When an object generates lift as a result of its motion through the air, it leaves a typical signature in its wake invariably featuring two parallel vortices. These structures are of great interest, both fundamentally considering their prevalence in fluid dynamics, and industrially for the critical impact they have on air traffic. This thesis is devoted to the study of the formation of such vortices in the wake of wings and helicopter rotors, and to the development of the numerical methods upon which the related analyses depend.

Wake vortices generally result from the roll-up of vortex sheets. We aim to simulate this entire process over space and time, starting with the shedding of vorticity from the aerodynamic devices (wings and blades). To this end, we develop and validate a novel immersed lifting-dragging line model, implemented in a vortex particle-mesh method which provides the necessary large eddy simulation capabilities.

Despite their inherently different generation processes, the far wakes of wings and rotors appear similar. With our simulations, we investigate their universal character, unveiling some intriguing specificities which depend on the device operating conditions. Focusing on the three-dimensional effects affecting the wake development, we emphasize the important role of vortex interactions and instabilities in the transition to turbulence. We also identify the airfoil parasitic drag as the leading cause of vortex wandering, one of such instabilities. Finally, taking advantage of the present numerical framework, we design multiple wake sensing strategies for airplane formation flight, a technique that could one day help commercial airliners save energy.