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A Physics-Based Approach to Hypersonic Nonequilibrium Chemistry

Marco Panesi

Abstract

The simulation of the aerothermal environment surrounding vehicles moving at hypersonic speed is a complex problem due to its multi-physics and multi-scale nature. Progress in the ability to accurately model these systems has been hindered by the lack of reliable physical and chemical models for collisional and radiative processes. Furthermore, the predictive capabilities of these models are often established by a simple comparison of the model predictions against results from legacy experimental measurements, the accuracy of which is often not well characterized. Substantial progress in the area of computational chemistry, along with increased computational resources, have allowed for the construction of realistic models based on molecular-scale dynamics. I propose to use state-specific collisional radiative models as a powerful tool to derive macroscopic conservation equations, energy exchange terms and chemical production rates for atmospheric entry plasmas. I will cover the key aspects involved in model development, namely: (1) using ab-initio quantum calculations as a powerful tool to construct high-fidelity physics-based models; (2) defining reduced-order models for the simulation of 2D and 3D flows (e.g., coarse-grain modeling). (3) validating physical models and determining the uncertainty in their predictive capabilities, based on the most recent developments in Uncertainty Quantification (UQ) algorithms (e.g., Bayesian inference).

Bio

Dr. Marco Panesi is currently Assistant Professor in the Aerospace Engineering Department at the University of Illinois at Urbana Champaign. He received his M.S. degree of Engineering (Aeronautical and Aerospace) in 2003 from the University of Pisa in Italy. In 2009, he received the Ph.D. degree from the von Kármán Institute for Fluid Dynamics in Belgium for his work on "Physical models for non-equilibrium plasma flow simulations at high speed re-entry conditions". He completed a post-doc with the PECOS center, one of the five DOE funded PSAAP centers, at the Institute for Computational Engineering and Sciences at UT Austin. He joined the faculty in the Department of Aerospace Engineering at the University of Illinois at Urbana-Champaign as an assistant professor in August 2012.

Awards

2015 - NASA Early Career Faculty (ECF) award.

2015 - Young Investigator Program (YIP) award.

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