NASA SBIR 2021 Phase I Solicitation

A1.08  Aeronautics Ground Test and Measurement Technologies

Lead Center: LaRC

Participating Center(s): ARC, GRC

Boundary Layer Velocity Profile Measurement On Models in Wind Tunnels

NASA’s aeroscience ground test facilities include wind tunnels, air-breathing engine test facilities, and simulation and loads laboratories. They play an integral role in the design, development, evaluation, and analysis of advanced aerospace technologies and vehicles. These facilities provide critical data and fundamental insight required to understand complex phenomena and support the advancement of computational tools for modeling and simulation. The primary objective of the Aeronautics Ground Test and Measurements Technologies subtopic is to develop innovative tools and technologies that can be applied in NASA’s aeroscience ground test facilities to revolutionize testing and measurement capabilities and improve utilization and efficiency. Of primary interest are technologies which can be applied to NASA’s portfolio of large-scale ground test facilities.

Spatially and temporally resolved velocity measurements are sought to study boundary layers on test articles in NASA’s large-scale ground test facilities. Proposed measurement capabilities could be used to measure boundary layer thickness, velocity profiles, and transition from laminar to turbulent flow, as well as detecting flow separation that could potentially be used for flow control. Measurement systems should be reliable and robust enough to be implemented in various wind tunnel facilities such as the National Transonic Facility, the 11-Foot Transonic Unitary Plan Facility, the Transonic Dynamics Tunnel, and 8- by 6-Foot Supersonic Wind Tunnel. These facilities operate using a variety of media, including air, nitrogen, and other gases such as R134a.

Technology for measuring boundary layers on models in cryogenic wind tunnels is relatively undeveloped so innovative techniques which can operate at cryogenic conditions are especially of interest. In one potential application in a transonic cryogenic wind tunnel, the boundary layer thickness can be as small as 0.1 mm (e.g., on a wing) but could be as large as 10 mm (e.g., on a fuselage). In this same application, the flow velocity could range from -50 to 200 m/sec. While light projection and remote detection capabilities will be considered, fiber optic light delivery could be advantageous, particularly if the fiber optic transmission could utilize an existing pressure tap (or multiple taps) in the wind tunnel model. Scattering from light transmitted by a fiber optic embedded in the model could be detected by a remote, high magnification detection system or locally on the model (though that would result in additional cost to modify the wind tunnel model, which is less attractive).

Discrete sensor systems could be proposed that both transmit and collect light from a single location. Considerations for selection include the following: the ability to measure at multiple spatial locations, with
higher spatial resolution, with higher temporal resolution, over a wider range of conditions, with higher accuracy and higher precision, and probes with potential for measuring multiple parameters (multiple velocity components or temperature, density, or other). Molecular- and particle-based approaches will also be considered. Such a sensor may have medical or industrial applications. Plans for device calibration and risk mitigation should be provided. Expected accuracy, precision, and spatial and temporal resolution should be estimated.

**Expected TRL or TRL Range at completion of the Project:** 2 to 5

**Primary Technology Taxonomy:**
Level 1: TX 13 Ground, Test, and Surface Systems
Level 2: TX 13.X Other Ground, Test, and Surface Systems

**Desired Deliverables of Phase I and Phase II:**

- Prototype
- Hardware

**Desired Deliverables Description:**

Phase I: The desired deliverable would be a detailed system design for measuring thin boundary layers on model surfaces in both air and cryogenic conditions. This concept or system design should preferably be verified by simulation or testing and capable of being developed into a prototype system as part of a Phase II effort.

Phase II: Desired deliverables include a prototype system to measure boundary layers on a representative aerodynamic surface at room and cryogenic temperatures, a robust process for calibrating the system, and well-documented results from functional/operation tests including quantified uncertainty. It is anticipated that the technology would be demonstrated in a NASA ground-based test facility as part of the Phase II effort or shortly thereafter under Phase III funding.

**State of the Art and Critical Gaps:**

As NASA continues in the quest to advance computational methods and predictive tools as part of CFD 2030, one of the nemeses to significant advancement and validation is the lack of velocity information in the boundary layer. At both low and high speeds, making this measurement requires probe-based systems to be positioned close to the surface or optical-based systems to be focused near the surface. This is quite challenging due to (1) the thickness of the boundary layer, which can be as small as 0.1 mm, (2) conditions on the surface of the test article, (3) vibration of the test article, and (4) drastic temperature changes in the wind tunnel, which can range from room temperature to as low as -200 °C at cryogenic temperatures. There is currently no measurement system available to measure thin boundary layers, especially at cryogenic conditions, and NASA’s inability to obtain this critical data in ground-based facilities at near-flight Reynolds numbers limits the validation of numerical simulations and predictive tools for use in design and certification by analysis. The proposed technology could possibly have application on flight vehicles and in the medical field as well.

