EXPERIMENTAL AND NUMERICAL AEROACOUSTICS RESULTS OF STRUT-BRACED WING CONFIGURATION

PRESENTERS:

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CONTRIBUTORS:

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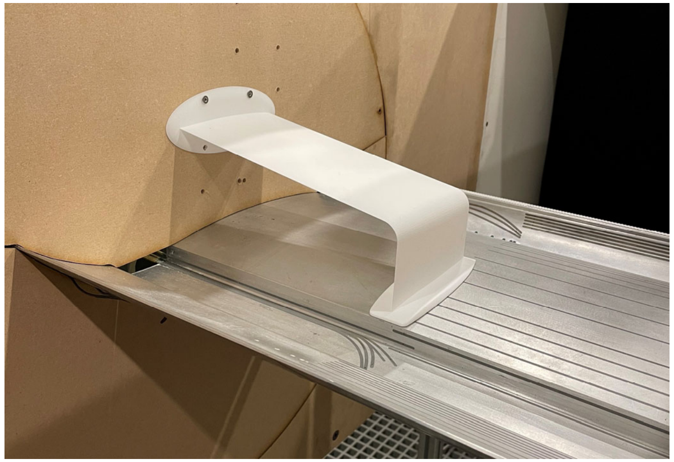
OUTLINE OF THE PRESENTATION

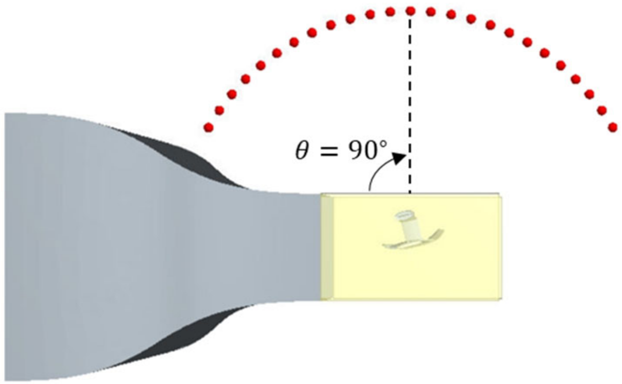
Introduction

I. Test campaign

II. Numerical simulations

Conclusions





Joint experimental and numerical study - UoB/Siemens collaboration

Main objectives from experimental side:

- Understand effect of the strut and junction on aeroacoustic characteristics of a high-lift device
- Conduct a parametric study on the strut height and mounting location

Main objectives from numerical side:

- Provide further insight into sound source mechanisms thanks to simulation
- Consolidate our best practices for aeroacoustic simulations

Modelling of wind tunnel conditions	Correlation with test data	Deep insight into flow and acoustic thanks to simulation	Performance of numerical models (LES, DES, U-RANS, …)

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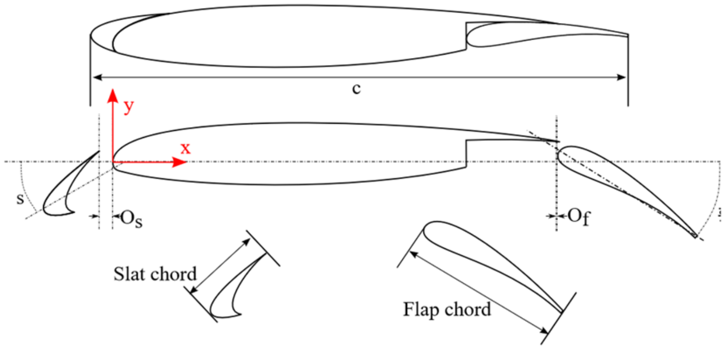
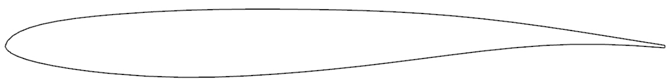
Objectives:

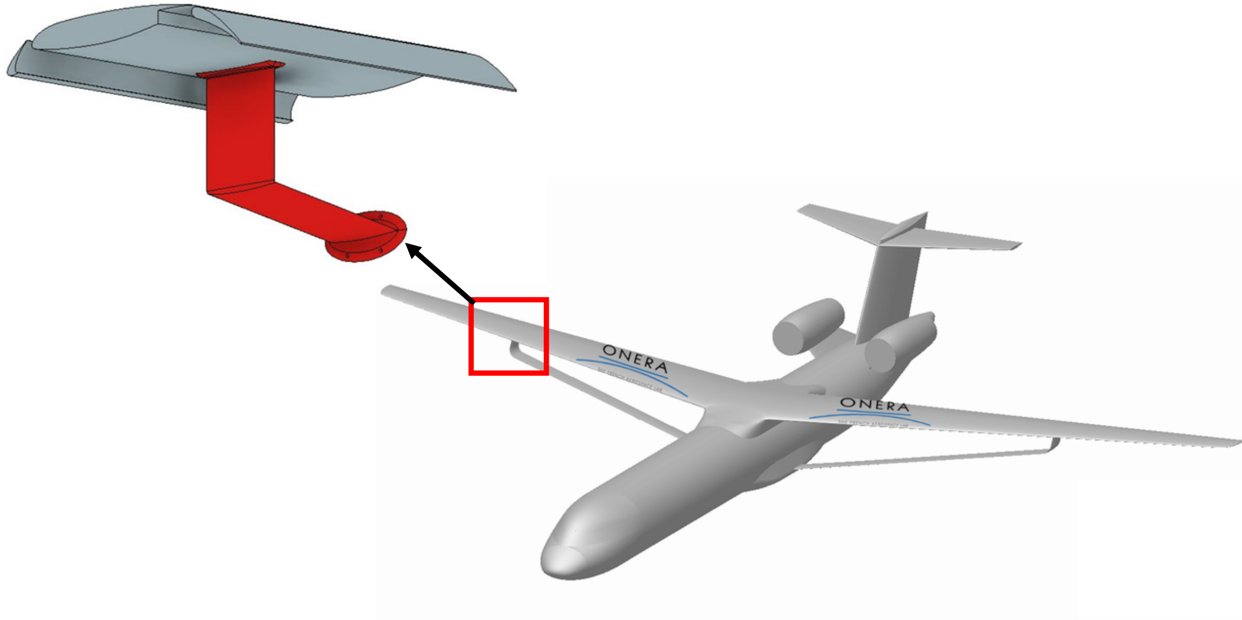
- To understand any potential noise signature changes from strut junction
- 30P30N retracted chord is like typical of this configuration
- Strut junction with wing likely to be around high-lift devices



30P30N HLD



Albatros wing aerofoil



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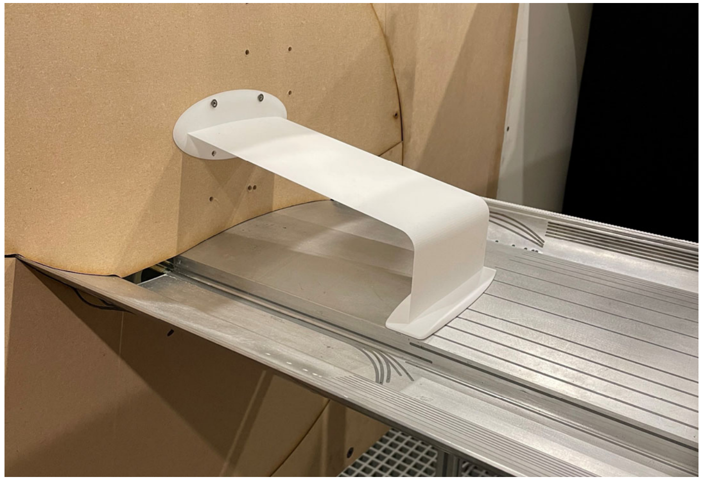
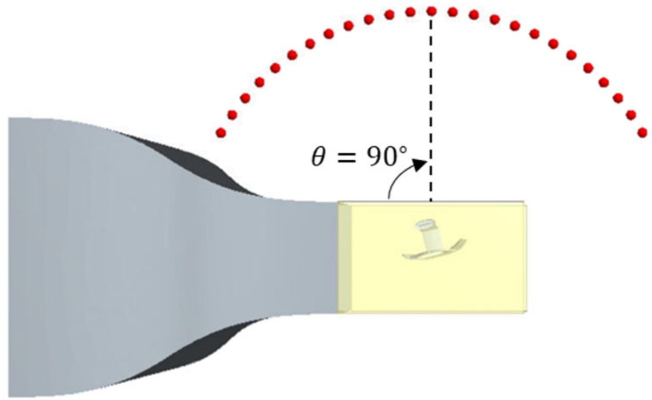
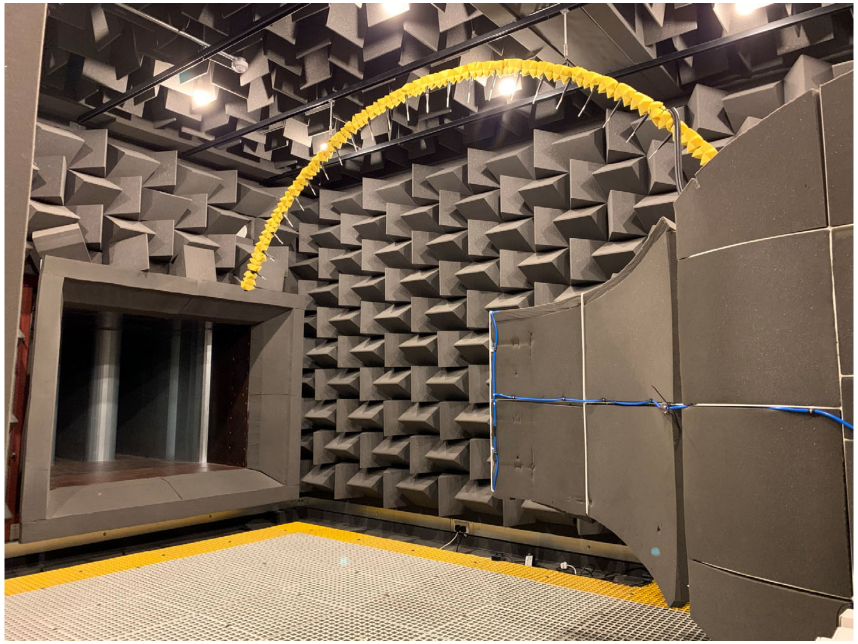




TEST CAMPAIGN

- University of Bristol Aeroacoustic Wind tunnel
- Far-field microphone array of 23x GRAS Free-field microphones

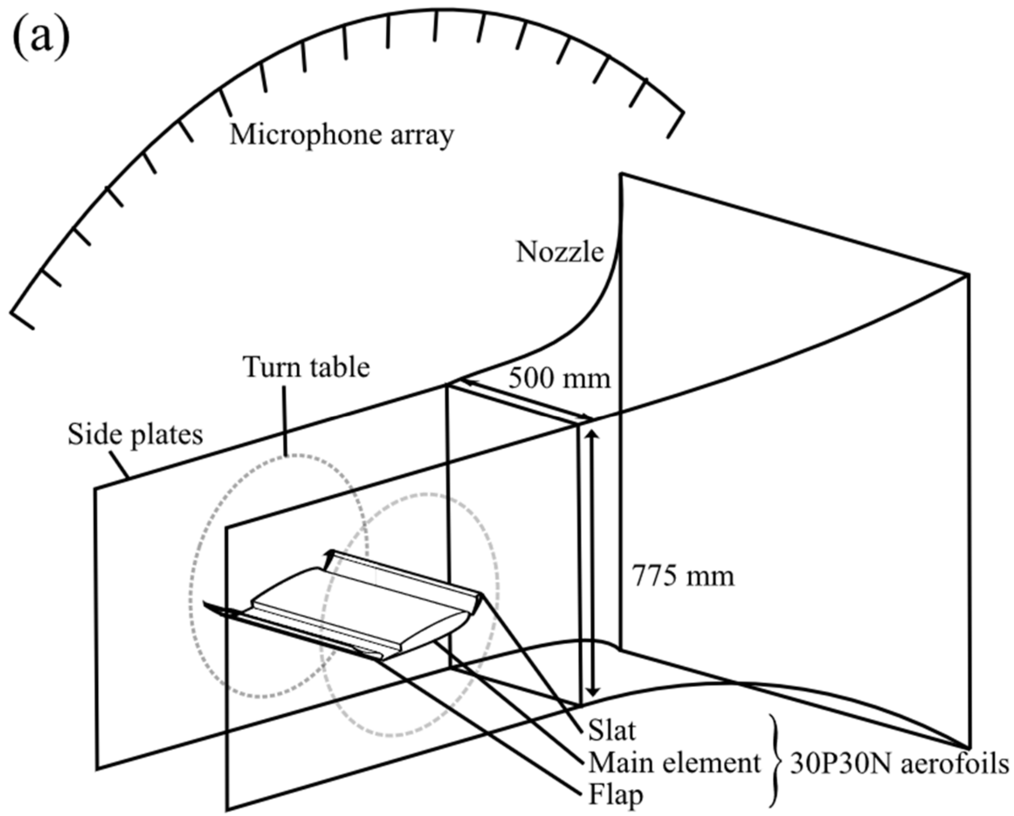


EXPERIMENTAL METHODS

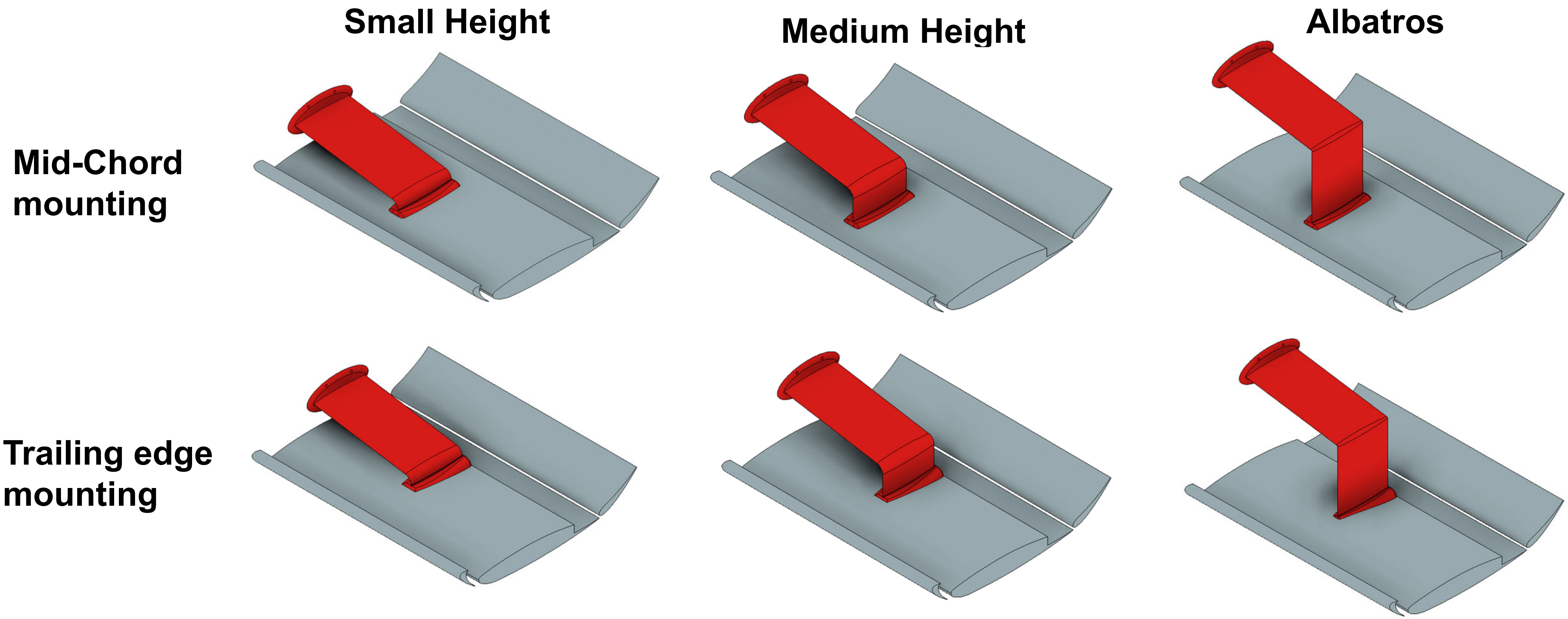
- 30P30N airfoil c=0.35m
- 3 strut heights at 2 chordwise locations
- Flow velocities U_∞=25,30 and 34 m/s
- Geometric angles of attack of α=12°,14°,16° and 18°

- 103 static pressure taps
- 18 surface pressure microphones at 3 chordwise locations

- Measurements of C_P, surface pressure fluctuations, velocity measurements using CTA hotwire.



STRUT CONFIGURATIONS



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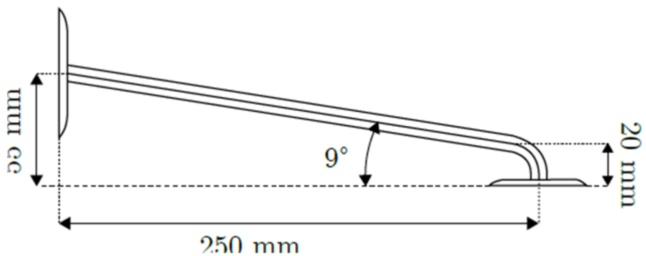
CLEAN AVIATION

