



NASA SBIR 2017 Phase I Solicitation

Aeronautics Research

A1.01 Structural Efficiency-Tailored Airframe & Structures

Lead Center: LaRC

Participating Center(s): AFRC

Technology Area: TA15 Aeronautics

A primary goal of structural efficiency is to reduce structural mass. Reduced mass has the direct benefit of fuel burn savings, and it also influences noise and emissions by enabling advances in airframe configurations and in propulsion. The state of the art for lightweight airframe structures are carbon fiber reinforced polymeric composite structures which make up approximately 50% of the weight of Boeing's 787. Further improvements in structural efficiency above the state of the art are possible with tailored materials and structures. Tailored materials can improve the mechanical properties that directly affect structural mass, can provide functional properties that eliminate systems that add parasitic mass (e.g., to accommodate thermal, electrical, acoustic loads), or both. Tailored structures can improve the structural efficiency of existing airframe configurations and can enable new, non-traditional airframes. The tailoring covered for this subtopic solicitation is intended to apply to fuselage structures, and is further focused on one or more of the following:

- Tailoring mechanical properties beyond the state of the art by taking advantage of newly available product forms and precision robotic fabrication such as to control composite ply thicknesses and orientations
- Tailoring mechanical and functional properties through “designer microstructures” such as alloys that enhance fatigue, polymer composites with advanced fibers and/or nanostructured constituents, or hybrid metal-composite laminates, where the additional functional capability eliminates a parasitic mass (e.g., lightning protection, cooling systems, acoustic dampening)
- Design and analysis codes that enable development of structural concepts that utilize the aforementioned tailored properties, product forms, and fabrication processes to developed fuselage structures for traditional tube-wing and for advanced configurations.

For this subtopic, the Phase I proposal should identify an airframe component/application that would be the target of the tailored material and/or structural approach, should describe how the proposed approach would provide a significant improvement in structural efficiency over the state of the art, and should describe how the feasibility of the innovation to achieve this improvement will be demonstrated in a Phase I effort. The intention of a Phase II follow-on effort would be to develop or to further mature the necessary design/analysis codes, and to validate the approach through design, build, and test of an article representative of the component/application identified in Phase I.

Note: This subtopic is distinctly addressing materials (including product forms and processing), structures and design technologies as they relate to tailored airframe structures. If you are interested in proposing technologies addressing sensors, simulation, and analysis for NDE (and specifically how they relate to space technology) you should NOT propose to this subtopic but instead view subtopics ID# 130 and 131.

A1.02 Quiet Performance - Airframe Noise Reduction

Lead Center: LaRC

Participating Center(s): GRC

Technology Area: TA15 Aeronautics

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable aircraft. In support of the Advanced Air Vehicles, Integrated Aviation Systems and Transformative Aero Concepts Programs, improvements in noise prediction, acoustic and relevant flow field measurement methods, noise propagation and noise control are needed for subsonic, transonic and supersonic vehicles targeted specifically at airframe noise sources and the noise sources due to the aerodynamic and acoustic interaction of airframe and engines. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design purposes.
- Prediction of aerodynamic noise sources including those from the airframe and those that arise from significant interactions between airframe and propulsion systems including those relating to sonic boom.
- Prediction of sound propagation from the aircraft through a complex atmosphere to the ground. This should include interaction between noise sources and the airframe and its flow field.
- Propagation of sonic boom through realistic atmospheres, especially turbulence effects.
- Innovative source identification techniques for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of separated flow regions, vortices, shear layers, etc.
- Concepts for active and passive control of aeroacoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, and noise control technology and methods that are enabled by advanced aircraft configurations, including integrated airframe-propulsion control methodologies. Innovative acoustic liner and porous surface concepts for the reduction of airframe noise sources and/or propulsion/airframe interaction are solicited but engine nacelle liner applications are specifically excluded.
- Concepts for novel acoustic calibration sources for both open- and closed-wall wind tunnel testing. Such sources should provide well-defined acoustic characteristics both without and with flow for typical frequency ranges of interest in scale-model wind tunnel testing, for the purposes of magnitude and phase calibration for both single microphones and microphone phased arrays.
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community noise, including sonic boom.

