Computational Aeroacoustics: High-Fidelity Simulations and Reduced-Order Models for Scientific and Technological Applications

William Wolf

School of Mechanical Engineering

University of Campinas

FAPESP Week France

Toulouse, France

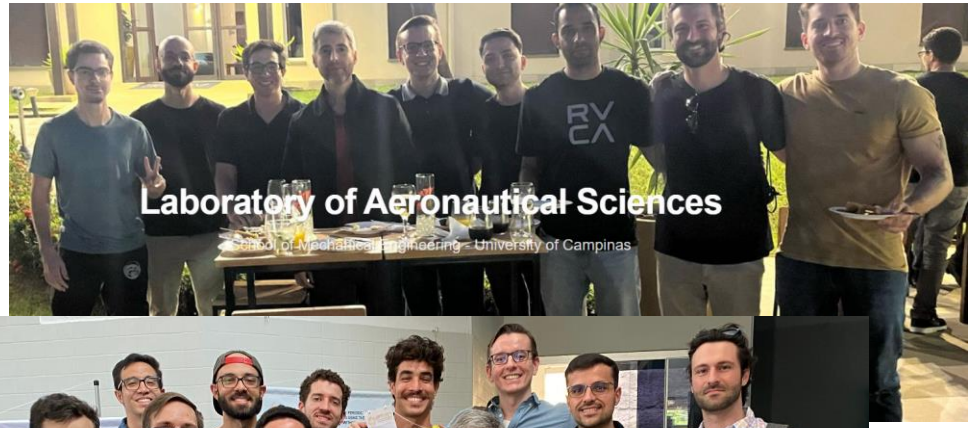
June 10 - 12, 2025

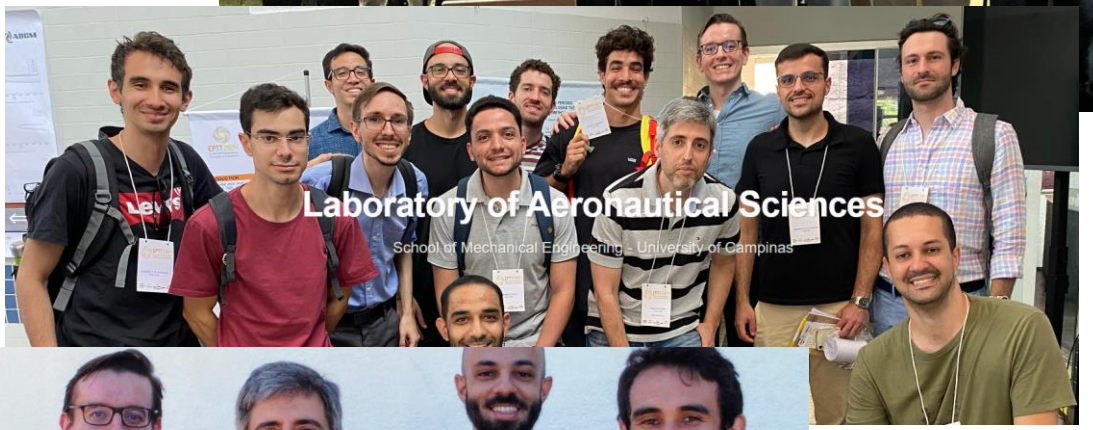
Laboratory of Aeronautical Sciences

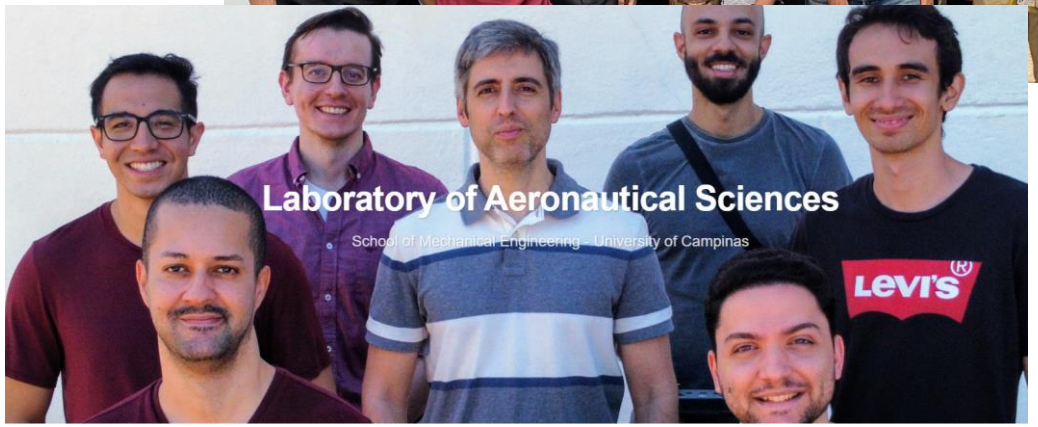






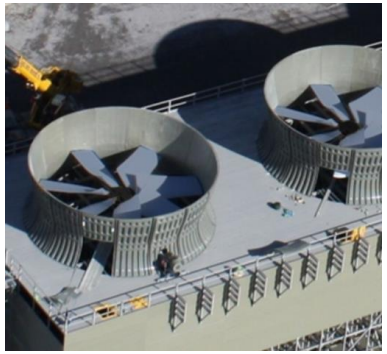






Aeroacoustics and airframe noise

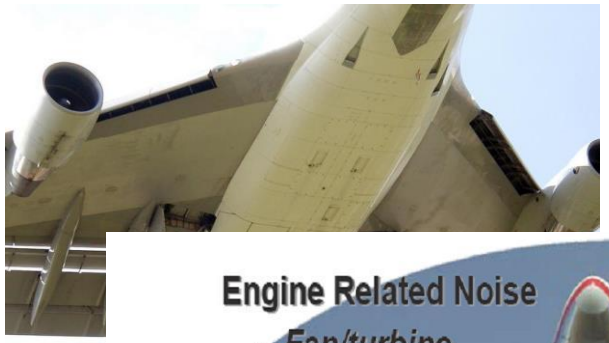




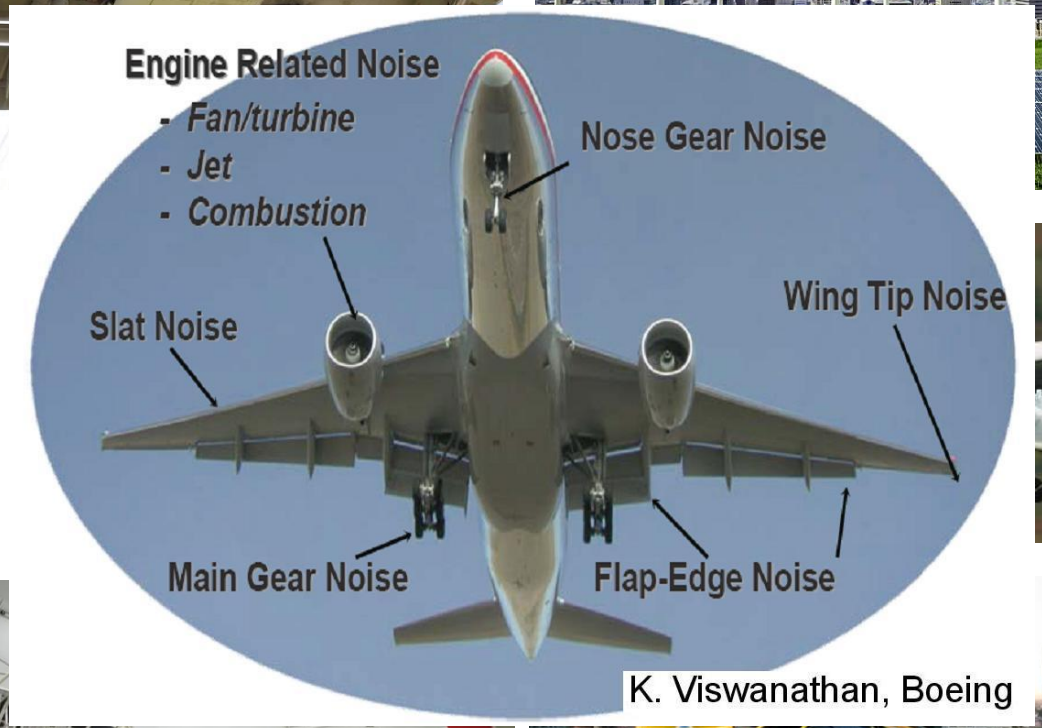


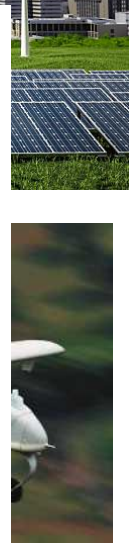