STRUT GEOMETRY

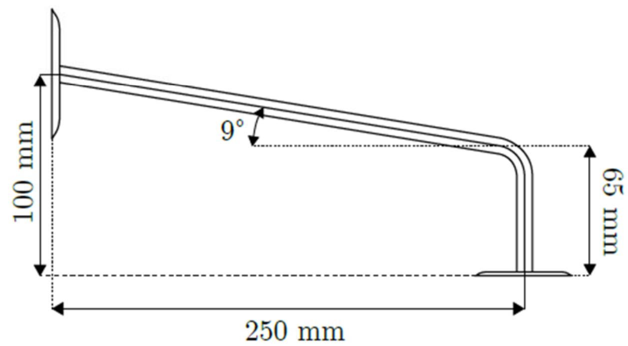
U-HARWARD

Geometric definition

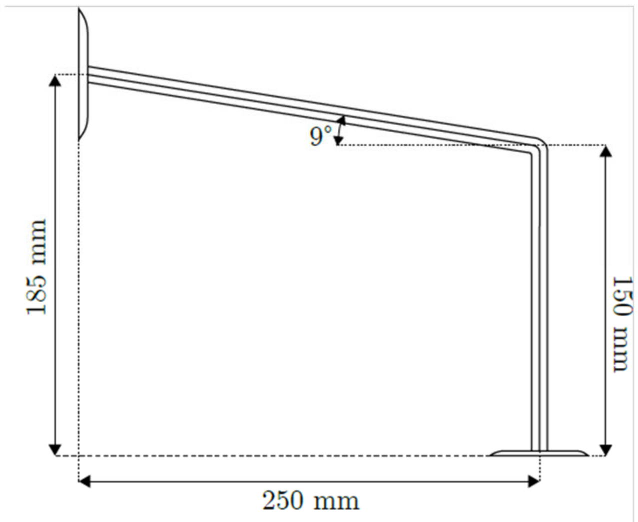
Small Height



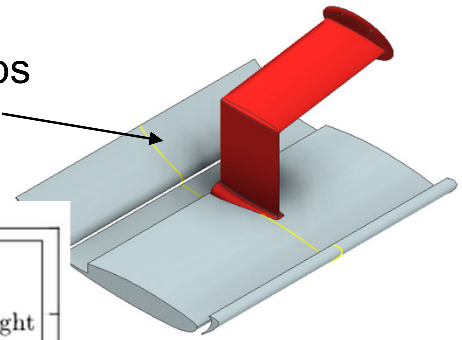
Medium Height



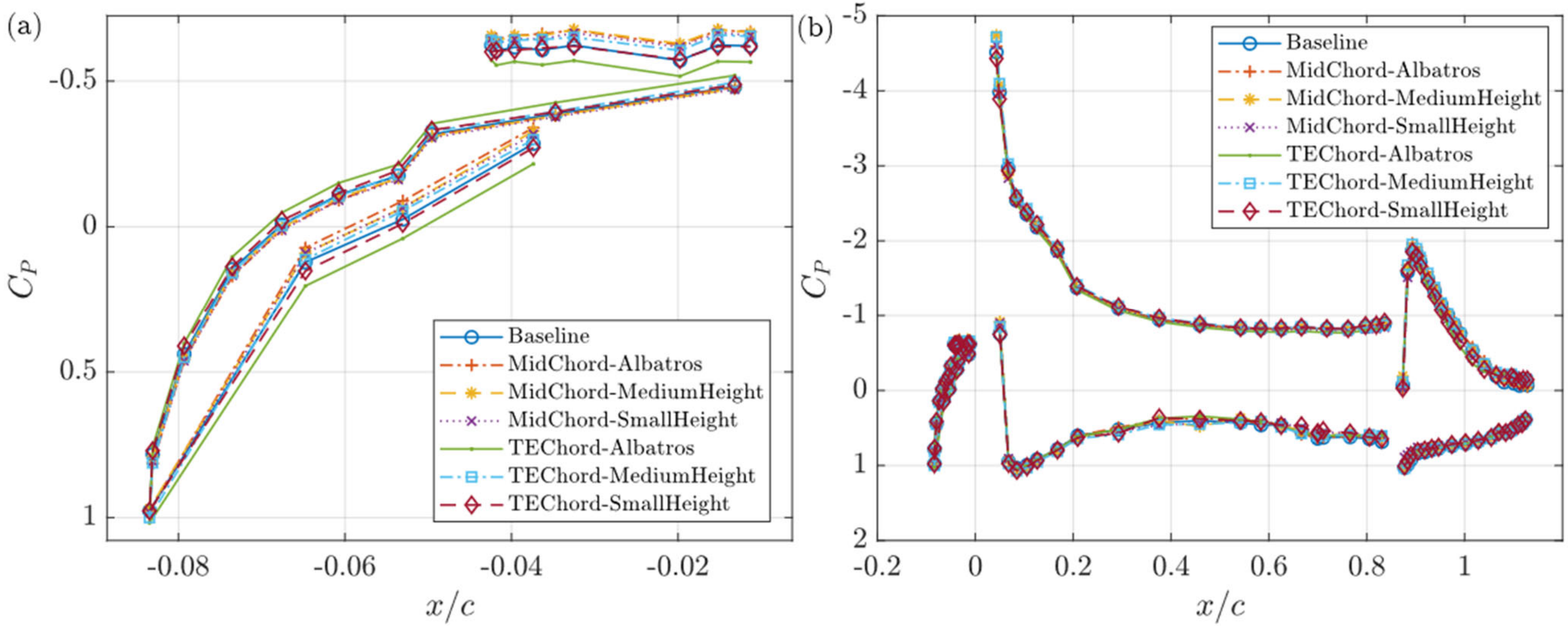
Albatros



PRESSURE COEFFICIENT

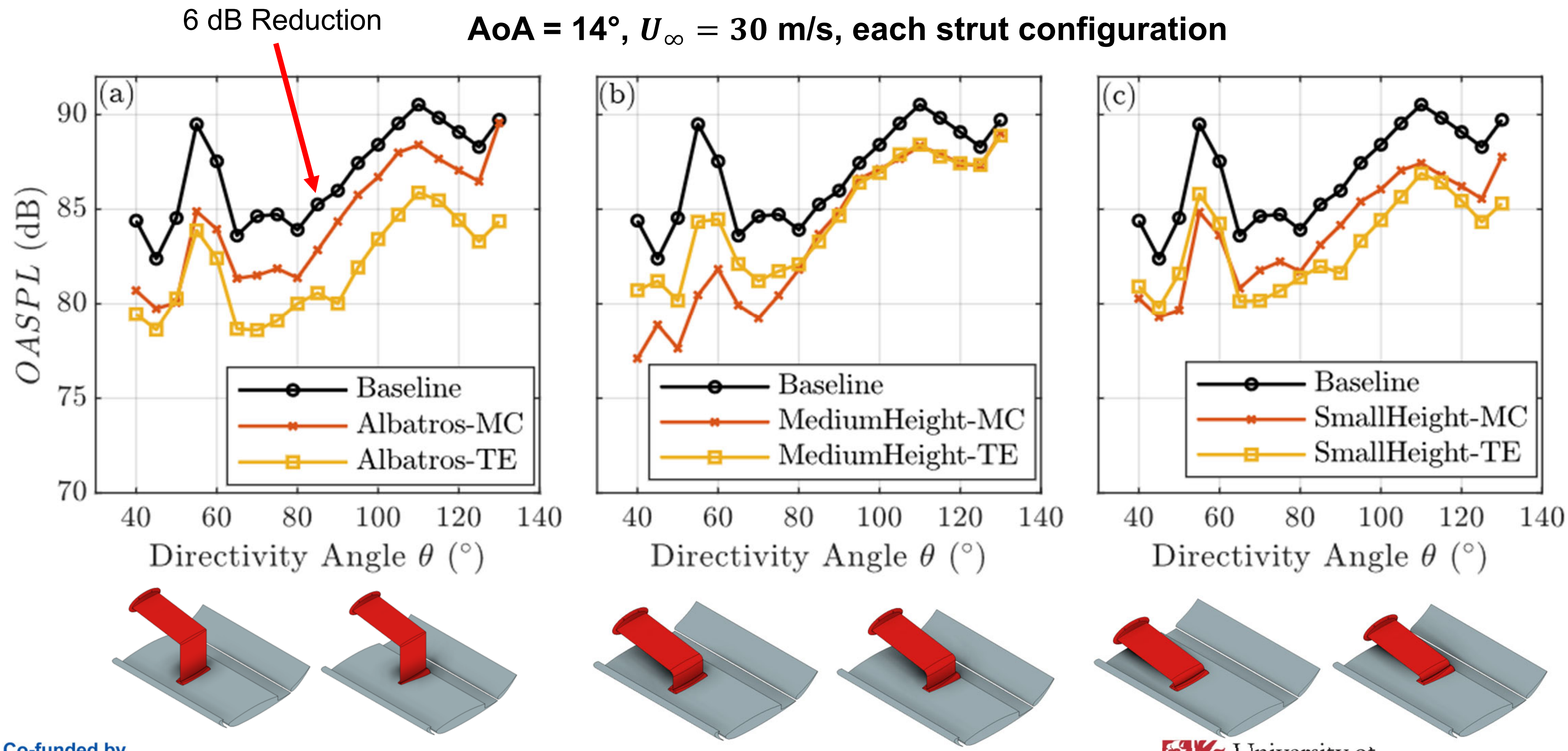


AoA = 14°, $U_\infty = 30$ m/s, each strut configuration

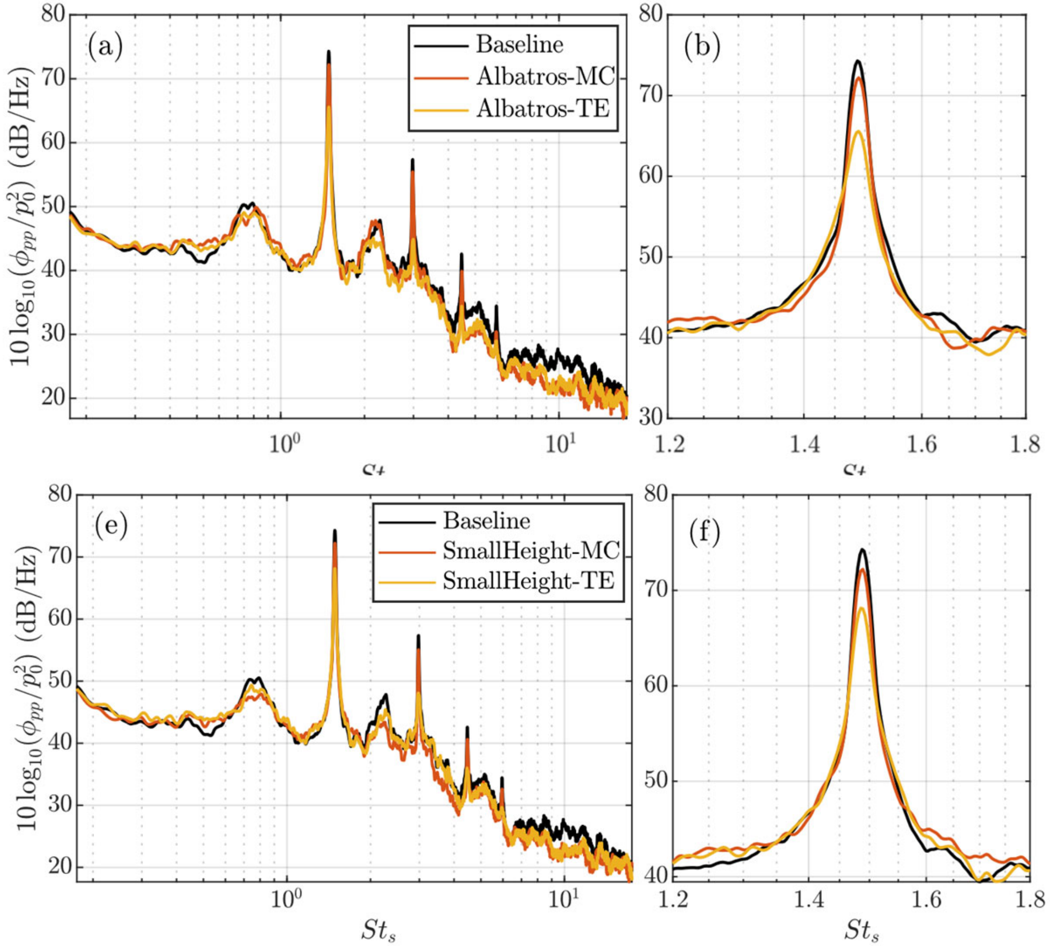


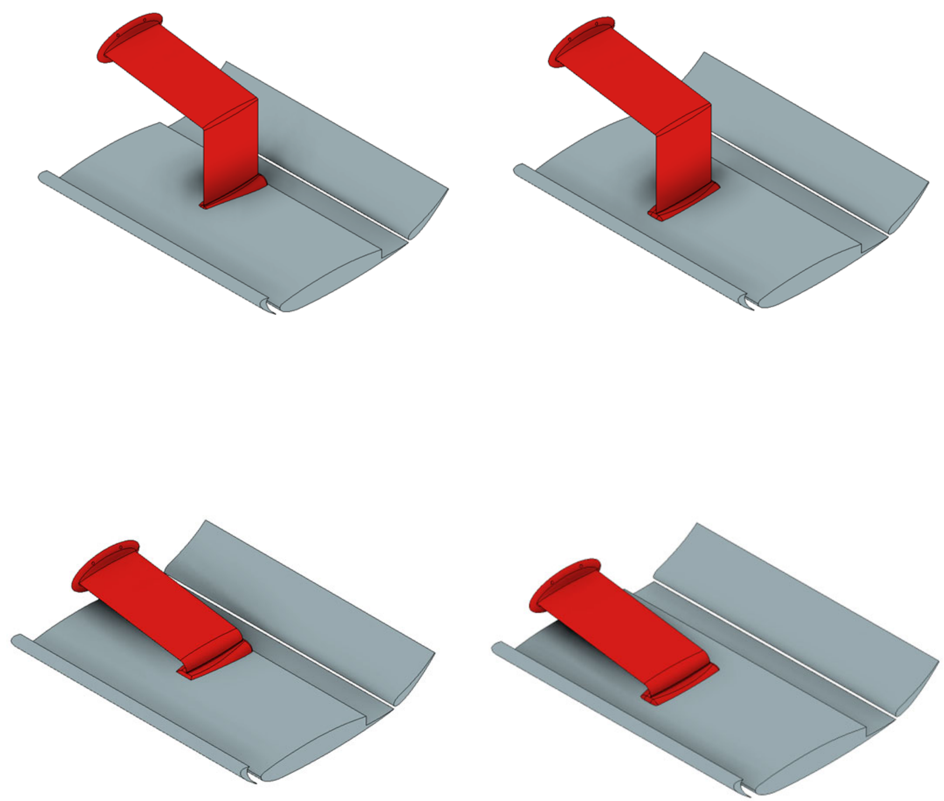
FAR-FIELD NOISE – OASPL DIRECTIVITY

AoA = 14°, $U_\infty = 30$ m/s, each strut configuration



FAR-FIELD NOISE – NARROWBAND PSD AT $\theta = 90°$





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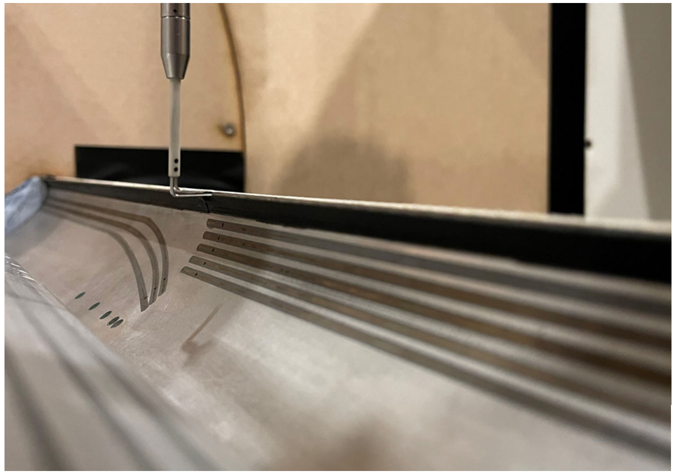
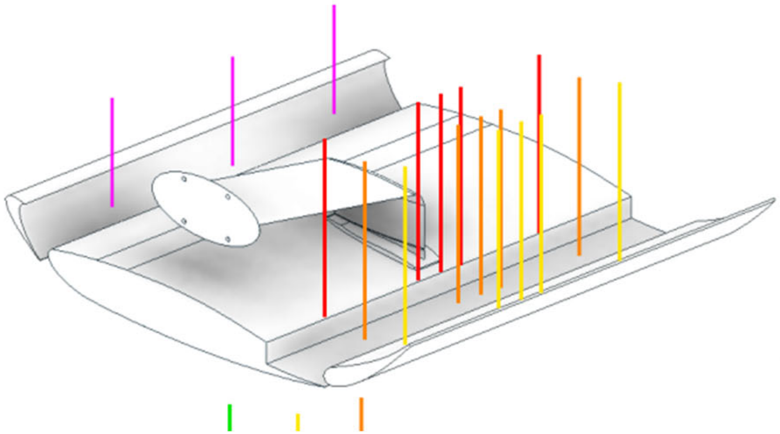
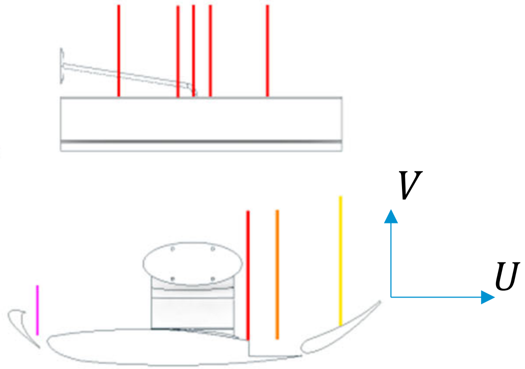
VELOCITY MEASUREMENTS

- Velocity measurements made with 2-component x-wire probe.
- Measuring U and V velocity
- Extensive measurements for small height and Albatros configurations







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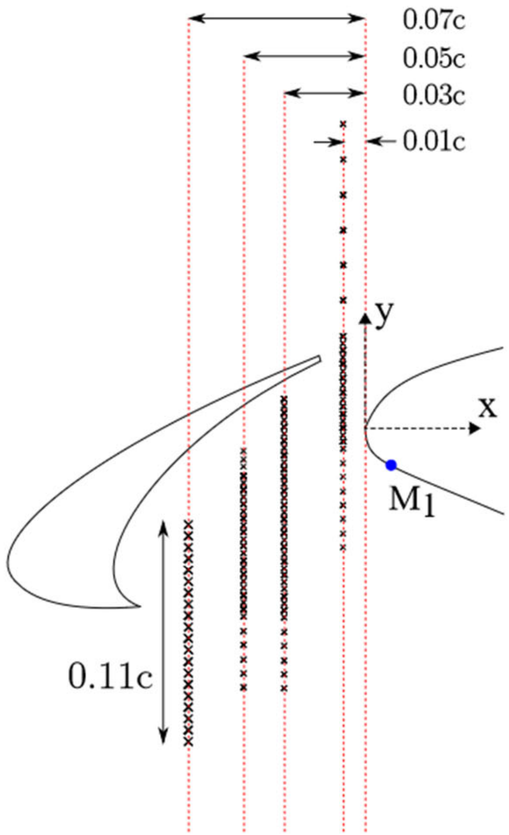

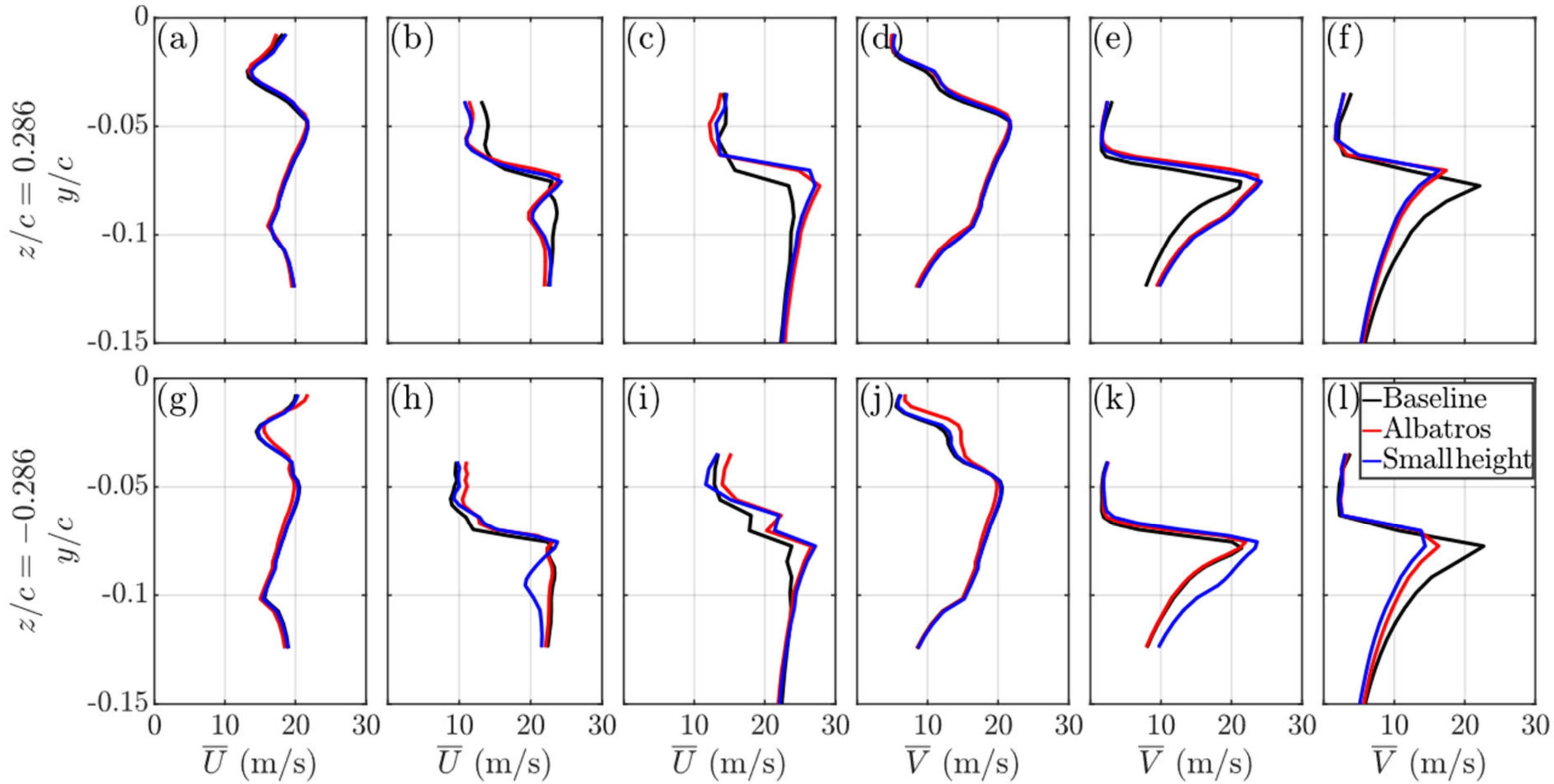

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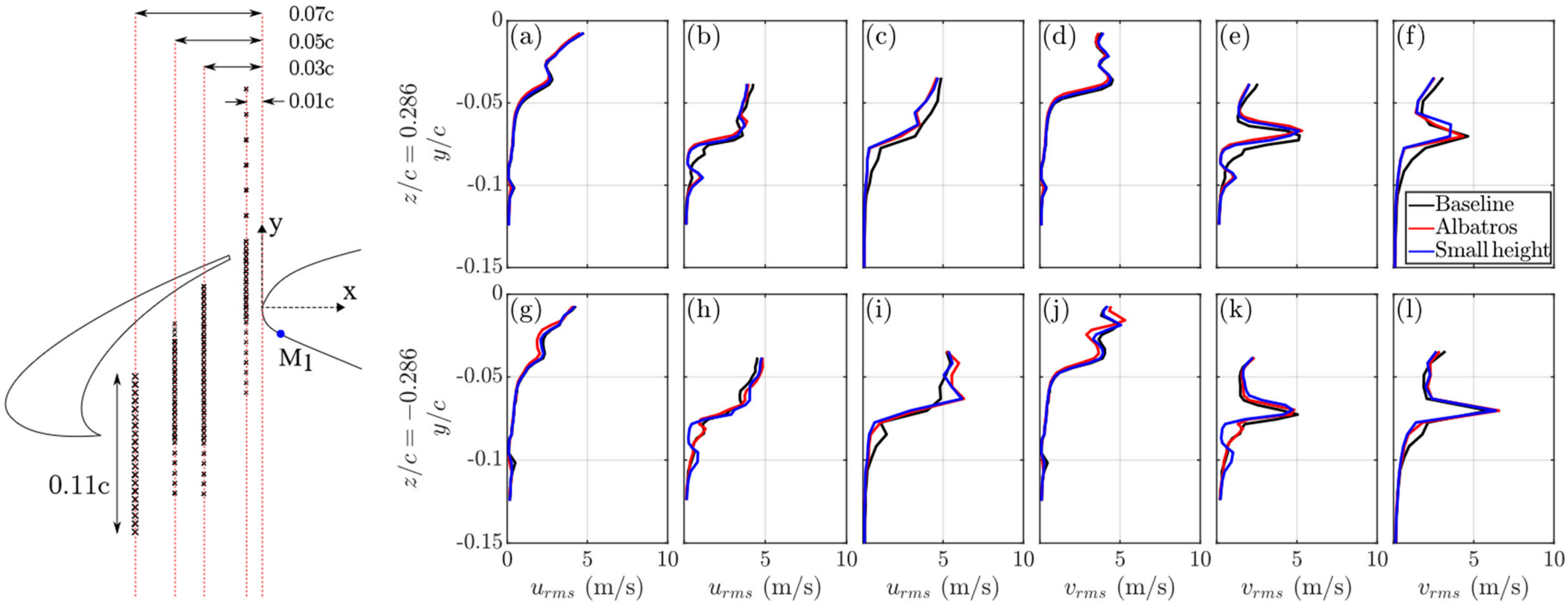
VELOCITY MEASUREMENTS



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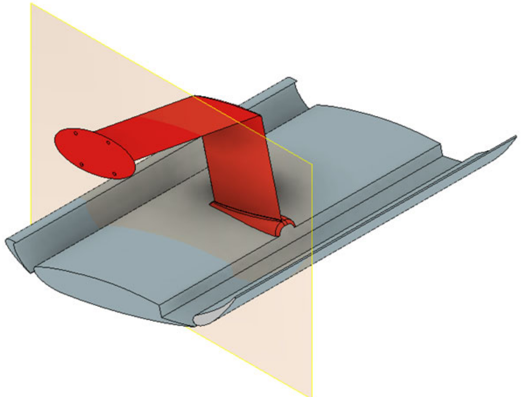
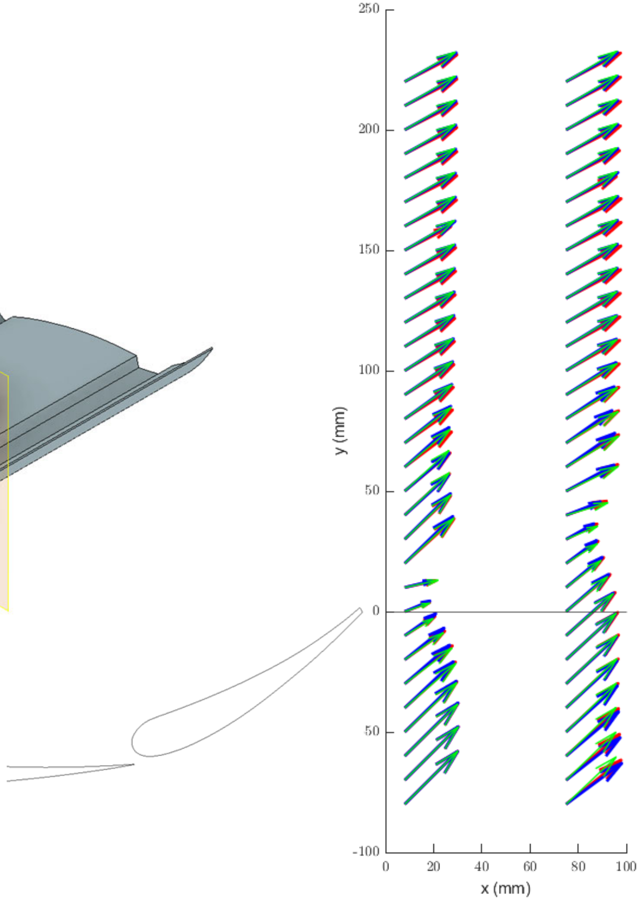
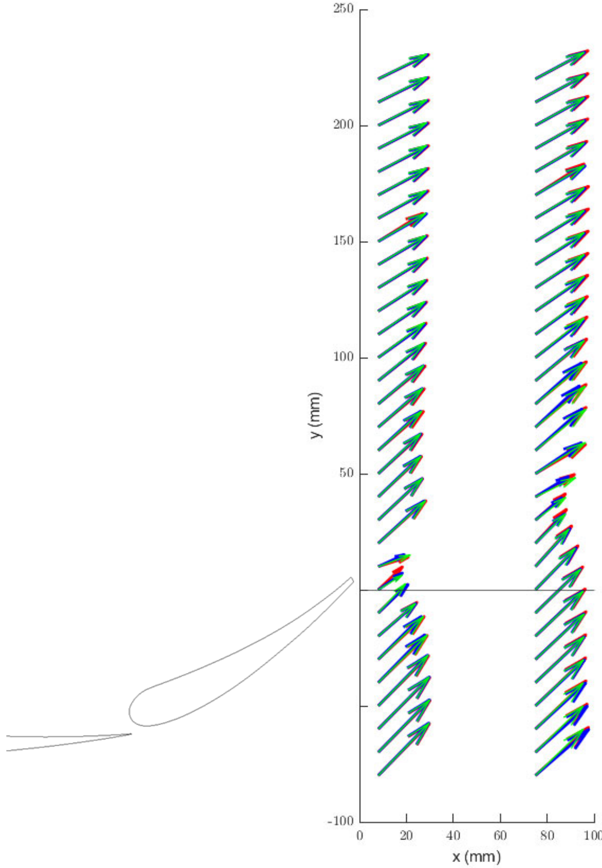
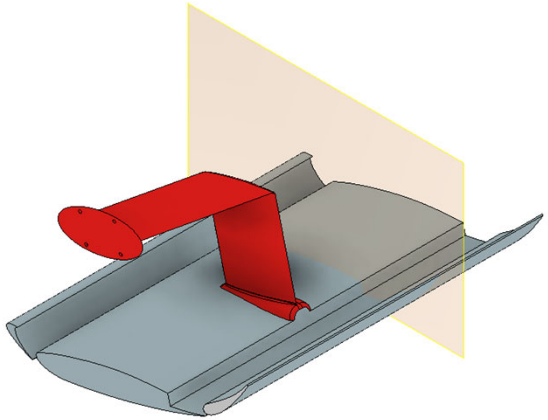


Strut Side



Non-strut Side





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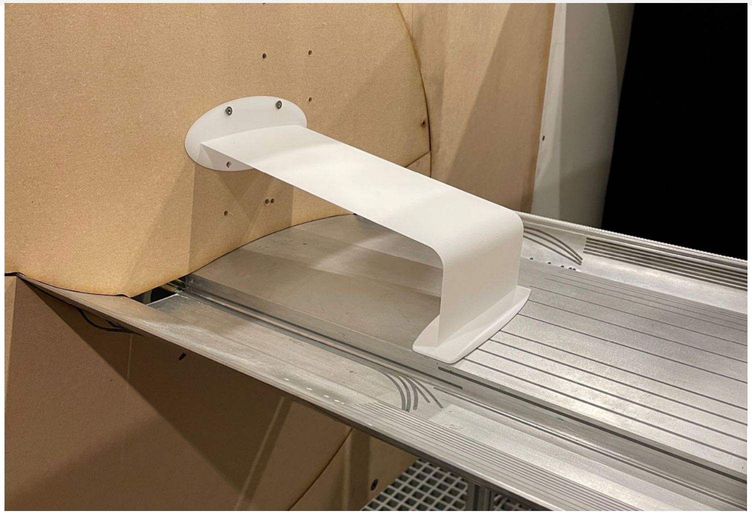
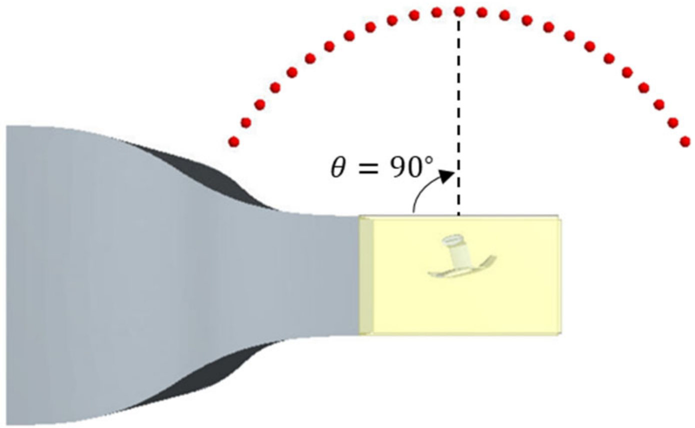
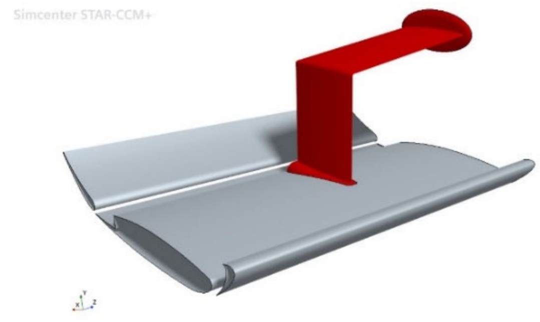




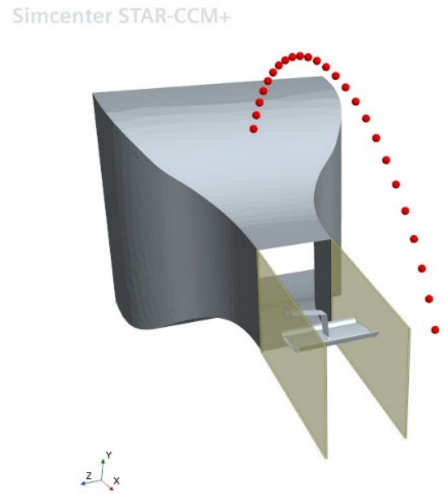
SELECTED CONFIGURATION FOR SIMULATIONS: ALBATROS

Albatros trailing-edge mounting case selected for its reduced noise footprint compared to the no-strut configuration



Main parameters

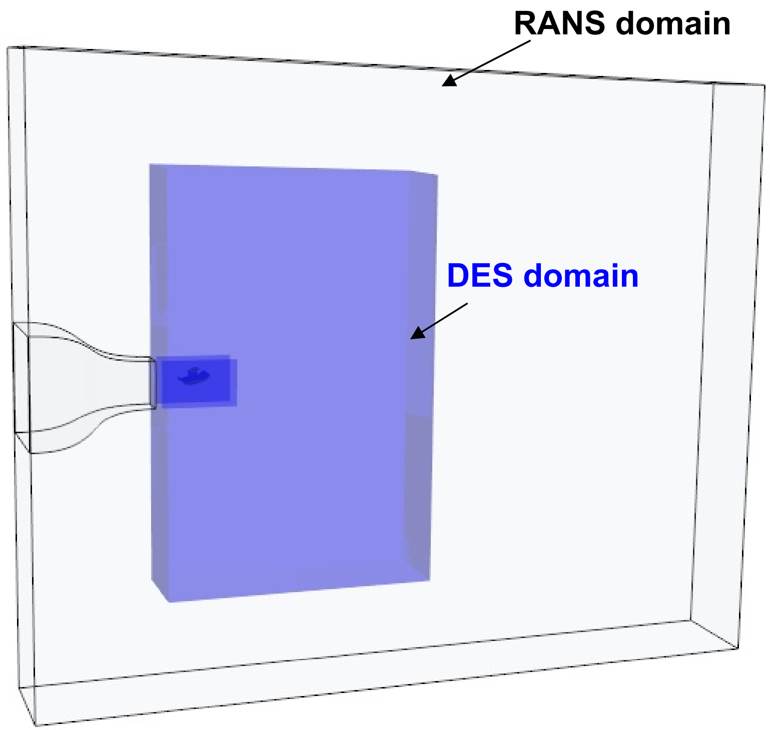
Stowed chord c	0.35 m
Span l	0.53 m
AoA	14 deg
Velocity U_∞	30 m/s
Mach number M_∞	0.0875
Chord-based Reynolds number Re_c	7.02×10^5



- Aeroacoustic simulations with/without strut
- For realistic flow conditions, wind tunnel nozzle and side-plates included in the simulations

DIRECT NOISE COMPUTATIONS

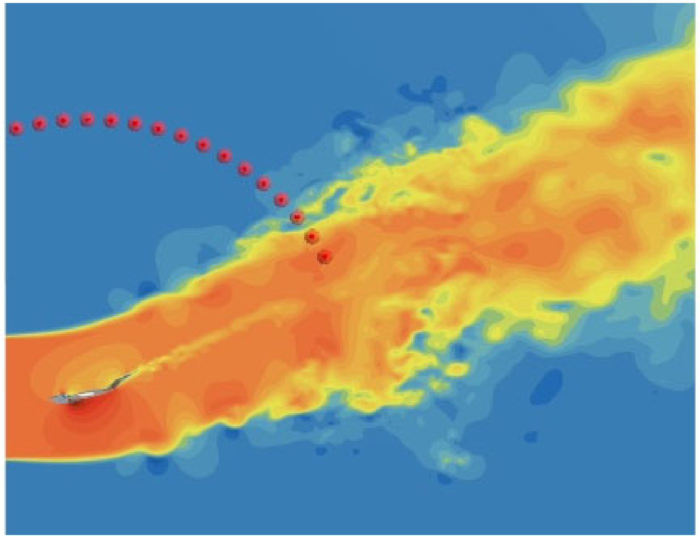
- Simcenter STAR-CCM+
  - Multiphysics CFD software
  - Finite-volume unstructured solver, 2nd order accurate in space and time
- Compressible simulations
  - To capture slat noise mechanisms
- Detached-Eddy Simulations (DES)
  - SST $k - \omega$ detached-eddy model
  - DES grids of 45M cells w/o strut and 60M cells with strut
    - $y^+ < 2$ at the airfoil walls
    - Mesh resolved up to 4 kHz in the acoustic region
  - Initial condition: RANS including the wind tunnel nozzle
  - Computations
    - 40 000 time steps per DES (T=0.32 s)
    - Statistics collected over of period of 0.24 s



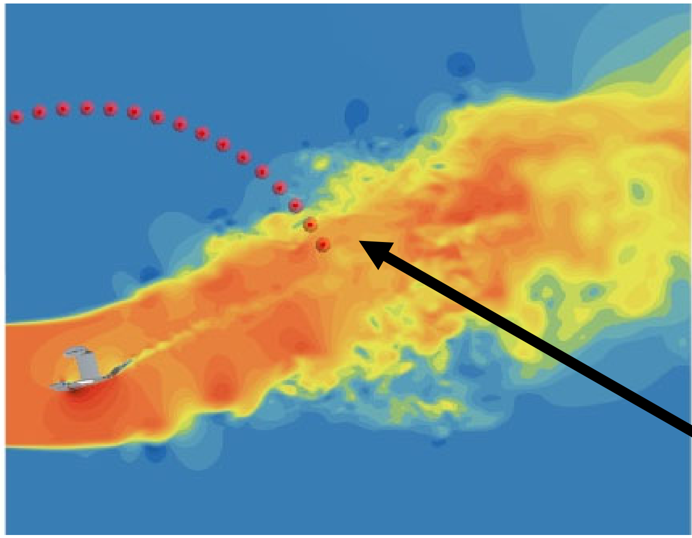
NUMERICAL RESULTS

- Instantaneous views of streamwise velocity field in the mid-span plane

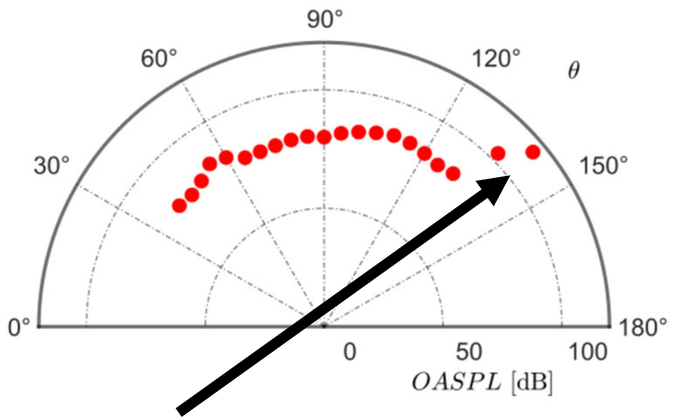
DES - no-strut case



DES - strut case



Exp OASPL



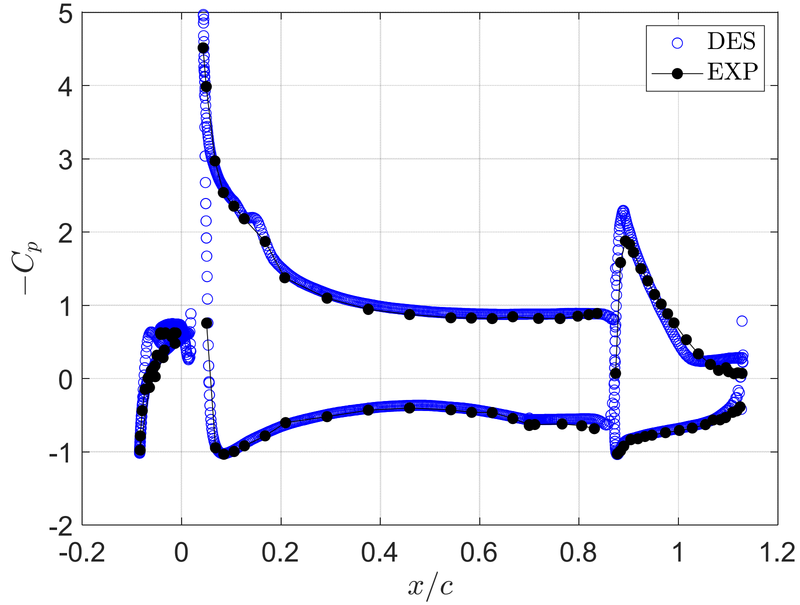
Microphones affected by flow

Wind tunnel jet flow strongly deflected by the presence of the wing, with jet shear layers reaching microphones located at extremity of the arc.

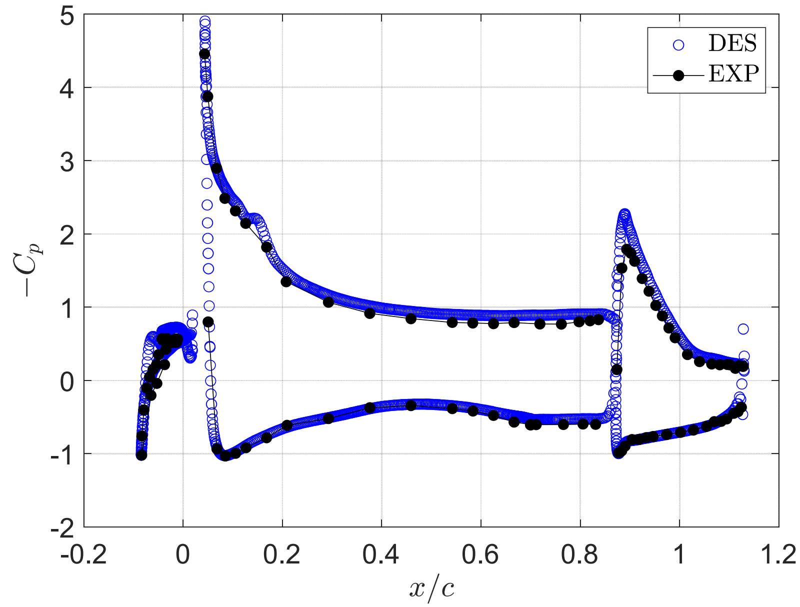
AERODYNAMIC RESULTS

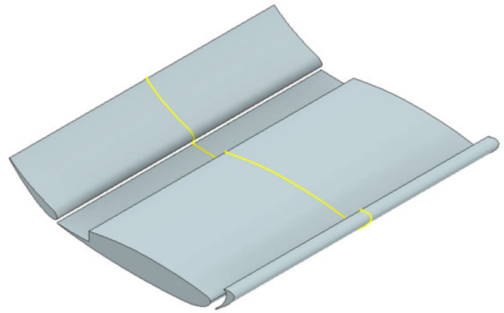
- Pressure coefficient on high-lift device in the mid-span plane

No-strut case



Strut case



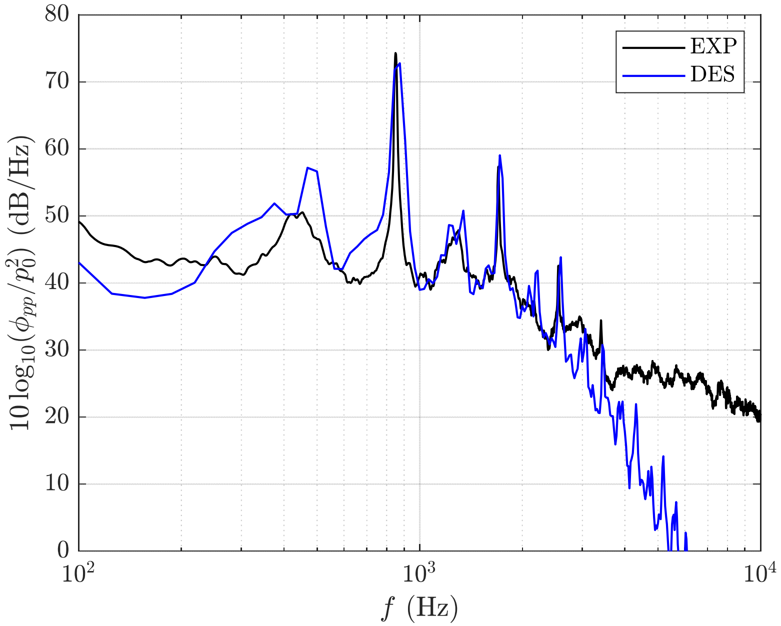


Numerical results obtained from time-averaged DES data. Excellent agreement with experimental data.

