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. The primary areas of program interest are 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; system-level integrated resilient control technologies; as well as effective vehicle-based flight/mission management under adverse, upset, and hazards conditions. 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 Vehicle-Centric 4D Trajectory and Mission Management

**Lead Center:** ARC

NASA is concerned with creating new and innovative methods for airborne detection, identification and resolution of tactical hazards to aviation. These hazards may include weather and other atmospheric phenomena, terrain, traffic, aircraft system failures, and aircraft/operator interactions. Research proposals are sought in the area of 4D vehicle-centric trajectory and mission management, with emphasis on mission planning, external hazard response, and workload reduction.

The three major research areas covered by this subtopic are:

**Mission Planning**

Dynamic changes in an aircraft's tactical situation require rapid generation of a flight plan that best accomplishes a global set of mission goals. Mission management (MM) uses cost functions and any-time planning algorithms to
produce feasible flight plans. The specific capabilities desired in this area are the generation and specification of 4D trajectories, and defining requirements and constraints (look-ahead time, ground system interface, aircraft system integration, etc.) related to the planning of such trajectories.

Response to Detected External Hazards
Sensing systems detect obstacles, weather and other constraints in the flight path; MM commands short-term trajectory change, with compensating downstream legs to minimize schedule impact. Capabilities expected from this research are automated decision making and path planning in the presence of external hazards, along with requirements for the creation of automation systems to accomplish such tasks.

Workload Reduction
On-the-fly generation of complex mission-driven flight plans for search patterns, data collection experiments, and tracking problems. Important activities in this area include design criteria and principles for the creation of pilot-flight deck automation interfaces and algorithmic approaches related to trajectory management.

Examples of outcomes NASA expects from these research areas are provided below (this list is not exclusive of other high-potential ideas):

- Automated trajectory generation capability given a short-to-medium term time horizon;
- A flexible input and interface capability for the flight deck in terms of widely varying constraints, goals, costs and supporting systems;
- Procedural and algorithmic methods of achieving mission management goals under different and varying constraints;
- Working interfaces that allow a pilot to view a 4D trajectory and accept or reject it, modify and retransmit a 4D trajectory uploaded from ground-based automation systems, or generate and trial plan a 4D trajectory for air traffic control approval;
- Automated decision making and path planning capability that allows an aircraft to decide what particular actions are most appropriate to respond to specific situations, along with requirements for and analysis of the appropriate circumstances under which this capability should be exercised.

A1.02 Integrated Resilient Aircraft Control

Lead Center: ARC

Participating Center(s): AFRC, GRC, LaRC

The overarching goals for the Aviation Safety topic are to develop technologies, tools, and methods to (1) improve the inherent safety attributes of new and legacy vehicles, and (2) overcome safety technology barriers that would otherwise constrain full realization of the Next Generation Air Transportation System.

The specific technologies, tools and methods emphasized in this subtopic are vehicle dynamics and hazards effects modeling and simulation methods for coupled hazard effects assessment; detection, identification and prediction methods for flight safety diagnostics and prognostics; control and guidance methods for hazard mitigation, control recovery, and vehicle autonomy under adverse and emergency conditions; robust design and risk analysis and mitigation methods; advanced control structures and materials for resilient control; instrumentation for intelligent sensing, monitoring, and control; validation methods for complex models and adaptive systems; and software safety assurance and formal verification methods for safety-critical systems, leading to multi-disciplinary analysis and optimization capabilities that enable the development and validation of system-level integrated resilient control technologies to provide graceful recovery from potentially catastrophic in-flight failures/damage, external disturbances, vehicle upsets, and system and control input errors; as well as effective vehicle-based flight/mission management under adverse, upset, and hazards conditions. Proposals are sought in the following areas:
Resilient Flight Control

- Fault tolerance and hazard effects protection
- Onboard hazard effects assessment, mitigation and control recovery

Resilient Propulsion Control

- Damage tolerance and design for extended envelope operation
- Onboard hazard effects assessment, mitigation and control recovery

Resilient Airframe Control

- Damage tolerance and structural damage avoidance
- Onboard damage detection and identification, mitigation and control recovery

Resilient Vehicle Mission Management

- Control and performance management
- Vehicle-based mission management and autonomous collision avoidance
- Interface and communication management

Safety-Critical Systems V&V

- Software safety assurance methods for complex avionics systems
- Integrated V&V methods, tools, and test techniques for adaptive control systems
- Predictive capability assessment methods and tools

A1.03 Aircraft Aging and Durability

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Aircraft aging is a significant national issue that is being addressed by government agencies, manufacturers, operators, and academia. NASA's contribution to solving the problem is research on aging and damage processes in "young" aircraft, rather than life extension of legacy vehicles. Its emphasis is on new and emerging material systems/fabrication techniques and the potential hazards associated with their aging-related degradation. The intent is to identify aging-related hazards before they become critical, and develop technology to anticipate aging and maintenance needs in the design of future aircraft.

