



NASA SBIR 2015 Phase I Solicitation

Aeronautics Research

Air Vehicle Technology Topic A1

The Air Vehicle Technology topic solicits cutting-edge research in aeronautics to overcome technology barriers and challenges in developing safe, new vehicles that will fly faster, cleaner, and quieter, and use fuel far more efficiently. The primary objective is the development of knowledge, technologies, tools, innovative concepts and capabilities needed as the Nation continues to experience growth in both domestic and international air transportation while needing to protect and preserve the environment.

This topic solicits tools, technologies and capabilities to facilitate assessment of new vehicle designs and their potential performance characteristics. These tools, technologies and capabilities will enable:

- The best design solutions to meet performance and environmental requirements and challenges.
- Technology innovations of future air vehicles.

It also solicits research in revolutionary aircraft concepts; lightweight high strength structures and materials; more efficient propulsion systems; low emissions propulsion concepts; measurement techniques, and advanced concepts for high lift and low drag aircraft that meet the performance, efficiency and environmental requirements of future aircraft, and the goals of the NextGen.

This topic covers aircraft technologies covered by the former Fundamental Aeronautics Program as well as ground test technologies formerly covered by the Ground and Flight Test Techniques and Measurement topic under the Aeronautics Test Program, which are now under the Advanced Air Vehicles Program (AAVP). The re-structuring will emphasize development of tools, technologies, test techniques, and knowledge to meet metrics derived from a definitive set of Technical Challenges responsive to the goals of the National Aeronautics Research and Development (R&D) Policy and Plan, the National Aeronautics R&D Test and Evaluation (T&E) Infrastructure Plan (2011), and the NASA Aeronautics Strategic Implementation Plan (2013). AAVP consists of five projects, three that target a specific vehicle class/type, and two crosscutting projects focused on commonly encountered challenges associated with composite materials and capabilities necessary to enable advanced technology development:

- Advanced Air Transport Technologies (AATT) Project explores and develops technologies and concepts for improved energy efficiency and environmental compatibility of fixed wing, subsonic transports.
- Revolutionary Vertical Lift Technologies (RVLT) Project develops and validates tools, technologies, and concepts to overcome key barriers for rotary wing vehicles.
- Commercial Supersonics Technology (CST) Project enables tools and technologies and validation capabilities necessary to overcome environmental and performance barriers to practical civil supersonic airliners and sustains NASA competence in hypersonic air-breathing propulsion necessary to support the nearer-term Department of Defense (DoD) hypersonic mission.
- Advanced Composites (AC) Project focuses on reducing the timeline for development and certification of innovative composite materials and structures.
- Aeronautics Evaluation & Test Capabilities (AETC) Project sustains and enhances those specific research

and test capabilities necessary to address and achieve the future air vehicles and operations as described above.

Sub Topics:

A1.01 Structural Efficiency-Hybrid Nanocomposites

Lead Center: LaRC

Two of the primary goals of the Advanced Air Vehicles program are safety and efficiency, which can be achieved simultaneously through designer materials tailored for future aircraft structures. The SOA for lightweight structures are carbon fiber reinforced polymeric composites which make up approximately 50% of the weight of Boeing's 787. Adoption of all-carbon nanotube (CNT) composites to exploit their potential for enhancing structural efficiency is viewed as too far term, given the current state of CNT technology maturation. A more attainable approach is to take advantage of the multifunctionality offered by CNTs through the use of hybrid composites where CNTs are integrated into conventional carbon fiber reinforced composite structures. Hybrid composites enable improved mechanical properties such as interlaminar strength, while simultaneously increasing electrical and thermal conductivity to enable features such as lightning strike protection, embedded sensing, etc. The targeted outcome is reduced weight and enhanced safety performance for future hybrid composite aircraft structures. For this subtopic, the plan is to start phase 1 with a systems analysis approach to identify the benefits and target areas for hybrid composite utility and to provide some direction and benefit analysis for applying hybrid composites in aircraft structures. Then the intention of the Phase II would be to tailor, build and test the materials to demonstrate the property enhancements identified in Phase I.

A1.02 Aerodynamic Efficiency Drag Reduction Technology

Lead Center: LaRC

The challenge of energy-efficient flight has at its foundation aerodynamic efficiency, and at the foundation of aerodynamic efficiency is low drag. Drag can be broadly decomposed into four components: viscous or skin friction drag, lift-induced drag, wave or compressibility drag, and excrescence drag due to various protruding items such as antennae, wipers, lights, etc. The relative impact of these four forces depends upon the targeted flight regime and vehicle-specific design requirements. The first force, however, viscous skin friction, stands out as particularly significant across most classes of flight vehicles and effective measures for its control would have a major impact of flight efficiency. In particular, supersonic, low-boom flight and new generations of energy-efficient subsonic transport airplanes including high L/D strut-braced designs, the blended wing body (BWB), so called "double-bubble" designs and other concepts with large expanses of surface area would benefit from effective viscous drag control.

Viscous skin friction can be classified as either laminar or turbulent. While the laminar case and its attendant laminar flow control (LFC) techniques remain important scientific and technological disciplines, the goal of high Reynolds number flight efficiency requires that the turbulent case receive renewed attention. In place of the first-principles-derived theoretical framework of the laminar flow stability problem, in the turbulence case we have a wide collection of experimental observations, data correlations, various CFD approaches requiring turbulence closure models and, at low Reynolds numbers, full direct numerical simulation of the Navier-Stokes equations (DNS). While such experimental and CFD-derived knowledge, has greatly increased our understanding of turbulent boundary layer physics over the past decades, key relationships between wall layer and outer layer dynamics essential to a full understanding remain to be identified and verified.

Inadequacies in our understanding of boundary layer turbulence increase reliance upon a more qualitative, physics-guided approach to discovery. For example, the experimental observation of reduced skin friction in the corners of triangular cross-section pipes lead to the discovery of drag-reducing V-groove riblets (subsequently also associated with the skin of certain shark species). The quasi-periodic, low-speed streak structures observed in the near-wall layer of turbulent boundary layers lead to the implementation of mechanically controlled spanwise waves or lateral oscillations of the wall to disrupt the processes associated with low speed streak bursting. Similar observations

have either been made or suggested with respect to the stabilizing influence of convex and in-plane curvature; long length-to-diameter ratio particulates; passive, active and reactive wall motion; manipulation of the wall layer by various geometrical devices (e.g., vortex generators (VG) and large eddy breakup devices (LEBU)), and various weakly ionized gas (WIG) and magnetohydrodynamic/electrohydrodynamic (MHD/EHD) concepts. This solicitation is offered in this spirit of innovation based on experimental or computational observations guided by a basic, though not necessarily complete, physical understanding of the turbulent processes.

In order to stimulate innovation in the area of turbulent viscous drag reduction, proposals are sought subject to the following guidelines:

- Proposals shall address passive, active or reactive concepts for external, attached, fully developed, turbulent boundary layer viscous drag reduction in air.
- Experimental, hardware-based proposals and theoretical/computational proposals based on realizable hardware are preferred.
- All practical physical concepts are acceptable including but not limited to: mechanical/electro-mechanical actuators, weakly-ionized-gas (WIG) concepts, laser/microwave energy deposition, MHD/EHD devices, surface microstructure/geometry, embedded mechanical devices (VG's, LEBU's), wall mass transpiration, heat transfer, wall motion, wall curvature effects and pressure gradient (vehicle shaping).
- Significant enhancements or refinements of existing concepts and technologies are acceptable.
- First order assessment or technically plausible discussion of any net system energy saving claims shall be provided.
- Proof-of-concept experimental demonstrations are encouraged for Phase I where applicable but are not required.
- Target conditions are flight-relevant Reynolds numbers at either high subsonic ($0.7 < M < 0.9$) or low supersonic ($M \sim 3$) speeds. Proposals at lower Mach and Reynolds numbers shall provide discussion of a developmental path towards flight-relevant conditions but not necessarily inclusive of actual flight.

A1.03 Low Emissions Propulsion and Power

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Proposals are sought which support electric propulsion of transport aircraft, including turboelectric propulsion (turbine prime mover with electric distribution of power to propulsors) and various hybrid electric concepts, such as gas turbine engine and battery combinations.

Turboelectric propulsion for transport aircraft applications will require components with high specific power (hp/lb or kW/kg) and high efficiency, and cryogenic and superconducting components will likely be required. The cryogenic components of interest include fully superconducting generators and motors (i.e., superconducting stators as well as rotors), cryogenic inverters and active rectifiers, and cryocoolers. Proposals related to the superconducting machines may include aspects of the machines themselves and their subcomponents, as well as low AC loss superconducting materials for the stator windings. Generators with at least 10 MW capacity and motors of 2 to 4 MW capacity are of interest. Technology is sought that can contribute to superconducting machines with specific power more than 10 hp/lb.

Hybrid propulsion with non-cryogenic components will likely require new materials and configurations to reach required high specific power and efficiency. Hence ideas are sought for achieving 2-3X increase in specific power at high efficiency for non-cryogenic motors through a multidisciplinary approach utilizing advanced motor designs, better materials, and new structural concepts.

New approaches to achieving conductors with lower electrical resistivity than copper are particularly sought, e.g., conductors based on carbon nanotubes. However, such approaches must be backed by plausible reasons why a resistivity lower than that of copper can be expected to be achieved, in contrast to the best reported resistivity values for carbon nanotube fibers, which are nearly an order of magnitude higher.

Ideas are also sought to address challenges related to high voltage power transmission in future hybrid electric aircraft.

New modeling and simulation tools for hybrid electric aircraft propulsion systems are also of interest.

Some studies of turboelectric distributed propulsion components and systems can be found in the following and referenced therein:

- “Stability, Transient Response, Control, and Safety of a High-Power Electric Grid for Turboelectric Propulsion of Aircraft”, Michael Armstrong, Christine Ross, Danny Phillips, and Mark Blackwelder, NASA/CR—2013-217865, 2013
- “Turboelectric Distributed Propulsion in a Hybrid Wing Body Aircraft”, J. Felder, G. Brown, H. Kim, J. Chu, 20th ISABE Conference, Göteborg, Sweden, 12-16 Sept., 2011
- “Weights and Efficiencies of Electric Components of a Turboelectric Aircraft Propulsion System”, G. V. Brown, 49th AIAA Aerospace Sciences Meeting, Orlando FL, January 4-7, 2011
- “Turboelectric Distributed Propulsion Engine Cycle Analysis for Hybrid-Wing-Body Aircraft”, J. L. Felder, H. D. Kim, G. V. Brown, 47th AIAA Aerospace Sciences Meeting, Orlando FL, January 5-8, 2009

A1.04 Quiet Performance

Lead Center: LaRC

Participating Center(s): GRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable aircraft. In support of the Advanced Air Vehicles, Integrated Aviation Systems and Transformative Aero Concepts Programs, improvements in noise prediction, acoustic and relevant flow field measurement methods, noise propagation and noise control are needed for subsonic, transonic and supersonic vehicles targeted specifically at airframe noise sources and the noise sources due to the aerodynamic and acoustic interaction of airframe and engines. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design purposes.
- Prediction of aerodynamic noise sources including those from the airframe and those that arise from significant interactions between airframe and propulsion systems including those relating to sonic boom.
- Prediction of sound propagation from the aircraft through a complex atmosphere to the ground. This should include interaction between noise sources and the airframe and its flow field.
- Propagation of sonic boom through realistic atmospheres, especially turbulence effects.
- Innovative source identification techniques for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of separated flow regions, vortices, shear layers, etc.
- Concepts for active and passive control of aeroacoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, and noise control technology and methods that are enabled by advanced aircraft configurations, including integrated airframe-propulsion control methodologies. Innovative acoustic liner and porous surface concepts for the reduction of airframe noise sources and/or propulsion/airframe interaction are solicited but engine nacelle liner applications are specifically excluded.
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community noise, including sonic boom.

A1.05 Physics-Based Conceptual Aeronautics Design Tools

Lead Center: GRC

Participating Center(s): LaRC

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the breadth of the flight speed regimes. Propulsion systems, such as open rotors and hybrid-electric propulsion, are

viewed as potential options for helping meet aggressive, long range (i.e., 'N+3' timeframe) emission reduction targets. Accurate representation of the propulsion system is critical in confidently assessing the potential of a concept. Conceptual design and analysis of unconventional propulsion concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull and independent technical assessment of new concepts. The agency's systems analysts need to have the best conceptual design/analysis tools possible to support these efforts. Substantial progress has been made recently in incorporating more physics-based analysis tools in the conceptual design process, and NASA has developed a capability that integrates several analysis tools and models in engineering frameworks, such as ModelCenter and OpenMDAO. However, modeling gaps still remain in many disciplines.

Historically, empirical and semi-empirical weight estimation methods have been utilized during the conceptual design phase. These techniques work well for the conceptual design of conventional propulsion systems with parameters that reside within the historical databases used to develop the methodologies. However, these methods are not well suited for unconventional propulsion concepts, or even conventional concepts which reside outside of the database. Developing higher order, more accurate tools suitable for conceptual design is a difficult challenge. The first issue is analysis turnaround time. To perform the configuration trades and optimization typical of conceptual design, runtimes measured in seconds or minutes, instead of hours or days, are required. However, rapid analysis turnaround time alone is insufficient. To be suitable for conceptual design, tools and methods are needed which accurately predict the 'as-built' characteristics. Because it is not possible to model every detail of the design and account for all the underlying physics in the problem formulation, it is difficult to predict the 'as-built' characteristics with physics-based methods alone. What is usually required is a combination of these methods with some semi-empirical corrections. A final challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods often require only gross design parameters as inputs. The gap between the analysis capability and the maturity of the design being analyzed currently limits the usefulness of high order analysis in conceptual design. Physics-based tools for conceptual design are needed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

NASA has a well-established propulsion systems analysis tool suite that is based on the Numerical Propulsion System Simulation (NPSS) and the Weight Analysis of Turbine Engines (WATE) codes. Ideally, new capabilities that arise from this solicitation should be compatible with NPSS and/or WATE or offer significantly increased capability beyond/outside of these state-of-the-art tools.

For FY 2015, the focus is on addressing remaining capability gaps. Examples of desired capability improvements include the following:

- Physics-based methodologies and sizing of hybrid-electric propulsion components.
 - Weight/volumetric estimates for major components (e.g., batteries, fuel cells, motors, generators, cryocoolers, transformers, inverters, rectifiers).
- Heat exchanger performance and weight/volume estimation modeling tools.
- Computational counter-rotating open rotor performance tools.
 - Low/Medium-fidelity modeling approaches for predicting open rotor performance based on key blade characteristics.
- Multi-fidelity environmental analysis tools.
 - Combustion emission indices generation consistent with advanced combustor architectures.
 - Advanced acoustic-modeling addressing propulsion/airframe shielding, Fan/turbomachinery noise and/or jet noise.
- Multi-fidelity Propulsion-Airframe Integration (PAI) performance analysis tools.
 - Propulsion installation analysis methods (inlet/nacelle/nozzle analysis in the presence of an airframe).
 - Advanced mission-analysis methods incorporating multiple degrees of freedom and including expansive/adaptable propulsion operability capability.
- Macro Systems Analysis tools addressing propulsion-related impacts.
 - Reduced-order atmospheric chemistry/global mixing tools.
 - Safety/reliability analysis tools consistent with conceptual-level design/analysis.
 - Global airport throughput network and commerce models.

A1.06 Vertical Lift

Lead Center: ARC

Participating Center(s): GRC, LaRC

The Vertical Lift subtopic is primarily interested in the following two areas:

- The use of small vertical lift UAVs has increased in recent times with many civilian missions being proposed, including autonomous surveillance, mapping, etc. Much of the current research associated with these vehicles has been in the areas of electric propulsion, batteries, small sensors and autonomous control laws, while very little attention has been paid to their acoustic signature. The generation and propagation of noise associated with this small class of vertical lift UAVs are not well understood and validated prediction tools do not currently exist. The objective of a proposed effort would be to develop tools for the modeling and prediction of the high frequency acoustics for small vertical lift UAVs, such as quad-copters, coaxials, ducted fan rotors, etc.
- A transition to low-carbon propulsion has the promise of dramatically reducing the emissions from full-scale rotorcraft, as well as reducing overall fuel consumption and operating cost. All electric and hybrid propulsion systems could be beneficial to rotorcraft due to high power requirements of hover and integrated motor-drive systems designs that could be realized. The objective of a proposed effort would be to develop and demonstrate hybrid/electric technologies for full-scale rotorcraft drive and propulsions systems that show benefits in-terms of weight, efficiency, emissions and fuel consumption. Validated modeling and analysis tools for all-electric and hybrid propulsions systems are also sought in this solicitation.

Proposals on other rotorcraft technologies will also be considered but the primary emphasis of the solicitation will be on the above two identified technical areas.

A1.07 Efficient Propulsion and Power

Lead Center: GRC

For 2014, this sub-topic will focus on propulsion controls and dynamics. Propulsion controls and dynamics research is being done under various projects in the Fundamental Aeronautics Program (FAP) and Aviation Safety Program (ASP). For turbine engines, work on Distributed Engine Control (DEC) and Active Combustion Control (ACC) is currently being done under the Aeronautics Sciences (AS) project, and is expected to transition to the new Transformative Tools and Technologies (TTT) project in FY15. Aero-Propulso-Servo-Elasticity (APSE) research will continue under the High Speed project. Model-Based Engine Control research is currently being conducted under the Vehicle System Safety Technologies project, and is expected to transition to the TTT project in FY15. Propulsion controls and dynamics technologies that help achieve the goals of the following NASA ARMD strategic thrusts: Innovation in Commercial Supersonic Aircraft; Ultra-Efficient Commercial Vehicles; and Assured Autonomy for Aviation Transformation, will be given preference. Following technologies are of specific interest:

- *High Efficiency Robust Engine Control* - Typical current operating engine control logic is designed using SISO (Single Input Single Output) PI (Proportional+Integral) control. The control logic is designed to provide minimum guaranteed performance while maintaining adequate safety margins throughout the engine operating life. Additionally, the control logic indirectly provides control of variables of interest such as Thrust, Stall Margin, etc. since these variables cannot be measured or are not measured in flight because of restrictions on sensor cost/placement/reliability, etc. All this results in highly conservative control design with resulting loss in efficiency. NASA is currently conducting research in Model-Based Engine Control (MBEC) where-in an on-board real-time engine model, tuned to reflect current engine condition, is used to generate estimate of quantities of interest that are to be regulated or limited and these estimates are used to provide direct control of Thrust, etc. Alternate methods such as Model Predictive Control, Adaptive Control, direct non-linear control, etc. are of interest. However, the alternative methods must achieve the same objectives as the current MBEC approach by providing practical application of the control logic in terms of operation

with sensor noise, operation across varying atmospheric conditions, operation across varying engine health condition over the operating life, and real-time operation within engine control hardware limits. The emphasis is on practical application of existing control methods rather than theoretical derivation of totally new concepts. Control design approaches that can accommodate small to medium engine component faults and can still provide desired performance with safe operation are of special interest. The pre-requisite for proposals for engine control design methods is that the NASA C-MAPSS40k (Commercial Modular Aero-Propulsion System Simulation for 40,000 lb class thrust engine) be used for control design and evaluation. This simulation can only be used by U.S. citizens since it is subject to export control laws. Methods for real-time engine parameter identification using flight data are also of interest by themselves.

- *Distributed Engine Control* - Current engine control architectures impose limitations on the insertion of new control capabilities primarily due to weight penalties and reliability issues related to complex wiring harnesses. Obsolescence management is also a primary concern in these systems because of the unscheduled cost impact and recertification issues over the engine life cycle. NASA in collaboration with AFRL (Air Force Research Lab) has been conducting research in developing technologies to enable Distributed Engine Control (DEC) architectures. Modularity is an inherent feature of distributed engine control architecture. Modularity enables the rapid integration of the individual functions of control into a cohesive system by virtue of common digital interfaces and the well-defined flow of data. This interface structure can persist regardless if the control function exists in hardware or simulation. At the engine system level, distributed architecture enables scalability and reuse of control functional elements across engine platforms, but it also simplifies the insertion of new control technologies within the smart devices. NASA is interested in the development and simulation of these distributed control functions for high temperature embedded application on the engine core. NASA is particularly interested in the design and development of these applications for assessing the benefit they bring to the engine system.
- *Active Combustion Control* - The overall objective is to develop all aspects of control systems to enable safe operation of low emissions combustors throughout the engine operating envelope. Low emission combustors are prone to thermo-acoustic instabilities. So far NASA research in this area has focused on modulating the main or pilot fuel flow to suppress such instability. Advanced, ultra-low emissions combustors utilize multi-point (multi-location) injection to achieve a homogeneous, lean fuel/air mixture. There is new interest in using precise control of fuel flow in such a manner as to suppress or avoid thermo-acoustic instabilities. Miniature fuel metering devices (and possibly also fuel flow measurement devices) are needed that can be physically distributed to be close to the multi-point fuel injector in order to enable the control system to accurately place a given proportion of the overall fuel flow to each of the fuel injection locations.
- *Aero-Propulso-Servo-Elasticity (APSE)* - The objective of NASA research effort in APSE is to develop a comprehensive variable cycle engine (VCE) type dynamic propulsion system model that can be utilized for thrust dynamics and integrated APSE vehicle controls and performance studies, like vehicle ride quality and vehicle stability under typical flight operations, vehicle maneuvering and atmospheric disturbances, for supersonic vehicles. Innovative approaches to dynamic modeling that are of interest include supersonic external compression inlets; multi flow paths convergent-divergent type nozzles with a spike; parallel flow path modeling of propulsion components upstream of the combustor to accurately model the distortion effects, maneuvering and atmospheric disturbances; and integration of dynamic propulsion models with aircraft simulations incorporating flexible vehicle structural modes.

A1.08 Ground Testing and Measurement Technologies

Lead Center: LaRC

Participating Center(s): GRC

This subtopic supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate, as well as the testing requirements of other government and commercial entities. The subject facilities are managed by the Aeronautics Evaluation and Test Capability (AETC) Project within the NASA Advanced Air Vehicles Program. The primary objective of this subtopic is to develop innovative tools and technologies that enhance testing and measurement capabilities, improve ground test resource utilization and efficiency, and provide capability sustainment. Where possible, the tools and technologies should be applicable for the broad national scope of government, commercial, and university capabilities.

Wind tunnel vehicle design databases have traditionally included the foundational measurements of forces and discrete surface pressures and temperatures. However, designing and testing future vehicles with non-traditional

aerodynamic geometries, possibly including highly integrated and distributed propulsion and flow control systems, will require enhanced, remotely sensed global surface measurements that cover a wide range of operational conditions. Enhanced optical systems are required to visualize the flow interactions both on and off the surface. Non-intrusive measurement systems offering multi-component velocities, density, and pressure in the tunnel stream are required to routinely quantify and baseline the test environment and to establish boundary conditions for advanced computational simulations. Non-intrusive measurements of off-body and near-body flow parameters both at a point and globally (i.e., planar or volumetric) are necessary to examine fluid-fluid and fluid-structure interactions for computational solution validation. The development of diagnostics for simultaneous volumetric measurements are particularly desired and will require a concentrated research effort in the development of enhanced laser and imaging techniques (including light field imaging), the development of new optical configurations, and the development of near real-time to real-time acquisition and processing architectures. In particular, development of techniques that significantly increase data capture per test point are needed, including the ability to simultaneously measure multiple flow parameters at high acquisition rates to capture rapidly evolving or oscillatory flow phenomena. Maturation of current particle-based, molecular, and/or surface diagnostics and unification of compatible instruments are desired. In all cases, significant measurement accuracy enhancements are required. Measurement systems must be robust and user-friendly for practical and routine application.

Proposals for clean seeding methods that do not contaminate wind tunnel walls or anti-turbulence screens are solicited. Seedless methods for velocity measurements near a model surface are particularly desired for adverse test environments where seeding contaminants are prohibited, may alter the model surface flow, or possibly damage gas reclamation systems. Two such environments occur at NASA Langley for -250°F cryogenic testing at the National Transonic Facility and heavy-gas testing using R134a at the Transonic Dynamics Tunnel.

Proposals are also solicited for shear stress sensors that are applicable to high-temperature/high-flow-rate environments such as those encountered in engine and high-speed testing where surface heating is important.

Small models and/or packaging constraints for large models can make model attitude measurements difficult. Testing in the non-gravity direction precludes use of traditional angle sensors. Many test configurations require multiple angle of attack systems, including redundant systems to guard against in-test failure. Maintaining calibration currency and accuracy of multiple systems significantly increases test costs and complexity. Proposals are solicited for accurate, real-time, optical, non-intrusive techniques for determining model attitude.

The impact of icing on vehicle performance for flight certification is increasingly important. Currently, the NASA Glenn Icing Research Tunnel cannot reproduce the full range of test conditions defined in the FAA Appendix O Supercooled Droplet Icing Conditions. Simulation of Appendix O conditions for freezing rain and drizzle scenarios requires a bimodal droplet distribution with much larger size droplets. These large droplets have an extended cooling period before entering the test section; and, they don't follow the flow, falling toward the test section floor. Innovative ideas and technology advancements are solicited to create and control Appendix O conditions in current facilities.

Many NASA wind tunnel facilities conduct tests at elevated temperatures (400°F to 700°F) or at extremely low temperatures (-250). Displacement measurement components in actuator systems for the setting of hydraulic cylinder positions and other hardware that is used in test article support and positioning systems must operate routinely in these environments. Innovative designs and hardware solutions are desired to provide accurate and reliable performance at these extreme conditions.

Additional information about the mission and facility capabilities may be obtained at (<http://www.aeronautics.nasa.gov/atp/index.html> [1]).

Integrated Flight Systems Topic A2

One of the greatest issues that NASA faces in transitioning advanced technologies into future aeronautics systems is the gap caused by the difference between the maturity level of technologies developed through fundamental research and the maturity required for technologies to be infused into future air vehicles and operational systems. Integrated Aviation Systems Program's (IASP) goal is to demonstrate integrated concepts and technologies to a maturity level sufficient to reduce risk of implementation for stakeholders in the aviation community. IASP conducts integrated system-level research on those promising concepts and technologies to explore, assess, and

demonstrate the benefits in an operationally relevant environment. IASP matures and integrates technologies for accelerated transition to practical application, and supports the flight research needs across the ARMD strategic thrusts, the Programs, and all research phases of technology development. IASP consists of three projects, the Environmentally Responsible Aviation (ERA) Project, the UAS Integration in the National Airspace System (NAS) Project and the Flight Demonstrations and Capabilities Project (FDC).

The FDC Project consists of an integrated set of flight test capabilities and demonstrations. The flight test capabilities include the Dryden Aeronautical Test Range, and the aircraft required to support research flight tests and mission demands. The project capabilities also include the Armstrong Flight Research Center (AFRC) Simulation and Flight Loads Laboratories, which include a suite of ground-based laboratories that support flight research and mission operations. These facilities and assets are able to perform tests covering the flight envelope from subsonic through hypersonic speeds and include unique capabilities ranging from simulating icing environments to modeling extreme dynamic situations

NASA will demonstrate the feasibility and maturity of new technologies through flight tests, utilizing collaborative partnerships from across the aeronautical industry, and including international partners as appropriate. These activities support research within all six aeronautics strategic thrust areas.

Sub Topics:

A2.01 Flight Test and Measurements Technologies

Lead Center: AFRC

Participating Center(s): LaRC

NASA continues to see flight research as a critical element in the maturation of technology. This includes developing test techniques that improve the control of in-flight test conditions, expanding measurement and analysis methodologies, and improving test data acquisition and management with sensors and systems that have fast response, low volume, minimal intrusion, and high accuracy and reliability. By using state-of-the-art flight test techniques along with novel measurement and data acquisition technologies, NASA and the aerospace industry will be able to conduct flight research more effectively and also meet the challenges presented by NASA and industry's cutting edge research and development programs. NASA's Flight Demonstrations and Capabilities Project supports a variety of flight regimes and vehicle types ranging from low speed, sub-sonic electric propulsion, transonic civil transport, and supersonic civil transport. Therefore, this solicitation can cover a wide range of flight conditions and craft. NASA also requires improved measurement and analysis techniques for acquisition of real-time, in-flight data used to determine aerodynamic, structural, flight control, and propulsion system performance characteristics. These data will also be used to provide test conductors the information to safely expand the flight and test envelopes of aerospace vehicles and components. This requirement includes the development of sensors (both in-situ and remotely) to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Flight test and measurement technologies proposals should significantly enhance the capabilities of major government and industry flight test facilities comparable to the following NASA aeronautical test facilities:

- Dryden Aeronautical Test Range.
- Aero-Structures Flight Loads Laboratory.
- Flight Research Simulation Laboratory.
- Research Test Bed Aircraft.

Proposals should address innovative methods and technologies to extend the health, maintainability and test capabilities of these types of flight research support facilities.

Areas of interest include:

- High performance, real time reconfigurable software techniques for data acquisition and processing

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- associated with IP based commands and/or IP based data input/output streams.
- High efficiency digital telemetry technique and/or system to enable high data rate, high volume IP based telemetry for flight test.
 - Improve time-constrained situational awareness and decision support via integrated secure cloud-based web services for real-time decision making.
 - Intelligent health monitoring for hybrid and/or all electric distributed propulsion systems.
 - Methods for significantly extending the life of electric aircraft propulsion energy sources (e.g., batteries, fuel cells, etc.).
 - Test techniques for conducting quantitative in-flight boundary layer flow visualization, global surface pressure, shock wave propagation, Schlieren photography, near and far-field sonic boom determination, atmospheric modeling.
 - Measurement technologies for in-flight steady & unsteady aerodynamics, juncture flow measurements, propulsion airframe integration, structural dynamics, stability & control, and propulsion system performance.
 - Remote optical-based measurement technologies enabling simultaneous spatial/spectral/temporal measurement capability in the infrared wavebands are desired to assess technology leaps in propulsion system efficiency and to evaluate impacts to the environment. Temporal acquisition rates greater than or equal to 1 kHz (full hyperspectral image cubes/sec) are desired to resolve performance information commensurate with the expected phenomenology. Miniaturized fiber optic fed measurement systems with low power requirements are desirable for migration to small business class jets or UAS platforms.
 - Innovative techniques that enable safer operations of aircraft (e.g., non-destructive examination of composites through ultrasonic techniques).

A2.02 Unmanned Aircraft Systems Technology

Lead Center: AFRC

Participating Center(s): LaRC

Unmanned Aircraft Systems (UAS) offer advantages over manned aircraft for applications which are dangerous to humans, long in duration, require great precision, and require quick reaction. Examples of such applications include remote sensing, disaster response, delivery of goods, agricultural support, and many other known and yet to be discovered. In addition, the future of UAS promises great economic and operational advantages by requiring less human participation, less human training, an ability to take-off and land at any location, and the ability to react to dynamic situations.

NASA is involved in research that would greatly benefit from breakthroughs in UAS capabilities. Flight research of basic aerodynamics and advanced aero-vehicle concept would be revolutionized with an ability of UAS teams to cooperate and interact while making real time decisions based upon sensor data with little human oversight. Commercial industry would likewise be revolutionized with such abilities.

There are multiple technological barriers that are restricting greater use and application of UAS in NASA research and in civil aviation. These barriers include, but are not limited to, the lack of methods, architectures, and tools which enable:

- The verification, validation, and certification of complex and/or nondeterministic systems.
- Humans to operate multiple UAS with minimal oversight.
- Multi-vehicle cooperation and interoperability.
- High level machine perception, cognition, and decision making.
- Inexpensive secure and reliable communications.

This solicitation is intended to break through these and other barriers with innovative and high-risk research.

The Integrated Aviation Systems Program's work on UAS Technology for the FY 2015 NASA SBIR solicitation is focused on breaking through barriers to enable greater use of UAS in NASA research and in civil aviation use. The following five research areas are the primary focus of this solicitation, but other closely related areas will also be considered for reward. The primary research areas are:

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- *Verification, Validation, and Certification* - New inexpensive methods of verification, validation, and certification need to be developed which enable application of complex systems to be certified for use in the national airspace system. Proposed research could include novel hardware and software architectures that enable or circumvent traditional verification and validation requirements.
 - *Operation of multiple UAS with minimal human oversight* - Novel methods, software, and hardware that enable the operation of multiple UAS by a single human with minimal oversight need to be developed which ensure robust and safe operations. Proposed research could include novel hardware and software architectures which provide guarantees of safe UAS operations.
 - *Multi-vehicle cooperation and interoperability* - Technologies that enable UAS to interact in teams, including legacy vehicles, need to be developed. This includes technologies that enable UAS to negotiate with others to find optimal routes, optimal task allocations, and optimal use of resources. Proposed research could include hardware and software architectures which enable UAS to operate in large cooperative and interactive teams
 - *Sensing, perception, cognition, and decision making* - Technologies need to be developed that provide the ability of UAS to detect and extract internal and external information of the vehicle, transform the raw data into abstract information which can be understood by machines or humans, and recognize patterns and make decisions based on the data and patterns.
 - *Inexpensive, reliable, and secure communications* - Inexpensive methods which ensure reliable and secure communications for increasingly interconnected and complex networks need to be developed that are immune from sophisticated cyber-physical attacks.

Phase I deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
- A technology demonstration in a simulation environment which clearly shows the benefits of the technology developed.
- A written plan to continue the technology development and/or to infuse the technology into the UAS market. This may be part of the final report.

Phase II deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
- A technology demonstration in a relevant flight environment which clearly shows the benefits of the technology developed.
- Evidence of infusing the technology into the UAS market or a clear written plan for near term infusion of the technology into the UAS market. This may be part of the final report.

Airspace Operations and Safety Topic A3

The Airspace Operations and Safety Program (AOSP) seeks innovative and feasible concepts and technologies to enable significant increases in the capacity and efficiency of the Next Generation Air Transportation System (NextGen) while maintaining or improving safety and environmental acceptability. AOSP activities and projects will target system-wide operational benefits of high impact for NextGen both in the arenas of airspace operations and safety management. Projects will be formulated with near-term end dates or deliberative evaluation points consistent with the accomplishment of program-defined Technical Challenges. AOSP aligns with the ARMD Strategic Thrusts of Safe and Efficient Growth in Global Aviation, Enable Real-Time System-Wide Safety Assurance, and Enable Assured Machine Autonomy for Aviation. Distribution of work area across the AOSP project structure is described below.

AOSP is comprised of three projects: Airspace Technology Demonstrations (ATD), Shadow Mode Assessment Using Realistic Technologies for the National Airspace System (SMART-NAS) Test-Bed for Safe Trajectory-Based Operations, and Safe Autonomous Systems Operations (SASO). The three projects are formulated to make major contributions to operational needs of the future through the development and research of foundational concepts and technologies and their analysis, integration, and maturation in relevant, system-level environments. Each of the projects are, much like the airspace system itself, highly integrated and require attention to critical system integration and transition interfaces with the NAS. The Airspace Technology Demonstrations (ATD) Project will accelerate the maturation of concepts and technologies to higher levels of maturity for transition to stakeholders, including research supporting the existing ATD-1:

- Interval Management - Terminal Area Precision Scheduling and Spacing effort.
- Integrated Arrivals/Departures/ Surface Operations.
- Applied Traffic Flow Management.
- Technologies for Assuring Safe Aircraft Energy and Attitude State (TASEAS).

The SMART-NAS Testbed for Safe Trajectory Based Operations Project will deliver an evaluation capability, critical to the ATM community, allowing full NextGen and beyond-NextGen concepts to be assessed and developed. This simulation and modeling capability will include the ability to assess multiple parallel universes, accepts data feeds, allows for live/virtual/constructive- distributed environment, and enable integrated examinations of concepts, algorithms, technologies, and NAS architectures. The Safe Autonomous System Operations (SASO) Project will develop autonomous system concepts and technologies; conduct demonstrations, and transfer application specific matured technologies to increase affordability, efficiency, mobility of goods and passengers, safety, and scalability and mix of airspace operations.

Proposals for this topic will develop innovative feasible concepts and technologies to enable significant increases in the capacity, efficiency, scalability and cost effectiveness of the Next Generation Air Transportation System (NextGen) while maintaining or improving safety and environmental acceptability.

Sub Topics:

A3.01 Advanced Air Traffic Management Systems Concepts

Lead Center: ARC

Participating Center(s): LaRC

This subtopic addresses user needs and performance capabilities, trajectory-based operations, and the optimal assignment of humans and automation to air transportation system functions, gate-to-gate concepts and technologies to increase capacity and throughput of the National Airspace System (NAS), and achieving high efficiency in using aircraft, airports, en route and terminal airspace resources, while accommodating an increasing variety of missions and vehicle types, including full integration of Unmanned Aerial Systems (UAS) operations. Examples of concepts or technologies that are sought include:

- Develop verification and validation methods and capabilities to enable safe, end-to-end NextGen Trajectory-Based Operations (TBO) functionality and seamless UAS operations, as well as other future aviation system concepts and architectures.
- The development of performance requirements, functional allocation definitions, and other critical data for integrated, end-to-end NextGen TBO functionality, and seamless UAS operations, as well as other future aviation system concepts and architectures.
- Development of prognostic safety risk management solutions and concepts for emergent risks.
- Development of TBO concepts and enabling technology solutions that leverage revolutionary capabilities and that enable capacity, throughput, and efficiency gains within the various phases of gate-to-gate operations.

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- Networked/cloud-based systems to increase system predictability and reduce total cost of National Airspace System operations.

It is envisioned that the outcome of these concepts and technologies will provide greater system-wide safety, predictability, and reliability through full NextGen (2025-2035 time frame) functionality.

A3.02 Autonomy of the National Airspace System (NAS)

Lead Center: ARC

Participating Center(s): LaRC

Develop concepts or technologies focused on increasing the efficiency of the air transportation system within the mid-term operational paradigm (2025-2035 time frame), in areas that would culminate in autonomy products to improve mobility, scalability, efficiency, safety, and cost-competitiveness. Proposals in the followings areas in product-oriented research and development are sought, but are not limited to:

- Autonomous and safe Unmanned Aerial Vehicle (UAV) operations for the last and first 50 feet, under diverse weather conditions.
- Autonomous or increasing levels of autonomy for, or towards, any of the following:
 - Networked cockpit management.
 - Traffic flow management.
 - Airport management.
 - Metroplex management.
 - Integrated Arrival/Departure/Surface operations.
 - Low altitude airspace operations.
- Autonomy (or self-management) -based architectures for the entirety, or parts, of airspace operations.
- Autonomous systems to produce any of the following system capabilities:
 - Prognostics, data mining, and data discovery to identify opportunities for improvement in airspace operations.
 - Weather-integrated flight planning, rerouting, and execution.
 - Fleet, crew, and airspace management to reduce the total cost of operations.
 - Predictions of unsafe conditions for vehicles, airspace, or dispatch operations.
- Performance driven, all-operations, human-autonomy teaming management.
- Verification and validation tools for increasingly autonomous operations.
- Machine learning and/or self-learning algorithms for Shadow Mode Assessment using Realistic Technologies for the National Airspace System (NAS).
- Autonomy/autonomous technologies and concepts for trajectory management and efficient/safe traffic flows.
- Adaptive automation/human-system integration concepts, technologies and solutions that increase operator (pilot and or controller) efficiency and safety, and reduce workload to enable advances in air traffic movement and operations.

A3.03 Future Aviation Systems Safety

Lead Center: ARC

Participating Center(s): LaRC

The Aeronautics Research Mission Directorate (ARMD) will be concluding the successful Aviation Safety Program (AvSP). The newly expanded Airspace Operations and Safety Program (AOSP) will be succeeding AvSP's significant achievements and stepping up to lead the ARMD research in the area of Real-Time System-Wide Safety Assurance (RSSA). As currently envisioned, ARMD sees its future, safety-related research focused in a forward looking, more comprehensive system-wide direction. Rather than be focused on the current National Airspace System (NAS), ARMD's RSSA will be focused towards a future NAS where a gate-to-gate trajectory-based system capability exists that satisfies a full vision for NextGen and beyond. The ultimate vision for RSSA would enable the delivery of a progression of capabilities that accelerate the detection, prognosis and resolution of system-wide threats. Proposals under this sub-topic are sought, but not limited to, these areas:

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- Research and development products to address technologies, simulation capabilities and procedures for reducing flight risk in areas of attitude and energy aircraft state awareness
 - Develop V&V tools and techniques for assuring the safety of air traffic applications during certification and throughout their lifecycles, and, techniques for supporting the real-time monitoring of safety requirements during operation.
 - Develop and demonstrate prognostic decision support tools and methods capable of supporting real-time safety assurance.

Structural Efficiency-Hybrid Nanocomposites Topic A1.01

Two of the primary goals of the Advanced Air Vehicles program are safety and efficiency, which can be achieved simultaneously through designer materials tailored for future aircraft structures. The SOA for lightweight structures are carbon fiber reinforced polymeric composites which make up approximately 50% of the weight of Boeing's 787. Adoption of all-carbon nanotube (CNT) composites to exploit their potential for enhancing structural efficiency is viewed as too far term, given the current state of CNT technology maturation. A more attainable approach is to take advantage of the multifunctionality offered by CNTs through the use of hybrid composites where CNTs are integrated into conventional carbon fiber reinforced composite structures. Hybrid composites enable improved mechanical properties such as interlaminar strength, while simultaneously increasing electrical and thermal conductivity to enable features such as lightning strike protection, embedded sensing, etc. The targeted outcome is reduced weight and enhanced safety performance for future hybrid composite aircraft structures. For this subtopic, the plan is to start phase 1 with a systems analysis approach to identify the benefits and target areas for hybrid composite utility and to provide some direction and benefit analysis for applying hybrid composites in aircraft structures. Then the intention of the Phase II would be to tailor, build and test the materials to demonstrate the property enhancements identified in Phase I.

Sub Topics:

Aerodynamic Efficiency Drag Reduction Technology Topic A1.02

The challenge of energy-efficient flight has at its foundation aerodynamic efficiency, and at the foundation of aerodynamic efficiency is low drag. Drag can be broadly decomposed into four components: viscous or skin friction drag, lift-induced drag, wave or compressibility drag, and excrescence drag due to various protruding items such as antennae, wipers, lights, etc. The relative impact of these four forces depends upon the targeted flight regime and vehicle-specific design requirements. The first force, however, viscous skin friction, stands out as particularly significant across most classes of flight vehicles and effective measures for its control would have a major impact of flight efficiency. In particular, supersonic, low-boom flight and new generations of energy-efficient subsonic transport airplanes including high L/D strut-braced designs, the blended wing body (BWB), so called "double-bubble" designs and other concepts with large expanses of surface area would benefit from effective viscous drag control.

Viscous skin friction can be classified as either laminar or turbulent. While the laminar case and its attendant laminar flow control (LFC) techniques remain important scientific and technological disciplines, the goal of high Reynolds number flight efficiency requires that the turbulent case receive renewed attention. In place of the first-principles-derived theoretical framework of the laminar flow stability problem, in the turbulence case we have a wide collection of experimental observations, data correlations, various CFD approaches requiring turbulence closure models and, at low Reynolds numbers, full direct numerical simulation of the Navier-Stokes equations (DNS). While such experimental and CFD-derived knowledge, has greatly increased our understanding of turbulent boundary layer physics over the past decades, key relationships between wall layer and outer layer dynamics essential to a full understanding remain to be identified and verified.

Inadequacies in our understanding of boundary layer turbulence increase reliance upon a more qualitative, physics-guided approach to discovery. For example, the experimental observation of reduced skin friction in the corners of triangular cross-section pipes lead to the discovery of drag-reducing V-groove riblets (subsequently also associated with the skin of certain shark species). The quasi-periodic, low-speed streak structures observed in the near-wall layer of turbulent boundary layers lead to the implementation of mechanically controlled spanwise waves or lateral

oscillations of the wall to disrupt the processes associated with low speed streak bursting. Similar observations have either been made or suggested with respect to the stabilizing influence of convex and in-plane curvature; long length-to-diameter ratio particulates; passive, active and reactive wall motion; manipulation of the wall layer by various geometrical devices (e.g., vortex generators (VG) and large eddy breakup devices (LEBU)), and various weakly ionized gas (WIG) and magnetohydrodynamic/electrohydrodynamic (MHD/EHD) concepts. This solicitation is offered in this spirit of innovation based on experimental or computational observations guided by a basic, though not necessarily complete, physical understanding of the turbulent processes.

In order to stimulate innovation in the area of turbulent viscous drag reduction, proposals are sought subject to the following guidelines:

- Proposals shall address passive, active or reactive concepts for external, attached, fully developed, turbulent boundary layer viscous drag reduction in air.
- Experimental, hardware-based proposals and theoretical/computational proposals based on realizable hardware are preferred.
- All practical physical concepts are acceptable including but not limited to: mechanical/electro-mechanical actuators, weakly-ionized-gas (WIG) concepts, laser/microwave energy deposition, MHD/EHD devices, surface microstructure/geometry, embedded mechanical devices (VG's, LEBU's), wall mass transpiration, heat transfer, wall motion, wall curvature effects and pressure gradient (vehicle shaping).
- Significant enhancements or refinements of existing concepts and technologies are acceptable.
- First order assessment or technically plausible discussion of any net system energy saving claims shall be provided.
- Proof-of-concept experimental demonstrations are encouraged for Phase I where applicable but are not required.
- Target conditions are flight-relevant Reynolds numbers at either high subsonic ($0.7 < M < 0.9$) or low supersonic ($M < \sim 3$) speeds. Proposals at lower Mach and Reynolds numbers shall provide discussion of a developmental path towards flight-relevant conditions but not necessarily inclusive of actual flight.

Sub Topics:

Low Emissions Propulsion and Power Topic A1.03

Proposals are sought which support electric propulsion of transport aircraft, including turboelectric propulsion (turbine prime mover with electric distribution of power to propulsors) and various hybrid electric concepts, such as gas turbine engine and battery combinations.

Turboelectric propulsion for transport aircraft applications will require components with high specific power (hp/lb or kW/kg) and high efficiency, and cryogenic and superconducting components will likely be required. The cryogenic components of interest include fully superconducting generators and motors (i.e., superconducting stators as well as rotors), cryogenic inverters and active rectifiers, and cryocoolers. Proposals related to the superconducting machines may include aspects of the machines themselves and their subcomponents, as well as low AC loss superconducting materials for the stator windings. Generators with at least 10 MW capacity and motors of 2 to 4 MW capacity are of interest. Technology is sought that can contribute to superconducting machines with specific power more than 10 hp/lb.

Hybrid propulsion with non-cryogenic components will likely require new materials and configurations to reach required high specific power and efficiency. Hence ideas are sought for achieving 2-3X increase in specific power at high efficiency for non-cryogenic motors through a multidisciplinary approach utilizing advanced motor designs, better materials, and new structural concepts.

New approaches to achieving conductors with lower electrical resistivity than copper are particularly sought, e.g., conductors based on carbon nanotubes. However, such approaches must be backed by plausible reasons why a resistivity lower than that of copper can be expected to be achieved, in contrast to the best reported resistivity values for carbon nanotube fibers, which are nearly an order of magnitude higher.

Ideas are also sought to address challenges related to high voltage power transmission in future hybrid electric aircraft.

New modeling and simulation tools for hybrid electric aircraft propulsion systems are also of interest.

Some studies of turboelectric distributed propulsion components and systems can be found in the following and referenced therein:

- “Stability, Transient Response, Control, and Safety of a High-Power Electric Grid for Turboelectric Propulsion of Aircraft”, Michael Armstrong, Christine Ross, Danny Phillips, and Mark Blackwelder, NASA/CR—2013-217865, 2013
- “Turboelectric Distributed Propulsion in a Hybrid Wing Body Aircraft”, J. Felder, G. Brown, H. Kim, J. Chu, 20th ISABE Conference, Göteborg, Sweden, 12-16 Sept., 2011
- “Weights and Efficiencies of Electric Components of a Turboelectric Aircraft Propulsion System”, G. V. Brown, 49th AIAA Aerospace Sciences Meeting, Orlando FL, January 4-7, 2011
- “Turboelectric Distributed Propulsion Engine Cycle Analysis for Hybrid-Wing-Body Aircraft”, J. L. Felder, H. D. Kim, G. V. Brown, 47th AIAA Aerospace Sciences Meeting, Orlando FL, January 5-8, 2009

Sub Topics:

Quiet Performance Topic A1.04

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable aircraft. In support of the Advanced Air Vehicles, Integrated Aviation Systems and Transformative Aero Concepts Programs, improvements in noise prediction, acoustic and relevant flow field measurement methods, noise propagation and noise control are needed for subsonic, transonic and supersonic vehicles targeted specifically at airframe noise sources and the noise sources due to the aerodynamic and acoustic interaction of airframe and engines. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design purposes.
- Prediction of aerodynamic noise sources including those from the airframe and those that arise from significant interactions between airframe and propulsion systems including those relating to sonic boom.
- Prediction of sound propagation from the aircraft through a complex atmosphere to the ground. This should include interaction between noise sources and the airframe and its flow field.
- Propagation of sonic boom through realistic atmospheres, especially turbulence effects.
- Innovative source identification techniques for airframe (e.g., landing gear, high lift systems) noise sources, including turbulence details related to flow-induced noise typical of separated flow regions, vortices, shear layers, etc.
- Concepts for active and passive control of aeroacoustic noise sources for conventional and advanced aircraft configurations, including adaptive flow control technologies, and noise control technology and methods that are enabled by advanced aircraft configurations, including integrated airframe-propulsion control methodologies. Innovative acoustic liner and porous surface concepts for the reduction of airframe noise sources and/or propulsion/airframe interaction are solicited but engine nacelle liner applications are specifically excluded.
- Development of synthesis and auditory display technologies for subjective assessments of aircraft community noise, including sonic boom.

Sub Topics:

Physics-Based Conceptual Aeronautics Design Tools Topic A1.05

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft concepts to improve fuel efficiency and reduce the environmental footprint of future generations of commercial transports across the breadth of the flight speed regimes. Propulsion systems, such as open rotors and hybrid-electric propulsion, are viewed as potential options for helping meet aggressive, long range (i.e., 'N+3' timeframe) emission reduction targets. Accurate representation of the propulsion system is critical in confidently assessing the potential of a concept. Conceptual design and analysis of unconventional propulsion concepts and technologies is used for technology portfolio investment planning, development of advanced concepts to provide technology pull and independent technical assessment of new concepts. The agency's systems analysts need to have the best conceptual design/analysis tools possible to support these efforts. Substantial progress has been made recently in incorporating more physics-based analysis tools in the conceptual design process, and NASA has developed a capability that integrates several analysis tools and models in engineering frameworks, such as ModelCenter and OpenMDAO. However, modeling gaps still remain in many disciplines.

Historically, empirical and semi-empirical weight estimation methods have been utilized during the conceptual

design phase. These techniques work well for the conceptual design of conventional propulsion systems with parameters that reside within the historical databases used to develop the methodologies. However, these methods are not well suited for unconventional propulsion concepts, or even conventional concepts which reside outside of the database. Developing higher order, more accurate tools suitable for conceptual design is a difficult challenge. The first issue is analysis turnaround time. To perform the configuration trades and optimization typical of conceptual design, runtimes measured in seconds or minutes, instead of hours or days, are required. However, rapid analysis turnaround time alone is insufficient. To be suitable for conceptual design, tools and methods are needed which accurately predict the 'as-built' characteristics. Because it is not possible to model every detail of the design and account for all the underlying physics in the problem formulation, it is difficult to predict the 'as-built' characteristics with physics-based methods alone. What is usually required is a combination of these methods with some semi-empirical corrections. A final challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods often require only gross design parameters as inputs. The gap between the analysis capability and the maturity of the design being analyzed currently limits the usefulness of high order analysis in conceptual design. Physics-based tools for conceptual design are needed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

NASA has a well-established propulsion systems analysis tool suite that is based on the Numerical Propulsion System Simulation (NPSS) and the Weight Analysis of Turbine Engines (WATE) codes. Ideally, new capabilities that arise from this solicitation should be compatible with NPSS and/or WATE or offer significantly increased capability beyond/outside of these state-of-the-art tools.

For FY 2015, the focus is on addressing remaining capability gaps. Examples of desired capability improvements include the following:

- Physics-based methodologies and sizing of hybrid-electric propulsion components.
 - Weight/volumetric estimates for major components (e.g., batteries, fuel cells, motors, generators, cryocoolers, transformers, inverters, rectifiers).
- Heat exchanger performance and weight/volume estimation modeling tools.
- Computational counter-rotating open rotor performance tools.
 - Low/Medium-fidelity modeling approaches for predicting open rotor performance based on key blade characteristics.
- Multi-fidelity environmental analysis tools.
 - Combustion emission indices generation consistent with advanced combustor architectures.
 - Advanced acoustic-modeling addressing propulsion/airframe shielding, Fan/turbomachinery noise and/or jet noise.
- Multi-fidelity Propulsion-Airframe Integration (PAI) performance analysis tools.
 - Propulsion installation analysis methods (inlet/nacelle/nozzle analysis in the presence of an airframe).
 - Advanced mission-analysis methods incorporating multiple degrees of freedom and including expansive/adaptable propulsion operability capability.
- Macro Systems Analysis tools addressing propulsion-related impacts.
 - Reduced-order atmospheric chemistry/global mixing tools.
 - Safety/reliability analysis tools consistent with conceptual-level design/analysis.
 - Global airport throughput network and commerce models.

Sub Topics:

Vertical Lift Topic A1.06

The Vertical Lift subtopic is primarily interested in the following two areas:

- The use of small vertical lift UAVs has increased in recent times with many civilian missions being proposed, including autonomous surveillance, mapping, etc. Much of the current research associated with these vehicles has been in the areas of electric propulsion, batteries, small sensors and autonomous control laws, while very little attention has been paid to their acoustic signature. The generation and propagation of noise associated with this small class of vertical lift UAVs are not well understood and validated prediction tools do not currently exist. The objective of a proposed effort would be to develop tools for the modeling and prediction of the high frequency acoustics for small vertical lift UAVs, such as quad-copters, coaxials, ducted fan rotors, etc.

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- A transition to low-carbon propulsion has the promise of dramatically reducing the emissions from full-scale rotorcraft, as well as reducing overall fuel consumption and operating cost. All electric and hybrid propulsion systems could be beneficial to rotorcraft due to high power requirements of hover and integrated motor-drive systems designs that could be realized. The objective of a proposed effort would be to develop and demonstrate hybrid/electric technologies for full-scale rotorcraft drive and propulsions systems that show benefits in-terms of weight, efficiency, emissions and fuel consumption. Validated modeling and analysis tools for all-electric and hybrid propulsions systems are also sought in this solicitation.

Proposals on other rotorcraft technologies will also be considered but the primary emphasis of the solicitation will be on the above two identified technical areas.

Sub Topics:

Efficient Propulsion and Power Topic A1.07

For 2014, this sub-topic will focus on propulsion controls and dynamics. Propulsion controls and dynamics research is being done under various projects in the Fundamental Aeronautics Program (FAP) and Aviation Safety Program (ASP). For turbine engines, work on Distributed Engine Control (DEC) and Active Combustion Control (ACC) is currently being done under the Aeronautics Sciences (AS) project, and is expected to transition to the new Transformative Tools and Technologies (TTT) project in FY15. Aero-Propulso-Servo-Elasticity (APSE) research will continue under the High Speed project. Model-Based Engine Control research is currently being conducted under the Vehicle System Safety Technologies project, and is expected to transition to the TTT project in FY15. Propulsion controls and dynamics technologies that help achieve the goals of the following NASA ARMD strategic thrusts: Innovation in Commercial Supersonic Aircraft; Ultra-Efficient Commercial Vehicles; and Assured Autonomy for Aviation Transformation, will be given preference. Following technologies are of specific interest:

- *High Efficiency Robust Engine Control* - Typical current operating engine control logic is designed using SISO (Single Input Single Output) PI (Proportional+Integral) control. The control logic is designed to provide minimum guaranteed performance while maintaining adequate safety margins throughout the engine operating life. Additionally, the control logic indirectly provides control of variables of interest such as Thrust, Stall Margin, etc. since these variables cannot be measured or are not measured in flight because of restrictions on sensor cost/placement/reliability, etc. All this results in highly conservative control design with resulting loss in efficiency. NASA is currently conducting research in Model-Based Engine Control (MBEC) where-in an on-board real-time engine model, tuned to reflect current engine condition, is used to generate estimate of quantities of interest that are to be regulated or limited and these estimates are used to provide direct control of Thrust, etc. Alternate methods such as Model Predictive Control, Adaptive Control, direct non-linear control, etc. are of interest. However, the alternative methods must achieve the same objectives as the current MBEC approach by providing practical application of the control logic in terms of operation with sensor noise, operation across varying atmospheric conditions, operation across varying engine health condition over the operating life, and real-time operation within engine control hardware limits. The emphasis is on practical application of existing control methods rather than theoretical derivation of totally new concepts. Control design approaches that can accommodate small to medium engine component faults and can still provide desired performance with safe operation are of special interest. The pre-requisite for proposals for engine control design methods is that the NASA C-MAPSS40k (Commercial Modular Aero-Propulsion System Simulation for 40,000 lb class thrust engine) be used for control design and evaluation. This simulation can only be used by U.S. citizens since it is subject to export control laws. Methods for real-time engine parameter identification using flight data are also of interest by themselves.
- *Distributed Engine Control* - Current engine control architectures impose limitations on the insertion of new control capabilities primarily due to weight penalties and reliability issues related to complex wiring harnesses. Obsolescence management is also a primary concern in these systems because of the unscheduled cost impact and recertification issues over the engine life cycle. NASA in collaboration with AFRL (Air Force Research Lab) has been conducting research in developing technologies to enable Distributed Engine Control (DEC) architectures. Modularity is an inherent feature of distributed engine control architecture. Modularity enables the rapid integration of the individual functions of control into a cohesive system by virtue of common digital interfaces and the well-defined flow of data. This interface structure can persist regardless if the control function exists in hardware or simulation. At the engine system level, distributed architecture enables scalability and reuse of control functional elements across engine

platforms, but it also simplifies the insertion of new control technologies within the smart devices. NASA is interested in the development and simulation of these distributed control functions for high temperature embedded application on the engine core. NASA is particularly interested in the design and development of these applications for assessing the benefit they bring to the engine system.

- *Active Combustion Control* - The overall objective is to develop all aspects of control systems to enable safe operation of low emissions combustors throughout the engine operating envelope. Low emission combustors are prone to thermo-acoustic instabilities. So far NASA research in this area has focused on modulating the main or pilot fuel flow to suppress such instability. Advanced, ultra-low emissions combustors utilize multi-point (multi-location) injection to achieve a homogeneous, lean fuel/air mixture. There is new interest in using precise control of fuel flow in such a manner as to suppress or avoid thermo-acoustic instabilities. Miniature fuel metering devices (and possibly also fuel flow measurement devices) are needed that can be physically distributed to be close to the multi-point fuel injector in order to enable the control system to accurately place a given proportion of the overall fuel flow to each of the fuel injection locations.
- *Aero-Propulso-Servo-Elasticity (APSE)* - The objective of NASA research effort in APSE is to develop a comprehensive variable cycle engine (VCE) type dynamic propulsion system model that can be utilized for thrust dynamics and integrated APSE vehicle controls and performance studies, like vehicle ride quality and vehicle stability under typical flight operations, vehicle maneuvering and atmospheric disturbances, for supersonic vehicles. Innovative approaches to dynamic modeling that are of interest include supersonic external compression inlets; multi flow paths convergent-divergent type nozzles with a spike; parallel flow path modeling of propulsion components upstream of the combustor to accurately model the distortion effects, maneuvering and atmospheric disturbances; and integration of dynamic propulsion models with aircraft simulations incorporating flexible vehicle structural modes.

Sub Topics:

Ground Testing and Measurement Technologies Topic A1.08

This subtopic supports the experimental modeling and simulation requirements of NASA's Aeronautics Research Mission Directorate, as well as the testing requirements of other government and commercial entities. The subject facilities are managed by the Aeronautics Evaluation and Test Capability (AETC) Project within the NASA Advanced Air Vehicles Program. The primary objective of this subtopic is to develop innovative tools and technologies that enhance testing and measurement capabilities, improve ground test resource utilization and efficiency, and provide capability sustainment. Where possible, the tools and technologies should be applicable for the broad national scope of government, commercial, and university capabilities.

Wind tunnel vehicle design databases have traditionally included the foundational measurements of forces and discrete surface pressures and temperatures. However, designing and testing future vehicles with non-traditional aerodynamic geometries, possibly including highly integrated and distributed propulsion and flow control systems, will require enhanced, remotely sensed global surface measurements that cover a wide range of operational conditions. Enhanced optical systems are required to visualize the flow interactions both on and off the surface. Non-intrusive measurement systems offering multi-component velocities, density, and pressure in the tunnel stream are required to routinely quantify and baseline the test environment and to establish boundary conditions for advanced computational simulations. Non-intrusive measurements of off-body and near-body flow parameters both at a point and globally (i.e., planar or volumetric) are necessary to examine fluid-fluid and fluid-structure interactions for computational solution validation. The development of diagnostics for simultaneous volumetric measurements are particularly desired and will require a concentrated research effort in the development of enhanced laser and imaging techniques (including light field imaging), the development of new optical configurations, and the development of near real-time to real-time acquisition and processing architectures. In particular, development of techniques that significantly increase data capture per test point are needed, including the ability to simultaneously measure multiple flow parameters at high acquisition rates to capture rapidly evolving or oscillatory flow phenomena. Maturation of current particle-based, molecular, and/or surface diagnostics and unification of compatible instruments are desired. In all cases, significant measurement accuracy enhancements are required. Measurement systems must be robust and user-friendly for practical and routine application.

Proposals for clean seeding methods that do not contaminate wind tunnel walls or anti-turbulence screens are solicited. Seedless methods for velocity measurements near a model surface are particularly desired for adverse test environments where seeding contaminants are prohibited, may alter the model surface flow, or possibly damage gas reclamation systems. Two such environments occur at NASA Langley for -250°F cryogenic testing at the National Transonic Facility and heavy-gas testing using R134a at the Transonic Dynamics Tunnel.

Proposals are also solicited for shear stress sensors that are applicable to high-temperature/high-flow-rate environments such as those encountered in engine and high-speed testing where surface heating is important.

Small models and/or packaging constraints for large models can make model attitude measurements difficult. Testing in the non-gravity direction precludes use of traditional angle sensors. Many test configurations require multiple angle of attack systems, including redundant systems to guard against in-test failure. Maintaining calibration currency and accuracy of multiple systems significantly increases test costs and complexity. Proposals are solicited for accurate, real-time, optical, non-intrusive techniques for determining model attitude.

The impact of icing on vehicle performance for flight certification is increasingly important. Currently, the NASA Glenn Icing Research Tunnel cannot reproduce the full range of test conditions defined in the FAA Appendix O Supercooled Droplet Icing Conditions. Simulation of Appendix O conditions for freezing rain and drizzle scenarios requires a bimodal droplet distribution with much larger size droplets. These large droplets have an extended cooling period before entering the test section; and, they don't follow the flow, falling toward the test section floor. Innovative ideas and technology advancements are solicited to create and control Appendix O conditions in current facilities.

Many NASA wind tunnel facilities conduct tests at elevated temperatures (400°F to 700°F) or at extremely low temperatures (-250). Displacement measurement components in actuator systems for the setting of hydraulic cylinder positions and other hardware that is used in test article support and positioning systems must operate routinely in these environments. Innovative designs and hardware solutions are desired to provide accurate and reliable performance at these extreme conditions.

Additional information about the mission and facility capabilities may be obtained at (<http://www.aeronautics.nasa.gov/atp/index.html> [1]).

Sub Topics:

Flight Test and Measurements Technologies Topic A2.01

NASA continues to see flight research as a critical element in the maturation of technology. This includes developing test techniques that improve the control of in-flight test conditions, expanding measurement and analysis methodologies, and improving test data acquisition and management with sensors and systems that have fast response, low volume, minimal intrusion, and high accuracy and reliability. By using state-of-the-art flight test techniques along with novel measurement and data acquisition technologies, NASA and the aerospace industry will be able to conduct flight research more effectively and also meet the challenges presented by NASA and industry's cutting edge research and development programs. NASA's Flight Demonstrations and Capabilities Project supports a variety of flight regimes and vehicle types ranging from low speed, sub-sonic electric propulsion, transonic civil transport, and supersonic civil transport. Therefore, this solicitation can cover a wide range of flight conditions and craft. NASA also requires improved measurement and analysis techniques for acquisition of real-time, in-flight data used to determine aerodynamic, structural, flight control, and propulsion system performance characteristics. These data will also be used to provide test conductors the information to safely expand the flight and test envelopes of aerospace vehicles and components. This requirement includes the development of sensors (both in-situ and remotely) to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Flight test and measurement technologies proposals should significantly enhance the capabilities of major government and industry flight test facilities comparable to the following NASA aeronautical test facilities:

- Dryden Aeronautical Test Range.
- Aero-Structures Flight Loads Laboratory.
- Flight Research Simulation Laboratory.
- Research Test Bed Aircraft.

Proposals should address innovative methods and technologies to extend the health, maintainability and test capabilities of these types of flight research support facilities.

Areas of interest include:

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- High performance, real time reconfigurable software techniques for data acquisition and processing associated with IP based commands and/or IP based data input/output streams.
 - High efficiency digital telemetry technique and/or system to enable high data rate, high volume IP based telemetry for flight test.
 - Improve time-constrained situational awareness and decision support via integrated secure cloud-based web services for real-time decision making.
 - Intelligent health monitoring for hybrid and/or all electric distributed propulsion systems.
 - Methods for significantly extending the life of electric aircraft propulsion energy sources (e.g., batteries, fuel cells, etc.).
 - Test techniques for conducting quantitative in-flight boundary layer flow visualization, global surface pressure, shock wave propagation, Schlieren photography, near and far-field sonic boom determination, atmospheric modeling.
 - Measurement technologies for in-flight steady & unsteady aerodynamics, juncture flow measurements, propulsion airframe integration, structural dynamics, stability & control, and propulsion system performance.
 - Remote optical-based measurement technologies enabling simultaneous spatial/spectral/temporal measurement capability in the infrared wavebands are desired to assess technology leaps in propulsion system efficiency and to evaluate impacts to the environment. Temporal acquisition rates greater than or equal to 1 kHz (full hyperspectral image cubes/sec) are desired to resolve performance information commensurate with the expected phenomenology. Miniaturized fiber optic fed measurement systems with low power requirements are desirable for migration to small business class jets or UAS platforms.
 - Innovative techniques that enable safer operations of aircraft (e.g., non-destructive examination of composites through ultrasonic techniques).

Sub Topics:

Unmanned Aircraft Systems Technology Topic A2.02

Unmanned Aircraft Systems (UAS) offer advantages over manned aircraft for applications which are dangerous to humans, long in duration, require great precision, and require quick reaction. Examples of such applications include remote sensing, disaster response, delivery of goods, agricultural support, and many other known and yet to be discovered. In addition, the future of UAS promises great economic and operational advantages by requiring less human participation, less human training, an ability to take-off and land at any location, and the ability to react to dynamic situations.

NASA is involved in research that would greatly benefit from breakthroughs in UAS capabilities. Flight research of basic aerodynamics and advanced aero-vehicle concept would be revolutionized with an ability of UAS teams to cooperate and interact while making real time decisions based upon sensor data with little human oversight. Commercial industry would likewise be revolutionized with such abilities.

There are multiple technological barriers that are restricting greater use and application of UAS in NASA research and in civil aviation. These barriers include, but are not limited to, the lack of methods, architectures, and tools which enable:

- The verification, validation, and certification of complex and/or nondeterministic systems.
- Humans to operate multiple UAS with minimal oversight.
- Multi-vehicle cooperation and interoperability.
- High level machine perception, cognition, and decision making.
- Inexpensive secure and reliable communications.

This solicitation is intended to break through these and other barriers with innovative and high-risk research.

The Integrated Aviation Systems Program's work on UAS Technology for the FY 2015 NASA SBIR solicitation is focused on breaking through barriers to enable greater use of UAS in NASA research and in civil aviation use. The following five research areas are the primary focus of this solicitation, but other closely related areas will also be considered for reward. The primary research areas are:

- *Verification, Validation, and Certification* - New inexpensive methods of verification, validation, and certification need to be developed which enable application of complex systems to be certified for use in the national airspace system. Proposed research could include novel hardware and software architectures that

enable or circumvent traditional verification and validation requirements.

- *Operation of multiple UAS with minimal human oversight* - Novel methods, software, and hardware that enable the operation of multiple UAS by a single human with minimal oversight need to be developed which ensure robust and safe operations. Proposed research could include novel hardware and software architectures which provide guarantees of safe UAS operations.
- *Multi-vehicle cooperation and interoperability* - Technologies that enable UAS to interact in teams, including legacy vehicles, need to be developed. This includes technologies that enable UAS to negotiate with others to find optimal routes, optimal task allocations, and optimal use of resources. Proposed research could include hardware and software architectures which enable UAS to operate in large cooperative and interactive teams
- *Sensing, perception, cognition, and decision making* - Technologies need to be developed that provide the ability of UAS to detect and extract internal and external information of the vehicle, transform the raw data into abstract information which can be understood by machines or humans, and recognize patterns and make decisions based on the data and patterns.
- *Inexpensive, reliable, and secure communications* - Inexpensive methods which ensure reliable and secure communications for increasingly interconnected and complex networks need to be developed that are immune from sophisticated cyber-physical attacks.

Phase I deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
- A technology demonstration in a simulation environment which clearly shows the benefits of the technology developed.
- A written plan to continue the technology development and/or to infuse the technology into the UAS market. This may be part of the final report.

Phase II deliverables should include, but are not limited to:

- A final report clearly stating the technology challenge addressed, the state of the technology before the work was begun, the state of technology after the work was completed, the innovations that were made during the work period, the remaining barriers in the technology challenge, a plan to overcome the remaining barriers, and a plan to infuse the technology developments into UAS application.
- A technology demonstration in a relevant flight environment which clearly shows the benefits of the technology developed.
- Evidence of infusing the technology into the UAS market or a clear written plan for near term infusion of the technology into the UAS market. This may be part of the final report.

Sub Topics:

Advanced Air Traffic Management Systems Concepts Topic A3.01

This subtopic addresses user needs and performance capabilities, trajectory-based operations, and the optimal assignment of humans and automation to air transportation system functions, gate-to-gate concepts and technologies to increase capacity and throughput of the National Airspace System (NAS), and achieving high efficiency in using aircraft, airports, en route and terminal airspace resources, while accommodating an increasing variety of missions and vehicle types, including full integration of Unmanned Aerial Systems (UAS) operations.

Examples of concepts or technologies that are sought include:

- Develop verification and validation methods and capabilities to enable safe, end-to-end NextGen Trajectory-Based Operations (TBO) functionality and seamless UAS operations, as well as other future aviation system concepts and architectures.
- The development of performance requirements, functional allocation definitions, and other critical data for integrated, end-to-end NextGen TBO functionality, and seamless UAS operations, as well as other future aviation system concepts and architectures.
- Development of prognostic safety risk management solutions and concepts for emergent risks.

- Development of TBO concepts and enabling technology solutions that leverage revolutionary capabilities and that enable capacity, throughput, and efficiency gains within the various phases of gate-to-gate operations.
- Networked/cloud-based systems to increase system predictability and reduce total cost of National Airspace System operations.

It is envisioned that the outcome of these concepts and technologies will provide greater system-wide safety, predictability, and reliability through full NextGen (2025-2035 time frame) functionality.

Sub Topics:

Autonomy of the National Airspace System (NAS) Topic A3.02

Develop concepts or technologies focused on increasing the efficiency of the air transportation system within the mid-term operational paradigm (2025-2035 time frame), in areas that would culminate in autonomy products to improve mobility, scalability, efficiency, safety, and cost-competitiveness. Proposals in the followings areas in product-oriented research and development are sought, but are not limited to:

- Autonomous and safe Unmanned Aerial Vehicle (UAV) operations for the last and first 50 feet, under diverse weather conditions.
- Autonomous or increasing levels of autonomy for, or towards, any of the following:
 - Networked cockpit management.
 - Traffic flow management.
 - Airport management.
 - Metroplex management.
 - Integrated Arrival/Departure/Surface operations.
 - Low altitude airspace operations.
- Autonomy (or self-management) -based architectures for the entirety, or parts, of airspace operations.
- Autonomous systems to produce any of the following system capabilities:
 - Prognostics, data mining, and data discovery to identify opportunities for improvement in airspace operations.
 - Weather-integrated flight planning, rerouting, and execution.
 - Fleet, crew, and airspace management to reduce the total cost of operations.
 - Predictions of unsafe conditions for vehicles, airspace, or dispatch operations.
- Performance driven, all-operations, human-autonomy teaming management.
- Verification and validation tools for increasingly autonomous operations.
- Machine learning and/or self-learning algorithms for Shadow Mode Assessment using Realistic Technologies for the National Airspace System (NAS).
- Autonomy/autonomous technologies and concepts for trajectory management and efficient/safe traffic flows.
- Adaptive automation/human-system integration concepts, technologies and solutions that increase operator (pilot and or controller) efficiency and safety, and reduce workload to enable advances in air traffic movement and operations.

Sub Topics:

Future Aviation Systems Safety Topic A3.03

The Aeronautics Research Mission Directorate (ARMD) will be concluding the successful Aviation Safety Program (AvSP). The newly expanded Airspace Operations and Safety Program (AOSP) will be succeeding AvSP's significant achievements and stepping up to lead the ARMD research in the area of Real-Time System-Wide Safety Assurance (RSSA). As currently envisioned, ARMD sees its future, safety-related research focused in a forward looking, more comprehensive system-wide direction. Rather than be focused on the current National Airspace System (NAS), ARMD's RSSA will be focused towards a future NAS where a gate-to-gate trajectory-based system capability exists that satisfies a full vision for NextGen and beyond. The ultimate vision for RSSA would enable the delivery of a progression of capabilities that accelerate the detection, prognosis and resolution of system-wide threats. Proposals under this sub-topic are sought, but not limited to, these areas:

- Research and development products to address technologies, simulation capabilities and procedures for reducing flight risk in areas of attitude and energy aircraft state awareness
- Develop V&V tools and techniques for assuring the safety of air traffic applications during certification and throughout their lifecycles, and, techniques for supporting the real-time monitoring of safety requirements

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- during operation.
- Develop and demonstrate prognostic decision support tools and methods capable of supporting real-time safety assurance.

Sub Topics:
