NASA SBIR 2008 Phase I Solicitation

Aeronautics Research

Aviation Safety Topic A1

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

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

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

NASA seeks highly innovative proposals that will complement its work in science and technologies that build upon and advance the Agency's unique safety-related research capabilities vital to aviation safety. Additional information is available at http://www.aeronautics.nasa.gov/programs_avsafe.htm [1].

Sub Topics:

A1.01 Mitigation of Aircraft Aging and Durability-related Hazards

Lead Center: GRC

Participating Center(s): ARC, LaRC

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

Proposals are sought for the development of moisture-resistant resins and new surface treatments/primers. Novel chemistries are sought to improve the durability of aerospace adhesives with potential use on subsonic aircraft.

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

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

Lead Center: LaRC

Participating Center(s): ARC, GRC

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

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

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

A1.03 Prediction of Aging Effects

Lead Center: LaRC

Participating Center(s): ARC, GRC

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

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

A1.04 Aviation External Hazard Sensor Technologies

Lead Center: LaRC

NASA is concerned with new and innovative methods for airborne detection, identification, evaluation, and monitoring of in-flight hazards to aviation. NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen) (information available at www.jpdo.gov [2]). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable sensors. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are needed.

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

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

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

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

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

A1.05 Crew Systems Technologies for Improved Aviation Safety

Lead Center: LaRC

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

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

Proposals should describe novel technologies with high potential to serve the objectives of the Robust Automation/Human Systems element of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/rahs.htm [3]). Successful Phase 1 proposals should culminate in a final report that specifies, and a Phase 2 proposal that would realize, technology that improves the effectiveness of joint human-automation systems in aviation, or improves the ability to assess effectiveness of such systems.

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

Lead Center: ARC

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

- Computational/modeling approaches to support determining appropriate human-automation function allocations with respect to safety and performance;
- Design tools and methods that improve the application of human-centered design principles to the design and certification of mixed human-automated systems;
- Tools and methods for modeling the complex information management systems required for future flight deck systems;
- Methods of data uncertainty estimation during the flight deck system design phase particularly as applied to predicting overall system integrity;

- Design and analysis methods or tools to better predict and assess human and system performance in relevant operational environments.

Proposals should describe novel design methods, metrics, and/or tools with high potential to serve the objectives of the System Design and Analysis element of NASA’s Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/sda.htm [4]). Successful Phase 1 proposals should culminate in a final report that specifies, and a Phase 2 proposal that would realize, tools that improve the design process for human-automation systems in aviation, or improves the ability to assess effectiveness of such systems during the design phase. All proposals should discuss means for verification and validation of proposed methods and tools in operationally valid, or end-user, contexts.

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

Lead Center: LaRC

Participating Center(s): ARC

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

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

- Adaptive mathematical framework for control-centric onboard aircraft models that can accommodate real-time changes to subsystem dynamics;
- Real-time system identification capability for updating an onboard vehicle model with an adaptive structure to satisfy sub-system constraints under adverse conditions;
- Real-time fault diagnostic and prognostics capability needed in adaptive flight, propulsion, structural control applications;
- Real-time control power map identification with inclusion of aircraft sub-system constraints under adverse conditions;
- Real-time dynamic flight envelope identification and prediction capability; and

- Metrics and assessment models for safety-of-flight diagnostics and prognostics.

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

Lead Center: GRC

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

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

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

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

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

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

Lead Center: ARC

Participating Center(s): AFRC, LaRC

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

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

A1.10 Detection of In-Flight Aircraft Anomalies

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

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

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

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

A1.11 Integrated Diagnosis and Prognosis of Aircraft Anomalies

Lead Center: ARC

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

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

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

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

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

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

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

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

- The development of an integrated approach for diagnostics and prognostics that demonstrate a mathematically rigorous method for propagating diagnostic uncertainty and its effect on subsequent estimates of remaining useful life.
- Physics-based damage propagation models for one or more relevant aircraft subsystems such as

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

- Novel approaches to assess the quality and accuracy of remaining useful life estimates through the fusion of different models, active probing of components, etc.
- Uncertainty representation and management methods. Proposers are encouraged to consider uncertainties due to measurement noise, imperfect models and algorithms, as well as uncertainties stemming from future anticipated loads and environmental conditions.
- Mathematically rigorous methodologies for assessing the quality of remaining useful life predictions and associated uncertainties.
- Verification and validation methods for prognostic algorithms.

A1.12 Mitigation of Aircraft Structural Damage

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

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

Healing Material System Concepts for IVHM/AAD

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

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

Fundamental Aeronautics Topic A2

The Fundamental Aeronautics Program (FAP) encompasses the principles of flight in any atmosphere, and at any speed. The program develops focused technological capabilities, starting with the most basic knowledge of underlying phenomena through validation and verification of advanced concepts and technologies at the component and systems level. Physics-based, multidisciplinary design, analysis, and optimization (MDAO) tools will be developed that make it possible to evaluate radically new vehicle designs and to assess, with known uncertainties, the potential impact of innovative technologies and concepts on a vehicle's overall performance. The development of advanced component technologies will realize revolutionary improvements in noise, emissions, and performance. The program also supports NASA's human and robotic exploration missions by advancing knowledge in aeronautical areas critical to planetary Entry, Descent, and Landing.

NASA has defined a four-level approach to technology development: conduct foundational research to further our fundamental understanding of the underlying physics and our ability model that physics; leverage the foundational research to develop technologies and analytical tools focused on discipline-based solutions; integrate methods and technologies to develop multi-disciplinary solutions; and solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration.

Structurally, the FAP is composed of four projects: hypersonic flight, supersonic flight, subsonic fixed-wing aircraft and subsonic rotary-wing aircraft.

Hypersonics

- Fundamental research in all disciplines to enable very-high speed flight and re-entry into planetary atmospheres
- High-temperature materials; thermal protection systems; advanced propulsion; aero-thermodynamics; multi-disciplinary analysis and design; guidance, navigation, and control (GNC); advanced experimental capabilities

Supersonics

- Eliminate environmental and performance barriers that prevent practical supersonic vehicles
- Supersonic deceleration technology for Entry, Descent, and Landing into Mars

Subsonic Fixed Wing (SFW)

- Develop revolutionary technologies and aircraft concepts with highly improved performance satisfying strict noise and emission constraints
- Focus on enabling technologies: acoustics predictions, propulsion/combustion, system integration, high-lift concepts, lightweight and strong materials, GNC

Subsonic Rotary Wing (SRW)

- Improve civil potential of rotary wing vehicles while maintaining their unique benefits
- Key advances in multiple areas through innovation in materials, aeromechanics, flow control, propulsion

Each project addresses specific discipline, multi-discipline, sub-system and system level technology issues relevant to that flight regime. A key aspect of the Fundamental Aeronautics Program is that many technical issues are common across multiple flight regimes and may be best resolved in an integrated coordinated manner. As such, the FAP subtopics are organized by discipline, not by flight regime, with a special subtopic for rotary-wing issues. Additional information is available at http://www.aeronautics.nasa.gov/fap/index.html [5].
Sub Topics:

A2.01 Materials and Structures for Future Aircraft

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Advanced materials and structures technologies are needed in all four of the NASA Fundamental Aeronautics Programs research thrusts (Subsonic Fixed Wing, Subsonic Rotary Wing, Supersonic, Hypersonic) to enable the design and development of advanced future aircraft. Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems and should be linked to improvements in aircraft performance indicators such as vehicle weight, noise, lift, drag, lifetime, and emissions. The technologies of interest cover five research subtopics:

Fundamental Materials Development, Processing and Characterization

- Multifunctional materials and structural concepts for engine and airframe structures, such as, novel approaches to mitigating lightning strike, aircraft engine fan cases with integrated acoustic treatments and ballistic impact resistance.
- Adaptive materials and structural concepts for engine and airframe structures, such as shape memory alloys and polymers for active and highly flexible airframe and engine components, piezoelectric ceramics and polymers for self-damping engine and airframe components, materials and structures with integrated self-diagnostic, self-healing and actuation capabilities.
- Advanced high temperature materials for aircraft engine and airframe components and thermal protection systems, including advanced blade and disk alloys, ceramics and CMCs, and coatings to improve environmental durability.
- Innovative processing methods to reduce component manufacturing costs and improve damage tolerance and reliability, including processing and joining of ceramics, metals, polymers, composites, and hybrids, as well as nanostructured and multifunctional materials and coatings.
- Innovative methods for the evaluation of advanced materials and structural concepts (in particular, multifunctional and/or adaptive) under simulated operating conditions, including combinations of electrical, thermal and mechanical loads.

Structural Analysis Tools and Procedures

- Design methods for advanced materials and structural concepts (in particular, multifunctional and/or adaptive components) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational modeling, and multi-physics modeling and simulation tools.
- Rapid design methods for airframe structures.
- Prediction tool for advanced engine containment systems, including multifunctional approaches.
- Integrated structural design and analysis methods for advanced composite materials.
- Design, development, analysis, and verification methods for structural joining technologies for high-temperature composite airframe and propulsion structures including bonding, fastening, and sealing.

Computational Materials Development Tools

- Computational materials tools for the development of durable high temperature materials.

- Computational tools to predict materials properties based upon chemistry and processing for conventional as well as nanostructured, multifunctional and/or adaptive materials.

Advanced Structural Concepts

- Innovative structural concepts and materials and/or robust thermal protection systems leading to reliable, high-mass planetary entry, descent and landing systems including deployable heat shields, high temperature films and fabrics.
- Improved thermal protection systems using innovative structural and material concepts, including structurally integrated multifunctional systems.
- Advanced mechanical component technologies including self lubricating coatings, oil-free bearings, and seals.
- Advanced material and component technologies to enable the development of a mechanical and electrical drive system to distribute power from a single engine core to drive multiple propulsive fans, in particular, AC-tolerant, low loss (< 10 W/kA-m) conductors or superconductors for the stators of synchronous motors or generators operating at > 1.5 T field and 500 Hz electrical frequency; and high efficiency (>30% of Carnot), low mass (<6kg/kW input) cryo-refrigerators for 20 to 65°K (lower efficiencies and mass-per-input-power that give the same or better refrigeration and mass are acceptable). Input power between 10 and 100 kW is envisioned in applications, but scalable small demonstrations are acceptable.

Durable Structural Sensor Technology for Extreme Environments (>1800°F)

- Development and validation of advanced high-temperature sensor technology to measure strain, temperature, heat flux, and/or acceleration of structural components.
- Development and validation of improved sensor bonding methods (i.e., adhesives, plasma spraying techniques, etc.) for attaching structural sensors on advanced high-temperature materials.

