Large Eddy Simulations of High-speed Combustion and Gas-surface Interactions for Hypersonic Propulsion

About DEVCOM ARL:

The Army Research Laboratory (ARL) is the U.S. Army's leading research institution, committed to delivering scientific discoveries, technological advancements, and innovative solutions that empower the Army to maintain its edge on the battlefield. ARL's research spans multiple disciplines, including materials science, computational modeling, and advanced engineering, with a strong focus on developing cutting-edge weapon systems and propulsion technologies. In the area of weapon development, ARL works on creating more lethal, precise, and adaptable systems that can operate in the most demanding environments. The lab is at the forefront of research in hypersonic weapons, which require advanced propulsion systems capable of withstanding extreme aerodynamic forces and high temperatures. ARL's work in propulsion includes the development of high-speed engines, such as scramjets, that enable sustained hypersonic flight and improve the range, speed, and maneuverability of future military platforms. Through collaboration with industry, academia, and other government agencies, ARL leverages a wide array of high-performance computing resources, experimental facilities, and modeling capabilities to push the boundaries of current technology. By addressing the challenges associated with high-speed flight, ARL plays a pivotal role in advancing the Army's modernization efforts.

RESEARCH LOCATION: Aberdeen Proving Ground, MD

PROJECT DESCRIPTION:

The project involves advancing hypersonic propulsion technologies by simulating high-speed turbulent combustion and material ablation in scramjet engines. The goal of this project is to advance foundational science models for hypersonic weapons, enhancing operational capabilities for the Army and DoD. Key challenges include extreme heating, structural integrity, and propulsion efficiency at varying altitudes and Mach numbers. To address these, this 10-week project will investigate high-speed turbulent combustion in scramjet environments, shock-induced heating, and material ablation physics. Simulations of reference hypersonic vehicle geometry under high enthalpy conditions will be conducted using Large Eddy Simulation (LES) on solvers like US3D, with ablation physics modeled through molecular dynamics in LAMMPS. The project will leverage ARL HPC resources to deploy the high-fidelity physics-based tools, investigate multi-physics models, and develop validation methods using DoD experimental data. This project will leverage HPC tools and resources, (e.g., Secure Remote Desktop, DoD Supercomputing Resources Centers) to generate computational meshes, perform CFD and MD simulations, and post process analyses.

During this internship, the intern(s) will engage in a series of challenging and educational activities designed to provide hands-on experience in advanced hypersonic research. The intern(s) will participate in the simulation and analysis of high-speed propulsion systems, including the use of Large Eddy Simulation (LES) tools like US3D and molecular dynamics approaches with LAMMPS. The intern will be part of a team in setting up and running simulations to investigate high-speed turbulent combustion, gas-flow chemistry, and material ablation processes under various Mach numbers.

The intern will be involved in collecting and analyzing data from these simulations, contributing to the validation of models using DoD experimental data. The intern will collaborate with our research teams to interpret results and refine models, gaining valuable insights into the complexities of hypersonic vehicle performance.

In addition to technical activities, the intern will have opportunities for professional development. They will participate in networking activities with experts in the field of hypersonic and propulsion, attend seminars, conferences, and workshops, and engage in laboratory and test center tours. These experiences will provide a comprehensive view of current research trends and technologies. The proposed activities are designed to be both challenging and educational, aligning with the intern's qualifications and providing a deep dive into state-of-the-art research at ARL.

This internship will enhance the intern's skills in computational modeling, data analysis, and research methodologies. By contributing to high-impact research projects, the intern will gain valuable experience that will improve their long-term career prospects in aerospace and defense research.

ANTICIPATED START DATE:

May 2025 – Exact start dates will be determined at the time of selection and in coordination with the selected candidate.

QUALIFICATIONS:

Prospective candidates should possess a strong educational foundation in fields related to aerospace engineering, mechanical engineering, physics, or a closely related discipline. A bachelor's degree in one of these areas is typically required, with a master's degree or higher being preferred for more advanced roles. Candidates should have a solid understanding of fluid dynamics, thermodynamics, and high-speed propulsion systems. Experience with computational fluid dynamics (CFD) tools or Molecular Dynamics (MD) tools is highly desirable. Familiarity with high-performance computing environments and relevant software platforms, such as US3D and LAMMPS, will be advantageous. Candidates should have a fundamental skill set in Unix. Additionally, applicants should demonstrate proficiency in analyzing and interpreting experimental data, as well as the ability to apply theoretical knowledge to practical problems. Strong problem-solving skills, attention to detail, and the ability to work effectively in a collaborative research setting are essential. Experience in hypersonic research, materials science, or aerothermochemistry will be considered favorable. Candidates with a track record of research publications, presentations, or previous internships related to hypersonic technologies or advanced propulsion systems will have a competitive edge. Overall, candidates who bring a blend of academic excellence, technical skills, and relevant research experience will be well-suited for this opportunity.

ACADEMIC LEVEL:

Degree received within the last 60 months or currently pursuing:

- Bachelor's
- Master's
- Doctoral

DISCIPLINE NEEDED:

- Engineering
- Physics