**Relevance / Science Traceability:**

The Transformational Tools and Technologies Project would use this technology to provide critical data to validate computational tools at near-flight Reynolds numbers as it pursues technical challenges to realize the CFD 2030 Vision and enable new aerospace vehicles to be certified by analysis. The technology would also have application for tests supporting the Advanced Air Transport Technology Project, the Commercial Supersonic Technology Project, the Revolutionary Vertical Lift Technology Project, and the Aerosciences Evaluation and Test Capabilities (AETC) Portfolio.

**References:**

https://www.nasa.gov/aeroresearch/programs/aavp/aetc/ground-facilities
https://ntrs.nasa.gov/search.jsp?R=20140003093

**Scope Title:**
Measurement Technologies for Vertical Lift Configurations and Concepts

Scope Description:

NASA is currently evaluating new vertical lift configurations and concepts to enable Advanced Air Mobility (AAM). The measurement capabilities needed for AAM research are varied depending on whether model- or full-scale test articles are involved, whether wind tunnel or flight testing is conducted, and whether customized or off-the-shelf hardware is utilized. Nevertheless, vertical lift concepts will require new methods of providing real-time or near real-time measurements of rotor blade and vehicle performance including blade surface pressure distributions, boundary layer transition, rotor performance and blade position, rpm/phasing measurements, rotor control positions (cyclic pitch and flapping) and off-body flow field measurements for examining multiblade vortex interactions and wake/fuselage interaction. Current capabilities for obtaining these data are limited due to lower sampling rates and spatial resolutions using remote sensing. Technologies are needed to (1) increase the temporal and spatial resolutions of remotely sensed/wireless measurements and (2) bring these remotely sensed/wireless measurements onboard the vehicle or test article, where possible, to allow data to be efficiently acquired across a range of operational envelopes. Instrumentation that can be embedded in the blades and fuselage or added to off-the-shelf vehicle or model hardware with efficient data telemetry are desired.

Expected TRL or TRL Range at completion of the Project: 2 to 5

Primary Technology Taxonomy:
Level 1: TX 13 Ground, Test, and Surface Systems
Level 2: TX 13.X Other Ground, Test, and Surface Systems

Desired Deliverables of Phase I and Phase II:

- Prototype
- Hardware
- Research

Desired Deliverables Description:

Phase I: The desired deliverable would be a detailed system design to enable remotely sensed/wireless measurements of blade surface pressure distributions, boundary layer transition, rotor performance and blade position, and off-body measurements. The system should enable efficient acquisition of performance data across the operating envelope of a representative AAM vehicle or model.

Phase II: Desired deliverables for Phase II include demonstration of a prototype system on a representative AAM vehicle, model, or test stand of the offeror's choosing or in collaboration with NASA during a Revolutionary Vertical Lift Technology- (RVLT-) sponsored test.

State of the Art and Critical Gaps:

As part of the AAM mission, NASA is seeking to develop vehicle concepts and technologies to define requirements and standards that address key challenges such as safety, affordability, passenger acceptability, noise, automation, etc. Evaluation of these concepts and technologies will inherently depend on the same type of vehicle performance data typically used to assess the performance of larger-scale vehicles. Unfortunately, the same measurement techniques used for larger-scale vehicles are not directly applicable to AAM vehicles due to the reduced scale and unique design. As such, new measurement capabilities are needed that can be applied or added to vehicles or models during and after development.

Relevance / Science Traceability:

This technology would help fulfill the vision of the Revolutionary Vertical Lift Technology (RVLT) Project to create a future where vertical takeoff and landing (VTOL) configurations operate quietly, safely, efficiently, affordably, and routinely as an integral part of everyday life. This scope has been endorsed by the RVLT Project Manager as well as the Technical Leads in RVLT for Validation Test Campaigns.
The system might also have application to other types of flight and ground-based testing within the NASA Enterprise. This would fall under the purview of the Aerosciences Evaluation and Test Capabilities (AETC) Project.

References:

https://www.nasa.gov/aam

https://www.nasa.gov/aeroresearch/programs/aavp/rvlt

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