A2.02 Combustion for Aerospace Vehicles

Lead Center: GRC

Participating Center(s): LaRC

A2.03 Aero-Acoustics

Lead Center: LaRC

Participating Center(s): ARC, GRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, and advanced aerospace vehicles. In support of the Fundamental Aeronautics Program, improvements in noise prediction, measurement methods and control are needed for subsonic and supersonic vehicles, including fan, jet, turbomachinery, and airframe noise sources. In addition, improvements in prediction and control of noise transmitted through aerospace vehicle structures are needed to reduce noise impact on passengers, crew and launch vehicle payloads. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid-dynamics techniques for aero-acoustic analysis, which can be adapted for design codes;
- Prediction of aero-acoustic noise sources including engine and airframe noise sources and sources which arise from significant interactions between airframe and propulsion systems;
- Prediction of sound propagation (including sonic booms) from the aircraft through a complex atmosphere to

the ground. This should include interaction between noise sources and the airframe and its flowfield;
- Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process;
- Prediction and control of high-amplitude aero-acoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue;
- Innovative source identification techniques for engine (e.g., fan, jet, combustor, or turbine noise) and air-frame (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise sources typical of jets, separated regions, vortices, shear layers, etc.;
- Concepts for active and passive control of aero-acoustic noise sources for conventional and advanced air-craft configurations, including adaptive flow control technologies, smart structures for nozzles and inlets, and noise control technology and methods that are enabled by advanced aircraft configurations, including advanced integrated airframe-propulsion control methodologies;
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aero-space vehicle structures;
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise, including sonic boom;
- Development and application of flight procedures for reducing community noise impact while maintaining or enhancing safety, capacity, and fuel efficiency.

A2.04 Aeroelasticity

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

The NASA Fundamental Aeronautics program has the goal to develop system-level capabilities that will enable the civilian and military designers to create revolutionary systems, in particular by integrating methods and technologies that incorporate multi-disciplinary solutions. Aeroelastic behavior of flight vehicles is a particularly challenging facet of that goal.

The program's work on aeroelasticity includes conduct of broad-based research and technology development to obtain a fundamental understanding of aeroelastic and unsteady-aerodynamic phenomena experienced by aerospace vehicles, in subsonic, transonic, supersonic, and hypersonic speed regimes. The program content includes theoretical aeroelasticity, experimental aeroelasticity, and advanced aeroservoelastic concepts. Of interest are aeroelastic, aeroservoelastic, and unsteady aerodynamic analyses at the appropriate level of fidelity for the problem at hand; aeroelastic, aeroservoelastic, and unsteady aerodynamic experiments, to validate methodologies and to gain valuable insights available only through testing; development of computational-fluid-dynamic, computational-aeroelastic, and computational-aeroservoelastic analysis tools that advance the state-of-the-art in aeroelasticity through novel and creative application of aeroelastic knowledge.

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for assuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure, and at times, active systems controlling the flight vehicle. Complex unsteady aerodynamic flow phenomena, particularly at transonic Mach numbers, are also very important because this is the speed regime most critical to encountering aeroelastic instabilities. In addition, aeroelasticity is presently being exploited as a means for improving the capabilities of high performance aircraft through the use of innovative active control systems using both aerodynamic and smart material concepts. Work to develop analytical and experimental methodologies for reliably predicting the effects of aeroelasticity and their impact on aircraft performance, flight dynamics, and safety of flight are valuable. Subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of methods to predict aeroelastic phenomena and complex steady and unsteady aerodynamic flow phenomena, especially in the transonic speed range. Aeroelastic phenomena of interest include flutter, buffet, buzz, limit cycle oscillations, and gust response. Flow phenomena of interest include viscous effects, vortex flows, separated flows, transonic nonlinearities, and unsteady shock motions.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight

vehicles for performing vibration, aeroelastic, and aeroservoelastic studies. Examples include (a) CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, and flutter issues and (b) integrated tool sets for fully coupled modeling and simulation of aeroservothermoelasticity/flight dynamic (ASTE/FD) and propulsion effects.
- Development of physics-based models for turbomachinery aeroelasticity related to highly separated flows, shedding, rotating stall, and non-synchronous vibrations (NSV). This includes robust, fast-running, accelerated convergence, reduced-order CFD approaches to turbomachinery aeroelasticity for propulsion applications. Development of blade vibration measurement systems (including closely spaced modes, blade-to-blade variations (mistuning), and system identification) and blade damping systems for metallic and composite blades (including passive and active damping methods) are of interest.
- Development of aeroservoelasticity concepts and models, including unique control concepts and architectures that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Development of techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroelastic phenomena.
- Investigation and development of techniques that incorporate structure-induced noise, stiffness and strength tailoring, propulsion-specific structures, data processing and interpretation methods, non-linear and time-varying methods development, unstructured grid methods, additional propulsion systems-specific methods, dampers, multistage effects, non-synchronous vibrations, coupling effects on blade vibration, probabilistic aerodynamics and aeroelastics, actively controlled propulsion system core components (e.g., fan and turbine blades, vanes), and advanced turbomachinery active damping concepts.
- Investigation and development of techniques that incorporate lightweight structures and flexible structures under aerodynamic loads, with emphasis on aeroelastic phenomena in the hypersonic domain. Investigation of high temperatures associated with high heating rates, resulting in additional complexities associated with varying thermal expansion and temperature dependent structural coefficients. Acquisition of data to verify analysis tools with these complexities.

A2.05 Aerodynamics

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

The challenge of flight has at its foundation the understanding, prediction, and control of fluid flow around complex geometries – aerodynamics. Aerodynamic prediction is critical throughout the flight envelope for subsonic, supersonic, and hypersonic vehicles – driving outer mold line definition, providing loads to other disciplines, and enabling environmental impact assessments in areas such as emissions, noise, and aircraft spacing.

In turn, high confidence prediction enables high confidence development and assessment of innovative aerodynamic concepts. This subtopic seeks innovative physics-based models and novel aerodynamic concepts, with an emphasis on flow control, applicable in part or over the entire speed regime from subsonic through hypersonic flight.

All vehicle classes will experience subsonic flight conditions. The most fundamental issue is the prediction of flow separation onset and progression on smooth, curved surfaces, and the control of separation. Supersonic and hypersonic vehicles will experience supersonic flight conditions. Fundamental to this flight regime is the sonic boom, which to date has been a barrier issue for a viable civil vehicle. Addressing boom alone is not a sufficient mission enabler however, as low drag is a prerequisite for an economically viable vehicle, whether only passing through the supersonic regime, or cruising there. Atmospheric entry vehicles and space access vehicles will experience hypersonic flight conditions. Reentry capsules such as the new Crew Exploration Vehicle deploy multiple parachutes during descent and landing. Predicting the physics of unsteady flows in supersonic and subsonic speeds is important for the design of these deceleration systems. The gas-dynamic performance of decelerators for vehicles entering the atmospheres of planets in the solar system is not well understood. Reusable hypersonic vehicles will be designed such that the lower body can be used as an integrated propulsion system in cruise condition. Their performance is likely to suffer in off-design conditions, particularly acutely at transonic speeds. Advanced flow control technologies are needed to alleviate the problem.

This solicitation seeks proposals to develop and validate:

- Turbulence models capturing the physics of separation onset at Reynolds numbers relevant to flight, where relevant to flight is dependent on a targeted vehicle class and mission profile;
- Boundary-layer transition models suitable for direct integration with state-of-the-art flow solvers;
- Active flow control concepts targeted at separation control and/or viscous drag reduction with an emphasis on the development of novel, practical, lightweight, low-energy actuators;
- Innovative aerodynamic concepts targeted at vehicle efficiency or control;
- Physics-based models for simultaneous low boom/low drag prediction and design;
- Aerodynamic concepts enabling simultaneous low boom and low drag objectives;
- Innovative methods to validate both flow models and aerodynamic concepts with an emphasis on aft-shock effects which are hindered by conventional wind tunnel model mounting approaches;
- Accurate aerodynamic analysis and multidisciplinary design tools for multi-body flexible structures in the atmospheres of planets and moons including the Earth, Mars, and Titan;
- Advanced flow control technologies to alleviate off-design performance penalties for reusable hypersonic vehicles.

A2.06 Aerothermodynamics

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

Development of accurate tools to predict aerothermal environments and their effects on space vehicles is critically important to achieving the goals of current NASA missions. These tools will also enable the development of advanced spacecraft for future missions by reducing uncertainties during design and development.

The large size and high re-entry velocity of the Crew Exploration Vehicle and the conditions encountered in proposed aerocapture missions to Titan, Neptune, and Venus require study of shock layer radiation phenomena, radiative heat transfer, and non-equilibrium thermodynamic and transport properties; these in turn require understanding of the internal structure and dynamics of the constituent gases.

Transition and turbulence effects are particularly complex in hypersonic flows, where unique problems are posed by shocks, real gas effects, body surfaces with complex and possibly time-dependent roughness, nose bluntness, ablation, surface catalyticity, separation, and an unknown free-stream disturbance environment.

At the heating rates encountered during hypersonic re-entry, surface ablation products blowing into the boundary layer introduce new interactions including chemical reactions and radiation absorption, that strongly affect surface heating rates and integrated heat loads.

Proposals suggesting innovative approaches to any of these issues are encouraged; specific research areas of interest include:

- Computational analysis methods for radiation and radiation transport in the shock layer surrounding planetary entry vehicles;
- Advanced physics-based thermal and chemical non-equilibrium models for thermodynamics, transport, and radiation;
- Studies of the interactions of gases in the shock layer with ablating materials from the vehicle thermal protection system;
- Experimental methods and diagnostics to measure the characteristics of hypersonic flow fields, either in flight or in ground-based facilities;
- Software tools coupling radiation, non-equilibrium chemistry, Reynolds-averaged Navier-Stokes, and large eddy simulation codes to enable the design and validation of mission configurations for en-try into planetary atmospheres.

A2.07 Flight and Propulsion Control and Dynamics

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Enabling advanced aircraft configurations for subsonic, supersonic and hypersonic flight, and high performance "Intelligent Engines" will require advancement in the state-of-the art dynamic modeling and flight/propulsion control. The need to minimize the carbon footprint will necessitate new trajectory planning and control concepts. Control methods need to be developed and validated for "optimal" and reliable performance of complex, unsteady, and nonlinear systems with significant modeling uncertainties while ensuring operational flexibility, enabling unique concepts of operations with novel configurations, lower emissions and noise, and safe operation over a wide operating envelope. New dynamic modeling and simulation techniques need to be developed to investigate dynamic performance issues and support development of control strategies for innovative aircraft configurations with enhanced control effectors and propulsion systems. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance, and load control including smart actuation and active aerostructural concepts, active control of propulsion system components, and drag minimization for high efficiency and range performance. Technology needs specific to different flight regimes are summarized in the following:

Subsonic Fixed Wing Aircraft
Technologies of interest, with application to both flight and propulsion control, include: methods for development of dynamic models and simulations of the integrated component/control system being considered; defining actuation requirements for novel control approaches and developing prototype actuators for flight-like environments; developing and applying innovative control methods and validating them through laboratory test, vehicle simulations and sub-scale flight test as appropriate. Technologies related to the development and integration of modular, open-system control elements leading to the transition to distributed control architecture in the engine environment are of special interest.

Supersonic Flight
Technologies of interest include: methods for developing integrated dynamic models and simulation including propulsion and aeroelastic effects and suitable for control design; novel control design methods for integrated aero-propulsion-servo-elastic control leading to acceptable flying qualities over the operating flight envelope; novel, and feasible, takeoff and approach to landing procedures to accommodate the visibility challenges due to long fore-bodies; integrated inlet/engine control to ensure safe (no inlet unstart or compressor surge/stall) and efficient operation.

Hypersonic Flight
Technologies of interest include: system dynamic models incorporating the essential coupled dynamic elements with varying fidelity for control design, analysis and evaluation; methods for characterizing uncertainty in the dynamic models to enable control robustness evaluation; hierarchical GNC (Guidance, Navigation and Control) architectures and energy management techniques to enable trajectory shaping and control over a wide operating envelope with integrated flight/propulsion control; adaptive and robust control methods that can handle large modeling uncertainties; simulation test beds for evaluating hypersonic concept vehicle control under various types of uncertainty, system wide coupling and associated model misspecification.

