Scope Title
Advanced Instrumentation for Rocket Propulsion Testing

Scope Description
Rocket propulsion system development is enabled by rigorous ground testing to mitigate the propulsion system risks inherent in spaceflight. Test articles and facilities are highly instrumented to enable a comprehensive analysis of propulsion system performance. Advanced instrumentation has the potential for substantial reduction in time and cost of propulsion systems development, with substantially reduced operational costs and evolutionary improvements in ground, launch, and flight system operational robustness.

Advanced instrumentation would provide a wireless, highly flexible instrumentation solution capable of measurement of heat flux, temperature, pressure, strain, and/or near-field acoustics. Temperature and pressure measurements must be acquired from within the facility mechanical systems or the rocket engine itself. These advanced instruments should function as a modular node in a sensor network, capable of performing some processing, gathering sensory information, and communicating with other connected nodes in the network. The collected sensor network must be capable of integration with data from conventional data acquisition systems adhering to strict calibration and timing standards to support static propulsion system testing standards. Synchronization with Inter-Range Instrumentation Group (IRIG-B) and National Institute of Standards and Technology (NIST) traceability is critical to propulsion test data analysis.

Rocket propulsion test facilities also provide excellent testbeds for testing and using the innovative technologies for possible application beyond the static propulsion testing environment. These sensors would be capable of addressing multiple mission requirements for remote monitoring such as vehicle health monitoring in flight systems, autonomous vehicle operation, or instrumenting inaccessible measurement locations, all while eliminating cabling and auxiliary power. It is envisioned this advanced instrumentation would support sensing and control applications beyond those of propulsion testing. For example, inclusion of expert system or artificial intelligence technologies might provide great benefits for autonomous operations, health monitoring, or self-maintaining systems.

This subtopic seeks to develop advanced wireless instrumentation capable of performing some processing, gathering sensory information and communicating with other connected nodes in the network. Sensor systems must provide the following functionality:

- Wireless acquisition and conversion to engineering units for quantifying heat flux, temperature, pressure, strain, and/or near-field acoustics such that it contributes to rocket engine system performance analysis.
within established standards for error and uncertainty.

- Self-contained to collect information and relay measurements through various means by a sensor-web approach to provide a self-healing, autoconfiguring method of collecting data from multiple sensors, and relaying for integration with other acquired datasets.
- Function reliably in extreme environments, including rapidly changing ranges of environmental conditions, such as those experienced in space. These ranges may be from extremely cold temperatures, such as cryogenic temperatures, to extremely high temperatures, such as those experienced near a rocket engine plume.
- Capable of in-place calibrations with NIST traceability.
- Collected data must be time-stamped to facilitate analysis with other collected datasets.
- Transfer data in real time to other systems for monitoring and analysis.
- Interface to flight-qualified sensor systems, which could be used for multivehicle use.
- Determine the quality of the measurement and instrument state of health.

This subtopic is specifically not interested in structural health monitoring applications; specifically, Fiber-Bragg-related sensors, which have been under development for a few decades. Those type of proposals will be considered outside of the scope for this subtopic.

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

3 to 6

**Primary Technology Taxonomy**

**Level 1**

TX 13 Ground, Test, and Surface Systems

**Level 2**

TX 13.1 Infrastructure Optimization

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

- A Prototype
- A Hardware
- A Software

**Desired Deliverables Description**

For all above technologies, research should be conducted to demonstrate technical feasibility with a final report at Phase I and show a path towards Phase II hardware/software demonstration with delivery of a demonstration unit or software package for NASA testing at the completion of the Phase II contract.

**State of the Art and Critical Gaps**

Highly modular, remote sensors are of interest to many NASA tests and missions. Real-time data from sensor networks reduces risk and provides data for future design improvements. Wireless sensors offer a highly flexible solution for scientists and engineers to collect data remotely. They can be used for thermal, structural, and acoustic measurement of systems and subsystems and also provide emergency system halt instructions in the case of leaks, fire, or structural failure. Other examples of potential NASA applications include (1) measuring temperature, strain, voltage, and current from power storage and generation systems, (2) measuring pressure, strain, and temperature in pumps and pressure vessels, and (3) measuring strain in test structures and ground support equipment and vehicles, including high-risk deployables.

There are many other applications that would benefit from increased real-time sensing in remote hard-to-test locations. For example, sensor networks on a vehicle body can give measurement of temperature, pressure, strain, and acoustics. This data is used in real time to determine safety margins and test anomalies. The data is also used
post-test to correlate analytical models and optimize vehicle and test design. Because these sensors are small and low mass, they can be used for ground test and for flight. Sensor module miniaturization will further reduce size, mass, and cost.

No existing wireless sensor network option meets NASA’s current needs for flexibility, size, mass, and resilience to extreme environments.

**Relevance / Science Traceability**

This subtopic is relevant to the development of liquid propulsion systems development and verification testing in support of the Human Exploration and Mission Operations Directorate. It supports all test programs at Stennis Space Center (SSC) and other propulsion system development centers, and potential advocates are the Rocket Propulsion Test (RPT) Program Office and all rocket propulsion test programs at SSC.

**References:**

7. Overview of Rocket Propulsion Testing at NASA Stennis Space Center, [https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20040053475.pdf](https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20040053475.pdf)
8. The E-3 Test Facility at Stennis Space Center: Research and Development Testing for Cryogenic and Storable Propellant Combustion Systems, [https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090026441.pdf](https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090026441.pdf)