



## NASA SBIR 2014 Phase I Solicitation

### Aeronautics Research

#### Aviation Safety Topic A1

The Aviation Safety Program conducts fundamental research and technology development of known and predicted safety concerns as the nation transitions to the Next Generation Air Transportation System (NextGen). Future challenges to maintaining aviation safety arise from expected significant increases in air traffic, continued operation of legacy vehicles, introduction of new vehicle concepts, increased reliance on automation, and increased operating complexity. Further design challenges also exist where safety barriers may prevent the technical innovations necessary to achieve NextGen capacity and efficiency goals. The program seeks capabilities furthering the practice of proactive safety management and design methodologies and solutions to predict and prevent safety issues, to monitor for them in-flight and mitigate against them should they occur, to analyze and design them out of complex system behaviors, and to constantly analyze designs and operational data for potential hazards. AvSP's top ten technical challenges are:

- Assurance of Flight Critical Systems
- Discovery of Precursors to Safety Incidents
- Assuring Safe Human-Systems Integration
- Prognostic Algorithm Design for Safety Assurance
- Maintain Vehicle Safety Between Major Inspections
- Improve Crew Decision-Making and Response in Complex Situations
- Assure Safe and Effective Aircraft Control under Hazardous Conditions
- Engine Icing Characterization and Simulation Capability
- Airframe Icing Simulation and Engineering Tool Capability
- Atmospheric Hazard Sensing and Mitigation Technology Capability

AvSP includes three research projects:

- The System-wide Safety Assurance Technologies Project identifies risks and provides knowledge required to safely manage increasing complexity in the design and operation of vehicles and the air transportation systems, including advanced approaches to enable improved and cost-effective verification and validation of flight-critical systems.
- By addressing important issues related to past accidents and considering emerging potential hazards associated with future operations, the Vehicle Systems Safety Technologies Project provides enhanced vehicle design, structure, systems, and operating concepts to enable a reduction in accidents and incidents.
- The Atmospheric Environment Safety Technologies Project investigates sources of risk and provides technology needed to help ensure safe flight in and around atmospheric hazards. NASA seeks highly innovative proposals that will complement its work in science and technologies that build upon and advance the Agency's unique safety-related research capabilities vital to aviation safety. Additional information is available at ([http://www.aeronautics.nasa.gov/programs\\_avsafe.htm](http://www.aeronautics.nasa.gov/programs_avsafe.htm) [1]).

Sub Topics:

#### A1.01 Aviation External Hazard Sensor Technologies

Lead Center: LaRC

Participating Center(s): AFRC, GRC

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NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Hazardous flight conditions of particular interest are: wake vortices, clear-air turbulence, in-flight icing, lightning, and low visibility. NASA is interested in new and innovative methods for detection, identification, evaluation, and monitoring of in-flight hazards to aviation. In the case of lightning, interest is centered on the mitigation and in-flight measurement of lightning damage, particularly to composite aircraft.

NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices. Proposed products may be for retrofit into current aircraft or for installation in future aircraft. Both manned and unmanned aircraft are of interest.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen). Additional information is available at (<http://www.jpdo.gov> [2]). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable, and effective sensors that will have a strong benefit to safety. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are required for NextGen.

Under this subtopic, proposals are invited that explore new and improved sensors and sensor systems for the detection and monitoring of hazards to aircraft before they are encountered. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest. With regard to hazardous lightning conditions, the emphasis is not on remote detection, but rather on developing systems that make aircraft more robust in a lightning environment or provide in-flight damage assessment or other hazard mitigating benefits. The design and development of composite materials and composite construction methods are not included in this subtopic. The scope of this subtopic does not include human factors and focused development of human interfaces, including displays and alerts. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported.

Areas of particular interest to NASA at this time are described in more detail below. The list and details are provided as encouragement but are not intended to exclude other proposals that fit the scope of this subtopic.

## Lightning

- *Lightning Strike Protection* - NASA is investigating means for mitigating damage to aircraft, with a particular interest in protecting composite aircraft. Currently, an electrically-conductive screen protects composite aircraft by functioning as a Faraday shield and is intended to confine lightning and electromagnetic effects to the outside or outermost skin of the aircraft. The lightning strike protection system, hereafter referred to as the LSP, is incorporated in the coatings, layers, and structure that comprise the skin of the aircraft. NASA is most interested in LSP solutions that will be cost effective and light-weight. The design and development of composite materials and construction methods is out of scope for this subtopic.
- *Mitigation of Lightning Strike Damage* - NASA is seeking solutions that will provide better protection from lightning damage by directing attachment points or lightning currents to safe or less hazardous areas and by reducing the susceptibility of the aircraft to thermal or other damage due to strikes.
- *In-flight Lightning Damage Measurement and Assessment* - A typical commercial aircraft is struck by lightning about once per year. At this time, composite aircraft that are struck in-flight are inspected upon landing for a damage assessment. Such assessments may be time-consuming and difficult. Innovations that will provide a measurement or damage detection system in the LSP are solicited. The objective would be to achieve a capability to have damage detection and assessment in the aircraft that will provide immediate information to the flight crew after a lightning attachment.

## Polarimetric Radar Technology

- *Polarimetric Antennas* - Recent investigations indicate that polarimetric capability would provide a substantial advancement in airborne weather radar. Flat plate, slot antenna (single polarity) arrays currently in use are cost-effective, light-weight, and rugged. An innovative polarimetric antenna design that meets the same criteria would be a major step toward implementation of polarimetric radar. Existing commercial

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aircraft dictate the antenna system requirements, and new antenna designs should be suitable for retrofit. Innovative techniques, designs, or developments that lead to polarimetric antennas that are affordable and effective and can be retrofit to existing commercial aircraft are solicited.

