Open Internship in the ESA Advanced Concepts Team in 2015

on

Numerical Analysis of Spacecraft Re-entry Trajectories under Magnetohydrodynamic Flow Control

Topic description

Magnetohydrodynamic (MHD) flow control is considered a method of great interest in order to provide spacecraft orbit control during, for example, re-entry or aerobraking/aerocapture. MHD flow control is based on the principle that the air is compressed and ionized in front of the spacecraft during high velocity atmospheric entry. Magnetic field interaction with this ionized gas then allows for effective drag control. In addition, the hot ionized gas, or plasma, can be pushed away from the spacecraft, hence reducing the heat flux to the spacecraft surface. This would make the use of less high demanding materials possible. Unfortunately, the major drawback of any type of MHD control is the power requirement to generate sufficiently high enough magnetic fields, although it is known that already at lower fields some form of flow control could be achieved [2].

In this project, we aim to investigate the impact of a hypothetical MHD flow control system on the dynamics of an optimal spacecraft re-entry trajectory [3,4]. The trajectories under consideration may include Earth re-entry from LEO and a high velocity Earth-Mars transfer with either direct capture and/or (regenerative) aerobraking [5,6].

Candidate's tasks

MHD modelling is considered to be a very challenging and complex field of study. Yet using the open source openFOAM DSMC modelling package [1], together with literature resources, an analysis can be made on the type of flow control achievable at supersonic speeds. Based on the model, the relevant parameters and scaling are investigated and linked to the trajectory optimization to explore the parameter space that takes maximum advantage of the MHD flow control [3].

<u>Tasks include:</u>

- Develop simplified Earth/Mars (re-entry) trajectory model considering main MHD flow control parameters and scaling
- Explore the impact of varying MHD operating conditions on the spacecraft trajectory
- Use of openFOAM MHD model to explore MHD flow control design behaviour and scaling

The ideal candidate

<u>Mandatory</u>:

- Good programming skills (C++ / Python / Matlab)
- Background in Aerodynamics
- Background in Trajectory Analysis

<u>Desirable</u>:

- Background in Plasma Physics (familiarity with magnetohydrodynamical modelling)

References

[1] OpenFOAM Programmers Guide

[2] Takashi Abe, Feasibility study of flight experiment for electrodynamic heatshield technology, Acta Astronautica Volume 66, Issues 5–6, March–April 2010, Pages 929–936

[3] Takayasu Fujino, Tomoyuki Yoshino, and Motoo Ishikawa, Numerical Analysis of Reentry Trajectory Coupled with Magnetohydrodynamics Flow Control, AIAA, JOURNAL OF SPACECRAFT AND ROCKETS, Vol. 45, No. 5, September–October 2008

[4] Joshua E. Johnson. Mark J. Lewis†, Ryan P. Starkey, Multiobjective Optimization of Earth-Entry Vehicle Heat Shields JOURNAL OF SPACECRAFT AND ROCKETS, Vol. 49, No. 1, January–February 2012

[5] Striepe, S.A.; Powell, R.W.; Braun, R.D.; and Fowler, W.: "Interplanetary Trajectory Optimization of Mars Aerobraking Missions with Constrained Atmospheric Entry Velocities." AAS 91-421. AAS/AIAA Astrodynamics Specialist Conference, Durango, CO, August 19-22, 1991.

[6] Robert W. Moses, Regenerative Aerobraking, NASA, 081846, 2005