Application of Porous Media for Airframe Noise Reduction

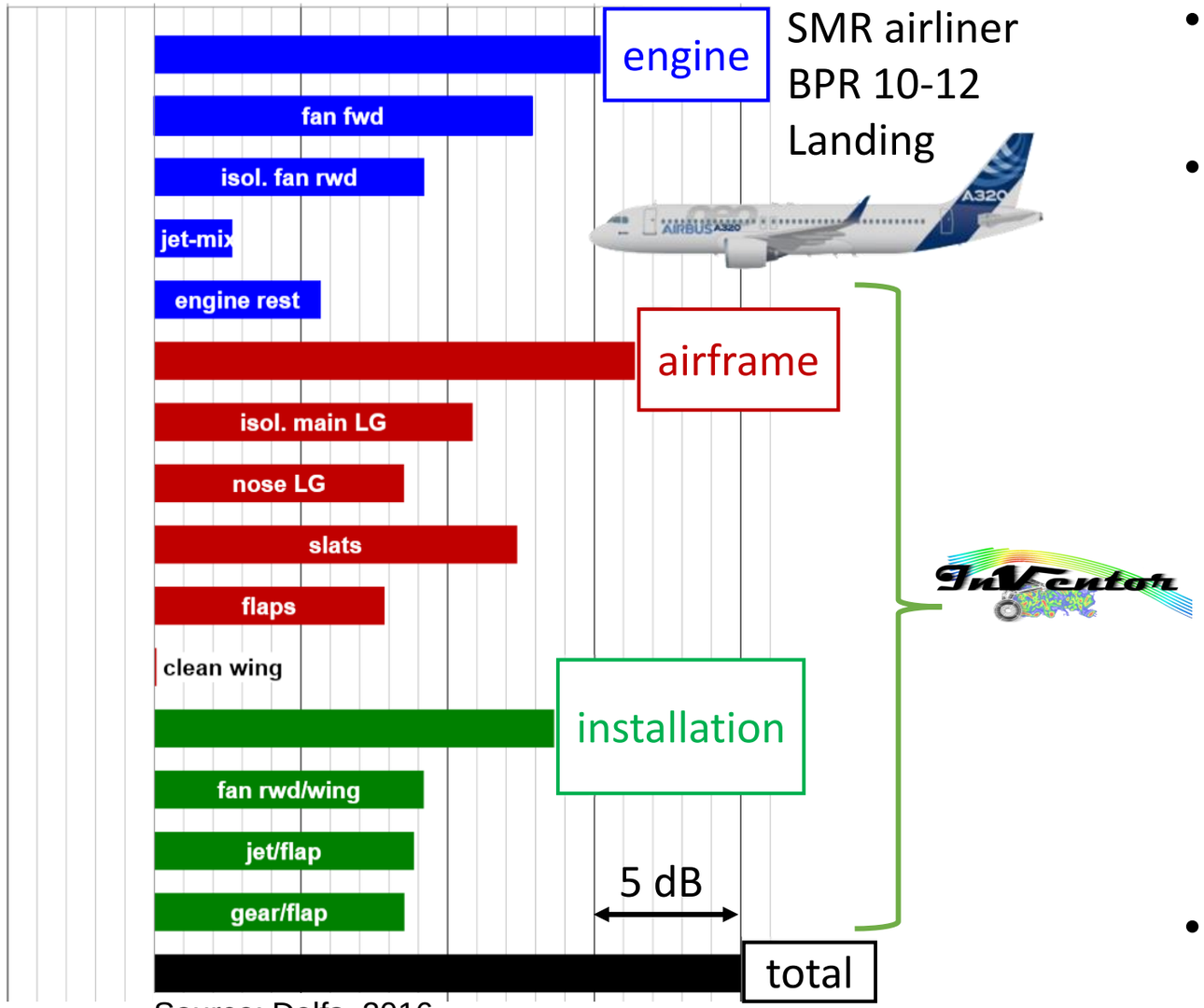
Michael Pott-Pollenske

SECOND ENODISE PUBLIC WORKSHOP
ADVANCED POROUS TREATMENT, LINERS AND META-MATERIALS
FOR ENGINE AND AIR FRAME NOISE MITIGATION
with the participation of DJINN and INVENTOR

07-November-2022, RWTH Aachen University, Germany

The INVENTOR project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860538

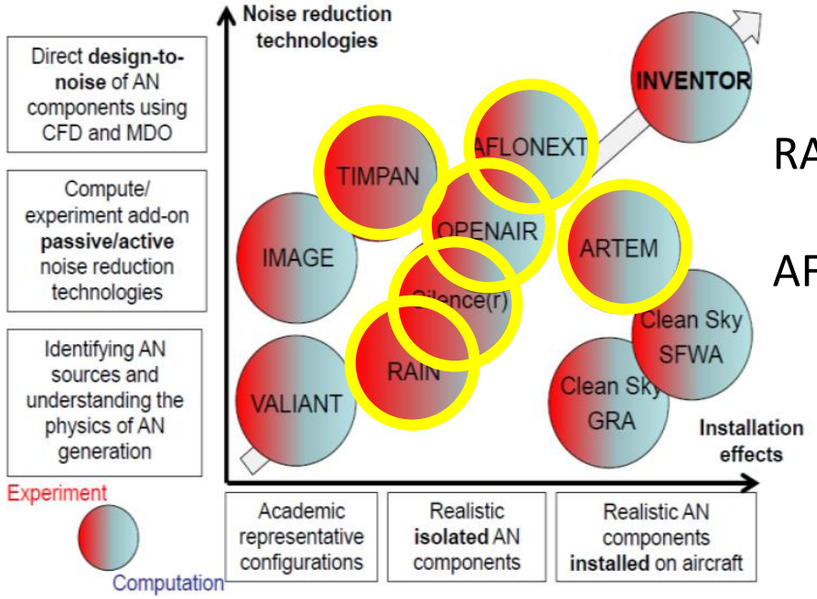
Motivation



SMR airliner
BPR 10-12
Landing

Source: Delfs, 2016

- Noise source breakdown for a „NEO“ type SMR airliner in landing configuration
- Airframe noise related EU-funded research projects



RAIN: ~year 2000

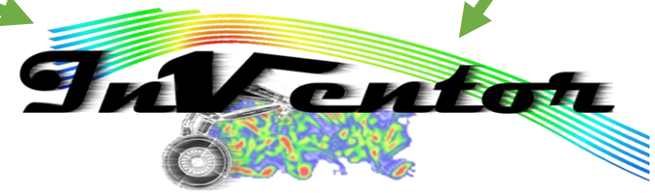
AFLoNext: end 2018

Source: Inventor Grant Agreement

- Yellow marked projects include reseach with porous media

Application of Porous Media for Noise Reduction

	Slat Noise	Landing Gear Wake-Flap Interaction Noise
Soure type	Classic high lift system related noise source	Installation noise source
Main Source mechanism(s)	• Accelerated turbulence in the slat cove • Slat trailing edge noise	• Turbulent landing gear wake impingement on flap leading edge, • flapleading edge noise
Noise reduction concepts	• Reduce / minimize slat gap • Very Long Chord Slat (VLCS) concept • Attenution of turbulence • Near field noise reduction	• Turbulence screen downstream of the landing gear • Porous flap leading edge
Relevant Projects	• TIMPAN (EU) • OPENAIR (EU) • ARTEM (EU) • **MOVE ON (German national)**	• SILENCE(R) (EU) • **ARTEM (EU)**





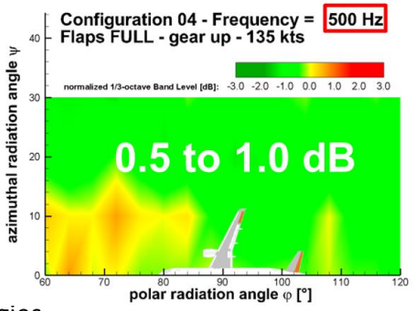
Other Applications

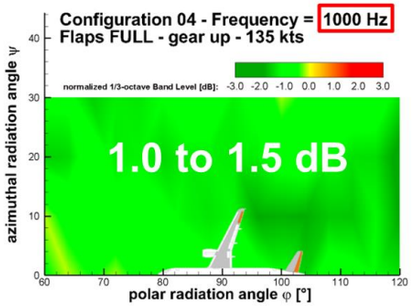
- Flap Side Edge (AFLonext):

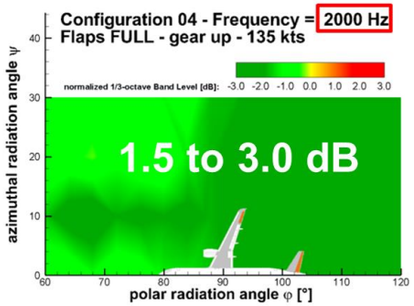


Aluminum foam


Open Cell Urethane foam







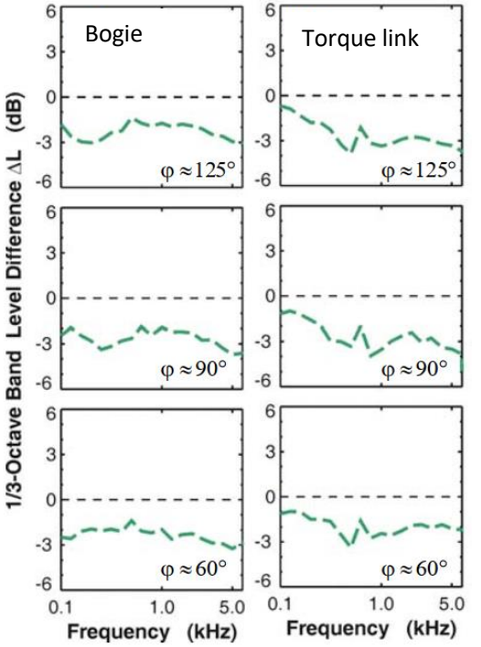
Low Noise ATRA – An Aircraft Noise Reduction Study based on Retro-Fit Technologies
Michael Pott-Pollenske
AIAA 2021-2117 Session: Airframe/High-Lift Noise I
Published Online:28 Jul 2021 https://doi.org/10.2514/6.2021-2117

- Landing Gear Mesh Fairings (Timpan, OPENAIR, AFLoNext)





- Negative bogie angle (toe down)
- Narrow wheel spacing (both forward and rear wheel sets)
- **Porous bogie and torque link fairings**
- TIMPAN brake fairings
- Articulated TIMPAN door with 45° ramp and
- TIMPAN side-stay design