- Aeroacoustics: field of study that deals with sound generation and propagation in unsteady aerodynamic flows
- Airframe noise is important: aircraft, automobiles, wind and gas turbines, industrial fans and rotors, home appliances
- Common feature: turbulence

Aeroacoustics and airframe noise

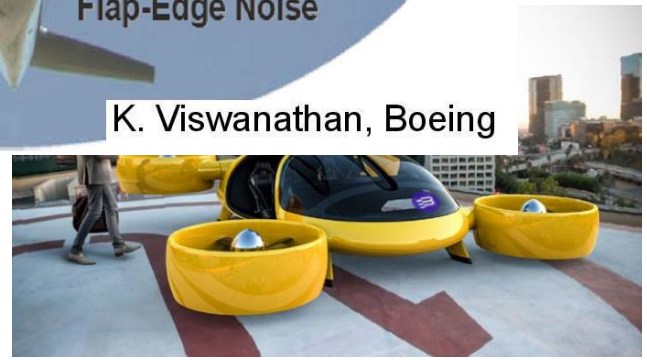












- Aeroacoustics: field of study that deals with sound generation and propagation in unsteady aerodynamic flows
- Airframe noise is important: aircraft, automobiles, wind and gas turbines, industrial fans and rotors, home appliances
- Common feature: turbulence