## **Turbulence and Wake Vortex**

- *Remote Detection of Kinetic Air Hazards* - The class of hazards including wake vortices, turbulence, and other hazards associated with air motion is referred to as kinetic air hazards. Within this class, wakes and turbulence are the highest priorities; however, NASA is particularly interested in sensor systems that can detect multiple hazards and thus provide greater utility. For example, air data systems are at times disabled by icing, and a multi-function, multi-hazard sensor that includes a robust alternative air data source would be a great asset in such conditions.
- *Airborne Detection of Wake Vortices* - Airborne detection of wake vortices is considered challenging due to the fact that detection must be possible in nearly all weather conditions, in order to be practical, and because of the size and nature of the phenomena. In particular, NASA is interested in the ability to detect and measure wake vortex hazards for arbitrary viewing angles.
- *Airborne Detection of Turbulence* - NASA has made a major investment in the development of new and enhanced technologies to enable detection of turbulence to improve aviation safety. Progress has been made in efforts to quantify hazard levels from convectively induced turbulence events and to make these quantitative assessments available to civil and commercial aviation. NASA is interested in expanding these prior efforts to take advantage of the newly developing turbulence monitoring technologies, particularly those focused on clear air turbulence (CAT). NASA welcomes proposals that explore the methods, algorithms and quantitative assessment of turbulence for the purpose of increasing aviation safety and augmenting currently available data in support of NextGen operations.

## **A1.02 Inflight Icing Hazard Mitigation Technology**

**Lead Center: GRC**

NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Under this subtopic, proposals are invited that explore new and dramatically improved research tools and technologies related to inflight airframe and engine icing hazards for manned and unmanned vehicles. Technologies of interest should address the detection, measurement, and/or the mitigation of the hazards of flight into super-cooled liquid water clouds and flight into regions of high mass concentrations of ice crystal.

Areas of particular interest include:

- Technology to measure the phase (ice or liquid), size, and mass concentration of ice and liquid density of water particles as they are ingested into a turbofan engine core flow path and in upstream wind tunnel ducts.
- Technology to measure the mass of water that impinges on the leading edge of airframe components for droplet spectra having median volumetric diameters from 20 to 1000 microns. Past measurement methods using dye-tracers and blotter paper have demonstrated limitations, particularly for larger drop sizes. More advanced methods are sought that can improve accuracy and measurement time.
- Non-destructive 3-D ice density measurements of ice accretions on wind tunnel models. NASA has a need for non-optical methods to digitize ice shapes with rough external surfaces and internal voids as can occur with accretions on highly swept wings. Technologies proposed must be compatible with working within a wind tunnel testing environment.

## **A1.03 Real-Time Safety Assurance under Unanticipated and Hazardous Conditions**

**Lead Center: LaRC**

Assuring safety of flight under uncertain, unanticipated, and multiple hazards is a core requirement for aircraft loss

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of control prevention and for safety-assured autonomous aircraft operations. Sources of hazards include adverse onboard conditions (e.g., system failures, vehicle impairment or damage), external disturbances (e.g., turbulence, inclement weather, wake vortices), and abnormal flight conditions (e.g., abnormal attitudes/rates, unsafe/abnormal flight trajectories, stall/departure). Research is sought that supports real-time flight safety assurance in either of the following critical areas:

- *Real-time Flight Safety Management* - Assuring flight safety requires the real-time ability to assess impacts and risks of current or impending hazards, and to enforce minimum flight safety margins. Research in this area includes:
  - Definition of flight safety and its core components.
  - Development of methodologies and algorithms for predicting impacts and risks to flight safety (or one or more key components) of uncertain, unanticipated, and multiple hazards.
  - Development of a supervisory control system that ensures a minimum margin of flight safety under uncertain, unanticipated, and multiple hazards.
  - Evaluation of flight safety prediction and supervisory control algorithms using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.
- *Real-time Sensor Integrity Management* - Assuring the integrity of information required for aircraft control is a core requirement in assuring flight safety. Research in this area focuses on assuring the integrity of flight dynamics and control parameters and includes:
  - Development of a methodology to utilize all available information from diverse physical and virtual sensors in order to rapidly detect, isolate, and mitigate erroneous behavior within a sensor or sensor suite in real time.
  - Utilization of information fusion across multiple sensors (physical and virtual) and algorithmic redundancy to estimate lost information from failed sensor(s).
  - Assurance of information integrity under turbulence, noise, and abnormal and highly nonlinear flight conditions associated with aircraft loss of control.
  - Evaluation of sensor integrity management algorithms and the integrated system using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.

#### **A1.04 Prognostics and Decision Making**

**Lead Center: ARC**

Research should be conducted to demonstrate technical feasibility during Phase I and to show a path toward a Phase II technology demonstration. Proposals are solicited that address aspects of the following areas:

- Remaining Useful Life (RUL) prediction techniques that address a set of fault modes for a device or component, for example by modeling the physics of the most critical fault modes and using (typically less accurate) data-driven methods for the remainder.
- Physics-based damage propagation models for one or more relevant aircraft subsystems such as airframe structures, avionics, electrical power systems, and electronics. Methods for damage propagation in composite structures are of a particular interest. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
- Uncertainty quantification and management for prognostics. Proposers are encouraged to quantify prognostic uncertainty by accounting for the effects of modeling uncertainty, measurement errors, algorithmic uncertainties, as well as uncertainties stemming from estimation of future loads and environmental conditions. Methods for reducing prognostic uncertainty estimates are of particular interest. Proposals can consider the fusion of different techniques for uncertainty quantification and management but must demonstrate (using the appropriate metrics) the direct benefits of using such an approach in improving uncertainty estimates.
- Aircraft-relevant test beds that can generate aging and degradation datasets for the development and validation of prognostic techniques.
- Verification and validation methods for prognostic algorithms.

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If prognostic algorithms are being developed, performance needs to be measured on benchmark data sets using prognostic metrics for accuracy, precision, and robustness. Metrics should include prognostic horizon (PH), alpha-lambda, relative accuracy (RA), convergence, and R\_delta.

