

M2 Internship at CNES (Toulouse, France)

Title: Application of Data Assimilation techniques to the modeling of atmospheric reentry dynamics of space debris. (link on CNES website [here](#))

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Start date and duration : spring 2026, five to six month duration

Mission

CNES (Centre National d'Études Spatiales) is the French space agency, responsible for proposing and implementing France's space policy. This work focuses on the physical and numerical modeling of the aerothermodynamic environment of a space vehicle at the end of its life, re-entering the dense layers of the atmosphere. The interaction between the hypersonic flow and the vehicle generates a shock front around it, where the resulting aerothermodynamic stresses not only alter its trajectory but also its attitude in the flow, as well as the state of its structure (fragmentation, ablation, etc.).

The challenge in studying the fragmentation of a vehicle at the end of its life during re-entry and the survival of its fragments lies in the fact that a multitude of physical phenomena (hypersonic flow, heat transfer, mechanical stresses, wall oxidation, etc.) are involved and are closely interconnected. It is therefore necessary to **simplify and model each phenomenon** in order to integrate them into a computational tool that allows for both realistic simulation and reasonable computation time.

PAMPERO, developed by CNES, is a six-degree-of-freedom code coupled with a library of physical and mathematical models used to determine, throughout the trajectory (in continuum, transitional, or rarefied regimes), the distribution of forces, heat fluxes, and ablation rates on a 3D object. The advantage of such an aerothermodynamic code is that it enables fast and reasonably accurate estimation of the aerothermodynamic stresses acting on a realistic object across a large number of flight points—something that cannot be achieved with more precise but significantly heavier simulations (RANS calculations, DSMC, flow/radiation/chemistry coupling, structural analysis, etc.). These more detailed simulations are nonetheless used to assess the accuracy of the estimation models contained in PAMPERO.

As part of our research and development projects, we are looking for an intern to contribute to the development of predictive models for aerodynamic forces acting on the surface of atmospheric debris along their re-entry trajectory, using methods such as **Data Assimilation** and **Machine Learning**. Videoconferences will be organized to present results and discuss perspectives with Marcello Meldi (LMFL Lille) and Eddy Constant (RTech Verniolle).

Required profile

The candidate will have skills in applied mathematics and / or aerospace engineering. Depending on the work accomplished and the intern's motivation, this internship may lead to a **PhD thesis** aimed at expanding and deepening this field of research.