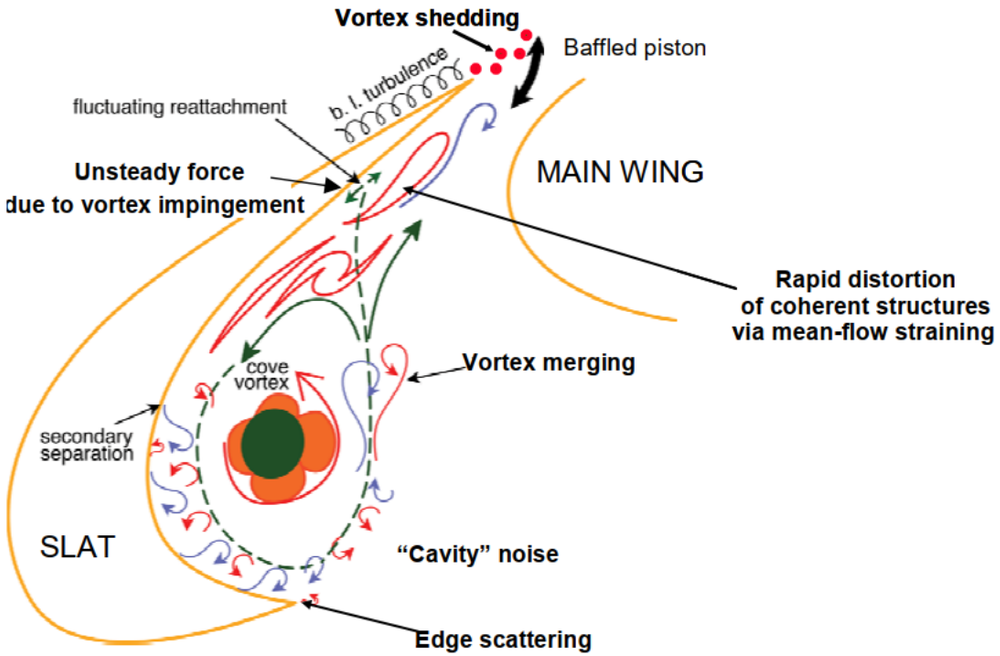


Experimental Assessment of Low Noise Landing Gear Component Design
Werner Dobrzynski, Leung Choi Chow, Malcolm Smith, Antoine Boillot, Olivier Dereure and Nicolas Molin
Published Online: 4 Nov 2012 https://doi.org/10.2514/6.2009-3276

Slat Noise

Slat Noise Reduction

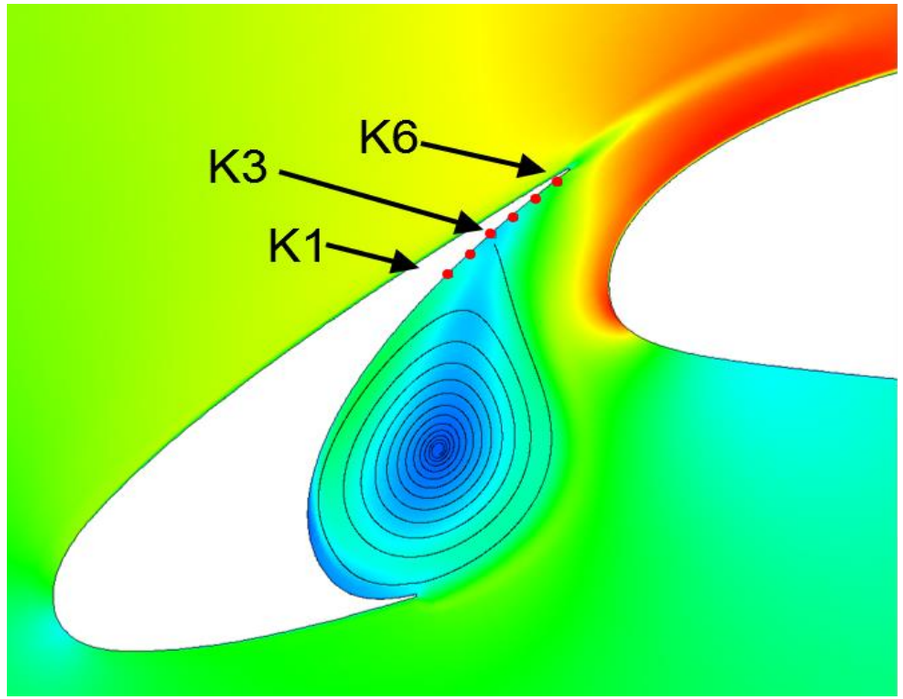
- Slat flow features



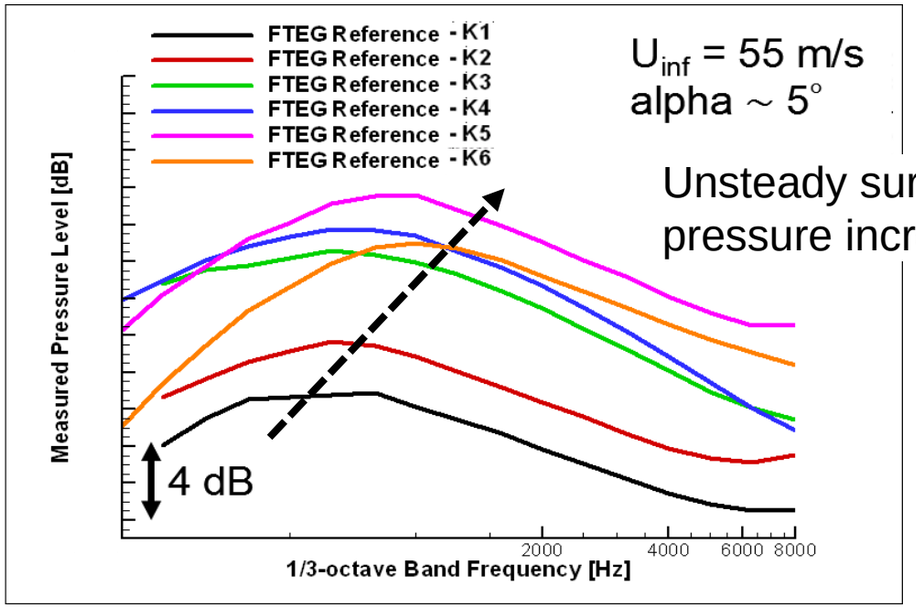
30P30N slat

Slat Cove Unsteadiness: Effect of 3D Flow Structures
AIAA-2006-0211
Meelan M. Choudhari* and Mehdi R. Khorrami*

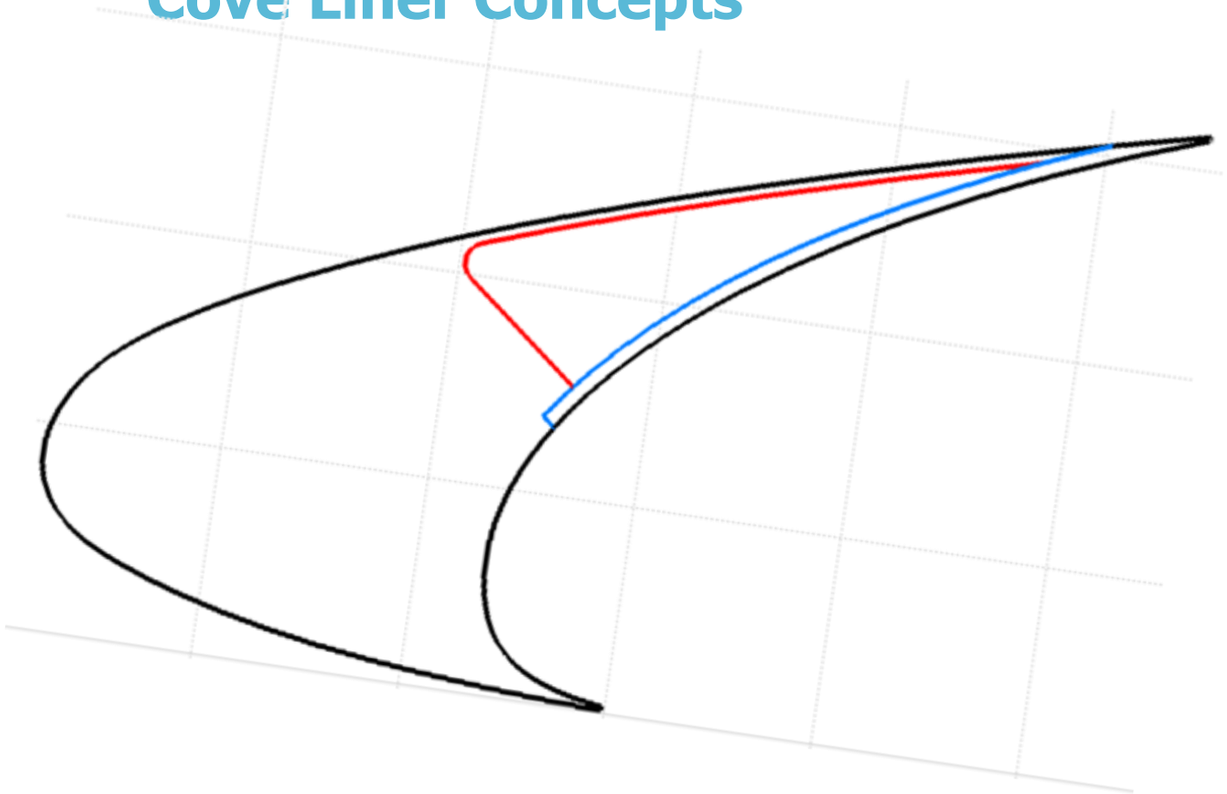
TAU mean flow field computation of DLR F15 LS high lift wing

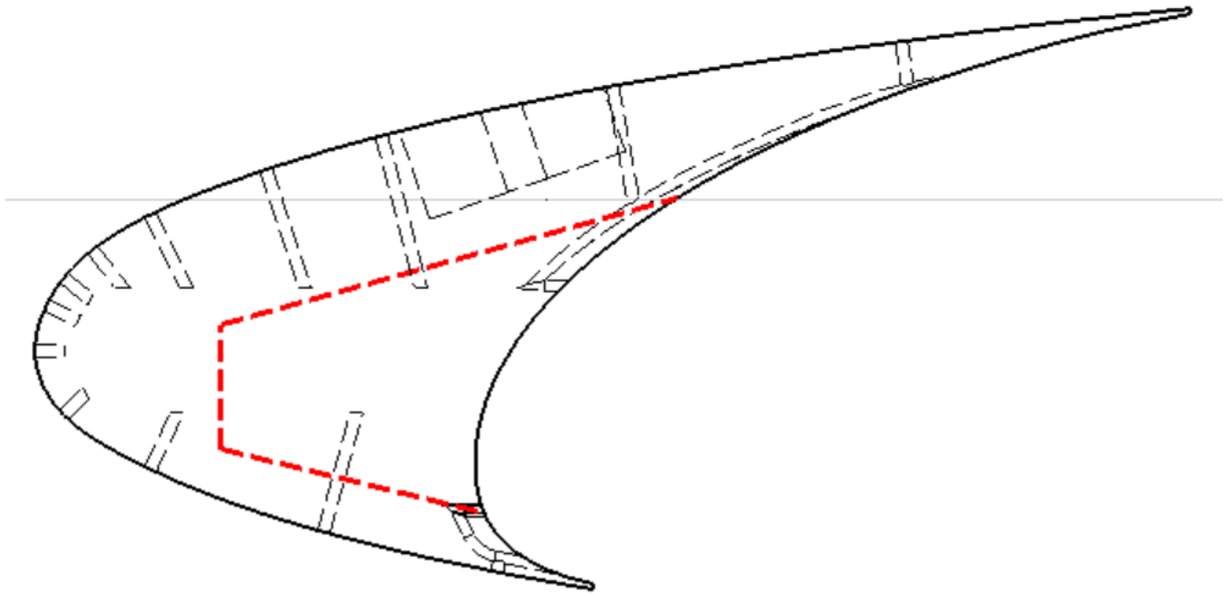


Measurement on DLR F15 LS high lift wing



Cove Liner Concepts

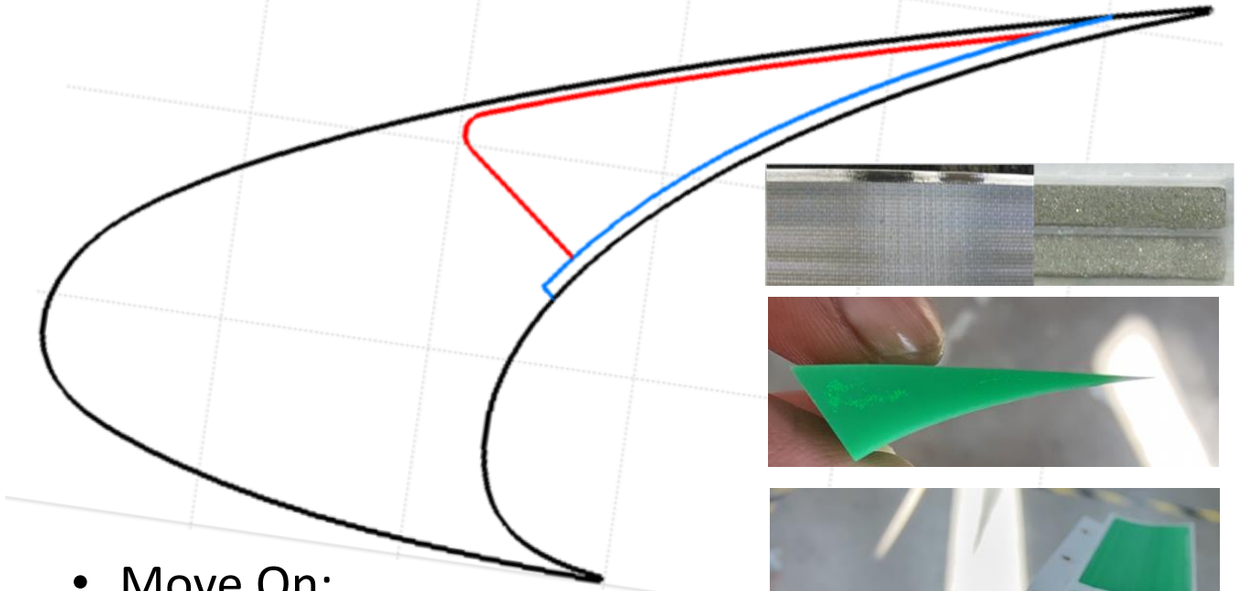


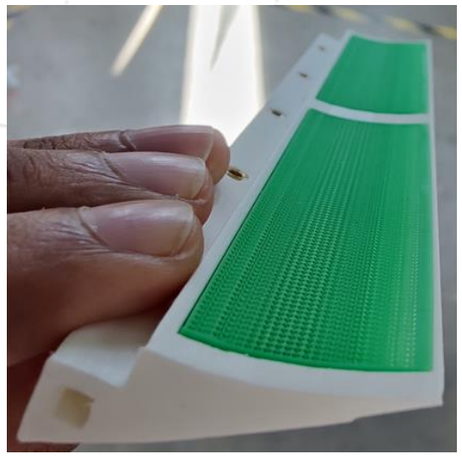


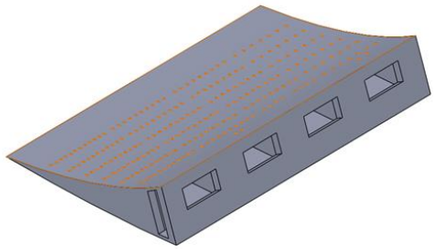
- Turbulence Attenuation Concept
- Scope:
  - reduce the noise generation
  - manipulate the noise source

- Near Field Absober
- Scope:
  - Near field noise reduction
  - Reduce sound wave propagation in the source region

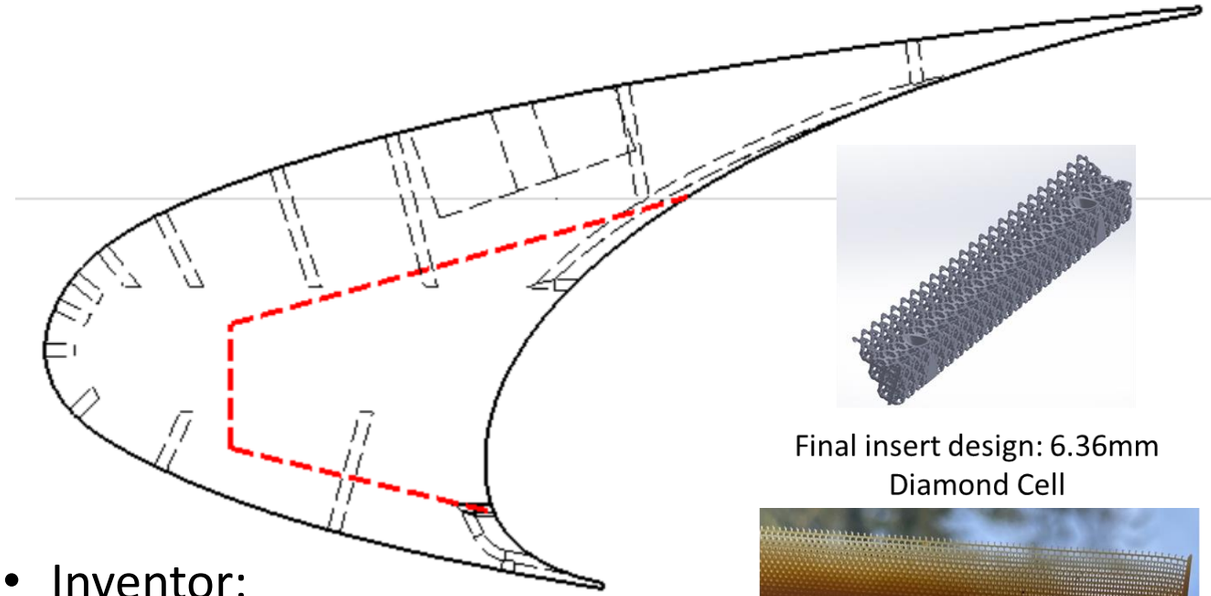
Cove Liner Concepts – Absorber Layout / Material





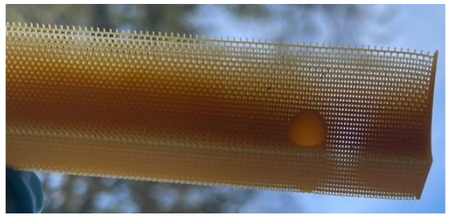


- Move On:
  - Foam with wire mesh
  - open cavity
  - honey comb inserts
- Inventor:
  - Diamond cell, Kelvin cell, MPPA
  - Foam covered with wire mesh

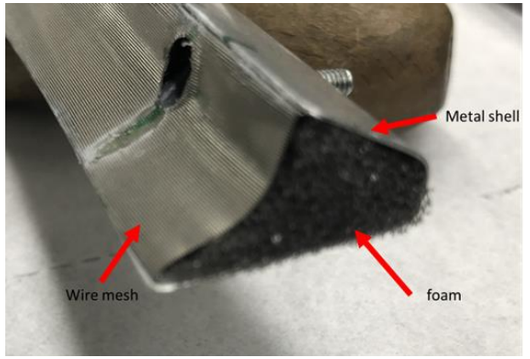


Final insert design: 6.36mm Diamond Cell

- Inventor:
  - Diamond lattice cells
  - Kelvin cell
  - Foam covered with wire mesh



Kelvin cell, very small pore size



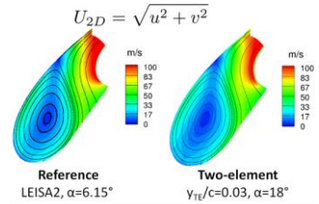
Cove Liner Tests

Facility	Model	Model features	Flow speed	Acoustic Measurements
DLR AWB	DLR F16 • 3-element high lift system	300 mm chord 800 mm span 0° sweep angle	40 m/s 50 m/s 60 m/s	• Acoustic freefield array • Single microphones
DNW-LLF	DLR F15L(arge) S(wept) • 3-element high lift system	1200 mm chord 7.2 m span 0° and 30° sweep	55 m/s	• Acoustic freefield array • Single microphones • Kulites
UoB AWT	DLR F16 • 2-element high lift system	300 mm chord 800 mm span 0° sweep	30 m/s 37 m/s	• Acoustic freefield array • Single microphones • Kulites
ONERA F2	DLR F16 • 3-element high lift system	300 mm chord 1400 mm span 30° sweep	71.0 m/s	• Acoustic wall mounted freefield array • Kulites

- All models feature the same slat shape
- All tests were carried out for an aerodynamic AoA of ~ 6°

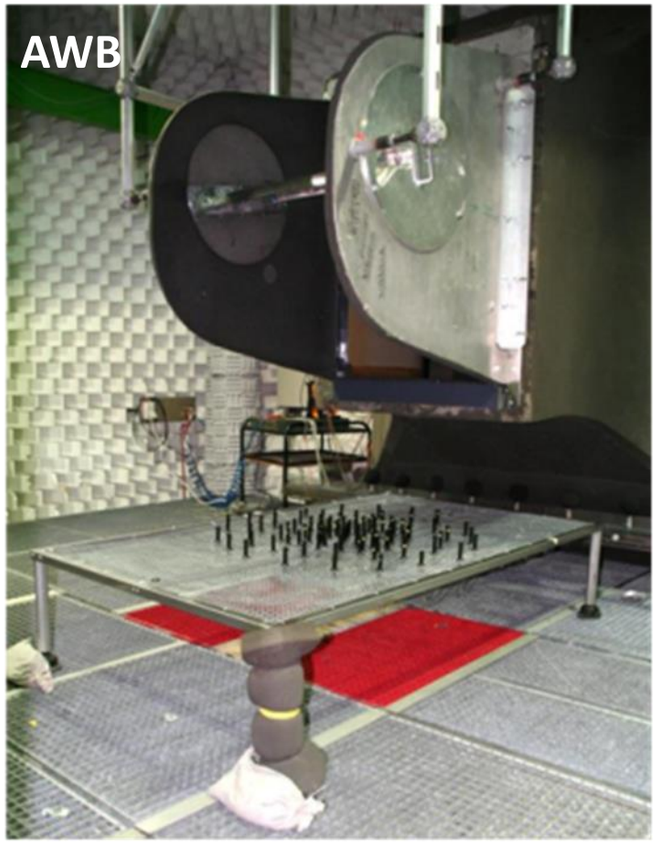


Shape optimization: Marc Terracol, ONERA

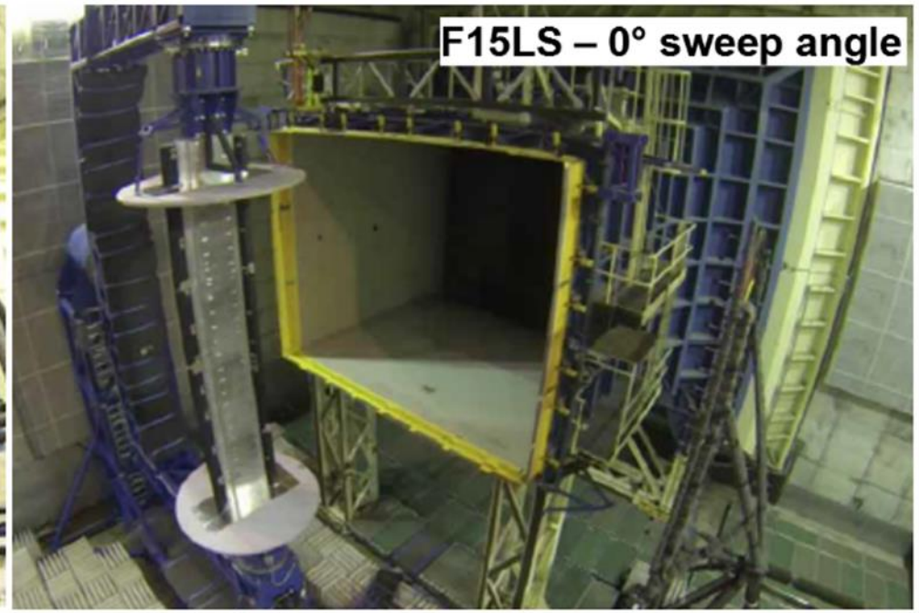


Facilities

- Slat flow features

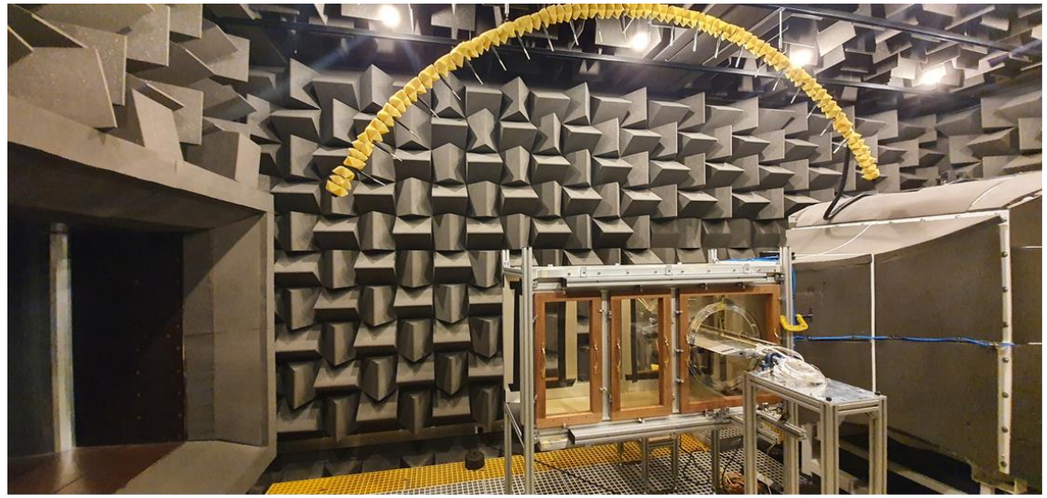








ONERA F2

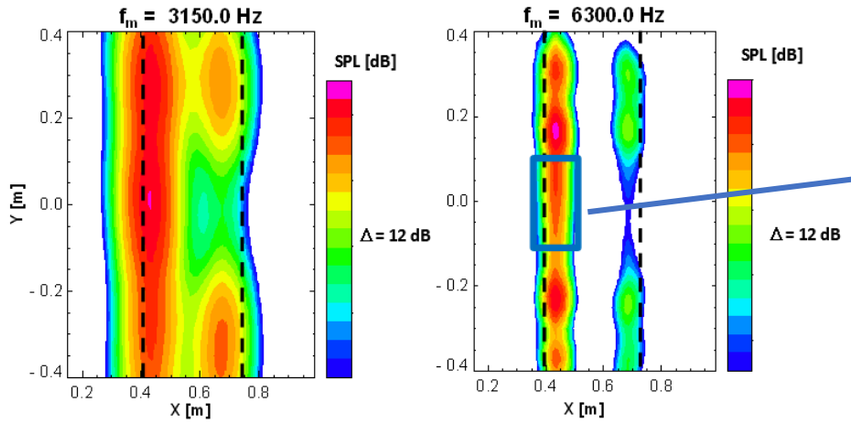


Experimental setup with Kevlar test section for directivity measurements

Results

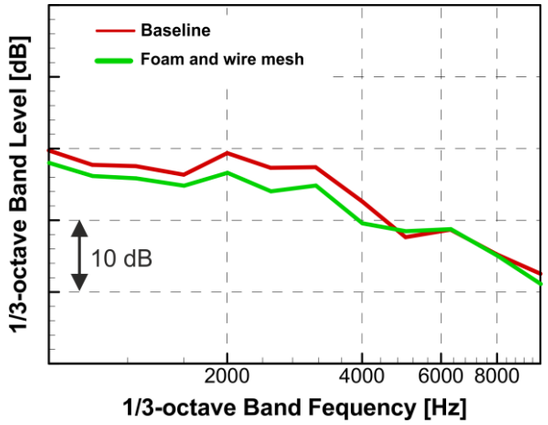
- **AWB**

Array data (Baseline)

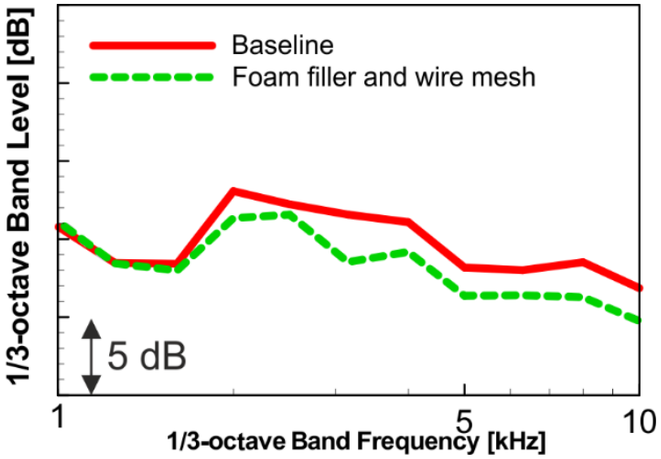


Region free of slat tracks

Array: integrated spectra

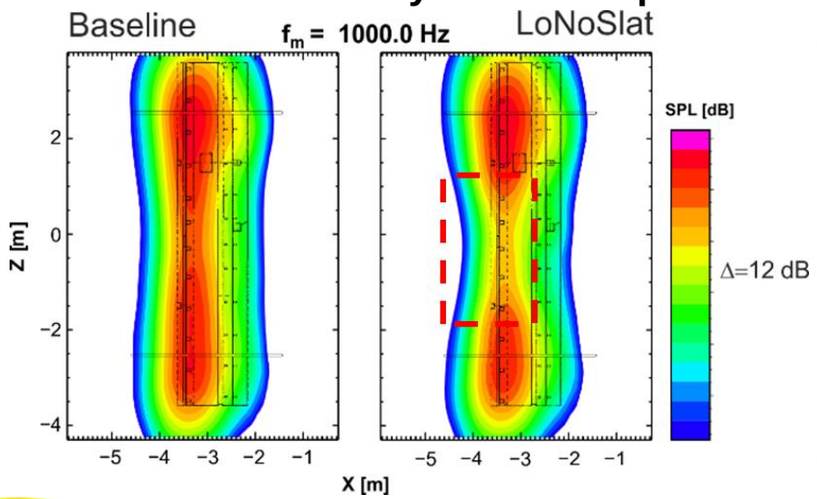


Single microphone farfield noise data

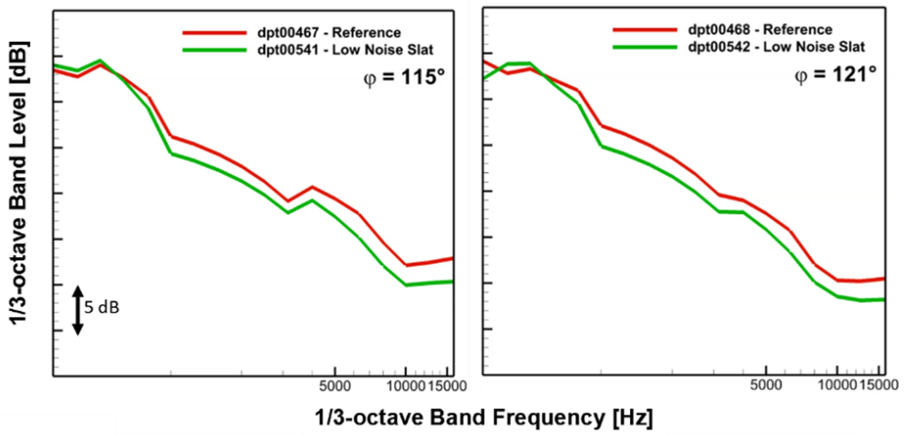


- **DNW-LLF**

Array source maps



Single microphone farfield noise data

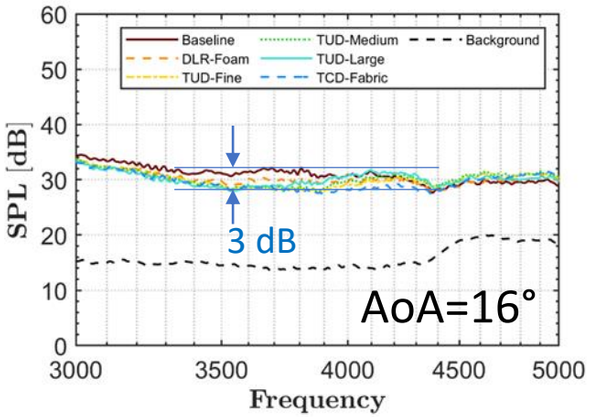


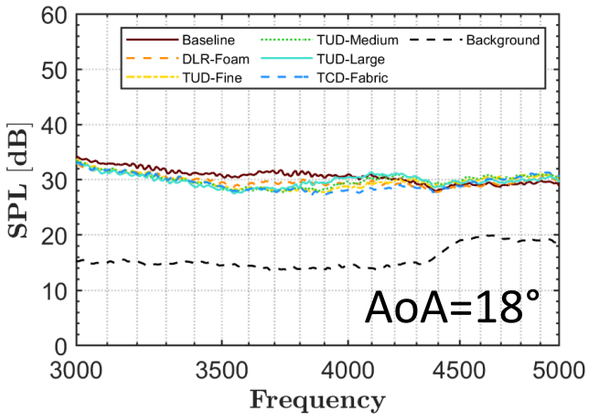
Broadband noise reduction of about 2 to 3 dB was achieved

Results

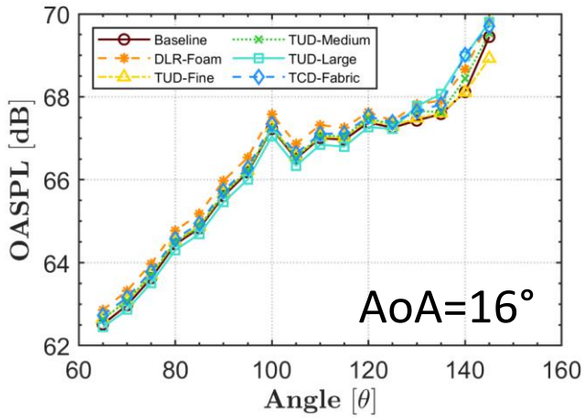
- **UoB**

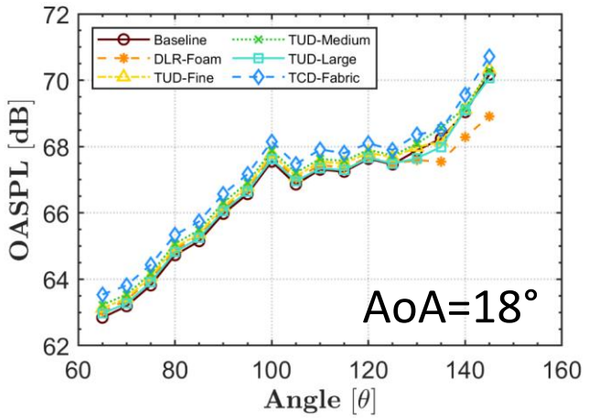
Single microphone farfield noise spectra





Single microphone farfield OASPL data



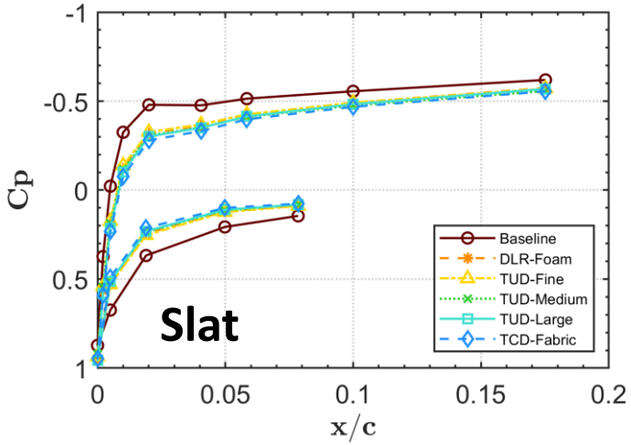


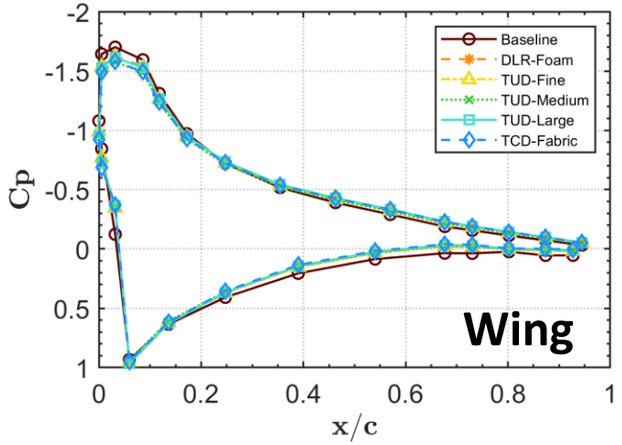
  - Up to 3 dB noise reduction in distinct frequency band between 3 kHz and 5 kHz

- **ONERA F2**
  - Test quite recently conducted
  - Data analysis is work in progress
  - Important: only test with data <u>for both liner configurations</u>.

Cove Liner Concepts - Conclusions

- **Aerodynamic**
  - UoB AWT

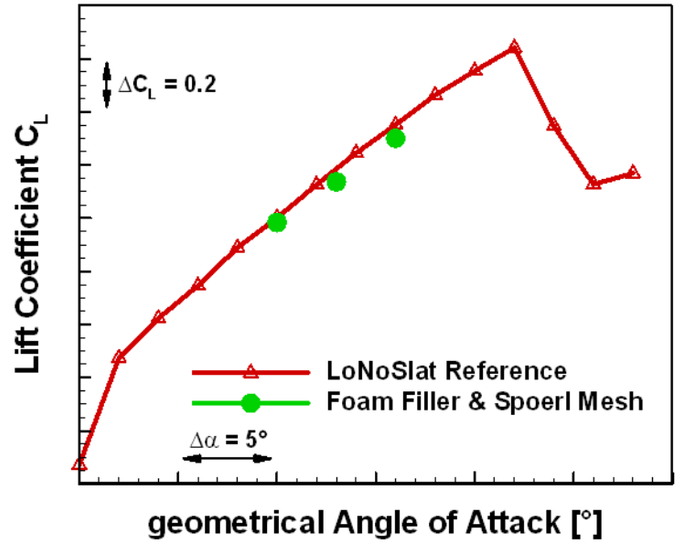




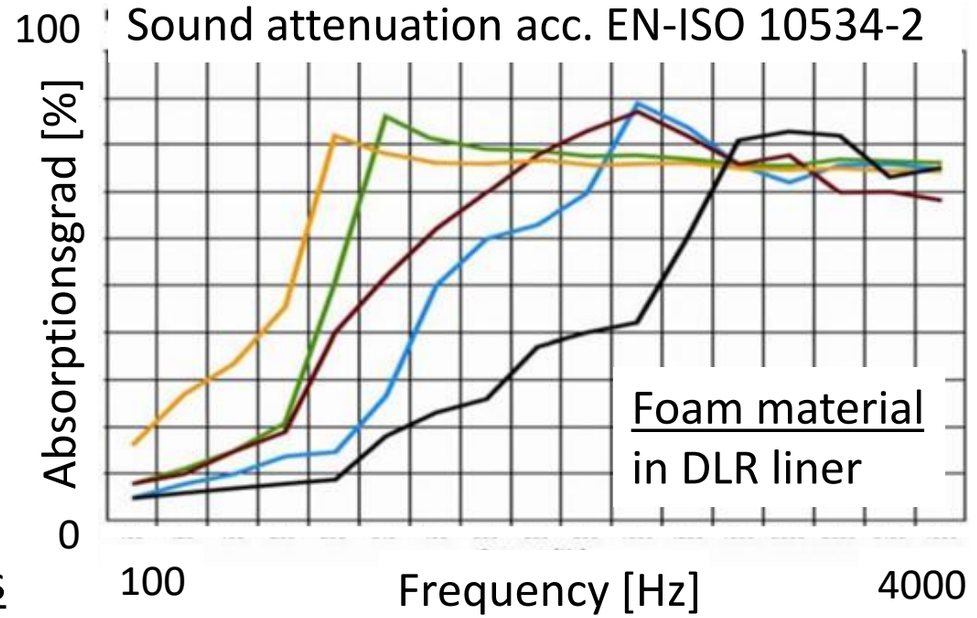
  - marginal lift degradation

- **Acoustic**
  - Up to 3 dB noise reduction achieved
  - Broadband effect for turbulence attenuation
  - Local noise reduction seems less effective
  - Effect of the acoustic properties of liner material is not known in any case → <u>no tailored solutions</u>

- DNW-LLF



Geometrical angle of attack	10°	13°	16°
C_L-Reference	2.00	2.19	2.35
C_L-Foam Cavity/dual layer mesh	1.98	2.14	2.30
C_L-Difference	0.02	0.05	0.05



Landing Gear Noise

Landing Gear Wake-Flap Interaction Noise

- ARTEM scope
  - quantify landing gear installation noise, 2 wheel SMR aircraft landing gear
  - identify previously unknown installation noise sources
  - use experiment and simulation
- Selection of models and configurations

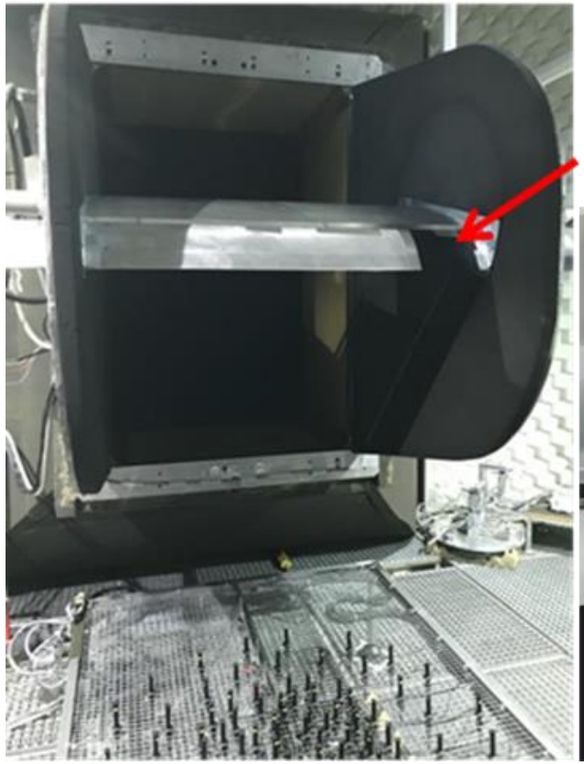
Configuration		Slat	Flap
High Lift System	Clean	0°	0°
400 mm chord	Intermediate	26°	30°
	Full	26°	34°
2D Clark Y		no slat	no flap

Focus for this presentation

- Wind speeds 40, 50 and 60 m/s and geometric angles of attack between 0° and 15°
- Balance and static and unsteady surface pressures
- Phased microphone array and single microphones

SILENCE(R)
An Experimental Study of Gear Wake/Flap Interaction Noise
Stefan Oerlemans and Michael Pott-Pollenske
Published Online:11 Nov 2012 https://doi.org/10.2514/6.2004-2886

Test Setup

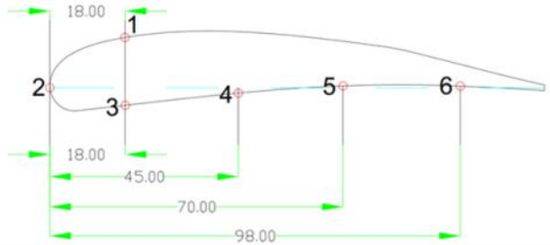


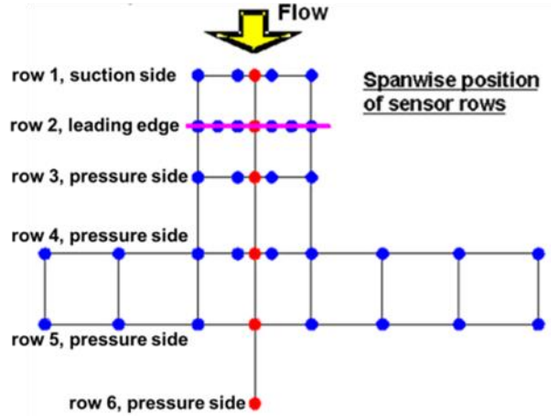
High Lift System Installation in AWB

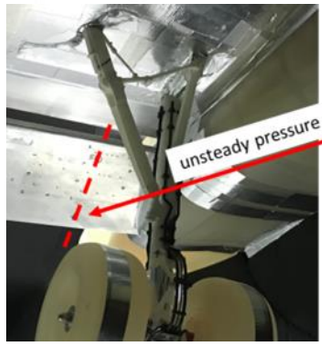
- High lift system

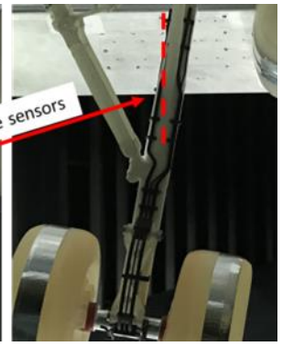


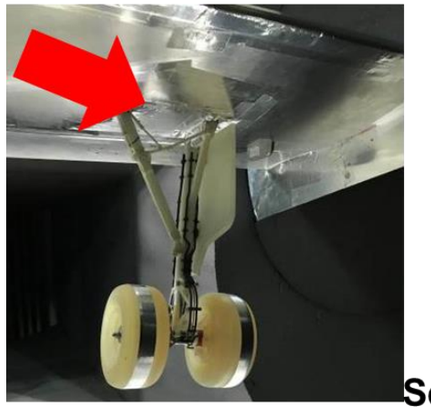




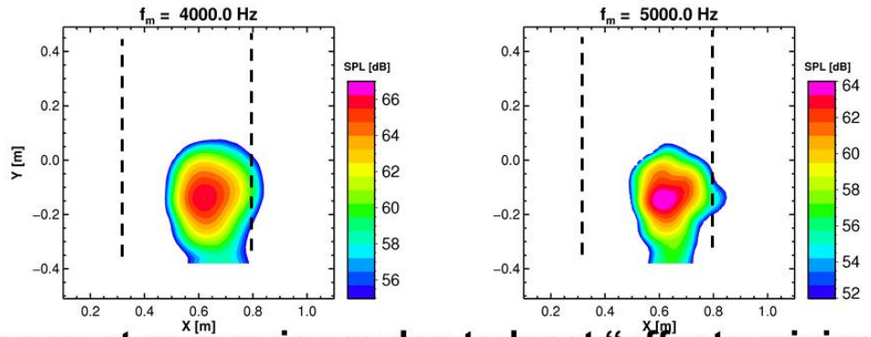








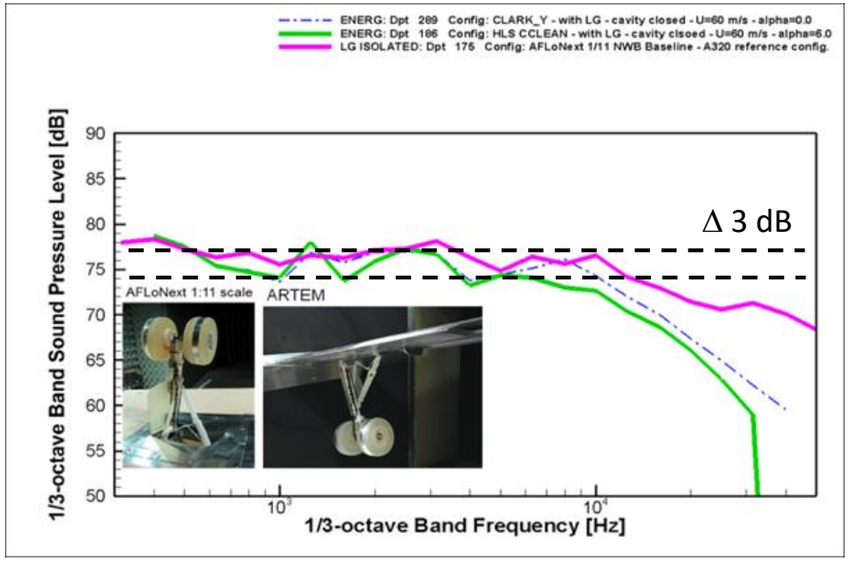
Effect of landing gear with closed cavity



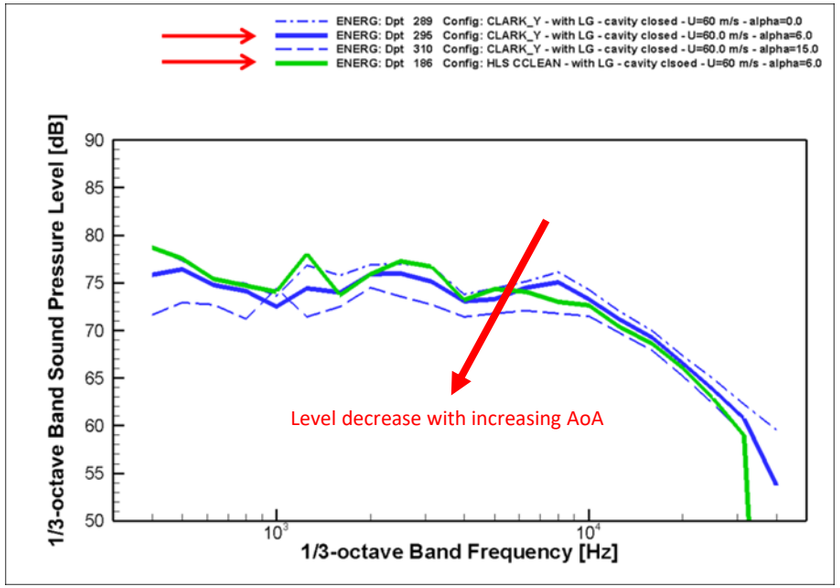
Selected for most comparisons due to least “effects mixing“

Acoustic Results

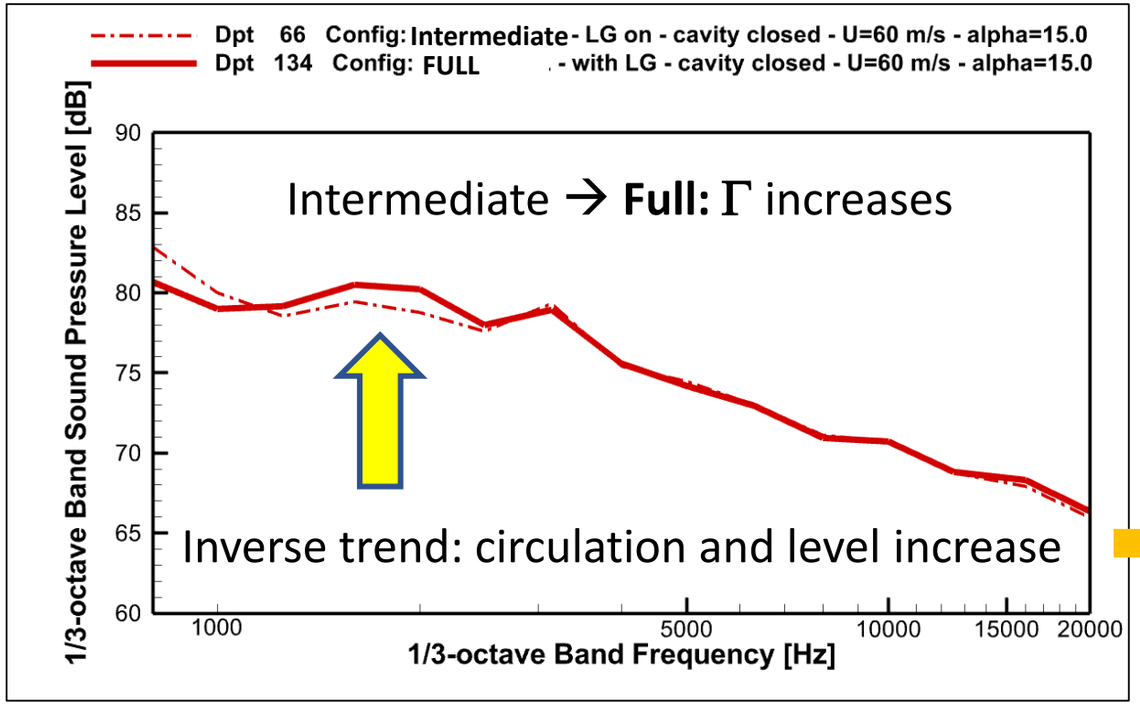
- Isolated landing gear noise
  - Compares reasonably well to landing gear noise generated under 2D wing and HLS clean
  - Deviations at high frequencies

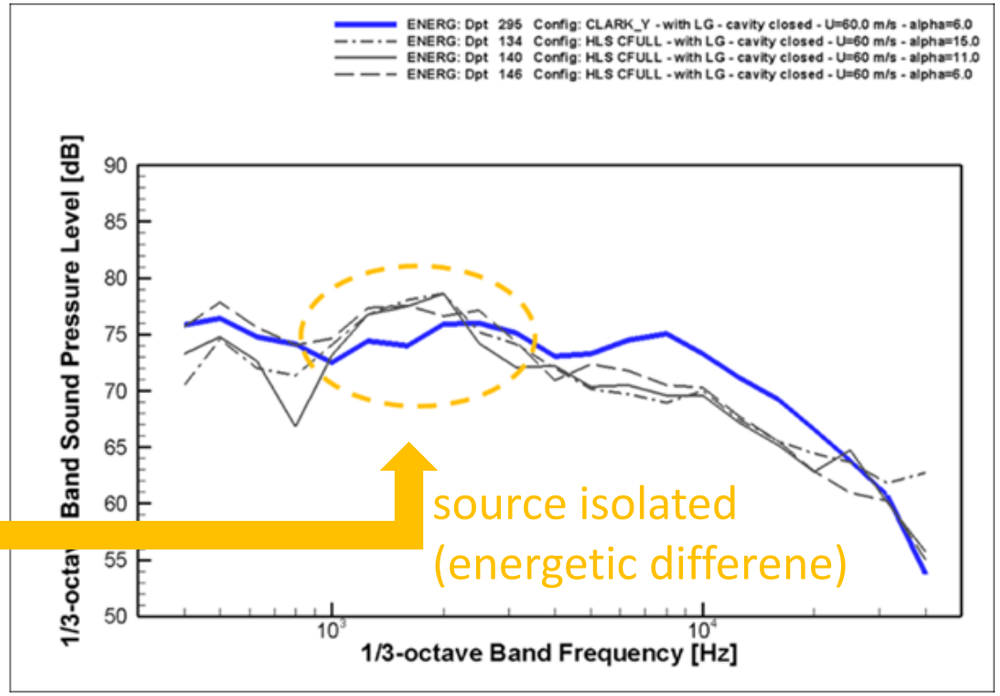


- Effect of angle of attack (no HLS)
  - Increasing the angle of attack leads to a landing gear noise reduction
  - Same findng with high lift system
  - Effect is based on circulation and is therefore also visible for different high lift settings