A2.08 Aircraft Systems Analysis, Design and Optimization

Lead Center: GRC

One of the approaches to achieve the NASA Fundamental Aeronautics Program goals is to solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration. The needs to meet this approach can be defined by four general themes:

1. Design Environment Development;
2. Variable Fidelity, Physics-Based Design/Analysis Tools;
3. Technology Assessment and Integration; and
4. Evaluation of Advanced Concepts.

Current interdisciplinary design/analysis involves a multitude of tools not necessarily developed to work together, hindering their application to complete system design/analysis studies. Multi-fidelity, multi-disciplinary optimization frameworks, such as Numerical Propulsion System Simulation (NPSS), have been developed by NASA but have limited capabilities to simulate complete vehicle systems. Solicited topics are aligned with these four themes that will support this NASA research area.

(1) Design Environment Development

Technology development is needed to provide complex simulation and modeling capabilities where the computer science details are transparent to the engineer. A framework environment is needed to provide a seamless integration environment where the engineer need not be concerned with where or how particular codes within the system level simulation will be run. Interfaces and utilities to define, setup, verify, determine the appropriate resources, and launch the system simulation are also needed.

Research challenges include the engineering details needed to numerically zoom (i.e., numerical analysis at various levels of detail) between multi-fidelity components of the same discipline, as well as, multi-discipline components of the same fidelity. A major computer science challenge is developing boundary objects that will be reused in a wide variety of simulations.

Proposals will be considered that enable coupling differing disciplines, numerical zooming within a single discipline, deploying large simulations, and assembling and controlling secure or non-secure simulations.

(2) Variable Fidelity, Physics-Based Design/Analysis Tools

An integrated design process combines high-fidelity computational analyses from several disciplines with advanced numerical design procedures to simultaneously perform detailed Outer Mold Line (OML) shape optimization, structural sizing, active load alleviation control, multi-speed performance (e.g., low takeoff and landing speeds, but efficient transonic cruise), and/or other detailed-design tasks. Current practice still widely uses sequential, single-discipline optimization, at best coupling low-fidelity modeling of other relevant disciplines during the detailed design phase. Substantial performance improvements will be realized by developing closely integrated design procedures coupled with highest-fidelity analyses for use during detailed-design. Design procedures must enable rapid determination of sensitivities (gradients) of a design objective with respect to all design variables and constraints, choose search directions through design space without violating constraints, and make appropriate changes to the vehicle shape (ideally both external OML shape and internal structural element size). Solicitations are for integrated design optimization tools that find combinations of design variables from more than one discipline and can vary synergistically to produce superior performance compared to the results of sequential, single-discipline optimization or repeated cut-and-try analysis.

(3) Technology Assessment and Integration

Improved analysis capability of integrated airframe and propulsion systems would allow more efficient designs to be created that would maximize efficiency and performance while minimizing both noise and emissions. Improved integrated system modeling should allow designers to consider trade-offs between various design and operating parameters to determine the optimum design for various classes of subsonic fixed wing aircraft ranging from personal aircraft to large transports. The modeling would also be beneficial if it had enough fidelity to enable it to analyze both conventional and unconventional systems. Current analysis tools capable of analyzing integrated systems are based on simplified physical and semi-empirical models that are not fully capable of analyzing aircraft and propulsion system parameters that would be required for new or unconventional systems.

Analysis tools are solicited that are capable of analyzing new and unconventional aircraft and propulsion integrated systems. These include: (1) New combustor designs, alternate fuel operation, and the ability to estimate all emissions, and (2) Noise source models (e.g., fan, jet, turbine, core and airframe components). Analyses tools that are scalable, especially to small aircraft, are desired.

(4) Evaluation of Advanced Concepts

Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. This capability will enable "virtual expeditions through the design space" for multi-mission trade studies and optimization. This will require an integrated variable fidelity concept design system. The aerospace flight vehicle conceptual design phase is, in contrast to the succeeding preliminary and detail design phases, the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information, and its chronic time pressure to find solutions. Currently, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using extremely simple analyses and heuristics. An integrated, variable fidelity system would have large benefits. Higher fidelity tools enabling unconventional configurations to be addressed in the conceptual design process are solicited.

A2.09 Rotorcraft

Lead Center: ARC

Participating Center(s): ARC, GRC, LaRC

The challenge of the Subsonic Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop validated physics-based multidisciplinary design-analysis-optimization tools for rotorcraft, integrated with technology development, enabling rotorcraft with advanced capabilities to fly as designed for any mission. Meeting this challenge will require innovative technologies and methods, with an emphasis on integrated, multidisciplinary, first-principle computational tools specifically applicable to the unique problems of rotary wing aircraft. Technologies of particular interest are as follows:

Propulsion-Variable Speed Drive Systems/Transmissions

Technologies, and predictive capability, related to enabling concepts and techniques for variable speed drive systems/transmissions suitable for large rotorcraft application are encouraged. Specifically, this would include concepts for controlling and enabling variable speed drives as well as lightweight and reliable drive system components. Efficient drive-system speed-variability on the order of 30-50% should be the focus of the proposed technologies and analysis tools.

Instrumentation and Techniques for Rotor Blade Measurements:

Instrumentation and measurement techniques are encouraged for assessing scale rotor blade boundary layer state (e.g., laminar, transition, turbulent flow) in simulated hover and forward flight conditions, measurement systems for large-field rotor wake assessment, fast-response pressure sensitive paints applicable to blade surfaces, and methods to measure the rotor tip path plane angle of attack, lateral and longitude flapping, and shaft angle in flight and in the wind tunnel.

Acoustics

Interior and exterior rotorcraft noise generation, propagation and control. Topics of interest include, but are not limited to, external noise prediction methods for manned and unmanned rotorcraft, improved acoustic propagation models, psychoacoustics analysis of rotorcraft noise, interior noise prediction methods and active/passive noise control applications for rotorcraft including engine and transmission noise reduction, advanced acoustic measurement systems for flight and wind tunnel applications, acoustic data acquisition/reduction/analysis, rotor noise reduction techniques, noise abatement flight operations. Rotor noise, including broadband, harmonic, blade-vortex interaction, high-speed impulsive; alternate tail rotor and auxiliary power concepts, rotor/tail rotor, and rotor/rotor interactional noise. Frequency range includes not only audible range, but very low frequency rotational noise (blade-passage frequency below 20 Hz) as well. Optimized active/passive concepts and noise tailoring, including rotorcraft designs that are inherently designed for lower noise as a constraint.

Proposals on other rotorcraft technologies will also be considered as resources and priorities allow, but the primary emphasis of the solicitation will be on the above three identified technical areas.

A2.10 Propulsion Systems

Lead Center: GRC

This subtopic is divided into two parts. The first part is the Turbomachinery and Heat Transfer and the second part is Propulsion Integration.

Turbomachinery and Heat Transfer

There is a critical need for advanced turbomachinery and heat transfer concepts, methods and tools to enable NASA to reach its goals in the various Fundamental Aeronautics projects. These goals include drastic reductions in aircraft fuel burn, noise, and emissions, as well as an ability to achieve mission requirements for Subsonic Rotary Wing, Subsonic Fixed Wing, Supersonics, and Hypersonics project flight regimes. In the compression system, advanced concepts and technologies are required to enable high stage loading and wider operating range while maintaining or improving aerodynamic efficiency. Such improvements will enable reduced weight and part count, and will enable advanced variable cycle engines for various missions. In the turbine, the very high cycle temperatures demanded by advanced engine cycles place a premium on the cooling technologies required to ensure adequate life of the turbine component. Reduced cooling flow rates and/or increased cycle temperatures enabled by these technologies have a dramatic impact on the engine performance. Proposals are sought in the turbomachinery and heat transfer area to provide the following specific items:

- Advanced design concepts to enable increased high stage loading in single and multi-stage axial compressors while maintaining or improving aerodynamic efficiency and operability. Technologies are sought that would reduce dependence on traditional range extending techniques (such as variable inlet guide vane and variable stator geometry) in compression systems. These may include flow control techniques near the compressor end walls and on the rotor and stator blade surfaces. Technologies are sought to reduce turbomachinery sensitivity to tip clearance leakage effects where clearance to chord ratios are on the order of 5% or above.
- Advanced flow analysis tools to enable design optimization of highly loaded compression systems that can accurately predict aerodynamic efficiency and operability. This includes computer codes with updated models for losses, turbulence, and other models that can simulate the flow through turbomachinery components with advanced design features such as swept and bowed blade shapes, flow range extension techniques, such as flow control and transition control to maintain acceptable operability and efficiency.
- Novel turbine cooling concepts are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art.
- Tools and methods are sought to optimize the turbine cooling design including film cooling and internal cooling, especially considering the ability to incorporate such tools into the engine design cycle. Currently, turbine cooling designs are developed via empirical information which may be derived from idealized cases not applicable to the actual turbine flow environment. It would benefit the community greatly to have a validated computational tool for optimizing the turbine cooling design. This tool should allow the prediction of turbine wall temperatures with sufficient accuracy and within reasonable time scales to allow optimization of the film and internal cooling geometrical features. Consideration should be given to the ability of the tool to handle CAD-based geometries.

Propulsion Integration

Proposals for Propulsion Integration will address engine and engine integration topics as outlined in this section in support of the Fundamental Aeronautics Program.

One objective of the Subsonic Fixed Wing Project is to develop verified analysis capabilities for the key technical issues related to integrating embedded propulsion systems for “N+2” hybrid wing/body configurations. These key technical issues include: inlet technologies for distorted engine inflows related to embedded engines with boundary layer ingestion; fan-face flow distortion and its effects on fan efficiency and operability, noise, flutter stability and aeromechanical stress and life; wide operability of the fan and core with a variable area nozzle; issues related to the implementation of a thrust vectoring variable area nozzle; and duct losses related to long flow paths associated with embedded engines. Specifically, proposals are sought to provide advanced technology, prediction methods and tools

The supersonics project would like proposals to develop tools and propulsion technologies that will enable the design of high performance fans; high-efficiency, low-boom, and stable inlets; high-performance, low-noise exhaust nozzles; and intelligent sensors and actuators for supersonic aircraft. The supersonics project is interested in both computational and experimental research, aimed at evaluating and analyzing promising technologies as well as understanding the fundamental flow physics that will enable improved prediction methods.

A mission class of interest to the Hypersonics Project is Highly Reliable Reusable Launch Systems (HRRLS). The HRRLS mission was chosen to build on work started in NASA’s Next Generation Launch Technology (NGLT) Program to provide new vehicle architectures and technologies to dramatically increase the reliability of future launch vehicles. The design of reusable entry vehicles that provide low-cost access to space is challenging in several technology areas. The development of hypersonic-unique air breathing propulsion systems and the integration of the propulsion system with the airframe impact vehicle performance and controllability and drive the need for an integrated physics-based design methodology.

For Propulsion Integration, topics will be solicited for two areas:

- Flow control concepts and analysis tools that enable
    - "Fail safe” systems to control shock wave boundary layer interactions and reduce dynamic distortion in supersonic inlets;
    - Innovative stability systems for highly integrated supersonic inlets utilizing flow control and minimizing bleed;
    - Control of subsonic diffuser flows to increase total pressure recovery and reduce distortion;
    - Nozzle area control;
    - Boat tail drag reduction and shock mitigation for low-boom supersonic applications;
    - Thrust vectoring.
- Unsteady coupled Inlet/Fan Analysis Tools to investigate
    - Engine transients affect on inlet unstart;
    - Mode transition for a hypersonic dual Turbine engine/RAM-SCRAM flowpath;
    - Inlet and fan aero/mechanical loads;
    - Engine/inlet control system development;
    - Distortion tolerance.

