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Aerodynamic predictions of a parameteric common research model for winged re-entry

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Abstract

Fully reusable winged re-entry vehicles remain a salient avenue for the cost reduction of access to space, despite the recent advances in reusable rocket stages. The means by which an orbital payload may re-enter the atmosphere and land on a conventional runway is of great engineering and scientific intrigue. However, winged re-entry and sample return vehicles present numerous aerodynamic challenges associated with achieving flight and controllability over such a wide speed range. These vehicles must simultaneously survive re-entry while achieving glider-like performance at transonic and subsonic speeds. Some of the engineering challenges include peak heat flux predictions, chemical reactions and dissociation, thermal non-equilibrium, shock-shock and shock wave boundary layer interactions, flow separation and more. The modeling techniques required are under continual development and require suitable test cases for verification and validation. Common research models (CRMs) provide a means to link fundamental theories developed on primitive models to more complicated shapes more closely representing a specific application. Some examples include the ONERA M6 wing, the NASA CRM (resembles a commercial airliner), the Ahmed body, or more generally the NACA series of airfoils. In hypersonic re-entry, the geometry most embodying a CRM is the Apollo family of capsule shapes. However, no such common model exists for winged re-entry. In our current work we have proposed a fully parametric 3D CRM model aimed at promoting the fundamental study of the aerodynamics linked to winged hypersonic flight. The aim is to (i) support verification and validation of numerical and diagnostic techniques in the domain of interest (ii) promote collaboration and (iii) provide a means to study and explore relevant flow physics. Of particular interest here is to use numerical techniques to examine the engineering trade-off between hypersonic heat flux management and control, with subsonic glider performance. In the present work, the geometry will be presented and numerical simulation work characterizing its behavior and suitability as a CRM are discussed. High fidelity simulations in OpenFOAM have been performed over a range of angles of attack in the fully incompressible subsonic regime. Additionally, simulations of Mach 10 hypersonic flow typical of a low enthalpy hypersonic flow facility have been performed. The impact of various geometric parameters on heat flux, vortex lift, and other features is discussed.