Turbulence and turbulent flows

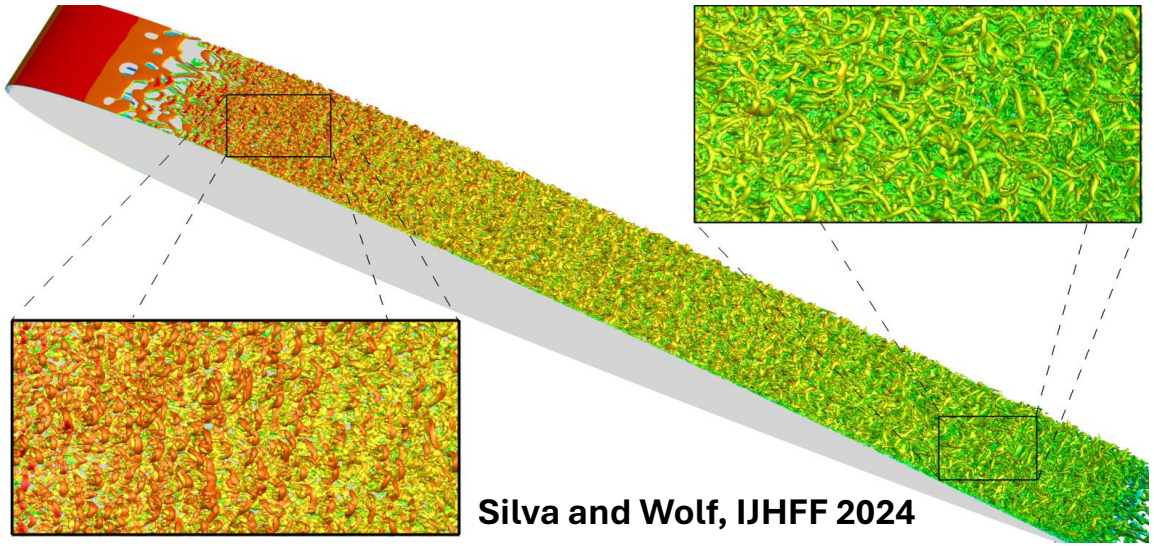




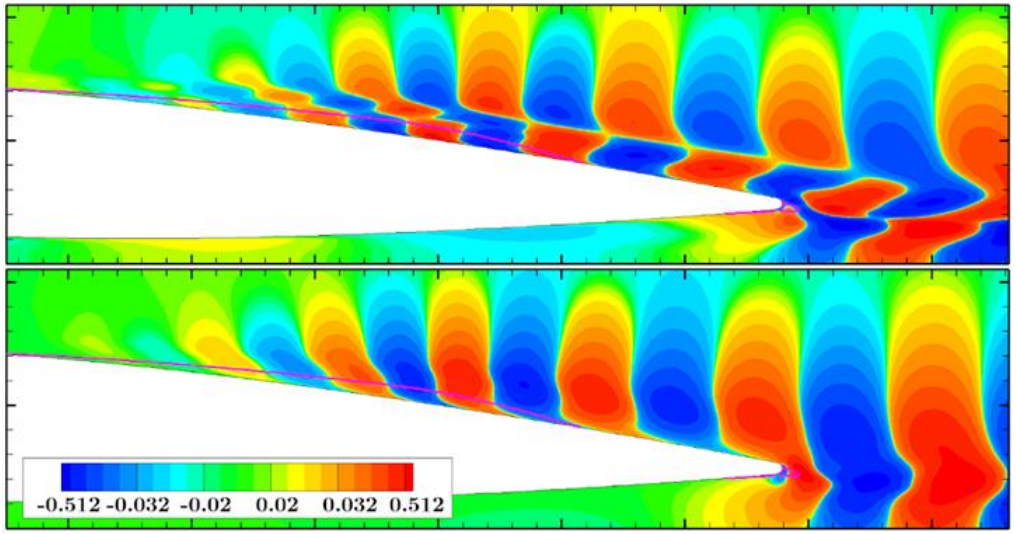


- Turbulence: “The most important unsolved problem of classical physics” (Feynman)
- Nature of turbulence: irregularity, mixing, three-dimensional, eddies
- Applications in nature, industry and everyday life: transportation and energy, weather, industrial processes
- Advances in computational power and numerical methods allow the accurate prediction of turbulent flows

What do we do in the laboratory?