Airspace Systems Topic A3

NASA's Airspace Systems (AS) Program is investing in the development of innovative concepts and technologies to support the development of the Next Generation Air Transportation System (NGATS is also commonly known as NextGen). NASA is working to develop, validate and transfer advanced concepts, technologies, and procedures through partnership with the Federal Aviation Administration (FAA) and other government agencies represented in the Joint Planning and Development Office (JPDO), and in cooperation with the U.S. aeronautics industry and academia. As such, the AS Program will develop and demonstrate future concepts, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency, while maintaining safety, to meet capacity and mobility requirements of NextGen. The AS Program integrates the two projects, NextGen Airspace and NextGen Airportal, to directly address the fundamental research needs of NextGen vision in partnership with the member agencies of the JPDO. The NextGen Airspace Project develops and explores fundamental concepts and integrated solutions that address the optimal allocation of ground and air automation technologies necessary for NextGen. The project will focus NASA's technical expertise and world-class facilities to address the question of where, when, how and the extent to which automation can be applied to moving aircraft safely and efficiently through the NAS. The NextGen Airportal Project develops and validates algorithms, concepts, and technologies to increase throughput of the runway complex and achieve high efficiency in the use of airportal resources such as gates, taxiways, runways, and final approach airspace. NASA research in this project will lead to development of solutions that safely integrate surface and terminal area air traffic optimization tools and systems with 4-D trajectory operations. Ultimately, the roles and responsibilities of humans and automation influence in the ATM will be addressed by both projects. Key objectives of NASA's AS Program are to:

- Improve mobility, capacity, efficiency and access of the airspace system;
- Improve collaboration, predictability, and flexibility for the airspace users;

- Enable accurate modeling and simulation of air transportation systems;
- Accommodate operations of all classes of aircraft; and
- Maintain system safety and environmental protection.

Additional information is available at http://www.aeronautics.nasa.gov/programs_asp.htm [6].

Sub Topics:

A3.01 NextGen Airspace

Lead Center: ARC

Participating Center(s): AFRC, ARC, LaRC

The primary goal of the NASA Next Generation Air Transportation System (NextGen) Airspace effort is to develop integrated solutions for a safe, efficient, and high-capacity airspace system. Of particular interest is the development of core capabilities, including: (1) Performance-based services, which will enable higher levels of performance in proportion with user equipage level; (2) Trajectory-based operations, which is the basis for changing the way traffic is managed in the system to achieve increases in capacity and efficiency; (3) Super-density operations, which maximizes the use of limited runways at the busiest airports; (4) Weather assimilated into decision making; (5) Equivalent visual operations, which will allow the system to maintain visual flight rule capacities in instrument flight rule conditions. These core capabilities are required to enable key NGATS-Airspace functions such as Dynamic Airspace Configuration, Traffic Flow Management, Separation Assurance, and the overarching Evaluator that integrates these air traffic management (ATM) functions over multiple planning intervals.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's NextGen Airspace effort. The general areas of primary interest are Dynamic Airspace Configuration, Traffic Flow Management, and Separation Assurance. Specific research topics for NextGen Airspace include:

- 4D trajectory based operations;
- Air/ground automation concepts and technologies;
- Airspace modeling and simulation techniques;
- Automated separation assurance;
- Collaborative decision making techniques involving multiple agents;
- Equivalent visual operations;
- "Evaluator" integrated solutions of ATM functions over multiple planning intervals;
- Human factors for ATM;
- Locus of control across humans and automation;
- Multi-aircraft flow and airspace optimization;
- Performance based services;
- Safety analysis methods;
- Spacing and sequencing management;
- Super density terminal area operations;
- Traffic complexity monitoring and prediction;
- Traffic flow management concepts/techniques;
- Trajectory design and conformance;
- Weather assimilated into ATM decision-making.

A3.02 NextGen Airportal

Lead Center: LaRC

Participating Center(s): AFRC, ARC, LaRC

The Airportal research of NASA's Airspace Systems (AS) Program focuses on key capabilities that will increase throughput of the Airportal environment and achieve the highest possible efficiencies in the use of Airportal resources such as terminal airspace, runways, taxiways, and gates. The primary capabilities addressed are: (1) Super-density operations, (2) Equivalent visual operations, (3) Aircraft trajectory-based operations, and (4) Improved understanding of wake vortices.

Super-density operations will include conflict detection and resolution for closely spaced approaches, reduced aircraft wake vortex separation standards, and less restrictive run-way/taxiway operations. Additional mechanisms to increase the feasible density of operations will also be considered.

Equivalent visual operations will provide aircraft with the critical information needed to maintain safe distances from other aircraft during non-visual conditions, including a capability to operate at "visual performance" levels on the airport surface during low-visibility conditions. Advances in equivalent visual operations for the Airportal air navigation service provider are also of interest.

Aircraft trajectory-based operations will utilize 4D trajectories (aircraft path from block-to-block, including path along the ground, and also including the time component) as the basis for planning and executing system operations.

Wake vortices are often the ultimate limitation for many advanced, high-efficiency operational concepts. Advances in sensors, simulations of wake vortices and sensors, weather modeling and measurements, and understanding of impacts to aircraft flight are all of interest.

NASA's AS Program has identified the following Next Generation Air Transportation System (Next Gen) Airportal research activities: optimization of surface aircraft traffic; dynamic airport configuration management (including the optimal balancing of Airportal resources for arrival, departure, and surface aircraft operations); predictive models to enable mitigation of wake vortex hazards; new procedures for performing safe, closely spaced, and converging approaches at closer distances than are currently allowed; modeling, simulation, and experimental validation research focused on single and multiple regional airports (metroplex); and other innovative opportunities for transformational improvements in Airportal/metroplex throughput. Inherent to the AS Program approach is the integration of airborne solutions within the overall surface management optimization scheme.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's Next Gen/Airportal effort. The general areas of interest are surface management optimization, converging and parallel runway operations, safety risk assessment methodologies, and wake vortex solutions inside Metroplex boundaries. Specific research topics for Next Gen/Airportal include:

- Airborne spacing algorithms and wake avoidance procedures for airports with closely spaced runways;
- Algorithms for determining wake vortex encounters from aircraft flight data recorders;
- Automated separation assurance and runway/taxiway incursion prevention algorithms ;
- Automatic taxi clearance and aircraft control technologies;
- Characterization of wake vortex and atmospheric hazards to flight in terms of aircraft and flight crew responses;
- Collaborative decision making between airlines and airport traffic control tower personnel for optimized surface operations, including push back scheduling and management of airport surface assets;
- Development of wake vortex hazard assessment algorithms;
- Dynamic airport configuration management;
- Fusion of data from weather sensors and models for input into weather prediction models;
- High resolution CFD and real-time modeling of wake vortex strength and location;
- Human/automation interaction and performance standards;
- Improved wake vortex circulation estimates derived from Pulsed Lidar;
- Innovations in wake vortex sensors;
- Integration of decision-support tools across different airspace domains;
- Lidar Simulation tools for wake vortices;
- Measurements of wind, temperature, and turbulence from departing and arriving aircraft;
- Methodologies and/or algorithms to estimate environmental impacts of increased traffic on the surface and in the terminal airspace, and to reduce the environmental impacts under increased levels of traffic;
- Methodologies to estimate and assess the risk of transformational airspace operations for which little

historical risk data may exist and for which operations may be constrained by the potential for extremely rare events;
- Modeling and simulation of airport operations for validating aircraft taxi planning concepts;
- Optimized 4D aircraft trajectory generation and conformance monitoring for surface and terminal airspace operations, including departure and arrival planning for individual flights;
- Radar simulation tools for wake vortices;
- Radically innovative approaches for detection of wake vortices;
- Scheduling algorithm for aircraft deicing and integration with a surface traffic decision-support tool;
- Surface and terminal airspace traffic modeling and simulation of multiple regional airports;
- Virtual airport traffic control towers;
- Weather sensors for supporting wake vortex predictions;
- Other technologies and approaches to achieving 2-3X improvement in the throughput of Airportal/metro-plexes.

Note: The development of technologies for the airborne detection of wake vortices is covered in Subtopic A1.04 [7].

Aeronautics Test Technologies Topic A4

NASA has implemented the Aeronautics Test Program (ATP) within its Aeronautics Research Mission Directorate (ARMD). The purpose of the ATP is to ensure the long term availability and health of NASA's major wind tunnels/ground test facilities and flight operations/test infrastructure that support NASA, DoD and U.S. industry research and development (R&D) and test and evaluation (T&E) needs. Furthermore, ATP provides rate stability to the aforementioned user community. The ATP facilities are located at the NASA Research Centers, including at Ames Research Center, Dryden Flight Research Center, Glenn Research Center and Langley Research Center. Classes of facilities within the ATP include low speed wind tunnels, transonic wind tunnels, supersonic wind tunnels, hypersonic wind tunnels, hypersonic propulsion integration test facilities, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support aircraft, test bed aircraft, and the simulation and loads laboratories. A key component of ensuring a test facility's long term viability is to implement and continually improve on the efficiency and effectiveness of that facility's operations. To operate a facility in this manner requires the use of state-of-the-art test technologies and test techniques, creative facility performance capability enhancements, and novel means of acquiring test data. NASA is soliciting proposals in the areas of instrumentation, test measurement technology, test techniques and facility development that apply to the ATP facilities to help in achieving the ATP goals of sustaining and improving our test capabilities. Proposals that describe products or processes that are transportable across multiple facility classes are of special interest. The proposals will also be assessed for their ability to develop products that can be implemented across government-owned, industry and academic institution test facilities. Additional information: http://www.aeronautics.nasa.gov/atp/index.html [8].
Sub Topics:

A4.01 Ground Test Techniques and Measurement Technology

Lead Center: GRC

Participating Center(s): ARC, LaRC

NASA is concerned with operating its ground test facilities with new and innovative methods for test measurement technology and with continually improving on the efficiency and effectiveness of operation of its ground test facilities. NASA's aeronautics and space research and development pushes the limits of technology, including the ground test facilities that are used to confirm theory and provide validation and verification of new technologies. By using state-of-the-art test measurement technologies, novel means of acquiring test data, test techniques and creative facility performance capability enhancements, NASA will be able to operate its facilities more efficiently and effectively and also be able to meet the challenges presented by NASA's cutting edge research and development programs. Therefore, NASA is seeking highly innovative and commercially viable test measurement technologies, test techniques, and facility performance technologies that would increase efficiency or overcome research and development technology barriers for ground test facilities.

The emphasis for this subtopic is in the area of test measurement technology. Examples of the types of technology solutions sought, but not limited to, are: skin friction experimental measurement techniques; improved flow transition detection methodologies; new or novel, non-intrusive measurement technologies for pressure, temperature, and force measurements; force measurement (balance) technology development; and improvement of current cutting edge technologies, such as particle imaging velocimetry (PIV), that allow the technology to be used more reliably in a production wind tunnel environment. Solutions are also sought with regards to the instrumentation used to characterize ground test facility performance. This could be in the area of aerodynamics performance characterization (flow quality, turbulence intensity, etc.) or, for example, in the case of specialty facilities, the measurement of liquid water content, ice water content, and cloud droplet size conditions in an icing wind tunnel.

