NASA SBIR 2019 Phase I Solicitation

A1.05 Computational Tools and Methods

Lead Center: LaRC

Participating Center(s): ARC, GRC

Technology Area: TA15 Aeronautics

Computational Fluid Dynamics (CFD) plays an important role in the design and development of a vast array of aerospace vehicles, from commercial transports to space systems. With the ever-increasing computational power and the usage of higher fidelity, fast CFD tools and processes will significantly improve the aerodynamic performance of airframe and propulsion systems, as well as greatly reduce non-recurring costs associated with ground-based and flight testing. Historically, the growth of CFD accuracy has allowed NASA and other organizations, including commercial companies, to reduce wind tunnel and single engine component tests. Going forward, increased CFD fidelity for complete vehicle or engine configurations holds the promise of significantly reducing development costs by enabling certification by analysis. Confidence in fast, accurate CFD allows engineers to reach out of their existing design space and accelerate technology maturation schedules.

NASA's CFD Vision 2030 Study (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140003093.pdf) highlighted the many shortcomings in the existing technologies used for conducting high-fidelity simulations and made specific recommendations for investments necessary to overcome these challenges. One of the technology areas recognized by the vision study is computational tools for knowledge extraction and visualization of simulation data. Managing the vast amounts of data generated by current and future large-scale simulations will continue to be problematic and is becoming increasingly complex due to changing high performance computing (HPC) hardware. These include effective, intuitive, and interactive visualization of high-resolution simulations, real time analysis and management of large data bases generated by these simulations. Currently, there is no NASA program or project that is directly funding this technology area. However, various programs and projects of NASA missions use CFD for advanced aircraft concepts, launch vehicle design, and planetary entry vehicles. Therefore, the developed technology will enable design decisions by Aeronautics Research Mission Directorate (ARMD) and Human Exploration Operations Mission Directorate (HEOMD).

As HPC systems become faster and more efficient, a single unsteady high-fidelity CFD simulation using more complicated physical models to solve for the flow about a complete aerospace system (e.g., airplane with full engine simulation, aircraft in maneuvering flight, space vehicle launch sequence, etc.), using a much higher number of grid points (~10-100 billion), will become commonplace in the 2030 timeframe. Effective use (visualization and in-situ analysis) of these very large high-fidelity CFD simulations will be paramount. Software and hardware methods to handle data input/output (I/O), memory, and storage for these simulations on emerging HPC systems must improve. Likewise, effective CFD visualization software algorithms and innovative information presentation, particularly for solutions obtained by using high-order methods, are also lacking. Continually increasing HPC capabilities will allow for the rapid and systematic generation of a large number (perhaps, thousands) of CFD simulations for flow physics exploration, trend analysis, experimental test design, design space exploration, etc.

The main goal of this subtopic will be to collect, synthesize, and interrogate this large array of computational data to make engineering decisions in real time. This is complicated by a lack of data standards which makes collection and analysis of results from different codes, researchers, and organizations difficult, time consuming, and prone to error. At the same time, there are no robust and effective techniques for distilling the important information contained in large collections of CFD simulation data into reduced-order models or meta-models that can be used for rapid predictive assessments of operational scenarios, such as the correlation of flow conditions with vehicle performance degradation or engine component failures, or assessments of engineering trade-offs as is required in typical design studies.

Thus, there are a number of technology gaps and impediments that must be overcome to efficiently analyze and utilize CFD simulations in the 2030 timeframe, and this solicitation seeks innovative approaches to overcome the challenges associated with knowledge extraction. Proposers can address one or more technology areas addressed above within the overall knowledge extraction and data analytics topic. The final deliverable will be a software tool that could be used in conjunction with fluid dynamic simulations—including multidisciplinary, such as aeroelastic - to extract information of relevance to NASA missions.

Another focused technology area for which innovative proposals are solicited requires the development of an automated aircraft drag optimization method using knowledge-based design tools. Current aircraft design methods are usually based on computationally intensive optimization approaches that are slow, or faster knowledge-based methods that can improve designs but may not find the optimal solution. The proposer shall develop a fast CFD-based design optimization method that couples NASA's CDISC (https://software.nasa.gov/software/LAR-18693-1) knowledge-based design tools with an optimization driver framework to enable rapid drag-based optimization. The method shall include robust mesh movement capabilities. The new design optimization method shall be demonstrated for configurations of interest to NASA aeronautics programs (http://www.aeronautics.nasa.gov/programs.htm). The deliverable shall be a software tool for computationally efficient design optimization studies.

The expected Technology Readiness Level (TRL) range at completion of the project is between 3-6.

References:

- https://www.nasa.gov/aeroresearch/programs/aavp
- https://www.nasa.gov/aeroresearch/programs/tacp