HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

RESEARCH PROJECT #: HPCMP-HIP-25-037

Uncertainty Across Fidelity: Data-driven Approaches to Quantify Model Uncertainty in High-Speed Propulsion Systems

About AFRL:

Air Force Research Laboratory (AFRL) is a scientific research organization operated by the United States Air Force Materiel Command. AFRL is dedicated to leading the discovery, development, and integration of aerospace warfighting technologies, planning, and executing the Air Force science and technology program, and providing warfighting capabilities to United States air, space, and cyberspace forces.

The Aerospace Systems Directorate brings together world-class facilities including a fuels research facility, structural testing labs, compressor research facility, rocket testing facilities, supersonic and subsonic wind tunnels, flight simulation lab, and many other cutting-edge research labs.

RESEARCH LOCATION: Wright-Patterson AFB, OH

PROJECT DESCRIPTION:

Among the technologies in development in the Aerospace Systems Directorate are scramjet engines, alternative fuels, unmanned vehicles, hypersonic vehicles, collision avoidance and aircraft energy optimization.

How should we best utilize our models? What level of fidelity is necessary for the risk we're willing to accept? How good is "good enough"? To address these questions, we must first understand how certain we are about our models and their pre-selected parameters.

This proposed project investigates the use of automation to define model-form uncertainty in components of dual-mode ramjet (DMRJ) engines. The goal is to utilize available datasets to establish the uncertainty in our input parameters and, ultimately, minimize that uncertainty with higher-fidelity computational models.

Under the guidance of mentors, the intern will write linking scripts between the Department of Energy's Dakota framework and Loci/CHEM, a computational fluid dynamics (CFD) solver. This will automate an inverse-uncertainty quantification framework.

The project offers opportunities to develop computational skills in Python programming, parallel computing, data analysis, and visualization. The intern will use HPC resources to couple Dakota to multi-core simulations using Loci/CHEM.

At the end of the internship, the intern will write a report and, depending on progress, may co-author a journal article reporting their findings.

The primary goal of this project is to enhance our understanding and management of uncertainty in scramjet simulations by leveraging inverse-UQ (Bayesian calibration) techniques.

The proposed project is as follows:

Weeks 1-2: Computers and access set up. Conduct a brief literature review and read appropriate theory and user manuals for the necessary tools. Collaborate with mentor to construct the 'building blocks' required to conduct our investigation.

Weeks 3-5: Write communication layers to couple the Dakota and Loci/CHEM solver packages.

Weeks 5-7: Run solver to construct low-fidelity emulator given the Dakota sampling using HPC resources.

Weeks 8-9: Run a MCMC of the emulator to construct posterior distributions and analyze data.

Week 10: Prepare report and final presentation.

The intern will engage in the following activities:

- Facility Tours: Gain firsthand exposure to AFRL's high-speed propulsion and aerodynamic tunnels.
- Networking Opportunities: Participate in social events within the division and connect with other AFRL summer interns.
- Script Development: Write Python scripts to integrate the DOE Dakota package with the Loci/CHEM CFD solver, enabling seamless communication and data exchange.
- High-Performance Computing: Utilize HEC systems to launch and manage a series of simulations for surrogate model development.
- Bayesian Calibration: Explore various Bayesian calibration techniques within Dakota, comparing their usage and outcomes in the context of scramjet simulations.
- Exposure to Complex Physics: Gain familiarity with the complex physics involved in scramjet simulations, with ample support and guidance from mentors.

The intern will be exposed to cutting-edge research tools and methodologies, fostering a deeper understanding of uncertainty quantification and its application in aerospace engineering. Mentorship and resources will be provided to ensure the intern can successfully navigate the complexities of the project.

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 be excited about computational modeling and fluid dynamics. Candidates with at least a bachelor's in aerospace/mechanical engineering, physics, or mathematics are preferred. The ideal candidate should have fundamental skill sets in Unix and have experience writing in Python. Ideal candidates will have experience using high performance computing architectures and any experience in parallel computing.

ACADEMIC LEVEL:

Degree received within the last 60 months or currently pursuing:

- Bachelor's
- Master's
- Doctoral

DISCIPLINE NEEDED:

- Engineering
- Mathematics and Statistics
- Physics
- Science & Engineering-related