Department of the Navy SBIR/STTR Transition Program

Topic # N232-084
Reduced-Order Modeling of Unstart in Liquid Fuel Scramjets
CFD Research Corporation

WHO

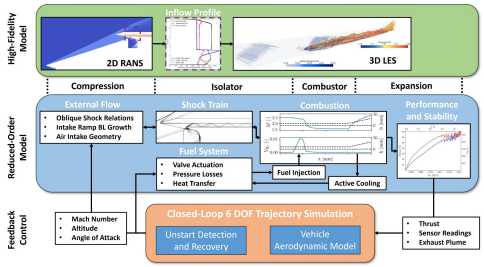
SYSCOM: NAVAIR

Sponsoring Program: PMA-201, NAWCAD

Transition Target:

TPOC: (240) 572-9856

Other Transition Opportunities: Air Force Hypersonic Attack Cruise Missile (HACM) and Expendable Hypersonic Air-Breathing Multi-Mission Intelligence, Surveillance, and Reconnaissance, and Strike program ("Project Mayhem"), TRMC Multi-Service Advanced Capability Hypersonics Test Bed (MACH-TB), NAWCWD Advanced Solid Fuel Ramjet (ASFRJ), and DARPA's proposed More Opportunities with Hypersonic Air-breathing Weapon Concept (MoHAWC).



Notes: Our system-level Reduced-Order Model (ROM) of scramjet propulsion is highly modular and extensible. Each component of the model is supported by high-fidelity CFD simulations which provide fundamental insights into the key physics and validation of the model accuracy. The model is capable of predicting unstart and has been coupled to trajectory simulations for use in mission planning and feedback control algorithms.

Acronyms: DOF: Degree of Freedom, RANS: Reynolds Averaged Navier Stokes, LES: Large Eddy Simulation

WHAT

Operational Need and Improvement: Current need exists for advanced, fast running reduced order models to simulate multi-phase, supersonic mixing, and combustion for air-breathing hypersonic flight vehicles to accurately predict engine operability and unstart in different flight regimes. Increased speed and accuracy enables rapid iteration over designs in a typical conceptual design cycle.

Specifications Required: Navy desires tools which capture the complex physics which can lead to unstart in scramjet engines, including supersonic turbulent mixing and combustion of advanced hydrocarbon fuels under supercritical/transcritical conditions, and which support realistic 3D Navy-relevant geometries. High-fidelity CFD approaches such as reactive LES should be leveraged to identify the mechanisms of unstart and drive the development of reduced-order models which quickly and accurately predict engine operability and unstart in different flight regimes.

Technology Developed: The core technology is a fast-running system-level model of scramjet propulsion, which can predict key performance metrics and unstart events for gas- and liquid-fueled configurations. This model is validated against high-fidelity CFD and experimental data and has been coupled to 6-DOF trajectory simulations for closed-loop feedback control. The framework of the model is designed to be modular and extensible – accommodating both physical and empirical models of varying fidelity – and take advantage of hardware accelerators such as GPUs, enabling real-time simulation of transient phenomena.

Warfighter Value: The predictive capability developed will improve scramjet engine performance and reliability, thus contributing to greater mission effectiveness. The ability to run fast running physics based reduced-order models will accelerate the design cycle, allowing faster deployment of high-speed weapons systems that maintain superiority in future naval warfare scenarios. The unstart prevention and recovery techniques which can be verified using this technology would substantially reduce in-flight risk and loss of vehicles.

WHEN

Contract Number: N68335-25-C-0132 **Ending on:** Jul 27, 2027

Milestone	Risk Level	Measure of Success	Ending TRL	Date
Improve scramjet ROM with relevant physics submodels and modern programming practices.	Low	Model accurately predicts key performance metrics and unstart over a range of configurations.	3	2nd QTR FY27
Develop coupling API to use ROM within trajectory simulations.	Low	Successfully demonstrate ROM operation within a representative vehicle on a range of missions.	3	3rd QTR FY26
Predict in-flight unstart events and evaluate feasibility of recovery via feedback control.	Medium	Demonstrate triggering of unstart within trajectory simulations. Document unstart recovery attempts and assess feasibility.	3	4th QTR FY27
Verify ROM accuracy against high-fidelity simulations of gas- and liquid-fuel scramjet configurations.	Medium	Produce a set of RANS + LES solutions which are validated against experimental data. Benchmark ROM against results.	3	2nd QTR FY27

HOW

Projected Business Model: Our commercialization strategy and anticipated Phase II activities from the current SBIR project will include: 1) Provide R&D and engineering services to DoD and commercial industry to couple and integrate our ROM prediction capabilities in their scramjet design cycle. 2) Provide software maintenance, support, and licensing to distribute and support software components developed under this project. 3) Further contract research to adapt our technology for relevant applications.

Company Objectives: The development of high-fidelity CFD and ROMs for unstart prediction in scramjets is of strategic value to CFDRC in its bid to be a major provider of R&D solutions and analysis support to Government's high-speed propulsion and hypersonic programs. The ultimate goal is to transition this technology into DoD design and mission planning workflows for air-breathing hypersonic vehicles to enhance weapon capabilities and reduce the time and cost required for hardware design iterations. We're seeking ongoing funding of tool development and technical support to increase the tool's capabilities and better support the targeted defense applications. Prime contractors such as Raytheon and Lockheed Martin Missiles and Fire Control could help us define test conditions and requirements and provide further validation of the modeling approaches.

Potential Commercial Applications: Commercial applications include aerospace transport and defense companies, especially those involved in the development and fielding of next generation hypersonic transport and offensive and defensive programs, including Hermeus, Lockheed Martin, Raytheon Technologies, Boeing, and Northrop Grumman. The modeling capability can also be readily integrated with and make use of the High-performance computing modernization program (HPCMP) Computational Research and Engineering Acquisition Tools and Environments (CREATE) framework. The foundational digital engineering framework has applications in various DoD modernization efforts such as the Digital Engineering campaign.

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