Ph.D. Proposal (M/F)

Probing the Hypersonic Boundary Layer: A DNS Investigation of the Turbulent Density Field at Various Regimes

Location:	Arts et Métiers (ENSAM), DynFluid Laboratory, Paris, France
Duration and Start Date:	36 months, from January 1, 2026
Funding:	ASTRID Programme (funded by the French ANR and AID Agencies)
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Scientific Context and Problem Description

Hypersonic flight is becoming the focus of many research efforts, both due to its increasing relevance in real-world applications and due to the scientific challenges it poses. From a physical point of view, one of the most critical regions to be considered is the thin layer of air near a vehicle's surface, known as the boundary layer. At hypersonic speeds, the boundary layer is highly compressible and often turbulent, leading to intense spatial and temporal variations in the fluid's density field. Several technical difficulties hinge upon the fluctuating density field in turbulent hypersonic boundary layers, hence the need for a detailed understanding of its dependence on various parameters such as the freestream Mach number, the boundary layer Reynolds number and the wall temperature. The non-trivial dependence of turbulence properties on these parameters has been highlighted in recent studies [1-4], along with the need to further explore different wall temperature conditions using direct numerical simulations (DNS) of spatially-evolving boundary layers over long domains.

Ph.D. Subject and Activities

The Ph.D. candidate will contribute to the foundational work package on high-fidelity simulations at the heart of a cross-institutional ANR Astrid project involving ENSAM, Sorbonne Université and ONERA. The main activities of the thesis will include:

- Testing, implementing and validating advanced tools in the high-performance computing codes of the DynFluid laboratory, including turbulence injection techniques and thermochemical models [5, 6].
- Conducting a thorough survey of existing simulations that have led to useful datasets for the study of the density fields in high-speed turbulent boundary layers. The most relevant cases to be simulated in the present thesis will then be identified in terms of Mach number, boundary layer Reynolds number and wall temperature.
- Performing DNS of hypersonic turbulent boundary layer flows.
- Post-processing the generated datasets, focussing on the statistical analysis of turbulence, the characterization of coherent structures, and the extraction of the radiated acoustic fields [7].

Candidate Profile

We seek an enthusiastic and motivated candidate with:

- A Master's degree in mechanical/aerospace engineering, applied physics, or a related field.
- A strong background in fluid mechanics (particularly in compressible flows and turbulence), numerical methods and thermodynamics.
- Proficiency in at least one programming language (Fortran, C++, Python), experience with Computational Fluid Dynamics (CFD); prior exposure to High-Performance Computing would be an asset.
- Rigor, autonomy, scientific curiosity, ability to work in a team and good command of English.

We encourage candidates from minorities in science and in particular women to send their applications. Only nationals from EU member states can be considered.

Application Process

Interested candidates are invited to send the following documents (in a single PDF file if possible) to the email addresses listed in the header:

- A detailed curriculum vitae (CV).
- A cover letter describing how the candidate's profile fits the Ph.D. subject.
- Academic transcripts from Bachelor's and Master's degrees.
- The name and contact information of one or two references (professor, internship supervisor, etc.).

The application deadline is **November 15, 2025**. Interviews for shortlisted candidates will be held in the two following weeks.

Selected References

1. Huang, J., Duan, L. and Choudhari, M.M. (2022). Direct numerical simulation of hypersonic turbulent boundary layers: effect of spatial evolution and Reynolds number. *Journal of Fluid Mechanics*, 937.
2. Cogo, M., Baù, U., Chinappi, M., Bernardini, M. and Picano, F. (2023). Assessment of heat transfer and Mach number effects on high-speed turbulent boundary layers. *Journal of Fluid Mechanics*, 974.
3. Szajnecki, L., Roy, D., Duan, L. and Bisek, N.J. (2025). Effect of Reynolds number on a high-speed cold-wall turbulent boundary layer. *Journal of Fluid Mechanics*, 1016.
4. Gibis, T., Sciacovelli, L., Kloker, M. and Wenzel, C. (2024). Heat-transfer effects in compressible turbulent boundary layersa regime diagram. *Journal of Fluid Mechanics*, 995.
5. Ceci A., Palumbo A., Larsson J. and Pirozzoli S. (2022). Numerical tripping of high-speed turbulent boundary layers. *Theoretical and Computational Fluid Dynamics*, 36, 865-886.
6. Passiatore D., Sciacovelli L., Cinnella P. and Pascazio G. (2022). Thermochemical non-equilibrium effects in turbulent hypersonic boundary layers. *Journal of Fluid Mechanics*, 941, A21.
7. Gloerfelt X. and Berland J. (2013). Turbulent boundary-layer noise: direct radiation at Mach number 0.5. *Journal of Fluid Mechanics*, 723, 318-351.