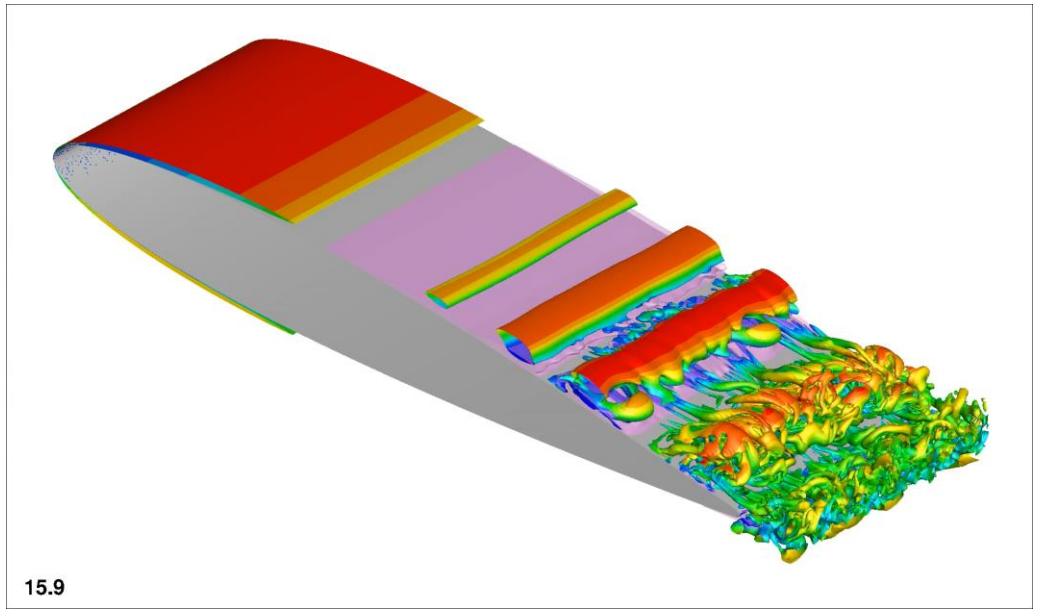
Silva and Wolf, IJHFF 2024

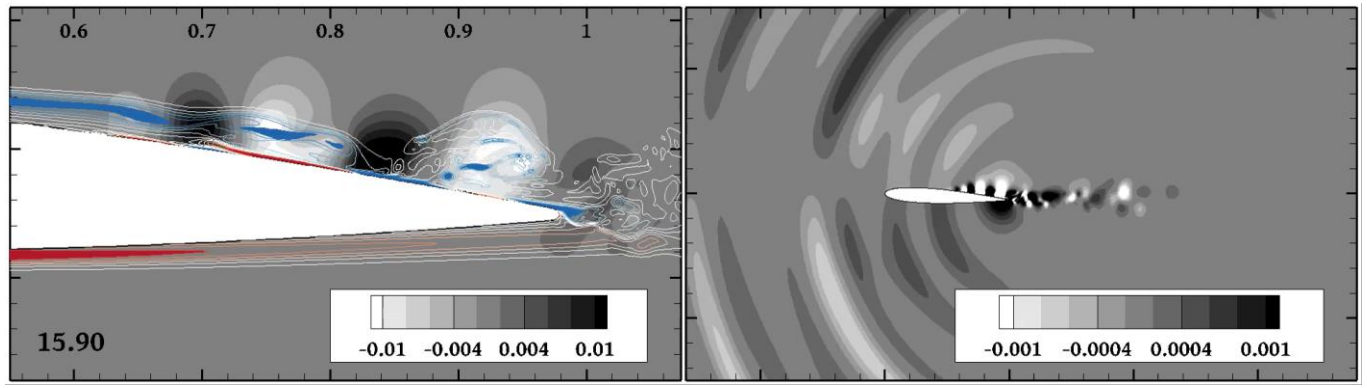


Ricciardi, Wolf and Taira, JFM 2022

- **High-fidelity simulations:** formulations based on first principles, avoid modeling, numerical algorithms that represent the physics, use of intense computational power, generation of large datasets
