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THE FRENCH AEROSPACE LAB

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PROPOSITION DE SUJET DE THESE

Intitulé : Experimental Investigations of Magnetohydrodynamic Actuators for Hypersonic Flights

Référence : **PHY-DPHY-2025-20**
(à rappeler dans toute correspondance)

Début de la thèse : 01/10/2025	**Date limite de candidature :** 01/06/2025

Mots clés

Plasma physics, magnetohydrodynamics, MHD, atmospheric reentry, MHD actuators, hypersonics

Profil et compétences recherchées

- Knowledge in plasma physics and/or fluid mechanics is desirable.
- Strong interest in experimental physics
- Master's degree in Plasma Physics, Fluid Mechanics, or Engineering.

Présentation du projet doctoral, contexte et objectif

The atmospheric re-entry of artificial or natural objects is a rich and complex scientific challenge. Indeed, within just a few seconds, the re-entering object experiences a vast range of flight conditions, transitioning, for example, from several thousand meters per second at high altitude to nearly zero speed at ground level in the case of a controlled landing. Applications of atmospheric re-entry span across civil space exploration (crewed flight, transport of materials), space exploration (sample return missions), and defense applications. In this context, future breakthrough technologies are primarily focused on managing heat fluxes, controlling trajectories, and addressing the issue of communication loss during re-entry (‘blackout’).

Magnetohydrodynamics (MHD) offers promising advancements for each of these challenges. By applying a magnetic field to the naturally ionized, conductive high-speed re-entry flow, induced currents can be generated, which react with the flow through the Laplace force. Experimental studies have shown that the shock wave in front of the vehicle can be pushed away by these forces. As a result, aerodynamic and thermal forces can be remotely modified by the presence of the magnetic field. A thorough understanding of the physics behind this interaction, necessary to master all its aspects, requires a combination of theoretical, numerical, and experimental work. For several years, ONERA has been developing tools to model and study MHD actuator configurations. The next major step in this research is to test these tools against richly instrumented hypersonic MHD experiments.

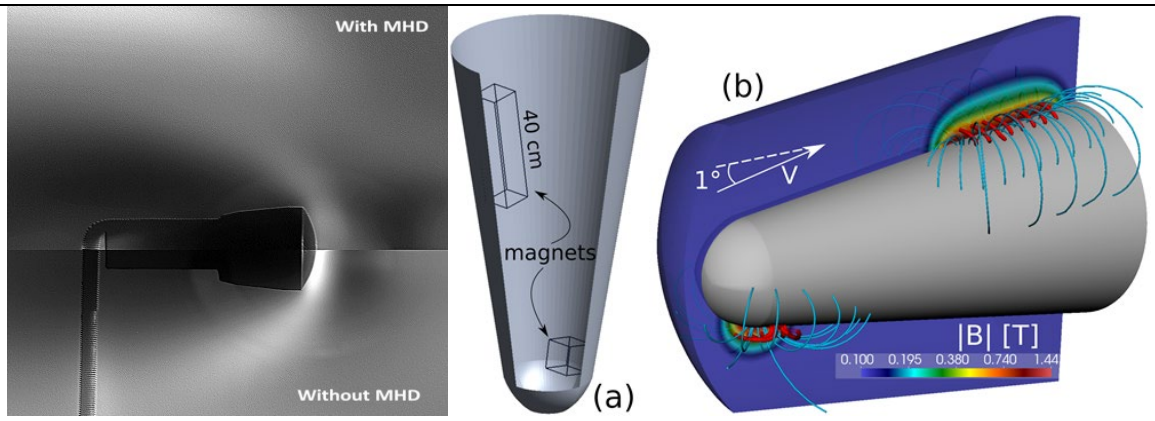

Figure 1 : On the left: Example of an MHD experiment at the ICARE laboratory. On the right: Example of 3D modeling (TARANIS) of a re-entry object assisted by MHD actuators.

To this end, this research project aims to design, set up, and conduct such experiments within the wind tunnels of the ICARE laboratory, which is equipped with resources dedicated to studying the physical processes involved in atmospheric re-entry. The student will rely on ICARE's expertise to carry out measurements evaluating the plasma conditions (electron densities, temperatures, etc.) around the model and the forces acting on it. At the same time, the student will familiarize with MHD computational codes developed at ONERA (CEDRE, TARANIS…) to size the models and compare the results. An important contribution to the understanding of non-equilibrium re-entry MHD is expected from this work. The student will also gain solid experience in experimental hypersonics, plasma diagnostics, and MHD modeling.

Collaborations envisagées

Laboratoire ICARE, CNRS

Laboratoire d'accueil à l'ONERA	**Directeur de thèse**
Département : Physique, Instrument, environnement, espace	Nom : Viviana Lago
Lieu (centre ONERA) : Palaiseau	Laboratoire : ICARE, Orléans
Contact : Benjamin Khiar	Tél. : 02 38 25 77 15
Tél. : 01 80 38 64 27 Email :benjamin.khiar@onera.fr	Email : viviana.lago@cnrs-orleans.fr

Pour plus d'informations : https://www.onera.fr/rejoindre-onera/la-formation-par-la-recherche
le moment