### **A1.05 Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems**

**Lead Center: ARC**

The fulfillment of the SSAT project's goal requires the ability to transform vast amounts of data produced by aircraft and associated systems and people into actionable knowledge that will aid in detection, causal analysis, and prediction at levels ranging from the aircraft-level, to the fleet-level, and ultimately to the level of the national airspace. For this topic, we are especially interested in automated discovery of previously unknown precursors to aviation safety incidents involving human - automation interaction. We expect to gain knowledge on latent deficiencies in crew training, communication, and operations that is of paramount importance to future SSAT project goals and objectives. The incorporation of human performance will be invaluable to the success of this effort, and as such it will be important to use heterogeneous data from varied sources that are matched on a per-flight basis with flight-recorded data, such as radar track data, airport information, weather data, flight crew schedule information, maintenance information, and Air Safety Reports. This topic will develop revolutionary and first-of-a-kind methods and tools that incorporate the limitations of human performance throughout the design lifecycle of human-automation systems to increase safety and reduce validation costs in NextGen.

The focus of this effort will be from the aircraft-level to fleet level and above. As such, the successful proposal will develop validated predictive analytics to uncover systemic human-automation interaction issues that manifest at a much broader level than those incidents that occur within a single flight or for a single aircraft. Real data from a defunct airline will be made available as GFE (government furnished equipment), representing the interactions between humans and automation found on flight systems, data from aircraft as well as supporting ground-based systems. As such, a deep knowledge of algorithmic development across multiple heterogeneous data sources and the ability to address recent developments in the growing area of "big data" should be clearly demonstrated. The successful proposer will have a proven track record of deploying groundbreaking, innovative approaches in a real-world setting to similar "big data" challenges.

#### **Unmanned Aircraft Systems Topic A2**

The Integrated Systems Research Program (ISRP) conducts research at an integrated system-level on promising concepts and technologies and explores, assesses and/or demonstrates their benefits in a relevant environment. The integrated system-level research in this program will be coordinated with on-going long-term, foundational research within the Aeronautics Research Mission Directorate's other research programs, as well as efforts within other Federal Government agencies. As the NextGen air transportation system evolves to meet the projected growth in demand for air transportation, researchers must address the national challenges of mobility, capacity, safety, and energy and the environment in order to meet the expected growth in air traffic. In particular, the environmental impacts of noise and emissions are a growing concern and could limit the ability of the system to accommodate growth. ISRP will explore and assess new vehicle concepts and enabling technologies through system-level experimentation and will focus specifically on maturing and integrating technologies in major vehicle systems/subsystems for accelerated transition to practical application. ISRP is comprised of two existing projects – the Environmentally Responsible Aviation (ERA) Project and the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project, and one new project starting in Fiscal year 2014, the Advanced Composites Project. The UAS Integration in the NAS Project, specifically, seeks to reduce or eliminate critical technical barriers of integrating UAS in to the national Airspace system through integrated system-level testing in relevant environments. At present, the project has four main focuses:

- *Separation Assurance* - Safely and seamlessly integrate UAS into NextGen separation assurance through demonstrate of 4DT applications that result in the same or fewer losses of separation as traditional

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separation services.

- *Human Systems Integration* - Demonstrate reduced workload of UAS pilots by advanced interface design and automation; Collect Human in the Loop (HITL) data to apply to computational model that provides for 100% situational awareness of aircraft within 5 nm and 1200 ft; and Develop at standard against which to assess UAS ground control stations.
- *Communication* - Demonstrate a secure UAS command and control datalink which meets communication confidentiality, availability and integrity requirements and which meets FAA communication latency requirements.
- *Certification* - Document applicability of possible certification method meeting airworthiness requirements for the full range of UAS and collect UAS-specific data in a civil context to support development of standards and regulations. Integrated Test and Evaluation:
  - Creation of an appropriate test environment.
  - Integration of the technical research to probe and evaluate the concepts; and
  - Coordination and prioritization of facility and aircraft schedules.

Sub Topics:

## **A2.01 Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research**

**Lead Center: AFRC**

**Participating Center(s): ARC, GRC, LaRC**

The following subtopic is in support of the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project under the Integrated Systems Research Program (ISRP). There is an increasing need to fly UAS in the NAS to perform missions of vital importance to National Security and Defense, Emergency Management, Science, and to enable commercial applications. The UAS Integration in the NAS Project is structured under the following technical challenges:

- *Airspace Integration* - Validate technologies and procedures for UAS to remain an appropriate distance from other aircraft, and to safely and routinely interoperate with NAS and NextGen Air Traffic Services (ATS).
- *Standards/Regulations* - Validate minimum system and operational performance standards and certification requirements and procedures for UAS to safely operate in the NAS.
- *Relevant Test Environment* - Develop an adaptable, scalable, and schedulable relevant test environment for validating concepts and technologies for UAS to safely operate in the NAS. The Federal Aviation Administration (FAA) regulations are built upon the condition of a pilot being in an aircraft.

There exist few, if any, regulations specifically addressing UAS today. The primary user of UAS to date has been the military. The technologies and procedures to enable seamless operation and integration of UAS in the NAS need to be developed, validated, and employed by the FAA through rule making and policy development.

The Project goal is to provide research findings to reduce technical barriers associated with integrating UAS into the NAS utilizing integrated system level tests in a relevant environment. The project is currently broken down into five subprojects:

- Separation Assurance/Sense and Avoid Interoperability (SSI)
- Communications
- Human Systems Integration
- Certification
- Integrated Test and Evaluation

The fifth subproject, Integrated Test and Evaluation, is responsible for developing a live, virtual, and constructive test environment for the other four subprojects. During the first phase, (May-2011 to September-2013) the project has:

- Conducted initial modeling, simulation, and flight testing.

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- Completed early subproject-focused deliverables (spectrum requirements, comparative analysis of certification methodologies, etc.).
  - Validated the key technical elements identified by the project.

The plan for the second phase includes the following:

- Conduct systems-level, integrated testing of concepts and/or capabilities that address barriers to routine access to the NAS.
- Develop a body of evidence (including validated data, algorithms, analysis, and recommendations) to support key decision makers in establishing policy, procedures, standards and regulations, enabling routine UAS access in the NAS.

This solicitation seeks proposals, but is not limited, to develop concepts that can reduce the technical barriers related to the safety and operational challenges of routine UAS operations in the NAS.

