

## PROPOSAL OF A PHD THESIS SUBJECT

**Title : Towards realistic urban air mobility predictions using Vortex Particle Method and experimental measurements**

Reference : **MFE-DAAA-2026-Numéro d'ordre**  
(à rappeler dans toute correspondance)

**Beginning of the PhD : January 2027**

**Application deadline : June 2026**

**Keywords** *Experimental study, Simulation, PIV, Propeller interaction, ambient turbulence, VPM*

### Context

The shift toward aerial urban mobility relies on novel configurations of drones, air taxis, and rotating-wing aircraft. Unlike conventional-size airplanes or helicopters, these vehicles operate at low altitude within a dense urban environment where the airflow is heavily disturbed. The presence of an urban canopy with varied shapes and vertical surfaces creates an aerodynamic topology that generates heavily turbulent regions, sometimes amplified by hostile weather phenomena such as wind gusts, rain, or even hail. Under these conditions, the incoming flow field is no longer homogeneous; it exhibits velocity gradients and pressure fluctuations, which directly affect the performance of rotating wings, the structure of the wake, and the aero-elastic stability.

ONERA has developed a high-performance code for the aerodynamic analysis of lifting surfaces based on the Vortex Particle Method [1]; however, the modelling of non-lifting surfaces is not yet implemented preventing the study of complex configurations such as the rotor/ground interaction (upwash/downwash), the impact of urban canopies and, multi-rotors with surrounding structures.

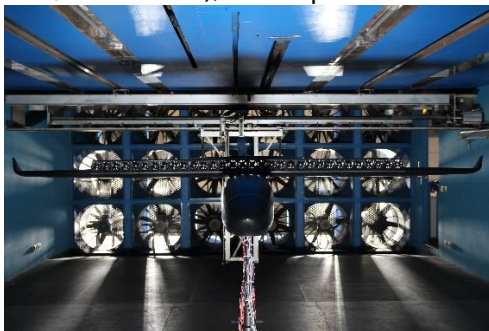


Figure 1 L2 wind tunnel at ONERA Lille.

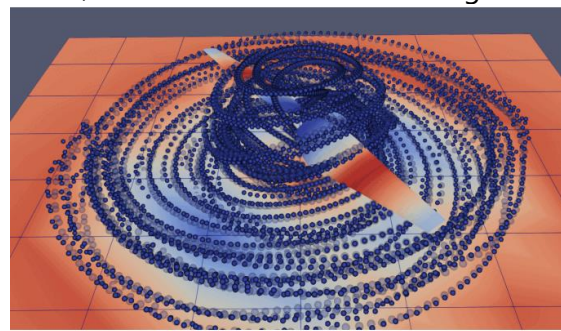


Figure 2 Rotor-ground interaction [2].

The lack of numerical reference databases linked to experimental campaigns is a major obstacle to validating new models. This thesis plans to carry out an experimental test campaign leveraging a range of facilities, including large scale wind tunnels (see Figure 1) and a multi-rotor bench (with PIV measurements, pressure data, and integrated loads) at ONERA's centre in Lille to provide the essential datasets for calibrating and validating the new implementations of the VPM solver. These experiments will not only confirm the relevance of the proposed models but also establish robust correlations between multiple rotors and non-lifting structures, hereby laying the foundation for fast, reliable simulation tools for the design of future urban drones and helicopters.

### Objectives of the PhD

First, the effect of non-lifting surfaces, such as the ground or the urban canopies, in the incoming flow particles will be theorized and incorporated into ONERA's Lagrangian Vortex Particle Method (VPM) solver. In the framework of this PhD, a bibliographic study of the previous implementations of solid surfaces interacting with Lagrangian flows will be carried out (e.g. [2-5]) in order to propose and implement a new modelling based on panel elements. Second, the upwash and downwash effect on the ground will be studied, thus, providing key insights for the safe design of new urban

vertiports. Third, isolated/multi-rotor configurations during take-off and landing conditions will be assessed to identify the safety margins when submitted to different gust properties (intensity, duration...).

Experimental campaigns in the facilities at ONERA in Lille will provide a comprehensive dataset (velocity fields, pressure distributions, integrated loads) from academic to complex cases to validate and calibrate the numerical models and to delineate the limits of current approaches.

### Activities of the PhD

The PhD thesis will begin with the numerical implementation and analyses in ONERA's Meudon centre. Then, during the second year of the PhD, the student will move to Lille to pursue the PhD carrying out subsequent experimental tests on isolated rotors and multi-rotors interacting with basic surfaces (plate, cube, cylinder...) in the wind tunnels at ONERA's Lille centre. A comprehensive set of experimental measurements, including Particle Image Velocimetry (PIV), pressure measurements and, integrated load measurements will be employed. These data will be primarily compared with the VPM predictions and, for selected critical cases, with results obtained from the URANS CFD model.

These datasets will be used to validate the formulation of the non-lifting panel theory. In addition, a new formulation of a rotor wake sheet model within the VPM code, developed in collaboration with Politecnico di Torino, will be validated against experimental data for rotor-surface interaction configurations.

The goal is to enrich the current VPM solver so that it can rapidly simulate the aerodynamic interactions of multi-rotor drones and urban helicopters interacting in realistic urban environment as well as enhancing the experimental capabilities for these complex cases.

The results will be published in peer-reviewed journals and presentations at conferences and doctoral-student workshops throughout the PhD.

### References

- [1] Valentin, J. (2024). *Multi-Fidelity Vortex Particles Coupling with Lifting Line and Eulerian Methods for 3D Viscous Aeronautical Simulations* (Doctoral dissertation, Normandie Université).
- [2] Anderson, R. and Ning, A., *A Coupled Source Panel, Actuator Line, and Viscous Vortex Particle Method in an O(n) Scheme*, AIAA SCITECH Forum, National Harbor, MD, Jan 2023.
- [3] P. Ploumhans, G.S. Winckelmans, J.K. Salmon, A. Leonard, M.S. Warren, *Vortex Methods for Direct Numerical Simulation of Three-Dimensional Bluff Body Flows: Application to the Sphere at Re=300, 500, and 1000*, Journal of Computational Physics, 2002.
- [4] Alvarez, E. J., Joseph, C., and Ning, A., *Vortex Particle Method for Electric Ducted Fan in NonAxisymmetric Flow*, AIAA Aviation Forum, San Diego, CA, June 2023.
- [5] Alvarez, Eduardo; Ahuja, Vineet; Lakshminarayan, Vinod; Perry, Aaron; Anderson, Ryan; and Ning, Andrew. *Actuator Disk Model for Aeropropulsive Coupling Effects in Vortex Particle Method*, Faculty Publications, 2005.

### Expected collaborations

This PhD is related to another Franco-Italian PhD between ONERA and Politecnico di Torino where the proposed methods will be complimentary and the capabilities of the VPM will be enhanced.

#### ONERA's center

Departement : Aérodynamique, Aéroélasticité, Acoustique  
Lieu (centre ONERA) : Meudon and Lille  
Supervisors : M. Balmaseda Aguirre, J. Valentin and G. Tanguy

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