FAR-FIELD NOISE RESULTS

- Power spectral density at $r = 1.75$ m and $\theta = 90^\circ$

No-strut case



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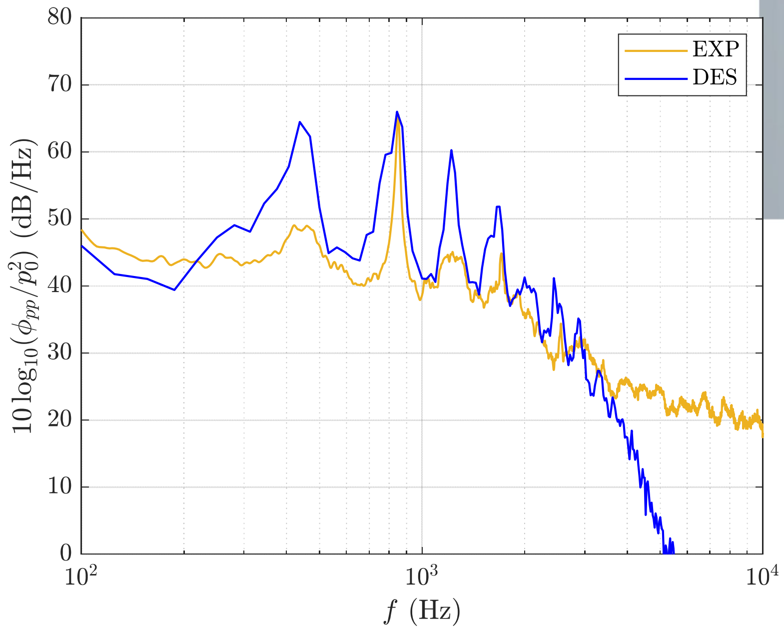
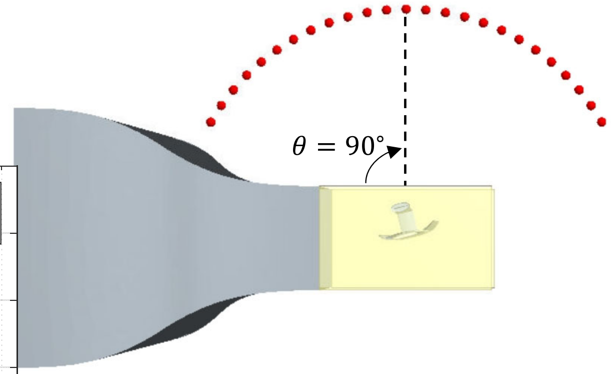


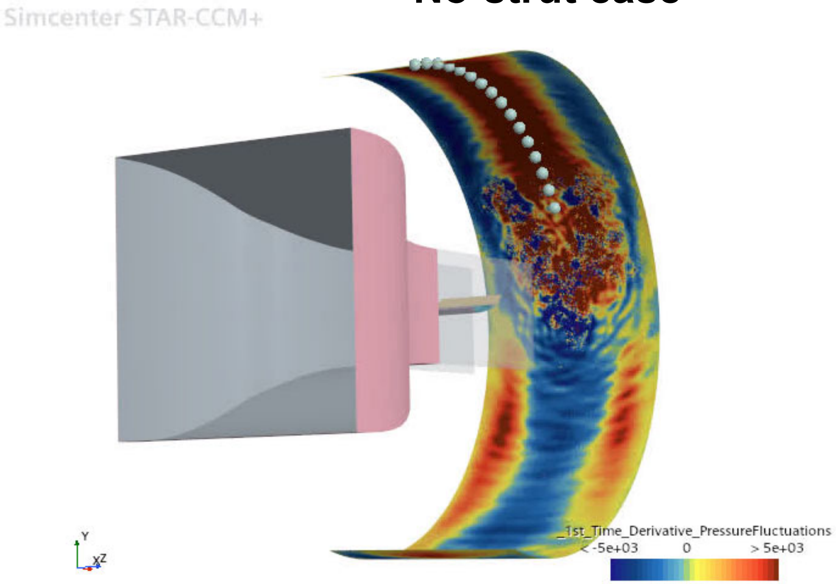


Tonal frequencies well-predicted in DES simulations, amplitude of the main peak well-captured.
With strut, overprediction of the higher modes maybe due to DES turbulence modelling. Under investigation.

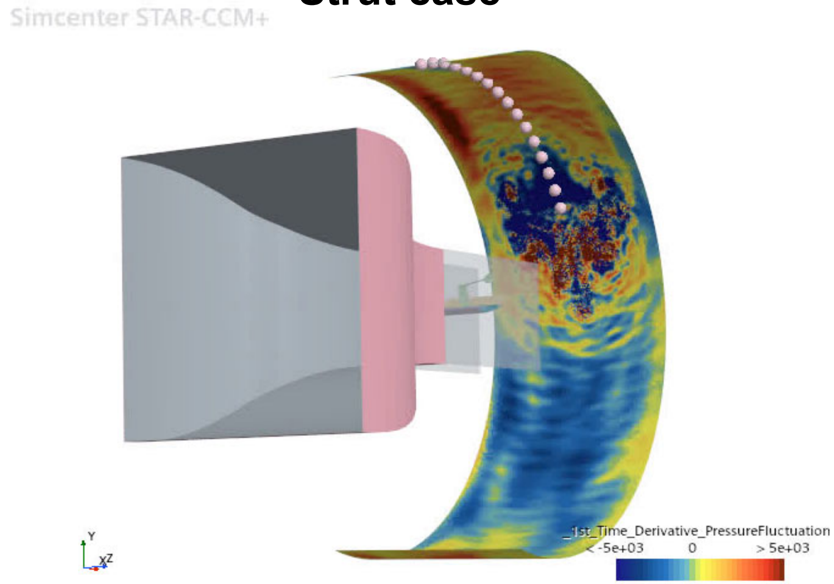
FURTHER INSIGHT INTO SOUND PROPAGATION THANKS TO SIMULATION

- Time derivative of the pressure fluctuations on a cylindrical section at 1 m from the wing

No-strut case



Strut case



With strut, the acoustic field becomes highly asymmetric.
On-going work to better understand the sound source mechanisms at stake.

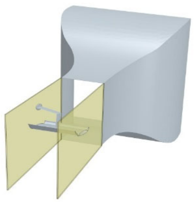
CONCLUSIONS

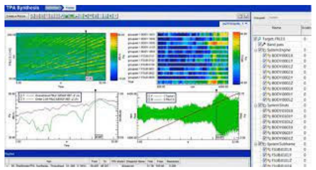
CLEAN AVIATION

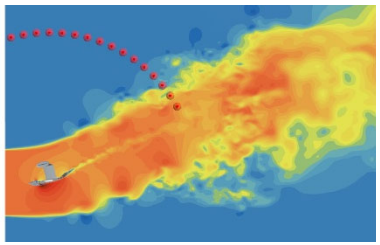
U-HARWARD

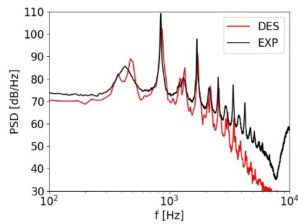
- Extensive experimental test campaign of strut configurations
  - Mean C_P values for each configuration show little change
  - Far-field noise demonstrates sensitivity to strut height and mounting location
  - Velocity results hint towards a local reduction of angle of attack on strut side in wake
- Numerical simulations carried out for one wing-strut configuration
  - DES results in very good agreement with experimental data
  - The presence of the strut leads to an asymmetry of the acoustic field
  - Towards improved best practices for aeroacoustic simulations

Modelling of wind tunnel conditions — Correlation with test data — Deep insight into flow and acoustic thanks to simulation — Performance of numerical models (LES, DES, U-RANS, …)









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CLEAN AVIATION

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ANY QUESTIONS?

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