NASA SBIR 2005 Phase I Solicitation

Aeronautics Research

Aviation Safety and Security Topic A1

The worldwide commercial aviation accident rate has been nearly constant over the past two decades. Although the rate is very low, increasing traffic over the years may result in the absolute number of accidents also increasing. Without improvements, doubling or tripling of air traffic by 2017 could lead to 50 or more major accidents a year. This number of accidents would have an unacceptable impact on the air transportation system. The goal of NASA's Aviation Safety and Security Program (AvSSP) is to develop and demonstrate technologies that contribute to a reduction in the fatal aviation accident rate. Research and technology will address accidents involving hazardous weather, controlled flight into terrain, human-error-caused accidents and incidents, and mechanical or software malfunctions. The Program will also develop and integrate information technologies needed to build a safer aviation system and provide information for the assessment of situations and trends that indicate unsafe conditions before they lead to accidents. NASA researchers are also looking at ways to adapt aviation technologies already being developed to improve aviation security. The AvSSP is focusing on areas where NASA expertise could make a significant contribution to security: 1) the hardening of aircraft and their systems, 2) secure airspace operation technologies, 3) improved systems to screen passenger and cargo information, and 4) sensors designed to better detect threats. NASA seeks highly innovative proposals that will complement its work in Aviation Safety and Security in the following subtopic areas:

Sub Topics:

A1.01 Crew Systems Technologies for Improved Aviation Safety

Lead Center: LaRC

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

- Intelligent systems monitoring and alerting technologies for improved failure mode identification, recovery, and threat mitigation
- Designs for human-error prevention, detection, and mitigation
- Decision-support tools and methods to improve communication, collaborative, and distributive decision-making
• Data fusion technologies to integrate flight-related information for improved situation awareness and appropriate workload modulation

• Support for crew response planning and selection

• Computational approaches to determine and appropriately modulate crew engagement, workload, and situation awareness

• Human-centered information technologies to improve the performance of less-experienced operators, and pilots from special population groups

• Avionics designers and/or certification specialist tools to improve the application of human-centered principles

• Human-error reliability approaches to analyzing flight deck displays decision aids, and procedures;

• Presentation and aiding concepts for the display and use of data with spatial or temporal uncertainty, and of integrated streams of data with various levels of integrity

• Individual and team performance metrics, analysis methods, and tools to better evaluate and certify human and system performance for use in operational environments, simulation, and model-based analyses

Proposals should describe technologies, tools, and approaches with high potential to serve NASA program objectives, and to be developed as marketable products.

A1.02 Aviation Safety and Security; Fire, Icing, Propulsion and Secure CNS Aircraft Systems

Lead Center: GRC

NASA is concerned with the prevention of hazardous in-flight conditions and the mitigation of their effects when they do occur. Aircraft fires represent a small number of actual accident causes, but the number of fatalities due to in-flight, post-crash, and on-ground fires is large. One particular emphasis is on early, false-alarm resistant detection of the location, spread, and suppression of in-flight fires in hidden, inaccessible areas of the aircraft. Examples of hidden areas are behind cabin panels, inside ductwork, and so on. Another area of interest is in-tank monitoring of fuel /air flammability factors to provide more efficient active control of fuel tank inerting systems.

A second emphasis for this subtopic is on propulsion system health management, in order to predict, prevent, or accommodate safety-significant malfunctions and damage. Past advances in this area have helped improve the reliability and safety of aircraft propulsion systems; however, propulsion system component failures are still a contributing factor in numerous aircraft accidents and incidents. Advances in technology are sought which help to further reduce the occurrence of and/or mitigate the effects of safety-significant propulsion system malfunctions and damage. Specifically the following are sought: propulsion health management technologies such as instrumentation, sensors, ground and on-wing nondestructive inspection, health monitoring algorithms, and fault accommodating logic, which will predict/prognose, diagnose, prevent, assess, and allow recovery from propulsion system malfunctions, degradation, or damage.
A third emphasis is to increase the level of safety for all aircraft flying in the atmospheric icing environment. To maximize the level of safety, aircraft must be capable of handling all possible icing conditions by either avoiding or tolerating the conditions. Proposals are invited that lead to innovative new approaches or significant improvements in existing technologies for in-flight icing conditions avoidance (icing weather information systems) or tolerance (airframe and engine ice protection systems and design tools). With these emphases in mind, products and technologies that can be made affordable and retrofittable within the current aviation system, as well as for use in the future, are sought:

- Ground and airborne radome technologies for microwave wavelength radar and radiometers that remain clear of liquid water and ice in all weather situations.

- In situ icing environment measurement systems that can provide practical, very low-cost validation data for emerging icing weather information systems and atmospheric modeling. Measured information must include location, altitude, cloud liquid water content, temperature, and ideally cloud particle sizing and phase information. Solutions envisioned would use radiosonde-based systems.

- Ice protection and detection technology submittal must provide significant improvements over current systems or address new design needs. Areas of improvement can be considered to be: efficient thermal protection systems, including composite wing or structures applications, ice sensors that provide detection and accretion rate for all possible icing conditions, wide area ice detection, detection that serves both ground and in-flight applications, ice crystal detection probe (for non-research aircraft applications), engine icing probe (that can measure Liquid Water Content and Total Water Content inside engine passages), and de-icing systems that operate at near anti-icing performance. Any submittal must be cost competitive to current technologies.

A fourth emphasis for this subtopic is protection and hardening of the aircraft’s communication, navigation, and surveillance (CNS) systems, as well as enabling new aviation security applications through improved air-to-ground data link communications and secure onboard information processing, computing, and air/ground networking. Technology is needed to harden the CNS systems, both onboard and air-to-ground, against abnormalities and deliberate attacks towards also enabling the next-generation airborne, ground- and space-based surveillance systems. Other communications related needs can be found in other NASA SBIR subtopics areas.

The final emphasis for this subtopic is on propulsion damage adaptive controls technologies and systems for new aircraft security applications. This technology is needed to enable a propulsion system to mitigate aircraft damage from hostile attacks.

A1.03 Aviation Security Technologies

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

The NASA Strategic Plan includes requirements to enable a more secure air transportation system and to create a more secure world by investing in technologies and collaborating with other agencies, industry, and academia.
NASA’s role in civil aeronautics has always been to develop high-risk, high-payoff technologies to meet critical national aviation challenges.

NASA aims to develop and advance technologies that will reduce the vulnerability of the Air Transportation System (ATS) to threats or hostile acts, and identify and inform users of potential vulnerabilities in a timely fashion. Specific technical focus areas include system-wide security risk assessment and incident precursor identification; enhanced flight procedures and on-board systems to protect critical infrastructures and key assets and enable the safe recovery of a seized aircraft; definition of directed energy threats to the aircraft and on/off-board systems that will provide surveillance and countermeasures of these threats; integrated adaptive control systems to detect and compensate for vehicle damage; hardened and security enhanced aircraft networks and datalinks; remote monitoring of the aircraft environment and systems; new materials for composite fire and explosive resistant fuselage structures; advanced, airborne, in situ detection of chemical and biological terror agents; and commercial aircraft fuel tank inerting. Technologies under development are intended for the next-generation ATS; however, issues such as retrofit, certification, system implementation, and cost-benefit must be considered during the technology development process.

NASA seeks highly innovative and commercially viable technologies that will improve aviation security by addressing threats to air vehicles as well as the ATS. Specific areas of focus include: preventing aircraft from being used as a weapon of mass destruction; protection from man-portable air defense systems (ManPADS) and electromagnetic energy (EME) attacks; light-weight, fire and explosive resistant composite materials; explosive resistant fuel systems; ground-based decision support tools needed to monitor airspace security concerns; reporting systems to monitor security violations; secure encrypted datalink systems, intrusion-tolerant communications networks and communications systems to support emerging aviation security applications; tools to support real-time management of security information; and Chem/Bio sensor development. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices:

- Intelligent Systems monitoring and alerting technologies;
- Secure communications systems to support emerging aviation security applications;
- Onboard and ground surveillance and interception systems for aircraft immunity to electromagnetic interference and electromagnetic pulse intrusions;
- Flight control systems that accommodate vehicle damage relative to changes in aircraft stability, control, and structural load characteristics;
- Material systems, fuselage structural concepts, and fuel systems that are resistant to fire and explosions;
- Fuel system technologies that prevent or minimize in-flight vulnerability of civil transport aircraft due to small arms or man-portable defense systems type projectiles;
- Computational approaches to monitoring crew health, stress level, state of duress, and performance;
- Validation methods and tools for advanced safety/security critical systems;
- Technologies that enable secure communications, navigation, and surveillance on-board the aircraft;
- Technologies and methods to provide accurate information and guidance to enable pilot avoidance of protected airspace, maintain positive identity verification of aircraft operators, determine pilot intent, and deny flight control access to unauthorized persons;
- Decision-support tools and methods to improve communication and collaborative and distributive decision-making; and
- Data fusion technologies for integrating disparate sources of flight-related information.

A1.04 Automated On-Line Health Management and Data Analysis

Lead Center: ARC
Participating Center(s): AFRC

Online health monitoring is a critical technology for improving air transportation safety in the 21st century. Safe, affordable, and more efficient operation of aircraft requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local- and wide-area networks. Online health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online health monitoring emphasizes algorithms that minimize the time between data acquisition and decision-making.

This subtopic seeks solutions for online aircraft subsystem health monitoring and prognostics. Solutions should exploit multiple computers communicating over standard networks where applicable. Solutions can be designed to monitor a specific subsystem or a number of systems simultaneously. Resulting commercial products might be implemented in a distributed decision-making environment such as onboard diagnostics and management systems, or maintenance and inspection networks of potentially global proportion.

Proposers should discuss who the users of resulting products would be, e.g., research/test/development, manufacturing; maintenance depots, flight crew, Unmanned Aerial Vehicles/Remotely Operated Aircraft (UAV/ROA) aircraft operators, airports, flight operations or mission control, or airlines. Proposers are encouraged to discuss data acquisition, processing, and presentation components in their proposal. Proposals that focus solely on sensor development should not be submitted to this subtopic. Such proposals should be addressed to sensor development subtopics such as the Flight Sensors and Airborne Instruments for Flight Research subtopic.

Examples of desired solutions targeted by this subtopic follow:

- Real-time autonomous sensor validity monitors;
- Flight control system or flight path diagnostics for predicting loss of control;
- Automated testing and diagnostics of mission-critical avionics;
- Structural fatigue, life cycle, static, or dynamic load monitors;
- Methods and tools for remaining life estimation and prognostics for critical aircraft components;
Vehicle Systems Topic A2

The Vehicle Systems Program (VSP) goal is to provide breakthrough technologies for significantly advanced future air vehicles. The approach is to develop these technologies and demonstrate them in flight to provide evidence of barrier breakthroughs. The benefits of these breakthrough technologies including opening more communities to air transportation, enabling new air transportation models by doubling vehicle speed capacity, eliminating aviation pollution, and enabling new science platforms. VSP will focus on four demonstration projects. The subsonic noise reduction project will start by demonstrating a 50% noise reduction compared to 1997 state of the art. The sonic boom reduction project will begin by demonstrating technology that could enable an acceptable sonic boom level. The high altitude, long endurance project will start by demonstrating a 14-day duration high-altitude aircraft. Finally, the zero emissions aircraft will begin by demonstrating an aircraft powered by hydrogen fuel cells.

Sub Topics:

A2.01 Noise Breakthrough Turbine-Based Propulsion Technologies

Lead Center: GRC

Future subsonic and supersonic aircraft may be required to achieve reduced noise levels up to 20 effective perceived noise levels (EPNdB) below FAR 36 Stage 3 certification levels without significant impacts to performance. The main emphasis of this subtopic is on high-risk, breakthrough technologies in order to reduce the technical risk associated with the development and deployment of new technologies in future commercial products. Subsonic noise reduction to date has predominantly been achieved via higher-bypass-ratio engines. With current practices, the nacelle diameter limit has physically been reached and engine noise is now comparable to airframe noise on approach. Engine noise reduction concepts proposed for subsonic applications must be compatible with low noise propulsion/airframe integration designs and continuous descent approach, low noise guidance flight procedures. Innovative noise reduction concepts need to be identified that provide economical alternatives to conventional propulsion systems.
Integrated, advanced propulsion systems with intelligent controls technologies will enable supersonic vehicles (up to Mach 2) having acceptable takeoff/landing noise and increased efficiency. Studies suggest that gas turbine engines with increased thrust-to-weight, bypass ratios, and decreased thrust specific fuel consumption are required to support quiet supersonic aircraft. NASA is interested in the development of advanced gas turbine engine concepts and key enabling technologies that can dramatically reduce the landing/take-off noise to an acceptable level, and which have the potential to dramatically improve the sustained cruise performance of a supersonic aircraft. Concepts proposed for supersonic applications must not adversely impact the airframe configurations to reduce sonic boom intensity, especially with regard to the formation of shaped waves and the human response to shaped waves.

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

**Subsonic Propulsion System Technologies**

- Innovative source identification techniques for fan, jet, combustor, or turbine noise;
- Advanced turbine engine cycles to achieve effective very high-bypass-ratio with smaller diameter engines;
- Innovative technologies for reduction of fan, jet, combustor, or turbine noise; and
- Advanced sound attenuating liners, including active and passive control.

**Supersonic Propulsion System Technologies**

- Advanced turbine engine cycle concepts to achieve low takeoff/landing noise and high supersonic cruise efficiency, including high pressure, high bypass multiple spool cycles, inter-stage turbine burning, variable cycle engines;
- Advanced propulsion system technologies, including advanced integrated airframe-propulsion control methodologies, adaptive flow control technologies, smart structures for nozzles and inlets, inlet technologies for weight/ performance/ operability/ stability; and
- High temperature materials such as monolithic ceramics and nano materials, evaporatively cooled turbine blades, and counter rotating stages enable more compact engine cores, greater thermal efficiency, and higher thrust to weight ratios.

Proposals must show improvements to the state-of-the art and viable application to aircraft.
Participating Center(s): AFRC

Fuel cells offer a promising technology for clean, efficient power generation important to both High Altitude Long Endurance (HALE) remotely piloted aircraft, and future envisioned environmentally friendly commercial transports. Both consumable fuel and regenerative fuel based fuel cells are of interest. The former type is applicable to both HALE and commercial transports, while the latter type is of interest for a solar-electric powered HALE capable of multi-month missions. The consumable fuel based fuel cell will likely use atmospheric air for the cathode gas, while the regenerative systems will likely use pure oxygen stored and regenerated on-board. For both applications, the focus of this subtopic is on hydrogen fuel based systems including liquid for consumable fuel systems and gaseous for regenerative fuel cell systems.

To realize these aircraft applications will require one or even two orders of magnitude improvement in unit power and power density (volume and weight) for the power generation system, and specifically the fuel cell stack, as compared to ground based systems. In addition, the systems are required to operate at altitude, including high altitudes (>= 60,000 ft) for the HALE applications, and provide service life and reliability significantly greater than ground-based systems. Thus, NASA is seeking "break-through" technologies necessary for aircraft instead of evolutionary improvement to current state-of-the-art.

Technologies of specific interest include:

- Innovative fuel cell power systems demonstrating high specific power and high efficiency using consumed liquid hydrogen fuel with scalability to 100's of kW and capable of high altitude operations;
- PEM stack demonstrating >= 2 kW/kg and >= 50% efficiency (LHV) with scalability to 100's of kW;
- SOFC stack demonstrating >= 1 kW/kg and >= 50% efficiency (LHV) with scalability to 100's of kW; and
- Innovative regenerative fuel cell energy storage systems and critical components (e.g., unitized fuel cell and electrolyzer stack, PEM or SOFC based systems, etc) demonstrating >= 600 watt-hr/kg and high round trip efficiency.

A2.03 Hydrogen Fuel Systems and Components for Aircraft Applications

Lead Center: GRC

Participating Center(s): AFRC, LaRC

Hydrogen is the most likely fuel to enable future zero emissions aircraft and High Altitude Long Endurance Remotely Operated Aircraft (HALE ROA). Due to the increased volume required for hydrogen systems as compared to current hydrocarbon fueled aircraft, key technologies are required to reduce feed system weight while maximizing propellant storage efficiency. To be a viable technology for future aircraft systems, hydrogen feed components most likely will require life cycles approaching 10,000+ with an expectation of 20+ years in service, a significant difference from current state-of-the-art for space flight systems. For HALE ROA systems, vehicle mass must be kept low enough for flights up to altitudes exceeding 60,000 ft. Insulation systems must be lightweight and designed for minimum maintenance. Hydrogen storage and feed systems can be either cryogenic or gaseous depending upon the vehicle configuration. Tank mass fraction requirements (mass of storage system/mass of
hydrogen) for liquid hydrogen on the order of 15% are expected to meet mission requirements. Hydrogen tank systems applications will be expected to provide storage for flight vehicles for up to 14 days duration with cryogenic systems and 6 months for aircraft with gaseous hydrogen. System safety is a critical factor in the design and development of any hydrogen system. To ensure public safety it is important that highly-sensitive, low-power-use sensors and instrumentation are developed to identify and diagnose potential problems with the hydrogen systems. Technology focus areas will include storage, distribution, and propellant conditions. Innovations are solicited in the following areas:

Storage and Distribution Components

- Lightweight, low thermal conductivity on-board cryogenic storage tanks, feed lines, valves, and relief devices;
- Lightweight, low thermal conductivity insulation for tanks and feed lines that requires minimal inspection and maintenance;
- Lightweight, low permeable gaseous hydrogen storage tanks and feed lines; and
- Low power, high-sensitivity sensors for hydrogen leak detection and condition monitoring.

Propellant Conditioning Components and Technologies

- Innovative methods to reduce the volume of stored hydrogen while minimizing system weight;
- Technologies for the reformation of hydrocarbon based fuels to hydrogen;
- Advanced technologies to minimize losses during loading and unloading of hydrogen, including autonomous operations, tank transfers, delivery to propulsion system, venting, and/or hydrogen recovery;
- Advanced technologies to minimize hydrogen losses and reduce energy requirements for system pre-chill, delivery to propulsion system, venting and/or hydrogen recovery, and long duration temperature.

Proposals must show improvements to the state-of-the-art and viable application to aircraft.

A2.04 Aircraft Systems Noise Prediction and Reduction

Lead Center: LaRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, rotorcraft, and advanced aerospace vehicles. In support of the goal of the Quiet Aircraft Technology Project for reduced noise impact on community residents, improvements in noise prediction and control are needed for jet, propeller, rotor, fan, 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 aircraft passengers and crew and on 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;
- Simulation and prediction of aero acoustic noise sources particularly for airframe noise sources and situations with significant interactions between airframe and propulsion systems;
- Concepts for active and passive control of aero acoustic noise sources for conventional and advanced aircraft configurations;
- Innovative active and passive acoustic treatment concepts for engine nacelle liners and concepts for high-intensity acoustic sources, which can be used to characterize engine nacelle liner materials;
- Reduction technologies and prediction methods for rotorcraft and advanced propeller aerodynamic noise;
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise;
- Development and application of flight procedures for reducing community noise impact of rotorcraft and subsonic and future supersonic commercial aircraft while maintaining safety, capacity, and fuel efficiency;
- Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process;
- Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures; and
- Prediction and control of high-amplitude aero acoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue.

A2.05 Electric Drive Components, Power Management and Distribution Technologies

Lead Center: GRC
Participating Center(s): GSFC, JPL, JSC

Future environmentally harmonious aircraft propulsion systems may be driven by electric power. These new systems will likely be fueled by hydrogen stored as a cryogenic liquid. Like all flight systems, these new electric based propulsion concepts will require each component to be extremely lightweight, especially when compared to similar ground-based systems. Future specific power requirements for the entire propulsion system from power supply to electric motor could reach 20-kW/kg. The total electric power supplied for aircraft will be orders of magnitude higher than for existing flight-rated secondary electrical systems. Future high power electric systems present a number of challenges for application to volume and weight limited aircraft. NASA is interested in the development of innovative technologies that demonstrate the feasibility of high power densities (>5kW/kg) for electric power delivery and propulsion. Specific areas of interest include but are not limited to the following:
• High power density electric motors and actuators, including superconducting, cryogenic and non-cryogenic systems;

• Cryogenically cooled lightweight, possibly superconducting, high power transmission lines;

• Cryogenically cooled and non-cryogenic lightweight power conditioning and control technology including technologies for isolation of noise-sensitive avionics power busses from main propulsion power busses;

• Cryogenically cooled and non-cryogenic lightweight high voltage high power density power management components;

• Highly integrated dual function components and systems that have the potential to reduce overall vehicle and subsystem weight (e.g., power conductors that are integrated into the airframe structure, motors directly integrated into the fan/propeller structure);

• Advanced enabling technologies such as nanoelectronics, smart sensors, and actuators;

• Advanced diagnostics, health monitoring and control concepts, smart sensors, electronics and actuators for enabling self-diagnosis and prognosis, and self-reconfiguration capabilities;

• Concepts that integrate distributed sensing with actuation and control logic for micro-level control of parameters (such as propulsion system internal flows, electrical states, etc. that impact performance and environment).

Proposals must show improvements to the state-of-the-art and viable application to aircraft.

A2.06 Smart, Adaptive Aerospace Vehicles With Intelligence

Lead Center: ARC

Participating Center(s): LaRC

This subtopic emphasizes the roles of aerodynamics, aerothermodynamics, adaptive software, vehicle dynamics in nonlinear flight regimes, and advanced instrumentation in research directed towards the identification, development, and validation of enabling technologies that support the design of future, autonomous aerospace vehicle and platform concepts for aviation safety, and security vehicle systems. Some of the vehicle attributes envisioned by this subtopic include: a) "Smart" vehicle attributes-using advanced sensor technologies, flight vehicle systems are "highly aware" of onboard health and performance parameters, as well as the external flow field and potential threat environments; b) "Adaptive" vehicle attributes-flight avionics systems are reconfigurable, structural elements are self-repairing, flight control surfaces and/or effectors respond to changing flight parameters and/or vehicle system performance degradation; and c) "Intelligent" vehicle attributes-vehicle onboard processing and artificial intelligence technologies, interfaced with advanced vehicle structural component and subcomponent designs and appropriate actuating devices, reacts rapidly and effectively to changing performance demands and/or external flight and security threat environments. Future air vehicles with the above attributes will manage complexity, "know" themselves, continuously tune themselves, adapt to unpredictable conditions, prevent and recover from failures, and provide a safe environment.
For atmospheric vehicles and platforms, both military and civil applications are sought, while for aviation applications, emphasis is placed on configurations that enable the discovery of new aviation safety and security concepts. Concepts and corresponding enabling technologies are sought which expand the traditional boundaries of conventional piloted vehicles categories such as General Aviation (GA) or Personal Air Vehicles (PAV), as well as significantly advance the state-of-the-art in remotely operated vehicle classes such as Long-Endurance Sensing Platforms (LESP), Unmanned Aerial Vehicles (UAV) or Unmanned Combat Aerial Vehicles (UCAV) as they can relate to aviation safety and security. Furthermore, for Earth applications, special emphasis is placed on research proposals that attempt to provide solutions for a future state in which revolutionary vehicles operate in a highly integrated airspace including hub and spoke, point-to-point, long-haul, unmanned aircraft, green aircraft, as well as a future state where air vehicle designs reflect a high level of integration in performance, safety and security, airspace capacity, environmental impact and cost factors.

There are a number of specific areas of interest:

- Conceptual flight vehicle/platform designs featuring variable levels of vehicle and airspace requirements integration, and/or smart, intelligent, and adaptive flight vehicle capabilities, as demonstrated by state-of-the-art systems analyses methods to determine enabling technologies and resulting impacts on future system integrated performance, environmental impact, and safety and security issues;
- New algorithms for predicting vehicle loads and response using minimal vehicle state information;
- Novel optimization methodologies to support conceptual design studies for highly-integrated flight vehicle and air space concepts and/or smart, intelligent and adaptive flight vehicle capabilities, which demonstrate appropriate design variable selection, scaling techniques, suitable cost functions, and improved computational efficiency;
- Physics-based modeling and simulation tools of multiple vehicle classes and corresponding airspace operations aspects to support scenario-based planning and requirements definition of highly integrated vehicle and airspace capacity concepts, including investigations of the potential use of virtual/immersive simulations on future engineering decision making processes; and
- Micro-scale wireless communications, health monitoring, energy harvesting, and power-distribution technologies for large arrays of vehicle-embedded MEMS sensors and actuators.

A2.07 Revolutionary Atmospheric Flight Concepts

Lead Center: AFRC

This subtopic solicits innovative flight test experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. The emphasis of this subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and may require a demonstration or validation in an actual flight environment to fully characterize or validate it.
The scope of this subtopic is broad and includes advanced flight experiments that accelerate the understanding, research, and development of advanced technologies and unconventional operational concepts. Examples extend to (but are not limited to) such things as inflatable aero-structures (new designs or innovative applications, new manufacturing methods, new materials, new in-flight inflation methods, and new methods for analysis of inflation dynamics), innovative control surface effectors (micro-surfaces, embedded boundary-layer control effectors, and micro-actuators), innovative engine designs for UAV aircraft, alternative engines/motors/concepts, alternative fuels research (hydrocarbon, hydrogen, or regenerative), sonic boom reduction, noise reduction for Conventional Take-off and Landing/Short Take-off and Landing (CTOL/STOL) aircraft and engines, advanced mass transportation concepts, aerodynamic systems optimization for planetary aircraft (Venus, Mars, Io, and/or Titan), flexible system stability derivative identification, innovative approaches to thermal protection that minimize aerodynamic performance degradation, innovative approaches to structures, stability, control, and aerodynamics integration schemes, and innovative approaches to incorporation of UAV operations into commercial airspace. This subtopic is intended to advance and demonstrate revolutionary concepts and is not intended to support evolutionary steps required in normal product development. Proposals should emphasize the need of flight testing a concept or technology as a necessary means of verifying or proving its worth; emphasis should also be given to multidisciplinary integration of advanced flight systems. The benefit of this effort will ultimately be more efficient aerospace vehicles, increased flight safety (particularly during flight research), and an increased understanding of the complex interactions between the vehicle or technology concept and the flight environment.

A2.08 Modeling, Identification, and Simulation for Control of Aerospace Vehicles to Prepare for Flight Test

Lead Center: AFRC

Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal of this subtopic is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influence 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 dynamical subsystems with an emphasis towards flight test 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, aero elastic maneuver performance, and load control including smart actuation and active aero structural 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, such as Unmanned Aerospace Vehicles/Remotely Operated Aircraft (UAV/ROA), and flight regimes ranging from low-speed High-Altitude Long-Endurance (HALE) to hypersonic and access-to-space aerospace vehicles. Proposals should address one or more of the following:

- Accurate prediction with validation of steady and unsteady pressure, stress, and thermal loads;
- Effective multidisciplinary dynamics analysis algorithms with flight-test correlation capability conducive to validation with test data, such as with finite-element aeroservoelastic computations;
- Time-accurate simulation systems from nonlinear multidisciplinary dynamics models with applications toward flight-testing, such as with reduced-order CFD-based methods;
• Novel and efficient schemes for control-oriented identification of nonlinear aeroservoelastic dynamics from test data with provisions for uncertainty estimation and model correlation;

• Online and autonomous model update schemes for loads, aerodynamic, and aero elastic model identification for stability and performance monitoring and prediction in adaptive control;

• Self-learning control strategies for aero structural vehicles and development of enhanced real-time controls software and hardware for long-term onboard systems operation;

• Integration of modeling, analysis, simulation, and identification techniques for control objectives in a unified, compatible manner; and

• Innovative, high-performance facilities for integrated simulation and graphical interface, or virtual reality systems, for multidisciplinary aerospace systems.

A2.09 Flight Sensors and Airborne Instruments for Flight Research

Lead Center: AFRC

Real-time measurement techniques are needed to acquire aerodynamic, structural, 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 or instrumentation systems for improving the state-of-the-art in aircraft flight testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, and minimizing the disturbance to the measured parameter from the sensor presence or deriving new information from conventional techniques. This subtopic solicits proposals for improving airborne sensors and instrumentation systems in all flight regimes. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability. Innovative concepts are solicited in the areas that follow below.

Vehicle Condition Monitoring

Sensor development in support of vehicle health and performance monitoring includes the monitoring of aerodynamic, structural, propulsion, electrical, pneumatic, hydraulic, navigation, control, and communication subsystems. Proposals that focus solely on health management algorithms and systems integration should be addressed in the Automated Online Health Management and Data Analysis subtopic.

Vehicle Environmental Monitoring

Sensor development in support of vehicle environmental monitoring includes the following:

• Non-intrusive air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, air density, and flow angle);

• Off-surface flow field measurement and/or visualization (laminar, vortical, and separated flow, turbulence)
zero to 50 meters from the aircraft;

- Boundary layer flow field, surface pressure distribution, acoustics or skin friction measurements or visualization; and

- Unusually small, light and low-power instrumentation for use on miniature aircraft and high altitude long endurance vehicles.

Airspace Systems Topic A3

NASA’s Airspace Systems (AS) program is investing in development of revolutionary improvements and modernization for the air traffic management (ATM) system. The AS Program will enable new aircraft, new aircraft technologies, and air traffic technology to safely maximize operational efficiency, flexibility, predictability, and access into airspace systems. The major challenges are to accommodate projected growth in air traffic while preserving and enhancing safety; provide all airspace system users more flexibility and efficiency in the use of airports, airspace and aircraft; reduce system delays; enable new modes of operation that support the FAA commitment to “Free Flight” and maintain pace with a continually evolving technical environment, and provide for doorstep to destination transportation developments. AS Program objectives are: improve mobility, capacity, efficiency and access of the airspace system; improve collaboration, predictability and flexibility for the airspace users; enable modeling and simulation of air transportation systems; enable runway-independent aircraft and general aviation operations; and maintain system safety and environmental protection. NASA is working to develop, validate, and transfer advanced concepts, technologies, and procedures through partnership with the Federal Aviation Administration (FAA), other government agencies, and in cooperation with the U.S. aeronautics industry.

Sub Topics:

A3.01 Next Generation Air-Traffic Management Systems

Lead Center: ARC
Participating Center(s): AFRC

The challenges in Air Traffic Management (ATM) are to create the next generation system and to develop the optimal plan for transitioning to the future system. This system should be one that (1) economically moves people and goods from origin to destination on schedule, (2) operates without fatalities or injuries resulting from system or human errors or terrorist intervention, (3) seamlessly supports the operation of unmanned aerial vehicles (UAVs) or remotely operated aircraft (ROAs), (4) is environmentally compatible, and (5) supports an integrated national transportation system and is harmonized with global transportation. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

To meet these challenges, innovative and economically attractive approaches are sought to advance technologies.
in the following areas:

- Decision support tools (DST) to assist pilots, controllers, and dispatchers in all parts of the airspace (surface, terminal, en route, command center);
- Integration of DST across different airspace domains;
- Next generation simulation and modeling capability-models of uncertainty and complexity, National Airspace System (NAS) operational performance, economic impact;
- Distributed decision making;
- Security of advanced ATM systems;
- System robustness and safety-sensor failure, threat mitigation, health monitoring;
- Weather modeling and improved trajectory estimation for traffic management applications;
- Role of data exchange and data link in collaborative decision-making;
- Modeling of the NAS;
- Distributed complex, real-time simulations-components with different levels of fidelity, human-in-the-loop decision agents;
- Integrated ATM/aircraft systems that reduce noise and emissions;
- Automation concepts for advanced ATM systems and methodologies that address transitioning to more automated systems;
- Application of methodologies from other domains to address ATM research issues;
- Intelligent software architecture;
- Runway-independent (e.g., Vertical Take-off Landing, Short Take-off and Landing, and Vertical/Short Take-off and Landing) aircraft technologies required to meet national air transportation needs, to satisfy requirements for airline productivity, passenger acceptance, and community friendliness, and autonomous operations;
- Automated, real-time detect, see, and avoid operations;
- Intermodal transportation technologies; and
- Each of the abovementioned technologies and other technologies specifically fostering the operation of unpiloted aircraft within NAS under control of the ATM system, including, but not limited to, innovative control, navigation, and surveillance (CNS) concepts; also considering high altitude, long endurance operations.
NASA seeks highly innovative, crew-centered, technologies to improve aerospace system safety. Such advanced technologies may meet this goal by ensuring appropriate situation awareness; facilitating and extending human perception, information interpretation, and response planning and selection; counteracting human information processing limitations, biases, and error-tendencies; assisting in response planning and execution; and ensuring appropriate access to airspace as constrained by safety and security concerns. We require improved methods and tools for characterizing current and future users of aerospace systems, and tailoring designs to users. Such advanced technologies must be evaluated sensitively and in operationally-valid contexts. Therefore, NASA also seeks tools and methods for measuring and evaluating aerospace system operator performance, and as this performance is reflected by system performance. Technologies may take the form of tools, models, operational procedures, instructional systems, prototypes, and devices for use in the flight deck, elsewhere by pilots, or by those who design systems for crew use. Specific topical areas of interest include the following:

- Intelligent systems monitoring and alerting technologies for improved failure mode identification, recovery, and threat mitigation
- Designs for human-error prevention, detection, and mitigation
- Decision-support tools and methods to improve communication, collaborative, and distributive decision-making
- Data fusion technologies to integrate flight-related information for improved situation awareness and appropriate workload modulation
- Support for crew response planning and selection
- Computational approaches to determine and appropriately modulate crew engagement, workload, and situation awareness
- Human-centered information technologies to improve the performance of less-experienced operators, and pilots from special population groups
- Avionics designers and/or certification specialist tools to improve the application of human-centered principles
- Human-error reliability approaches to analyzing flight deck displays decision aids, and procedures;
- Presentation and aiding concepts for the display and use of data with spatial or temporal uncertainty, and of integrated streams of data with various levels of integrity
- Individual and team performance metrics, analysis methods, and tools to better evaluate and certify human and system performance for use in operational environments, simulation, and model-based analyses
Proposals should describe technologies, tools, and approaches with high potential to serve NASA program objectives, and to be developed as marketable products.

Sub Topics:

Aviation Safety and Security; Fire, Icing, Propulsion and Secure CNS Aircraft Systems Topic A1.02

NASA is concerned with the prevention of hazardous in-flight conditions and the mitigation of their effects when they do occur. Aircraft fires represent a small number of actual accident causes, but the number of fatalities due to in-flight, post-crash, and on-ground fires is large. One particular emphasis is on early, false-alarm resistant detection of the location, spread, and suppression of in-flight fires in hidden, inaccessible areas of the aircraft. Examples of hidden areas are behind cabin panels, inside ductwork, and so on. Another area of interest is in-tank monitoring of fuel/air flammability factors to provide more efficient active control of fuel tank inerting systems.

A second emphasis for this subtopic is on propulsion system health management, in order to predict, prevent, or accommodate safety-significant malfunctions and damage. Past advances in this area have helped improve the reliability and safety of aircraft propulsion systems; however, propulsion system component failures are still a contributing factor in numerous aircraft accidents and incidents. Advances in technology are sought which help to further reduce the occurrence of and/or mitigate the effects of safety-significant propulsion system malfunctions and damage. Specifically the following are sought: propulsion health management technologies such as instrumentation, sensors, ground and on-wing nondestructive inspection, health monitoring algorithms, and fault accommodating logic, which will predict/prognose, diagnose, prevent, assess, and allow recovery from propulsion system malfunctions, degradation, or damage.

A third emphasis is to increase the level of safety for all aircraft flying in the atmospheric icing environment. To maximize the level of safety, aircraft must be capable of handling all possible icing conditions by either avoiding or tolerating the conditions. Proposals are invited that lead to innovative new approaches or significant improvements in existing technologies for in-flight icing conditions avoidance (icing weather information systems) or tolerance (airframe and engine ice protection systems and design tools). With these emphases in mind, products and technologies that can be made affordable and retrofittable within the current aviation system, as well as for use in the future, are sought:

- Ground and airborne radome technologies for microwave wavelength radar and radiometers that remain clear of liquid water and ice in all weather situations.
- *In situ* icing environment measurement systems that can provide practical, very low-cost validation data for emerging icing weather information systems and atmospheric modeling. Measured information must include location, altitude, cloud liquid water content, temperature, and ideally cloud particle sizing and phase information. Solutions envisioned would use radiosonde-based systems.
- Ice protection and detection technology submittal must provide significant improvements over current systems or address new design needs. Areas of improvement can be considered to be: efficient thermal protection systems, including composite wing or structures applications, ice sensors that provide detection and accretion rate for all possible icing conditions, wide area ice detection, detection that serves both ground and in-flight applications, ice crystal detection probe (for non-research aircraft applications), engine icing probe (that can measure Liquid Water Content and Total Water Content inside engine passages), and de-icing systems that operate at near anti-icing performance. Any submittal must be cost competitive to current technologies.
A fourth emphasis for this subtopic is protection and hardening of the aircraft's communication, navigation, and surveillance (CNS) systems, as well as enabling new aviation security applications through improved air-to-ground data link communications and secure onboard information processing, computing, and air/ground networking. Technology is needed to harden the CNS systems, both onboard and air-to-ground, against abnormalities and deliberate attacks towards also enabling the next-generation airborne, ground- and space-based surveillance systems. Other communications related needs can be found in other NASA SBIR subtopics areas.

The final emphasis for this subtopic is on propulsion damage adaptive controls technologies and systems for new aircraft security applications. This technology is needed to enable a propulsion system to mitigate aircraft damage from hostile attacks.

Sub Topics:
Aviation Security Technologies Topic A1.03

The NASA Strategic Plan includes requirements to enable a more secure air transportation system and to create a more secure world by investing in technologies and collaborating with other agencies, industry, and academia. NASA's role in civil aeronautics has always been to develop high-risk, high-payoff technologies to meet critical national aviation challenges.

NASA aims to develop and advance technologies that will reduce the vulnerability of the Air Transportation System (ATS) to threats or hostile acts, and identify and inform users of potential vulnerabilities in a timely fashion. Specific technical focus areas include system-wide security risk assessment and incident precursor identification; enhanced flight procedures and on-board systems to protect critical infrastructures and key assets and enable the safe recovery of a seized aircraft; definition of directed energy threats to the aircraft and on/off-board systems that will provide surveillance and countermeasures of these threats; integrated adaptive control systems to detect and compensate for vehicle damage; hardened and security enhanced aircraft networks and datalinks; remote monitoring of the aircraft environment and systems; new materials for composite fire and explosive resistant fuselage structures; advanced, airborne, in situ detection of chemical and biological terror agents; and commercial aircraft fuel tank inerting. Technologies under development are intended for the next-generation ATS; however, issues such as retrofit, certification, system implementation, and cost-benefit must be considered during the technology development process.

NASA seeks highly innovative and commercially viable technologies that will improve aviation security by addressing threats to air vehicles as well as the ATS. Specific areas of focus include: preventing aircraft from being used as a weapon of mass destruction; protection from man-portable air defense systems (ManPADS) and electromagnetic energy (EME) attacks; light-weight, fire and explosive resistant composite materials; explosive resistant fuel systems; ground-based decision support tools needed to monitor airspace security concerns; reporting systems to monitor security violations; secure encrypted datalink systems, intrusion-tolerant communications networks and communications systems to support emerging aviation security applications; tools to support real-time management of security information; and Chem/Bio sensor development. Technologies may take the form of tools, models, techniques, procedures, substantiated guidelines, prototypes, and devices:

- Intelligent Systems monitoring and alerting technologies;
- Secure communications systems to support emerging aviation security applications;
- Onboard and ground surveillance and interception systems for aircraft immunity to electromagnetic interference and electromagnetic pulse intrusions;
- Flight control systems that accommodate vehicle damage relative to changes in aircraft stability, control, and structural load characteristics;
- Material systems, fuselage structural concepts, and fuel systems that are resistant to fire and explosions;
- Fuel system technologies that prevent or minimize in-flight vulnerability of civil transport aircraft due to small arms or man-portable defense systems type projectiles;
- Computational approaches to monitoring crew health, stress level, state of duress, and performance;
- Validation methods and tools for advanced safety/security critical systems;
- Technologies that enable secure communications, navigation, and surveillance on-board the aircraft;
- Technologies and methods to provide accurate information and guidance to enable pilot avoidance of protected airspace, maintain positive identity verification of aircraft operators, determine pilot intent, and deny flight control access to unauthorized persons;
- Decision-support tools and methods to improve communication and collaborative and distributive decision-making; and
- Data fusion technologies for integrating disparate sources of flight-related information.

Sub Topics:
Automated On-Line Health Management and Data Analysis Topic A1.04

Online health monitoring is a critical technology for improving air transportation safety in the 21st century. Safe, affordable, and more efficient operation of aircraft requires advances in online health monitoring of vehicle subsystems and information monitoring from many sources over local- and wide-area networks. Online health monitoring is a general concept involving signal-processing algorithms designed to support decisions related to safety, maintenance, or operating procedures. The concept of online health monitoring emphasizes algorithms that minimize the time between data acquisition and decision-making.

This subtopic seeks solutions for online aircraft subsystem health monitoring and prognostics. Solutions should exploit multiple computers communicating over standard networks where applicable. Solutions can be designed to monitor a specific subsystem or a number of systems simultaneously. Resulting commercial products might be implemented in a distributed decision-making environment such as onboard diagnostics and management systems, or maintenance and inspection networks of potentially global proportion.

Proposers should discuss who the users of resulting products would be, e.g., research/test/development, manufacturing; maintenance depots, flight crew, Unmanned Aerial Vehicles/Remotely Operated Aircraft (UAV/ROA) aircraft operators, airports, flight operations or mission control, or airlines. Proposers are encouraged to discuss data acquisition, processing, and presentation components in their proposal. Proposals that focus solely on sensor development should not be submitted to this subtopic. Such proposals should be addressed to sensor development subtopics such as the Flight Sensors and Airborne Instruments for Flight Research subtopic.
Examples of desired solutions targeted by this subtopic follow:

- Real-time autonomous sensor validity monitors;
- Flight control system or flight path diagnostics for predicting loss of control;
- Automated testing and diagnostics of mission-critical avionics;
- Structural fatigue, life cycle, static, or dynamic load monitors;
- Methods and tools for remaining life estimation and prognostics for critical aircraft components;
- Automated nondestructive evaluation for faulty structural components;
- Electrical system monitoring and fire prevention;
- Architectures for online monitoring, including architectures that exploit wireless communication technology to reduce costs;
- Model-reference or model-updating schemes based on measured data, which operate autonomously;
- Proactive maintenance concepts for aircraft engines, including engine life-cycle monitors;
- Predicting or detecting any equipment malfunction;
- Middleware or software toolkits to lower the cost of developing online aircraft health monitoring applications; and
- Innovative solutions for harvesting, managing, archiving, and retrieving aircraft health data.

Sub Topics:

Noise Breakthrough Turbine-Based Propulsion Technologies Topic A2.01

Future subsonic and supersonic aircraft may be required to achieve reduced noise levels up to 20 effective perceived noise levels (EPNdB) below FAR 36 Stage 3 certification levels without significant impacts to performance. The main emphasis of this subtopic is on high-risk, breakthrough technologies in order to reduce the technical risk associated with the development and deployment of new technologies in future commercial products. Subsonic noise reduction to date has predominantly been achieved via higher-bypass-ratio engines. With current practices, the nacelle diameter limit has physically been reached and engine noise is now comparable to airframe noise on approach. Engine noise reduction concepts proposed for subsonic applications must be compatible with low noise propulsion/airframe integration designs and continuous descent approach, low noise guidance flight procedures. Innovative noise reduction concepts need to be identified that provide economical alternatives to conventional propulsion systems.
Integrated, advanced propulsion systems with intelligent controls technologies will enable supersonic vehicles (up to Mach 2) having acceptable takeoff/landing noise and increased efficiency. Studies suggest that gas turbine engines with increased thrust-to-weight, bypass ratios, and decreased thrust specific fuel consumption are required to support quiet supersonic aircraft. NASA is interested in the development of advanced gas turbine engine concepts and key enabling technologies that can dramatically reduce the landing/take-off noise to an acceptable level, and which have the potential to dramatically improve the sustained cruise performance of a supersonic aircraft. Concepts proposed for supersonic applications must not adversely impact the airframe configurations to reduce sonic boom intensity, especially with regard to the formation of shaped waves and the human response to shaped waves.

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

**Subsonic Propulsion System Technologies**

- Innovative source identification techniques for fan, jet, combustor, or turbine noise;
- Advanced turbine engine cycles to achieve effective very high-bypass-ratio with smaller diameter engines;
- Innovative technologies for reduction of fan, jet, combustor, or turbine noise; and
- Advanced sound attenuating liners, including active and passive control.

**Supersonic Propulsion System Technologies**

- Advanced turbine engine cycle concepts to achieve low takeoff/landing noise and high supersonic cruise efficiency, including high pressure, high bypass multiple spool cycles, inter-stage turbine burning, variable cycle engines;
- Advanced propulsion system technologies, including advanced integrated airframe-propulsion control methodologies, adaptive flow control technologies, smart structures for nozzles and inlets, inlet technologies for weight/ performance/ operability/ stability; and
- High temperature materials such as monolithic ceramics and nano materials, evaporatively cooled turbine blades, and counter rotating stages enable more compact engine cores, greater thermal efficiency, and higher thrust to weight ratios.

Proposals must show improvements to the state-of-the art and viable application to aircraft.

Sub Topics:
**Fuel Cell Technologies for Aircraft Propulsion & Power Topic A2.02**

Fuel cells offer a promising technology for clean, efficient power generation important to both High Altitude Long Endurance (HALE) remotely piloted aircraft, and future envisioned environmentally friendly commercial transports. Both consumable fuel and regenerative fuel based fuel cells are of interest. The former type is applicable to both HALE and commercial transports, while the latter type is of interest for a solar-electric powered HALE capable of
multi-month missions. The consumable fuel based fuel cell will likely use atmospheric air for the cathode gas, while the regenerative systems will likely use pure oxygen stored and regenerated on-board. For both applications, the focus of this subtopic is on hydrogen fuel based systems including liquid for consumable fuel systems and gaseous for regenerative fuel cell systems.

To realize these aircraft applications will require one or even two orders of magnitude improvement in unit power and power density (volume and weight) for the power generation system, and specifically the fuel cell stack, as compared to ground based systems. In addition, the systems are required to operate at altitude, including high altitudes (>= 60,000 ft) for the HALE applications, and provide service life and reliability significantly greater than ground-based systems. Thus, NASA is seeking "break-through" technologies necessary for aircraft instead of evolutionary improvement to current state-of-the-art.

Technologies of specific interest include:

- Innovative fuel cell power systems demonstrating high specific power and high efficiency using consumed liquid hydrogen fuel with scalability to 100's of kW and capable of high altitude operations;
- PEM stack demonstrating >= 2 kW/kg and >= 50% efficiency (LHV) with scalability to 100's of kW;
- SOFC stack demonstrating >= 1 kW/kg and >= 50% efficiency (LHV) with scalability to 100's of kW; and
- Innovative regenerative fuel cell energy storage systems and critical components (e.g., unitized fuel cell and electrolyzer stack, PEM or SOFC based systems, etc) demonstrating >= 600 watt-hr/kg and high round trip efficiency.

Sub Topics:

Hydrogen Fuel Systems and Components for Aircraft Applications Topic A2.03

Hydrogen is the most likely fuel to enable future zero emissions aircraft and High Altitude Long Endurance Remotely Operated Aircraft (HALE ROA). Due to the increased volume required for hydrogen systems as compared to current hydrocarbon fueled aircraft, key technologies are required to reduce feed system weight while maximizing propellant storage efficiency. To be a viable technology for future aircraft systems, hydrogen feed components most likely will require life cycles approaching 10,000+ with an expectation of 20+ years in service, a significant difference from current state-of-the-art for space flight systems. For HALE ROA systems, vehicle mass must be kept low enough for flights up to altitudes exceeding 60,000 ft. Insulation systems must be lightweight and designed for minimum maintenance. Hydrogen storage and feed systems can be either cryogenic or gaseous depending upon the vehicle configuration. Tank mass fraction requirements (mass of storage system/mass of hydrogen) for liquid hydrogen on the order of 15% are expected to meet mission requirements. Hydrogen tank systems applications will be expected to provide storage for flight vehicles for up to 14 days duration with cryogenic systems and 6 months for aircraft with gaseous hydrogen. System safety is a critical factor in the design and development of any hydrogen system. To ensure public safety it is important that highly-sensitive, low-power-use sensors and instrumentation are developed to identify and diagnose potential problems with the hydrogen systems. Technology focus areas will include storage, distribution, and propellant conditions. Innovations are solicited in the following areas:

Storage and Distribution Components
• Lightweight, low thermal conductivity on-board cryogenic storage tanks, feed lines, valves, and relief devices;

• Lightweight, low thermal conductivity insulation for tanks and feed lines that requires minimal inspection and maintenance;

• Lightweight, low permeable gaseous hydrogen storage tanks and feed lines; and

• Low power, high-sensitivity sensors for hydrogen leak detection and condition monitoring.

Propellant Conditioning Components and Technologies

• Innovative methods to reduce the volume of stored hydrogen while minimizing system weight;

• Technologies for the reformation of hydrocarbon based fuels to hydrogen;

• Advanced technologies to minimize losses during loading and unloading of hydrogen, including autonomous operations, tank transfers, delivery to propulsion system, venting, and/or hydrogen recovery;

• Advanced technologies to minimize hydrogen losses and reduce energy requirements for system pre-chill, delivery to propulsion system, venting and/or hydrogen recovery, and long duration temperature.

Proposals must show improvements to the state-of-the-art and viable application to aircraft.

Sub Topics:

Aircraft Systems Noise Prediction and Reduction Topic A2.04
Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable airplanes, rotorcraft, and advanced aerospace vehicles. In support of the goal of the Quiet Aircraft Technology Project for reduced noise impact on community residents, improvements in noise prediction and control are needed for jet, propeller, rotor, fan, 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 aircraft passengers and crew and on 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;

• Simulation and prediction of aero acoustic noise sources particularly for airframe noise sources and situations with significant interactions between airframe and propulsion systems;

• Concepts for active and passive control of aero acoustic noise sources for conventional and advanced aircraft configurations;
• Innovative active and passive acoustic treatment concepts for engine nacelle liners and concepts for high-intensity acoustic sources, which can be used to characterize engine nacelle liner materials;

• Reduction technologies and prediction methods for rotorcraft and advanced propeller aerodynamic noise;

• Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise;

• Development and application of flight procedures for reducing community noise impact of rotorcraft and subsonic and future supersonic commercial aircraft while maintaining safety, capacity, and fuel efficiency;

• Computational and analytical structural acoustics techniques for aircraft and advanced aerospace vehicle interior noise prediction, particularly for use early in the airframe design process;

• Technologies and techniques for active and passive interior noise control for aircraft and advanced aerospace vehicle structures; and

• Prediction and control of high-amplitude aero acoustic loads on advanced aerospace structures and the resulting dynamic response and fatigue.

Sub Topics:
Electric Drive Components, Power Management and Distribution Technologies Topic A2.05
Future environmentally harmonious aircraft propulsion systems may be driven by electric power. These new systems will likely be fueled by hydrogen stored as a cryogenic liquid. Like all flight systems, these new electric based propulsion concepts will require each component to be extremely lightweight, especially when compared to similar ground-based systems. Future specific power requirements for the entire propulsion system from power supply to electric motor could reach 20-kW/kg. The total electric power supplied for aircraft will be orders of magnitude higher than for existing flight-rated secondary electrical systems. Future high power electric systems present a number of challenges for application to volume and weight limited aircraft. NASA is interested in the development of innovative technologies that demonstrate the feasibility of high power densities (>5kW/kg) for electric power delivery and propulsion. Specific areas of interest include but are not limited to the following:

• High power density electric motors and actuators, including superconducting, cryogenic and non-cryogenic systems;

• Cryogenically cooled lightweight, possibly superconducting, high power transmission lines;

• Cryogenically cooled and non-cryogenic lightweight power conditioning and control technology including technologies for isolation of noise-sensitive avionics power busses from main propulsion power busses;

• Cryogenically cooled and non-cryogenic lightweight high voltage high power density power management components;

• Highly integrated dual function components and systems that have the potential to reduce overall vehicle and subsystem weight (e.g., power conductors that are integrated into the airframe structure, motors directly integrated into the fan/propeller structure);

• Advanced enabling technologies such as nanoelectronics, smart sensors, and actuators;

• Advanced diagnostics, health monitoring and control concepts, smart sensors, electronics and actuators for enabling self-diagnosis and prognosis, and self-reconfiguration capabilities;
• Concepts that integrate distributed sensing with actuation and control logic for micro-level control of parameters (such as propulsion system internal flows, electrical states, etc. that impact performance and environment).

Proposals must show improvements to the state-of-the-art and viable application to aircraft.

Sub Topics:

Smart, Adaptive Aerospace Vehicles With Intelligence Topic A2.06

This subtopic emphasizes the roles of aerodynamics, aero thermodynamics, adaptive software, vehicle dynamics in nonlinear flight regimes, and advanced instrumentation in research directed towards the identification, development, and validation of enabling technologies that support the design of future, autonomous aerospace vehicle and platform concepts for aviation safety, and security vehicle systems. Some of the vehicle attributes envisioned by this subtopic include: a) "Smart" vehicle attributes-using advanced sensor technologies, flight vehicle systems are "highly aware" of onboard health and performance parameters, as well as the external flow field and potential threat environments; b) "Adaptive" vehicle attributes-flight avionics systems are reconfigurable, structural elements are self-repairing, flight control surfaces and/or effectors respond to changing flight parameters and/or vehicle system performance degradation; and c) "Intelligent" vehicle attributes-vehicle onboard processing and artificial intelligence technologies, interfaced with advanced vehicle structural component and subcomponent designs and appropriate actuating devices, reacts rapidly and effectively to changing performance demands and/or external flight and security threat environments. Future air vehicles with the above attributes will manage complexity, "know" themselves, continuously tune themselves, adapt to unpredictable conditions, prevent and recover from failures, and provide a safe environment.

For atmospheric vehicles and platforms, both military and civil applications are sought, while for aviation applications, emphasis is placed on configurations that enable the discovery of new aviation safety and security concepts. Concepts and corresponding enabling technologies are sought which expand the traditional boundaries of conventional piloted vehicles categories such as General Aviation (GA) or Personal Air Vehicles (PAV), as well as significantly advance the state-of-the-art in remotely operated vehicle classes such as Long-Endurance Sensing Platforms (LESP), Unmanned Aerial Vehicles (UAV) or Unmanned Combat Aerial Vehicles (UCAV) as they can relate to aviation safety and security. Furthermore, for Earth applications, special emphasis is placed on research proposals that attempt to provide solutions for a future state in which revolutionary vehicles operate in a highly integrated airspace including hub and spoke, point-to-point, long-haul, unmanned aircraft, green aircraft, as well as a future state where air vehicle designs reflect a high level of integration in performance, safety and security, airspace capacity, environmental impact and cost factors.

There are a number of specific areas of interest:

• Conceptual flight vehicle/platform designs featuring variable levels of vehicle and airspace requirements integration, and/or smart, intelligent, and adaptive flight vehicle capabilities, as demonstrated by state-of-the-art systems analyses methods to determine enabling technologies and resulting impacts on future system integrated performance, environmental impact, and safety and security issues;

• New algorithms for predicting vehicle loads and response using minimal vehicle state information;
• Novel optimization methodologies to support conceptual design studies for highly-integrated flight vehicle and air space concepts and/or smart, intelligent and adaptive flight vehicle capabilities, which demonstrate appropriate design variable selection, scaling techniques, suitable cost functions, and improved computational efficiency;

• Physics-based modeling and simulation tools of multiple vehicle classes and corresponding airspace operations aspects to support scenario-based planning and requirements definition of highly integrated vehicle and airspace capacity concepts, including investigations of the potential use of virtual/immersive simulations on future engineering decision making processes; and

• Micro-scale wireless communications, health monitoring, energy harvesting, and power-distribution technologies for large arrays of vehicle-embedded MEMS sensors and actuators.

Sub Topics:
Revolutionary Atmospheric Flight Concepts Topic A2.07
This subtopic solicits innovative flight test experiments that demonstrate breakthrough vehicle or system concepts, technologies, and operations in the real flight environment. The emphasis of this subtopic is the feasibility, development, and maturation of advanced flight research experiments that demonstrate advanced or revolutionary methodologies, technologies, and concepts. It seeks advanced flight techniques, operations, and experiments that promise significant leaps in vehicle performance, operation, safety, cost, and capability; and may require a demonstration or validation in an actual flight environment to fully characterize or validate it.

The scope of this subtopic is broad and includes advanced flight experiments that accelerate the understanding, research, and development of advanced technologies and unconventional operational concepts. Examples extend to (but are not limited to) such things as inflatable aero-structures (new designs or innovative applications, new manufacturing methods, new materials, new in-flight inflation methods, and new methods for analysis of inflation dynamics), innovative control surface effectors (micro-surfaces, embedded boundary-layer control effectors, and micro-actuators), innovative engine designs for UAV aircraft, alternative engines/motors/concepts, alternative fuels research (hydrocarbon, hydrogen, or regenerative), sonic boom reduction, noise reduction for Conventional Take-off and Landing/Short Take-off and Landing (CTOL/STOL) aircraft and engines, advanced mass transportation concepts, aerodynamic systems optimization for planetary aircraft (Venus, Mars, Io, and/or Titan), flexible system stability derivative identification, innovative approaches to thermal protection that minimize aerodynamic performance degradation, innovative approaches to structures, stability, control, and aerodynamics integration schemes, and innovative approaches to incorporation of UAV operations into commercial airspace. This subtopic is intended to advance and demonstrate revolutionary concepts and is not intended to support evolutionary steps required in normal product development. Proposals should emphasize the need of flight testing a concept or technology as a necessary means of verifying or proving its worth; emphasis should also be given to multidisciplinary integration of advanced flight systems. The benefit of this effort will ultimately be more efficient aerospace vehicles, increased flight safety (particularly during flight research), and an increased understanding of the complex interactions between the vehicle or technology concept and the flight environment.

Sub Topics:
Modeling, Identification, and Simulation for Control of Aerospace Vehicles to Prepare for Flight Test Topic A2.08
Safer and more efficient design of advanced aerospace vehicles requires advancement in current predictive design and analysis tools. The goal of this subtopic is to develop more efficient software tools for predicting and understanding the response of an airframe under the simultaneous influence 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 dynamical subsystems with an
emphasis towards flight test 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, aero elastic maneuver performance, and load control including smart actuation and active aero structural 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, such as Unmanned Aerospace Vehicles/Remotely Operated Aircraft (UAV/ROA), and flight regimes ranging from low-speed High-Altitude Long-Endurance (HALE) to hypersonic and access-to-space aerospace vehicles. Proposals should address one or more of the following:

- Accurate prediction with validation of steady and unsteady pressure, stress, and thermal loads;
- Effective multidisciplinary dynamics analysis algorithms with flight-test correlation capability conducive to validation with test data, such as with finite-element aeroservoelastic computations;
- Time-accurate simulation systems from nonlinear multidisciplinary dynamics models with applications toward flight-testing, such as with reduced-order CFD-based methods;
- Novel and efficient schemes for control-oriented identification of nonlinear aeroservoelastic dynamics from test data with provisions for uncertainty estimation and model correlation;
- Online and autonomous model update schemes for loads, aerodynamic, and aero elastic model identification for stability and performance monitoring and prediction in adaptive control;
- Self-learning control strategies for aero structural vehicles and development of enhanced real-time controls software and hardware for long-term onboard systems operation;
- Integration of modeling, analysis, simulation, and identification techniques for control objectives in a unified, compatible manner; and
- Innovative, high-performance facilities for integrated simulation and graphical interface, or virtual reality systems, for multidisciplinary aerospace systems.

Sub Topics:
Flight Sensors and Airborne Instruments for Flight Research Topic A2.09
Real-time measurement techniques are needed to acquire aerodynamic, structural, 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 or instrumentation systems for improving the state-of-the-art in aircraft flight testing. This includes the development of sensors to enhance aircraft safety by determining atmospheric conditions. The goals are to improve the effectiveness of flight testing by simplifying and minimizing sensor installation, measuring new parameters, improving the quality of measurements, and minimizing the disturbance to the measured parameter from the sensor presence or deriving new information from conventional techniques. This subtopic solicits proposals for improving airborne sensors and instrumentation systems in all flight regimes. These sensors and systems are required to have fast response, low volume, minimal intrusion, and high accuracy and reliability. Innovative concepts are solicited in the areas that follow below.

Vehicle Condition Monitoring

Sensor development in support of vehicle health and performance monitoring includes the monitoring of
aerodynamic, structural, propulsion, electrical, pneumatic, hydraulic, navigation, control, and communication subsystems. Proposals that focus solely on health management algorithms and systems integration should be addressed in the Automated Online Health Management and Data Analysis subtopic.

Vehicle Environmental Monitoring

Sensor development in support of vehicle environmental monitoring includes the following:

- Non-intrusive air data parameters (airspeed, air temperature, ambient and stagnation pressures, Mach number, air density, and flow angle);
- Off-surface flow field measurement and/or visualization (laminar, vortical, and separated flow, turbulence) zero to 50 meters from the aircraft;
- Boundary layer flow field, surface pressure distribution, acoustics or skin friction measurements or visualization; and
- Unusually small, light and low-power instrumentation for use on miniature aircraft and high altitude long endurance vehicles.

Sub Topics:

Next Generation Air-Traffic Management Systems Topic A3.01

The challenges in Air Traffic Management (ATM) are to create the next generation system and to develop the optimal plan for transitioning to the future system. This system should be one that (1) economically moves people and goods from origin to destination on schedule, (2) operates without fatalities or injuries resulting from system or human errors or terrorist intervention, (3) seamlessly supports the operation of unmanned aerial vehicles (UAVs) or remotely operated aircraft (ROAs), (4) is environmentally compatible, and (5) supports an integrated national transportation system and is harmonized with global transportation. This can only be achieved by developing ATM concepts characterized by increased automation and distributed responsibilities. It requires a new look at the way airspace is managed and the automation of some controller functions, thereby intensifying the need for a careful integration of machine and human performance. As these new automated and distributed systems are developed, security issues need to be addressed as early in the design phase as possible.

To meet these challenges, innovative and economically attractive approaches are sought to advance technologies in the following areas:

- Decision support tools (DST) to assist pilots, controllers, and dispatchers in all parts of the airspace
(surface, terminal, en route, command center);

- Integration of DST across different airspace domains;
- Next generation simulation and modeling capability—models of uncertainty and complexity, National Airspace System (NAS) operational performance, economic impact;
- Distributed decision making;
- Security of advanced ATM systems;
- System robustness and safety—sensor failure, threat mitigation, health monitoring;
- Weather modeling and improved trajectory estimation for traffic management applications;
- Role of data exchange and data link in collaborative decision-making;
- Modeling of the NAS;
- Distributed complex, real-time simulations—components with different levels of fidelity, human-in-the-loop decision agents;
- Integrated ATM/aircraft systems that reduce noise and emissions;
- Automation concepts for advanced ATM systems and methodologies that address transitioning to more automated systems;
- Application of methodologies from other domains to address ATM research issues;
- Intelligent software architecture;
- Runway-independent (e.g., Vertical Take-off Landing, Short Take-off and Landing, and Vertical/Short Take-off and Landing) aircraft technologies required to meet national air transportation needs, to satisfy requirements for airline productivity, passenger acceptance, and community friendliness, and autonomous operations;
- Automated, real-time detect, see, and avoid operations;
- Intermodal transportation technologies; and
- Each of the abovementioned technologies and other technologies specifically fostering the operation of unpiloted aircraft within NAS under control of the ATM system, including, but not limited to, innovative control, navigation, and surveillance (CNS) concepts; also considering high altitude, long endurance operations.