NASA SBIR 2012 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:

- Discovery of Precursors to Safety Incidents.
- Assuring Safe Human-Systems Integration.
- Prognostic Algorithm Design for Safety Assurance.
- Vehicle Health Assurance.
- Crew-System Interactions and Decisions.
- Loss of Control Prevention, Mitigation, and Recovery.
- Engine Icing.
- Airframe Icing.
- Atmospheric Hazard Sensing & Mitigation.

AvSP includes three research projects:

- The System-wide Safety Assurance Technologies Project provides knowledge.
- Concepts and methods to proactively manage increasing complexity in the design and operation of vehicles.
- Air transportation systems, including advanced approaches to enable improved and cost-effective verification and validation of flight-critical systems.

The Vehicle Systems Safety Technologies Project identifies risks and provides knowledge to avoid, detect, mitigate, and recover from hazardous flight conditions, and to maintain vehicle airworthiness and health. 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) (information available at 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. 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 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. Approaches that use multiple sensors in combination to improve hazard detection and quantification of hazard levels are also of interest.

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.

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.

**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.

- **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 capability in the aircraft that will provide immediate information to the flight crew after a lightning attachment.

**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 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 supercooled liquid water clouds and flight into regions of high ice crystal density. With these emphases in mind, products and technologies that can be made affordable and capable of retrofit into the current aviation system and aircraft, as well as for use in the future are sought.
Areas of interest include, but are not limited to:

- Non-destructive 3-D ice density measurements of ice accretions on wind tunnel wing 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 for comparison to computational simulations. Current methods based upon scanning with line-of-sight, visible-spectrum digitization methods have been found inadequate for many of these very complex ice shapes.

- Remote and in-situ technologies that can accurately quantify the super-cooled liquid water environment in the volume surrounding an airport. Of primary interest are remote sensing technologies that can, by themselves or with other instruments, quantify the temperature, liquid water content, and cloud droplet size spectrum to allow the production of a 3-D icing hazard map of the terminal airspace. Low-cost, expendable in-situ instruments are also of interest for validating and calibrating these remotely sensed measurements.

A1.03 Flight Deck Interface Technologies for NextGen

Lead Center: LaRC

Public benefits derived from continued growth in the transport of passengers and cargo are dependent on the improvement of the intrinsic safety attributes of current and future air vehicles that will operate in NextGen. The Aviation Safety Program (AvSP) is addressing this challenge by conducting cutting-edge fundamental and applied research that will yield innovative algorithms, tools, concepts and technologies from the discipline level up to the subsystem and system level. As a part of the AvSP, the Vehicle System Safety Technology (VSST) Project has initiated a Technical Challenge (TC) toward the improvement of Crew Decision-Making and response in complex situations (CDM), in current-day and NextGen operations.

To address this TC, NASA seeks innovative flight deck interface research and technology that address the following major topic areas:

- The flight crew's needs for situation awareness/information in current-day and emerging NextGen operations. Research and technology development focused on novel display technologies and display methods that allow for new means of NextGen information portrayal and creating visual and aural interface methods to provide hazard and aircraft state awareness and protection during terminal maneuvering area operations.

- The development of flight deck interface technologies that assure pilot awareness and appropriate engagement (balancing awareness and workload) in current-day and emerging NextGen operations. Research and technology development to proactively address the potential impact of changing roles and responsibilities between the Air Navigation Services Providers (ANSP) and pilots as well as between the human and automation, and the robustness of these interfaces when responding to unexpected events.

- Integrated information management systems that assure the information needed by flight crews to make critical decisions is complete and not misleading. Research and technology development to better manage
flight deck information during NextGen "Net-Centric" operations without overloading or underwhelming the operators/users.

- Understanding demographics and proficiency that impact human (pilot) decision-making. Research and technology development which addresses emerging pilot demographics and pilot proficiency standards to improve pilot decision-making and interactions with other human and automation.

A1.04 Vehicle Level Diagnostics

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

This SBIR subtopic augments on-going activities in the Vehicle Systems Safety Technology (VSST) project within NASA's Aviation Safety Program. Specifically, this subtopic addresses the "Maintain Vehicle Safety between Major Inspections" (MVS) technical challenge. The MVS technical challenge concentrates on capabilities to maintain vehicle safety between major inspection intervals with an emphasis on the subsystems of airframe, avionics, and propulsion. NASA is seeking proposals to combine information from, and within, the various subsystems to perform overall vehicle level diagnostics. The objective of this work is to provide an infrastructure to assess the health state of aircraft though the integration of full vehicle sensors and diagnostic information. Partnering with organizations that can provide relevant data is encouraged.

A1.05 Data Mining and Knowledge Discovery

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 on the fleet level or above. As such, the successful proposal will develop validated data mining and machine learning based methods 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. Simulated data that is representative of the interactions between humans and automation found on flight systems and on data from real world aircraft and supporting ground-based systems should be used. The total of the data set under study should be at least 10 TB in size, and exhibit appropriate statistical and operational complexities found in real world human automation interactions. Furthermore, a deep knowledge of human-automation interaction from the human-factors perspective as well as the ability to create novel machine learning and data mining algorithms should be clearly demonstrated.
The purpose of this subtopic is to invest in mid- and long-term research to establish rigorous, systematic, scalable, and repeatable verification and validation methods for flight-critical systems, with a deliberate focus on safety for NextGen (http://www.jpdo.gov). This subtopic targets NextGen safety activities and interests encompassing vehicles, vehicle systems, airspace, airspace concept of operations, and air traffic technologies, such as communication or guidance and navigation. Methods for assessing issues with technology, human performance and human-systems integration are all included in this sub-topic, nothing that multi-disciplinary research is required that does not focus on one type of component or phenomenon to the exclusion of other important drivers of safety.

Proposals are sought for the development of:

- Safety-case methods and supporting technologies capable of analyzing the system-wide safety properties suitable for civil aviation vehicles and for complex concepts of operation involving airborne systems, ground systems, human operators and controllers.
- Technologies and mathematical models that enable rigorous, comprehensive analysis of novel integrated, and distributed, systems interacting through various mechanisms such as communication networks and human-automation and human-human interaction.
- Techniques, tools and policies to enable efficient and accurate analysis of safety aspects of software-intensive systems, ultimately reducing the cost of software V&V to the point where it no longer inhibits many safety innovations and NextGen developments.
- Tools and techniques that can facilitate the use of formal methods in V&V throughout the lifecycle such as graphical-based development environments (e.g., eclipse plug-ins for static analyzers, model checkers, or theorem provers) or tools facilitating translation from design formats used in industry to formal languages supporting automated reasoning.

This subtopic is intended to address those flight-critical systems that directly conduct flight operations by controlling the aircraft, such as on-board avionics and flight deck systems, and safety-critical ground-based functions such as air traffic control and systems for communication, navigation and surveillance. It is not intended to cover V&V of computational models of physical systems (e.g., CFD codes or finite element analysis).

In Phase II, a functional system shall be delivered to NASA for its retention and ownership.