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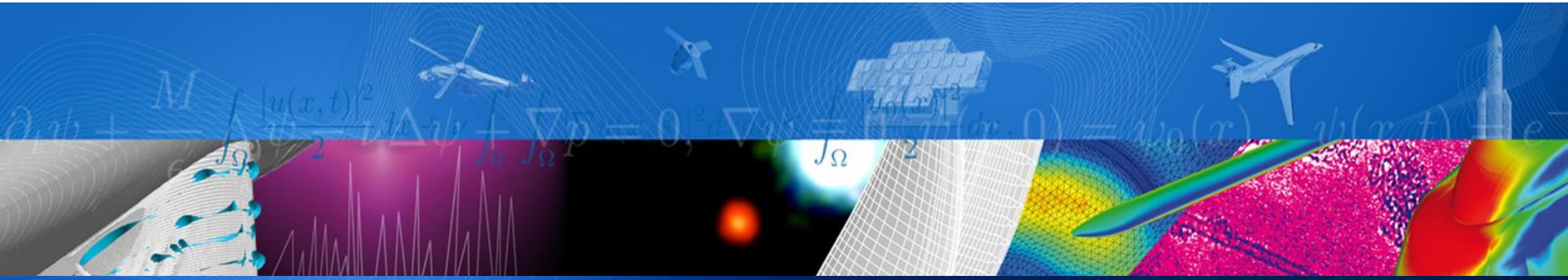
Experimental aerodynamic and acoustic database of a 2D high lift wing with and without sweep angle

Eric Manoha (ONERA), Michael Pott-Polenske (DLR)

with contributions from Nicolas Réau (Dassault-Aviation)



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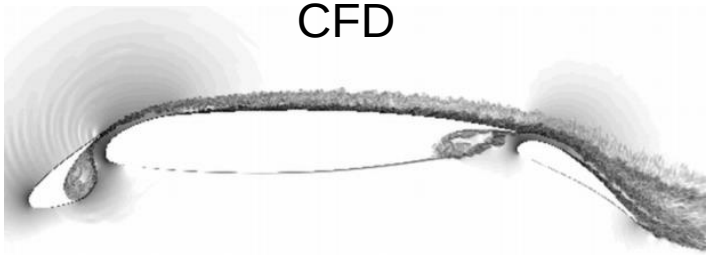
return on innovation

Context and objectives



- Context : numerical prediction of high lift device flow/noise (slat & flap side edge)
- Objectives : to build reliable aerodynamic and acoustic data for the validation of high lift wing noise computations
- Dissemination : Benchmark for Airframe Noise Computations (BANC)

Projects	Airfoil	Sweep	Partners
LEISA2	2D	0°	Onera/DLR
SWAHILI	2D	30°	Onera/DLR
SWAHILI-FSE	3D with flap side edge	30°	Onera/DLR/Dassault-Aviation

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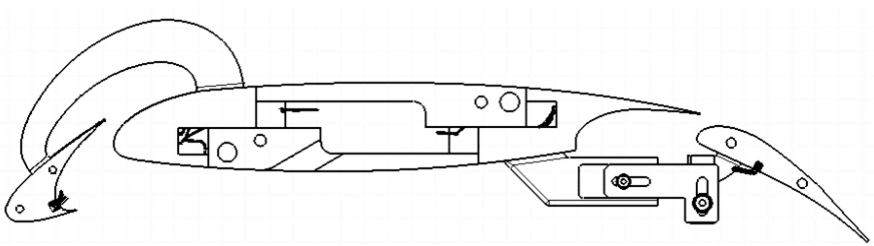
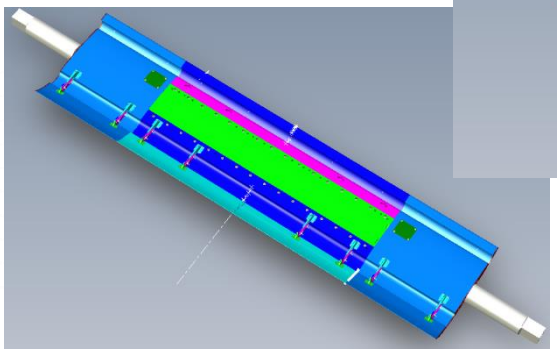
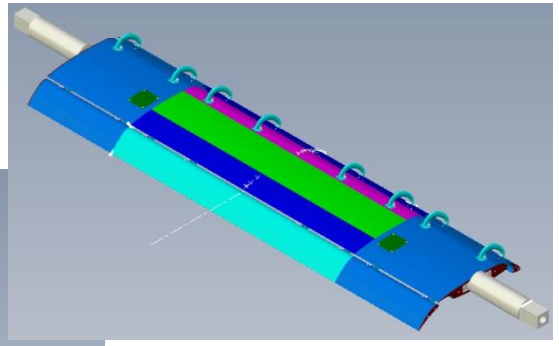
High Lift Configuration
DLR's F16 model







- Total "clean" chord (slat/flap retracted) : 300 mm
- Span: 800 mm (DLR/AWB) or 1.4 m (Onera/F2)
- Adjustables brackets on flap
- Non adjustables brackets on slat suction side (PIV, LDV access)
- Slat : Chord : 55.8 mm - Deflection angle: 27.8°
- Flap : Chord : 84 mm - Deflection angle: 35.0°

On-board instrumentation

- One section of 46 static pressure taps
- 12 Kulite pressure sensors at the wing leading edge

Model's family (same airfoil section)

- F16 option : VLCS (very long chord slat)
- F15 : chord 600 mm – span 2400-2800 mm
- FTEG : chord 1200 mm – span 6 - 8 m

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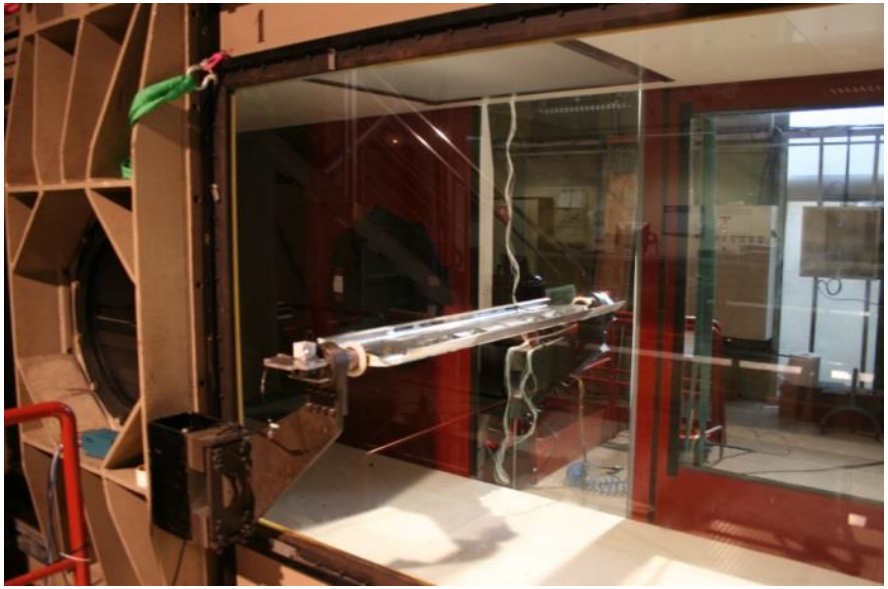
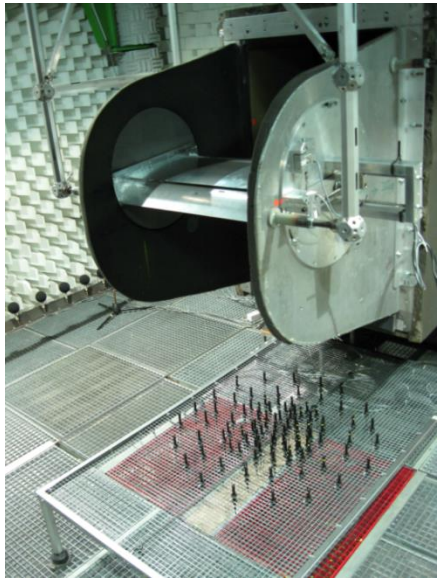
2-facility strategy

- Constraint : very difficult to get aerodynamic and acoustic data in the same facility …
- Strategy : **2-facility** approach : Onera/F2 and DLR/AWB



- Closed test section 1.4 m x 1.8 m
- Aerodynamics : LDV, PIV, hotwire
- Acoustics: array with 120 condenser microphones



- Open test section 0.8 m x 1.2 m
- Acoustics:
  - Array with 96 Electret sensors
  - Line of 8 condenser microphones

Assumption : the flows will be globally different in both wind-tunnels, but we can minimize the differences in the slat region through adequate incidence adjustment

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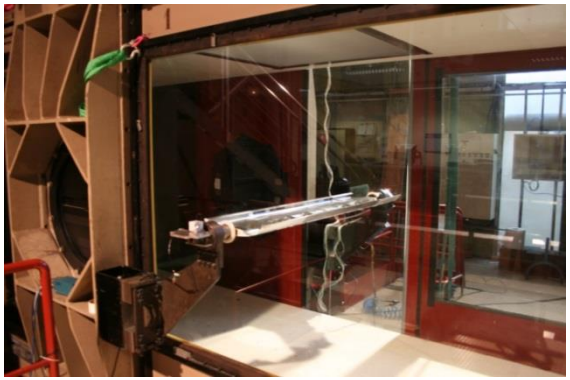
Outline

- Context and objectives
- Airfoil characteristics
- 2-facility strategy
- LEISA2 database description
  - Aerodynamic tests in F2
  - Acoustic tests in AWB and F2
- SWAHILI and SWAHILI-FSE
  - Aerodynamic/acoustic tests in F2
  - Acoustic tests in AWB (in preparation)
- Conclusions

LEISA2 (2D airfoil without sweep)
Aerodynamic measurements in F2



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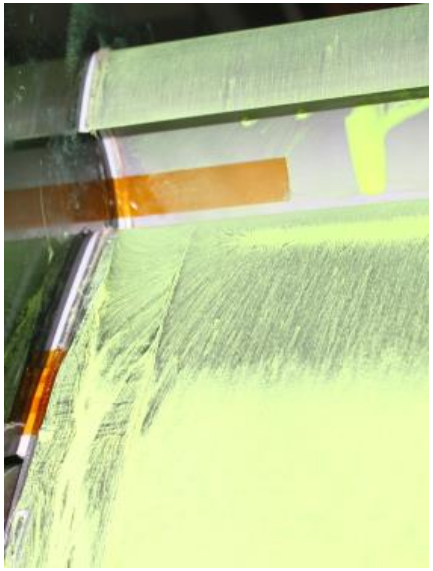
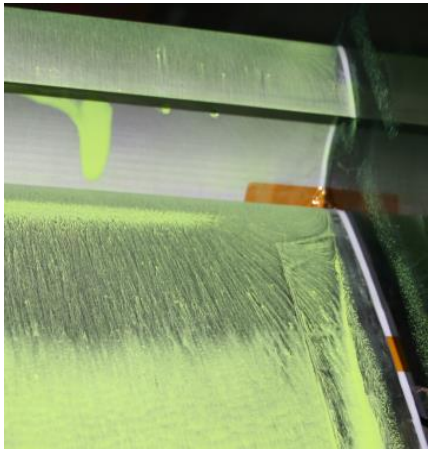
Flow streamlines visualizations with oil