Proposals that lead to products or processes that are applicable specifically to the ATP facilities (see http://www.aeronautics.nasa.gov/atp [9]) and across multiple facility classes are especially important. The proposals will also be assessed for their ability to develop products that can be used in government-owned, industry and academic institution aerospace ground test facilities.

A4.02 Flight Test Techniques and Measurement Technology

Lead Center: AFRC

Participating Center(s): ARC, GRC, LaRC

NASA's flight research is reliant on a combination of both ground and flight research facilities. By using state-of-the-art techniques, measurement and data acquisition technologies, NASA will be able to operate its flight research facilities more effectively and also meet the challenges presented by NASA's cutting edge research and development programs. The scope of this subtopic is broad, with emphasis on emissions, noise, and performance. Research technologies applicable to this subtopic should address (but are not limited to): Western Aeronautical Test Range (WATR), Flight Loads Laboratory (FLL), Research Flight Simulation Hardware-in-the-Loop Simulation (HILS), Testbed and Support Aircraft (e.g. F-15, F-18, ER-2, Gulfstream-III, Ikhana), as well as modeling, identification, simulation, and control of aerospace vehicle applications in flight research, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts. Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight research validation methods for control-oriented applications. Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude long-endurance to hypersonic and access-to-space aerospace vehicles. Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight research. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight research by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor instrumentation systems in all flight regimes – particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability. This subtopic further solicits innovative flight research experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment.

Therefore, NASA is seeking highly innovative and viable research technologies that would increase efficiency or overcome limitations for flight research. Other areas of interest include: Verification & Validation techniques for non-deterministic and complex redundant systems; Design Tools integrated into the simulation environment for early research and validation; Flight Measurements & Data Acquisition: Aerodynamic forces, flow quality & conditions; Skin Friction; Flight Hardened Systems & Miniaturization; Signal Processing & Reconfigurable Systems; Wireless technologies.

Mitigation of Aircraft Aging and Durability-related Hazards Topic A1.01

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.

Sub Topics:

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

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

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

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

Sub Topics:
Prediction of Aging Effects Topic A1.03
In order to assess the long-term effects of potential hazards and aging-related degradation of new and emerging material systems/fabrication techniques, NASA is performing research to anticipate aging and to predict its effects on the designs of future aircraft. To support this predictive capability, structural integrity analytical tools, lifing methods, and material durability prediction tools are being developed. Physics-based and continuum-based models, computational methods, and validation techniques are needed to provide the basis for these higher level (e.g., design) tools. Proposals are sought that apply innovative methods, models and analytic tools to the following specific applications:

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

Sub Topics:
Aviation External Hazard Sensor Technologies Topic A1.04
NASA is concerned with new and innovative methods for airborne detection, identification, evaluation, and monitoring of in-flight hazards to aviation. NASA seeks to foster research and development that leads to innovative new technologies and methods, or significant improvements in existing technologies, for in-flight hazard avoidance and mitigation. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices.

A key objective of the NASA Aviation Safety Program is to support the research of technology, systems, and methods that will facilitate transformation of the National Airspace System to Next Generation Air Transportation System (NextGen) (information available at www.jpdo.gov [2]). The general approach to the development of airborne sensors for NextGen is to encourage the development of multi-use, adaptable sensors. The greatest impact will result from improved sensing capability in the terminal area, where higher density and more reliable operations are needed.

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

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

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

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

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

Sub Topics:
Crew Systems Technologies for Improved Aviation Safety Topic A1.05
NASA seeks highly innovative, crew-centered, technologies to improve aerospace system safety through the

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

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

Proposals should describe novel technologies with high potential to serve the objectives of the Robust Automation/Human Systems element of NASA's Aviation Safety Integrated Intelligent Flight Deck program (http://www.aeronautics.nasa.gov/avsafe/iifd/rahs.htm [3]). 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.

Sub Topics:

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

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 [4]). 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.

Sub Topics:
On-Board Flight Envelope Estimation for Unimpaired and Impaired Aircraft Topic A1.07
A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including failed actuators, failed sensors, damaged surfaces or abrupt changes in aerodynamics or large changes in aerodynamics during upsets. As part of the Aviation Safety Program research, the Integrated Resilient Aircraft Control (IRAC) Project is investigating advanced control system concepts to provide greater aircraft resiliency to adverse events. The goal of the IRAC project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions.

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

- Adaptive mathematical framework for control-centric onboard aircraft models that can accommodate real-time changes to subsystem dynamics;
- Real-time system identification capability for updating an onboard vehicle model with an adaptive structure to satisfy sub-system constraints under adverse conditions;
- Real-time fault diagnostic and prognostics capability needed in adaptive flight, propulsion, structural control applications;
- Real-time control power map identification with inclusion of aircraft sub-system constraints under adverse conditions;

- Real-time dynamic flight envelope identification and prediction capability; and
- Metrics and assessment models for safety-of-flight diagnostics and prognostics.

Sub Topics:
Engine Lifing and Prognosis for In-Flight Emergencies Topic A1.08
The object of this research topic is to develop innovative methodologies to determine probability of an engine system failure under emergency flight conditions that demand a boost in the engine performance, thus potentially sacrificing the engine, to increase the engine control effectiveness for a safe take-off or landing.

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

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

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

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

Sub Topics:
Robust Flare Planning and Guidance for Unimpaired and Impaired Aircraft Topic A1.09
A primary goal of the NASA Aviation Safety Program is to develop technology for safe aircraft operation under different types of anomalies. These may occur in a variety of forms, including damaged surfaces or failed actuators that can limit the maneuverability and achievable flight envelope of the vehicle. As part of the Aviation Safety Program research, the goal of the Integrated Resilient Aircraft Control (IRAC) Project is to arrive at a set of validated multidisciplinary aircraft control design tools and techniques for enabling safe flight in the presence of adverse conditions. Research on advanced technical approaches includes adaptive flight control for providing stability, flight and maneuvering envelope identification for determining safe operability limits, and emergency flight planning and guidance for achieving a flyable path to an approach for landing.

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

Sub Topics:

Detection of In-Flight Aircraft Anomalies Topic A1.10

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

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

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

Sub Topics:

Integrated Diagnosis and Prognosis of Aircraft Anomalies Topic A1.11

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

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

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

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

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

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

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

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

Sub Topics:

Mitigation of Aircraft Structural Damage Topic A1.12

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

Healing Material System Concepts for IVHM/AAD

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

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

Sub Topics:

Materials and Structures for Future Aircraft Topic A2.01

Advanced materials and structures technologies are needed in all four of the NASA Fundamental Aeronautics Programs research thrusts (Subsonic Fixed Wing, Subsonic Rotary Wing, Supersonic, Hypersonic) to enable the design and development of advanced future aircraft. Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems and should be linked to improvements in aircraft performance indicators such as vehicle weight, noise, lift, drag, lifetime, and emissions. The technologies of interest cover five research subtopics:

Fundamental Materials Development, Processing and Characterization

- Multifunctional materials and structural concepts for engine and airframe structures, such as, novel approaches to mitigating lightning strike, aircraft engine fan cases with integrated acoustic treatments and ballistic impact resistance.
- Adaptive materials and structural concepts for engine and airframe structures, such as shape memory alloys and polymers for active and highly flexible airframe and engine components, piezoelectric ceramics and polymers for self-damping engine and airframe components, materials and structures with integrated self-diagnostic, self-healing and actuation capabilities.
- Advanced high temperature materials for aircraft engine and airframe components and thermal protection

systems, including advanced blade and disk alloys, ceramics and CMCs, and coatings to improve environmental durability.
- Innovative processing methods to reduce component manufacturing costs and improve damage tolerance and reliability, including processing and joining of ceramics, metals, polymers, composites, and hybrids, as well as nanostructured and multifunctional materials and coatings.
- Innovative methods for the evaluation of advanced materials and structural concepts (in particular, multifunctional and/or adaptive) under simulated operating conditions, including combinations of electrical, thermal and mechanical loads.

Structural Analysis Tools and Procedures

- Design methods for advanced materials and structural concepts (in particular, multifunctional and/or adaptive components) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational modeling, and multi-physics modeling and simulation tools.
- Rapid design methods for airframe structures.
- Prediction tool for advanced engine containment systems, including multifunctional approaches.
- Integrated structural design and analysis methods for advanced composite materials.
- Design, development, analysis, and verification methods for structural joining technologies for high-temperature composite airframe and propulsion structures including bonding, fastening, and sealing.

Computational Materials Development Tools

- Computational materials tools for the development of durable high temperature materials.
- Computational tools to predict materials properties based upon chemistry and processing for conventional as well as nanostructured, multifunctional and/or adaptive materials.

Advanced Structural Concepts

- Innovative structural concepts and materials and/or robust thermal protection systems leading to reliable, high-mass planetary entry, descent and landing systems including deployable heat shields, high temperature films and fabrics.
- Improved thermal protection systems using innovative structural and material concepts, including structurally integrated multifunctional systems.
- Advanced mechanical component technologies including self lubricating coatings, oil-free bearings, and seals.
- Advanced material and component technologies to enable the development of a mechanical and electrical drive system to distribute power from a single engine core to drive multiple propulsive fans, in particular, AC-tolerant, low loss (< 10 W/kA-m) conductors or superconductors for the stators of synchronous motors or generators operating at > 1.5 T field and 500 Hz electrical frequency; and high efficiency (>30% of Carnot), low mass (<6kg/kW input) cryo-refrigerators for 20 to 65°K (lower efficiencies and mass-per-input-power that give the same or better refrigeration and mass are acceptable). Input power between 10 and 100 kW is envisioned in applications, but scalable small demonstrations are acceptable.

Durable Structural Sensor Technology for Extreme Environments (>1800°F)

- Development and validation of advanced high-temperature sensor technology to measure strain, temperature, heat flux, and/or acceleration of structural components.
- Development and validation of improved sensor bonding methods (i.e., adhesives, plasma spraying techniques, etc.) for attaching structural sensors on advanced high-temperature materials.

Sub Topics:
Combustion for Aerospace Vehicles Topic A2.02

Sub Topics:

Aero-Acoustics Topic A2.03

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, and advanced aerospace vehicles. In support of the Fundamental Aeronautics Program, improvements in noise prediction, measurement methods and control are needed for subsonic and supersonic vehicles, including fan, jet, turbomachinery, and airframe noise sources. In addition, improvements in prediction and control of noise transmitted through aerospace vehicle structures are needed to reduce noise impact on passengers, crew and launch vehicle payloads. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid-dynamics techniques for aero-acoustic analysis, which can be adapted for design codes;
- Prediction of aero-acoustic noise sources including engine and airframe noise sources and sources which arise from significant interactions between airframe and propulsion systems;
- Prediction of sound propagation (including sonic booms) from the aircraft through a complex atmosphere to the ground. This should include interaction between noise sources and the airframe and its flowfield;
- Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process;
- Prediction and control of high-amplitude aero-acoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue;
- Innovative source identification techniques for engine (e.g., fan, jet, combustor, or turbine noise) and airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise sources typical of jets, separated regions, vortices, shear layers, etc.;
- Concepts for active and passive control of aero-acoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, smart structures for nozzles and inlets, and noise control technology and methods that are enabled by advanced aircraft configurations, including advanced integrated airframe-propulsion control methodologies;
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures;
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise, including sonic boom;
- Development and application of flight procedures for reducing community noise impact while maintaining or enhancing safety, capacity, and fuel efficiency.

