

Aerodynamic problems of a gust-safe and green low-altitude economy

Bernd R. Noack^{1,2,3,4,*}

¹Shenzhen University, P. R. China

²Guangdong Province VTOL Aircraft Manufacturing Innovation Center, Shenzhen, P. R. China

³Shenzhen Technology University, P. R. China

⁴Harbin Institute of Technology, Shenzhen campus, P. R. China

Bernd.Noack@szu.edu.cn

Abstract. The rapidly evolving low-altitude economy transforms mankind into an aerial society: Drones and air taxis allow unprecedented transport and mobility over traffic jams in congested metropolises and to remote rural destinations. Yet, steady winds and wind gusts challenge the safety of air taxi and delivery drone operation in urban environments. These winds lead to unintended displacements and may result potential collisions and accidents. In addition, current air taxis and drones offer numerous opportunities for aerodynamic optimization.

We address this safety challenge for multicopter drones and similarly designed air taxis on several fronts. First, an aerodynamic drone model is developed for low and high-speed operation [1]. This plant serves for the assessment and optimization of cruise performance and flight control under wind gusts. Second, the urban wind conditions are emulated in simulations and experiments with a self-build fan array wind generator (FAWG) with 40×40 individually controllable fans (Guinness World Record 2025), [2]. Thus, flow estimation methodologies are developed for sparse optimized sensors [3]. Finally, the flight control is optimized for take-off, landing and cruise under gusty wind conditions. The control design employs the aerodynamic model, artificial intelligence based learning and is further improved by estimated flow conditions. Energy efficiency improvement are addressed by rotor shape optimization [4] and smart skin separation control [5].

This lecture is based on work of Prof. Noack's team in collaboration with Tianjing DongTeng Technology Development Co, Ltd., SZUAVIA, and the teams of Profs. Franz Raps, Jun Yang, Nan Gao, Yang Yang, Yannian Yang, Dmitry Kolomenskiy, Xiaozhou He, Hongwei Zhang, Gang Hu, Andrea Ianiro, Stefano Discetti and Angelo Iollo.

References

- 1. LIU, Y. T. ET AL. 2025 Rotor force model for drones. *Physics of Fluids* **37**, 015218:1–15.
- 2. LIU, Y.T. ET AL. 2025 Aerodynamic characterization of a wind generator with 40×40 individually controllable fans (Editor's pick). *Phys. Fluids* **37**, 02511:1–12.
- 3. HOU, C., ET AL. 2024 Machine-learned flow estimation with sparse data—exemplified for the rooftop of an UAV vertiport (Featured article). *Physics of Fluids* textbf36, **125198**:1–19.
- 4. WANG, T.Y., ET AL. 2023 Topologically assisted optimization for rotor design. *Phys. Fluids* **35** (5) **055105**:1–14.
- 5. JIANG, Z.T., ET AL. 2024 Jet mixing optimization using a flexible nozzle, distributed actuators and machine learning. *Phys. Fluids* **36**, 095126:1–19.