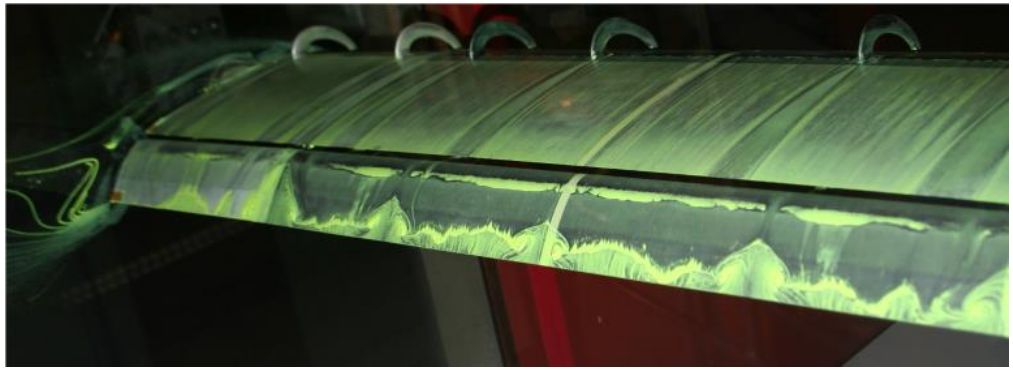


Side wall flow

Slat brackets wake



Side wall flow



Separation on flap suction side

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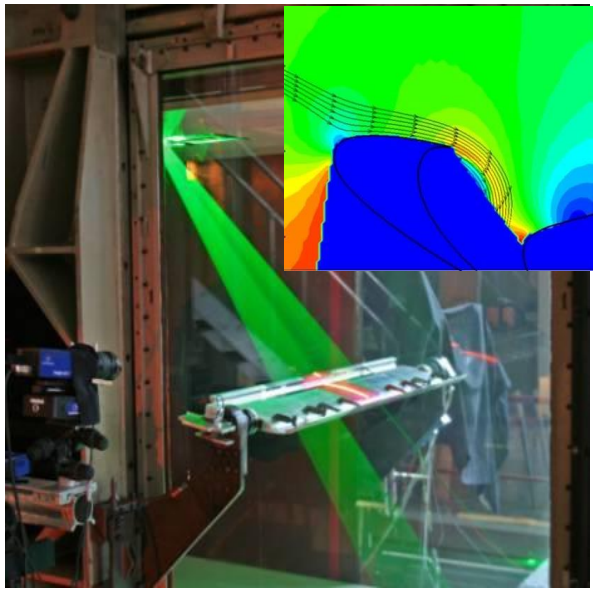
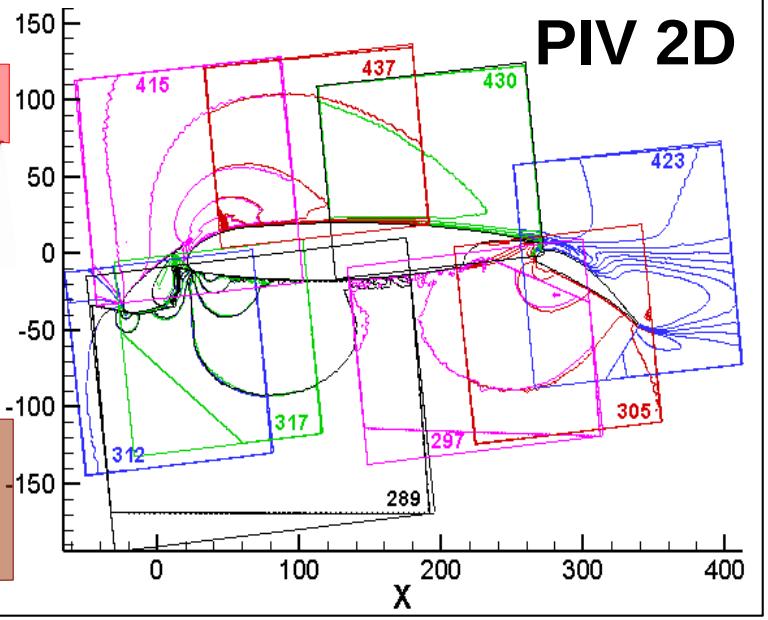
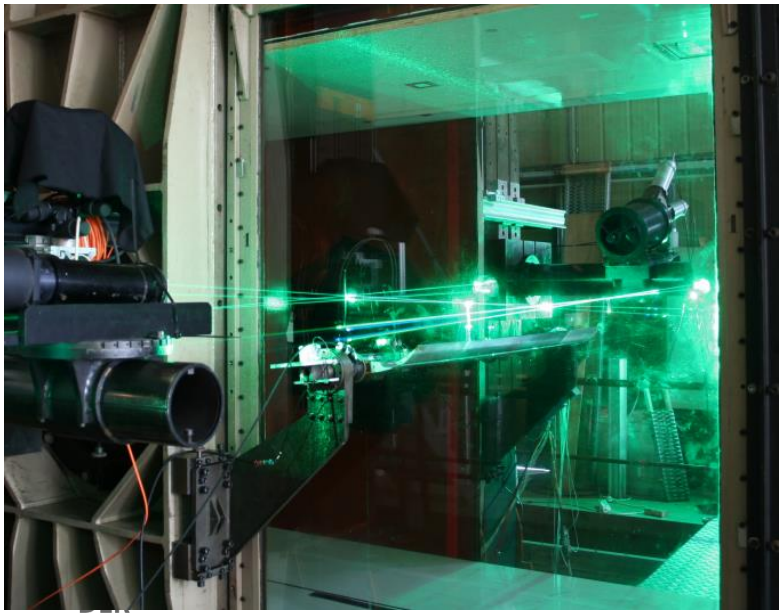
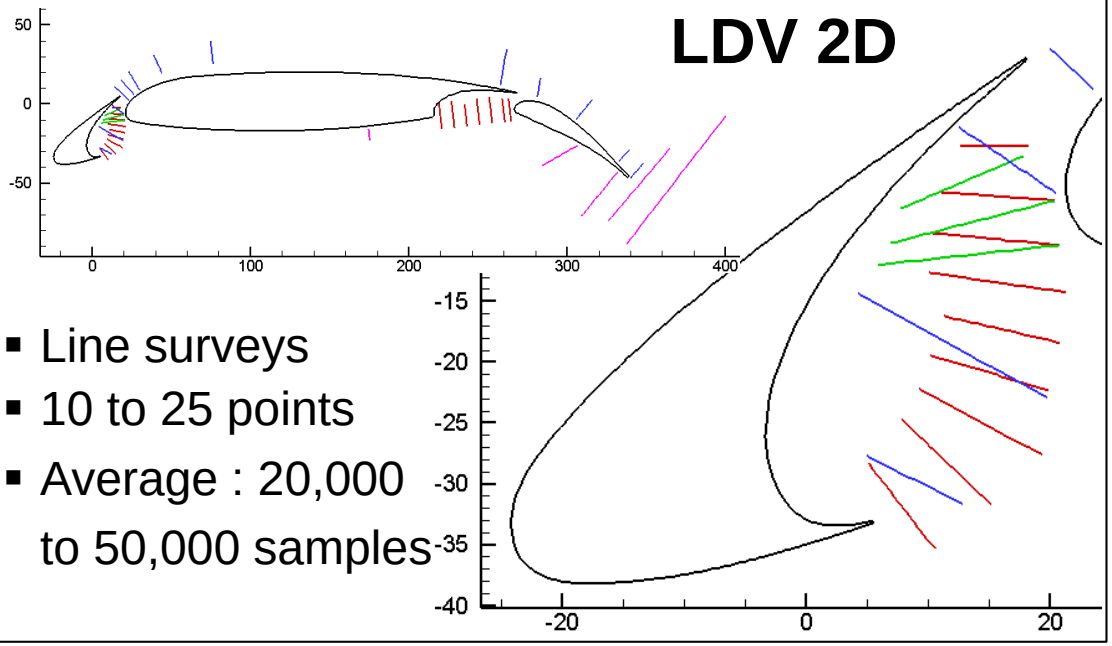
Acquisition of mean flow data by PIV 2D and LDV 2D





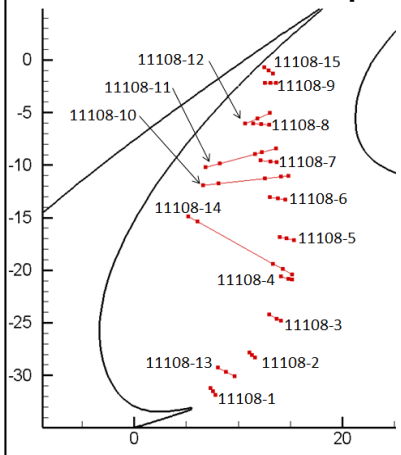




- Line surveys
- 10 to 25 points
- Average : 20,000 to 50,000 samples

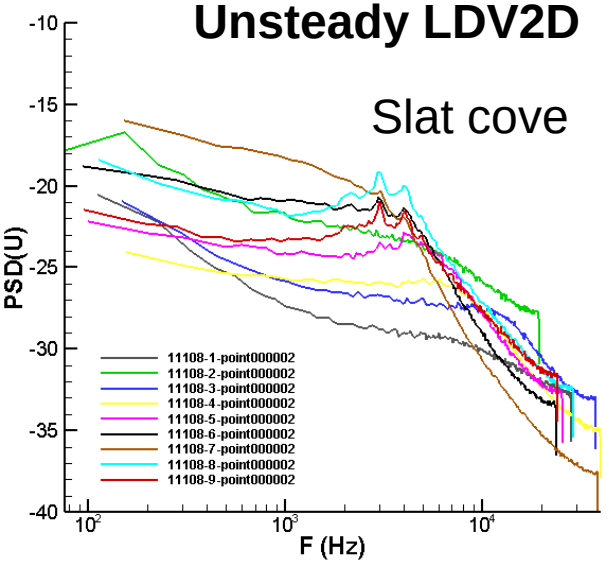
Acquisition of unsteady flow data using LDV2D and hotwire

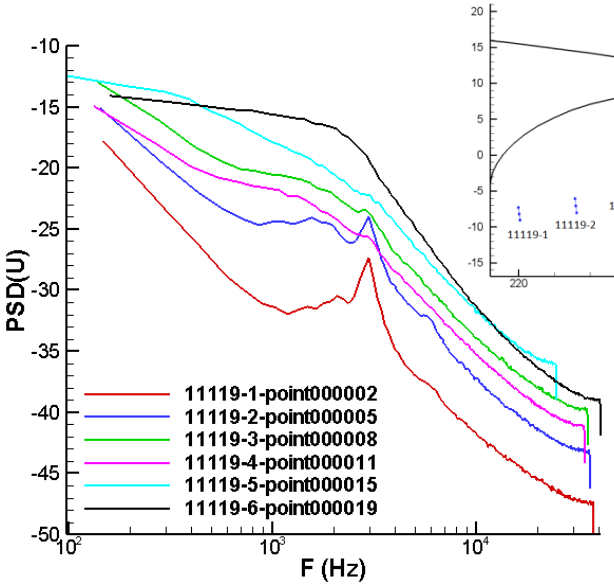
- Isolated points
- 300,000 samples

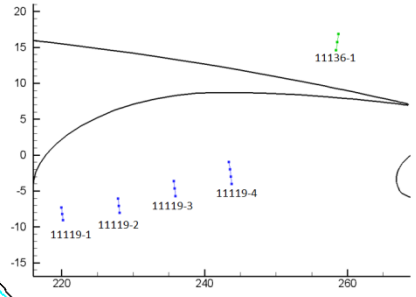


Unsteady LDV2D

Slat cove



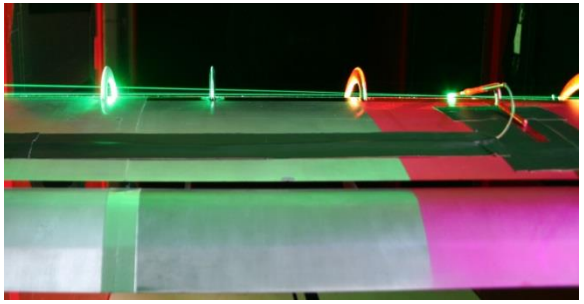


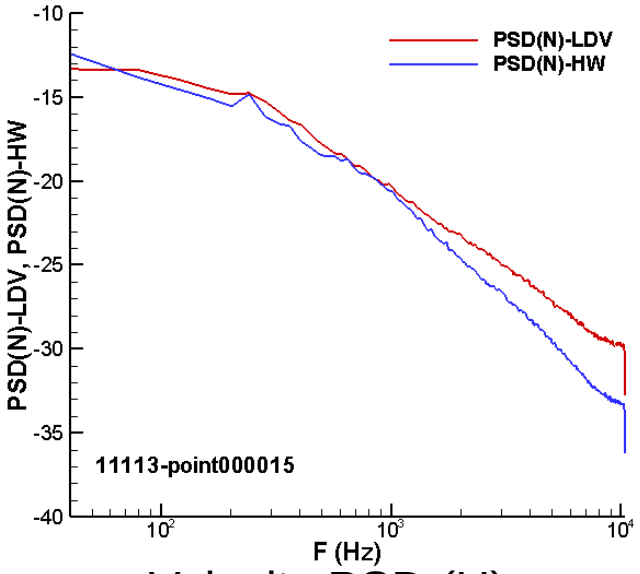


Flap cove

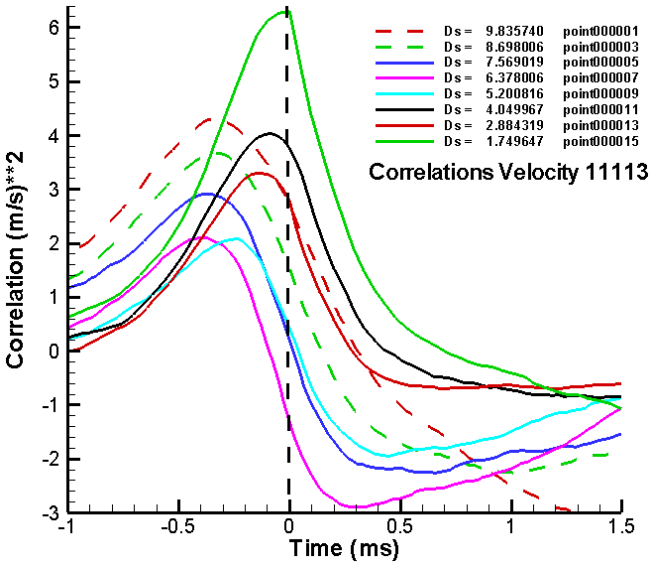
Unsteady LDV2D and double-hotwire

- 2-point measurements
- Space-time correlations



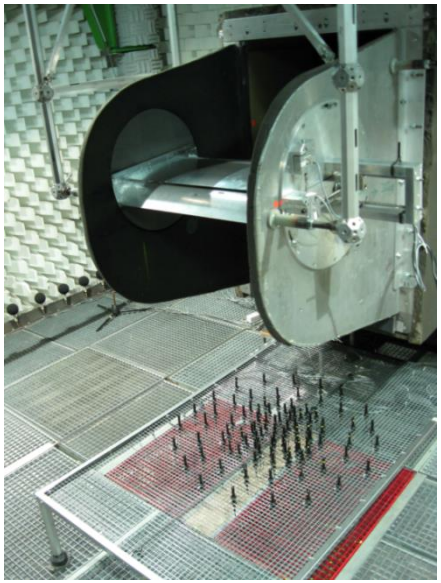


Velocity PSD (U)



Correlations (N)

LEISA2 (2D airfoil without sweep)
Acoustic measurements in AWB



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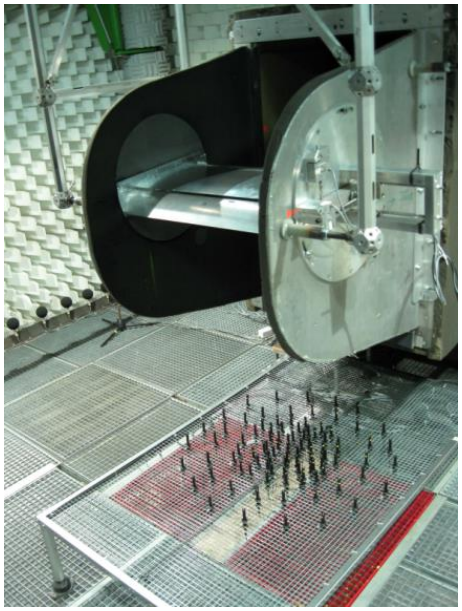
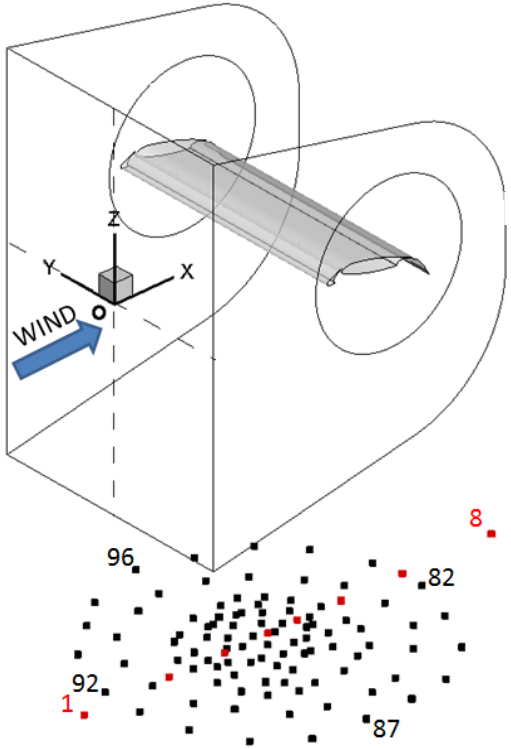
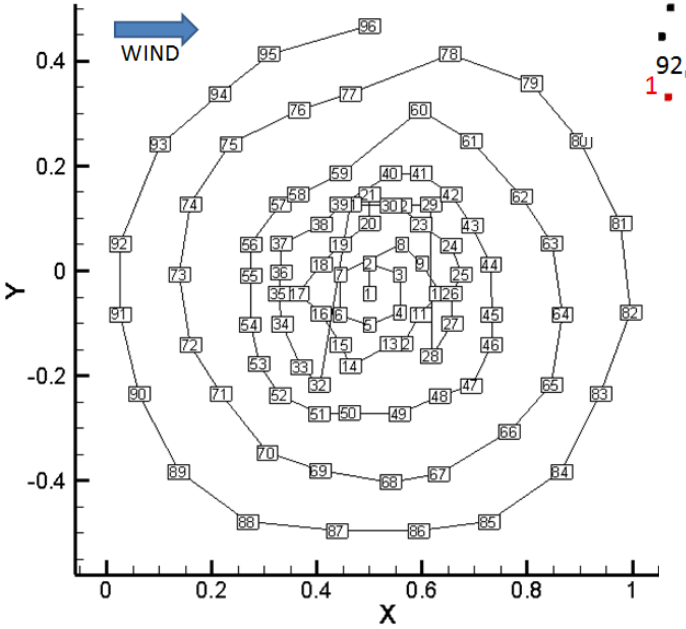
Microphone array and scan grid



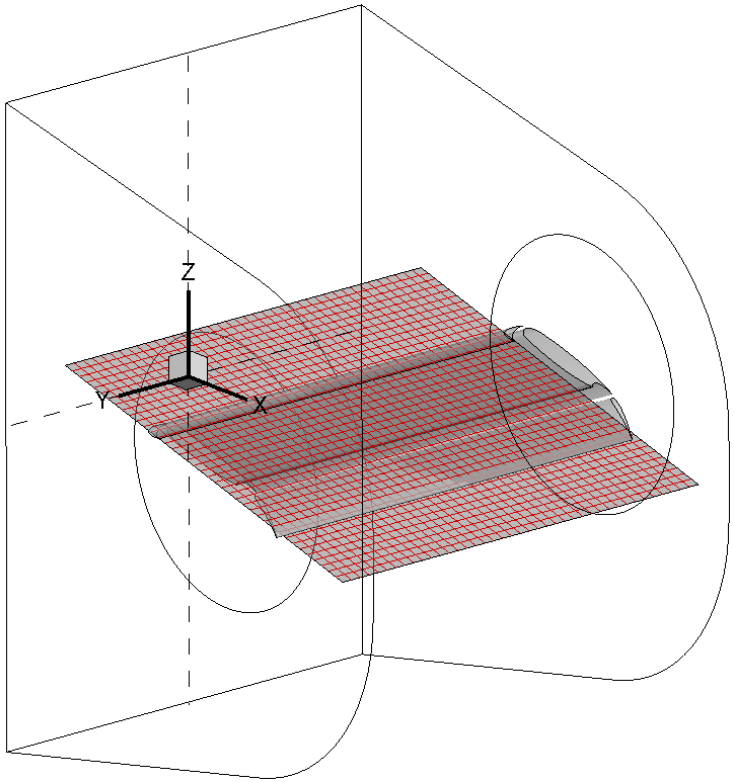




96 Electret sensors

Scan grid

- Planar, cartesian
- Located in the airfoil plane
- Span 0.8 m (airfoil area)
- Same resolution as in F2 (2 cm x 2 cm)
- Frequencies : [0-25 kHz] Δf = 50.4 Hz



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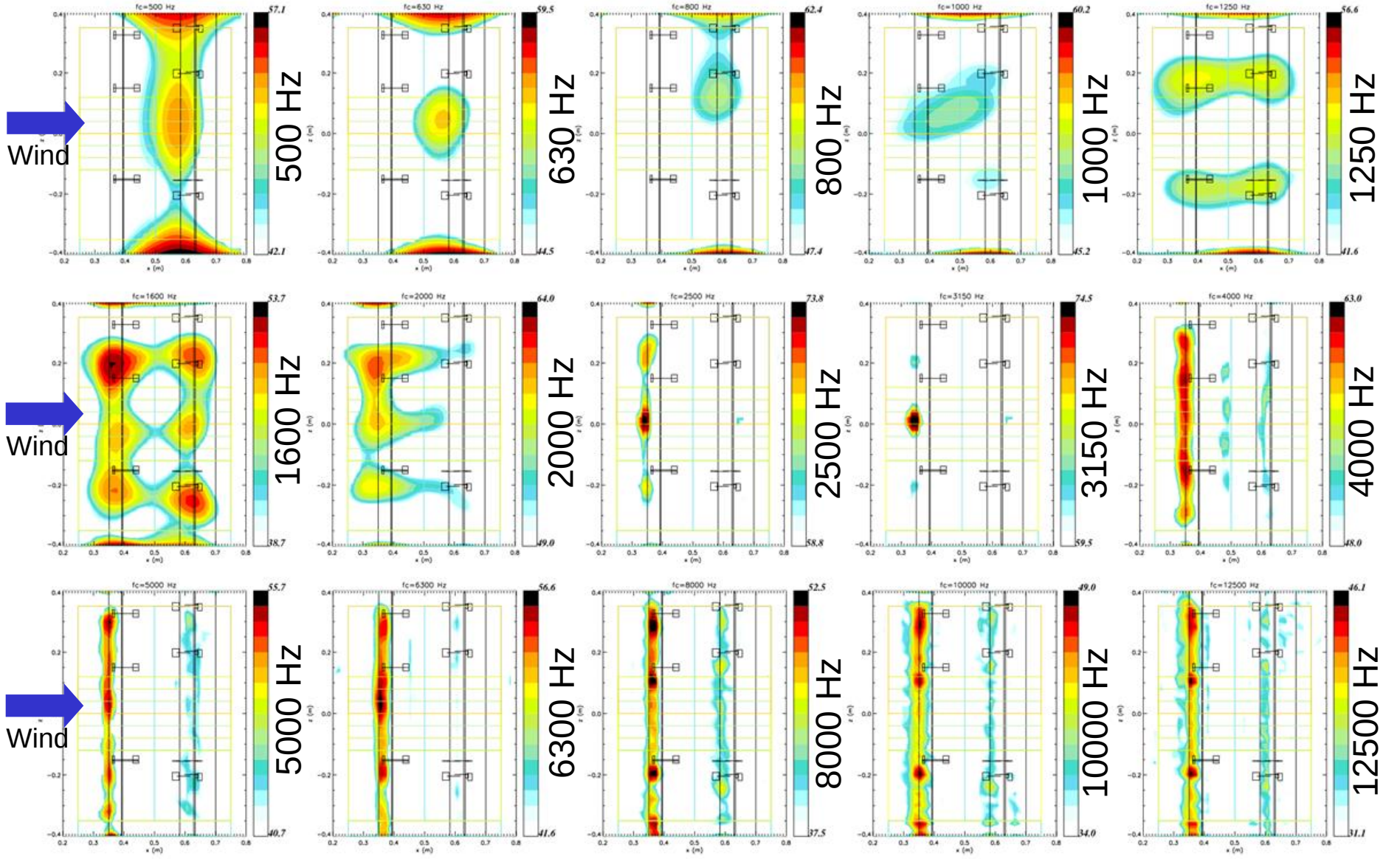
De-convoluted noise maps (DAMAS process)



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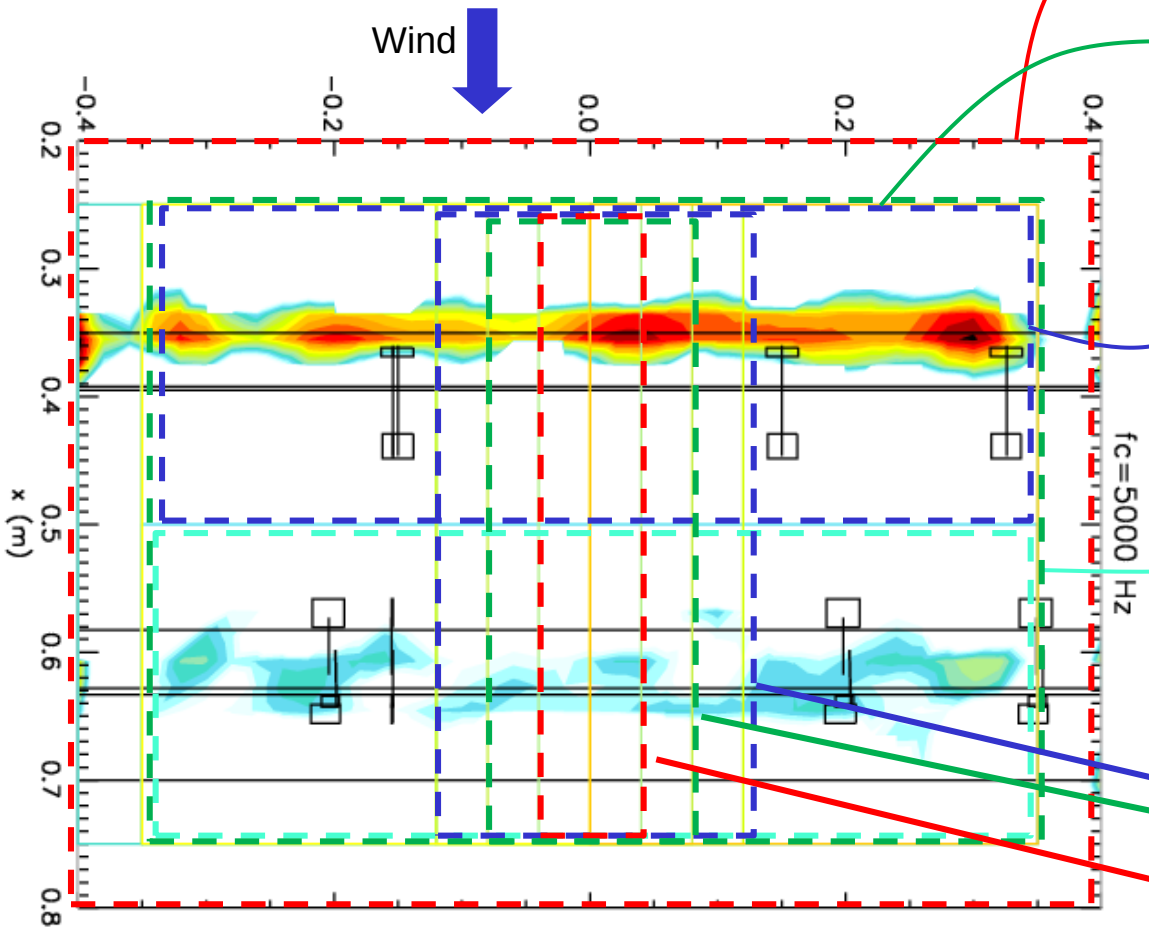
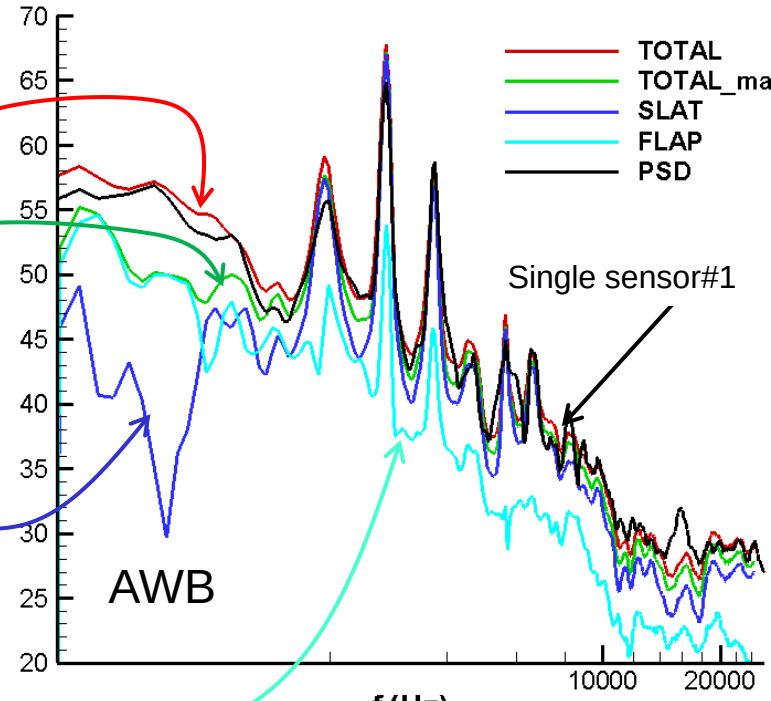
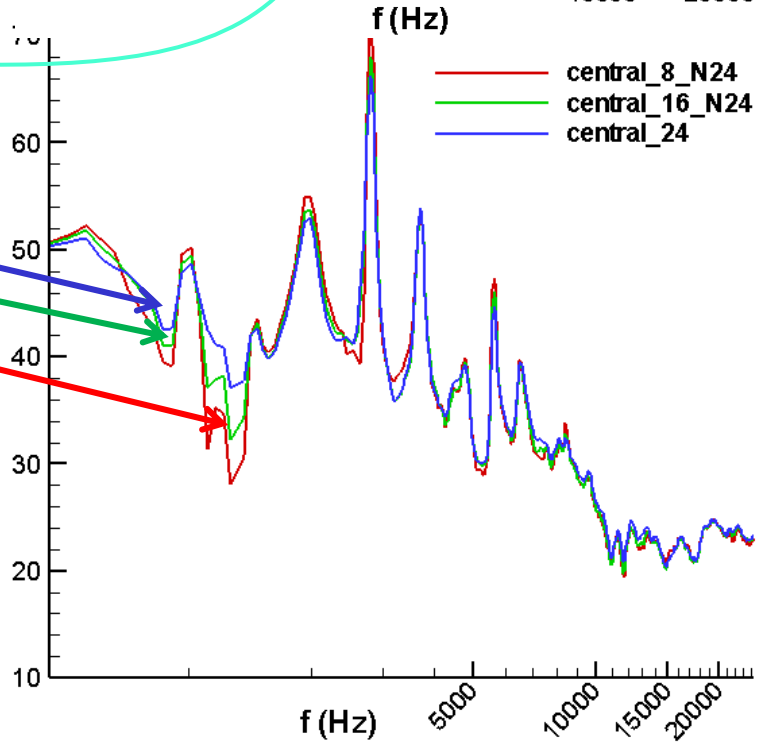
PSDs from noise maps (DAMAS) integrations



5000 Hz





PSD from central areas, span S = 8, 16 and 24 cm normalized by S/S_{ref} (S_{ref}=24 cm)

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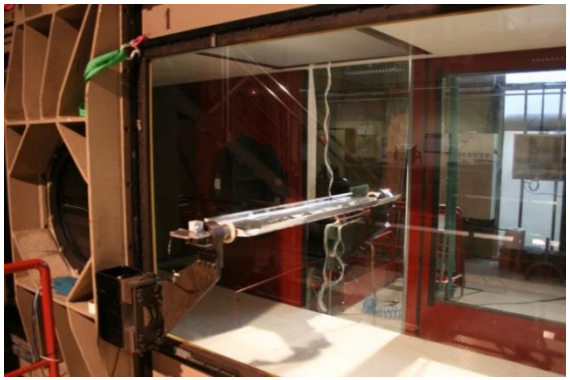
LEISA2 (2D airfoil without sweep)
Acoustic measurements in F2



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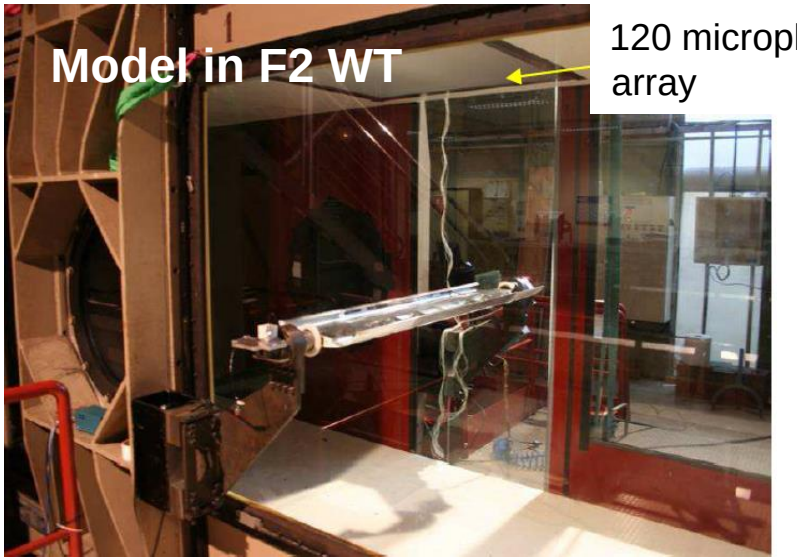
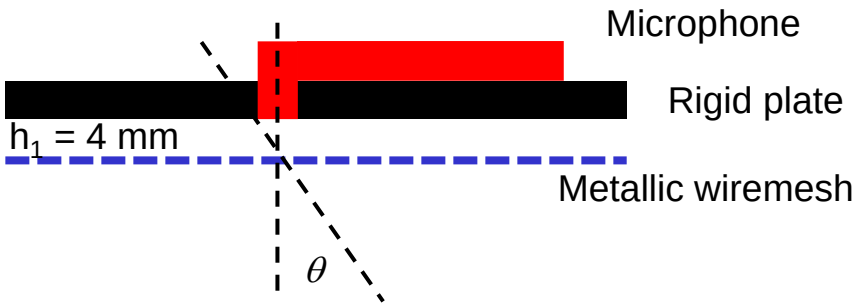
Acoustic measurements in F2 : microphone array at ceiling

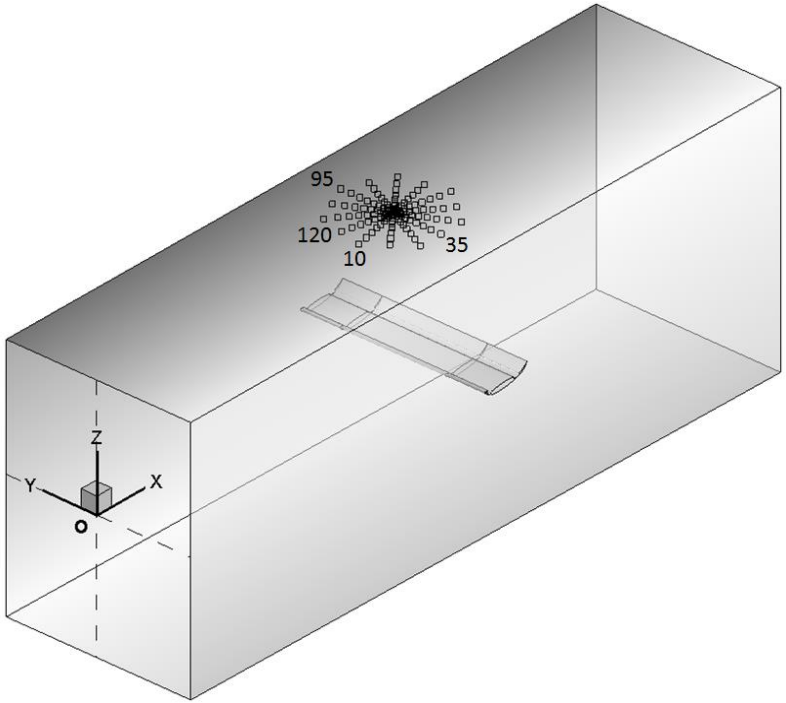


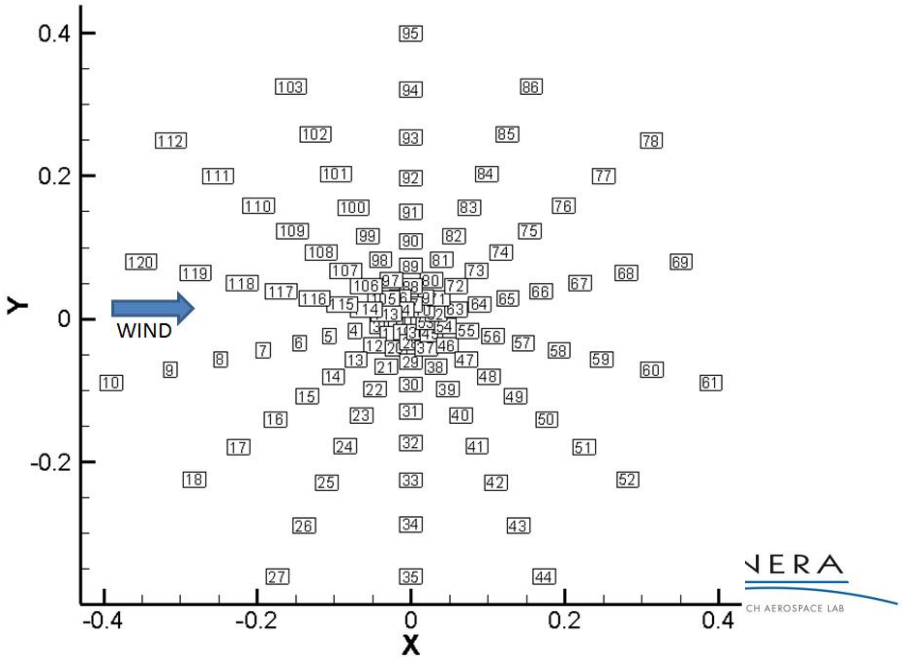
120 microphone array



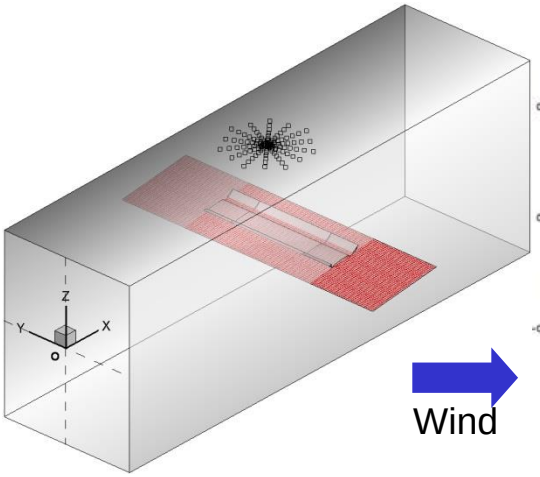
Microphone installation effects evaluation:

- Pressure doubling on rigid plate
- Wiremesh effect
- Source images on lateral walls and floor

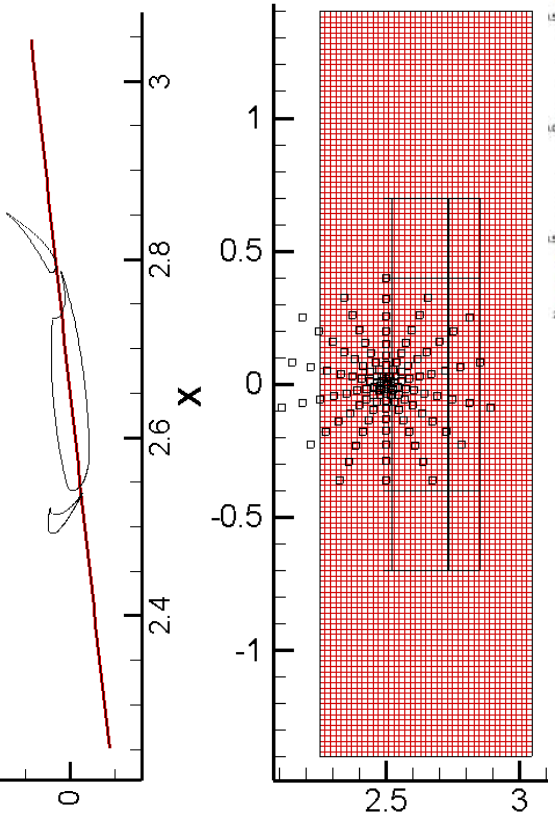




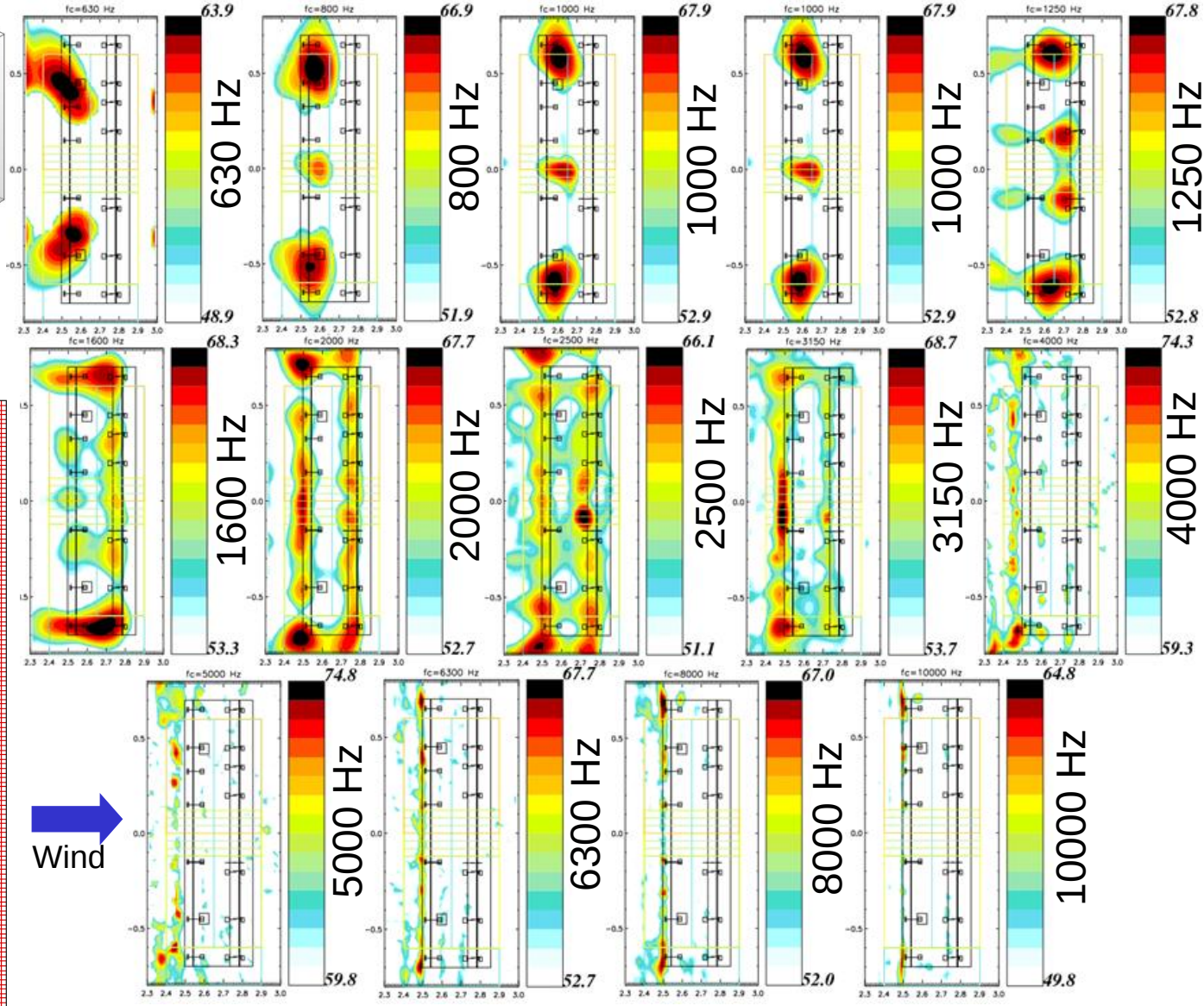
De-convoluted noise maps (DAMAS process)



Wind



Wind



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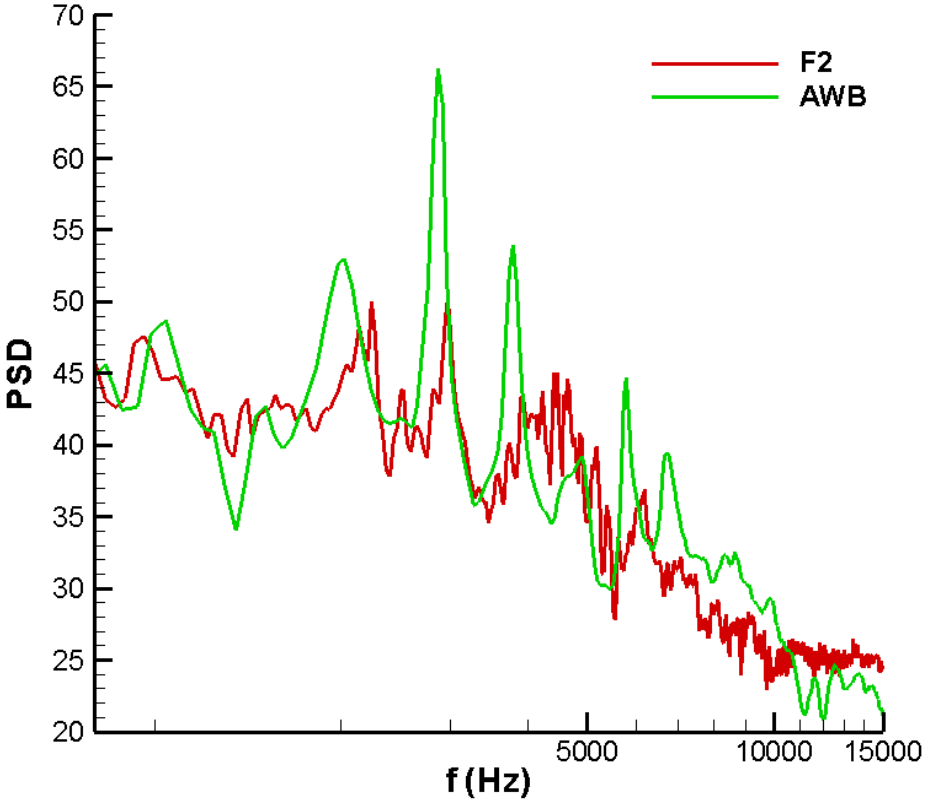
Comparison of acoustic data (AWB/F2)
PSDs from noise maps (DAMAS) integrations on a central airfoil section with 0.24 m span



- Fair agreement on broadband levels
- Tones are present in both measurements, but with small frequency shifts and lower levels in the closed test section windtunnel

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- LEISA2 database and documents (« Database Description » and « Problem Statement »
  - *https://info.aiaa.org/tac/ASG/FDTC/DG/BECAN_files_/BANCIII.htm*
    → "*DLR Slat Noise Configuration*"
- E. Manoha and M. Pott-Polenske, "*LEISA2: an experimental database for the validation of numerical predictions of slat unsteady flow and noise*", AIAA Paper 2015-3137

SWAHILI : SWept Airfoil with HIgh Lift
SWAHILI – FSE : Flap Side Edge

- Model adaptation
  - Design/manufacture of 2D swept model by DLR
  - Design/manufacture of 2D/3D flap by Dassault-Aviation
- Aerodynamic/acoustic tests in F2 (Feb-May 2016)
- Acoustic tests in AWB (in preparation)

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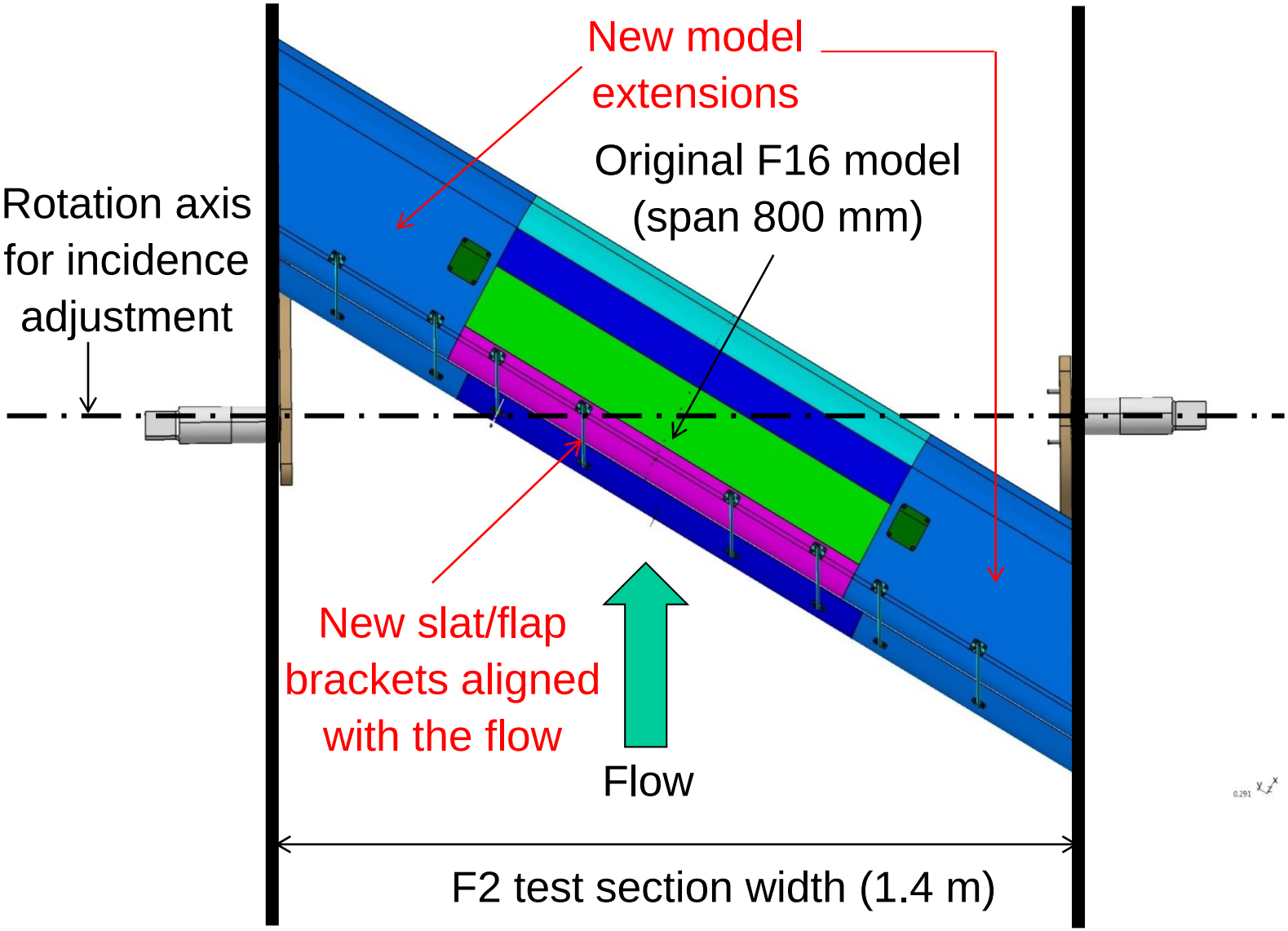
Design/manufacture of 2D swept model by DLR



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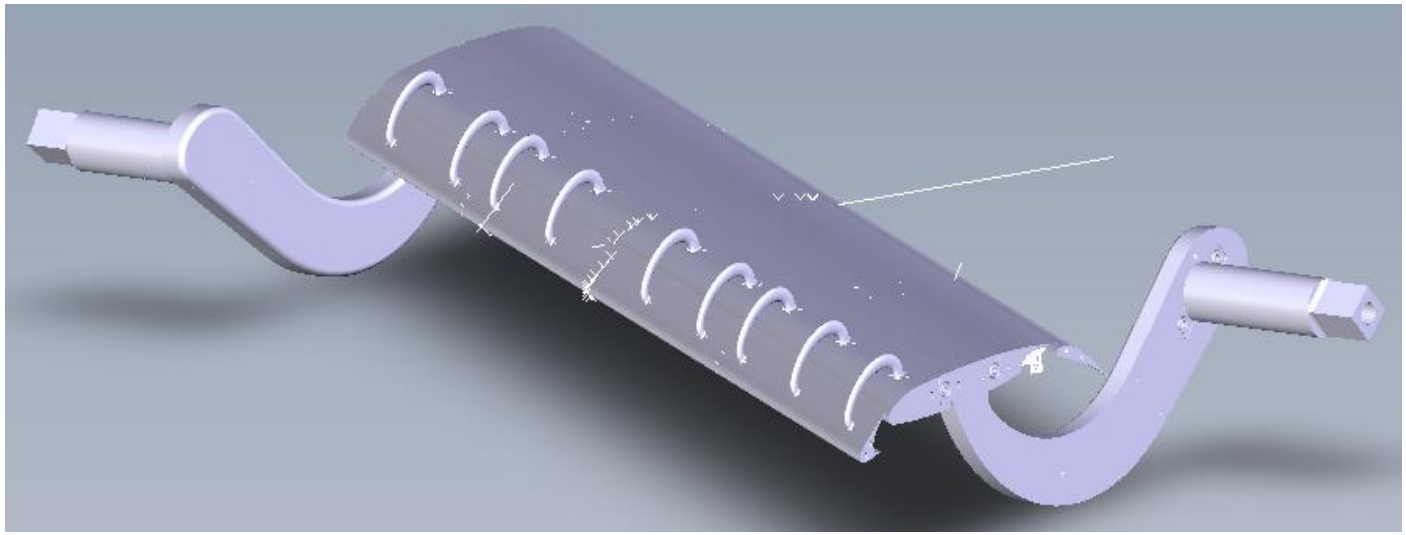
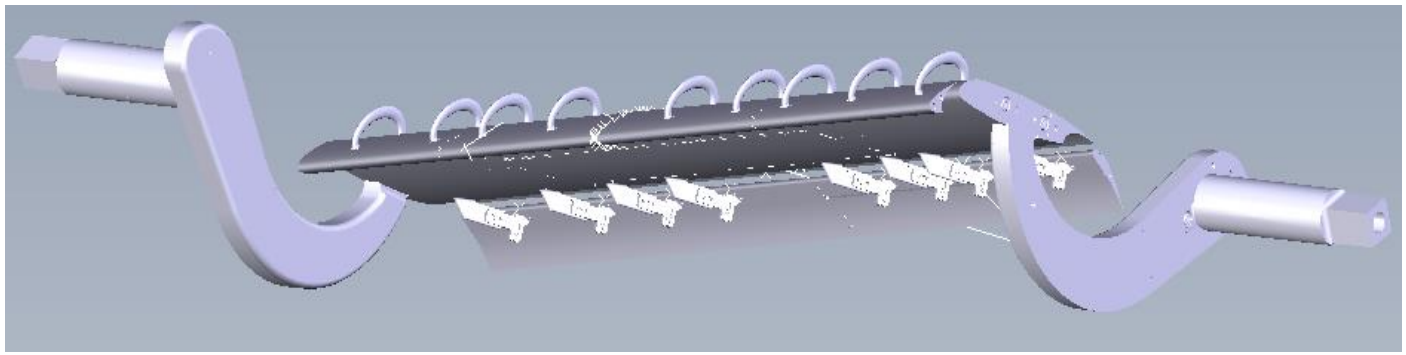
Design/manufacture of 2D swept model by DLR

DLR : design and manufacture of wing and slat extensions
The onboard instrumentation is maintained : one section of static pressure taps on slat (13) and wing (11), 12 Kulite sensors on wing





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2D swept model in F2 windtunnel

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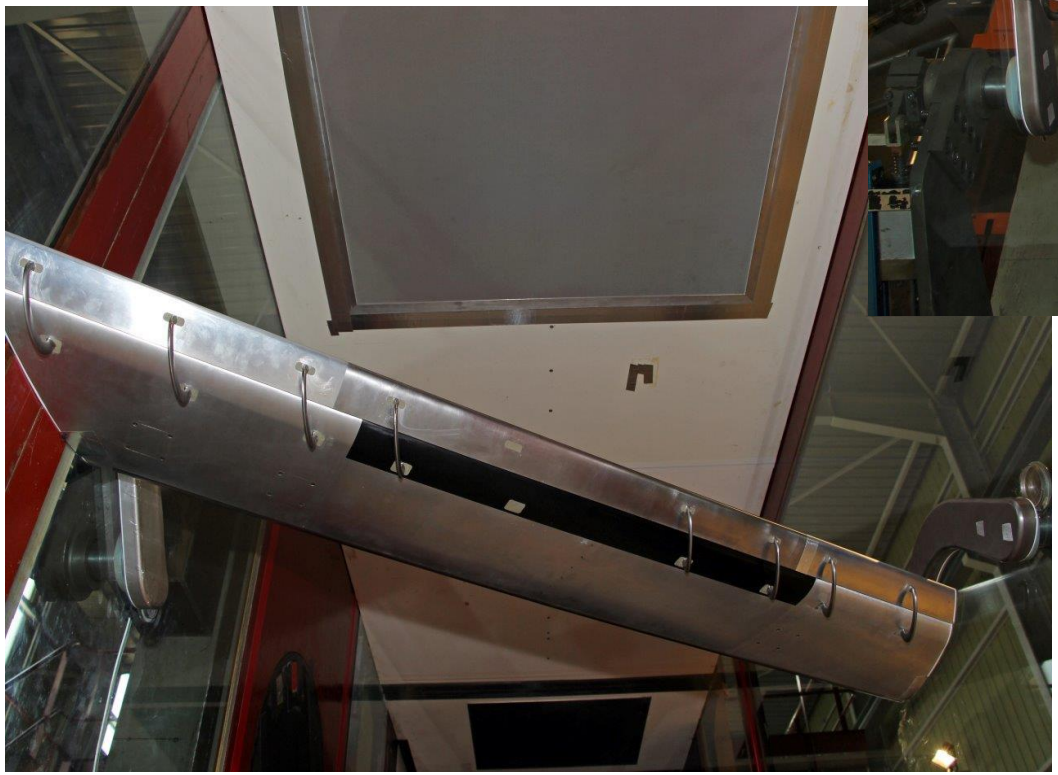
2D swept model in F2 windtunnel



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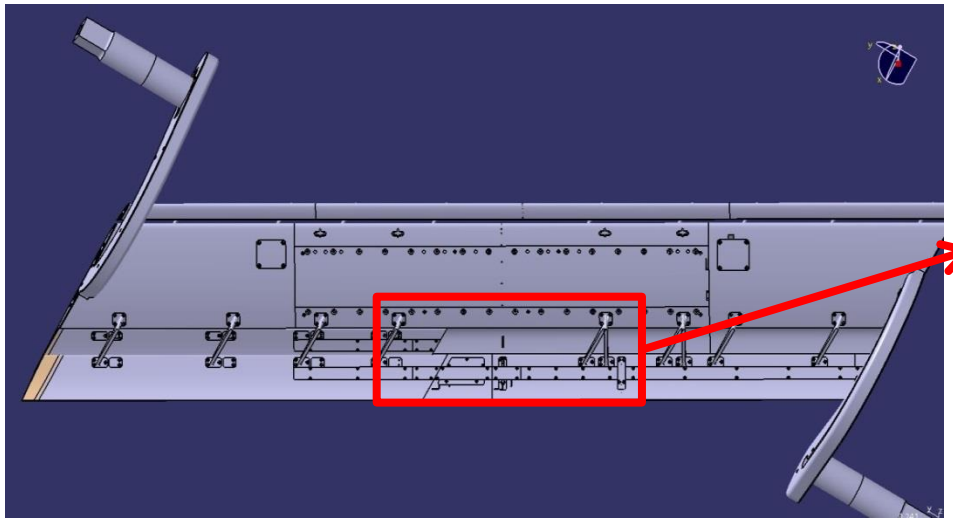
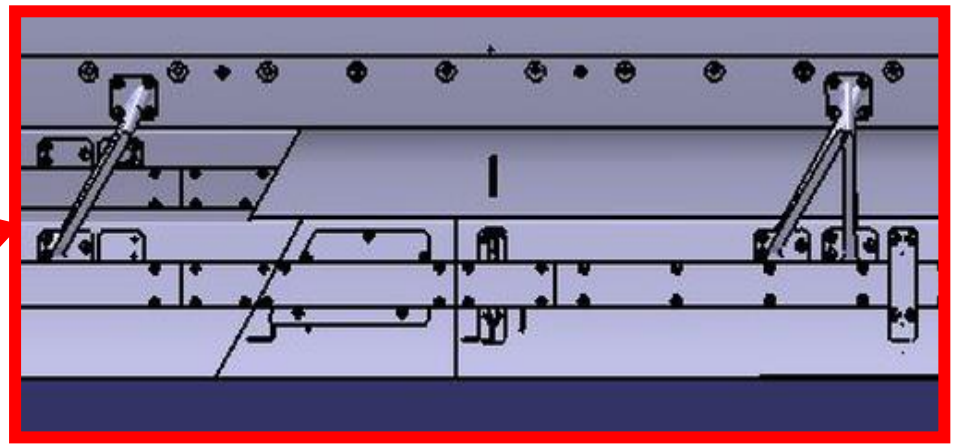
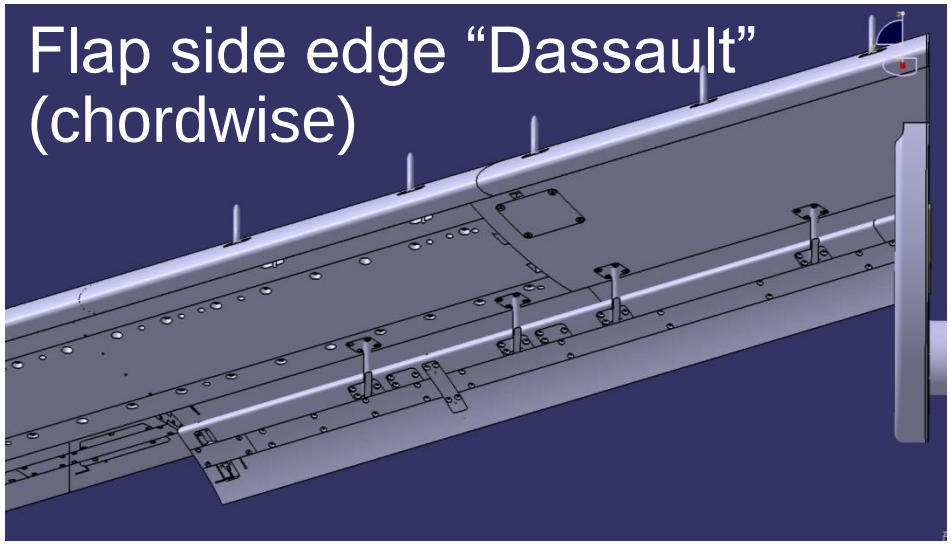
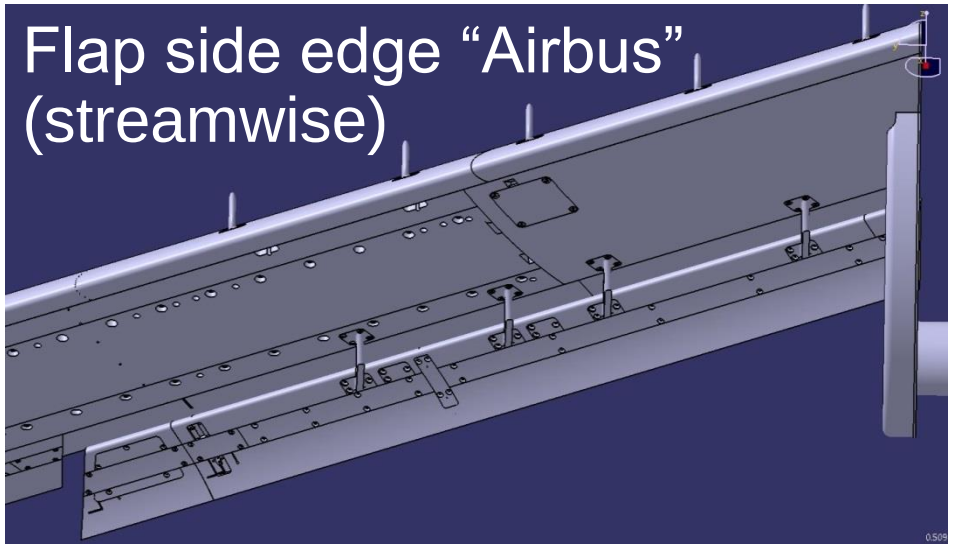
SWAHILI-FSE :
Design/manufacture of 3D flap by Dassault-Aviation (1/2)









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DASSAULT AVIATION

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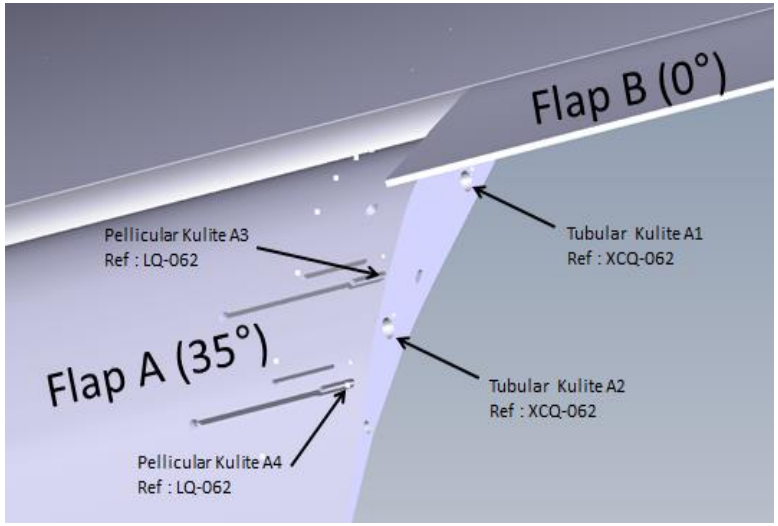
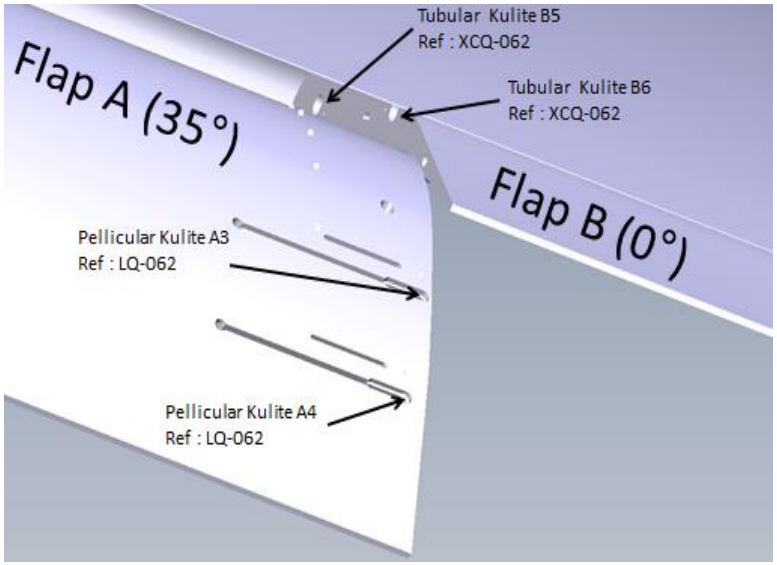
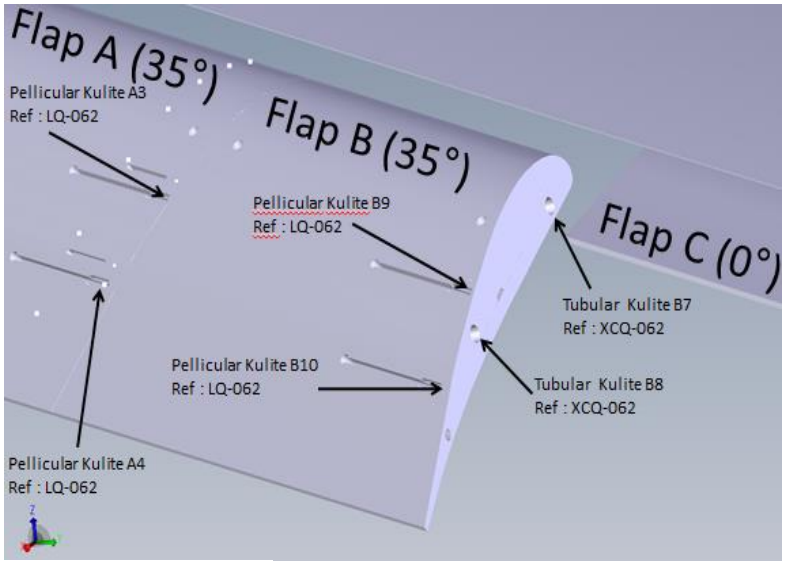
SWAHILI-FSE :
Design/manufacture of 3D flap by Dassault-Aviation (1/2)



New 3-element flap equipped with :

- 2 sections of 11 static pressure taps
- 10 Kulite sensors on flap suction side (close to flap side edge) and on flap edges





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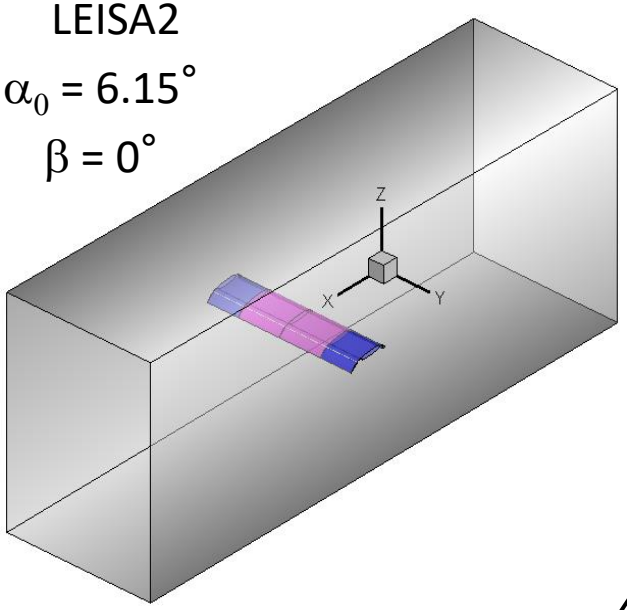
F2 tests : Choice of reference flow conditions
1) Equivalent angle of attack

LEISA2

$\alpha_0 = 6.15°$

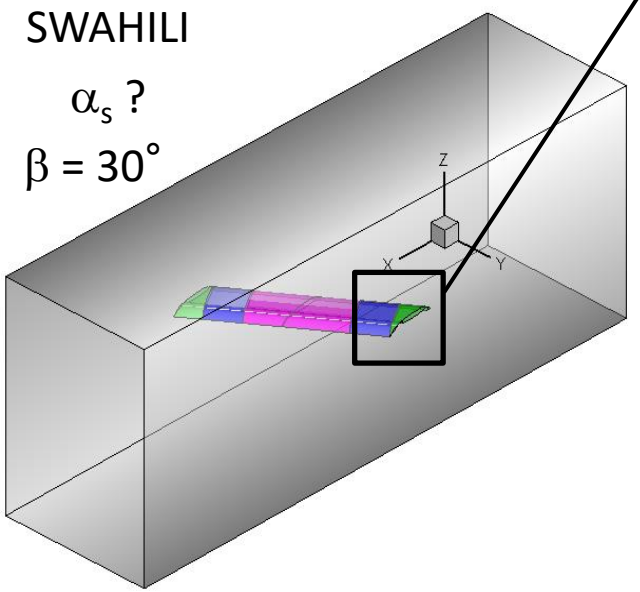
$\beta = 0°$

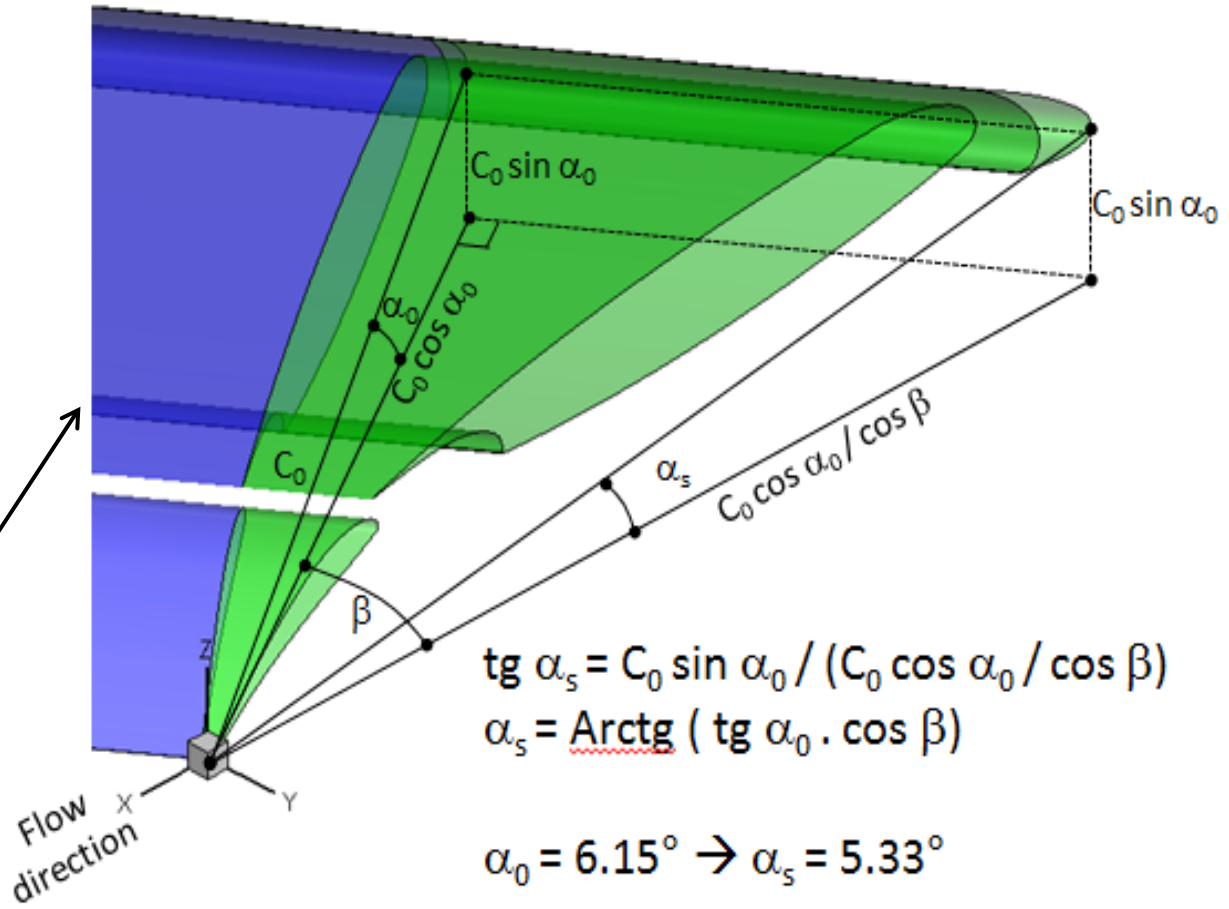


SWAHILI

α_s ?

$\beta = 30°$





$$\text{tg } \alpha_s = C_0 \sin \alpha_0 / (C_0 \cos \alpha_0 / \cos \beta)$$

$$\alpha_s = \text{Arctg } (\text{tg } \alpha_0 . \cos \beta)$$

$\alpha_0 = 6.15° \rightarrow \alpha_s = 5.33°$

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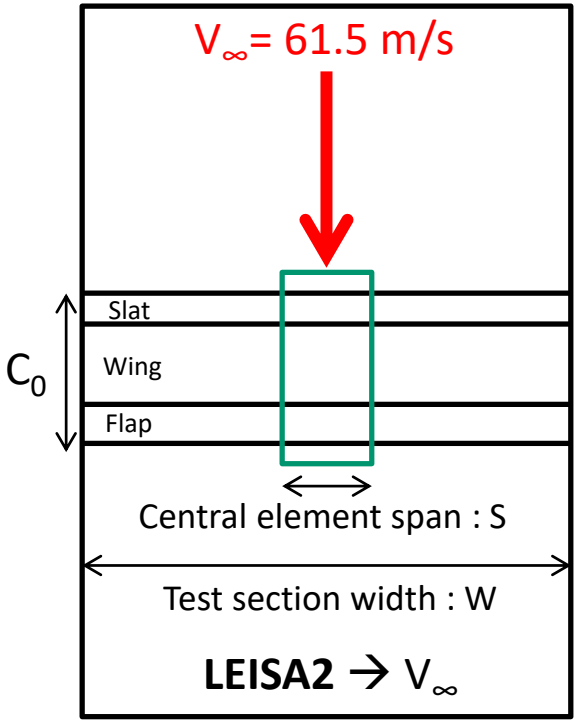
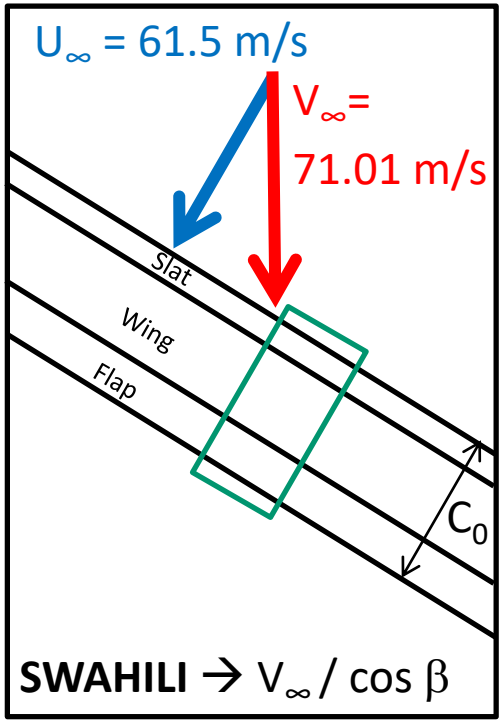
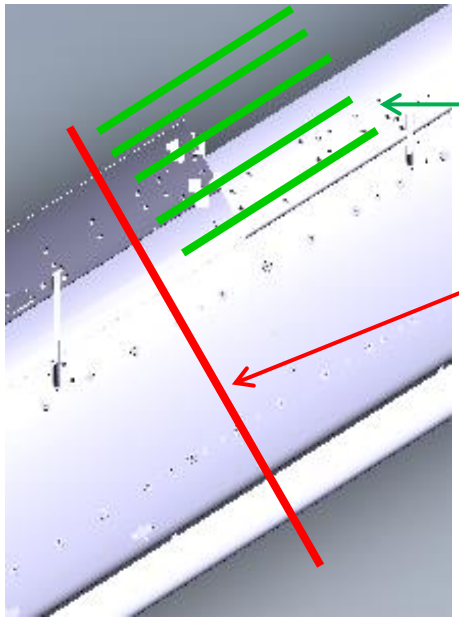
F2 tests : Choice of reference flow conditions
2) Equivalent flow velocity

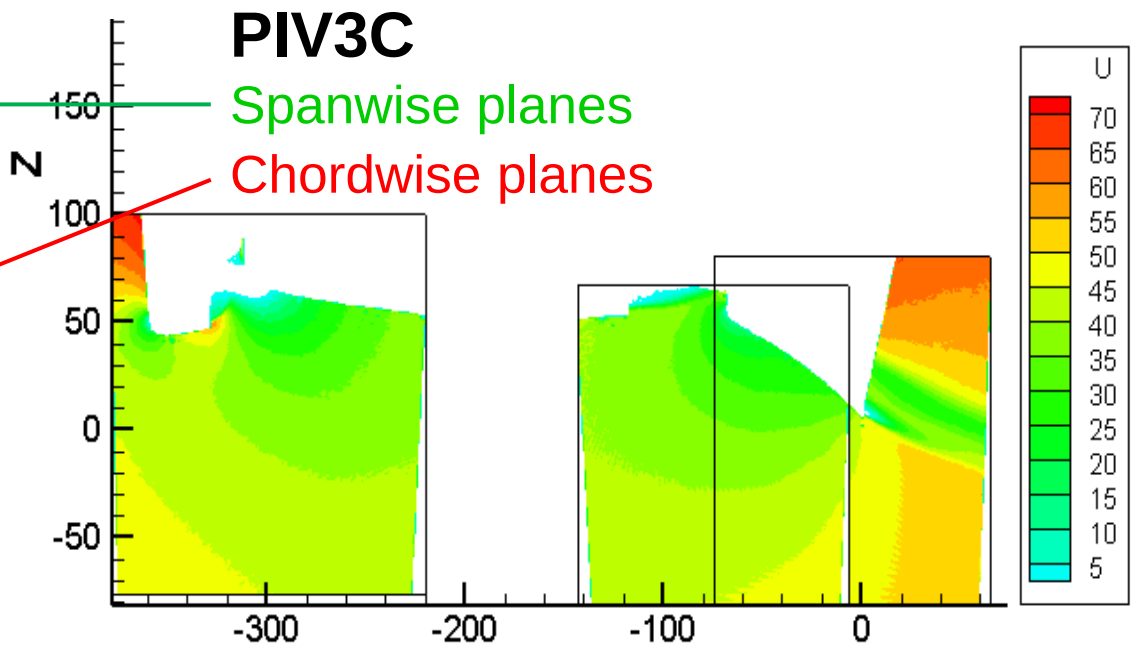




	LEISA2 → V_∞	**SWAHILI** → V_∞ / cos β
Local pressure	**P**	**P**
Full airfoil area	**A** = C_0.W	C_0.W / cos β **> A**
Lift of full airfoil	**L** = P.C_0.W	P.C_0.W / cos β **> L**
Lift of central element	**L_s** = P.C_0.S	P.C_0.S **= L_s**

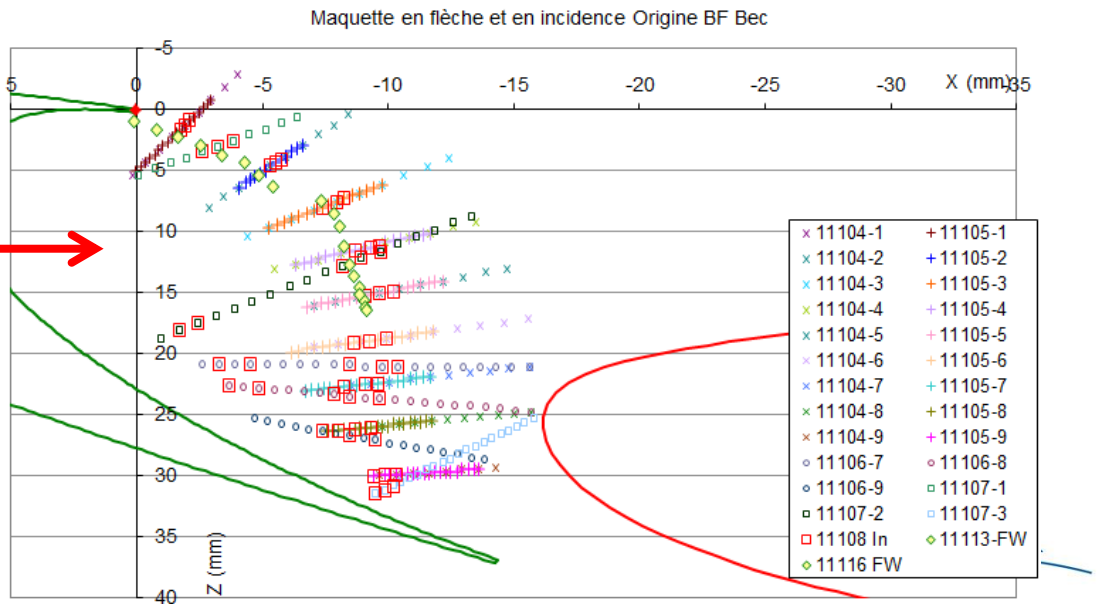
SWAHILI tests in F2: PIV 3C and LDV 2D



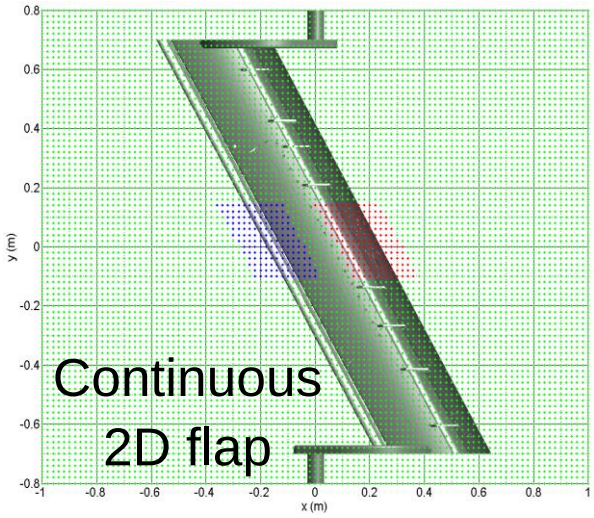


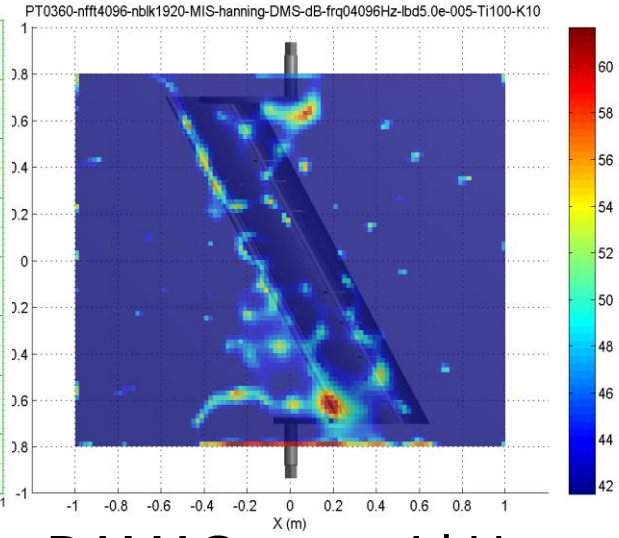
LDV 2D

- Same points distribution in slat/wing/flap as in LEISA2
- For flap side edge configurations : additional points around flap side edge

