

## Internship opportunity 2023

### Title: Large Eddy Simulation of a rotor with an impedance patch on its blades

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#### Background

UAVs are taking a significant space in our daily life since they share with us more and more common places due to their wide range of applications. We can find them in the film industry, health assistance, and they are forecast to be used for commercial deliveries (Fig.1). This translates into an increase in noise that not only affects the daily life of the people, but becomes an environmental problem. That is the reason why different approaches have been proposed to mitigate the acoustic footprint of drones ranging from the test of materials, optimization of rotor geometries and the use of bioinspired rotor blades.



Figure 1: Examples of drones in commercial applications. Left: Drone for film recording, Right: Drone for commercial delivery

To do so, acoustic liners are well established devices in the aeronautical industry aiming to reduce the noise levels. We can find them mainly in the nacelle of turbofans in the form of honeycomb structures acting as Helmholtz resonators. A novel approach is the integration of a recently developed liner called LEONAR [2] inside the blades of a drone rotor intended to reduce the generated noise. The objective is to propose a first design of this new rotor with an advanced liner concept and for that aim, numerical predictions are required to optimise the involved parameters.

Acoustic liners are modelled in terms of impedance. The acoustic impedance is analogous to the concept of electric impedance which is composed of a resistive and a reactive parts. However, they are usually defined in the frequency domain, which makes them difficult to apply on time-marching code. To overcome this issue, TDIBC (Time-Delayed Impedance Boundary Conditions) has been introduced, but further validations are still required. This is the main objective of this internship, which is the validation of the proposed concept with

Computational Fluid Dynamics (CFD) simulations coupled with a Time-Domain Impedance Boundary Condition (TDIBC).

### Program of internship

In order to predict accurately the noise of rotors with impedance patches, a state-of-the-art simulation method, namely high-order large eddy simulations (HO-LES) of the full 3D Navier-Stokes problem, will be used. This flow solver is an in-house HO-LES code solving the 3D compressible Navier-Stokes equations, named IC3, and developed at ISAE-SUPAERO. It is based on high-order spectral methods for the spatial discretization, which allow high order of convergence, up to 5th order [1]. These methods are well adapted to propagate the turbulent structures inside the jet mixing layer, as well as the acoustic waves with a very low dissipation. This solver has been used recently on regional, national and European supercomputing facilities on various subsonic and supersonic flows.

In recent simulations, the noise from a rotor typical of a small unmanned aerial vehicle (UAV) has been investigated. This work has been performed using meshes of about 160 millions points and up to 10.000 processors were used simultaneously to run the simulations. Figure 1 shows the hydrodynamics and the acoustics fields of the rotor.

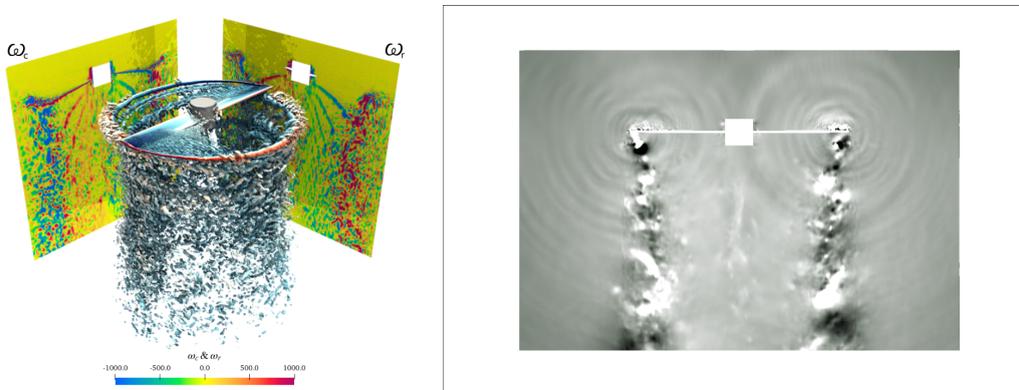


Figure 2: Aerodynamic field on the right and acoustic pressure fluctuation in grey scale ranging from 5 Pa to 5 Pa on the right

In the proposed Internship, the mesh and the solution of the previous simulation will be used, and an impedance patch will be added to mimic the presence of an acoustic liner on some part of the blade. This internship will be in collaboration with a PhD whose subject is to develop liners integrated into the blades, thanks to advanced acoustic liner concepts, like the LEONAR [2].

To achieve such a complex simulations, the internship will follow the following steps:

- (i) The impedance, measured experimentally, will have to be fitted for a TDIBC in terms of a pole-based function (pbf), for example through a vector fitting approach.
- (ii) While fitted, the whole implementation of the TDIBC in the HO-LES code will have to be validated on a simple case, for instance a simple duct with an impedance patch and an injected acoustic wave, for which analytical solutions exist.
- (iii) Further validations in presence of mean flows will then be considered.
- (iv) Depending on how the internship goes, a first simulation of the rotor with an impedance patch will be carried out.

The results will be compared with a formulation based on a tailored Green's function [3] and will be used to test the validity of the proposed concept.

## Bibliography

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- [3] Matthew A. Nobile and Sabih I. Hayek. (1982). Sound propagation over an impedance plane. *The Journal of the Acoustical Society of America* 71, S36-S36