- *Certified Control and Non-Payload Communications (CNPC) system* - Current civil UAS operations are significantly constrained by the lack of a standardized, certified control and non-payload communications (CNPC) system. The UAS CNPC system is to provide communications functions between the Unmanned Aircraft (UA) and the UA ground control station for such applications as: telecommands; non-payload telemetry; navigation aid data; air traffic control (ATC) voice relay; air traffic services (ATS) data relay; sense and avoid data relay; airborne weather radar data; and non-payload situational awareness video. New and innovative approaches to providing terrestrial and space-based high-bandwidth CNPC systems that are inexpensive, small, low latency, reliable, and secure offer opportunities for quantum jumps in UAS utility and capabilities. Of particular interest are:
  - Technologies for High power C-band amplifiers and highly linear C-band power amplifiers/linearization of high power C-band amplifiers.
  - Miniaturization of C-band terrestrial radio components/systems and C- Ku- and Ka-Band satellite communications components/systems.
  - Conformal steerable antennas for satellite communications links in C-, Ku- and Ka Band.
- *Weather Information Systems for GCS* - On-board, real-time graphic aviation weather information products have been developed and successfully implemented for manned cockpits. Their use is now widespread and their safety impact widely recognized. The applicability of such products for operators and ground control pilots to enhance situation awareness and improve mission planning and execution is of interest to NASA. Systems such as the NASA developed Aviation Weather Information (AWIN) system that included software, data and data-link applications, color weather graphics such as composite-radar mosaic, lightning-strike data, wind data, satellite images and forecasts could be integrated into a ground control station to provide pilots with weather awareness before and during mission execution. Improved weather awareness should allow aircrews to avoid most weather-related problems through both pre-flight and en-route planning. While the use of these systems has been explored for military UAS operations, their applicability to civil and public operations has not yet been explored.
- *Safety Analysis and Methodologies* - UAS operations are untried in the civil NAS. Unlike other aircraft, there is not an extensive record of civil operations upon which to forecast the safety of UAS operations in the NAS. The introduction of UAS into the NAS raises many safety issues and concerns. Typically, anytime a new capability is added into the NAS, an Operational Safety Assessment (OSA) is performed by the FAA, to determine whether that introduction of new capability will enhance or detract from the safety of the NAS. As these UAS represent a wholly new operational system, traditional approaches cannot suffice. Research is needed to identify and develop new safety analysis approaches, as well as prognostic indicators and potential new safety metrics.
- *Autonomous Operations* - As vehicle capabilities and machine intelligence continue to evolve, it is expected that future air vehicles, especially unmanned vehicles, will assume an increasing level of independent decision-making, flight monitoring and management, and trajectory management. As the Next-Generation Air Traffic Management System (NextGen) continues to evolve and expand, the future system will need to concurrently develop operational accommodations for these aircraft that manifest increasing levels of autonomy. Thus, autonomous vehicles and NextGen must evolve in complementary ways to accommodate these future operational considerations. At a minimum, future autonomous systems must demonstrate successfully the following characteristics:
  - Collision/hazard avoidance.

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- Autonomous navigation under uncertain conditions.
  - Cooperative task completion (if more than one aircraft is needed for a particular operation).
  - Recognition of anomalies.
  - Long term system diagnostics, failure prediction and correction.
  - *Development of a UAS Flight Inspection and Cargo Aircraft Capability Concept* - Currently the FAA conducts flight inspections of the ground based air navigational aids and guidance systems (MLS, TACAN, VASI) in Antarctica using a CL-601 Challenger corporate executive jet type of aircraft, not certified for operations from ice and gravel runways. The risk for damage to these costly aircraft is high and no flights are made to remote areas, like Antarctica, without the inclusion of maintenance personnel among the crew. A UAS, RPV equipped for flight inspection work in Antarctica and other remote areas utilizing a simple rugged STOL type of vehicle, ski or wheel equipped, (thus capable of operating from rough snow, ice and short gravel runways) would greatly reduce the risks and costs of flight inspecting and light air logistics in Antarctica. The environment in Antarctica is a perfect venue to demonstrate an efficient, practical and environmental friendly use of unmanned aircraft technologies to a worldwide audience. Basic requirements for a drone utilized in this type of operation include:
    - Ability to carry a 1000-pound payload 800 nautical miles and return with no need for additional fuel.
    - Be TCAS responsive and “visible” to other traffic.
    - Be equipped with bubble observation windows and mounts for various surveillance and photography systems.
    - Have the capability to operate from the short gravel runways.

#### Air Vehicle Technology Topic A3

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 &



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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.

Sub Topics:

### **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

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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.

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### **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

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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

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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 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 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.

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- 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.

#### Ground and Flight Test Techniques and Measurement Topic A4

The Aeronautics Test Program (ATP) supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate from takeoff speeds through Mach 10. It ensures the long-term availability and health of NASA's major wind tunnels/ground test facilities and flight operations/test infrastructure, providing support for NASA, DoD and U.S. industry research and development (R&D) and test and evaluation (T&E) requirements. Furthermore, ATP provides rate stability to the aforementioned user community. The ATP is divided into the Flight Test and the Ground Test Projects with facilities are located at four NASA Centers, including the Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities include low speed, transonic, supersonic, and hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support & test bed aircraft, and the simulation and loads laboratories. A key component of ensuring a test facility's long-term viability is to implement and continually improve on the efficiency and effectiveness of that facility's operations along with developing new technologies to address the nation's future aerospace challenges. To operate a facility in this manner requires the use of state-of-the-art test technologies and test techniques, creative facility performance capability enhancements, and novel means of acquiring test data. This year the primary emphasis is on ground testing requirements. NASA is soliciting proposals in the areas of instrumentation, test measurement technology, test techniques and facility development that apply to the ATP facilities to help in achieving the ATP goals of sustaining and improving our test capabilities. Proposals that describe products or processes that are transportable across multiple facility classes are of special interest. The proposals will also be assessed for their ability to develop products that can be implemented across government-owned, industry and academic institution test facilities. Additional information is available at (<http://www.aeronautics.nasa.gov/atp/index.html> [3]).

