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Title

Multi-physics Atmospheric Entry Simulations in Pursuit of Magnetic Shielding Techniques

Authors

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Abstract

The renewed interest in high altitude and interplanetary space travel has drawn fresh attention to the physical challenges of atmospheric entry/re-entry. The need to improve the reliability of entry vehicles has drawn sharp focus to the limitations of our current understanding of weakly ionised non-equilibrium plasmas as well as our limited predictive capabilities. This paper presents the work conducted by the University of Southampton and our consortium partners, within the 'Magnetohydro-dynamic Enhanced Entry System for Space Transportation' (MEESST) project [1]. This project is currently engaged in both numerical and experimental work to develop magnetic shielding techniques for atmospheric entry vehicles. Such techniques aim to mitigate the effects of radio blackout and provide additional avenues for heat flux mitigation. Herein we present the results of multi-physics simulations conducted with the University of Southampton's HANSA toolkit, together with comparisons both experimental and numerical produced by our consortium partners. These include simulations of multiple capsules undergoing atmospheric entry, as well as simulations of ground based experimental campaigns. The effects of thermo-chemical non-equilibrium and MHD modeling are given particular attention, and comparisons are drawn between different atmospheres. We demonstrate the impacts of various physical models upon obtained results, with particular emphasis on mission critical parameters, such as surface heat fluxes and electron densities. We also present conclusions drawn regarding the impact of these results upon magnetic shielding designs. Exact atmospheric conditions are shown to strongly affect electron density levels, and the ramifications of this are discussed regarding radio blackout mitigation techniques. Differences in thermal relaxation rates are shown in terms of their effects upon impinging heat fluxes. We then explore the effect of these rate differences upon magnetic heat shielding techniques. Lastly, we present an overview of current knowledge gaps in areas critical to MEESST and lay out plans for future simulations and experiments, both within the MEESST project and beyond.

References

[1] Lani A. et al, *A Magnetohydrodynamic enhanced entry system for space transportation: MEESST*, Journal of Space Safety Engineering 2468-8967 (2022)