Aeronautics Ground Test and Measurement Technologies

Lead Center: LaRC

Participating Center(s): ARC, GRC

Scope Title
Electromagnetic Interference (EMI) Detection and Mitigation in Higher Voltage/Higher Power Applications

Scope Description
NASA is developing electric-powered aircraft under both the Electrified Aircraft Propulsion Technologies (EAPT) and Revolutionary Vertical Lift Technology (RVLT) projects, where testbeds are being used to investigate system interactions and power quality (PQ) to feed associated standards for these classes of vehicles. NASA is also working with the Federal Aviation Administration (FAA) to provide pertinent data for drafting of the certification processes. As part of the testbed development, NASA is in need of EMI and PQ test equipment for higher voltage/higher power applications, which does not currently exist. Additionally, NASA is investigating the use of fiber-Bragg-grating- (FBG-) based temperature sensors for monitoring temperatures in electric-powered vehicles, both in the electric motors and in the aircraft thermal management systems being developed. While the fiber optic sensing of temperature is immune to EMI, the interrogators used to send the broadband pulses of light down the fiber and process the reflected return signals to measure the temperature at the FBG locations along the fiber are currently not immune to EMI. The objective of the Small Business Innovation Research (SBIR) subtopic is twofold: first to develop EMI and PQ test equipment, and secondly, to develop EMI immune optical interrogators for use on electrified aircraft. For RVLT applications, the requirements are to develop EMI equipment (power amplifiers, isolation transformers, ripple and surge injection units, etc.) and power equipment (power amplifiers, isolation transformers, fault injection units, dynamic load banks, and wide bandwidth emulators/power supplies) capable of testing systems/loads with operating voltages of at least 650 Vdc (1 kV preferred), 150 A (300 A preferred), with minimum bandwidths of direct current (DC) to 250 kHz (although may vary depending on application), and operating up to altitudes of 15,000 ft. The 250 kHz is of interest for investigation of EMI noise. For EAPT applications, the requirements are to develop similar EMI and power equipment capable of testing systems/loads with operating voltages of at least 1 kVdc and 1 kA, with a bandwidth of DC to 50 kHz and operating at altitudes up to 35,000 ft. EAPT also seeks to develop optical interrogators with a nominal optical bandwidth of at least 40 nm and a high spectral resolution (1 pm) that are immune to EAPT-specified level of EMI above. These high-EMI environments are endemic to both ground- and flight-based hybrid electric systems, and, hence, will have applicability to both test regimes. Initial systems for ground testing will not be constrained by weight, however, future flight-based systems should also be designed for minimized system weight and size.

Expected TRL or TRL Range at completion of the Project
4 to 6

Primary Technology Taxonomy
Level 1

TX 01 Propulsion Systems

Level 2

TX 01.3 Aero Propulsion

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

- Research
- Analysis
- Prototype
- Hardware

**Desired Deliverables Description**

The desired deliverables for Phase I would be, at a minimum, detailed design and analysis of proposed equipment. An added benefit would be the build of breadboard units to validate the proposed approach. The desired deliverables for Phase II would be prototype hardware validated through test.

**State of the Art and Critical Gaps**

EMI and PQ test equipment for these higher voltage/higher power applications does not exist. With the advent of electrified aircraft efforts, this type of test equipment will be critical in evaluating safety and system interaction aspects for the myriad of designs being proposed for the urban air mobility market.

**Relevance / Science Traceability**

This scope ties directly to Aeronautics Research Mission Directorate (ARMD) via the RVLT project by providing technology critical for evaluating architectures under investigation at NASA, and most likely would also have application to the larger aircraft testbed under development through EAPT.

**References**

ARMD Strategic Implementation Plan: [https://www.nasa.gov/aeroresearch/strategy](https://www.nasa.gov/aeroresearch/strategy)

**Scope Title**

Flow Diagnostics for High-Speed Flows

**Scope Description**

Spatially and temporally resolved, molecular-based diagnostics are sought for high-speed wind tunnel flows (supersonic, hypersonic), both with and without combustion. Improved measurement capabilities are needed for velocity, temperature, density, and/or species concentrations in harsh wind tunnel environments, from short-duration (~msec) to long-duration (~min) flow facilities. Measurement systems should be reliable and robust and preferably would be able to be implemented in multiple wind tunnel facilities and facility types including blowdown tunnels, combustion-heated tunnels, shock tubes, shock tunnels, and arc jets. Planar or volumetric, spatially resolved measurements are preferred. Ability to measure multiple parameters simultaneously is desirable. The ability to time-resolve unsteady flows so that frequency spectra of the measured phenomena can be obtained is also desirable. Measurement systems should be validated against accepted standards (thermocouples, calibration flames, etc.) to determine measurement accuracy and precision. Proposals should project anticipated accuracies and precisions of the proposed measurement system(s) based on prior cited or demonstrated work.

One area of emphasis is measurement of temperature, water vapor concentrations, and velocity at the nozzle exit of large (up to 8-ft diam.) hypersonic tunnels to quantify facility performance and to determine test article inflow...
conditions. Such flow fields may contain water droplets and the size, quantity, and distribution of these droplets is also of interest to NASA. Measurements are needed at high repetition rates (tens of kilohertz) and should be able to operate continuously or repeatedly for a duration of several minutes to obtain appropriate amount of data to improve statistical error and provide detailed information about the time varying nature of these flow fields. The technologies described above are all critical for evaluating and analyzing high-speed vehicle concepts and technologies in support of several different NASA missions.

**Expected TRL or TRL Range at completion of the Project**

4 to 7

**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**

- Hardware
- Prototype
- Analysis
- Research
- Software

**Desired Deliverables Description**

The deliverables for the Phase I research should include proof of concept of proposed idea along with a design for the comprehensive system that would be developed in Phase II, including detailed analysis of the expected performance (spatial resolution, time response, accuracy, precision, etc.). The expected deliverables at the end of the Phase II effort is a usable system to be deployed in a NASA facility and training for NASA personnel. Demonstration of the measurement system in a NASA facility would be beneficial and strongly encouraged.

**State of the Art and Critical Gaps**

There are very limited technologies for measuring nozzle exit conditions in hypersonic facilities. Some systems exist but there have been very limited applications. A technology that can measure nozzle exit conditions could also be used for engine inlet and outflow conditions as well. A promising technology was developed and used to study aircraft engine outflow plumes using Air Force Small Business Innovation Research (SBIR) support. This included using an array of laser beams to perform absorption spectroscopy at the exit of a J-85 jet engine. Temperature and water vapor concentrations were measured over an ~1- by 1-m area. A gap in this technology is that the gas velocity, a highly desirable parameter, was not measured. Another gap that exists is the need expressed by facility managers and customers at some of the larger combustion-heated hypersonic facilities at NASA to measure water vapor droplet size and concentration (water droplets are an undesirable consequence of combustion heating and can affect engine performance).

**Relevance / Science Traceability**

The target application of this technology is in facilities like the 8-Foot High-Temperature Tunnel at NASA Langley. However, the technology also has other applications such as measuring inflow or outflow for engines being tested at NASA Glenn. The technology could also be applied to measure inflow conditions in other types of facilities like shock tube and shock tunnels as well as conventional aeronautical testing facilities.
References

ARMD Strategic Implementation Plan: https://www.nasa.gov/aeroresearch/strategy