A1.03 Low Emissions Propulsion and Power-Turboelectric and Hybrid Electric Aircraft Propulsion

Lead Center: LaRC

Participating Center(s): AFRC, LaRC

Technology Area: TA15 Aeronautics

Proposals are sought for the development of enabling power systems, electric machines, power converters, and related materials that will be required for future small (9 + pax) to large (500 + pax) commercial transport vehicles which use turboelectric or hybrid electric power generation as part of the propulsion system. Turboelectric and hybrid electric power generation as well as distributed propulsive power have been identified as candidate transformative aircraft configurations with reduced fuel burn and emissions. However, components and management methods for power generation, distribution, and conversion are not currently available in the high power ranges with the necessary efficiency, power density, electrical stability and safety required for transport-class aircraft. Novel developments are sought in:

Power Systems:

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- Aircraft power systems operating above 1000V.
 - Novel power system topologies that minimize the weight and electrical losses.

Power Components:

- Electric machines (motors/generators) with efficiency >98% and specific power >13 kW/kg, power >200kW.
- Converters (inverters/rectifiers) with efficiency >99% and specific power >19kW/kg, power >200kW.
- Circuit protection devices significantly lighter and with lower losses than the state of the art.
- Aircraft Energy Storage:
 - Rechargeable energy storage with usable specific energy at the integrated level (packaging and power management system included) >500 W-hr / kg.
 - Rechargeable energy storage with usable specific energy at the integrated level (packaging and power management system included) >250 W-hr / kg, >5C charge rate and full discharge cycle life >10,000 cycles.

Materials:

- Soft magnetic material with magnetic saturation >2.5 T.
- Hard magnetic materials with an energy product greater than neodymium iron boron.
- Conductors with a specific resistivity less than copper.
- Cable insulation materials with significantly higher dielectric strength and thermal conductivity than the state of the art.

Individual components should target the 50kW-3MW size range and would be combined into power systems in the range of 500kW-10MW total power.

A1.04 Aerodynamic Efficiency-Active Flow Control Actuators and Design Tools

Lead Center: LaRC

Participating Center(s): AFRC

Technology Area: TA15 Aeronautics

NASA's Aeronautical Research Mission Directorate (ARMD) has developed the Strategic Implementation Plan (SIP) that describes its research plan for advancing aeronautics research to meet the aviation industry's demands over the next 25 years and beyond. One element of the plan focuses on developing ultra-efficient commercial vehicles. Improved vehicle efficiency will be achieved by reducing fuel burn and emissions. Active flow control (AFC) is a technology that has the potential to aid in achieving the efficiency goals of the next two generations of commercial vehicles. Active flow control is the on-demand addition of energy into a boundary layer for maintaining, recovering, or improving vehicle performance. AFC actuation methods have included steady mass transfer via suction or blowing, and unsteady perturbations created by zero net mass flux actuators, pulsed jets, and fluidic oscillators. Previous wind tunnel and flight tests demonstrated that this technology is capable of improving vehicle performance by reducing and/or eliminating separation and increasing circulation. When integrated into a transport aircraft, therefore, AFC would result in smaller control surfaces creating less drag and thereby less fuel consumption during flight. Widespread application of the technology on commercial transports, however, requires that AFC actuation systems be energy-efficient, reliant, and robust. Another challenging aspect of the design of the actuation system involves understanding how and where to integrate the actuator into the vehicle. Computational tool development is needed, in parallel with actuator development, to enable a more synergistic approach to active flow control system design thus maximizing the potential benefits of an AFC system.

This solicitation is for innovative AFC actuator concepts and design tools, applicable to subsonic transports and/or civil aircraft that incorporate vertical lift capability, that take advantage of reduced order models to develop AFC actuators and AFC actuation systems that will aid in advancing AFC technology.

Areas of specific interest where research is solicited include but are not limited to the following:

- Development of simple, low-cost, and efficient tools for modeling AFC actuator performance.
- Development of design tools for optimizing AFC actuator system integration.
- Development of actuator concepts capable of controlling separation due to large adverse pressure gradients or shock/boundary layer interactions.
- Development of novel, energy-efficient, and robust actuation systems.
- Development of closed-loop active flow control systems with demonstrated improvements in AFC efficiency measured by the energy consumed by the AFC actuator.
- Experimental or computational studies that demonstrate the efficiency of a proposed actuation system.

