NASA SBIR 2008 Phase I Solicitation

A1 Aviation Safety

The Aviation Safety Program focuses on the Nation's aviation safety challenges of the future. This vigilance for safety must continue in order to meet the projected increases in air traffic capacity and realize the new capabilities envisioned for the Next Generation Air Transportation System (NextGen). The Aviation Safety Program will conduct research to improve the intrinsic safety attributes of future aircraft and to eliminate safety-related technology barriers. The program is focusing on a foundational approach to advancing knowledge in core disciplines (e.g., computational methods, material science), which in turn are used to build integrated multidisciplinary system-level models, tools, and technologies. This year, the scope of the aviation safety subtopics has been focused to develop specific technologies that are needed to accomplish program goals. It is expected there will be approximately one award per A1 subtopic with quality proposals.

This approach focuses on furthering our understanding of the underlying physics, chemistry, materials, etc. of aeronautics phenomena when broken down to these most basic elements. The results at the fundamental level will be integrated at the discipline and multi-discipline levels to ultimately yield system-level integrated capabilities, methods, and tools for analysis, optimization, prediction, and design that will enable improved safety for a range of missions, vehicle classes, and crew configurations.

Example areas of program interest include research directed at the detection, prediction and mitigation/management of aging-related hazards of future civilian and military aircraft; designs of revolutionary adaptive flight decks; in-flight detection, diagnosis, prognosis of aircraft health, preventative and adaptive systems for in-flight operability; informed logistics and maintenance graceful recovery from in-flight failures; software safety assurance and formal verification methods for safety-critical systems; as well as system-level integrated resilient control technologies.

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 Mitigation of Aircraft Aging and Durability-related Hazards

Lead Center: GRC

Participating Center(s): ARC, LaRC

The mitigation and management of aging and durability-related hazards in future civilian and military aircraft will require advanced materials, concepts, and techniques. NASA is engaged in the research of materials (metals, ceramics, and composites) and characterization/validation test techniques to mitigate aging and durability issues and to enable advanced material suitability and concepts.

Proposals are sought for the development of moisture-resistant resins and new surface treatments/primers. Novel chemistries are sought to improve the durability of aerospace adhesives with potential use on subsonic aircraft. This research opportunity is focused on the development of novel chemistries for coupling agents, surface treatments for adherends and their interfaces, leading to aerospace structural adhesives with improved durability. Work may involve chemical modification and testing of adhesives, coupling agents, surface treatments or combinations thereof and modeling to predict behavior and guide the synthetic approaches. Examples of adhesive characteristics to model and/or test may include, but are not limited to, hydrolytic stability of the interfacial chemistry, moisture permeability at the interface, and hydrophobicity of coupling agents and surface primers. Examples of adherends to model and/or test include carbon fiber/epoxy composites used in structural applications on subsonic aircraft, and aluminum, as well as their respective surface treatments. Additionally, proposals are sought for test techniques to fully characterize aging history and strain rate effects on thermoset and/or thermoplastic resins as well as on advanced composites manufactured of such resins and reinforced with 3D fiber preforms such as the triaxial braid used in advanced composite fan containment structures. Technology innovations may take the form of tools, models, algorithms, prototypes, and/or devices.

A1.02 Sensing and Diagnostic Capability for Aircraft Aging and Damage

Lead Center: LaRC

Participating Center(s): ARC, GRC

Many conventional nondestructive evaluation (NDE) techniques have been used for flaw detection, but have shown little potential for much broader application. One element in NASA's contribution to solving the problem of aging and damage processes in future vehicles is research to identify changes in fundamental material properties as indicators of material aging-related hazards before they become critical. Degraded and failing fiber composites can exhibit a number of micromechanisms such as fiber buckling and breakage, matrix cracking, and delamination.

In order to provide early detection of these processes and hazards, new sensing and diagnostic capabilities to support nondestructive evaluation (NDE) systems are needed, as well as associated computational techniques and maintenance methods. 'Virtual' inspection methods are being sought for composite materials. 'Virtual' inspections would include modeling the changes in critical material properties as indicators of material aging and then quantifying the levels of detectability of these material properties with a particular NDE technique. This computational tool should accurately model the interaction between the changes in the material properties and the probing energy of a particular NDE technique to allow the development of the inspection parameters needed for application on a particular structure. Actual NDE technologies are also being sought for the nondestructive characterization of age-related degradation in complex composite materials. Innovative and novel approaches to using NDE technologies to measure properties related to material aging (i.e. thermal diffusivity, elastic constants, density, microcrack formation, fiber buckling and breakage etc.) in complex composite material systems, adhesively bonded/built-up and/or polymer-matrix composite sandwich structures.

The anticipated outcome of successful proposals would be a both Phase 2 prototype NDE technology for the use of the developed technique to characterize age-related degradation and a demonstration of the technology showing its ability to measure a relevant material property in a carbon fiber/epoxy composite used for structural applications on subsonic aircraft.

A1.03 Prediction of Aging Effects

Lead Center: LaRC

Participating Center(s): ARC, GRC

In order to assess the long-term effects of potential hazards and aging-related degradation of new and emerging material systems/fabrication techniques, NASA is performing research to anticipate aging and to predict its effects on the designs of future aircraft. To support this predictive capability, structural integrity analytical tools, lifing methods, and material durability prediction tools are being developed. Physics-based and continuum-based models, computational methods, and validation techniques are needed to provide the basis for these higher level (e.g., design) tools. Proposals are sought that apply innovative methods, models and analytic tools to the following specific applications:

- Probabilistic models are sought for improved structural analysis of complex metallic and composite airframe components. The methods used for these solutions need to detail the initiation and progression of damage to determine accurate estimates of residual life and/or strength of complex airframe structures.
- Tools and models are needed to predict the onset and rates of type-II hot corrosion attack in nickel-based turbine disk superalloys that allow for prolonged disk operation at high temperatures. Typically hot corrosion of turbine alloys is a product of molten salt exposure and is manifested by a localized pitting corrosion attack. Prolonged high temperature exposures of turbine disk alloys to sulfur-rich low temperature melting eutectic salts can lead to an onset of Type II hot corrosion attack causing serious degradation to the durability of the turbine components.
- Computational methods are sought to simulate of the response of advanced composite fan case/containment structures in aged conditions to jet engine fan blade-out events using impact mechanics and structural system dynamics modeling techniques.

A1.04 Aviation External Hazard Sensor Technologies

Lead Center: LaRC

NASA is concerned with new and innovative methods for airborne detection, identification, evaluation, and monitoring of in-flight hazards to aviation. 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.

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 sensors. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are needed.

Under this subtopic, proposals are invited that explore new and improved airborne sensors and sensor systems for the detection and monitoring of hazards to aircraft. This subtopic solicits technology that is focused on developing capabilities to detect and evaluate hazards. The development of human interfaces, including displays and alerts, is not within the scope of this subtopic. In some cases the development of ground-based sensor technology may be supported as a precursor to eventual airborne applications.

At this time, the following hazards are of particular interest: in-flight icing conditions and wake vortices. Proposals associated with sensor investigations addressing these hazards are encouraged, and some suggestions follow.

To enable remote detection and classification of in-flight icing hazards for the future airspace system and emerging aircraft, NASA is soliciting proposals for the development of sensor systems for the detection of icing conditions. Examples include the following practical remote sensing systems:

- Low-cost, ground-based, vertical-pointing with potential scanning capability X-band radar that can operate unattended 24/7/365 and provide calibrated reflectivity and velocity data with hydrometer/cloud particle classification (based upon the reflectivity and velocity data).
- Low-cost, high-frequency (> 89 GHz) microwave or infrared radiometer technology capable of providing air temperature, water vapor, and liquid water measurements for both ground-based and airborne applications.

Wake vortex detection in the terminal area is of particular interest, because closer spacing between aircraft is necessary to facilitate the high-density operations expected in NextGen. 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. Lidar systems have been used successfully for wake detection from off-axis viewing angles, and there is reason to believe that detection is possible from near-axial viewing angles. Other sensor technologies may have untapped potential for wake detection. NASA is soliciting new and innovative research toward the detection of wakes from aircraft, particularly in the terminal area. Specific areas suggested for investigation are sensor measurables (i.e. physical aspects of the hazard that are detectable or measurable by a sensor) associated with wake detection and wake strength; sensor capabilities for detection, tracking, and strength measurement; practical methods for wake hazard analysis, including hazard level evaluation and the bounding of hazardous airspace; and the removal of technical barriers to the use of sensors for airborne wake detection. Proposals may address any or all of the suggested areas. Additional wake vortex research topics are covered in Subtopic A3.02. Proposals may address any or all of the suggested areas.

