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NUMERICAL MODELLING VERIFICATION FOR RE-ENTRY VEHICLES USING ENHANCED MHD SIMULATION TOOLS

Abstract

Atmospheric entry into a planetary atmosphere is a critical phase for space missions, because spacecraft have to face harsh conditions involving thermal loads in the order of MW/m^2. During the entry, the atmospheric gas can be dissociated and (partly) ionized thus creating a plasma boundary layer. This sheath subjects the spacecraft to high heat fluxes and leads to communication blackout. Since both aspects can compromise the safety of the vehicle, a design which employs advanced protection systems is necessary to ensure the success of future planetary missions. As proven in previous studies, charged particles in a plasma flow can be manipulated by applying a sufficiently strong electromagnetic field, which modifies the shock structure and distance, mitigates the heat flux, and creates a transmission window that can reduce the communication blackout period.

The MHD Enhanced Entry System for Space Transportation (MEESST) Horizon 2020 project will exploit magnetohydrodynamic (MHD) effects and develop a demonstrator implementing active magnetic shielding by means of a superconductive coil system. MEESST includes experimental campaigns in the plasma wind tunnels of the Von Karman Institute (VKI) and the Institute of Space System (IRS), and numerical simulations relying upon improved models. Enhanced MHD simulation tools will allow the prediction of the plasma environment experienced during atmospheric entry, which involves electromagnetic phenomena, thermochemical non-equilibria, and radiation.

This work presents the enhancement and verification of three pre-existing tools for plasma modelling: SAMSA (by IRS), COOLFluiD (by VKI/KU Leuven), and HANSA (by the University of Southampton). Current numerical modelling capabilities are assessed and displayed synoptically, and recent extensions to the capabilities of these tools are elaborated upon. Simulation results from four test cases selected for the MEESST project are then presented: two wind tunnel experiments utilising MHD effects in argon plasmas (demonstrating heat flux modelling), and two external flow scenarios (demonstrating multispecies thermochemical nonequilibria and radio blackout raytracing). Of the external flow simulations, one models

the entry of an ARD capsule into Earth's atmosphere, while the other models the ExoMars aeroshell entering the atmosphere of Mars. The successful rebuilding of these test cases allows for verification of the enhanced numerical tools and provides a first milestone towards validating the target experimental data involving multispecies air plasma flows with simulations within the MEESST consortium.