- **Reduced-order models:** appropriate for design, optimization and flow control, lower computational power, should represent the physics with higher fidelity possible, need for data

Airfoil noise



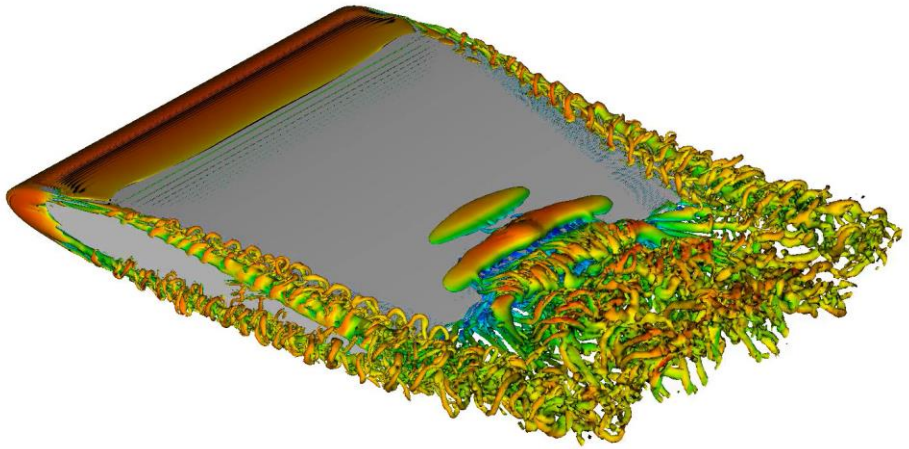


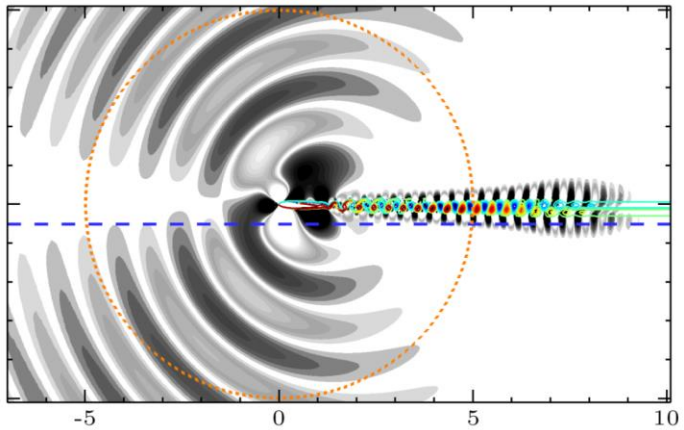
Ricciardi, Wolf and Taira, JFM 2022
Ricciardi and Wolf, PRF 2022

