NASA SBIR 2012 Phase I Solicitation

A3 Air Vehicle Technologies

The Vehicle Systems Technology topic solicits cutting-edge research in aeronautics to overcome technology barriers and challenges in developing highly efficient aircraft systems of the future, with limited impact to the environment. The primary objective is the development of innovative design tools, capabilities and technologies that provide design and system solutions and capabilities to meet the national goals in cleaner environment, reduced noise and highly energy efficient and revolutionary aircraft for the next generation (NextGen) air transportation system.

This topic solicits physics-based, multidisciplinary design, analysis and optimization tools and capabilities to facilitate assessment of new vehicle designs and their potential performance characteristics. These tools and capabilities will enable the best design solutions to meet the performance and environmental requirements and challenges, and technology innovations of future air vehicles. It also solicits research in revolutionary aircraft concepts; lightweight high strength structures and materials; more efficient propulsion systems; advanced concepts for high lift and low drag aircraft that meet the performance, efficiency and environmental requirements of future aircraft, and the goals of NextGen.

Beginning in FY12, this topic covers aircraft technologies formerly covered by the Fundamental Aeronautics topic as well as ground and flight test technologies formerly covered by the Aeronautics Test topic. 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 Plan (2010) and the NASA Strategic Plan (2011).

- **Fixed Wing Vehicles** - Technologies and concepts for subsonic transport aircraft, propulsion system energy efficiency and environmental compatibility supported by enabling tools and methods. Targeted challenges include drag and weight reduction for fuselages and high aspect ratio wings, quiet high performance high-lift and propulsion systems, high performance clean, alternative-fuel burning gas generators, paradigm-changing hybrid-electric propulsion systems, innovative propulsion-airframe integration concepts.

- **Rotary Wing Vehicles** - Advanced Efficient Propulsion (multi-speed lightweight rotorcraft drive trains and variable speed efficient engines), Advanced Concepts and Configurations (aerodynamically efficient
rotorcraft, NextGen configurations, and multi-fidelity design and analysis tools), and Community and Passenger Acceptance (NextGen operations and standards, and comfort and safety).

- **High Speed** - Focused on supersonic research, design, and boom mitigation techniques to achieve low boom strength and other elements that will help enable a low-boom experimental aircraft; System Integration Assessment; Supersonic Cruise Efficiency - Propulsion; Supersonic Cruise Efficiency-Airframe; Sonic Boom Modeling; and Jet Noise Research.

- **Aeronautical Sciences** - Broad, cross-cutting discipline research (e.g., some CFD and structures & materials research) that is pervasive across flight regimes, helps develop some low-level concepts and ideas, and provides program-level systems analysis capability to assess balance and impact of program-wide investments.

- **Aeronautics Test Technologies** - Focused on instrumentation, test measurement technology, test techniques, and facility development that apply to NASA aeronautics facilities to help in sustaining and improving our test capabilities at four NASA Centers: Ames Research Center, Dryden Flight Research Center, Glenn Research Center, and Langley Research Center. Classes of facilities include low speed, transonic, and supersonic wind tunnels, air-breathing engine test facilities, the Western Aeronautical Test Range (WATR), support and test bed aircraft, and simulation and loads laboratories.

### Subtopics

**A3.01 Structural Efficiency - Airframe**

**Lead Center:** LaRC

**Materials and Structural Concepts for Aeroelastically-Tailored Aircraft Wings**

The Fixed Wing and High Speed projects are focused on development of enabling technologies and advanced concepts for subsonic and supersonic cruise transport category aircraft, respectively, demonstrated to TRL 4-6 in the 2025 time frame. Both projects require simultaneous reduction of weight and drag to achieve their respective performance objectives. For subsonic transport aircraft, lift-induced drag is approximately 40% of the total drag at cruise and can be directly addressed via increased wing aspect ratio. For supersonic flight, speed requirements dictate highly swept wings with a very thin airfoil section. Both of these wing geometries, with higher aspect ratio or thinner airfoil section, result in more flexible structure that can exhibit aeroelastic instability and thus require more complicated aeroelastic design, analysis and control. The traditional solution to these aeroelastic issues has been primarily to stiffen the wing by adding additional structure, thus creating a weight penalty. Solutions that favorably modify the aeroelastic response of thin or high aspect ratio wings with no or little weight increase are needed. Furthermore, maneuverability of the vehicle is dependent upon the control authority achievable by wing-located control surfaces in traditional aircraft designs, and possibly actively tailorable portions of wings in more integrated aircraft designs. Designing the wing to have desired aeroelastic characteristics makes the wing amenable to minimal-input active control solutions to further modify the aeroelastic response. Using a building block approach in this research topic, the current solicitation focuses on materials and structural concepts for aeroelastically-tailored aircraft wings, while the more complex aeroservoelastic solution will be the subject of a future solicitation.

This solicitation topic seeks innovative materials and/or structural concepts and technologies for lightweight wings with aeroelastic tailoring, such as tailored bending and torsional stiffness as an example. Proposals should involve novel materials, processes and structural concepts with significant potential to improve the structural efficiency and reduce specific weight. Laboratory scale approaches may be proposed for proof of concept, but must be scalable.
to application across a broad range of fixed wing aircraft sizes and speeds.

Tailored stiffness may include spatial or temporal variations in stiffness achieved by a combination of passive stiffness tailoring of anisotropic or functionally graded materials, novel structural topologies, or active integrated elements to change structural and/or material properties. The use of existing design and analysis tools and techniques to the greatest extent possible is encouraged, as it is not the intent of this solicitation to develop new computational tools. Specifically, the following concepts and technologies are sought:

- Materials and processing routes to fabricate engineered materials with tailored material properties along all three axes.
- Aeroelastically-tailored structural concepts by which desired static or dynamic aeroelastic responses can be achieved.

Phase I: Identify candidate material systems and structural concepts that enable aeroelastic tailoring of wing structure for reduced weight, for example, variable bending and torsional stiffness. Assess the feasibility and benefits of the proposed concept, including scale-up, necessary material property quantification, and design trade studies. The studies must include quantification of expected structural weight benefits. Identify limiting factors and recommendations for further technology development to address the shortfalls. For novel material systems and structural concepts requiring development, conduct initial proof of concept computational studies and/or element tests.

Phase II: Perform scale-up of materials and processes as necessary, and produce a detailed structural design and hardware build of a subscale wing suitable for laboratory testing to assess structural performance of the concept. Structural testing of the subscale wing will be performed subsequently by NASA and is beyond the scope of the Phase II effort.

A3.02 Quiet Performance

Lead Center: LaRC

Innovative technologies and methods are necessary for the design and development of efficient, environmentally acceptable aircraft. In support of the Fundamental Aeronautics Program, improvements in noise prediction, measurement methods and control are needed for subsonic, transonic and supersonic vehicles targeted specifically at airframe noise sources and the interaction of airframe and engine noise. Innovations in the following specific areas are solicited:

- Fundamental and applied computational fluid dynamics techniques for aeroacoustic analysis, which can be adapted for design codes.
- Prediction of aerodynamic noise sources including those from airframe and sources which arise from
significant interactions between airframe and propulsion systems.

- 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.

- 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 aeracoustic 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.

- Development of synthesis and auditory display technologies for subjective assessments of aircraft community and interior noise, including sonic boom.

A3.03 Low Emissions/Clean Power

Lead Center: GRC

Proposals are sought which support electric propulsion of transport aircraft, which includes various hybrid electric concepts, such as gas turbine engine-battery combinations and turboelectric propulsion (turbine prime mover with electric distribution of power to propulsors). Turboelectric propulsion for aircraft applications will require high specific power (hp/lb or kW/kg) and high efficiency components. Cryogenic and superconducting components will be required to achieve high specific power and high efficiency. The cryogenic components 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 as well as low AC loss superconducting materials for the stator windings. Generators with at least 10 MW capacity and motors of 2 to 3 MW capacity are of interest. Technology is sought that can contribute to superconducting machines with specific power more than 10 hp/lb. Superconducting wires with filaments less than 10 micrometers in diameter are of interest. Ideas are also sought for achieving 2-3X increase in specific power for non-cryogenic motors through a multidisciplinary approach utilizing advanced motor designs, better materials, and new structural concepts. 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.

A3.04 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
on 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), the 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 led 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 led 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<~ 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.

A3.05 Controls/Dynamics - Propulsion Systems

Lead Center: GRC
Participating Center(s): AFRC

Propulsion controls and dynamics research is being done under various projects in the Fundamental Aeronautics Program (FAP). For turbine engines, work on Distributed Engine Control (DEC) and Model-Based Engine Control (MBEC) is currently being done under the Subsonic Fixed Wing (SFW) project, and Active Combustion Control research is currently being done under the Supersonics (SUP) project. These 3 efforts are expected to transition to the new Aeronautics Sciences (AS) project in FY13. Aero-Propulsion-Servo-Elasticity (APSE) research will continue under the SUP project. Research activity on Controls/Dynamics for electric propulsion systems is expected to be initiated in FY13 under the reformulated Fixed Wing (FW) project. Propulsion control and dynamics technologies that help achieve the goals of FAP, in terms of: reducing emissions; increasing fuel efficiency; tool and technology development and validation to address challenges in High Speed flight; and enabling fast, efficient design and analysis of advanced aviation systems, are of interest. Proposed activities that are compatible with current propulsion controls and dynamics activities supported by the FAP 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 provides control of variables of interest such as Thrust, Stall Margin etc. indirectly 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. which will achieve the same objectives as the current MBEC approach while 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, are of interest. 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. The current need is to develop a DEC test-bed which can be used to investigate a wide range of issues such as system robustness, stability and performance of various DEC architectures, the development of network communications requirements, network
performance evaluation, robustness of DEC architectures to data transmission faults and impact on system performance. The tools just described must be compatible with the NASA C-MAPSS40k simulation software and easily integrated into the Hardware-in-the-Loop research facility currently being developed under a separate contract. Restrictions on access to these technologies require that any proposed effort will be limited to work being done by U.S. citizens.

- **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-Propulsion-Servo-Elasticity (APSE)** - The objective of NASA research effort in APSE is to develop a comprehensive 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 vehicle maneuvering and atmospheric disturbances, for supersonic vehicles. Innovative approaches to dynamic modeling of supersonic external compression inlets; parallel flow path modeling of the compression and whole propulsion system to accurately model the distortion effects of flexible modes, maneuvering and atmospheric disturbances; and integration of dynamic propulsion models with aircraft simulations incorporating flexible modes, are of interest.

- **Electric Propulsion Systems** - The objective is to achieve the required increase in the specific power of high efficiency electric components to make a 10 mega-watt onboard power generation and/or utilization feasible for propulsion. Specific areas of interest are: advanced electric power control systems for energy management of battery and fuel cell systems including potentiostatic sensor array to determine battery state-of-charge (SOC) and battery cycle affected state lifetimes; advanced phase angle control systems for electric motors; and advanced power control systems for effective management of large multi-motor arrays designated for use in newer turbo-electric aircraft and embedded boundary layer electric propulsion systems.

**A3.06 Physics-Based Conceptual Design Tools**

**Lead Center:** GRC  
**Participating Center(s):** LaRC

Conceptual design and analysis of unconventional vehicle concepts and technologies is needed for technology portfolio investment planning, development of advanced concepts to provide technology pull and independent technical assessment of new concepts. The aerospace flight vehicle conceptual design phase is the most important step in the product development sequence, because of its predefining function. However, the conceptual design phase is the least well understood part of the entire flight vehicle design process, owing to its high level of abstraction and associated risk, its multidisciplinary design complexity, its permanent shortage of available design information and its chronic time pressure to find solutions. Often, the important primary aerospace vehicle design decisions at the conceptual design level (e.g., overall configuration selection) are still made using simple analyses and heuristics. Progress has been made recently in incorporating more physic-based analysis tools in the conceptual design process, especially in the aerodynamics area, and NASA has developed a capability that integrates several analysis tools and models in engineering architectures, such as ModelCenter and OpenMDAO. However, gaps still remain in many disciplines.
Developing higher order, high fidelity 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 turn around 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. Ignoring this aspect can lead to higher order tools which are lower fidelity (less accurate) than the lower order tools they are intended to replace. Another challenge in conceptual design is a lack of detailed design information. Lower order, empirical-based methods typically used in the past for conceptual design often require only gross design parameters as inputs. It is, therefore, not necessary to know design details to obtain a reasonable estimate of the design's performance. High-order, physics-based methods currently require detailed design knowledge to be useful. For example, whereas semi-empirical drag prediction tools provide estimates for wing drag without needing full 3-D geometry including an airfoil design, such detail is necessary to successfully utilize CFD tools. This gap in the analysis capability and the maturity of the design being analyzed limits the usefulness of the high order analysis in conceptual design. Physics-based tools for conceptual design must be developed which are consistent with the amount of design knowledge that is available at the conceptual design stage.

NASA continues to investigate the potential of advanced, innovative propulsion and aircraft to improve fuel efficiency (i.e, reduce CO₂ emissions) and to reduce the environmental footprint (noise and NOx) of future generations of commercial transports across the flight speed regime. As such, the agency's systems analysts need to have the best design/analysis tools possible. The intention of this sub-topic is to solicit proposals for robust, physics-based tools enabling unconventional configurations to be addressed in the conceptual design process. Specifically for 2012, the solicitation will center on new tools and methods that pertain to the propulsion system. Modeling areas where enhanced capabilities are desired include the following:

- **Electric/Turbo-electric performance & weight estimation methodologies.** Some examples:
  - Electric component performance/weight estimation.
  - Electric grid performance and analysis.
  - Thermal management analysis.

- **Enhanced propulsion system performance & weight methodologies.** Some examples:
  - Turbomachinery loss modeling.
  - "Rapid" boundary layer ingestion performance.
  - Physics-based component weight estimation.
  - Engine controls & accessories weight/volume.

- **High order environmental tools.** Some examples:
  - Sonic boom modeling.
  - Combustion emission indices generation.
  - Advanced (beyond ANOPP) acoustics models.
A3.07 Rotorcraft

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

The challenge of the Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop and validate tools, technologies and concepts to overcome key barriers for rotary wing vehicles. Technologies of particular interest are as follows:

- **Modeling and Analysis for Conceptual Design and Sizing** - Tools are sought that enable rotorcraft conceptual design and sizing for a wide range of missions. Such tools should also enable systems studies to assess technology benefits. These tools typically model the various rotorcraft components using lower fidelity, approximate and/or empirically based models, and improvements in these tools can be made through developing more accurate rotorcraft component models that are appropriate for conceptual design. The development of methodologies, tools and techniques that include rotorcraft handling qualities during conceptual design is of particular interest with topics including: flight control architecture and handling qualities measures; rotorcraft configuration and data requirements; and methods for integration into conceptual design and sizing codes and analyses. Additional topics of interest include, but are not limited to: engine and drive system models over large rotor speed ranges; auto generation of airfoil tables and analysis and optimization of airfoil sections; noise estimation methods for rotor, engine and drive systems; and airspace performance analysis tools for rotorcraft.

- **Advanced Turboshaft Engines with Variable-Speed Power-Turbine Capability** - Research (modeling, computational work, experiments) that addresses variable-speed power turbine (VSPT) and gas-generator aerothermodynamic, mechanical, and materials challenges is sought. The Rotary Wing Project of the Fundamental Aeronautics Program performs research and development of engine/driveline technologies to enable large civil tilt-rotor vehicles with variable-speed-rotor capability. Options for achieving main-rotor speed variability include a variable-speed transmission and/or a variable-speed power turbine. Key challenges for turboshaft engines of future rotary wing vehicles include high-efficiency power-turbine performance over a wide variable-speed range (50%

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

A3.08 Propulsion Efficiency - Turbomachinery Technology

Lead Center: GRC

There is a critical need for advanced turbomachinery and heat transfer concepts, methods and tools to enable NASA to reach its goals under the Fundamental Aeronautics Program. These goals include dramatic reductions in aircraft fuel burn, noise, and emissions, as well as an ability to achieve mission requirements for, Subsonic, Rotary Wing, and High Speed Project flight regimes and fundamental research under the Aeronautical Sciences Project. Turbomachinery includes rotating machinery in the high and low pressure spools, transition ducts, purge and bleed...
flows, casing and hub. In the compression system, advanced concepts and technologies are required to enable higher overall pressure ratio, high stage loading and wider operating range while maintaining or improving aerodynamic efficiency. Such improvements will enable reduced weight and part count, and will enable advanced variable cycle engines for various missions. In the turbine, the very high cycle temperatures demanded by advanced engine cycles place a premium on the cooling technologies required to ensure adequate life of the turbine component. Reduced cooling flow rates and/or increased cycle temperatures enabled by these technologies have a dramatic impact on the engine performance.

Proposals are sought in the turbomachinery and heat transfer area to provide the following specific items:

- Advanced instrumentation to enable time-accurate, detailed measurement of unsteady velocities, pressures and temperatures in three-dimensional flowfields such as found in turbomachinery components and transition ducts. This may include instrumentation and measurement systems capable of operating in conditions up to 900 °F and in the presence of shock-blade row interactions, as well as in high speed, transonic cascades. The instrumentation methods may include measurement probes, non-intrusive optical methods and post-processing techniques that advance the state-of-the-art in turbomachinery unsteady flowfield measurement for purposes of accurately resolving these complex flowfield. Instrumentation enabling measurements and characterization of unsteady turbulent flows at combustor exit temperatures that can be implemented in warm test rigs and actual engines is also included. Instrumentation specific to turbomachinery and heat transfer should be proposed under this subtopic.

- Advanced turbomachinery active and passive flow control concepts to enable increased high stage loading in single and multi-stage axial compressors while maintaining or improving aerodynamic efficiency and operability. Technologies are sought that would reduce dependence on traditional range extending techniques (such as variable inlet guide vane and variable stator geometry) in compression systems. These may include flow control techniques near the compressor end walls and on the rotor and stator blade surfaces. Technologies are sought to reduce turbomachinery sensitivity to tip clearance leakage effects where clearance to chord ratios may be on the order of 5% or above. Technologies are sought to eliminate flow separation in low pressure turbines and transition ducts, improve off-design operation and enable variable cycle operation.

- Novel turbine cooling concepts are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art. Concepts are also sought for the cooling of ceramic-based turbine materials such as ceramic matrix composite (CMC) vanes and blades.

- Computational technologies allowing accurate predictions of turbomachinery flows and heat transfer including active and passive flow control features. Advanced turbulence and LES models that can account for complex three-dimensional flows common in turbomachinery. Models of flow control devices that enable incorporating them in RANS based CFD codes. Particular interest is in CFD method based on overset moving grids that will enable flexibility in studies of small features as cooling holes and active and passive flow control devices.
NASA is committed to effective support and execution of flight research. 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 will be able to conduct flight research more effectively and also meet the challenges presented by NASA's cutting edge research and development programs. NASA's Aeronautical Test Program (ATP) supports a variety of flight regimes and vehicle types ranging from civil transports, low-speed, to high-altitude long-endurance to supersonic and access-to-space. 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 to enhance the monitoring of test aircraft safety and atmospheric conditions during flight testing.

Flight research and test capability proposals should be relevant to the following NASA aeronautical test facilities: Western Aeronautical Test Range, Aero-Structures Flight Loads Laboratory, Flight Research Simulation Laboratory, and Research Test Bed Aircraft. Proposals should address innovative methods and technologies to extend the health, maintainability and test capabilities of these flight research support facilities. Areas of interest include:

- Multi-disciplinary nonlinear dynamic systems prediction, modeling, identification, simulation, and control of aerospace vehicles.
- Test techniques for conducting in-flight boundary layer flow visualization, shock wave propagation, Schlieren photography, near and far-field sonic boom determination, atmospheric modeling.
- Active flow control techniques for performance and acoustic noise reduction.
- Intelligent health monitoring for hybrid or all electric distributed propulsion systems.
- Methods for significantly extending the life of electric aircraft propulsion energy sources (e.g., batteries).
- Innovative acoustic noise reduction technology for structural and propulsion systems.
- Techniques for manufacturing lighter, thinner, and tougher engine fan blades than current state-of-the-art.
- Verification & Validation (V&amp;V) of complex highly integrated flight systems including hardware-in-the-loop testing.
- Innovative techniques that enable safer operations of aircraft (e.g., non-destructive examination of composites through ultrasonic techniques).