PhD thesis proposal

Gust load alleviation through real-time 3D wind estimation for flexible wings

Host institution: INSA Lyon, Ampère Lab (UMR CNRS 5005), Lyon, France
Supervisors: Paolo Massioni (Ampère Lab, INSA Lyon) and Aristeidis Antonakis (ONERA)
Starting date: As soon as possible, and **no later than September 2026**

Keywords Distributed control; turbulence/wind-field estimation; aerodynamic modeling; gust load alleviation; flexible wings; Kalman filtering/data fusion.

Candidate profile and required skills

We are looking for excellent candidates from engineering schools or top universities with strong background in:

- Control theory and state-space methods (estimation and control)
- Linear algebra and dynamical systems
- Aerospace systems / flight dynamics (aeroelasticity is a plus)
- Scientific programming in **Matlab/Simulink** and **Python**
- Very good written and spoken **English.**

Project context and objectives

As civil aviation evolves rapidly toward lighter and more energy-efficient aircraft, new challenges arise in aircraft design and flight control. Future concepts increasingly rely on **flexible high aspect-ratio wings** to reduce induced drag and fuel consumption. However, these slender and compliant structures are also more sensitive to atmospheric disturbances such as **turbulence and gusts**, which can increase structural loads, vibrations, and passenger discomfort.

Current Stability Augmentation Systems (SAS) are not sufficient for these new configurations: they typically rely on a limited number of control surfaces and on sparse/local airflow measurements, which are not adequate to anticipate and mitigate **three-dimensional, time-varying turbulence**. Meanwhile, recent sensor technologies (e.g., **lidar and cameras**) open new opportunities to estimate wind disturbances in real time and to enable more responsive, higher-performance control of flexible wings.

The main objective of this PhD is to develop and implement **distributed control methods** based on **real-time turbulence/wind estimation**, in order to compensate for variable aerodynamic forces along flexible wings and to alleviate gust-induced loads. The approach is inspired by former results on the adaptive optics control for ground-based telescopes. This work contributes to a long-term vision of improved aircraft performance and safety by integrating advanced estimation-and-control techniques into future flight management systems.

Main research steps

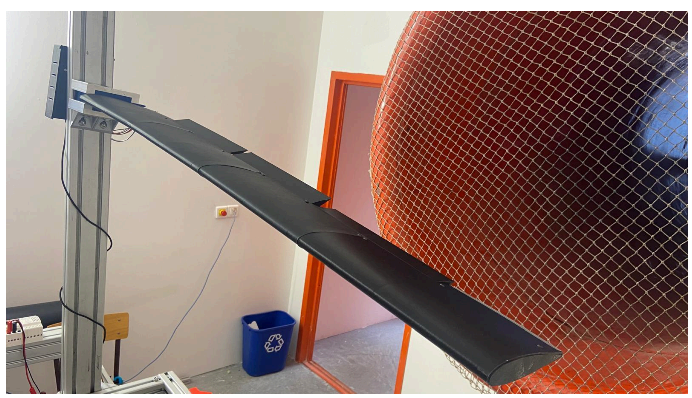
The PhD will be structured around three key components:

- **Turbulence / wind modeling:** develop 3D, time-varying turbulence models inspired by fluid dynamics and suitable for real-time estimation and control.

- **Real-time wind estimation:** design estimation methods (e.g., Kalman-filter-based approaches) using distributed sensors (potentially including lidar) to reconstruct the air-velocity field in real time.

- **Distributed gust load alleviation control:** develop control algorithms that use the estimated wind information to command a network of actuators distributed along the wing, enabling local adjustments that improve stability, reduce loads, and enhance efficiency in disturbed conditions.

Experimental validation is foreseen at the end of the project, based on an active wing wind-tunnel testbed.



Impact

Beyond its academic interest, this PhD has strong practical relevance for civil aviation. Improved gust load alleviation can reduce structural constraints, improve passenger comfort, and support fuel savings. The methods may also translate to other domains where environmental disturbances affect flexible vehicles or structures.

To apply: send your CV to paolo.massioni@insa-lyon.fr and aristeidis.antonakis@onera.fr

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