# LESFOS (aeroacoustic Large Eddy Simulation of a 360° Fan-OGV Stage)

The increase of airports capacities and stringent noise regulations have turned noise pollution in the vicinity of airports into a significant challenge for aircraft manufacturers. Modern Ultra-High Bypass Ratio (UHBR) engines have enabled a significant decrease of jet and tonal fan noise. Yet, in these engines, fan BroadBand Noise (BBN) has become a major contributor.

This project focuses on the source mechanisms and the topological organisation of tonal noise and BBN in the fan/OGV stage of a turbofan engine. The current inability to accurately predict BBN sources' frequencies and amplitudes, and the resulting distribution of acoustic modes propagating inside the engine, is a major impediment to the development of quieter UHBR engines. This prevents the design of disruptive configurations that could bring significant noise reduction as for now such new geometries require expensive tests in real configurations.

Only a few aeroacoustics-oriented LES have been achieved so far for fan stages in modern engines. They usually consider a periodic angular sector of the stage, which may require some rescaling of the OGV, and often rely on a zonal approach in which part of the configuration is represented through its Reynolds-Averaged Navier Stokes (RANS) solution. However, the exact number of blades and vanes of the stage strongly influences rotor-stator interaction noise. Current LES methods suffer from the fact that the acoustic duct modes distribution associated with BBN requires the simulation of a full 360° configuration. Considering only an angular sector forces the periodicity of the acoustic field, which would lead to a spurious distribution of duct modes in a simulation aiming at directly predicting the acoustic field in the vicinity of the fan/OGV stage.

Furthermore, in the tip gap region, structures evolve from a well-defined vortex forming at the tip to a complex flow comprising numerous turbulent secondary flow regions. This transition leads to a specific far-field acoustic signature comprising both tonal and broadband components. Also, the blade-to-blade unsteady loads correlation decreases progressively downstream of the fan blade leading-edge, which impacts the acoustic radiation as sources from one sector do not simply add to the ones from another sector. To provide low-order models with the proper blade-to-blade correlations in the tip-gap region and in the rest of the flow, a full-span 360° simulation is required.

The main objective of the project LESFOS is to perform for the first time Large Eddy Simulations of a full fan stage, designed for a direct aeroacoustic analysis. The configuration considered will be the object of an experimental campaign at Ecole Centrale de Lyon, thus providing validation data for the simulation. An extensive use of the numerical results will allow for the improvement of reduced-order models for BBN prediction. Another objective of this work is to assess the reproducibility of the methodology applied for high fidelity calculations aiming at the prediction of BBN in a realistic configuration. The large size and the high geometrical complexity of the fan stage considered in this project requires the use of High-Performance Computing (HPC).

To precisely define the CPU cost of this reference simulation, the authors have developed and tested a pre-processing tool named LESCOTT. LESCOTT is used for mesh pre-dimensioning and gives an estimation of the computational time of the LES computation for fan/OGV stage applications. Different mesh refinement zones are defined based on both turbulent and acoustic criteria, considering the numerical scheme and mesh properties (especially dissipation and dispersion properties). A CPU allocation of $30 \times 10^9$ CPU h was granted to the present 360° configuration comprising 16 rotor blades and 31 stator vanes.