NASA SBIR 2007 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 (NGATS). 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., fluid dynamics, computational methods, material science), which in turn is used to build integrated multidisciplinary system-level models, tools, and technologies.

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 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.

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 for mitigation of aging and durability issues and to enable advanced material suitability and concepts. Proposals are sought for innovations in these mitigation technologies:

- 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.

- Concepts for autonomous self-healing of composite aerospace structures. NASA is interested only in passive approaches, i.e., approaches that do not require sensors or external energy 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.

- 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 Crew Systems Technologies for Improved Aviation Safety

Lead Center: LaRC

Participating Center(s): ARC

NASA seeks highly innovative and crew-centered technologies to improve aerospace system safety. Such advanced technologies may meet this goal by ensuring appropriate situation awareness: facilitating and extending human perception, information interpretation, and response planning and selection; counteracting human information processing limitations, biases, and error-tendencies; assisting in response planning and execution; and fostering successful, closely-coupled joint cognitive human/automation systems. NASA requires improved methods and tools for characterizing current and future users of aerospace systems, and tailoring designs to users. Such advanced technologies must be evaluated sensitively in operationally-valid contexts. Therefore, NASA also seeks tools and methods for ascertaining, measuring and evaluating aerospace system operator performance in advance aviation contexts, and how this performance is reflected in system performance.
Technologies may take the form of tools, models, operational procedures, instructional systems, prototypes, and/or devices for use in the flight deck, elsewhere by pilots, or by those who design systems for crew use. Specific topical areas of interest include the following:

- Intelligent systems monitoring and alerting technologies for improved failure mode identification, recovery, and threat mitigation;
- Designs for human-error prevention, detection, and mitigation;
- Support for crew response planning and selection;
- New sensors and/or new associated algorithms for determining operator states of attention, awareness, engagement, and intent;
- Approaches that appropriately modulate crew attention, engagement, workload, and situation awareness;
- Human-centered technologies to improve the performance of less-experienced operators and of pilots from special population groups;
- Human-error reliability approaches to analyzing flight deck displays, decision aids, procedures, and human/automation integration policies;
- Presentation and aiding concepts for the display and use of data with spatial or temporal uncertainty and of integrated streams of data with various levels of integrity;
- Naturalistic dialog approaches for interacting with aircraft systems and external agents in flight;
- Individual and team performance metrics, analysis methods, and tools to better evaluate and certify human and system performance for use in operational environments, simulation, and model-based analyses with focus on sequential behavior analysis.

A1.03 Aviation External Hazard Sensor Technologies

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

NASA is concerned with new and innovative methods for airborne detection, identification, and evaluation of in-flight hazards to aviation. These hazards may include weather and other atmospheric phenomena, terrain, traffic, and runway contamination. Examples of hazards include: icing conditions, convective weather, wind shear, wind gusts, turbulence, volcanic ash, hail, low visibility, wake vortices, lightning, terrain, air traffic, runway incursions, man-made obstacles, and wet/icy runways. Proposals are invited that lead to innovative new technologies and approaches or significant improvements in existing technologies for in-flight hazard avoidance.
Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices. Although the emphasis is on airborne hazard detection, prediction, and avoidance, the following are also of interest: the sharing of information to support hazard avoidance by other aircraft; multi-sensor and multi-source hazard information utilization; collaborative decision-making; updates to terrain/obstacle databases; and provision of observations for input to weather models and forecast/now-cast products. Examples include:

- New and improved airborne forward-looking sensor systems;
- Data fusion technologies for integrating disparate sources of flight-related information with on-board and off-board sensor data to detect and evaluate aviation hazards;
- Innovative technologies and methods to detect, predict, and quantify hazards in order to provide accurate information and guidance to enable avoidance of hazards or to instigate strategies for mitigation; and
- Decision-support tools and methods to improve collaborative and distributive decision-making.

While this subtopic is focused on remote detection and avoidance of hazards, the same systems that provide for avoidance can be utilized for mitigation and escape. Proposals that explore these applications in addition to avoidance are welcome.

