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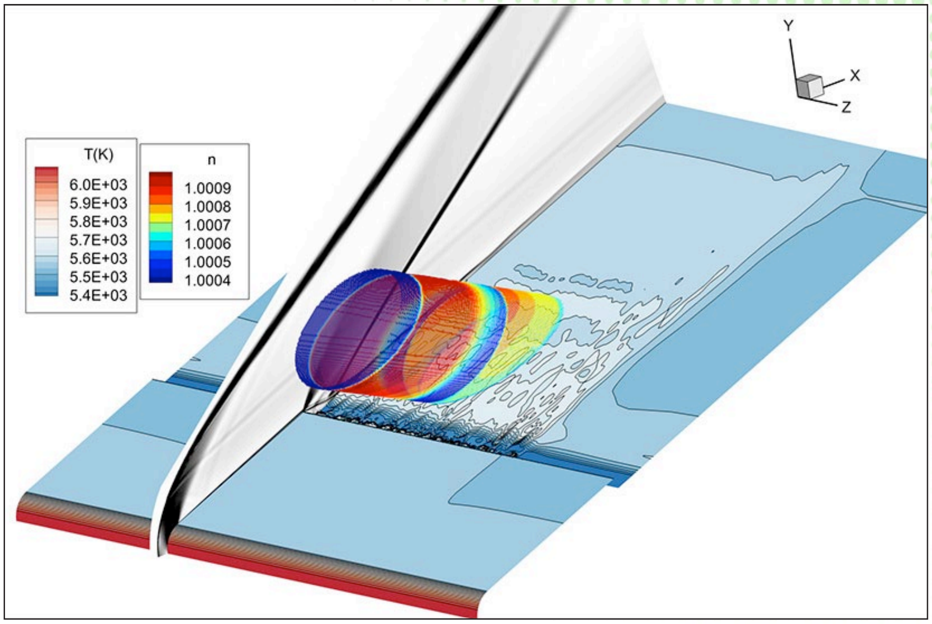
High-Fidelity Multi-Physics Simulations for Hypersonics

Technology Office | Lincoln Laboratory

Predicting the performance of hypersonic vehicles and their sub-systems is an inherently multi-disciplinary problem. The complex aero-thermal-chemical environment around a vehicle is challenging to simulate and highly coupled. This can impact performance and survivability for both the vehicle as well as any onboard sensors (such as infrared or radio-frequency seekers). Pure fluid dynamic simulations of hypersonic flow are already challenging due to high speeds, thin boundary layers, and chemical reactivity. Adding additional physics, such as structural-thermal coupling or aero-optics, increases the complexity and computational cost. This leads vehicle designers to use lower-fidelity tool sets, which often produce erroneous results due to simplification of complex and critical phenomena.

The goal of this work, supported with Engineering Research allocated funding, is to develop a high-fidelity, hypersonic multi-physics solver by coupling a state-of-the-art hypersonic fluid dynamics code (US3D) with the Lincoln Laboratory Integrated Modeling and Analysis Software (LLIMAS) tool. US3D is a widely used and validated hypersonic computational fluid dynamics code developed by Professor Graham Candler at the University of Minnesota.



This image shows an example simulation of a side-mounted seeker window in a hypersonic flow. A film of Nitrogen gas is used to cool the window, and the impact of this film cooling is included in the aero-optic calculation.

LLIMAS is a simulation framework developed by staff in Engineering, Division 7, to enable data exchange as well as supercomputing and design exploration across multiple disciplines, including academic, commercial, and government codes, and often on terabyte-class models. LLIMAS has been used extensively for low-speed aero-optics modeling but has yet to be expanded to hypersonic flows.

For this work, US3D will be integrated into the LLIMAS framework and the tool set will be developed to enable aero-optical simulations as a first step to wider multi-physics problems. The results of these simulations will be validated against historical aero-optics data from hypersonic ground testing facilities. After validation, additional capabilities will be included, such as thermal-structural coupling, to get a more complete picture of the vehicle's performance.

For more information, contact Dr. William Flaherty, Structural and Thermal-Fluids Engineering, Group 74, or visit the program page.

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