- **High-fidelity simulations:**
  - DNS and LES of airfoil flows
  - Transitional airfoil noise, secondary tones and acoustic feedback loop
  - Airfoil noise in turbulent regime
  - Rotor noise: LBM applications
- **Reduced-order models:**
  - Boundary integral equations
  - Amiet model for realistic airfoils
  - Novel strategies of acoustic analogy
  - Vortex particle methods

Airfoil noise

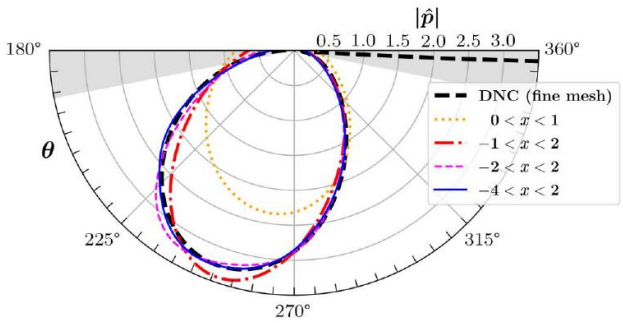
LBM simulation





Ricciardi, Wolf and Spalart, AIAAJ 2023

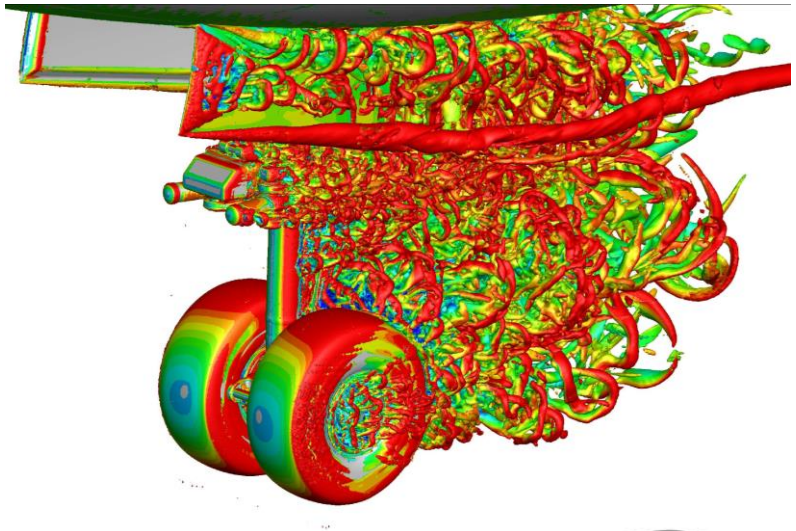
Incomplete FWH surface

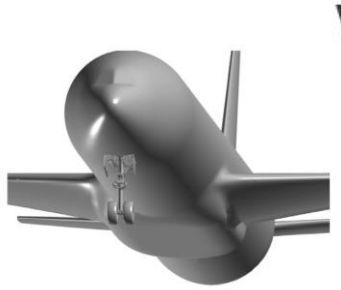


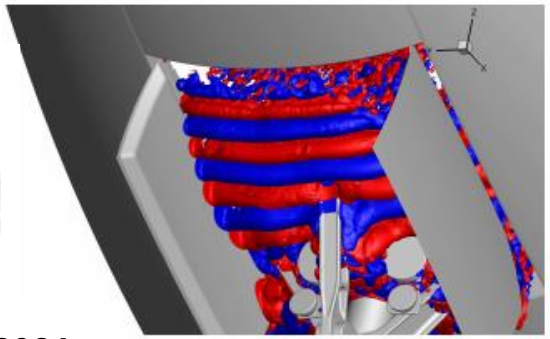
- **High-fidelity simulations:**
  - DNS and LES of airfoil flows
  - Transitional airfoil noise, secondary tones and acoustic feedback loop
  - Airfoil noise in turbulent regime
  - Rotor noise: LBM applications
- **Reduced-order models:**
  - Boundary integral equations
  - Amiet model for realistic airfoils
  - Novel strategies of acoustic analogy
  - Vortex particle methods