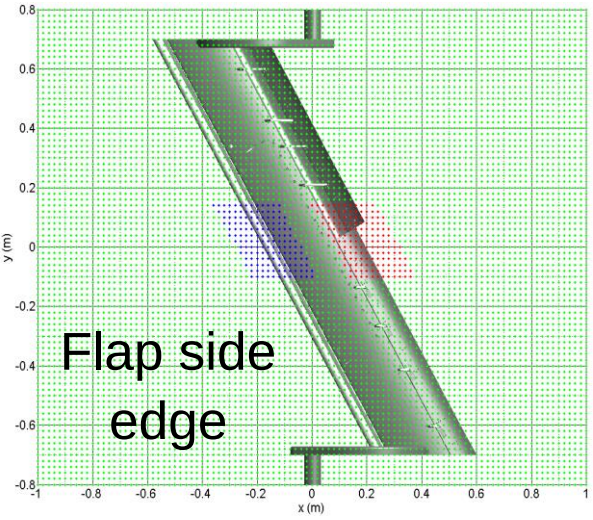


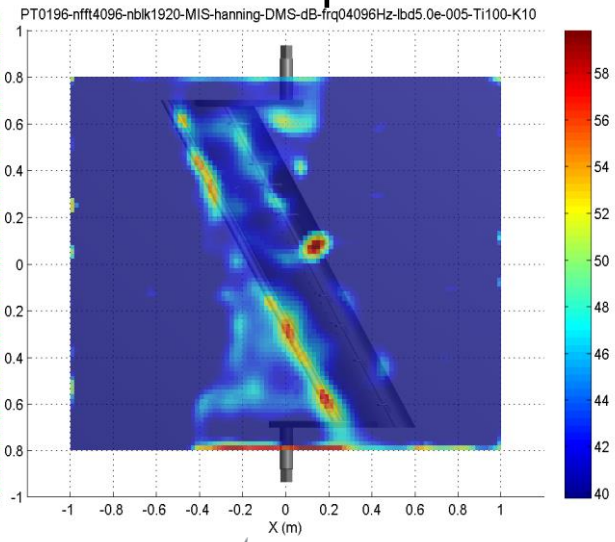
SWAHILI tests in F2 : acoustics

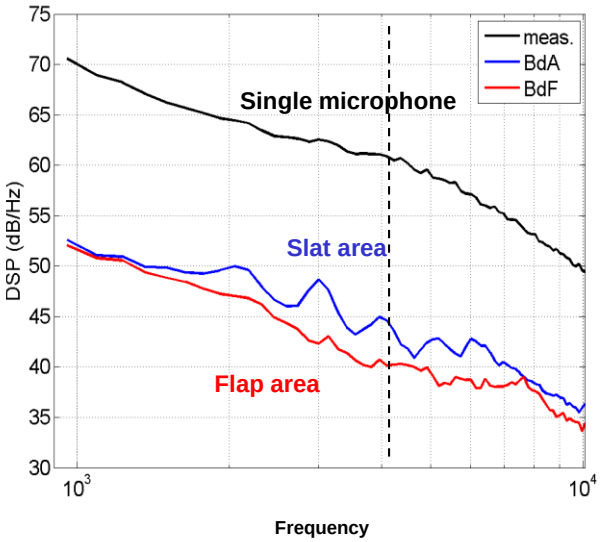


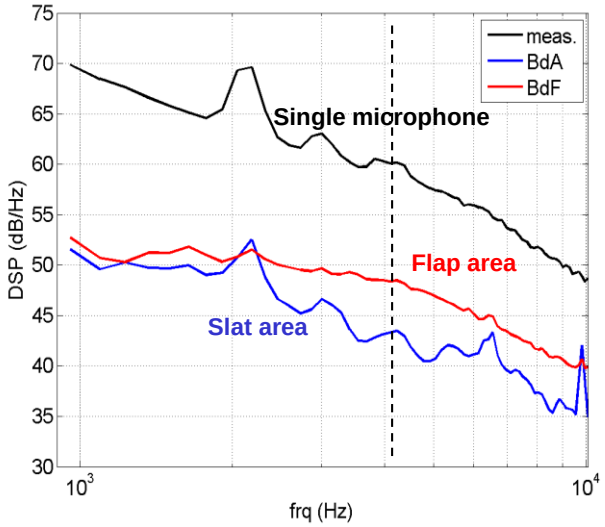


DAMAS maps 4 kHz









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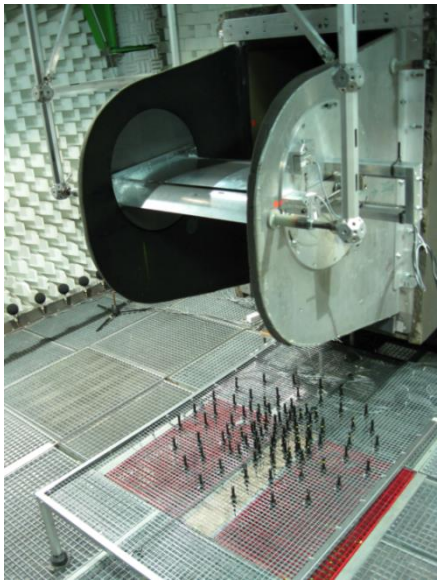
SWAHILI (3D airfoil with sweep)
Acoustic measurements in AWB
(in preparation)



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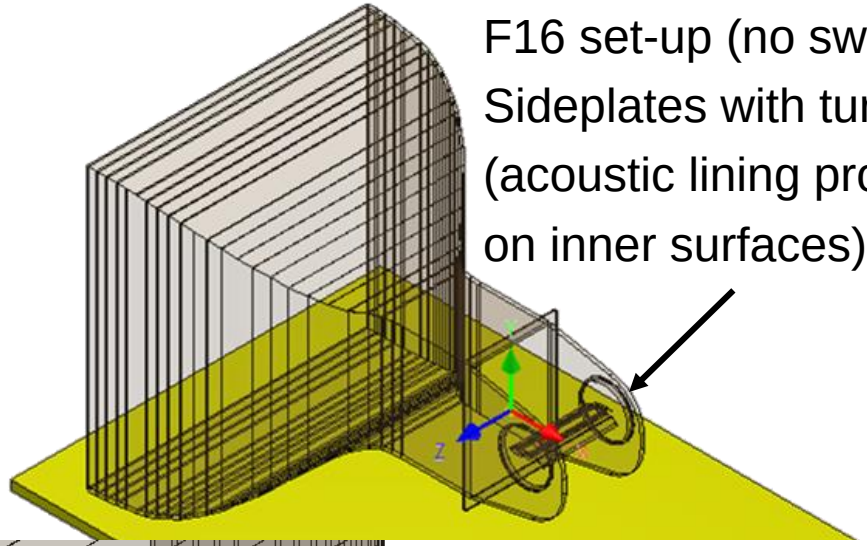
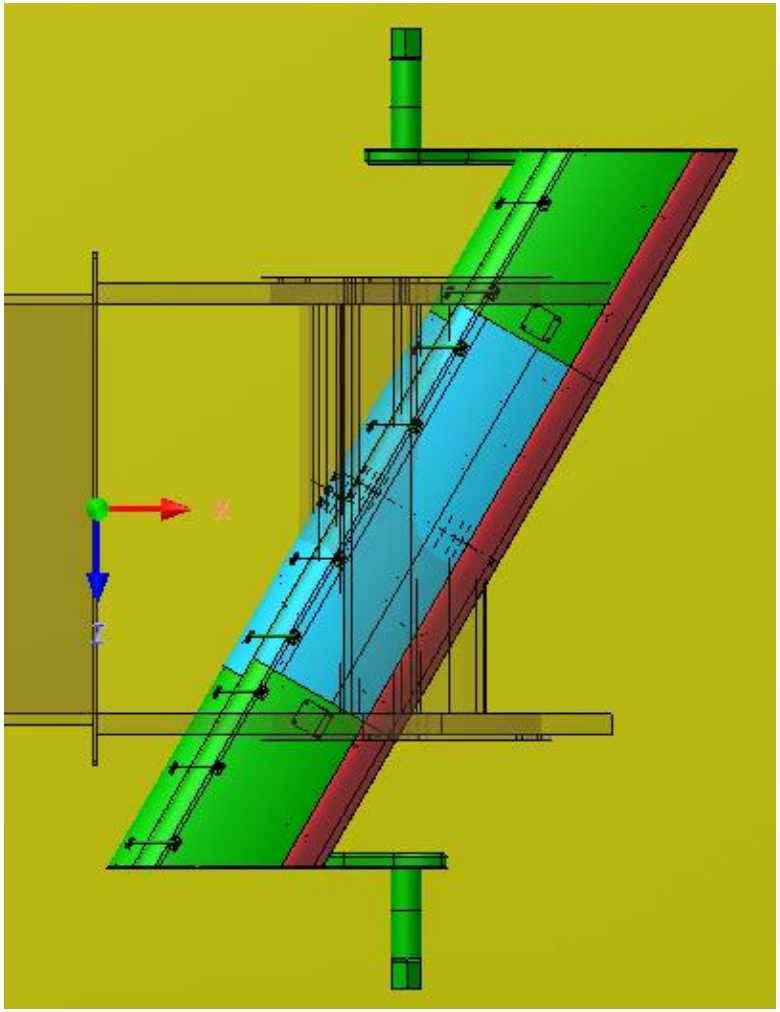
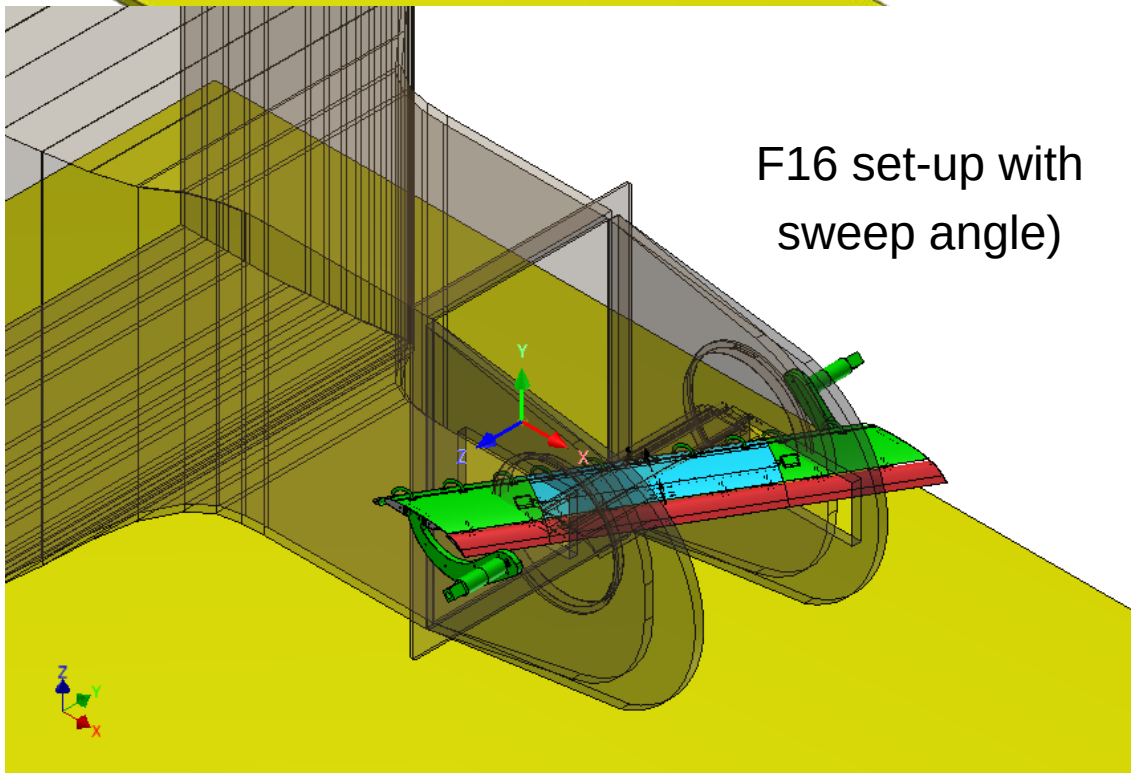
SWAHILI acoustic tests in AWB (in preparation)

F16 set-up (no sweep angle).
Sideplates with turntables
(acoustic lining provided
on inner surfaces)





F16 set-up with
sweep angle)



Midspan cross-section at
identical downstream
position for both test cases

Conclusions

- Achievement of large aerodynamic/acoustic databases for the validation of CFD/CAA computations
- LEISA2 database (2D airfoil with 0° sweep angle)
  → already available through the BANC (Benchmark for Airframe Noise Computations)
- SWAHILI (2D airfoil with 30° sweep angle)
- SWAHILI-FSE (flap side edge configurations)
  → will be available in 2017 through BANC

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