A1.05 Crew Systems Technologies for Improved Aviation Safety

Lead Center: LaRC

NASA seeks highly innovative, crew-centered, technologies to improve aerospace system safety through the development of more effective joint human-automation systems in aviation. This is to be accomplished through increased awareness of operator and crew functional state (both in terms of functional readiness and in situ assessment), and through improved interactions among intelligent agents (human and automated) while participating in flight operations on the flightdeck. We seek proposals for the development of advanced technologies that:

- Allow flightdeck systems to conform to individual operator's characteristics in a manner that improves performance, and that help characterize such individual differences;
- Improve our capability to non-intrusively sense and characterize operator and crew functional state in the ambient conditions of flight, or in flight simulation facilities;
- Convey operators state information to other intelligent agents (human and automated, proximal and remote) to improve coordinated performance;
- Modulate interactions among intelligent agents so as to minimize risk and optimize performance objectives across all possible mission scenarios;
- Intelligently aid operators such that the potential for and effects of human error are minimized, and so that operators can maintain appropriate functional states during flight operations; and/or
- Provide methods, metrics, and tools that help to assess the effectiveness of the above-mentioned technologies in human-in-the loop simulation and/or flight studies.

Proposals should describe novel technologies with high potential to serve the objectives of the Robust Automation/Human Systems element of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/rahs.htm). Successful Phase 1 proposals should culminate in a final report that specifies, and a Phase 2 proposal that would realize, technology that improves the effectiveness of joint human-automation systems in aviation, or improves the ability to assess effectiveness of such systems.

A1.06 Technologies for Improved Design and Analysis of Flight Deck Automation

Lead Center: ARC

Information complexity in flight deck systems is increasing exponentially, and flight deck designers need tools to understand, manage, and estimate the performance and safety characteristics of these systems early in the design process - this is particularly true due to the multi-disciplinary nature of these systems. NASA seeks innovative design methods and tools for representing the complex human-automation interactions that will be part of future flight deck systems. In addition, NASA seeks tools and methods for estimating, measuring, and/or evaluating the performance of these designs throughout the lifecycle from preliminary design to operational use - with an emphasis on the early stages of conceptual design. Specific areas of interest include the following:

- Computational/modeling approaches to support determining appropriate human-automation function allocations with respect to safety and performance;

- Design tools and methods that improve the application of human-centered design principles to the design and certification of mixed human-automated systems;
- Tools and methods for modeling the complex information management systems required for future flight deck systems;
- Methods of data uncertainty estimation during the flight deck system design phase particularly as applied to predicting overall system integrity;
- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments.

Proposals should describe novel design methods, metrics, and/or tools with high potential to serve the objectives of the System Design and Analysis element of NASAÂ’s Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/sda.htm). Successful Phase 1 proposals should culminate in a final report that specifies, and a Phase 2 proposal that would realize, tools that improve the design process for human-automation systems in aviation, or improves the ability to assess effectiveness of such systems during the design phase. All proposals should discuss means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

A1.07 On-Board Flight Envelope Estimation for Unimpaired and Impaired Aircraft

Lead Center: LaRC

Participating Center(s): ARC

A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including failed actuators, failed sensors, damaged surfaces or abrupt changes in aerodynamics or large changes in aerodynamics during upsets. As part of the Aviation Safety Program research, the Integrated Resilient Aircraft Control (IRAC) Project is investigating advanced control system concepts to provide greater aircraft resiliency to adverse events. The goal of the IRAC project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions.

Research on advanced technical approaches (such as direct and indirect adaptive control) has focused on accomplishing stability and safe operability in the presence of anomalies. To be able to effectively develop and apply such methods, it is highly desirable, if not essential, to characterize each anomaly and assess the limits of operation of the impaired vehicle, as control application without regard to the vehicle impairment or adverse condition could have significant detrimental consequences. In particular, it would be desirable to characterize and isolate the anomalous condition, and then estimate the level of controllability, limits of maneuverability, and achievable flight envelope of the vehicle. This SBIR subtopic will develop analytical tools and prototype software to assess the ability of the vehicle to accomplish safe operation under specified anomalous conditions. Specific technology areas where contributions are sought include the following:

- Adaptive mathematical framework for control-centric onboard aircraft models that can accommodate real-time changes to subsystem dynamics;
- Real-time system identification capability for updating an onboard vehicle model with an adaptive structure

to satisfy sub-system constraints under adverse conditions;

- Real-time fault diagnostic and prognostics capability needed in adaptive flight, propulsion, structural control applications;
- Real-time control power map identification with inclusion of aircraft sub-system constraints under adverse conditions;
- Real-time dynamic flight envelope identification and prediction capability; and
- Metrics and assessment models for safety-of-flight diagnostics and prognostics.

A1.08 Engine Lifing and Prognosis for In-Flight Emergencies

Lead Center: GRC

The object of this research topic is to develop innovative methodologies to determine probability of an engine system failure under emergency flight conditions that demand a boost in the engine performance, thus potentially sacrificing the engine, to increase the engine control effectiveness for a safe take-off or landing.

Aircraft engine design and life are based on a theoretical operation flight profile that in practice is not seen by most engines in service. The ability to predict remaining engine life with a defined reliability in real time is a condition precedent to emergency operation risk assessment. It is expected that this research will result in a demonstration of an integrated life monitoring and prognosis methodology that will utilize existing and under development probabilistic codes for engine life usage and for risk assessment for future operations that may require enhanced performance.

The expected outcome of the research will be a demonstration of an integrated engine life module for:

- Engine life prediction, including a reliability model for off-nominal conditions.
- Risk assessment and trade-off tool for emergency operation.

NASA resources available for the research will be an engine component database for turbine disks and blades, and probabilistic computer codes for life prediction and reliability.

A1.09 Robust Flare Planning and Guidance for Unimpaired and Impaired Aircraft

Lead Center: ARC

Participating Center(s): AFRC, LaRC

A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including damaged surfaces or failed actuators that can limit the maneuverability and achievable flight envelope of the vehicle. As part of the Aviation Safety Program research, the goal of the Integrated Resilient Aircraft Control (IRAC) Project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions. Research on advanced technical approaches includes adaptive flight control for providing stability, flight and maneuvering envelope identification for determining safe operability limits, and emergency flight planning and guidance for achieving a flyable path to an approach for landing.

This SBIR subtopic seeks innovations in providing flare planning and guidance technologies that aid aircraft during the critical phase of landing under damage conditions and weather disturbances such as heavy crosswind or wind shear. The research will develop feasibility studies of different methods for safe landing under these hazardous conditions when the aircraft performance is impaired due to damage and failures. The research will address automatic flare maneuvers of aircraft with a large crab angle and possibly bank angle for a stable trim approach, different flap deployment strategies, high speed approaches, and large trim alpha variations. Differential engine throttle may be used to compensate for large sideslip, as may other novel automatic flare methods for off-nominal landing. The research should also determine when a different approach profile (such as a lateral offset and/or shallower glide-slope) is desired, so that this information could be used by a flight planning system as a target endpoint.

A1.10 Detection of In-Flight Aircraft Anomalies

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Adverse events that occur in aircraft can lead to potentially serious consequences if they go undetected. This effort is to develop the technologies, tools, and techniques to detect anomalies from adverse events in hardware, software, and the interactions between these two classes of systems. This involves the integration of novel sensor technologies for structures, propulsion systems, and other subsystems within the aircraft and/or the development of novel methods to detect failures in software systems. The emphasis of this work is not on diagnosing the exact nature of the failure but on identifying its presence. Proposals are solicited that address aspects of the following topics:

- Analytical and data-driven technologies required to interpret the sensor data to enable the detection of fault and failure events;
- Methods to detect failures in software systems which have already undergone verification and validation;
- Methods to differentiate sensor failure from actual system or component failure;
- Characterizing, quantifying, and interpreting multi-sensor outputs;
- Integration of propulsion, airframe, and software health information for improved vehicle state-awareness;
- New sensors and sensory materials that operate in harsh environments; and
- New methods to provide better and more accurate information to diagnostic computational algorithms that reconstruct damage fields from sensor values.

Emphasis is on novel methods to detect failures in electrical, electromechanical, electronic, structural, propulsion, and software systems. Where possible, a rigorous mathematical framework should be employed to ensure the detection rates and detection time constants are acceptable according to published baselines as characterized by statistical measures. Understanding and addressing validation issues are critical components of this effort.

A1.11 Integrated Diagnosis and Prognosis of Aircraft Anomalies

Lead Center: ARC

Participating Center(s): AFRC, GRC, LaRC, SSC

The capability to identify faults and predict their progression is critical to determining appropriate mitigation actions to maintain aircraft safety. This effort is to develop innovative methods and tools for the diagnosis and prognosis of aircraft faults and failures. Proposals are sought for the development of a health management methodology which integrates a prognosis approach with the nature, severity, and uncertainty information from the diagnosis of the faulted system.

Diagnosis: The diagnosis element of IVHM includes the development of integrated technologies, tools, and techniques to determine the causal factors, nature, and severity of an adverse event and to distinguish that event from within a family of potential adverse events. These requirements go beyond standard fault isolation techniques. The emphasis is on the development of mathematically rigorous diagnostic technologies that are applicable to structures, propulsion gas path monitoring, software, and other subsystems within the aircraft. Technologies developed must be able to perform diagnosis given heterogeneous and asynchronous signals coming from the health management components of the vehicle and integrating information from each of these components.

The ability to actively query health management systems, use advanced decision making techniques to perform the diagnosis, and then assess the severity using these techniques are critical. As an example, the mathematical rigor of the diagnosis and severity assessment could be treated through a Bayesian methodology since it allows for characterization and propagation of uncertainties through models of aircraft failure and degradation.

Computational demonstrations using realistic data or prototype hardware implementations of the diagnostic capabilities would be expected at the conclusion of a Phase 2 effort. Other methods could also be employed that appropriately model the uncertainties in the subsystem due to noise and other sources of uncertainty. The ability to actively query the underlying health management systems (whether they are related to detection or not) is critical to reducing the uncertainty in the diagnosis. As an example, if there is ambiguity in the diagnosis about the type and location of a particular failure in the aircraft structure, the diagnostic engine should be able to actively query that system or related systems to determine the true location and severity of the anomaly. Where possible, a rigorous mathematical framework should be employed to provide a rank ordered list of diagnoses, an assessment of the severity of each diagnosed event, along with a measure of the certainty in the diagnosis. Understanding and addressing the system integration and validation issues are critical components of this effort.

Prognosis: The prognosis element of IVHM includes the development of technologies, tools, and techniques to determine, given information from detection and diagnosis health management systems and other systems, estimates (with a measure of confidence) of the remaining useful life (RUL) of candidate faults generated by diagnostic engines. The assessment of the RUL could be used by other aircraft systems to place additional restrictions, such as a new operating envelope on the flight control systems. Areas of interest include developing methods for making predictions of RUL which take the uncertainties provided by a candidate diagnostic engine into account, representing and managing uncertainties inherent in such predictions, and developing and applying assessment methodologies for comprehensive and objective evaluation of prognostic algorithm performance.

Research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path toward a Phase 2 technology demonstration. Proposals are solicited that address aspects of the following areas:

Research should be conducted to demonstrate technical feasibility during Phase 1 and to show a path toward a Phase 2 technology demonstration. Proposals are solicited that address aspects of the following areas:

- The development of an integrated approach for diagnostics and prognostics that demonstrate a mathematically rigorous method for propagating diagnostic uncertainty and its effect on subsequent estimates of remaining useful life.
- Physics-based damage propagation models for one or more relevant aircraft subsystems such as composite or metallic airframe structures, engine turbo-machinery and hot structures, avionics, electrical power systems, electromechanical systems, and electronics. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.
- Novel approaches to assess the quality and accuracy of remaining useful life estimates through the fusion of different models, active probing of components, etc.
- Uncertainty representation and management methods. Proposers are encouraged to consider uncertainties due to measurement noise, imperfect models and algorithms, as well as uncertainties stemming from future anticipated loads and environmental conditions.
- Mathematically rigorous methodologies for assessing the quality of remaining useful life predictions and associated uncertainties.
- Verification and validation methods for prognostic algorithms.

A1.12 Mitigation of Aircraft Structural Damage

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

This topic is jointly supported by the Integrated Vehicle Health Management (IVHM) project and the Aircraft Aging and Durability (AAD) project.

Healing Material System Concepts for IVHM/AAD

The development of integrated multifunctional self-sensing, self-repairing structures will enable the next generation of light-weight, reliable and damage-tolerant aerospace vehicle designs. Prototype multifunctional composite and/or metallic structures are sought to meet these needs, as are concepts for their analytical and experimental interrogation. Specifically, structural and material concepts are sought to enable in situ monitoring and repair of service damage (e.g., cracks, delaminations) to improve structural durability and enhance safe operation of aerospace structural systems. Emphasis is placed on the development of new materials and systems for the mitigation of structural damage and/or new concepts for activation of healing mechanisms using new or existing materials. These advanced structural and material concepts must be robust, consider all known damage modes for specific material systems, and be validated through experiment.

Similarly, the mitigation and management of aging and other durability-related hazards in future civilian and military aircraft will require the development of advanced materials, concepts, and techniques. NASA is engaged in the research of materials (metals, ceramics, and composites) and characterization/validation test techniques for mitigation of aging and durability issues and to enable advanced material suitability and concepts. Innovations are sought for in these mitigation technologies: concepts for autonomous self-healing of composite aerospace structures. Passive approaches are sought where sensors or external energy are not required to activate the healing process. Desired performance objectives include improved compression-after-impact performance and retarded/arrested damage growth. To be competitive with lightweight traditional (non-healing) aerospace structures, self-healing concepts must not introduce extensive passive weight, such as a reservoir tank of resin, etc.