NASA SBIR 2022 Phase I Solicitation

H10.01 Advanced Propulsion Systems Ground Test Technology

Lead Center: SSC

Participating Center(s): KSC

Scope Title
Advanced Propulsion Test Technology Development

Scope Description
Rocket propulsion development is enabled by rigorous ground testing to mitigate the propulsion system risks that are inherent in spaceflight. This is true for virtually all propulsive devices of a space vehicle including liquid and solid rocket propulsion, chemical and nonchemical propulsion, boost stage, in-space propulsion, and so forth. It involves a combination of component and engine-level testing to demonstrate the propulsion devices were designed to meet the specified requirements for a specified operational envelope over robust margins and shown to be sufficiently reliable prior to its first flight.

This topic area seeks to develop advanced ground test technology components and system-level ground test systems that enhance chemical and advanced propulsion technology development and certification. The goal is to advance propulsion ground test technologies to enhance environment simulation; minimize test program time, cost, and risk; and meet existing environmental and safety regulations. It is focused on near-term products that augment and enhance proven, state-of-the-art propulsion test facilities. This project is especially interested in ground test and launch environment technologies with potential to substantially reduce the costs and improve safety/reliability of NASA's test and launch operations.

In particular, current technology needs include advanced computational simulation capabilities for robust and rapid modeling of large-scale high-speed chemical reacting multiphase flows, and advanced instruments and monitoring systems capable of operating in those extreme temperature and harsh environments. For example, this might include applications such as launch or test stand rocket plume deflectors which involve shock-laden rocket exhaust plumes impinging and mixing with water sprays and pools.

This subtopic seeks innovative technologies in the following areas:

- Development of innovative rocket test facility components (e.g., valves, flowmeters, actuators, tanks, etc.) for ultra-high pressure (>8,000 psi), high flow rate (>100 lbm/sec), and cryogenic environments.
- Robust and reliable component designs that are oxygen compatible and can operate efficiently in high-vibroacoustic environments.
- Computational tools which can robustly, accurately, and efficiently capture unsteady sharp gradients in rocket flows such as propagating shock and blast waves, free surfaces at liquid/gas interfaces, etc. Specifically, new nondissipative flux techniques to fully eliminate the carbuncle phenomena that occur in
Roe/HLLE-based schemes is of interest (numerical routines to solve governing fluid equations). In addition, more efficient and novel adaptive meshing techniques for unsteady, large-scale applications is desired.

- Improved capabilities to predict and model the behavior of components (valves, check valves, chokes, etc.) during the facility design process are needed. This capability is required for modeling components in high pressure (to 12,000 psi), with flow rates up to several thousand pounds per second, in cryogenic environments and must address two-phase flows. Challenges include: accurate, efficient, thermodynamic state models; cavitation models for propellant tanks, valve flows, and run lines; reduction in solution time; improved stability; acoustic interactions; and fluid-structure interactions in internal flows.

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

4 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**

- Prototype
- Hardware
- Software

**Desired Deliverables Description**

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I as a final report and show a path toward 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**

This subtopic seeks to provide technological advances that provide the ability to test next generation rocket propulsion systems while reducing costs, increasing efficiencies, and improving safety/reliability within the static rocket engine test environment. Specifically, the goal is to reduce costs of propellants and other fluids, reduce logistics costs, reduce times required for ground processing and launch, reduce mission risk, and reduce hazards exposure to personnel.

There is a broad range of technologies needed to support rocket propulsion testing. Dynamic fluid flow simulation is used to characterize and model the facility performance in a highly dynamic environment with NASA, Department of Defense (DOD), and commercial customers. Multiple issues remain with modeling combustion instabilities and component/facility performance. These issues can have catastrophic results if not understood completely. New test programs will require the materials to withstand extreme temperatures and harsh environments. Next-generation testing requires the ability to produce very high-temperature hydrogen at high near-continuous flow rates to verify component and facility performance. The extreme and harsh environment also requires advancements in mechanical components and instrumentation.

**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 (HEOMD), all test programs at Stennis Space Center (SSC), and other propulsion system development centers.
References

- https://www.nasa.gov/centers/stennis/home/index.html
- https://technology.ssc.nasa.gov/
- CFD Vision 2030 Study: A Path to Revolutionary Computational Aerosciences - NASA Technical Reports Server (NTRS)