NASA performs multi-level research in aging science leading ultimately to multi-disciplinary analysis and optimization capabilities that will enable system-level integrated detection, prediction and mitigation of aging-related hazards in future civilian and military aircraft. To further the fundamental understanding of the underlying physics and to develop an ability to model the physical processes, foundational research is conducted in the following areas: sensing and diagnostic technologies; physics-based modeling; continuum-based models and computational methods; material science (metals, ceramics, composites); and characterization/validation test techniques. Building upon foundational research yields discipline-based products: nondestructive evaluation (NDE) systems; structural integrity tools; lifing methods; and concepts to mitigate aging-effects. By integration of discipline-based tools, multi-disciplinary methods and technologies are developed; e.g., detection capability is enhanced by coupling NDE with
structural integrity analysis, prediction capability is enhanced by applying NDE (and vehicle health monitoring data) to improve model input and provide improved predictions of remaining life and strength, and mitigation capability is enhanced by applying predictive models to help develop advanced mitigation concepts.

Specifically, NASA requests proposals that assimilate the above multi-layer approach, which provide innovative solutions to one of the following problems:

- The use of integral metallic structure in airframe application provides unique crack growth and fracture characteristics that are not consistent with traditional metallic structure characteristics. Computational methods for elasto-plastic crack propagation, including non-self-similar growth and bifurcation of 2D and 3D cracks, are needed for predicting crack growth in complex metallic geometries. Computational methods must be incorporated into a user interface software tool.
- Computational methods for the prediction of strength of composite and metal/composite hybrid skin-stringer fuselage present the following technical challenges: numerical regularization techniques to improve convergence of delamination propagation simulation; and X-FEM for failure prediction that address interaction between in-plane and interlaminar failure modes. Solutions to these two challenges are sought.
- Novel techniques for large-area nondestructive evaluation (detection of damage and material degradation) of metallic and composite fuselage and wing structure are needed.
- Adhesive bonds are critical to integrity of built-up structure. Disbonds (i.e., gaps) can often be detected, but the strength of the adhesion between surfaces in contact is not obvious. Methods to detect bond degradation, predict disbond growth, and characterize weak bonds are needed.
- Advanced composite concepts for jet engine containment structures have unknown long-term service/environment effects. Better models and tools are needed for understanding these effects and for predicting engine blade-off event physics (i.e., the high strain-rate impact) to reduce risk and cost.
- New nickel-based superalloys which enable higher turbine disk operating temperatures have been developed. However, tools to understand and mitigate the long term durability and aging characteristics (e.g., microstructural instability and corrosion) of these alloys are needed.
- Degradation and damage that develops over time in engine hot section components can lead to catastrophic failure. Methods and sensors for characterization of degradation processes of these components (including ceramics) in harsh environments during system development are needed.
- Faults and hazards in aging vehicle wiring persist as a problem in legacy vehicles, and will pose risks in new vehicles. Novel methods (i.e., have not already been researched by FAA and DoD) are sought to detect and characterize degradation, and to predict useful life of wiring systems.

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

A1.04 Aircraft Icing Avoidance and Tolerance

Lead Center: GRC
Participating Center(s): ARC

NASA is concerned with preventing encounters with hazardous in-flight conditions and the mitigation of their effects when they do occur. To maximize the level of safety, aircraft must be capable of handling all possible icing conditions by either avoiding or tolerating the conditions. Proposals are invited that lead to innovative new approaches or significant improvements in existing technologies for in-flight icing conditions avoidance (icing weather information systems) or tolerance (airframe and engine ice protection systems and design tools). With these emphases in mind, products and technologies that can be made affordable and retrofitable within the current aviation system, as well as for use in the future are sought:

- Ground and airborne radome technologies for microwave wavelength radar and radiometers that remain clear of liquid water and ice in all weather situations.
• In situ icing environment measurement systems that can provide practical, very low-cost validation data for emerging icing weather information systems and atmospheric modeling. Measured information must include location, altitude, cloud liquid water content, temperature, and cloud particle sizing and phase information. Solutions envisioned would use radiosonde-based systems.
• Ice protection and detection technology submittal must provide significant improvements over current systems or address new design needs. Areas of improvement can be considered to be: efficient thermal protection systems, including composite wing or structures applications; ice sensors that provide detection and accretion rate for all possible icing conditions; wide area ice detection; detection that serves both ground and in-flight applications; ice crystal detection probe (for non-research aircraft applications); engine icing probe (that can measure Liquid Water Content and Total Water Content inside engine passages); and de-icing systems that operate at near anti-icing performance. Any submittal must be cost competitive to current technologies.

A1.05 Crew Systems Technologies for Improved Aviation Safety
Lead Center: LaRC
Participating Center(s): ARC

A1.06 Aviation External Hazard Sensor Technologies
Lead Center: LaRC
Participating Center(s): ARC

NASA is concerned with new and innovative methods for airborne detection and identification of tactical hazards to aviation. These hazards may include weather and other atmospheric phenomena, terrain, traffic, and runway contamination. Examples of hazards include: 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. 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; mitigation techniques using real-time sensor data, sharing of information to support hazard avoidance by other aircraft, collaborative decision-making, updates to terrain/obstacle databases, and provision of observations for input to weather models and forecast/nowcast products are also of interest. 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 generate alerts of aviation hazards;
• Innovative technologies and methods to detect, predict, and quantify hazards in order to provide accurate information and guidance to enable pilot avoidance hazards, or to instigate strategies for mitigation;
• Decision-support tools and methods to improve collaborative and distributive decision-making.