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# Modelling of MHD flow control for atmospheric re-entry

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The use of magnetohydrodynamics (MHD) to assist vehicles as they experience the challenging environment of atmospheric re-entry has been a long-standing aspiration for space mission designers. Very early after the space age started, some authors considered to take advantage of the electric properties of the shock-generated re-entry plasma to modify the flow [1]. In particular, it was quickly realized that by applying a magnetic field on the incoming plasma, the bow shock standoff distance in front of the vehicle could be repelled away from the surface [2]. As a direct consequence, the thermal heat flux could be reduced providing valuable assistance to the vehicle's thermal protection system. A second aspect of the MHD interaction is the generation of a reaction force acting directly on the magnetic field generation device (magnet, coils). This force adds up to the aerodynamic forces and it was suggested this could be used as a drag enhancement mechanism, especially at altitude where atmospheric density is too small to provide useful drag: this defines the concept of MHD aero-braking [3]. Past practical use of MHD-devices for re-entry has been hampered by limitations associated to the field-generation technologies. Nowadays, high-temperature compact superconducting technologies enables a new surge of interest in this promising solution [4].
We present in this work recent investigations of numerical MHD-assisted hypersonic flows at ONERA. Over the last few years, we have developed a series of numerical tools leveraging ONERA knowledge in high-mach number CFD, reacting and non-equilibrium plasmas, discharge and magnetized plasmas modelling… We provide here insights on some phenomena occurring during MHD-assisted re-entry from Earth atmospheric conditions to Mars conditions. A special attention is paid to high interaction parameter regimes for which strong modifications of the flow properties are frequently overlooked in the scientific literature.

## References

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