Sub Topics:

#### **A4.01 Ground Test Techniques and Measurement Technologies**

**Lead Center: LaRC**

**Participating Center(s): AFRC, ARC, GRC**

The Ground and Flight Test Techniques and Measurements topic supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate from takeoff speeds to Mach 10, as well as the testing requirements of other government and commercial entities. The primary objective is to develop innovative tools and technologies that enhance measurement capabilities, improve ground and flight resource utilization, and provide capability sustainment. This year the primary emphasis is on ground testing requirements.

Wind tunnel vehicle design databases have traditionally included the foundational measurements of forces, discrete surface pressures, and discrete surface temperatures. However, designing and testing future vehicles with highly integrated and possibly distributed propulsion and flow control systems will require enhanced, remotely sensed global surface measurements to accurately define the vehicle performance and acoustic levels covering a

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wide range of operational conditions. Enhanced optical systems are required to visualize the flow interactions both on and off the surface. Non-intrusive measurement systems offering multi-component velocities, density, and pressure in the tunnel stream are required to routinely quantify and baseline the test environment and to establish boundary conditions for advanced computational simulations. Non-intrusive measurements of off-body and near-body flow parameters both at a point and globally (i.e., planar or volumetric) are necessary to examine fluid-fluid and fluid-structure interactions for computational solution validation. In all cases, significant measurement accuracy enhancements are required to achieve the revolutionary aircraft systems of the future. Measurement systems must be robust and user-friendly to achieve the level of utility required for practical and routine application. Clean seeding methods that do not contaminate anti-turbulence screens are required in the wind tunnel testing environment; seedless methods for velocity measurements are particularly desired. Compact measurement systems and analysis techniques with dual use capability in both ground and flight test environments are valuable, enabling smooth transition between each. Since wind tunnel test data must ultimately represent free-air conditions, techniques and/or analysis methods that can demonstrate and articulate novel ground to flight extrapolation methodologies are sought. In all cases, measurement methods that can significantly increase data capture per test point are desired, including the simultaneous measurement of multiple flow parameters. Accordingly, the topic solicits cutting-edge enhancements that significantly improve existing test and measurement capabilities, and enabling tools that provide new opportunities for aerodynamic and aerothermodynamic discovery for NextGen and high-speed transportation systems.

The contraction of the Nation's ground-based testing resources emphasizes the technological need to improve wind tunnel utilization. Advanced methods that aid pre-test planning, improve data collection, enhance visual display in a data rich environment, and provide rapid analysis are solicited.

With an aging and reduced workforce comes the challenge of capability sustainment. Tools and technologies are solicited that enable knowledge capture, offer ubiquitous training, and provide workforce agility.

#### Aviation External Hazard Sensor Technologies Topic A1.01

NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Hazardous flight conditions of particular interest are: wake vortices, clear-air turbulence, in-flight icing, lightning, and low visibility. NASA is interested in new and innovative methods for detection, identification, evaluation, and monitoring of in-flight hazards to aviation. In the case of lightning, interest is centered on the mitigation and in-flight measurement of lightning damage, particularly to composite aircraft.

NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices. Proposed products may be for retrofit into current aircraft or for installation in future aircraft. Both manned and unmanned aircraft are of interest.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen). Additional information is available at (<http://www.jpdo.gov> [2]). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable, and effective sensors that will have a strong benefit to safety. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are required for NextGen.

Under this subtopic, proposals are invited that explore new and improved sensors and sensor systems for the detection and monitoring of hazards to aircraft before they are encountered. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest. With regard to hazardous lightning conditions, the emphasis is not on remote detection, but rather on developing systems that make aircraft more robust in a lightning environment or provide in-flight damage assessment or other hazard mitigating benefits. The design and development of composite materials and composite construction methods are not included in this subtopic. The scope of this subtopic does not include human factors and focused development of human interfaces, including displays and alerts. Primary emphasis is on airborne applications, but in some cases the development of ground-based sensor technology may be supported.

Areas of particular interest to NASA at this time are described in more detail below. The list and details are

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provided as encouragement but are not intended to exclude other proposals that fit the scope of this subtopic.

## Lightning

- *Lightning Strike Protection* - NASA is investigating means for mitigating damage to aircraft, with a particular interest in protecting composite aircraft. Currently, an electrically-conductive screen protects composite aircraft by functioning as a Faraday shield and is intended to confine lightning and electromagnetic effects to the outside or outermost skin of the aircraft. The lightning strike protection system, hereafter referred to as the LSP, is incorporated in the coatings, layers, and structure that comprise the skin of the aircraft. NASA is most interested in LSP solutions that will be cost effective and light-weight. The design and development of composite materials and construction methods is out of scope for this subtopic.
- *Mitigation of Lightning Strike Damage* - NASA is seeking solutions that will provide better protection from lightning damage by directing attachment points or lightning currents to safe or less hazardous areas and by reducing the susceptibility of the aircraft to thermal or other damage due to strikes.
- *In-flight Lightning Damage Measurement and Assessment* - A typical commercial aircraft is struck by lightning about once per year. At this time, composite aircraft that are struck in-flight are inspected upon landing for a damage assessment. Such assessments may be time-consuming and difficult. Innovations that will provide a measurement or damage detection system in the LSP are solicited. The objective would be to achieve a capability to have damage detection and assessment in the aircraft that will provide immediate information to the flight crew after a lightning attachment.

## Polarimetric Radar Technology

- *Polarimetric Antennas* - Recent investigations indicate that polarimetric capability would provide a substantial advancement in airborne weather radar. Flat plate, slot antenna (single polarity) arrays currently in use are cost-effective, light-weight, and rugged. An innovative polarimetric antenna design that meets the same criteria would be a major step toward implementation of polarimetric radar. Existing commercial aircraft dictate the antenna system requirements, and new antenna designs should be suitable for retrofit. Innovative techniques, designs, or developments that lead to polarimetric antennas that are affordable and effective and can be retrofit to existing commercial aircraft are solicited.

## Turbulence and Wake Vortex

- *Remote Detection of Kinetic Air Hazards* - The class of hazards including wake vortices, turbulence, and other hazards associated with air motion is referred to as kinetic air hazards. Within this class, wakes and turbulence are the highest priorities; however, NASA is particularly interested in sensor systems that can detect multiple hazards and thus provide greater utility. For example, air data systems are at times disabled by icing, and a multi-function, multi-hazard sensor that includes a robust alternative air data source would be a great asset in such conditions.
- *Airborne Detection of Wake Vortices* - Airborne detection of wake vortices is considered challenging due to the fact that detection must be possible in nearly all weather conditions, in order to be practical, and because of the size and nature of the phenomena. In particular, NASA is interested in the ability to detect and measure wake vortex hazards for arbitrary viewing angles.
- *Airborne Detection of Turbulence* - NASA has made a major investment in the development of new and enhanced technologies to enable detection of turbulence to improve aviation safety. Progress has been made in efforts to quantify hazard levels from convectively induced turbulence events and to make these quantitative assessments available to civil and commercial aviation. NASA is interested in expanding these prior efforts to take advantage of the newly developing turbulence monitoring technologies, particularly those focused on clear air turbulence (CAT). NASA welcomes proposals that explore the methods, algorithms and quantitative assessment of turbulence for the purpose of increasing aviation safety and augmenting currently available data in support of NextGen operations.

### Sub Topics:

Inflight Icing Hazard Mitigation Technology Topic A1.02

NASA is concerned with the prevention of encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. Under this subtopic, proposals are invited that explore new and dramatically improved



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research tools and technologies related to inflight airframe and engine icing hazards for manned and unmanned vehicles. Technologies of interest should address the detection, measurement, and/or the mitigation of the hazards of flight into super-cooled liquid water clouds and flight into regions of high mass concentrations of ice crystal.

Areas of particular interest include:

- Technology to measure the phase (ice or liquid), size, and mass concentration of ice and liquid density of water particles as they are ingested into a turbofan engine core flow path and in upstream wind tunnel ducts.
- Technology to measure the mass of water that impinges on the leading edge of airframe components for droplet spectra having median volumetric diameters from 20 to 1000 microns. Past measurement methods using dye-tracers and blotter paper have demonstrated limitations, particularly for larger drop sizes. More advanced methods are sought that can improve accuracy and measurement time.
- Non-destructive 3-D ice density measurements of ice accretions on wind tunnel models. NASA has a need for non-optical methods to digitize ice shapes with rough external surfaces and internal voids as can occur with accretions on highly swept wings. Technologies proposed must be compatible with working within a wind tunnel testing environment.

Sub Topics:

Real-Time Safety Assurance under Unanticipated and Hazardous Conditions Topic A1.03

Assuring safety of flight under uncertain, unanticipated, and multiple hazards is a core requirement for aircraft loss of control prevention and for safety-assured autonomous aircraft operations. Sources of hazards include adverse onboard conditions (e.g., system failures, vehicle impairment or damage), external disturbances (e.g., turbulence, inclement weather, wake vortices), and abnormal flight conditions (e.g., abnormal attitudes/rates, unsafe/abnormal flight trajectories, stall/departure). Research is sought that supports real-time flight safety assurance in either of the following critical areas:

- *Real-time Flight Safety Management* - Assuring flight safety requires the real-time ability to assess impacts and risks of current or impending hazards, and to enforce minimum flight safety margins. Research in this area includes:
  - Definition of flight safety and its core components.
  - Development of methodologies and algorithms for predicting impacts and risks to flight safety (or one or more key components) of uncertain, unanticipated, and multiple hazards.
  - Development of a supervisory control system that ensures a minimum margin of flight safety under uncertain, unanticipated, and multiple hazards.
  - Evaluation of flight safety prediction and supervisory control algorithms using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.
- *Real-time Sensor Integrity Management* - Assuring the integrity of information required for aircraft control is a core requirement in assuring flight safety. Research in this area focuses on assuring the integrity of flight dynamics and control parameters and includes:
  - Development of a methodology to utilize all available information from diverse physical and virtual sensors in order to rapidly detect, isolate, and mitigate erroneous behavior within a sensor or sensor suite in real time.
  - Utilization of information fusion across multiple sensors (physical and virtual) and algorithmic redundancy to estimate lost information from failed sensor(s).
  - Assurance of information integrity under turbulence, noise, and abnormal and highly nonlinear flight conditions associated with aircraft loss of control.
  - Evaluation of sensor integrity management algorithms and the integrated system using analysis, simulation, and/or experimental testing under a variety of hazardous conditions.

Sub Topics:

Prognostics and Decision Making Topic A1.04

Research should be conducted to demonstrate technical feasibility during Phase I and to show a path toward a Phase II technology demonstration. Proposals are solicited that address aspects of the following areas:

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- Remaining Useful Life (RUL) prediction techniques that address a set of fault modes for a device or component, for example by modeling the physics of the most critical fault modes and using (typically less accurate) data-driven methods for the remainder.
  - Physics-based damage propagation models for one or more relevant aircraft subsystems such as airframe structures, avionics, electrical power systems, and electronics. Methods for damage propagation in composite structures are of a particular interest. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
  - Uncertainty quantification and management for prognostics. Proposers are encouraged to quantify prognostic uncertainty by accounting for the effects of modeling uncertainty, measurement errors, algorithmic uncertainties, as well as uncertainties stemming from estimation of future loads and environmental conditions. Methods for reducing prognostic uncertainty estimates are of particular interest. Proposals can consider the fusion of different techniques for uncertainty quantification and management but must demonstrate (using the appropriate metrics) the direct benefits of using such an approach in improving uncertainty estimates.
  - Aircraft-relevant test beds that can generate aging and degradation datasets for the development and validation of prognostic techniques.
  - Verification and validation methods for prognostic algorithms.

If prognostic algorithms are being developed, performance needs to be measured on benchmark data sets using prognostic metrics for accuracy, precision, and robustness. Metrics should include prognostic horizon (PH), alpha-lambda, relative accuracy (RA), convergence, and R\_delta.

Sub Topics:

Identification of Sequences of Atypical Occurrences in Massive Heterogeneous Datasets Representing the Operation of a System of Systems Topic A1.05

The fulfillment of the SSAT project's goal requires the ability to transform vast amounts of data produced by aircraft and associated systems and people into actionable knowledge that will aid in detection, causal analysis, and prediction at levels ranging from the aircraft-level, to the fleet-level, and ultimately to the level of the national airspace. For this topic, we are especially interested in automated discovery of previously unknown precursors to aviation safety incidents involving human - automation interaction. We expect to gain knowledge on latent deficiencies in crew training, communication, and operations that is of paramount importance to future SSAT project goals and objectives. The incorporation of human performance will be invaluable to the success of this effort, and as such it will be important to use heterogeneous data from varied sources that are matched on a per-flight basis with flight-recorded data, such as radar track data, airport information, weather data, flight crew schedule information, maintenance information, and Air Safety Reports. This topic will develop revolutionary and first-of-a-kind methods and tools that incorporate the limitations of human performance throughout the design lifecycle of human-automation systems to increase safety and reduce validation costs in NextGen.

The focus of this effort will be from the aircraft-level to fleet level and above. As such, the successful proposal will develop validated predictive analytics to uncover systemic human-automation interaction issues that manifest at a much broader level than those incidents that occur within a single flight or for a single aircraft. Real data from a defunct airline will be made available as GFE (government furnished equipment), representing the interactions between humans and automation found on flight systems, data from aircraft as well as supporting ground-based systems. As such, a deep knowledge of algorithmic development across multiple heterogeneous data sources and the ability to address recent developments in the growing area of "big data" should be clearly demonstrated. The successful proposer will have a proven track record of deploying groundbreaking, innovative approaches in a real-world setting to similar "big data" challenges.

Sub Topics:

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Research Topic A2.01

The following subtopic is in support of the Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project under the Integrated Systems Research Program (ISRP). There is an increasing need to fly UAS in the NAS to perform missions of vital importance to National Security and Defense, Emergency Management, Science, and to enable commercial applications. The UAS Integration in the NAS Project is structured under the following technical challenges:

- *Airspace Integration* - Validate technologies and procedures for UAS to remain an appropriate distance from other aircraft, and to safely and routinely interoperate with NAS and NextGen Air Traffic Services

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(ATS).

- *Standards/Regulations* - Validate minimum system and operational performance standards and certification requirements and procedures for UAS to safely operate in the NAS.
- *Relevant Test Environment* - Develop an adaptable, scalable, and schedulable relevant test environment for validating concepts and technologies for UAS to safely operate in the NAS. The Federal Aviation Administration (FAA) regulations are built upon the condition of a pilot being in an aircraft.

There exist few, if any, regulations specifically addressing UAS today. The primary user of UAS to date has been the military. The technologies and procedures to enable seamless operation and integration of UAS in the NAS need to be developed, validated, and employed by the FAA through rule making and policy development.

The Project goal is to provide research findings to reduce technical barriers associated with integrating UAS into the NAS utilizing integrated system level tests in a relevant environment. The project is currently broken down into five subprojects:

- Separation Assurance/Sense and Avoid Interoperability (SSI)
- Communications
- Human Systems Integration
- Certification
- Integrated Test and Evaluation

The fifth subproject, Integrated Test and Evaluation, is responsible for developing a live, virtual, and constructive test environment for the other four subprojects. During the first phase, (May-2011 to September-2013) the project has:

- Conducted initial modeling, simulation, and flight testing.
- Completed early subproject-focused deliverables (spectrum requirements, comparative analysis of certification methodologies, etc.).
- Validated the key technical elements identified by the project.

The plan for the second phase includes the following:

- Conduct systems-level, integrated testing of concepts and/or capabilities that address barriers to routine access to the NAS.
- Develop a body of evidence (including validated data, algorithms, analysis, and recommendations) to support key decision makers in establishing policy, procedures, standards and regulations, enabling routine UAS access in the NAS.

This solicitation seeks proposals, but is not limited, to develop concepts that can reduce the technical barriers related to the safety and operational challenges of routine UAS operations in the NAS.

- *Certified Control and Non-Payload Communications (CNPC) system* - Current civil UAS operations are significantly constrained by the lack of a standardized, certified control and non-payload communications (CNPC) system. The UAS CNPC system is to provide communications functions between the Unmanned Aircraft (UA) and the UA ground control station for such applications as: telecommands; non-payload telemetry; navigation aid data; air traffic control (ATC) voice relay; air traffic services (ATS) data relay; sense and avoid data relay; airborne weather radar data; and non-payload situational awareness video. New and innovative approaches to providing terrestrial and space-based high-bandwidth CNPC systems that are inexpensive, small, low latency, reliable, and secure offer opportunities for quantum jumps in UAS utility and capabilities. Of particular interest are:
  - Technologies for High power C-band amplifiers and highly linear C-band power amplifiers/linearization of high power C-band amplifiers.
  - Miniaturization of C-band terrestrial radio components/systems and C- Ku- and Ka-Band satellite communications components/systems.
  - Conformal steerable antennas for satellite communications links in C-, Ku- and Ka Band.

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- *Weather Information Systems for GCS* - On-board, real-time graphic aviation weather information products have been developed and successfully implemented for manned cockpits. Their use is now widespread and their safety impact widely recognized. The applicability of such products for operators and ground control pilots to enhance situation awareness and improve mission planning and execution is of interest to NASA. Systems such as the NASA developed Aviation Weather Information (AWIN) system that included software, data and data-link applications, color weather graphics such as composite-radar mosaic, lightning-strike data, wind data, satellite images and forecasts could be integrated into a ground control station to provide pilots with weather awareness before and during mission execution. Improved weather awareness should allow aircrews to avoid most weather-related problems through both pre-flight and en-route planning. While the use of these systems has been explored for military UAS operations, their applicability to civil and public operations has not yet been explored.
  - *Safety Analysis and Methodologies* - UAS operations are untried in the civil NAS. Unlike other aircraft, there is not an extensive record of civil operations upon which to forecast the safety of UAS operations in the NAS. The introduction of UAS into the NAS raises many safety issues and concerns. Typically, anytime a new capability is added into the NAS, an Operational Safety Assessment (OSA) is performed by the FAA, to determine whether that introduction of new capability will enhance or detract from the safety of the NAS. As these UAS represent a wholly new operational system, traditional approaches cannot suffice. Research is needed to identify and develop new safety analysis approaches, as well as prognostic indicators and potential new safety metrics.
  - *Autonomous Operations* - As vehicle capabilities and machine intelligence continue to evolve, it is expected that future air vehicles, especially unmanned vehicles, will assume an increasing level of independent decision-making, flight monitoring and management, and trajectory management. As the Next-Generation Air Traffic Management System (NextGen) continues to evolve and expand, the future system will need to concurrently develop operational accommodations for these aircraft that manifest increasing levels of autonomy. Thus, autonomous vehicles and NextGen must evolve in complementary ways to accommodate these future operational considerations. At a minimum, future autonomous systems must demonstrate successfully the following characteristics:
    - Collision/hazard avoidance.
    - Autonomous navigation under uncertain conditions.
    - Cooperative task completion (if more than one aircraft is needed for a particular operation).
    - Recognition of anomalies.
    - Long term system diagnostics, failure prediction and correction.
  - *Development of a UAS Flight Inspection and Cargo Aircraft Capability Concept* - Currently the FAA conducts flight inspections of the ground based air navigational aids and guidance systems (MLS, TACAN, VASI) in Antarctica using a CL-601 Challenger corporate executive jet type of aircraft, not certified for operations from ice and gravel runways. The risk for damage to these costly aircraft is high and no flights are made to remote areas, like Antarctica, without the inclusion of maintenance personnel among the crew. A UAS, RPV equipped for flight inspection work in Antarctica and other remote areas utilizing a simple rugged STOL type of vehicle, ski or wheel equipped, (thus capable of operating from rough snow, ice and short gravel runways) would greatly reduce the risks and costs of flight inspecting and light air logistics in Antarctica. The environment in Antarctica is a perfect venue to demonstrate an efficient, practical and environmental friendly use of unmanned aircraft technologies to a worldwide audience. Basic requirements for a drone utilized in this type of operation include:
    - Ability to carry a 1000-pound payload 800 nautical miles and return with no need for additional fuel.
    - Be TCAS responsive and "visible" to other traffic.
    - Be equipped with bubble observation windows and mounts for various surveillance and photography systems.
    - Have the capability to operate from the short gravel runways.

#### Sub Topics:

##### Structural Efficiency-Aeroservoelasticity Topic A3.01

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:

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- 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.

Sub Topics:

Quiet Performance Topic A3.02

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.

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- Innovative measurement of radiated acoustic fields from aeroacoustics sources.

Sub Topics:

Low Emissions/Clean Power Topic A3.03

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.

Sub Topics:

Aerodynamic Efficiency Topic A3.04

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.

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Sub Topics:

Physics-Based Conceptual Design Tools Topic A3.05

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.

Sub Topics:

Rotorcraft Topic A3.06

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

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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.

Sub Topics:

Propulsion Efficiency - Propulsion Materials and Structures Topic A3.07

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 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 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.



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- 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.

#### Sub Topics:

##### Ground Test Techniques and Measurement Technologies Topic A4.01

The Ground and Flight Test Techniques and Measurements topic supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate from takeoff speeds to Mach 10, as well as the testing requirements of other government and commercial entities. The primary objective is to develop innovative tools and technologies that enhance measurement capabilities, improve ground and flight resource utilization, and provide capability sustainment. This year the primary emphasis is on ground testing requirements.

Wind tunnel vehicle design databases have traditionally included the foundational measurements of forces, discrete surface pressures, and discrete surface temperatures. However, designing and testing future vehicles with highly integrated and possibly distributed propulsion and flow control systems will require enhanced, remotely sensed global surface measurements to accurately define the vehicle performance and acoustic levels covering a wide range of operational conditions. Enhanced optical systems are required to visualize the flow interactions both on and off the surface. Non-intrusive measurement systems offering multi-component velocities, density, and pressure in the tunnel stream are required to routinely quantify and baseline the test environment and to establish boundary conditions for advanced computational simulations. Non-intrusive measurements of off-body and near-body flow parameters both at a point and globally (i.e., planar or volumetric) are necessary to examine fluid-fluid and fluid-structure interactions for computational solution validation. In all cases, significant measurement accuracy enhancements are required to achieve the revolutionary aircraft systems of the future. Measurement systems must be robust and user-friendly to achieve the level of utility required for practical and routine application. Clean seeding methods that do not contaminate anti-turbulence screens are required in the wind tunnel testing environment; seedless methods for velocity measurements are particularly desired. Compact measurement systems and analysis techniques with dual use capability in both ground and flight test environments are valuable, enabling smooth transition between each. Since wind tunnel test data must ultimately represent free-air conditions, techniques and/or analysis methods that can demonstrate and articulate novel ground to flight extrapolation methodologies are sought. In all cases, measurement methods that can significantly increase data capture per test point are desired, including the simultaneous measurement of multiple flow parameters. Accordingly, the topic solicits cutting-edge enhancements that significantly improve existing test and measurement capabilities, and enabling tools that provide new opportunities for aerodynamic and aerothermodynamic discovery for NextGen and high-speed transportation systems.

The contraction of the Nation's ground-based testing resources emphasizes the technological need to improve wind tunnel utilization. Advanced methods that aid pre-test planning, improve data collection, enhance visual display in a data rich environment, and provide rapid analysis are solicited.

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With an aging and reduced workforce comes the challenge of capability sustainment. Tools and technologies are solicited that enable knowledge capture, offer ubiquitous training, and provide workforce agility.  
Sub Topics: