PHD THESIS PROPOSAL

Title: Numerical investigation of the fluctuating field around grid fins of reusable launch vehicles for the definition of aerodynamically optimized designs

Reference: **MFE-DAAA-2025-26**
(to be mentioned in all correspondence)

Starting date: 1st October 2025	**Application deadline: 14th March 2025**

Keywords

Unsteady aerodynamics, ZDES, reusable launch vehicle, grid fins, loads, moments, wall pressure, CFD

Education and Skills

School of Engineering + Master 2, School of Engineering, Master 2

Fluid Mechanics, Aerodynamics and CFD. Interest in computer programming (Python, Fortran, C++) and physical analysis

Summary and objectives

Over the past decade, mastering the reusability of launch vehicles has become a major strategic stake for the access to space. Such a capability enables reduced launch costs as well as an increase of their frequency. In this context, numerous current configurations of reusable space launchers include grid fins to permit the controlled recovery of first stages. Depending on geometric features and physical conditions (angles of attack and sideslip, Mach number, stagnation pressure and temperature, etc.), the flow around these devices varies significantly. As a consequence, during the preliminary design phases, it is mandatory to rapidly predict average aerodynamic performances for a wide range of configurations. To this end, efficient numerical simulation tools such as ONERA's SoNICS computational framework can be used as it takes advantage of automatic mesh adaptation methods, facilitating the set-up and execution of CFD calculations. Subsequently, during more advanced development phases or risk mitigation studies, it appears crucial to anticipate the levels of fluctuating quantities that lead to the dynamic loads of the launch vehicles in order to ensure the structural integrity of the stages to recover. However, the accuracy of unsteady numerical strategies capable of estimating these levels for this type of configuration is still poorly understood. The same observation is made for the underlying phenomena responsible for these fluctuations near the grid fins for the flight regimes encountered during the return phase.

The aim of this thesis is thus to numerically investigate the ability of existing models to reproduce the fluctuating aerodynamic properties of grid fins to achieve an in-depth physical understanding of unsteady phenomena and develop future concepts with optimized performances. Initially, a literature review will report well-documented test cases of grid fins providing detailed measurements of both average and fluctuating physical quantities. Among the identified cases, the most comprehensive database will be selected to serve as a reference for the steady and unsteady numerical simulation results obtained during the PhD thesis. In these calculations, various turbulence models, numerical schemes, and mesh techniques available in the SoNICS computational framework would be assessed to investigate their ability to reproduce the flow phenomena and characteristic levels of relevant physical quantities (e.g. pressure fields, aerodynamic forces and moments, etc.). This research falls within the scope of increasing the Technology Readiness Level (TRL) of the SoNICS software and its ability to accurately simulate unsteady flows with automatically adapted or non-adapted unstructured meshes fitting the required grid resolution for hybrid RANS/LES approaches such as ZDES (Zonal Detached Eddy Simulation). A reflection will also be initiated to define criteria for the automatic generation of unstructured meshes for high-fidelity approaches (LES/DNS/ZDES) based on a preliminary RANS simulation. The long-term goal is to automate these simulations as much as possible to meet the deadlines of the preliminary design phase.

Finally, it will be necessary to confirm the solver's ability to reproduce the mean field using steady approaches and extend the study to unsteady methods. Particular attention will be paid to draw guidelines regarding the best compromises in terms of numerical strategy to reproduce the fluctuating physical quantities of interest as quickly and accurately as possible depending on the flight regime considered. After validation, efforts will focus on the identification of receptivity zones that govern the flow dynamics. These areas of receptiveness should pave the way to the definition of optimal design criteria for grid fins.

Overall, the three major scientific objectives associated with this topic are, for grid fin configurations, the evaluation using high-fidelity approaches (e.g. ZDES) of the fluctuating flow field, the study of the main unsteady phenomena responsible for flow dynamics, and the identification of receptivity zones to optimize the dynamic load of these grid fins.

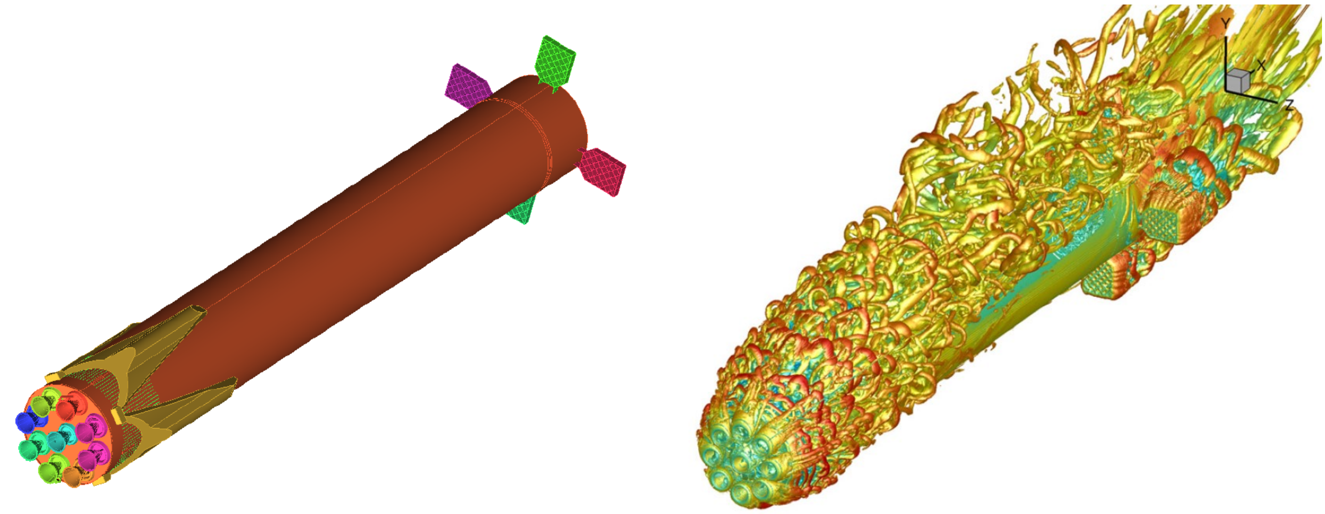

Figure 1 : ZDES simulation of a post-Ariane 6 reusable launch vehicle configuration at a Mach number of 0.8 with an angle of attack of 10°. Left: Geometry of the reusable launcher concept. Right: Isosurface of the dimensionless Q criterion coloured by the streamwise velocity component (adapted from [1]).

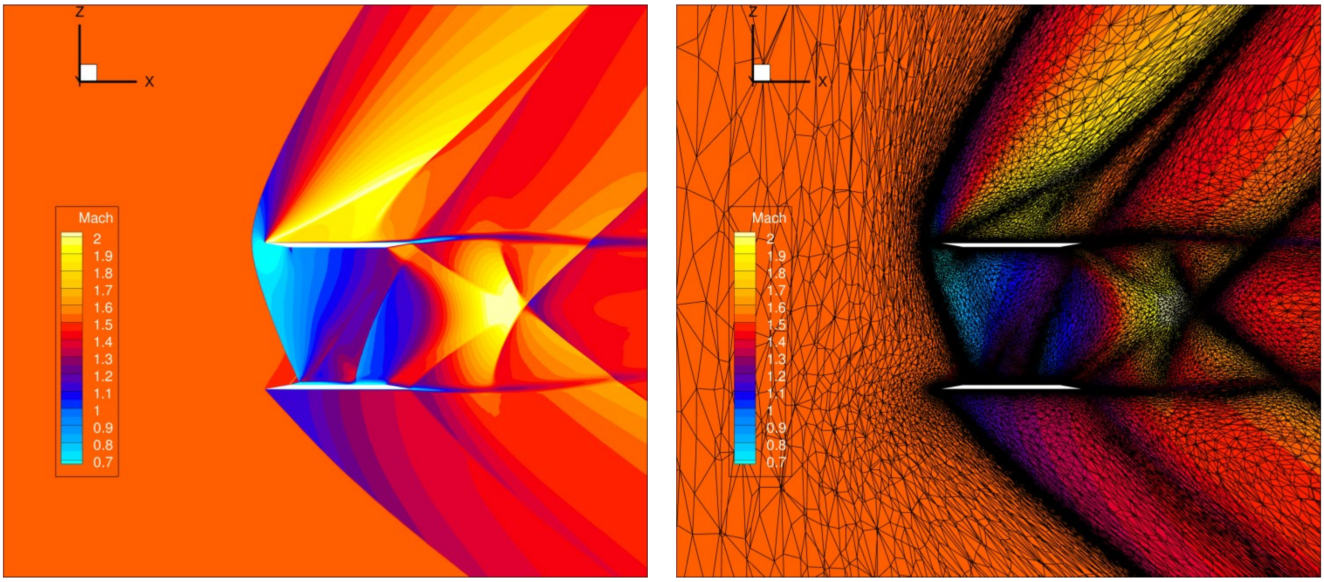

Figure 2 : RANS simulation of an isolated grid fin cell carried out with an automatic mesh adaptation process and ONERA's SoNICS software.

[1] Weiss P.-E. and Deck S. *Towards a numerical multi-fidelity strategy for unsteady aerodynamics studies of reusable launch vehicles: Application to Ariane Next*, 9th European Conference for Aeronautics and Space Sciences (EUCASS), Flight Physics, Launcher Aerodynamics, Lille, France, 27 June - 1 July 2022. http://dx.doi.org/10.13009/EUCASS2022-4816

External collaborations

This PhD thesis is expected to be co-funded by CNES and ONERA.

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