NASA SBIR 2015 Phase I Solicitation

A1.07 Efficient Propulsion and Power

Lead Center: GRC

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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:*Â*

- *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.