Sub Topics:

Aeroelasticity Topic A2.04

The NASA Fundamental Aeronautics program has the goal to develop system-level capabilities that will enable the civilian and military designers to create revolutionary systems, in particular by integrating methods and technologies that incorporate multi-disciplinary solutions. Aeroelastic behavior of flight vehicles is a particularly challenging facet of that goal.

The program's work on aeroelasticity includes conduct of broad-based research and technology development to obtain a fundamental understanding of aeroelastic and unsteady-aerodynamic phenomena experienced by aerospace vehicles, in subsonic, transonic, supersonic, and hypersonic speed regimes. The program content includes theoretical aeroelasticity, experimental aeroelasticity, and advanced aeroservoelastic concepts. Of interest are aeroelastic, aeroservoelastic, and unsteady aerodynamic analyses at the appropriate level of fidelity for the problem at hand; aeroelastic, aeroservoelastic, and unsteady aerodynamic experiments, to validate methodologies and to gain valuable insights available only through testing; development of computational-fluid-dynamic, computational-aeroelastic, and computational-aeroservoelastic analysis tools that advance the state-of-the-art in aeroelasticity through novel and creative application of aeroelastic knowledge.

The technical discipline of aeroelasticity is a critical ingredient necessary in the design process of a flight vehicle for assuring freedom from catastrophic aeroelastic and aeroservoelastic instabilities. This discipline requires a thorough understanding of the complex interactions between a flexible structure and the unsteady aerodynamic forces acting on the structure, and at times, active systems controlling the flight vehicle. Complex unsteady aerodynamic flow phenomena, particularly at transonic Mach numbers, are also very important because this is the speed regime most critical to encountering aeroelastic instabilities. In addition, aeroelasticity is presently being exploited as a means for improving the capabilities of high performance aircraft through the use of innovative active control systems using both aerodynamic and smart material concepts. Work to develop analytical and experimental methodologies for reliably predicting the effects of aeroelasticity and their impact on aircraft performance, flight dynamics, and safety of flight are valuable. Subjects to be considered include:

- Development of design methodologies that include CFD steady and unsteady aerodynamics, flexible structures, and active control systems.
- Development of methods to predict aeroelastic phenomena and complex steady and unsteady aerodynamic flow phenomena, especially in the transonic speed range. Aeroelastic phenomena of interest include flutter, buffet, buzz, limit cycle oscillations, and gust response. Flow phenomena of interest include viscous effects, vortex flows, separated flows, transonic nonlinearities, and unsteady shock motions.
- Development of efficient methods to generate mathematical models of wind-tunnel models and flight vehicles for performing vibration, aeroelastic, and aeroservoelastic studies. Examples include (a) CFD-based methods (reduced-order models) for aeroservoelasticity models that can be used to predict and alleviate gust loads, ride quality issues, and flutter issues and (b) integrated tool sets for fully coupled modeling and simulation of aeroservothermoelasticity/flight dynamic (ASTE/FD) and propulsion effects.
- Development of physics-based models for turbomachinery aeroelasticity related to highly separated flows, shedding, rotating stall, and non-synchronous vibrations (NSV). This includes robust, fast-running, accelerated convergence, reduced-order CFD approaches to turbomachinery aeroelasticity for propulsion applications. Development of blade vibration measurement systems (including closely spaced modes, blade-to-blade variations (mistuning), and system identification) and blade damping systems for metallic and composite blades (including passive and active damping methods) are of interest.
- Development of aeroservoelasticity concepts and models, including unique control concepts and architectures that employ smart materials embedded in the structure and/or aerodynamic control surfaces for suppressing aeroelastic instabilities or for improving performance.
- Development of techniques that support simulations, ground testing, wind-tunnel tests, and flight experiments of aeroelastic phenomena.
- Investigation and development of techniques that incorporate structure-induced noise, stiffness and strength tailoring, propulsion-specific structures, data processing and interpretation methods, non-linear and time-varying methods development, unstructured grid methods, additional propulsion systems-specific methods, dampers, multistage effects, non-synchronous vibrations, coupling effects on blade vibration, probabilistic aerodynamics and aeroelastics, actively controlled propulsion system core components (e.g., fan and turbine blades, vanes), and advanced turbomachinery active damping concepts.
- Investigation and development of techniques that incorporate lightweight structures and flexible structures under aerodynamic loads, with emphasis on aeroelastic phenomena in the hypersonic domain. Investigation of high temperatures associated with high heating rates, resulting in additional complexities associated with varying thermal expansion and temperature dependent structural coefficients. Acquisition of data to verify analysis tools with these complexities.

Sub Topics:

Aerodynamics Topic A2.05

The challenge of flight has at its foundation the understanding, prediction, and control of fluid flow around complex geometries – aerodynamics. Aerodynamic prediction is critical throughout the flight envelope for subsonic, super-sonic, and hypersonic vehicles – driving outer mold line definition, providing loads to other disciplines, and enabling environmental impact assessments in areas such as emissions, noise, and aircraft spacing.

In turn, high confidence prediction enables high confidence development and assessment of innovative aerodynamic concepts. This subtopic seeks innovative physics-based models and novel aerodynamic concepts, with an emphasis on flow control, applicable in part or over the entire speed regime from subsonic through hypersonic flight.

All vehicle classes will experience subsonic flight conditions. The most fundamental issue is the prediction of flow separation onset and progression on smooth, curved surfaces, and the control of separation. Supersonic and hyper-sonic vehicles will experience supersonic flight conditions. Fundamental to this flight regime is the sonic boom, which to date has been a barrier issue for a viable civil vehicle. Addressing boom alone is not a sufficient mission enabler however, as low drag is a prerequisite for an economically viable vehicle, whether only passing through the supersonic regime, or cruising there. Atmospheric entry vehicles and space access vehicles will experience hypersonic flight conditions. Reentry capsules such as the new Crew Exploration Vehicle deploy multiple parachutes during descent and landing. Predicting the physics of unsteady flows in supersonic and subsonic speeds is important for the design of these deceleration systems. The gas-dynamic performance of decelerators for vehicles entering the atmospheres of planets in the solar system is not well understood. Reusable hypersonic vehicles will be designed such that the lower body can be used as an integrated propulsion system in cruise condition. Their performance is likely to suffer in off-design conditions, particularly acutely at transonic speeds. Advanced flow control technologies are needed to alleviate the problem.

This solicitation seeks proposals to develop and validate:

- Turbulence models capturing the physics of separation onset at Reynolds numbers relevant to flight, where relevant to flight is dependent on a targeted vehicle class and mission profile;
- Boundary-layer transition models suitable for direct integration with state-of-the-art flow solvers;
- Active flow control concepts targeted at separation control and/or viscous drag reduction with an emphasis on the development of novel, practical, lightweight, low-energy actuators;
- Innovative aerodynamic concepts targeted at vehicle efficiency or control;
- Physics-based models for simultaneous low boom/low drag prediction and design;
- Aerodynamic concepts enabling simultaneous low boom and low drag objectives;
- Innovative methods to validate both flow models and aerodynamic concepts with an emphasis on aft-shock effects which are hindered by conventional wind tunnel model mounting approaches;
- Accurate aerodynamic analysis and multidisciplinary design tools for multi-body flexible structures in the atmospheres of planets and moons including the Earth, Mars, and Titan;
- Advanced flow control technologies to alleviate off-design performance penalties for reusable hypersonic vehicles.

Sub Topics:

Aerothermodynamics Topic A2.06

Development of accurate tools to predict aerothermal environments and their effects on space vehicles is critically important to achieving the goals of current NASA missions. These tools will also enable the development of advanced spacecraft for future missions by reducing uncertainties during design and development.

The large size and high re-entry velocity of the Crew Exploration Vehicle and the conditions encountered in proposed aerocapture missions to Titan, Neptune, and Venus require study of shock layer radiation phenomena, radiative heat transfer, and non-equilibrium thermodynamic and transport properties; these in turn require understanding of the internal structure and dynamics of the constituent gases.

Transition and turbulence effects are particularly complex in hypersonic flows, where unique problems are posed by shocks, real gas effects, body surfaces with complex and possibly time-dependent roughness, nose bluntness, ablation, surface catalyticity, separation, and an unknown free-stream disturbance environment.

At the heating rates encountered during hypersonic re-entry, surface ablation products blowing into the boundary layer introduce new interactions including chemical reactions and radiation absorption, that strongly affect surface heating rates and integrated heat loads.

Proposals suggesting innovative approaches to any of these issues are encouraged; specific research areas of interest include:

- Computational analysis methods for radiation and radiation transport in the shock layer surrounding planetary entry vehicles;
- Advanced physics-based thermal and chemical non-equilibrium models for thermodynamics, transport, and radiation;
- Studies of the interactions of gases in the shock layer with ablating materials from the vehicle thermal protection system;
- Experimental methods and diagnostics to measure the characteristics of hypersonic flow fields, either in flight or in ground-based facilities;
- Software tools coupling radiation, non-equilibrium chemistry, Reynolds-averaged Navier-Stokes, and large

eddy simulation codes to enable the design and validation of mission configurations for en-try into planetary atmospheres.

Sub Topics:
Flight and Propulsion Control and Dynamics Topic A2.07
Enabling advanced aircraft configurations for subsonic, supersonic and hypersonic flight, and high performance "Intelligent Engines" will require advancement in the state-of-the art dynamic modeling and flight/propulsion control. The need to minimize the carbon footprint will necessitate new trajectory planning and control concepts. Control methods need to be developed and validated for "optimal" and reliable performance of complex, unsteady, and nonlinear systems with significant modeling uncertainties while ensuring operational flexibility, enabling unique concepts of operations with novel configurations, lower emissions and noise, and safe operation over a wide operating envelope. New dynamic modeling and simulation techniques need to be developed to investigate dynamic performance issues and support development of control strategies for innovative aircraft configurations with enhanced control effectors and propulsion systems. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance, and load control including smart actuation and active aerostructural concepts, active control of propulsion system components, and drag minimization for high efficiency and range performance. Technology needs specific to different flight regimes are summarized in the following:

Subsonic Fixed Wing Aircraft
Technologies of interest, with application to both flight and propulsion control, include: methods for development of dynamic models and simulations of the integrated component/control system being considered; defining actuation requirements for novel control approaches and developing prototype actuators for flight-like environments; developing and applying innovative control methods and validating them through laboratory test, vehicle simulations and sub-scale flight test as appropriate. Technologies related to the development and integration of modular, open-system control elements leading to the transition to distributed control architecture in the engine environment are of special interest.

Supersonic Flight
Technologies of interest include: methods for developing integrated dynamic models and simulation including propulsion and aeroelastic effects and suitable for control design; novel control design methods for integrated aero-propulsion-servo-elastic control leading to acceptable flying qualities over the operating flight envelope; novel, and feasible, takeoff and approach to landing procedures to accommodate the visibility challenges due to long fore-bodies; integrated inlet/engine control to ensure safe (no inlet unstart or compressor surge/stall) and efficient operation.