A1.05 Computational Methods & Tools - High Fidelity Mesh and Geometry Tools

Lead Center: LaRC

Participating Center(s): AFRC, GRC

Technology Area: TA15 Aeronautics

During 2012-2014, NASA sponsored a study aimed at determining future directions for Computational Fluid Dynamics (CFD) research that would subsequently enable significant advancements in aeronautics. This study (CFD 2030 Study: A Path to Revolutionary Computational Aerosciences (<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140003093.pdf> [1])), noted many shortcomings in the existing technologies used for conducting high-fidelity simulations, and made specific recommendations for investments necessary to overcome these challenges. Chief among the recommendations was the need for robust higher-order discretization schemes, scalable solvers on high-performance computing (HPC) platforms, and adaptive h-p mesh refinement. It was recognized that the generation of meshes suitable for high-accuracy CFD simulations constitutes a principal bottleneck in the simulation workflow process as it requires significant human intervention. Similarly, providing access to the underlying geometry definition, as needed for both high-order simulations and adaptive gridding, is currently not available and is a further roadblock to the ubiquitous use of these technologies.

In the area of geometry definition, a critical need arises from the fact that laser scans of the aircraft surfaces are often used to generate computer aided design (CAD) files. This often leads to surface geometries with unphysical surface waviness as part of the surface fitting process of the laser scan point clouds resulting in poor CFD meshes and, hence, erroneous CFD solutions. Also, in some cases the CAD geometry is only represented as a tessellated surface while continuous and differentiable surfaces are needed for meshes that would yield accurate solutions and accurate mesh refinement results. A tool that could remove unphysical surface waviness as well as fit tessellated CAD surfaces and output a continuous and watertight spline surface is needed for practical applications.

To enable accurate CFD solutions, proposals are solicited in two areas:

- To develop robust means for generating meshes suitable for high-order accurate flow solvers, that can be demonstrated not to compromise the accuracy of the simulations. The three-dimensional unstructured grid tool developed during this research effort should be capable of creating mixed-element meshes. In conjunction with these meshes, geometry information must be easily accessible in a heterogeneous distributed computing environment through well-defined, yet lightweight, Application Programming Interface (API).
- To develop a CAD tool that could generate high-quality, continuously splined surfaces free of unphysical waviness and tessellated faces.

The new capability will be demonstrated for configurations of interest to NASA aeronautics (<http://www.aeronautics.nasa.gov/programs.htm> [2]) in terms of accuracy, speed and robustness. The proposers must present a convincing case that the proposed approach has the potential of meeting these metrics.

Phase I research is expected to develop the technology and demonstrate it on relatively simpler configurations, while Phase II will increase the technology readiness level and include demonstration on more complex configurations.

Note: This subtopic is focused on addressing high fidelity meshes and geometry tools as they relate to large scale, complex fluid dynamics simulations. If you are interested in proposing to the broader topic of computational technologies addressing emerging high performance computing hardware, you should NOT propose to this subtopic but instead view subtopic ID# S5.01.

A1.06 Vertical Lift Technology

Lead Center: LaRC

Participating Center(s): ARC, LaRC

Technology Area: TA15 Aeronautics

The Vertical Lift subtopic is primarily interested in innovative technologies to improve reliability and performance and reduce environmental impact of small-scale, autonomous, vertical lift UAVs.

The use of small UAVs for commercial operations is rapidly increasing, and the rapid pace of technology advancements in electric and hybrid-electric power and autonomy systems expands the range of commercial missions that these vehicles are performing. With increased vehicle use there will be challenges self-monitoring performance and health status to efficiently maintain these vehicles, while detecting faults and degradations before they impact mission performance or cause the loss of the vehicle or payload. In addition, there will be trade-offs in vehicle operation between maximizing mission and propulsion system performance, while minimizing the environmental impact and annoyance from noise. These trade-offs will have to be taken into account within the vehicle health management system for mission planning and execution, given that the trade-offs may be different for different parts of a mission.

Areas of interest include:

- Development and demonstration of all-electric and/or hybrid-electric technologies for vertical lift UAV propulsion systems, including validated modeling and analysis tools and prototype demonstrations, that show benefits in-terms of weight, efficiency, low noise, emissions and fuel consumption and include:
 - Development and demonstration of reconfigurable power and energy management system technologies that can maintain performance, noise and efficiency based on vehicle mission, operating environment and system status.
 - Development and demonstration of design tools integrated with on-board health-state awareness and regime recognition technologies that can predict the system life cycle and degradation over the dynamic operational life of the vehicle.
 - Development and demonstration of integrated flight/propulsion control and energy management systems that can maintain optimal power efficiency while adapting to changes in mission from the on-board intelligent health-state awareness and regime recognition technologies.

