PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
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DEVELOPMENT OF ADVANCED INSTRUMENTATION FOR HIGH-ENTHALPY FLOW CHARACTERIZATION FOR THE ONR-UTA ARC-JET ”LESTE” FACILITY

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Abstract

Developing the next generation of hypersonic vehicle platforms that enable cost-effective space access serves both military interests, including ensuring national security and future space-based warfare, and civilian interests, such as hypersonic transportation and space tourism, and stimulating economic growth. The complexities associated with the realization of this technology motivate the need for a greater understanding of the unique challenges these platforms experience. Sustained hypersonic flight is an exceedingly challenging task requiring the understanding of several complex physical processes. This quest for a fundamental understanding sets the stage for a fascinating field in the aerospace sciences: wind tunnel testing. Wind tunnel testing, or ground testing, refers to the production of flight-relevant flow conditions that can emulate the physical phenomena an actual flight vehicle would experience. No single wind tunnel can simulate every expected phase of flight. The scope of testing campaigns is tailored to the technology being tested. Arc-jet wind tunnels are chosen for hypersonic flow fundamental science research and hypersonic flight vehicle development due to their unique ability to capture the relevant aerothermochemical processes on time scales necessary for research and development (R&E) and testing and evaluation (T&E) of thermal protection systems (TPS), advanced air-breathing propulsion technologies, and other critical flight sub-systems. This work presents advances in both intrusive and nonintrusive diagnostic techniques for the characterization of high-enthalpy flow. First, an approach to the design and successful experimental validation of a slug-type calorimeter for long-duration high-enthalpy flows is presented. Next, the direct measurement of skin friction in an arc-jet flow environment and associated design methodology are presented. Lastly, the world's first application of hybrid femtosecond/picosecond Coherent Anti-Stokes Raman Scattering (fs/ps-CARS) to measure the vibrational temperature of molecular nitrogen in an arc-jet environment is detailed. This work has demonstrated the capability of fs/ps-CARS to overcome the challenges posed by the intense background radiation and the spatial and temporal precision required for successful implementation in arc-jet flows. The diagnostic techniques and instrumentation developed in this dissertation represent a step forward in the field’s capability to characterize and understand high-enthalpy flows. By providing accurate measurements of critical flow properties, this work supports the advancement of hypersonic vehicle design and testing.