NASA SBIR 2009 Phase I Solicitation

A1 Aviation Safety

The Aviation Safety Program focuses on the Nation's future aviation safety challenges. 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 legacy and future aircraft and their operations in the Next Generation Air Transportation system, and to eliminate safety-related technology barriers.

The program has focused on furthering our understanding of the fundamental questions that need to be addressed for mid- and long-term improvements to aviation safety through engineering analysis and technology design. 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 operating concepts, vehicle classes, and crew configurations. The Aviation Safety Program is divided into four complementary and highly interlinked projects:

- The Aircraft Aging and Durability Project performs foundational research in aging science that will ultimately yield multi-disciplinary analysis and optimization capabilities that will enable system-level integrated methods for the detection, prediction, and mitigation/management of aging-related hazards for future civilian and military aircraft.

- The Integrated Intelligent Flight Deck Project develops tools, methods, principles, guidelines, and technologies for revolutionary flight deck systems that enable transformations toward safer operations.

- The Integrated Resilient Aircraft Control Project conducts research to advance the state of aircraft flight control to provide onboard control resilience for ensuring safe flight in the presence of adverse conditions.

- The Integrated Vehicle Health Management Project develops validated tools, technologies and techniques for automated detection, diagnosis and prognosis that enable mitigation of adverse events during flight.

Examples areas of program interest include research directed at fundamental knowledge of legacy and future aircraft structures and systems durability; on-board detection, diagnosis, prognosis, prediction and mitigation of system failures and faults; monitoring vehicle and airspace issues to identify problems before they become accidents; understanding aircraft dynamics of current and future vehicles in damaged and upset conditions; robust

control systems; aircraft guidance for emergency operation; airborne sensors and sensor systems for the detection and monitoring of external hazards to aircraft (e.g., in-flight icing conditions, wake vortices); design of robust collaborative work environments; effective and robust human-automation systems; and information management for effective decision making. In addition, general methods for dramatically advancing the community's capability for thorough, cost-effective and time-effective verification and validation of safety-critical systems are of interest to the program as a whole, including rigorous methods for validating design requirements for vehicles and aviation operations, verifying integrated and distributed aircraft and air traffic systems (including assumptions about human performance), and verifying software-intensive systems.

 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): AFRC, ARC, GRC, MSFC

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.

 Methodologies are being sought that allow engineers, using advanced modeling tools to predict the remaining useful life of components, the ability to make use of nondestructive evaluation (NDE) data more effectively. One

proposed methodology would be an automated means of processing NDE data to extract defect characteristics (i.e. crack length and depth, or delamination size and location) and map these directly to a computer aided drafting model of the component being inspected. This model (which now contains defect information) could then be used by engineers to perform structural analysis on the component. A successful proposal should demonstrate the performance of the methodology proposed by using the data from at least one conventional NDE technique (i.e. Thermography, Ultrasonics, etc.) and a standard CAD drawing file format.

Additionally, 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 encapsulated as computational methods (software) are needed to provide the basis for these higher level (e.g., design) tools. Proposals are sought that apply innovative computational methods, models and analytic tools to the following specific applications:

- Probabilistic computational code is sought for improved structural analysis of complex metallic and composite airframe components. The methods used in 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.

- Software tools 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 software is 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.

The anticipated outcome of successful Phase 2 proposals would be analytic code (software) delivered to NASA suitable for use in material evaluation studies.

A1.04 Aviation External Hazard Sensor Technologies

Lead Center: LaRC

Participating Center(s): AFRC, GRC

NASA is concerned with new and innovative methods for 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, and affordable sensors. 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. 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 except where explicitly requested in association with special topics. 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, such as new sensor technologies in conjunction with existing X-band airborne radar, to improve hazard detection and quantification of hazard levels are of interest.

At this time, the following hazards are of particular interest: in-flight icing conditions, wake vortices, and turbulence. Proposals associated with sensor investigations addressing these hazards are encouraged, and some suggestions follow. Emphasis on vortices and icing is not intended to discourage proposals targeting other or additional hazards such as reduced visibility, terrain, airborne or ground obstacles, convective weather, gust fronts, cross winds, and wind shear.

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 around the clock (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.

Proposals are encouraged for the development of novel coherent and direct detection lidar systems and associated components that allow accurate meteorological wind and aerosol measurements suitable for wake vortex characterization. Proposed techniques shall provide range-resolved clear air wind and aerosol measurements in the near-IR wavelength region from 1.5 microns to 2.1 microns. Wind and aerosol measurement with

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.