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

A1.07 Propulsion Efficiency-Propulsion Materials and Structures

Lead Center: LaRC

Participating Center(s): AFRC, LaRC

Technology Area: TA15 Aeronautics

Materials and Structures research and development contributes to NASA's ability to achieve its long-term Aeronautics goals, including the development of advanced propulsion systems. Responding to this call will require a proposal describing the intent to conduct novel research in materials and structures that is 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 the development of new, reliable, higher performance materials. Research in the areas of high-temperature metals/alloys and ceramics and polymers (and their composites) provides fundamental understanding of the underlying process-structure-property relationships of these materials.

Study of the interactions of material systems with harsh environmental conditions and the modes of failure of these systems are of particular importance to developing more advanced materials for future aircraft propulsion systems, which will be operating at higher temperatures than today's 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 engine 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, testing and characterization, and modeling.
- Innovative approaches to enhance the durability, processability, performance, and reliability of advanced materials including advanced blade and disk alloys, ceramics and CMCs (ceramic matrix composites), polymers and PMCs (polymer matrix composites), 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 760°C (1400°F).
- High strength fibers for reinforcing ceramic matrix composites and environmental barrier coatings to enable a CMC temperature capability of 1482°C (2700°F) or higher.
- Innovative methods for the evaluation of advanced materials and structural concepts under simulated operating conditions, including combinations of thermal loads and mechanical loads during environmental (application) exposure.
- Innovative processing methods that enhance high temperature material and coating properties and reliability, and/or lower cost.
- 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 tailor 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 manufacturing 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.

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- Robust and efficient modeling/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.
 - Development of physics-based models of the various failure mechanisms of the EBC (environmental barrier coatings), 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.

A1.08 Aeronautics Ground Test and Measurements Technologies

Lead Center: LaRC

Participating Center(s): GRC

Technology Area: TA15 Aeronautics

NASA's ground-based test facilities, which include low speed, transonic, supersonic, and hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, and simulation and loads laboratories, play an integral role in the design, development, evaluation, and analysis of advanced aerospace technologies and vehicles. In addition to design databases, these facilities provide critical data and fundamental insight required to understand complex phenomena and support the advancement of computational tools for modeling and simulation. The primary objective of the Aeronautics Ground Test and Measurements Technologies subtopic is to develop innovative tools and technologies that can be applied in NASA's ground-based test facilities to revolutionize wind tunnel testing and measurement capabilities and improve utilization and efficiency. For this solicitation, NASA seeks proposals for innovative research and development in the following areas:

- *Wind Tunnel Calibration and Characterization* - Capabilities for wind tunnel calibration and characterization are critical for overall enhancement of facilities and will play a critical role in achieving the CFD 2030 Vision [1]. Systems that can provide planar or volumetric measurements of flow quantities such as multi-component velocities, density, and pressure in the airflow upstream and downstream of test articles are required to quantify tunnel inflow and outflow conditions and specify boundary conditions for numerical simulations. NASA envisions using these systems in large test sections (6 feet wide by 6 feet high and larger) and desires the system design to include provisions for combining these data into the regular stream of test data provided by a given facility.
- *Model Attitude and Position Monitoring* - Measurements of wind tunnel model attitude and position (e.g., roll, pitch, yaw angles and spatial coordinates X, Y, Z relative to a defined origin and coordinate system) are critical but are often difficult to make due to packaging constraints and model orientations where gravity based sensors are not applicable. To address some of these limitations, optical and non-optical techniques are needed to provide real-time or near real-time measurements of model attitude at high data rates of 10 Hz and with sufficient accuracy (0.005± 0.0025 degrees in pitch 0.025±0.025 degrees in roll and yaw). The setup and calibration time required for these systems should be 4 hours or less to minimize the impact on tunnel operations. With regard to position monitoring, many NASA wind tunnel facilities conduct tests at elevated temperatures (above 300°F) or at extremely low temperatures (-250°F). Displacement measurement components used in actuator systems for setting hydraulic cylinder positions and other hardware used in test article support and positioning systems must operate routinely in these extreme environments. Innovative designs for sensors, position measurement and monitoring, and hardware solutions are desired to provide accurate and reliable performance at these extreme conditions.
- *Technologies for Engine Simulators* - The need to assess aerodynamic performance at higher system levels with respect to fuel-burn and noise has created a great demand for propulsion-airframe integration