A1.04 Adaptive Flight Control

Lead Center: ARC
Participating Center(s): AFRC, GRC, LaRC

Small Business Innovative Research in adaptive flight control should address stability and performance, maneuverability, and safe landing of aircraft in adverse conditions (e.g., faults and failures, damage, and environmental upsets). This includes analysis and design methods for adaptive/intelligent reconfigurable control by developing practical and theoretic metrics. The approach must be able to address the following:

- Unmodeled dynamics (e.g., aeroelastic modes);
- Parametric uncertainty (e.g., stability and control derivative variations due to aerodynamic changes);
- Time-scale separation inherent in different actuators (e.g., slow engines as actuators);
- Nonlinear dynamic nature of the actuator response including time lag (e.g., engine variable spool-up time and actuator rate limiting);
- Stability of adaptive control methods in the presence of unmodeled dynamics and exogenous disturbances (e.g., wind shear and atmospheric turbulence).
Effective adaptive control methods need to be developed to mitigate multiple faults, failures, and damage conditions under uncertain (and potentially deteriorating) conditions. These methods include but are not limited to the following:

- Multi-objective adaptive optimal control;
- Aeroservoelastic mode filtering adaptive control;
- Direct adaptive control;
- Indirect adaptive control;
- Hybrid (direct and indirect) adaptive control.

These methods must be capable of achieving good performance (e.g., rise time, gain and phase margins, and command tracking) under adverse conditions while obeying system constraints (e.g., load limits and actuator rate saturation).

Innovative proposals are sought which can address the areas above and provide substantial improvements, in capability and range of applicability, over existing commercial technology.

A1.05 Data Mining for Integrated Vehicle Health Management

Lead Center: ARC
Participating Center(s): AFRC, GRC, LaRC

Innovative data mining technologies are being solicited to incorporate within systems and continuous risk management processes covering the life cycles of aircraft and their related ground support systems as well as spacecraft, in particular the Orion Crew Exploration Vehicle and the Aries launch vehicle and their related ground support systems. The life cycle includes design, development, integration, testing, operation (nominal and off-nominal), maintenance, enhancement (upgrades), and failure analysis.

Relevant technologies include those that:

- Detect anomalies and faults;
- Detect trends;
- Discover similarities;
- Infer models from data;
- Detect topics from text;
- Classify instances or events;
- Fuse data from multiple sources;
- Display data mining results in an intuitive manner.

To achieve the above capabilities, relevant technologies are expected to meet a subset of the following criteria:

- Perform automated learning, both supervised and unsupervised;
- Permit the user to define the search criteria and heuristics;
- Support a mixed-initiative approach combing automated learning and user search control;
- Perform real-time analyses on continuous streams of data;
- Perform off-line analyses on static databases;
- Process one or more data types including numeric sequences, character sequences, English free-form text, image sequences, and combinations of these forms;
- Perform real-time analyses on continuous streams of data;
- Perform on-demand, scheduled, or triggered analyses on periodic and/or aperiodic data streams;
- Perform off-line analyses on static databases.

NASA has a broad range of potential applications for these technologies. The following list provides a few examples:

- Enhance diagnostic and prognostic capabilities of an onboard integrated health management system;
- Perform clustering and topic identification on reports from a Problem Reporting and Corrective Action system;
- Detect faults from image sequences;
- Enhance acceptance tests to reduce false positive and false negative classifications;
- Enhance information-based security systems by detecting anomalies;
- Improve the design process by discovering similar applicable designs given requirements;
Support analyses that assess risk of component or system failure.

Proposals are expected to identify commercial state-of-the-art technology that will be extended as well as the relevant research that will be implemented as the result of an award.

A1.06 Sensing and Diagnostic Capability

Lead Center: GRC

Participating Center(s): ARC, LaRC

One element in NASA’s contribution to solving the problem of aging and damage processes in future vehicles is research to identify aging-related hazards before they become critical. 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. Proposals are sought that provide innovations in sensing technologies and diagnostic solutions for these specific structural, material, and systems problems:

- "Virtual" inspections on both monolithic homogeneous materials (i.e., metals) and composite materials using computational NDE tools. "Virtual" inspections would include determining the size of flaws detectable with a particular technique, the parameters needed for inspections on a particular structure, or determining if a technique is applicable for a particular inspection. Techniques modeled could include (but are not limited to) terahertz imaging, thermography, ultrasonics, eddy current or radiographics.

- Chafing of wiring insulation is the primary reason for wire failure in both military and commercial aircraft. Computational methods are being solicited for analyzing data from nondestructive inspection techniques to detect and characterize chafing as early as possible, thus enabling useful life predictions.

