NASA SBIR 2011 Phase I Solicitation

A2.07 Flight and Propulsion Control and Dynamics

Lead Center: ARC

Participating Center(s): AFRC, GRC, LaRC

NASA is conducting fundamental aeronautic research to develop innovative ideas that can lead to next generation aircraft design concepts with improved aerodynamic efficiency, lower emissions, less fuel burn, and reduced noise and carbon footprints. To realize these potential benefits, innovative vehicle design concepts can exhibit many complex modes of interactions due to many different effects of flight physics such as aerodynamics, vehicle dynamics, propulsion, structural dynamics, and external environment in all three flight regimes. Advanced flight control strategies for innovative aircraft design concepts are seen as an enabling technology that can harvest potential benefits derived from these complex modes of interaction. The following technology areas are of particular interest:

Active Aeroelastic Wing Shape Tailoring for Aircraft Performance and Control

Modern aircraft are increasingly designed with light-weight, 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.

Technology development of active aeroelastic wing shape tailoring may include, but are not limited to the following:

- 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 include novel modes of operation and concepts of actuation for actively controlling wing shape in-flight.
- Vehicle dynamic modeling capability that includes effects of aero-propulsive-servo-elasticity for vehicle control and dynamics.
- Integrated approaches for active aeroelastic wing shape tailoring control with novel control effector concepts that will provide multi-objective advanced optimal or adaptive control strategies to achieve simultaneously aerodynamic performance such as trim drag reduction, aeroelastic stabilization or mode suppression, and load limiting.

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. Airframe flexibility 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 light-weight 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, but are not limited to the following:

- Novel sensor methods 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 approaches or other effective methods 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.

Advanced Control Concepts for Propulsion Systems

Enabling high performance "Intelligent Engines" will require advancement in the state of the art of propulsion system control. Engine control architectures/methods need to be developed that provide a tighter bound control on engine parameters for improved propulsion efficiency while maintaining safe operation. The ability of the controller to maintain its designed improvement of engine operation over the entire life and particular health condition of the propulsion system is critical. The controller needs to adapt to the specific health conditions of each engine to eventually allow for a "personalized" control, which will maintain the most efficient operation throughout the engine lifetime and increase the useful operating life. Possible advanced engine control concepts could include:

- Direct nonlinear control design such as predictive model based methods to directly control engine thrust while maintaining safety limits such as stall margins.
- Model-Based Multivariable control to allow direct control of quantities of interest such as thrust, temperature and stall margins while using all available actuators for feedback.
- Adaptive control schemes to maintain robust performance with changing engine condition with usage.