(PAI) testing. Currently, PAI tests can be quite expensive due to issues related to the integration of the system into the model, reliability, complexity of the calibration, and the high pressure air and/or power which must cross the force and moment balance. NASA seeks innovative propulsion simulation systems that are more compact and capable of accurately simulating the flow, speed, and volume of actual propulsion systems, including approach and landing conditions for the assessment of airframe noise. Hydraulic, pneumatic, electric, or hybrid approaches are solicited.

NASA also seeks innovative measurement systems and techniques for monitoring and evaluating the performance of these propulsion simulation systems. Example measurement systems and techniques include, but are not limited to, simulators that permit the measurement of loads on individual blades for studies involving boundary layer ingestion, force and moment balances capable of transferring high pressure air and/or power across the balance and operating at high temperatures (up to 350°F), and wireless sensor networks that are self-powered, intelligent (e.g., self-organizing, sensor fusion), and capable of performing preprocessing at or near the sensor to reduce bandwidth requirements.

Reference:

Slotnick, J., et al., "CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences", NASA/CR-2014-218178, March 2014.

A1.09 Vehicle Safety- Internal Situational Awareness and Response

Lead Center: LaRC

Participating Center(s): AFRC, ARC, LaRC

Technology Area: TA15 Aeronautics

Achieving a vision for a safer and more efficient National Airspace (NAS) with increasing traffic and the introduction of new vehicle types requires increasingly intelligent vehicle systems able to respond to complex and changing environments in a resilient and trustworthy manner. Future air vehicles, especially autonomous vehicles, must operate with a high degree of awareness of their own well-being, and possess the internal intelligence to provide warning and potentially take action in response to off-nominal states. A vehicle's capability to independently assure safety may be the only recourse in some situations, and addresses the recurring issue of inappropriate crew response. Further, early warning of impending maintenance conditions reduces maintenance cost and vehicle down-time through improved vehicle availability and throughput. Understanding the vehicle state also has impact on vehicle performance, efficiency, and environmental impact. This Subtopic seeks technologies to enable intelligent vehicle systems with an internal situational awareness and ability to respond to off-nominal conditions for piloted vehicles augmented with autonomous capabilities, as well as increasingly autonomous unmanned air systems (excluding vertical lift vehicles).

Areas of interest include:

- Networked sensors and algorithms to provide necessary vehicle full-field state information ranging from the component level to the subsystem and system level.
- On-board hardware and software systems that are modular, scalable, redundant, high reliability, and secure with minimal vehicle impact.
- Information fusion technologies to integrate information from multiple, disparate sources and evaluate that information to determine health and operational state.
- Diagnostic and prognostic technologies that inform decision making functions with critical markers trending to unsafe state.
- Decision-making algorithms and approaches to enable trustworthy real-time operations, take preventive actions as needed in complex uncertain environments, and appropriately communicate status to other components of the NAS.
- Develop integrated systems technologies that enable the mitigation of multiple hazards, while effectively dealing with uncertainties and unexpected conditions.

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- Develop approaches that combine improved inflight vehicle state safety awareness with adaptive methods to achieve improved efficiency, performance, and reduced environmental impact.
 - Significantly enhance the fidelity and relevance of information provided to ground systems by the vehicle in-flight for use in on-demand maintenance.

A1.10 Hypersonic Technology-Improvement in Solar Operability Predictions using Computational Algorithms

Lead Center: LaRC

Participating Center(s): GRC

Technology Area: TA15 Aeronautics

The improvement of isolator operability (as defined by unstart) and performance prediction are of import to a practical dual-mode scramjet design, since the operability limits determine the optimal performance bounds of the system. Due to uncertainties in these bounds, which are typically obtained via computations and/or experiments (and extrapolated to flight environments), one must accept degraded system performance. To this end, this solicitation seeks innovative concepts to significantly advance the state-of-the-art in the predictive capability of computational algorithms, with the ultimate goal of incorporating these advances into RANS-CFD algorithms, in order to both reduce and quantify the margins and uncertainty of the coupled inlet-isolator-combustor (engine) unstart mechanism/process, applicable to relevant flight regimes and relevant dual-mode scramjet designs.