- Hard shell composite fan containment components that include sandwich structures. Of interest are practical large-area rapid inspection and/or health monitoring methods that can monitor the bulk interior as well as the surface of the component over significant distances as the component goes through its service life. Techniques could include (but are not limited to) ultrasonic guided waves that interrogate the bulk while traveling laterally along the component surface, acoustic emission systems, and robust pressure-sensitive film systems that can visually record impacts and impact paths while surviving the service and impact conditions.

- Increased use of composite structure and components in aircraft will create new challenges for visual inspection which still constitutes 80-90% of all inspections. Because surface indicators of damage or delamination may be subtle or barely visible, NASA is interested in technologies and techniques that can enhance visual detectibility in the operational environment. Such innovations could include (but are not limited to) treatments of the composite materials, enhancements to the work environment, or job aids for visual inspectors or maintenance technicians (outside the realm of NDE systems). Desirable features include ease of use and minimal change to the operational process.

Technology innovations may take the form of tools, models, algorithms, prototypes, and/or devices.
A1.07 Advanced Health Management for Aircraft Subsystems

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

The purpose of this solicitation is to seek highly innovative and commercially viable technologies that will improve aircraft safety for current and future civilian and military aircraft, and to overcome aircraft safety technological barriers that would otherwise constrain the full realization of the Next Generation Air Transportation System (NGATS). Specifically, this subtopic seeks technologies in support of the Integrated Vehicle Health Management Project (IVHM) that will contribute to the reduction of aircraft system and component failures and malfunctions that cause and contribute to aircraft accidents and incidents.

The goal of IVHM is to develop technologies to determine system/component degradation and damage early enough to prevent or gracefully recover from in-flight failures in both the near-future and next-generation air transportation systems. These technologies will enable nearly continuous on-board situational awareness of the vehicle health state for use by the flight crew, ground crew, and maintenance depot. To achieve this, NASA will advance the state-of-the-art technology in on-board health state assessment to enable the continuous diagnosis and prognosis of the integrated vehicle’s health status. To help meet this goal, NASA seeks innovative technology development activities in the following areas:

- **Airframe Health Management** - including self-awareness and prognosis, anomaly detection and identification, and in-flight damage, degradation and failure mitigation;
- **Propulsion Health Management** - including self-awareness and prognosis of gas path, combustion, and overall engine state (containment systems and rotating and static components), and fault-tolerant system architectures;
- **Aircraft Systems Health Management** - including state-awareness and prognosis of landing gear, hydraulic and pneumatic systems, electrical and power systems, fuel and lubrication systems, avionics/communications, navigation, surveillance/flight critical and flight management systems, and robust, distributed, fault-tolerant, self-recoverable architectures for flight critical aircraft applications;
- **Environmental Hazard Management** - including the prevention, detection, and mitigation of hazards such as ice accretion, lightning strikes, EMI/EMC, and ionizing radiation, as well as the direct and indirect effects of these hazards;
- **IVHM Architectures and Databases** - including system design, analysis and optimization, information management, data flow and communication, control and reconfiguration, architecture development and validation, and database development and management;
- **Validation and Predictive Capability Assessment** - including analysis, simulation, ground testing, flight testing, environmental testing, and software assurance.

NASA’s IVHM research will ultimately yield integrated, multi-disciplinary analysis and optimization capabilities that
enable system-level designs providing graceful recovery from in-flight failures, computationally efficient tools for in-flight prognosis of aircraft health including integrated predictive and sensor capabilities, and preventative and adaptive systems for in-flight operability and informed logistics and maintenance. Innovative technology solutions are being sought for the following IVHM technical challenges:

- Large-scale distributed anomaly, fault, malfunction, degradation, and failure detection with data/decision/information fusion (multiple sensors, actuators, and processing nodes);
- Prevention, detection, isolation, and mitigation of multiple independent/correlated anticipated and unanticipated failures (modeling of correlated failures and system/vehicle effects, diagnosis and prognosis, real-time processing and decision-making for very large state spaces, and health state reasoning);
- Adaptive diagnostic and prognostic algorithms (adapts as systems and components age, are repaired, or replaced);
- Analytical methods to set local decision criteria so that global performance criteria are met (multi-dimensional optimization);
- Performance optimization in distributed systems (high probability of detection, low probability of false alarm);
- Vehicle-wide state and function monitoring of systems and structures (including digital avionics, auto-flight and control, propulsion, hydraulic, mechanical, pneumatic, electrical, and power generation and distribution systems);
- Large-scale distributed adaptive fault-tolerant processing architecture that is robust in adverse operating environments (EMI/EMC, ionizing radiation, low/high temperatures);
- Distributed hierarchical threat-tolerant self-healing embedded sensors and systems (embedded self-recovery mechanisms, adaptive, programmable and reconfigurable devices);
- Technology integration, verification, and validation (diagnostic and prognostic flight, airframe, and propulsion systems, environmental hazard management, advanced sensors and system architectures, Verification and Validation (V&V) with predictive capability).

Technology innovations may take the form of tools, models, algorithm, prototypes, and/or devices.

A1.08 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 these specific applications:

- Improved structural analysis of complex metallic and composite airframe components through the use of novel multi-scale as well as global-local analytical codes. 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.

- Type II 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. Tools and models are needed to predict the onset and the rates of hot corrosion attack in these types of alloys.

- Simulation of the response to jet engine fan blade-out events of advanced composite fan case/containment structures in aged conditions, using relevant impact mechanics and structural system dynamics modeling techniques.

Technology innovations may take the form of tools, models, and algorithms.

A1.09 Integrated Avionics Systems for Small Scale Remotely Operated Vehicles

Lead Center: LaRC

Participating Center(s): AFRC, ARC

Small scale remotely operated vehicles are becoming an increasingly attractive option for experimental research in flight dynamics, vehicle state assessment, and automatic flight control as well as a growing number of commercial applications. Small scale vehicles (nominally 20 lbs to 80 lbs total weight) place constraints on the amount of on-board avionics that can be accommodated and these systems can benefit from integration of components. For flight research activities key avionic systems are:

- Inertial navigation units which combine gyroscopic measurements with GPS position data;
- The capabilities to implement an autopilot fail-safe should RF uplink be lost;
- The ability to log instrumentation data from analog, pulse-width and serial stream inputs;
- The ability to read and generate serial-port data streams for RF communication systems;
- Telemetry systems to provide for both ground-based piloting and real-time data downlink.
When used as experimental research test beds the requirements for data quality (resolution, bandwidth, linearity, etc.) are often higher than would be derived just for automated flight operations on the vehicle itself. Although existing commercial technology can individually address each of these areas, an integrated high-fidelity system that is commensurate with the low-power, low-weight, and EMI sensitive environment of subscale remotely piloted vehicles is not available. For safety of flight a fail-safe autopilot should be able to recover vehicle stability from a range of entry conditions and also have GPS waypoint return-and-hold or full auto landing capability. Programmability of the avionics unit is important to allow the system to be extended to a wide range of platforms, application environments, and experimental requirements. Telemetry systems are flight critical for remotely piloted vehicles and therefore must have high reliability in addition to meeting bandwidth requirements imposed by the data downlink from a fully instrumented vehicle.

Innovative system concepts are sought which can address some or all of the areas above and provide substantial improvements, in capability and range of applicability, over existing commercial technology.

**A1.10 Adaptive Structural Mode 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.

Adaptive, reconfigurable structural mode suppression methods that address the following are needed:
• Suppression of all ASE interactions with no a priori knowledge of structural modes;
• Minimal interference/interaction with rigid body controller;
• Implementable in a real-time flight control processor.

Research areas of interest include, but are not limited to, the following:

• Adaptive filtering techniques;
• Self-tuning notch filters;
• ASE modeling and predictive techniques;
• Online margin measurement techniques;
• Online identification of structural vibrations;
• Global stability proofs for adaptive systems.

A1.11 Universal Enabling IVHM Technologies in Architecture, System Integration, Databases, and Verification and Validation

Lead Center: LaRC
Participating Center(s): AFRC, ARC, GRC

A vehicle-wide Integrated Vehicle Health Management (IVHM) Project system must be information rich with embedded monitoring and diagnostic/prognostic functions that will penetrate deeper and with smaller granularity into physical components and structures. This will necessitate the development of safety-critical, real-time, distributed, embedded sensing and computing system design, development, integration, and assessment capability for applications with huge numbers of sensing and computing nodes which are networked and dynamically reconfigurable in response to changing physical conditions, modes of operation, failures, damage, and environmental disturbances. Furthermore, the development of advanced anomaly detection, prognostic, and diagnostic architectures will be required. The architecture will be designed to optimize multi-dimensional/objective criteria, enable optimal adaptive redundancy management, support large-scale data, decision, and information fusion, and meet safety, cost, and performance criteria for the IVHM system. However, the development of such a vehicle-wide system must be done by many teams of different disciplines at different locations. Therefore, a standard project database is needed that stores and manages test data, failure statistics, fault modes and effects, diagnostic and prognostic models, simulations, and related documentation for all the systems, subsystems, and components that are part of the complex system for which an IVHM system is being developed.