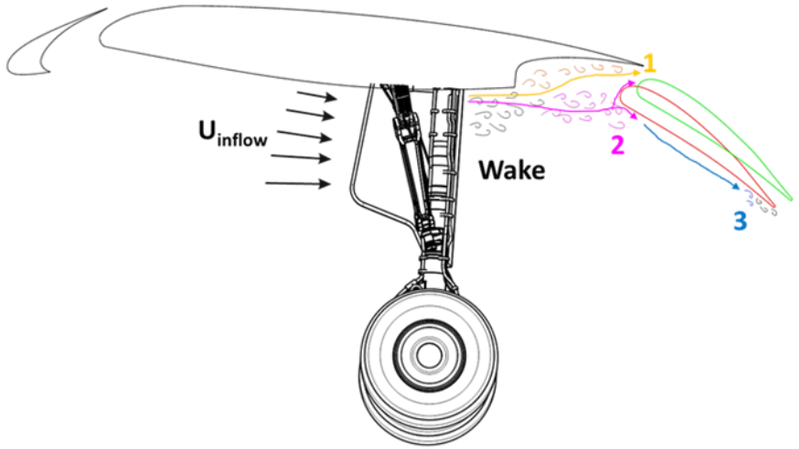


Acoustic Results

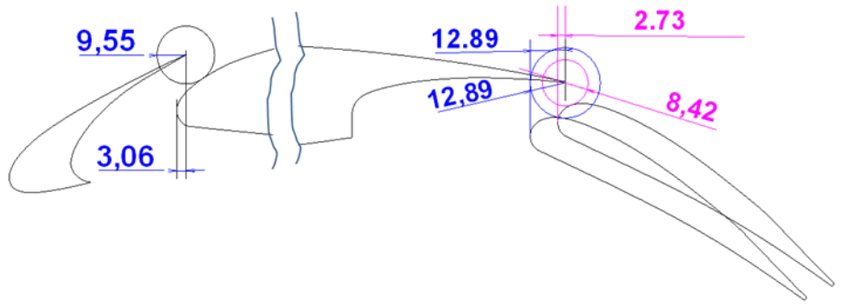




- Source mechanism?



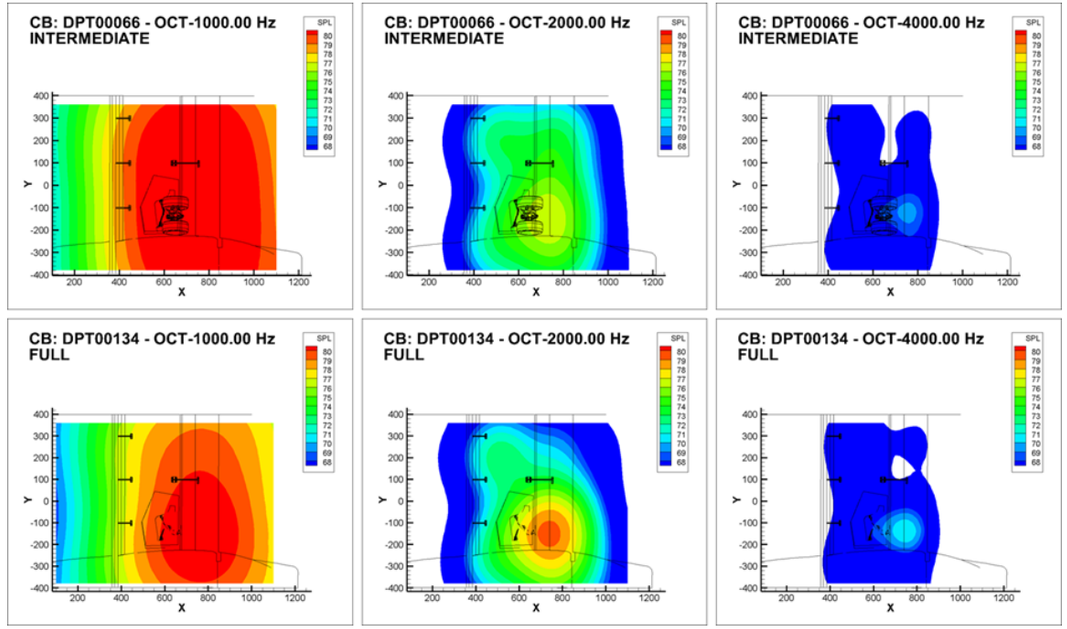
	Slat			Flap		
	δ_S [°]	GAP [mm]	OVERLAP [mm]	δ_F [°]	GAP [mm]	OVERLAP [mm]
CLEAN	0	0	0	0	0	0
INTERMEDIATE	26	9.55	3.06	30	8.42	2.73
FULL				34	12.89	12.89



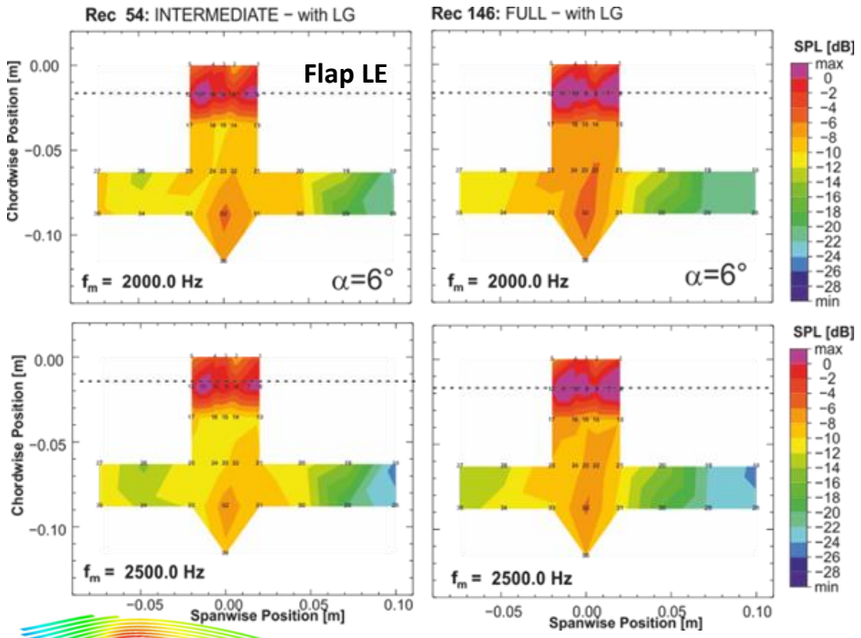
Array Data and Surface Pressures

Array data

- Shows landing gear / flap leading edge region as dominant noise source (@conf FULL)
- Insufficient spatial resolution to resolve more details

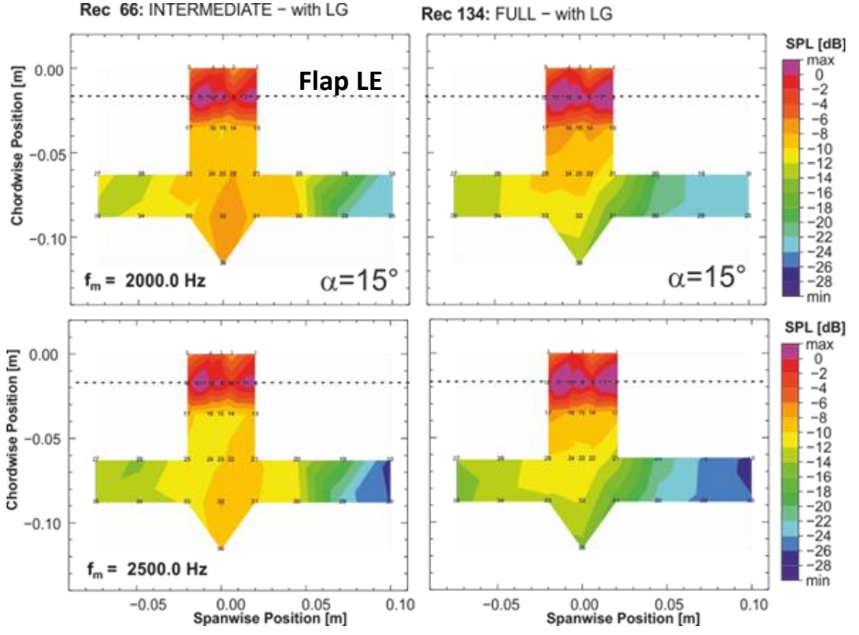


INTERMEDIATE FULL

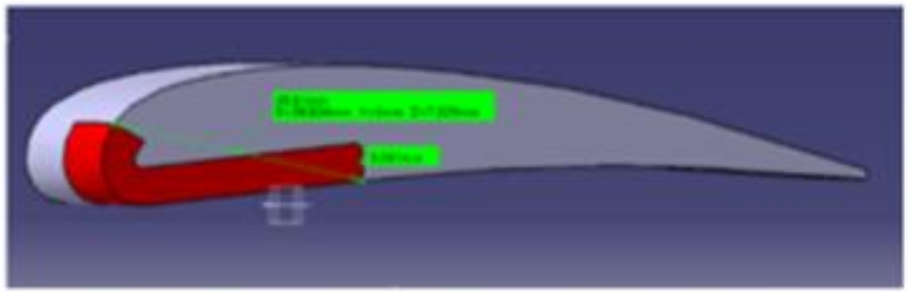


Unsteady surface pressures

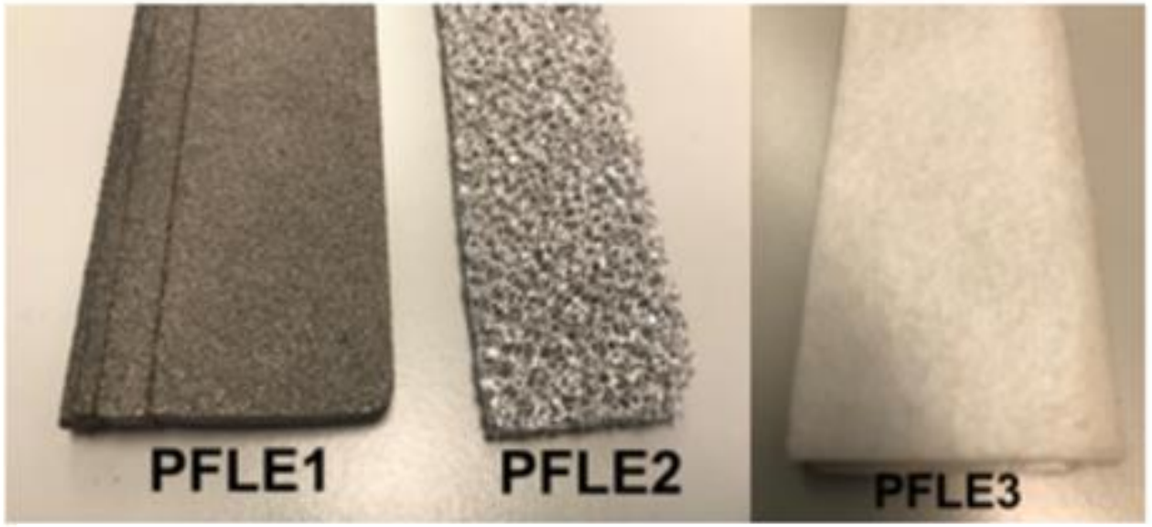
- Left: α = 6°
- Right: α = 15°
- Highest levels at leading edge
- No level decrease at higher α
- Indicates that the LE is source region due to impinging turbulence