A2.01 Flight Test and Measurements Technologies

Lead Center: AFRC

Participating Center(s): GRC, LaRC

Technology Area: TA15 Aeronautics

NASA continues to see flight research as a critical element in the maturation of technology. This includes developing test techniques that improve the control of in-flight test conditions, expanding measurement and analysis methodologies, and improving test data acquisition and management with sensors and systems that have fast response, low volume, minimal intrusion, and high accuracy and reliability. By using state-of-the-art flight test techniques along with novel measurement and data acquisition technologies, NASA and aerospace industry will be able to conduct flight research more effectively and also meet the challenges presented by NASA and industry's cutting edge research and development programs.

NASA's Flight Demonstrations and Capabilities Project supports a variety of flight regimes and vehicle types ranging from low speed, sub-sonic electric propulsion, transonic civil transport, supersonic civil transport and hypersonic speeds for trans-atmospheric flight or space access vehicles. Therefore, this solicitation can cover a wide range of flight conditions and vehicles. NASA also requires improved measurement and analysis techniques for acquisition of real-time, in-flight data used to determine aerodynamic, structural, flight control, and propulsion system performance characteristics. These data will also be used to provide information necessary to safely expand the flight and test envelopes of aerospace vehicles and components. This requirement includes the development of sensors for both in-situ and remote sensing to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Flight test and measurement technologies proposals should significantly enhance the capabilities of major government and industry flight test facilities comparable to the following NASA aeronautical test facilities:

- Aeronautical Test Range.
- Aero-Structures Flight Loads Laboratory.

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- Flight Research Simulation Laboratory.
 - Research Test Bed Aircraft.

Proposals should address innovative methods and technologies to reduce costs and extend the health, maintainability, communication and test techniques of these types of flight research support facilities.

Areas of interest emphasizing flight test and measurement technologies include the following:

- High performance, real time reconfigurable software techniques for data acquisition and processing associated with IP based commands and/or IP based data input/output streams.
- High efficiency digital telemetry techniques and/or systems to enable high data rate, high volume IP based telemetry for flight test; this includes Air-to-Air and Air-to-Ground communication.
- Improve time-constrained situational awareness and decision support via integrated, secure, cloud-based web services for real-time decision making.
- Prognostic and intelligent health monitoring for hybrid and/or all electric distributed propulsion systems using an adaptive embedded control system.
- Methods for significantly extending the life of electric aircraft propulsion energy source (e.g., batteries, fuel cells, etc.).
- Test techniques, including optical-based measurement methods that capture data in various spectra, for conducting quantitative in-flight boundary layer flow visualization, Schlieren photography, near and far-field sonic boom determination, and atmospheric modeling as well as measurements of global surface pressure and shock wave propagation.
- Measurement technologies for in-flight steady and unsteady aerodynamics, juncture flow measurements, propulsion airframe integration, structural dynamics, stability & control, and propulsion system performance.
- Miniaturized fiber optic-fed measurement systems with low power requirements are desirable for migration to small business class jets or UAS platforms.
- Innovative techniques that enable safer operation of aircraft.
- Wireless sensor/sensing technologies and telecommunication that can be used for flight test instrumentation applications for manned and unmanned aircraft. This includes wireless (non-intrusion) power transferring techniques and/or wirelessly powering remote sensors.
- Innovative measurement methods that exploit autonomous remote sensing measurement technologies for supporting advanced flight testing.
- Fast imaging spectrometry that captures all dimensions (spatial/spectral/temporal) and can be used on UAS platforms.

The emphasis of this work is on flight test and flight test facility needs. Aspects of specific development of the above technologies is also addressed as appropriate elsewhere in the NASA SBIR call.

A2.02 Unmanned Aircraft Systems Technology

Lead Center: AFRC

Participating Center(s): GRC, LaRC

Technology Area: TA15 Aeronautics

Unmanned Aircraft Systems (UAS) offer advantages over manned aircraft for applications which are dangerous to humans, long in duration, require great precision, and require quick reaction. Examples of such applications include remote sensing, disaster response, delivery of goods, agricultural support, and many other known and yet to be discovered. In addition, the future of UAS promises great economic and operational advantages by requiring less human participation, less human training, an ability to take-off and land at any location, and the ability to react to dynamic situations.

