A predictive framework for aerothermal assessment of an atmospheric reentry vehicle

Jeswin Joseph[1], Jean-Pierre Hickey[1] & Ryan Whitside[2]
1 Department of Mechanical and Mechatronics Engineering, University of Waterloo, 200 University Ave. W., Waterloo, Ontario, Canada
2 Unmanned Vehicle Applied Dynamics (UVAD), Alberta, Canada

Thermal management poses a significant challenge in designing a realizable hypersonic vehicle. Identification and characterization of the maximum and integrated aerothermal load, drive the design features of the thermal protection systems used for hypersonic flight. External vehicle geometry, reentry or mission profile, and attitude control can impart important changes to unsteady thermal loading. The accurate characterization of maximum and time integrated thermal load represents a multi-scale problem, with strong coupling of multi-physics including, but not limited to, atmospheric physics, curved shock structure, boundary layer dynamics, aerodynamics and conjugate heat transfer. The present work proposes a nimble predictive framework to assist in the initial design considerations of high-speed reentry capsules or vehicles. Using a low-fidelity modeling approach, we propose the use of physics-based models for reentry trajectory simulation, spatio-temporal aerothermal load prediction, and conductive heat transfer to the vehicle. These effects are integrated with the unsteady time history of the estimated reentry trajectory within the open-source Stanford University Aerospace Vehicle Environment (SUAVE) framework, which enables vehicle geometry build-up and visualization. This work first compares the accuracy of various low-fidelity model considerations with the test results available in the literature for both blunt and sharp geometries, which are followed by the application of the framework to a realistic reentry case. The results show promising accuracy in aerothermal predictions of commonly used hypersonic geometries, and identify shock structure as the most sensitive feature towards predictive accuracy of reentry aerothermodynamics.

Email address for correspondence: *jean-pierre.hickey@uwaterloo.ca*