Summary

Unmanned Aircraft Systems (UAS) are state of the art in aerospace industry for both commercial and military applications. In particular, small scale multicopters have gained momentum owing to their simple design, vertical take-off and landing as well as hover capabilities.

In the past years efforts were made to improve autopilot performance developing advanced Guidance, Navigation and Control (GNC) algorithms. Limited research studies focused on experimental characterization of small scale UAS and a way to assess and improve their design. However, the integration of unmanned aircraft with manned aviation within the context of Unmanned Aircraft System Traffic Management (UTM) requires a step forward to fully understand UAS potential even when unconventional weather conditions occur. Hence, detailed experimental data have a major role and provide an important basis to improve simulation tools required to predict vehicle performance. However, experimental testing has an important economical impact and requires a lot of time to collect high quality data. When extreme environmental conditions are considered, challenges on sensing device as a result of low temperatures and/or high altitudes arise; moreover, a systematic test approach is essential. The lack of experimental data as well as accurate prediction models to evaluate propeller coefficients over the UAS flight envelope are two major limitations in UAS science.

The aim of the following PhD thesis is the design and implementation of testing methodologies to assess performance of UAS. Among all type of unmanned systems, the attention is given to small scale multicopters and their propulsion systems. The PhD dissertation focuses on the experimental activity performed in terraXcube laboratory. Compared to other facility such as wind tunnels, this laboratory allowed to investigate desired atmospheric conditions combining different temperatures and altitudes (pressures).The main contribution of this thesis is related to the design of an experimental setup to collect thrust, torque, motor speed and electrical data of multicopters and propeller propulsion systems. Low temperature and high altitude effects were highlighted on performance: the corresponding air densities simulated inside the lab were exploited to characterize mechanical and electrical quantities with a systematic approach.

In the following PhD thesis attention was also given to simulation tools to predict propeller performance. Small scale thrust, torque and power data were simulated based on the Blade Element Momentum Theory combining both geometrical and aerodynamic

data for the propeller leveraged during the experimental tests. Results showed numerical and experimental data are overlapped when standard temperature and altitude conditions were considered. As soon as very low Reynolds numbers (below 100,000) were set, numerical prediction tools were not able to properly describe experimental data as a result of *laminar separation bubble* condition, responsible for performance degradation.

Experimental testing still remains a valuable instrument for the development of new UAS technologies, especially when unconventional flight conditions are considered. At the same time, improvements of simulation models are needed to describe unconventional flight conditions. These considerations lead to future works. Firstly, the investigation of other test cases such cold temperature effect on batteries and propeller performance sensitivity to icing conditions. Secondly, the definition of a mathematical model for Computational Fluid Dynamics (CFD) simulations able to predict non linearities arising from low Reynolds numbers.

The ultimate objective of this study is to support manufacturers, operators and regulatory authorities with a methodology to assess UAS capabilities in order to improve the overall safety related to these vehicle operations.