of particular interest are as follows:

- The use of small vertical lift UAVs has increased in recent times with many civilian applications missions being proposed, including autonomous surveillance, mapping, etc. Much of the current research associated with these vehicles has been in the areas of electric propulsion, batteries, small sensors and autonomous control laws, while very little attention has been paid to their acoustic characteristics. The generation and propagation of noise associated with this small class of vertical lift UAVs are not well understood and prediction tools have not been developed or validated for this class of vehicles. The objective of a proposed effort is to develop design and analysis tools for the prediction of acoustics for small vertical lift UAVs, such as quad-copters, coaxial rotor UAVs, ducted fan rotors, etc. Proposals are also sought that include measurement and characterization of noise associated with this class of small vertical lift UAVs.
- A transition to low-carbon propulsion has the promise of dramatically reducing the emissions from full-scale rotorcraft, as well as reducing overall fuel consumption and operating cost. All-electric and hybrid electric propulsion systems could be beneficial to rotorcraft due to high power requirements of hover and integrated motor-drive systems designs that could be realized. The objective of a proposed effort is to investigate, develop and/or demonstrate all-electric and hybrid electric architectures specific to full-scale rotorcraft drive and propulsion system applications. Validated modeling and analysis tools for all-electric and hybrid electric propulsions systems are also sought in this solicitation, as are system studies of various hybrid/electric architectures to show their relative benefits in-terms of weight, efficiency, emissions and fuel consumption for full-scale rotorcraft applications.

Proposals on other rotorcraft technologies will also be considered but the primary emphasis of the solicitation will be on the above two identified technical areas.

A3.07 Propulsion Efficiency - Propulsion Materials and Structures

Lead Center: GRC

Participating Center(s): AFRC

Research and development of both materials and structures is essential to the NASA Aeronautics Programs, Fundamental Aeronautics and Aviation Safety, contributing to their ability to achieve their long-term goals in developing advanced propulsion systems. Responding to this call will require a proposal describing the intent to conduct novel research in materials and structures linked to enhancing aircraft propulsion efficiency. Reductions in vehicle weight, fuel consumption and increased component durability/life will increase propulsion efficiency. The extreme temperature and environmental stability requirements of advanced aircraft propulsion systems demand development of new, reliable, higher performance materials. Research in the areas of high-temperature metals, alloys, ceramics, polymers and their composites provides the fundamental understanding of the underlying process-structure-property relationships of these materials. Study of material systems interactions with harsh environmental conditions and their modes of failure are of particular importance to developing more advanced materials for future aircraft propulsion systems, which will be operating at higher temperatures than todays turbine engines. Heat transport, diffusion, oxidation and corrosion, deformation, creep, fatigue and fracture are among the complex phenomena that can occur in the component materials in the extreme environment of turbine engines propulsion systems. Many of the significant advances in aircraft propulsion have been enabled by improved materials and materials manufacturing processes. Additional advances in the performance and efficiency of jet propulsion systems will be strongly dependent on the development of lighter, more durable high-temperature materials.

The specific topics of interest include:

- Advanced High Temperature Materials Technologies Including Fundamental Materials Development, Processing and Characterization. Innovative approaches to enhance the durability, processability, performance and reliability of advanced materials including advanced blade and disk alloys, ceramics and CMCs, polymers and PMCs, nanostructured materials, hybrid materials and coatings to improve environmental durability. In particular, proposals are sought in:
    - Disk materials and concepts such as innovative joining methodologies for bonding powder metallurgy disk material to directionally solidified/single crystal rim alloy.
    - Corrosion/oxidation resistant coatings for turbine disk materials operating at temperatures in excess of 1400 °F.
    - High strength fibers for ceramic matrix composites and environmental barrier coatings to enable a CMC temperature capability greater than 2700 °F.
    - Innovative methods for the evaluation of advanced materials and structural concepts under simulated operating conditions, including combinations of thermal loads, mechanical loads during environmental (application) exposure.
    - Innovative processing methods that enhance high temperature material and coating properties and reliability.
    - Development and evaluation of shape memory alloys for applications across the lower temperature range of the subsonic aircraft flight path, i.e., experiencing shape changing phase transitions between 0° to -50 °C.
    - Using the unique properties of nanomaterials to tailoring composite properties using nanocomposites, nano-engineered, thermally-conductive composites and micro-engineered porous structures with metals, polymer and ceramic composites.
- Advanced Structural Concepts. New concepts for propulsion components incorporating new lightweight concepts as well as smart structural concepts to reduce mass and improve durability.
- 3-D additive fabrication of complex structures/subelements demonstrating mechanical properties and environmental durability for propulsion system applications.
- Multifunctional materials and structural concepts for gas turbine engine structures, such as novel approaches to power harvesting, thermal management, self-sensing, and materials for actuation.
- Fabrication of unique structures (such as lattice block) using shape memory alloys for lightweight multifunctional/adaptive structures for engine component applications.
- Innovative approaches for use of shape memory alloys for actuation of components in gas turbine engines.
- 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. And robust and efficient design methods and tools for advanced materials and structural concepts (in particular multifunctional and/or adaptive components) including variable fidelity methods, uncertainty-based design and optimization methods, multi-scale computational modeling, and multi-physics modeling tools. In particular proposals are sought in:

- Development of physics-based models of the various failure mechanisms of the EBC, particularly those associated with environmental degradation (e.g., oxidation, diffusion, cracking, crack + oxygen interaction, creep, etc.).
- Multiscale design tools for aircraft engine structures that integrate novel materials, mechanism design, and structural subcomponent design into systems level designs.
- Use of multiscale modeling tools to design multifunctional and adaptive structures.
- Robust and efficient methods/tools to design advanced high temperature materials based on first principles and microstructural models that can be used in a multi-scale framework.
- Development of models to predict degradation of CMCs due to combined effect of environment and mechanical loading at high temperatures.