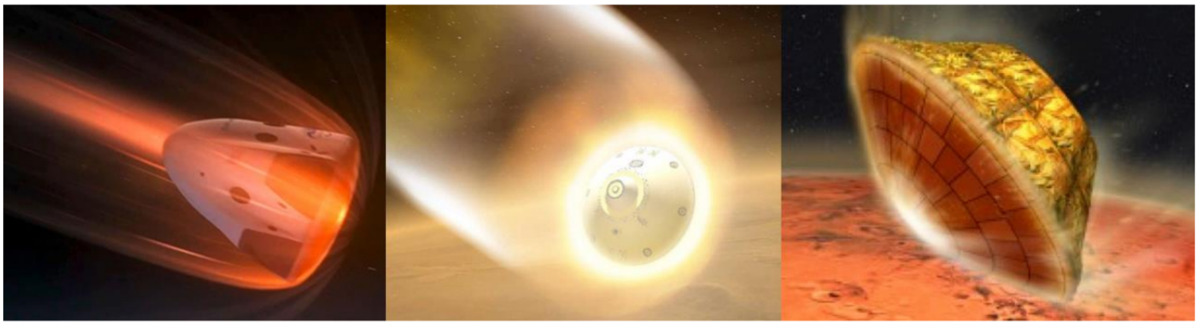
End-of-study internship - engineer level

February - July 2023

Development of a vector compressible solver in OpenFoam for aerospace applications

Context

Hypersonic atmospheric entry is a growing scientific topic in connection with various applications. We can mention the disintegration of satellites at the end of their life by atmospheric re-entry - mandatory in order to avoid the accumulation of space debris, the atmospheric entry of space vehicles - linked to a revival of space exploration, or the atmospheric entry of meteorites - probable source of life on Earth.



The hypersonic entry of an object is characterized by a very dense shock wave where the temperature reaches several thousands of degrees and the gas becomes a highly reactive plasma. No known material can resist despite the short duration of re-entry which is about a minute. Materials degrade: meteorites and metal debris from satellites melt and vaporize, and the thermal shields of ceramic space vehicles gradually lose mass (sacrificial) following a controlled degradation mechanism called ablation. Thus, numerical calculation is necessary to determine the conditions at the limits that apply on incoming bodies. In this context, the OpenFOAM-based HYPPO solver is being developed as a PATO module, PATO being a NASA code developed in conjunction with I2M, VKI and CEA. HYPPO is developed in a collaboration involving researchers from I2M, IMB and LCTS on the Bordeaux site, as well as external collaborations with the PATO team.

Objectives

Complete numerical simulations for hypersonic atmospheric entries involve complex and coupled physics: flow (Navier-Stokes equations), chemistry, thermodynamic non-equilibrium and radiation. They must therefore be taken into account by precise, efficient and robust numerical methods. HYPPO currently includes a number of features. In particular, a vectorial Navier-Stokes solver including equilibrium chemistry is already available. This internship aims at continuing this effort by adding more physics to model very high speed entries surch as meteorites that entrer at up to Mach 100. The steps that will be taken are : becoming familiar with the coding environment by running verification cases, implementing more avanced numerical schemes and new features such as non-equilibrium chemistry and thermodynamics. The final goal will be to simulate the atmospheric entry of a meteorite.
This work will be done on the site of the University of Bordeaux in cooperation with an international team involved in the development of the PATO software (www.pato.ac).

Expected skills

Numerical methods (finite volume method and numerical resolution of linear systems), bases in C++ programming, rigor, ability to work in a team and English.
Knowledge of flow physics (Navier-Stokes equations) will be appreciated.

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