Hypersonic Flight
Technologies of interest include: system dynamic models incorporating the essential coupled dynamic elements with varying fidelity for control design, analysis and evaluation; methods for characterizing uncertainty in the dynamic models to enable control robustness evaluation; hierarchical GNC (Guidance, Navigation and Control) architectures and energy management techniques to enable trajectory shaping and control over a wide operating envelope with integrated flight/propulsion control; adaptive and robust control methods that can handle large modeling uncertainties; simulation test beds for evaluating hypersonic concept vehicle control under various types of uncertainty, system wide coupling and associated model misspecification.

Sub Topics:
Aircraft Systems Analysis, Design and Optimization Topic A2.08
One of the approaches to achieve the NASA Fundamental Aeronautics Program goals is to solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration. The needs to meet this approach can be defined by four general themes:

1. Design Environment Development;
2. Variable Fidelity, Physics-Based Design/Analysis Tools;
3. Technology Assessment and Integration; and
4. Evaluation of Advanced Concepts.

Current interdisciplinary design/analysis involves a multitude of tools not necessarily developed to work together, hindering their application to complete system design/analysis studies. Multi-fidelity, multi-disciplinary optimization frameworks, such as Numerical Propulsion System Simulation (NPSS), have been developed by NASA but have limited capabilities to simulate complete vehicle systems. Solicited topics are aligned with these four themes that will support this NASA research area.

(1) Design Environment Development

Technology development is needed to provide complex simulation and modeling capabilities where the computer science details are transparent to the engineer. A framework environment is needed to provide a seamless integration environment where the engineer need not be concerned with where or how particular codes within the system level simulation will be run. Interfaces and utilities to define, setup, verify, determine the appropriate resources, and launch the system simulation are also needed.

Research challenges include the engineering details needed to numerically zoom (i.e., numerical analysis at various levels of detail) between multi-fidelity components of the same discipline, as well as, multi-discipline components of the same fidelity. A major computer science challenge is developing boundary objects that will be reused in a wide variety of simulations.

Proposals will be considered that enable coupling differing disciplines, numerical zooming within a single discipline, deploying large simulations, and assembling and controlling secure or non-secure simulations.

(2) Variable Fidelity, Physics-Based Design/Analysis Tools

An integrated design process combines high-fidelity computational analyses from several disciplines with advanced numerical design procedures to simultaneously perform detailed Outer Mold Line (OML) shape optimization, structural sizing, active load alleviation control, multi-speed performance (e.g., low takeoff and landing speeds, but efficient transonic cruise), and/or other detailed-design tasks. Current practice still widely uses sequential, single-discipline optimization, at best coupling low-fidelity modeling of other relevant disciplines during the detailed design phase. Substantial performance improvements will be realized by developing closely integrated design procedures coupled with highest-fidelity analyses for use during detailed-design. Design procedures must enable rapid determination of sensitivities (gradients) of a design objective with respect to all design variables and constraints, choose search directions through design space without violating constraints, and make appropriate changes to the vehicle shape (ideally both external OML shape and internal structural element size). Solicitations are for integrated design optimization tools that find combinations of design variables from more than one discipline and can vary synergistically to produce superior performance compared to the results of sequential, single-discipline optimization or repeated cut-and-try analysis.

(3) Technology Assessment and Integration

Improved analysis capability of integrated airframe and propulsion systems would allow more efficient designs to be created that would maximize efficiency and performance while minimizing both noise and emissions. Improved integrated system modeling should allow designers to consider trade-offs between various design and operating parameters to determine the optimum design for various classes of subsonic fixed wing aircraft ranging from personal aircraft to large transports. The modeling would also be beneficial if it had enough fidelity to enable it to analyze both conventional and unconventional systems. Current analysis tools capable of analyzing integrated systems are based on simplified physical and semi-empirical models that are not fully capable of analyzing aircraft and propulsion system parameters that would be required for new or unconventional systems.

Analysis tools are solicited that are capable of analyzing new and unconventional aircraft and propulsion integrated systems. These include: (1) New combustor designs, alternate fuel operation, and the ability to estimate all emissions, and (2) Noise source models (e.g., fan, jet, turbine, core and airframe components). Analyses tools that are scalable, especially to small aircraft, are desired.

(4) Evaluation of Advanced Concepts

Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull, and independent technical assessment of new concepts. This capability will enable "virtual expeditions through the design space" for multi-mission trade studies and optimization. This will require an integrated variable fidelity concept design system. The aerospace flight vehicle conceptual design phase is, in contrast to the succeeding preliminary and detail design phases, the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information, and its chronic time pressure to find solutions. Currently, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using extremely simple analyses and heuristics. An integrated, variable fidelity system would have large benefits. Higher fidelity tools enabling unconventional configurations to be addressed in the conceptual design process are solicited.

Sub Topics:

Rotorcraft Topic A2.09

The challenge of the Subsonic Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop validated physics-based multidisciplinary design-analysis-optimization tools for rotorcraft, integrated with technology development, enabling rotorcraft with advanced capabilities to fly as designed for any mission. Meeting this challenge will require innovative technologies and methods, with an emphasis on integrated, multidisciplinary, first-principle computational tools specifically applicable to the unique problems of rotary wing aircraft. Technologies of particular interest are as follows:

Propulsion-Variable Speed Drive Systems/Transmissions

Technologies, and predictive capability, related to enabling concepts and techniques for variable speed drive systems/transmissions suitable for large rotorcraft application are encouraged. Specifically, this would include concepts for controlling and enabling variable speed drives as well as lightweight and reliable drive system components. Efficient drive-system speed-variability on the order of 30-50% should be the focus of the proposed technologies and analysis tools.

Instrumentation and Techniques for Rotor Blade Measurements:

Instrumentation and measurement techniques are encouraged for assessing scale rotor blade boundary layer state (e.g., laminar, transition, turbulent flow) in simulated hover and forward flight conditions, measurement systems for large-field rotor wake assessment, fast-response pressure sensitive paints applicable to blade surfaces, and methods to measure the rotor tip path plane angle of attack, lateral and longitude flapping, and shaft angle in flight and in the wind tunnel.

Acoustics

Interior and exterior rotorcraft noise generation, propagation and control. Topics of interest include, but are not limited to, external noise prediction methods for manned and unmanned rotorcraft, improved acoustic propagation models, psychoacoustics analysis of rotorcraft noise, interior noise prediction methods and active/passive noise control applications for rotorcraft including engine and transmission noise reduction, advanced acoustic measurement systems for flight and wind tunnel applications, acoustic data acquisition/reduction/analysis, rotor noise reduction techniques, noise abatement flight operations. Rotor noise, including broadband, harmonic, blade-vortex interaction, high-speed impulsive; alternate tail rotor and auxiliary power concepts, rotor/tail rotor, and rotor/rotor interactional noise. Frequency range includes not only audible range, but very low frequency rotational noise (blade-passage frequency below 20 Hz) as well. Optimized active/passive concepts and noise tailoring, including rotorcraft designs that are inherently designed for lower noise as a constraint.

Proposals on other rotorcraft technologies will also be considered as resources and priorities allow, but the primary emphasis of the solicitation will be on the above three identified technical areas.

Sub Topics:

Propulsion Systems Topic A2.10

This subtopic is divided into two parts. The first part is the Turbomachinery and Heat Transfer and the second part is Propulsion Integration.

Turbomachinery and Heat Transfer

There is a critical need for advanced turbomachinery and heat transfer concepts, methods and tools to enable NASA to reach its goals in the various Fundamental Aeronautics projects. These goals include drastic reductions in aircraft fuel burn, noise, and emissions, as well as an ability to achieve mission requirements for Subsonic Rotary

Wing, Subsonic Fixed Wing, Supersonics, and Hypersonics project flight regimes. In the compression system, advanced concepts and technologies are required to enable high stage loading and wider operating range while maintaining or improving aerodynamic efficiency. Such improvements will enable reduced weight and part count, and will enable advanced variable cycle engines for various missions. In the turbine, the very high cycle temperatures demanded by advanced engine cycles place a premium on the cooling technologies required to ensure adequate life of the turbine component. Reduced cooling flow rates and/or increased cycle temperatures enabled by these technologies have a dramatic impact on the engine performance. Proposals are sought in the turbomachinery and heat transfer area to provide the following specific items:

- Advanced design concepts to enable increased high stage loading in single and multi-stage axial compressors while maintaining or improving aerodynamic efficiency and operability. Technologies are sought that would reduce dependence on traditional range extending techniques (such as variable inlet guide vane and variable stator geometry) in compression systems. These may include flow control techniques near the compressor end walls and on the rotor and stator blade surfaces. Technologies are sought to reduce turbomachinery sensitivity to tip clearance leakage effects where clearance to chord ratios are on the order of 5% or above.
- Advanced flow analysis tools to enable design optimization of highly loaded compression systems that can accurately predict aerodynamic efficiency and operability. This includes computer codes with updated models for losses, turbulence, and other models that can simulate the flow through turbomachinery components with advanced design features such as swept and bowed blade shapes, flow range extension techniques, such as flow control and transition control to maintain acceptable operability and efficiency.
- Novel turbine cooling concepts are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art.
- Tools and methods are sought to optimize the turbine cooling design including film cooling and internal cooling, especially considering the ability to incorporate such tools into the engine design cycle. Currently, turbine cooling designs are developed via empirical information which may be derived from idealized cases not applicable to the actual turbine flow environment. It would benefit the community greatly to have a validated computational tool for optimizing the turbine cooling design. This tool should allow the prediction of turbine wall temperatures with sufficient accuracy and within reasonable time scales to allow optimization of the film and internal cooling geometrical features. Consideration should be given to the ability of the tool to handle CAD-based geometries.

Propulsion Integration

Proposals for Propulsion Integration will address engine and engine integration topics as outlined in this section in support of the Fundamental Aeronautics Program.

One objective of the Subsonic Fixed Wing Project is to develop verified analysis capabilities for the key technical issues related to integrating embedded propulsion systems for “N+2” hybrid wing/body configurations. These key technical issues include: inlet technologies for distorted engine inflows related to embedded engines with boundary layer ingestion; fan-face flow distortion and its effects on fan efficiency and operability, noise, flutter stability and aeromechanical stress and life; wide operability of the fan and core with a variable area nozzle; issues related to the implementation of a thrust vectoring variable area nozzle; and duct losses related to long flow paths associated with embedded engines. Specifically, proposals are sought to provide advanced technology, prediction methods and tools

The supersonics project would like proposals to develop tools and propulsion technologies that will enable the design of high performance fans; high-efficiency, low-boom, and stable inlets; high-performance, low-noise exhaust nozzles; and intelligent sensors and actuators for supersonic aircraft. The supersonics project is interested in both computational and experimental research, aimed at evaluating and analyzing promising technologies as well as understanding the fundamental flow physics that will enable improved prediction methods.

A mission class of interest to the Hypersonics Project is Highly Reliable Reusable Launch Systems (HRRLS). The HRRLS mission was chosen to build on work started in NASA’s Next Generation Launch Technology (NGLT)

Program to provide new vehicle architectures and technologies to dramatically increase the reliability of future launch vehicles. The design of reusable entry vehicles that provide low-cost access to space is challenging in several technology areas. The development of hypersonic-unique air breathing propulsion systems and the integration of the propulsion system with the airframe impact vehicle performance and controllability and drive the need for an integrated physics-based design methodology.