NASA is involved in research that would greatly benefit from breakthroughs in UAS capabilities. Flight research of

basic aerodynamics and advanced aero-vehicle concept would be revolutionized with an ability of UAS teams to cooperate and interact while making real time decisions based upon sensor data with little human oversight. Commercial industry would likewise be revolutionized with such abilities.

There are multiple technological barriers that are restricting greater use and application of UAS in NASA research and in civil aviation. These barriers include, but are not limited to, the lack of methods, architectures, and tools which enable:

- The verification, validation, and certification of complex and/or nondeterministic systems.
- Humans to operate multiple UAS with minimal oversight.
- Multi-vehicle cooperation and interoperability.
- High level machine perception, cognition, and decision making.
- Inexpensive secure and reliable communications.

This solicitation is intended to break through these and other barriers with innovative and high-risk research.

The Integrated Aviation Systems Program's work on UAS Technology for the FY 2016 NASA SBIR solicitation is focused on breaking through barriers to enable greater use of UAS in NASA research and in civil aviation use. The following five research areas are the primary focus of this solicitation, but other closely related areas will also be considered for reward. The primary research areas are:

- *Verification, Validation, and Certification* - New inexpensive methods of verification, validation, and certification need to be developed which enable application of complex systems to be certified for use in the national airspace system. Proposed research could include novel hardware and software architectures that enable or circumvent traditional verification and validation requirements.
- *Operation of Multiple UAS with Minimal Human Oversight* - Novel methods, software, and hardware that enable the operation of multiple UAS by a single human with minimal oversight need to be developed which ensure robust and safe operations. Proposed research could include novel hardware and software architectures which provide guarantees of safe UAS operations.
- *Multi-Vehicle Cooperation and Interoperability* - Technologies that enable UAS to interact in teams, including legacy vehicles, need to be developed. This includes technologies that enable UAS to negotiate with others to find optimal routes, optimal task allocations, and optimal use of resources. Proposed research could include hardware and software architectures which enable UAS to operate in large cooperative and interactive teams
- *Sensing, Perception, Cognition, and Decision Making* - Technologies need to be developed that provide the ability of UAS to detect and extract internal and external information of the vehicle, transform the raw data into abstract information which can be understood by machines or humans, and recognize patterns and make decisions based on the data and patterns.
- *Inexpensive, Reliable, and Secure Communications* - Inexpensive methods which ensure reliable and secure communications for increasingly interconnected and complex networks need to be developed that are immune from sophisticated cyber-physical attacks.

Phase I deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
- A technology demonstration in a simulation environment which clearly shows the benefits of the technology developed.
- A written plan to continue the technology development and/or to infuse the technology into the UAS market. This may be part of the final report.

Phase II deliverables should include, but are not limited to:

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- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
 - A technology demonstration in a relevant flight environment which clearly shows the benefits of the technology developed.
 - Evidence of infusing the technology into the UAS market or a clear written plan for near term infusion of the technology into the UAS market. This may be part of the final report.

A3.01 Advanced Air Traffic Management Systems Concepts

Lead Center: ARC

Participating Center(s): LaRC

Technology Area: TA15 Aeronautics

This subtopic addresses user needs and performance capabilities, trajectory-based operations, and the optimal assignment of humans and automation to air transportation system functions, gate-to-gate concepts and technologies to increase capacity and throughput of the National Airspace System (NAS), and achieving high efficiency in using aircraft, airports, en-route and terminal airspace resources, while accommodating an increasing variety of missions and vehicle types, including full integration of Unmanned Aerial Systems (UAS) operations. Examples of concepts or technologies that are sought include:

- Verification and validation methods and capabilities to enable safe, end-to-end NextGen Trajectory-Based Operations (TBO) functionality and seamless UAS operations, as well as other future aviation system concepts and architectures.
- Performance requirements, functional allocation definitions, and other critical data for integrated, end-to-end NextGen TBO functionality, and seamless UAS operations, as well as other future aviation system concepts and architectures.
- Prognostic safety risk management solutions and concepts for emergent risks.
- TBO concepts and enabling technology solutions that leverage revolutionary capabilities and that enable capacity, throughput, and efficiency gains within the various phases of gate-to-gate operations.
- Networked/cloud-based systems to increase system predictability and reduce total cost of National Airspace System operations.

