NASA SBIR 2014 Phase I Solicitation

A1 Aviation Safety

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).

Subtopics

A1.01 Aviation External Hazard Sensor Technologies

Lead Center: LaRC

Participating Center(s): AFRC, GRC

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). 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 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 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.

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.