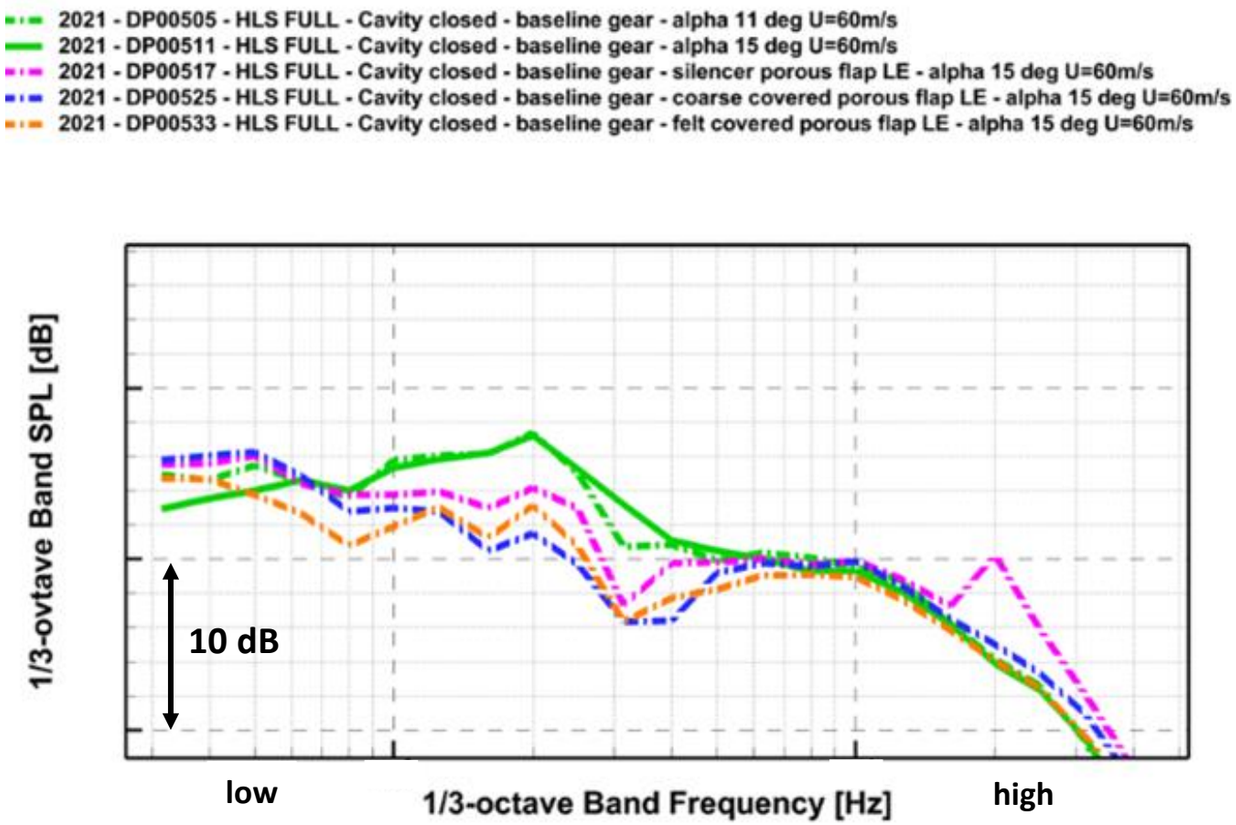
Flap Leading Edge Liner Design and Performance



Porous LeadingEdge Inserts – location in the flap



Porous Leading Edge Inserts

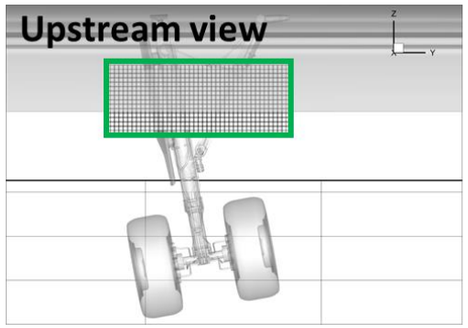


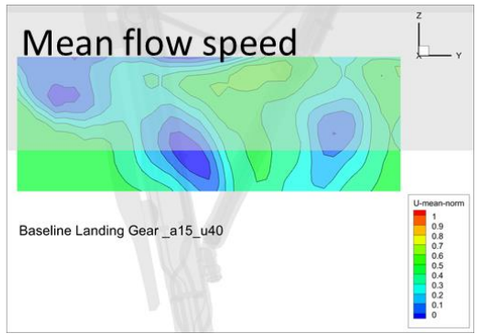
- All inserts show a noise reduction
- The coarse insert is least effective
- Noise reduction is accompagnied by aerodynamic loss at the flap

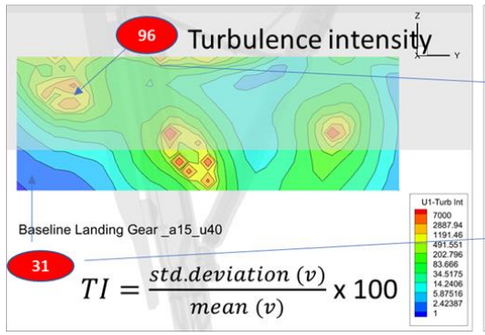
Landing Gear Wake – Flap Interaction - Conclusions

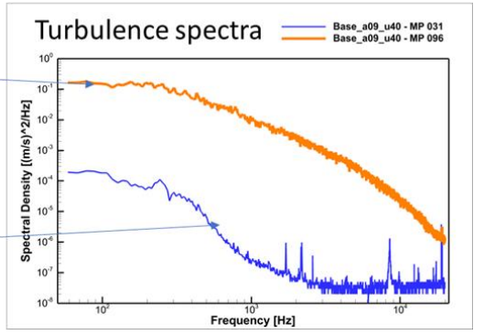
- ARTEM resuts proved the presence of landing gear installation effects and the effect of landing gear wake-flap interaction noise
- Landing Gear Wake-Flap interaction noise superimposes landing gear and high lift system noise
- Further information on alternative noise mitigation concepts can be obtained from :

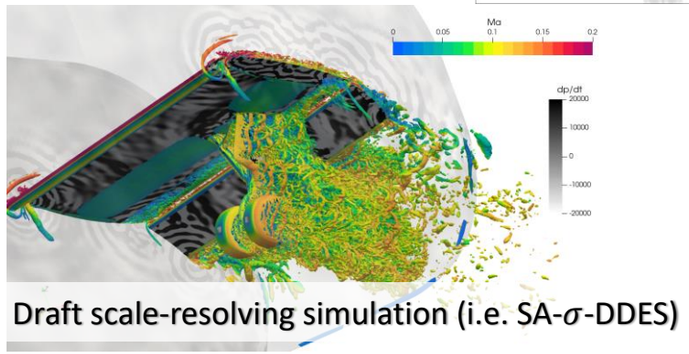
The Use of Porous Meshes to Reduce Landing Gear Wake - Flap Interaction Noise
Francisco Javier Martinez Lara and David Angland
AIAA 2022-3044, Published Online:13 Jun 2022https://doi.org/10.2514/6.2022-3044











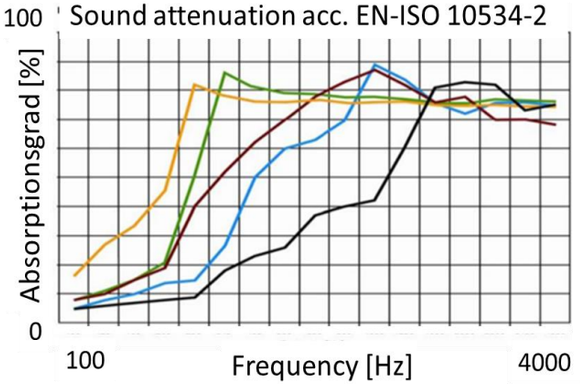
Draft scale-resolving simulation (i.e. SA-σ-DDES)

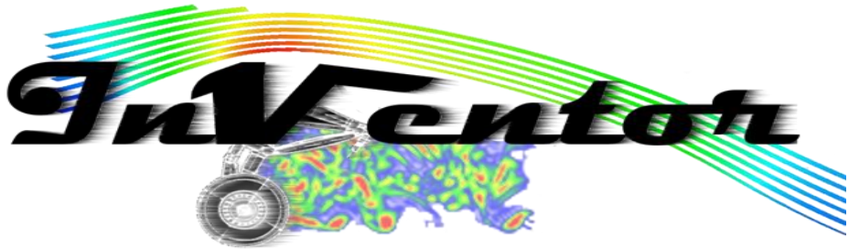
- Scale resolving numerical simulation (Upstream CFD)
- Reproduce liner effect by CAA (DLR PIANO)

→ Enable liner characteristics definition and optimization

Summary

- Two airframe noise reduction concepts based on porous media were presented
- Both concepts are based on experimental studies with limitted parametric studies on the porous media itself
  - Poly-Urethane Foam → sound absorbtion is very broadband and known by manufacturers data
  - Metal foam → acoustic performance needs to be determined
- A hydraulic smooth wire mesh to separate porous media from the mean flow seems mandatory
- Both noise reduction concepts provide room for improvements on both the aerodynamic and acoustic performance → INVENTOR scope
  - Aerodynamic: prerequisite for acceptance by airframer
  - Acoustics: push the limits, challenge for researchers and engineers
- Further application, next presenation: Porous flap trailing edges for the reduction of jet-flap interaction noise (DJINN) - Christian Jente (DLR)





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The INVENTOR project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860538