For Propulsion Integration, topics will be solicited for two areas:

- Flow control concepts and analysis tools that enable
  - "Fail safe" systems to control shock wave boundary layer interactions and reduce dynamic distortion in supersonic inlets;
  - Innovative stability systems for highly integrated supersonic inlets utilizing flow control and minimizing bleed;
  - Control of subsonic diffuser flows to increase total pressure recovery and reduce distortion;
  - Nozzle area control;
  - Boat tail drag reduction and shock mitigation for low-boom supersonic applications;
  - Thrust vectoring.
- Unsteady coupled Inlet/Fan Analysis Tools to investigate
  - Engine transients affect on inlet unstart;
  - Mode transition for a hypersonic dual Turbine engine/RAM-SCRAM flowpath;
  - Inlet and fan aero/mechanical loads;
  - Engine/inlet control system development;
  - Distortion tolerance.

Sub Topics:

NextGen Airspace Topic A3.01

The primary goal of the NASA Next Generation Air Transportation System (NextGen) Airspace effort is to develop integrated solutions for a safe, efficient, and high-capacity airspace system. Of particular interest is the development of core capabilities, including: (1) Performance-based services, which will enable higher levels of performance in proportion with user equipage level; (2) Trajectory-based operations, which is the basis for changing the way traffic is managed in the system to achieve increases in capacity and efficiency; (3) Super-density operations, which maximizes the use of limited runways at the busiest airports; (4) Weather assimilated into decision making; (5) Equivalent visual operations, which will allow the system to maintain visual flight rule capacities in instrument flight rule conditions. These core capabilities are required to enable key NGATS-Airspace functions such as Dynamic Airspace Configuration, Traffic Flow Management, Separation Assurance, and the overarching Evaluator that integrates these air traffic management (ATM) functions over multiple planning intervals.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's NextGen Airspace effort. The general areas of primary interest are Dynamic Airspace Configuration, Traffic Flow Management, and Separation Assurance. Specific research topics for NextGen Airspace include:

- 4D trajectory based operations;
- Air/ground automation concepts and technologies;
- Airspace modeling and simulation techniques;
- Automated separation assurance;
- Collaborative decision making techniques involving multiple agents;
- Equivalent visual operations;
- "Evaluator" integrated solutions of ATM functions over multiple planning intervals;
- Human factors for ATM;
- Locus of control across humans and automation;
- Multi-aircraft flow and airspace optimization;
- Performance based services;
- Safety analysis methods;
- Spacing and sequencing management;

- Super density terminal area operations;
- Traffic complexity monitoring and prediction;
- Traffic flow management concepts/techniques;
- Trajectory design and conformance;
- Weather assimilated into ATM decision-making.

Sub Topics:

NextGen Airportal Topic A3.02

The Airportal research of NASA's Airspace Systems (AS) Program focuses on key capabilities that will increase throughput of the Airportal environment and achieve the highest possible efficiencies in the use of Airportal resources such as terminal airspace, runways, taxiways, and gates. The primary capabilities addressed are: (1) Super-density operations, (2) Equivalent visual operations, (3) Aircraft trajectory-based operations, and (4) Improved understanding of wake vortices.

Super-density operations will include conflict detection and resolution for closely spaced approaches, reduced aircraft wake vortex separation standards, and less restrictive run-way/taxiway operations. Additional mechanisms to increase the feasible density of operations will also be considered.

Equivalent visual operations will provide aircraft with the critical information needed to maintain safe distances from other aircraft during non-visual conditions, including a capability to operate at "visual performance" levels on the airport surface during low-visibility conditions. Advances in equivalent visual operations for the Airportal air navigation service provider are also of interest.

Aircraft trajectory-based operations will utilize 4D trajectories (aircraft path from block-to-block, including path along the ground, and also including the time component) as the basis for planning and executing system operations.

Wake vortices are often the ultimate limitation for many advanced, high-efficiency operational concepts. Advances in sensors, simulations of wake vortices and sensors, weather modeling and measurements, and understanding of impacts to aircraft flight are all of interest.

NASA's AS Program has identified the following Next Generation Air Transportation System (Next Gen) Airportal research activities: optimization of surface aircraft traffic; dynamic airport configuration management (including the optimal balancing of Airportal resources for arrival, departure, and surface aircraft operations); predictive models to enable mitigation of wake vortex hazards; new procedures for performing safe, closely spaced, and converging approaches at closer distances than are currently allowed; modeling, simulation, and experimental validation research focused on single and multiple regional airports (metroplex); and other innovative opportunities for transformational improvements in Airportal/metroplex throughput. Inherent to the AS Program approach is the integration of airborne solutions within the overall surface management optimization scheme.

In order to meet these challenges, innovative and technically feasible approaches are sought to advance technologies in research areas relevant to NASA's Next Gen/Airportal effort. The general areas of interest are surface management optimization, converging and parallel runway operations, safety risk assessment methodologies, and wake vortex solutions inside Metroplex boundaries. Specific research topics for Next Gen/Airportal include:

- Airborne spacing algorithms and wake avoidance procedures for airports with closely spaced runways;
- Algorithms for determining wake vortex encounters from aircraft flight data recorders;
- Automated separation assurance and runway/taxiway incursion prevention algorithms ;
- Automatic taxi clearance and aircraft control technologies;
- Characterization of wake vortex and atmospheric hazards to flight in terms of aircraft and flight crew responses;
- Collaborative decision making between airlines and airport traffic control tower personnel for optimized surface operations, including push back scheduling and management of airport surface assets;

- Development of wake vortex hazard assessment algorithms;
- Dynamic airport configuration management;
- Fusion of data from weather sensors and models for input into weather prediction models;
- High resolution CFD and real-time modeling of wake vortex strength and location;
- Human/automation interaction and performance standards;
- Improved wake vortex circulation estimates derived from Pulsed Lidar;
- Innovations in wake vortex sensors;
- Integration of decision-support tools across different airspace domains;
- Lidar Simulation tools for wake vortices;
- Measurements of wind, temperature, and turbulence from departing and arriving aircraft;
- Methodologies and/or algorithms to estimate environmental impacts of increased traffic on the surface and in the terminal airspace, and to reduce the environmental impacts under increased levels of traffic;
- Methodologies to estimate and assess the risk of transformational airspace operations for which little historical risk data may exist and for which operations may be constrained by the potential for extremely rare events;
- Modeling and simulation of airport operations for validating aircraft taxi planning concepts;
- Optimized 4D aircraft trajectory generation and conformance monitoring for surface and terminal airspace operations, including departure and arrival planning for individual flights;
- Radar simulation tools for wake vortices;
- Radically innovative approaches for detection of wake vortices;
- Scheduling algorithm for aircraft deicing and integration with a surface traffic decision-support tool;
- Surface and terminal airspace traffic modeling and simulation of multiple regional airports;
- Virtual airport traffic control towers;
- Weather sensors for supporting wake vortex predictions;
- Other technologies and approaches to achieving 2-3X improvement in the throughput of Airportal/metroplexes.

Note: The development of technologies for the airborne detection of wake vortices is covered in Subtopic A1.04 [7].

Sub Topics:

Ground Test Techniques and Measurement Technology Topic A4.01

NASA is concerned with operating its ground test facilities with new and innovative methods for test measurement technology and with continually improving on the efficiency and effectiveness of operation of its ground test facilities. NASA's aeronautics and space research and development pushes the limits of technology, including the ground test facilities that are used to confirm theory and provide validation and verification of new technologies. By using state-of-the-art test measurement technologies, novel means of acquiring test data, test techniques and creative facility performance capability enhancements, NASA will be able to operate its facilities more efficiently and effectively and also be able to meet the challenges presented by NASA's cutting edge research and development programs. Therefore, NASA is seeking highly innovative and commercially viable test measurement technologies, test techniques, and facility performance technologies that would increase efficiency or overcome research and development technology barriers for ground test facilities.

The emphasis for this subtopic is in the area of test measurement technology. Examples of the types of technology solutions sought, but not limited to, are: skin friction experimental measurement techniques; improved flow transition detection methodologies; new or novel, non-intrusive measurement technologies for pressure, temperature, and force measurements; force measurement (balance) technology development; and improvement of current cutting edge technologies, such as particle imaging velocimetry (PIV), that allow the technology to be used more reliably in a production wind tunnel environment. Solutions are also sought with regards to the instrumentation used to characterize ground test facility performance. This could be in the area of aerodynamics performance characterization (flow quality, turbulence intensity, etc.) or, for example, in the case of specialty facilities, the measurement of liquid water content, ice water content, and cloud droplet size conditions in an icing wind tunnel.

Proposals that lead to products or processes that are applicable specifically to the ATP facilities (see http://www.aeronautics.nasa.gov/atp [9]) and across multiple facility classes are especially important. The proposals will also be assessed for their ability to develop products that can be used in government-owned, industry and academic institution aerospace ground test facilities.

Sub Topics:

Flight Test Techniques and Measurement Technology Topic A4.02

NASA's flight research is reliant on a combination of both ground and flight research facilities. By using state-of-the-art techniques, measurement and data acquisition technologies, NASA will be able to operate its flight research facilities more effectively and also meet the challenges presented by NASA's cutting edge research and development programs. The scope of this subtopic is broad, with emphasis on emissions, noise, and performance. Research technologies applicable to this subtopic should address (but are not limited to): Western Aeronautical Test Range (WATR), Flight Loads Laboratory (FLL), Research Flight Simulation Hardware-in-the-Loop Simulation (HILS), Testbed and Support Aircraft (e.g. F-15, F-18, ER-2, Gulfstream-III, Ikhana), as well as modeling, identification, simulation, and control of aerospace vehicle applications in flight research, flight sensors, sensor arrays and airborne instruments for flight research, and advanced aerospace flight concepts. Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influences of structural dynamics, thermal dynamics, steady and unsteady aerodynamics, and the control system. The benefit of this effort will ultimately be an increased understanding of the complex interactions between the vehicle dynamics subsystems with an emphasis on flight research validation methods for control-oriented applications. Proposals for novel multidisciplinary nonlinear dynamic systems modeling, identification, and simulation for control objectives are encouraged. Control objectives include feasible and realistic boundary layer and laminar flow control, aeroelastic maneuver performance and load control (including smart actuation and active aerostructural concepts), autonomous health monitoring for stability and performance, and drag minimization for high efficiency and range performance. Methodologies should pertain to any of a variety of types of vehicles ranging from low-speed, high-altitude long-endurance to hypersonic and access-to-space aerospace vehicles. Real-time measurement techniques are needed to acquire aerodynamic, structural, control, and propulsion system performance characteristics in-flight and to safely expand the flight envelope of aerospace vehicles. The scope of this subtopic is the development of sensors, sensor systems, sensor arrays, or instrumentation systems for improving the state-of-the-art in aircraft ground or flight research. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight research by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, minimizing the disturbance to the measured parameter from the sensor presence, deriving new information from conventional techniques, or combining sensor suites with embedded processing to add value to output information. This topic solicits proposals for improving airborne sensors and sensor instrumentation systems in all flight regimes – particularly transonic and hypersonic. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability. This subtopic further solicits innovative flight research experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment.

Therefore, NASA is seeking highly innovative and viable research technologies that would increase efficiency or overcome limitations for flight research. Other areas of interest include: Verification & Validation techniques for non-deterministic and complex redundant systems; Design Tools integrated into the simulation environment for early research and validation; Flight Measurements & Data Acquisition: Aerodynamic forces, flow quality & conditions; Skin Friction; Flight Hardened Systems & Miniaturization; Signal Processing & Reconfigurable Systems; Wireless technologies.

Sub Topics: