A2  Fundamental Aeronautics

The Fundamental Aeronautics Program (FAP) encompasses the principles of flight in any atmosphere, and at any speed. The program develops focused technological capabilities, starting with the most basic knowledge of underlying phenomena through validation and verification of advanced concepts and technologies at the component and systems level. Physics-based, multidisciplinary design, analysis, and optimization (MDAO) tools will be developed that make it possible to evaluate radically new vehicle designs and to assess, with known uncertainties, the potential impact of innovative technologies and concepts on a vehicle's overall performance. The development of advanced component technologies will realize revolutionary improvements in noise, emissions, and performance. The program also supports NASA's human and robotic exploration missions by advancing knowledge in aeronautical areas critical to planetary Entry, Descent, and Landing. NASA has defined a four-level approach to technology development: conduct foundational research to further our fundamental understanding of the underlying physics and our ability model that physics; leverage the foundational research to develop technologies and analytical tools focused on discipline-based solutions; integrate methods and technologies to develop multi-disciplinary solutions; and solve the aeronautics challenges for a broad range of air vehicles with system-level optimization, assessment and technology integration.

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

Hypersonics (HYP)

- Fundamental research in all disciplines to enable very-high speed flight (for airbreathing launch vehicles) and Entry, Descent and Landing into planetary atmospheres

- High-temperature materials, thermal protection systems (single and multi-use), airbreathing propulsion, aero-thermodynamics, multi-disciplinary analysis and design, guidance, navigation, and control GN&C, advanced experimental capabilities, and supersonic decelerator technologies

Supersonics (SUP)
• Eliminate environmental and performance barriers that prevent practical supersonic vehicles (cruise efficiency, noise and emissions, vehicle integration and control)

Subsonic Fixed Wing (SFW)

• Develop revolutionary technologies and aircraft concepts with highly improved performance while satisfying strict noise and emission constraints

• Focus on enabling technologies: acoustics predictions, propulsion / combustion, system integration, high-lift concepts, lightweight and strong materials, GNC

Subsonic Rotary Wing (SRW)

• Improve civil potential of rotary wing vehicles (vs. fixed wing) while maintaining their unique benefits

• Key advances in multiple areas through innovation in materials, aeromechanics, flow control, propulsion

Each project addresses specific discipline, multi-discipline, sub-system and system level technology issues relevant to that flight regime. A key aspect of the Fundamental Aeronautics Program is that many technical issues are common across multiple flight regimes and may be best resolved in an integrated coordinated manner. As such, the FAP subtopics are organized by discipline, not by flight regime, with a special subtopic for rotary-wing issues.

Additional information: [http://www.aeronautics.nasa.gov/fap/index.html](http://www.aeronautics.nasa.gov/fap/index.html)

Subtopics

A2.01 Materials and Structures for Future Aircraft

Lead Center: GRC

Participating Center(s): AFRC, ARC, LaRC

Advanced materials and structures technologies are needed in all four of the NASA Fundamental Aeronautics Program research thrusts (Subsonics Fixed Wing, Subsonics Rotary Wing, Supersonics, and Hypersonics) to enable the design and development of advanced future aircraft. Proposals are sought that address specific design and development challenges associated with airframe and propulsion systems. These proposals should be linked to improvements in aircraft performance indicators such as vehicle weight, fuel consumption, noise, lift, drag, durability, and emissions. In general, the technologies of interest cover five research themes:

• **Fundamental materials development, processing and characterization** - innovative approaches to enhance the durability, processability, performance and reliability of advanced materials (metals, ceramics, polymers, composites, nanostructured materials, hybrids and coatings). In particular, proposals are sought in:
Advanced high temperature materials for aircraft engine and airframe components and thermal protection systems, including advanced blade and disk alloys, ceramics and CMCs, polymers and PMCs, nanostructured materials, hybrid materials and coatings to improve environmental durability.

Adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers, and variable stiffness materials and methods to integrate these materials into airframe and/or aircraft engine structures to change component shape, dampen vibrations, and/or attenuate acoustic transmission through the structure.

Multifunctional materials and structural concepts for engine and airframe structures, such as novel approaches to power harvesting and thermal management, lightning strike mitigating, self-sensing, and materials for wireless sensing and actuation.

New high strength fibers, in particular low density, high strength and stiffness carbon fibers.

Innovative processing methods to reduce component manufacturing costs and improve damage tolerance and reliability of ceramics, metals (especially oxide dispersion strengthened nickel-based alloys), polymers, composites, and hybrids, nanostructured and multifunctional materials and coatings.

Development of joining and integration technologies including fasteners and/or chemical joining methods for ceramic-to-ceramic, metal-to-metal, and metal-to-ceramic as well as solid state joining methods such as advanced friction stir welding.

Innovative methods for the evaluation of advanced materials and structural concepts (in particular multifunctional and/or adaptive) under simulated operating conditions, including combinations of electrical, thermal and mechanical loads.

Nondestructive evaluation (NDE) methods for the detection of as-fabricated flaws and in-service damage for textile polymeric, ceramic and metal matrix composites, nanostructured materials and hybrids. NDE methods that provide quantitative information on residual structural performance are preferred.

**Structural analysis tools and procedures** - robust and efficient design methods and tools for advanced materials and structural concepts (in particular multifunctional and/or adaptive components) including variable fidelity methods, uncertainty based design and optimization methods, multi-scale computational modeling, and multi-physics modeling and simulation tools. In particular, proposals are sought in:

Multiscale design tools for aircraft and engine structures that integrate novel materials, mechanism design, and structural subcomponent design into systems level designs.

Life prediction tools for textile composites including fiber architecture modeling methods that enable the development of physics-based hierarchical analysis methods. Fiber architecture models that address yarn-to-yarn and ply-to-ply interactions covering a wide range of textile preform structures in either a relaxed or compressed deformation state as well as tools to predict debonding and delamination of through thickness reinforced (stitched, z-pinned) composites are of particular interest.

Tools to predict durability and damage tolerance of new material forms including metallic-composite hybrids, friction stir-welded metallic materials and powder metallurgy-formed materials.

Meso scale tools to guide materials placement to enable tailored load paths in multifunctional structures for enhanced damage tolerance.
• **Computational materials development tools** - methods to predict properties, damage tolerance, and/or durability of both airframe and propulsion materials, thermal protection systems and ablative based upon chemistry and processing for conventional as well as functionally graded, nanostructured, multifunctional and adaptive materials. In particular proposals are sought in:

  - Ab-initio methods that enable the development of coatings for multiple uses at temperatures above 3000°F in an air environment.
  - Computational tool development for structure-property modeling of adaptive materials such as piezoelectric ceramics, shape memory alloys, shape memory polymers to characterize their physical and mechanical behavior under the influence of an external stimulus.
  - Computational and analytical tools to enable molecular design of polymeric and nanostructured materials with tailored multifunctional characteristics.
  - Computational microstructural and thermodynamic analysis tools and technique development for designing new lightweight alloy compositions for subsonic airframe and engines from first principles, functionally graded (chemically or microstructurally) materials, and/or novel metals processing techniques to accelerate materials development and understanding of processing-structure-property relationships.
  - Software tools to predict temperature dependent phase chemistries, volume fractions, shape and size distributions, and lattice parameters of phases in a broad range of nickel and iron-nickel based superalloys. Toolset should utilize thermodynamic and kinetic databases and models that are fully accessible, which allow modifications and user-input to expand experimental databases and refine model predictions.

• **Advanced Structural Concepts** - new concepts for airframe and propulsion components incorporating new light weight concepts as well as "smart" structural concepts such as those incorporating self-diagnostics with adaptive materials, multifunctional component concepts to reduce mass and improve durability and performance, lightweight, efficient drive systems and electric motors for use in advanced turboelectric propulsion systems for aircraft, and new concepts for robust thermal protection systems for high-mass planetary entry, descent and landing. In particular, proposals are sought in:

  - Innovative structural concepts, materials, manufacturing and fabrication leading to reliable, entry descent and landing systems including deployable rigid and flexible heat shields and structurally integrated multifunctional systems. Of particular interest are high temperature honeycombs, hat stiffeners, rigid fibrous and foam insulators, as well as high temperature adhesives, films and fabrics for advanced flexible heat shields.
  - Advanced mechanical component technologies including self lubricating coatings, oil-free bearings, and seals.
  - Advanced material and component technologies to enable the development of mechanical and electrical drive system to enable the development of turboelectric propulsion systems, which utilize power from a single turbine engine generator to drive multiple propulsive fans. Innovative concepts are sought for AC-tolerant, low loss (1.5 T field and 500 Hz electrical frequency; and high efficiency ≥30% of Carnot), low mass (
  - Novel structural designs for integrated fan cases that combine hardwall composite cases for blade containment with acoustic treatments as well as concepts that integrate the case with the fan inlet to maximize structural, acoustic attenuation and weight benefits.
  - Innovative approaches to structural sensors for extreme environments (>1800°F) including the development and validation of improved methods (i.e. adhesives, plasma spraying techniques, etc.) for attaching sensors to advanced high-temperature materials as well as approaches to measure strain, temperature, heat flux and/or acceleration of structural components.
A2.02 Combustion for Aerospace Vehicles
Lead Center: GRC
Participating Center(s): LaRC

A2.03 Aero-Acoustics
Lead Center: LaRC
Participating Center(s): ARC, GRC

A2.04 Aeroelasticity
Lead Center: LaRC
Participating Center(s): AFRC, ARC, GRC

A2.05 Aerodynamics
Lead Center: LaRC
Participating Center(s): AFRC, ARC, GRC, JSC, MSFC

A2.06 Aerothermodynamics
Lead Center: ARC
Participating Center(s): AFRC, GRC, LaRC
A2.07 Flight and Propulsion Control and Dynamics

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

Active Aeroelastic Wing Shape Tailoring for Aircraft Performance and Control

Modern aircraft are increasingly designed with lightweight, flexible airframe structures. By employing distributed flight control surfaces, a modern wing structure (which implies aircraft wing, horizontal stabilizer, and vertical stabilizer) can be strategically tailored in-flight by actively controlling the wing shape so as to bring about certain desired vehicle characteristics. For example, active aeroelastic wing shape tailoring can be employed to control the wash-out distribution and wing deflection in such a manner that could result in improved aerodynamic performance such as reduced drag during cruise or increased lift during take-off. Another novel use of active aeroelastic wing shape tailoring is for flight control. By actively controlling flexible aerodynamic surfaces differentially or collectively, the motion of an aircraft can be controlled in all three stability axes. In high speed supersonic or hypersonic vehicles, effects of airframe-propulsion-structure interactions can be significant. Thus, propulsion control can play an integral role with active aeroelastic wing shape tailoring control in high speed flight regimes.

This technology area involves the development of various technical elements including:

- Innovative aircraft concepts that can significantly improve aerodynamic performance and control by leveraging active aeroelastic wing shape tailoring.
- Sensor technology that will enable in-flight wing twist and deflection static and dynamic measurements for control development.
- Actuation methods that examine novel modes of actuation for actively controlling wing shape in-flight, and effective placements of distributed control effectors on a wing structure.
- Vehicle dynamic modeling capability for aero-propulsive-servo-elasticity that will provide a knowledge foundation upon which vehicle control and dynamics can be developed.
- Integrated approaches for active aeroelastic wing shape tailoring control with distributed control surfaces that will provide effective advanced control strategies to achieve aerodynamic performance and flight control objectives, taken into account airframe-propulsion-structure interactions that can exist in all three flight regimes.

Gust Load Alleviation Control

In a future NextGen operational concept, close separation between aircraft in super density operations could lead to more frequent wake vortex encounters. The increasing use of flexible airframe design in modern aircraft will inherently lead to a potential increase in vehicle dynamic response to turbulence and wake vortices. Gust load alleviation control technology can improve ride qualities and reduce undesired structural dynamic loading on flexible airframes that could shorten aircraft service life. Gust load alleviation control technology can be either reactive or predictive. In a traditional reactive control framework, flight control systems can be designed to provide sufficient aerodynamic damping characteristics that suppress vehicle dynamic response as rapidly as possible upon a turbulence encounter. There is a trade off, however, between increased damping for mode suppression and command-following objectives of a flight control system. Large damping ratios, while desirable for mode suppression, may result in poor flight control performance.
Predictive control can provide a novel gust load alleviation strategy for future aircraft design with lightweight flexible structures. Novel look-ahead sensor technology can measure or estimate turbulent intensity to provide such information to a predictive gust load alleviation control system which in turn would dynamically reconfigure flight control surfaces as an aircraft enters a turbulent atmospheric region. Technology development of predictive gust load alleviation control may include the following:

- Novel sensor technology for Optical Air Data Systems based on LIDAR or other novel detection methods that can measure near-field air turbulent velocity components directly in front of an aircraft in the order of one-body length scale to provide nearly instantaneous predictive capability to significantly improve the effectiveness of a gust load alleviation control system.

- Predictive gust load alleviation control technology that can reliably reconfigure flight control surfaces dynamically based on the sensor information of the near-field turbulence to mitigate the vehicle structural dynamic response upon a turbulence encounter. The predictive control strategies should be cognizant of potential adverse effects due to potential latency issues that can counteract the objective of gust load alleviation, or potential structural mode interactions due to control input signals that may contain frequencies close to the natural frequencies of the airframe.

**Modular and Distributed Control for Propulsion Systems**

Modular and flexible control architecture for propulsion systems is an essential technology, which will enable the full realization of turbine engine system performance. Distributed technology can alleviate the thermal constraints on engine control electronics by improving tolerance to elevated temperature and creating opportunities for relocating electronics to a more compatible environment. It will enable the implementation of more complex control law, paving the way for further integration of performance-enhancing control for reduced fuel burn, lower emissions, and operability. Directly, distributed control will reduce engine system weight. This is a multi-disciplinary research area involving high temperature electronics, sensing and actuation, control system integration, and engine system stability.

**A2.08 Aircraft Systems Analysis, Design and Optimization**

*Lead Center:* LaRC

*Participating Center(s):* ARC, GRC

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

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

**Design Environment Development**

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

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

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

**Variable Fidelity, Physics-Based Design/Analysis Tools**

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

**Technology Assessment and Integration**

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

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

**Evaluation of Advanced Concepts**

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

**A2.09 Rotorcraft**

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

The challenge of the Subsonic Rotary Wing thrust of the NASA Fundamental Aeronautics Program is to develop validated physics-based multidisciplinary design-analysis-optimization tools for rotorcraft, integrated with technology development, enabling rotorcraft with advanced capabilities to fly as designed for any mission. Technologies of particular interest are as follows:

**Experimental Capabilities: Instrumentation and Techniques for Rotor Blade Measurements**

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

**Acoustics: Interior and Exterior Rotorcraft Noise Generation, Propagation and Control**

Interior noise topics of interest include, but are not limited to, prediction and/or experimental methods that enhance the understanding of noise generation and transmission mechanisms for cabin noise sources (e.g., power-train noise), active and combined active/passive methods to reduce cabin noise, and novel structural systems or materials to reduce cabin noise without an excessive weight penalty. Exterior noise topics of interest include, but are not limited to, noise prediction and/or experimental methods that address the understanding of issues such as noise generation, propagation, and control. These methods may address topics such as novel or drastically improved source noise prediction methods, novel or drastically improved noise propagation methods (e.g., through the atmosphere), novel or drastically improved experimental techniques (e.g., wind tunnel testing methods, flight testing of noise abatement paths and/or maneuvering acoustics, etc.) to understand and/or control noise sources and their impact on the community. Methods should address one or more of the major noise components such as: harmonic noise, broadband noise, blade-vortex interaction noise, high-speed impulsive noise, interactional noise, and/or low frequency noise (e.g., propagation, psychoacoustic effects, etc).

**Rotorcraft Diagnostics and Condition Based Maintenance**

Health management of rotorcraft power trains is critical. Predictive, condition-based maintenance improves safety, decreases maintenance costs, and increases system availability. Topics of interest include algorithm development, software tools and innovative sensor technologies to detect and predict the health and usage of rotorcraft dynamic mechanical systems in the engine and drive system. Automatic rotor imbalance detection and rotor smoothing is also of interest. Additionally, rotorcraft health management technologies can include, but are not limited to, tools to: increase fault detection coverage and decrease false alarm rates; detect onset of failure, isolate damage, and assess damage severity; predict remaining useful life and maintenance actions required; integration of health monitoring information with maintenance processes and procedures; data management and automated techniques to acquire/process diagnostic information; system models, material failure models and correlation of failure under bench fatigue, seeded fault test and fielded data; data collection/management for analysis of operational data; in-flight pilot cueing and warning of impending catastrophic events.

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

**A2.10 Propulsion Systems**

**Lead Center: GRC**

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

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

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

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

- **Advanced flow analysis tools** to enable design optimization of highly loaded compression systems that can accurately predict aerodynamic efficiency and operability. This includes computer codes with updated models for losses, turbulence, and other models that can simulate the flow through turbomachinery components with advanced design features such as swept and bowed blade shapes, flow range extension techniques, such as flow control and transition control to maintain acceptable operability and efficiency.

- **Novel turbine cooling concepts** are sought to enable very high turbine cooling effectiveness especially considering the manufacturability of such concepts. These concepts may include film cooling concepts, internal cooling concepts, and innovative methods to couple the film and internal cooling designs. Concepts proposed should have the potential to be produced with current or forthcoming manufacturing techniques. The availability of advanced manufacturing techniques may actually enable improved cooling designs beyond the current state-of-the-art.

- **Methods** are sought to enable more efficient use of coolant air in the turbine through coolant flow modulation. These methods could consist of open-loop or closed-loop coolant flow modulation. Modulations could be high frequency with frequencies on the order of the turbine blade passing frequency or longer time scales on the order of engine thermal transients. Development of methods to measure turbine local and/or average surface temperatures to enable the closed-loop capability will be considered. Feedback control of the coolant flow rates and/or methods to produce modulation in actual turbine thermal environments are desired. Finally, a description of how the proposed technology will work in a vision modulated turbine cooling turbine system will be needed.

**Propulsion Integration**

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

One objective of the Subsonic Fixed Wing Project is to develop verified analysis capabilities for the key technical issues related to integrating embedded propulsion systems for “N+2” hybrid wing/body configurations. These key
technical issues include: inlet technologies for distorted engine inflows related to embedded engines with boundary layer ingestion; fan-face flow distortion and its effects on fan efficiency and operability, noise, flutter stability and aeromechanical stress and life; wide operability of the fan and core with a variable area nozzle; issues related to the implementation of a thrust vectoring variable area nozzle; and duct losses related to long flow paths associated with embedded engines. Specifically, proposals are sought to provide advanced technology, prediction methods and tools. The supersonics project would like proposals to develop tools and propulsion technologies that will enable the design of high performance fans; high-efficiency, low-boom, and stable inlets; high-performance, low-noise exhaust nozzles; and intelligent sensors and actuators for supersonic aircraft. The supersonics project is interested in both computational and experimental research, aimed at evaluating and analyzing promising technologies as well as understanding the fundamental flow physics that will enable improved prediction methods.

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

For Propulsion Integration, topics will be solicited for design concepts and analysis tools that enable:

- Technologies and/or concepts to enable integrated, high-performance, lightweight supersonic inlets and nozzles that have minimal impact on an aircraft's sonic boom signature.
- Technologies and/or concepts to enable high-pressure recovery, low distortion and low-weight subsonic diffusers.
- Practical, validated CFD models for flow control devices such as micro-ramps, vaned vortex generators, air jets, or synthetic jets.
- The reduction of system complexity of turbine-based combined-cycle propulsion systems.
- The rapid assessment of CFD solutions (e.g. automatically interpolating numerical solutions to the measurement locations, generating "metrics of goodness" for parameters of interest, etc.).
- Develop methodologies that provide installed propulsion performance, specifically nozzle conceptual level design/analysis methods, capable of addressing conventional and unconventional nozzle geometries. Geometries should be valid for subsonic, supersonic, and hypersonic flight applications. Documentation of methodologies should include: underlying theory and mathematical models, computational solution methods, source-code, validation data, and limitations.