The IVHM database must also allow for seamless integration with a variety of IVHM algorithms, including data mining, machine learning, and exploratory data analysis tools, in order to enable algorithm development and knowledge discovery using the same database of historical data. The IVHM database will be owned and operated
by NASA and will be provided as a service to the aircraft industry, U.S. government, and the R&D community. The database will provide industry standard access controls to protect proprietary data rights as well as to ensure compliance with ITAR and EAR restrictions. Additionally, design tools/decision support systems that enable the design of aircraft while accounting for the sensing, processing, and data mining/analysis needs of IVHM is vital. These tools/systems must enable the designers and the analysts/discipline specialists to work together, rather than as separate entities, and must allow IVHM system design, including study of IVHM system tradeoffs, at the early aircraft design stage.

In order to ensure the safe and reliable application of IVHM technologies to civil aviation, advances in verification and validation (V&V) processes and underlying methods and tools are needed to assure the safety of systems that will become increasingly complex and nondeterministic. Advances are needed in compositional verification that will enable the safe integration of complex adaptive systems with strong guarantees of integrity, fault-tolerance, partitioning, and real-time. New tools, methods, and processes are needed for the V&V of diagnostic algorithms with non-deterministic behavior. The goal of the V&V research is to enable compelling evidence that required system properties are guaranteed by the composition of constituent parts, and to develop tools, methods and processes that mitigate concerns about design validity, safety, and reliability for complex, nondeterministic software-intensive systems.

Proposals are sought that advance the state-of-the-art in architecture, system integration, databases, and V&V technologies that will facilitate the deployment of IVHM systems that satisfy safety and performance requirements. The potential impact of the proposed technologies should be linked to improvements in large-scale systems design, deployment, safety and reliability, quality and performance. Specific technology areas where contributions are sought include, but are not limited to the following:

- Design tools/decision support systems that account for the needs of IVHM, including sensing, processing, data collection, onboard data mining, and fault diagnostics and prognostics algorithms.

- A project database that stores and manages test data, failure statistics, fault modes and effects, diagnostic and prognostic models, simulations, and related documentation for all the systems, subsystems, and components. The IVHM database must also allow for seamless integration with a variety of IVHM algorithms, including data mining, machine learning, and exploratory data analysis tools, in order to enable algorithm development and knowledge discovery using the same database of historical data.

- Advances in compositional verification supported by High Confidence Real-Time Operating Systems (RTOS), Middleware (MW), and/or Virtual Machines (VM) that may be independently designed and verified. Desired system properties include dynamic re-allocation of computational resources; correct and consistent disambiguation of fault syndromes, particularly with respect to segregating faults within the computational infrastructure from faults in other vehicle systems; and graceful evolution of system capabilities, with minimum adverse effects due to parts and software obsolescence.

- New tools, methods, and processes for verification and validation of diagnostic algorithms with non-deterministic behavior. A desired outcome from this research effort would be a demonstration of the relevance of the tools, methods, and processes towards flight software acceptance as applied to a specific non-deterministic algorithm (e.g., neural network, genetic algorithm, fuzzy rule-based inference, etc.).
A1.12 Technologies for Improvement Design and Analysis of Flight Deck Automation

Lead Center: ARC
Participating Center(s): LaRC

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 flight deck systems. NASA seeks innovative design methods and tools for representing the complex human-automation interactions that will be part of future adaptive 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. Specific areas of interest include the following:

- Computational 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 with respect to overall system integrity;
- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments;
- Tools to extract information from analog information flows and transform to usable information content.

All proposals should include a means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

A1.13 On-Board Flight Envelope Estimation for Unimpaired and Impaired Aircraft

Lead Center: LaRC
Participating Center(s): AFRC, ARC, GRC

A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomaly. Anomalies may occur in a variety of forms such as 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 under anomaly. To be able to effectively develop and apply such methods, it is highly desirable, if not essential, to characterize the anomaly and assess the limits of operation of the impaired vehicle. 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 topic 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, but are not limited to, 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 adaptive structure to satisfy sub-system constraints under adverse conditions;
- Real-time fault diagnostic and prognostics capability needed in adaptive flight, propulsion, structural control application;
- 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;
- Metrics and assessment models for safety-of-flight diagnostics and prognostics.