NASA SBIR 2015 Phase I Solicitation

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:Â

- 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.