A1.05 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). We seek proposals for the development of advanced technologies that:

- Effectively convey information and aid decision making to enable novel NextGen operational requirements (e.g., 4D trajectory-based operations, visual operations in non-visual meteorological conditions, etc. as described in http://www.faa.gov/about/initiatives/nextgen/media/NGIP_0130.pdf);

- Foster the appropriate use of automation and complex information sources by, for example, conveying constraints on automation reliability and information certainty/timeliness;

- Support effective joint cognitive systems by improving the communication and collaboration among multiple intelligent agents (human and automated, proximal and remote), and provide assessment techniques and

metrics for evaluating mixed H/A team performance;

- Characterize the operational status of the human crew members, effectively modulate this state, and/or effectively adapt interfaces and automation in response to functional status (e.g., situationally-aware display reconfiguration, aiding, and multi-modal presentation of information to maximize system performance and minimize information processing bottlenecks);

- 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 Systems

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 NASA'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 Adaptive Aeroservoelastic Suppression

Lead Center: AFRC

Participating Center(s): ARC, LaRC

NASA has initiated an Integrated Resilient Aircraft Control (IRAC) effort under the Aviation Safety Program. The main focus of the effort is to advance the state-of-the-art technology in adaptive controls to provide a design option that allows for increased resiliency to failures, damage, and upset conditions. These adaptive flight control systems will automatically adjust the control feedback and command paths to regain stability, maneuverability, and eventually a safe landing. One potential consequence of changing the control feedback and command paths is that an undesired aeroservoelastic (ASE) interaction could occur. The resulting limit cycle oscillation could result in structural damage or potentially total loss of vehicle control.

Current airplanes with non-adaptive control laws usually include roll-off or notch filters to avoid ASE interactions. These structural mode suppression filters are designed to provide 8 dB of gain attenuation at the structural mode frequency. Ground Vibration Testing (GVT), Structural Mode Interaction (SMI) testing, and finally full scale flight testing are performed to verify that no adverse ASE interactions occur. Until a significant configuration or control system change occurs, the structural mode suppression filters provide adequate protection.

When an adaptive system changes to respond to off-nominal rigid body behavior, the changes in control can affect the structural mode attenuation levels. In the case of a damaged vehicle, the frequency and damping of the structural modes can change. The combination of changing structural behavior with changing control system gains results in a system with a probability of adverse interactions that is very difficult to predict a priori. An onboard, measurement based method is needed to ensure that the system adjusts to attenuate any adverse ASE interaction before a sustained limit cycle and vehicle damage are encountered. This system must work in concert with the adaptive control system to allow the overall goal of re-gaining rigid body performance as much as possible without exacerbating the situation with ASE interactions.

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

Lead Center: GRC

The object of this research topic is to develop innovative methodologies and tools to determine the consumed life of an engine and the probability of an engine system failure for future operations.

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 from sensor measurements 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 risk assessment for future operations that may require enhanced performance.

The expected outcome of the research will be an on-line simulation demonstration of an integrated engine life module for:

- Probabilistic engine life usage calculation.

- Methodologies for engine failure prediction for future operations.

- Risk assessment and trade-off tools for off-nominal operations.

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

A1.09 Pilot Interactions with Adaptive Control Systems under Off-Nominal Conditions

Lead Center: ARC

Participating Center(s): AFRC

Adaptive control is a promising control technology that can enhance flight safety and performance. Adaptive control has been demonstrated to provide improved performance in many unmanned aerial systems. When operated in an autonomous mode such as in an autopilot, the behavior of an adaptive flight control system can be modeled and simulated with a sufficient degree of repeatability.

The presence of a pilot working in a closed-loop fashion with an adaptive flight control presents an important problem that has not been well addressed. Adaptive control generally requires sufficiently rich input signals to improve parameter convergence, as the adaptive control system adapts to parametric changes in the vehicle dynamics or exogenous disturbances. The condition for rich input signals is known as persistent excitation. During adaptation under off-nominal conditions such as aircraft with damage, the pilot provides persistently exciting signals to the adaptive control system. There is generally a trade-off between adaptation and stability due to persistent excitation. With a high persistent excitation in the pilot inputs, the speed of adaptation increases and in theory better handling performance could be achieved. However, in practice, the high persistent excitation in the control signals can potentially cause significant cross-coupling between different flight control axes and or excite unmodeled dynamics such as aeroservoelastic modes. The overall effect of high persistent excitation could aggravate stability robustness of an adaptive flight control system with a pilot in the loop that results in poor handling qualities.

Another aspect of pilot interactions with an adaptive control system is the potential interactions between two adaptive elements in a closed-loop fashion, because the pilot can also be viewed as an adaptive control system with a learning ability. With the pilot adaptive element providing high persistently exciting inputs into an adaptive flight control system with a predetermined adaptation rate, the issue of stability can be important and difficult to assess.

To enable an adaptive flight control system to be operated with a pilot in the loop, it is necessary to develop new research techniques that can assess the effects of pilot interactions with an adaptive flight control system. These techniques should address pilot control responses via an adaptive model with features that can capture relevant interactions with an adaptive flight control system. Techniques for assessing pilot interactions via metrics that can quantify the pilot-vehicle system responses with an adaptive flight control system are also needed. Other aspects of the research can include new methods and tools that can provide an advisory function to limit the pilot control inputs in order to trade off between command-following performance and stability robustness.

Research in adaptive control methods will address the system requirements to provide good flying characteristics when the human operator closes the control loop. In the presence of damage, failures, etc. the adaptive system must trade the stability requirements with closed loop handling requirements. Methods for selecting the best achievable handling are needed. The adaptation system needs to find a good compromise between suppression of coupling between the axis (i.e. pitch into roll, etc.) and good in-axis behavior. Better metrics to assess cross-coupled (asymmetric) behavior are needed. These metrics could provide a quantitative measurement of the severity of a given failure, as well as a measure of the improvement due to adaptation. As the adaptation changes the flying characteristics of the vehicle, some means of informing the operator is required to ensure that the system is not overdriven by a pilot who is expecting nominal performance.

A1.10 Detection of 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 in-flight anomalies from adverse events. This involves the integration of novel sensor and advanced analytical technologies for airframe, propulsion systems, and other subsystems within the aircraft. 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 differentiate sensor failure from actual system or component failure;

- Characterizing, quantifying, and interpreting multi-sensor outputs; and

- New sensors, sensory materials and sensor systems that improve the detection of an adverse event or

permit increased sensory coverage for an adverse event.

Emphasis is on novel methods to detect failures in electrical, electromechanical, electronic, structural, and propulsion systems. Along with these system failures, condition sensors are desired for both the detection of internal engine icing as well as composite aircraft lightning strikes (location and intensity). 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 Diagnosis of Aircraft Anomalies

Lead Center: LaRC

Participating Center(s): AFRC, GRC, SSC

The capability to identify faults is critical to determining appropriate mitigation actions to maintain aircraft safety. This effort is to develop innovative methods and tools for the diagnosis of aircraft faults and failures. It 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 systems, 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.

Both computational and prototype hardware implementations of the diagnostic capabilities are expected outcomes of this 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.

A1.12 Prognosis of Aircraft Anomalies

Lead Center: ARC

Participating Center(s): AFRC, GRC, LaRC

The ability to accurately and precisely predict the remaining useful life (RUL) of aircraft components and subsystems enables decision making and action taking that can avert or mitigate failures, thereby enhancing aircraft safety. Furthermore, it can improve operational efficiency by facilitating condition-based maintenance and reducing unscheduled maintenance. This effort here addresses the development of innovative methods, technologies, and tools for the prognosis of aircraft faults and failures. 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 or it could be used by flight or maintenance personnel to take preventative actions. Areas of interest include developing methods for making predictions of RUL which take into account operational and environmental uncertainties (pure data-driven approaches are discouraged); physics-based models of degradation; generation of aging and degradation datasets on relevant components or subsystems; and development of validation and verification methodologies for prognostics.

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:

- 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 composite or metallic airframe structures, engine turbomachinery and hot structures, avionics, electrical power systems, electromechanical systems, and electronics. Proposals that focus on technologies envisioned for next generation aircraft are strongly encouraged.

- Uncertainty representation and management (reduction of prediction uncertainty bounds) 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. Methods can also consider the fusion of different techniques but must show how this helps to improve the uncertainty using appropriate metrics.

- Aircraft relevant testbeds that can generate aging and degradation datasets for the development and testing of prognostic techniques.

- Verification and validation methods for prognostic algorithms.

A1.13 Healing Material System Concepts for IVHM

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

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.

A1.14 Verification and Validation of Flight-Critical Systems

Lead Center: ARC

Participating Center(s): AFRC, LaRC

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/nextgen.asp). 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.

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).