It is envisioned that the outcome of these concepts and technologies will provide greater system-wide safety, predictability, and reliability through full NextGen (2025-2035 timeframe) functionality.

A3.02 Autonomy of the National Airspace Systems (NAS)

Lead Center: ARC

Participating Center(s): LaRC

Technology Area: TA15 Aeronautics

Develop concepts or technologies focused on increasing the efficiency of the air transportation system within the mid-term operational paradigm (2025-2035 timeframe), in areas that would culminate in autonomy products to improve mobility, scalability, efficiency, safety, and cost-competitiveness. Proposals in the followings areas in product-oriented research and development are sought, but are not limited to:

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- Autonomous and safe Unmanned Aerial Vehicle (UAV) operations for the last and first 50 feet, under diverse weather conditions.
 - Autonomous or increasing levels of autonomy for, or towards, any of the following:
 - Networked cockpit management.
 - Traffic flow management.
 - Airport management.
 - Metroplex management.
 - Integrated Arrival/Departure/Surface operations.
 - Low altitude airspace operations.
 - Autonomy (or self-management) -based architectures for the entirety, or parts, of airspace operations.
 - Autonomous systems to produce any of the following system capabilities:
 - Prognostics, data mining, and data discovery to identify opportunities for improvement in airspace operations.
 - Weather-integrated flight planning, rerouting, and execution.
 - Fleet, crew, and airspace management to reduce the total cost of operations.
 - Predictions of unsafe conditions for vehicles, airspace, or dispatch operations.
 - Performance driven, all-operations, human-autonomy teaming management.
 - Verification and validation tools for increasingly autonomous operations.
 - Machine learning and/or self-learning algorithms for Shadow Mode Assessment using Realistic Technologies for the National Airspace System (NAS).
 - Autonomy/autonomous technologies and concepts for trajectory management and efficient/safe traffic flows.
 - Adaptive automation/human-system integration concepts, technologies and solutions that increase operator (pilot and or controller) efficiency and safety, and reduce workload to enable advances in air traffic movement and operations.

A3.03 Future Aviation Systems Safety

Lead Center: ARC

Participating Center(s): LaRC

Technology Area: TA15 Aeronautics

The Aeronautics Research Mission Directorate (ARMD) Airspace Operations and Safety Program (AOSP) is leading research in the area of integrated safety monitoring and assurance that detects, predicts and prevents safety problems in real-time. ARMD sees its future, safety-related research focused in a forward looking, more comprehensive system-wide direction and is currently vetting a roadmap for Real-Time System-Wide Safety Assurance (RSSA) strategic activities.

Tools are being sought for use in creating a prototype of a RSSA capability. The ultimate vision for RSSA is the delivery of a progression of capabilities that accelerate the detection, prognosis and resolution of system-wide threats.

Proposals under this subtopic are sought, but not limited to, these areas:

- Develop and demonstrate data mining tools and techniques to detect and identify anomalies and precursors to safety threats system-wide.
- Develop and demonstrate tools and techniques to assess and predict safety margins system-wide to assure airspace safety.
- Develop and demonstrate prognostic decision support tools and techniques capable of supporting real-time safety assurance.
- Develop and demonstrate V&V tools and techniques for assuring the safety of air traffic applications during

certification and throughout their lifecycles, and, techniques for supporting the real-time monitoring of safety requirements during operation.

- Develop and demonstrate products to address technologies, simulation capabilities and procedures for reducing flight risk in areas of attitude and energy aircraft state awareness.
- Develop and demonstrate decision support tools and automation that will reduce safety risks on the airport surface for normal operations and during severe weather events.
- Develop and demonstrate alerting strategies/protocols/techniques that consider operational context, as well as operator state, traits, and intent.
- Develop methodologies and tools for integrated prevention, mitigation, and recovery plans with information uncertainty and system dynamics in a TBO environment
- Develop and demonstrate strategies for optimal human-machine coordination for real-time hazard mitigation.
- Develop measurement methods and metrics for human-machine team performance and mitigation resolution.
- Develop system-level performance models and metrics that include interdependencies and relationships among human and machine system elements.