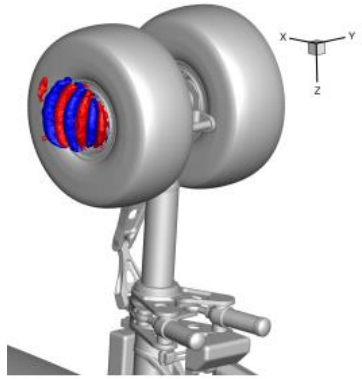
Complex industrial configurations



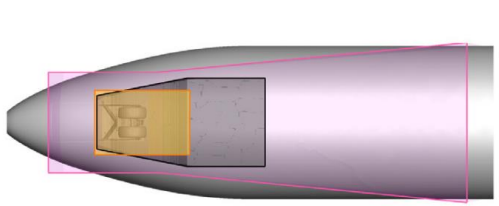


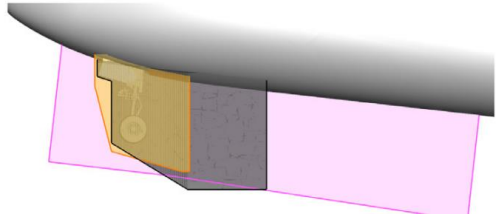






Ricciardi et al., JSV 2021





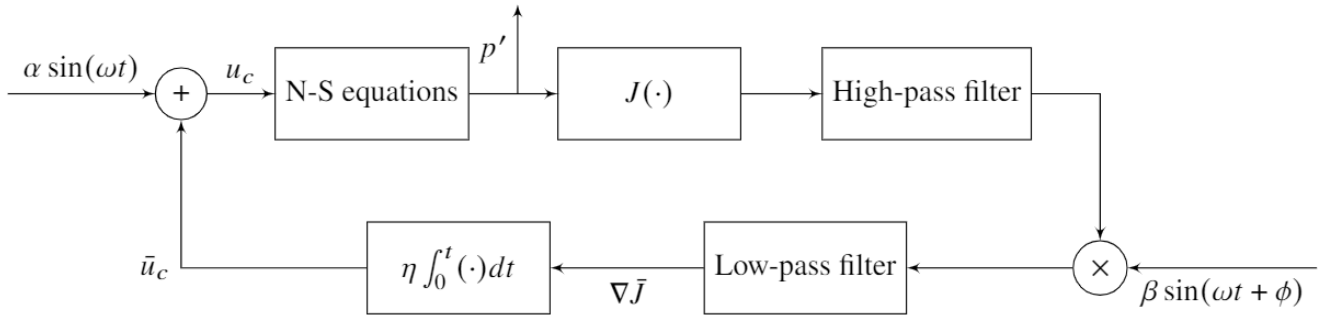
- **High-fidelity simulations:**
- Design of modern aircraft depends on noise reduction to meet more stringent regulations
- Landing gear becomes important noise source on landing
- DDES of full aircraft: 8M CPU hours, 80+ TB data
- Noise prediction: Incomplete FWH surface
- Flow modal decomposition for noise source identification
- Theoretical models for cavity noise

Flow control for noise reduction



Déda and Wolf, AIAAJ 2021

- Airfoil noise reduction with closed-loop active flow control
- Application of extremum seeking control (ESC) and slope seeking control
- ESC module implemented on high-fidelity CFD code
- ESC seeks to minimize noise emission in real time



Conclusions and acknowledgements

FAPESP France Week 2025

- Presentation of research topics in aeroacoustics developed in the Laboratory of Aeronautical Sciences at Unicamp
- Applied research can only be possible after fundamental science (thanks to FAPESP Young Investigator grants I & II)
- Open for collaboration

FAPESP

CCES UNICAMP

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

CENAPAD SP

BOEING

Computational Aeroacoustics: High-Fidelity Simulations and Reduced-Order Models for Scientific and Technological Applications

William Wolf

School of Mechanical Engineering

University of Campinas

FAPESP Week France

Toulouse, France

June 10 - 12, 2025