NOISE REDUCTION AT FLAP SIDE EDGE AND UNDERCARRIAGE

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Presented by Michael Pott-Pollenske (DLR)
on behalf of the Workpackage 4 – Airbus - DLR and Safran Landing Systems team

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AFLoNext project coordinator: Martin Wahlich (Airbus)

Presentation Outline

1. Flap Side Edge
   - ➢ Technology development
   - ➢ Progress in AFLoNext

2. Landing Gear
   - ➢ Technology Development
   - ➢ Progress in AFLoNext

3. Flight Test
   - ➢ Conduct
   - ➢ Results

4. Conclusions

Workpackage 4

Objectives

- Technical solution of flap modification and low-noise treatment integration
- Proof of noise reduction potential of different treatments on A/C level
- Material specifications wrt. acoustic attenuation target.

Flap Side Edge for Airliner

- Preliminary producability analysis on material.
- Effects of FSE cut-out design on local flow field and implications on material specifications .

Flap Side Edge for BizJet

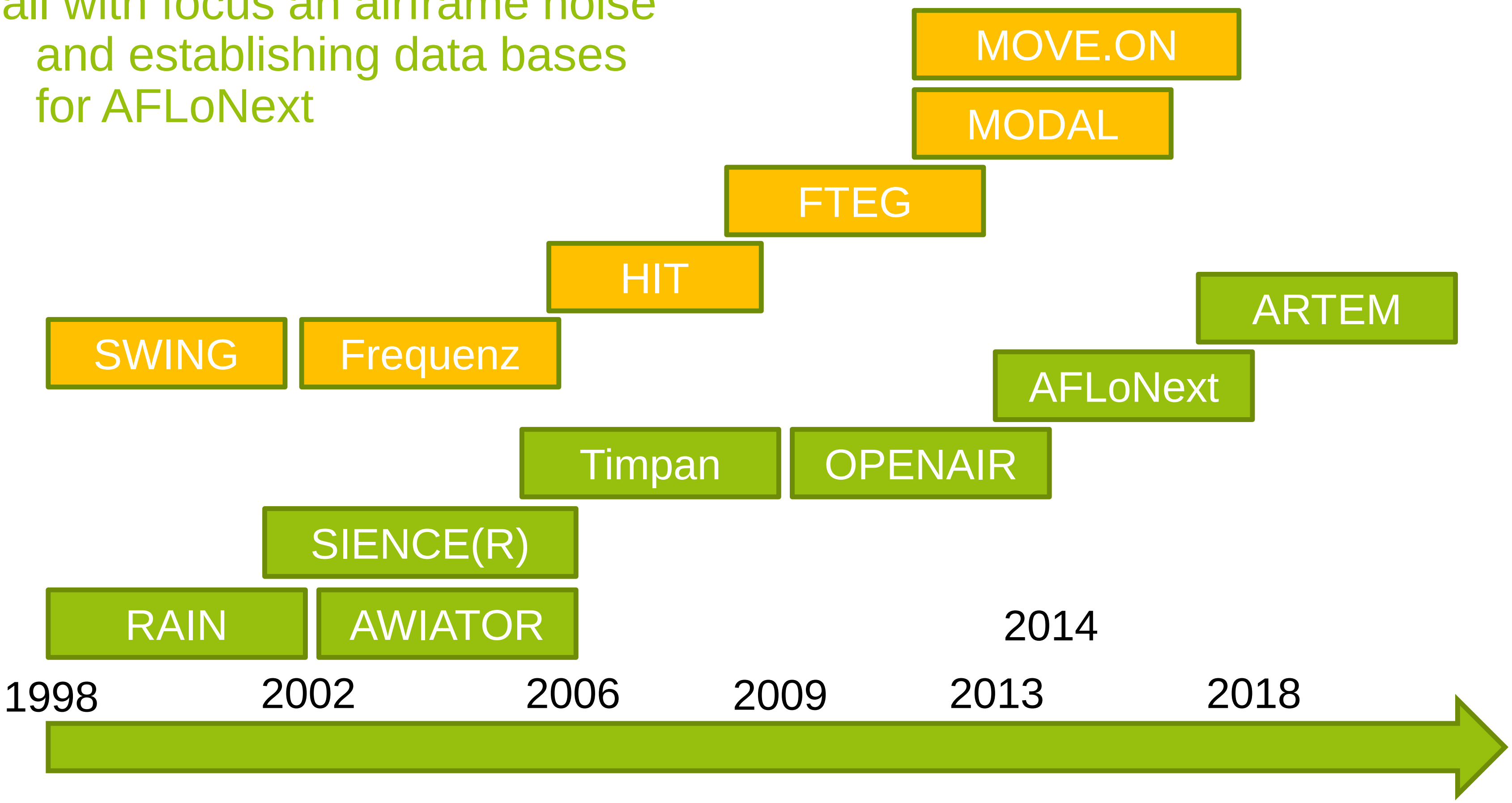
- Improve understanding of landing gear wake and flap flow interaction regarding interaction noise.
- Proof of noise reduction potential of different treatments on A/C level

Landing Gear for Airliner

European Research Projects

- **European research projects**
- **German research project**

all with focus an airframe noise and establishing data bases for AFLoNext



1. FLAP SIDE EDGE

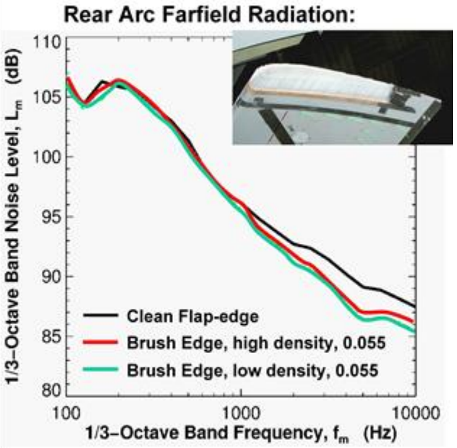
Flap Side Edge Noise Studies

First attempts to reduce flap side edge noise by means of porous edge treatments were published by Fink in 1980

\ Fink M, Bailey D. "Model tests of airframe noise reduction concepts", 6th Aeroacoustics Conference 04 - 06 June 1980 Hartford, CT, USA

First European highlight: RAIN - Reduction of Airframe and Installation Noise

\ Dobrzynski W, Gehlhar B, Buchholz H: RAIN Task 3.2: High Lift Devices Noise Reduction Study - A320 Full-scale Wing in DNW-LLF, DLR IB /18, Braunschweig

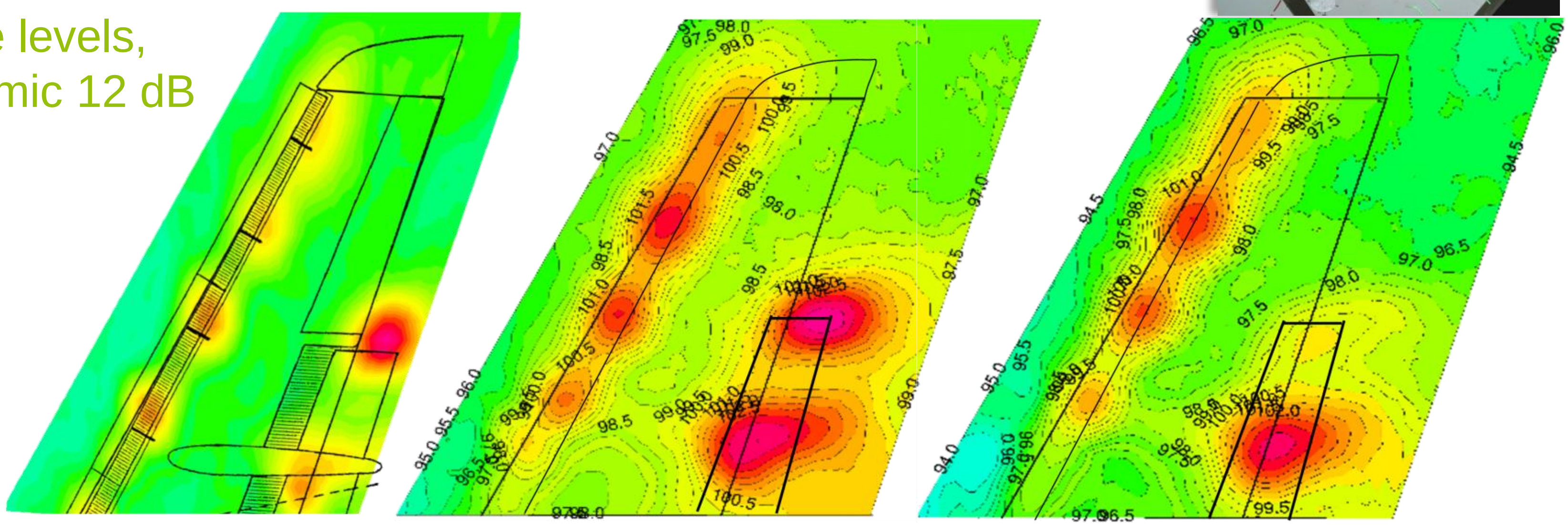


Flap Side Edge Noise Studies

Noise source maps for the 1600 Hz 1/3-octave band show

- original flap side edge → dominant noise source
- clean flap side edge → significant noise reduction, noise levels compare to those of slat tracks and flap track fairings
- FSE noise is significantly reduced by the "porous" brush edge

same levels,
dynamic 12 dB



Original FSE | Clean FSE | Brush FSE

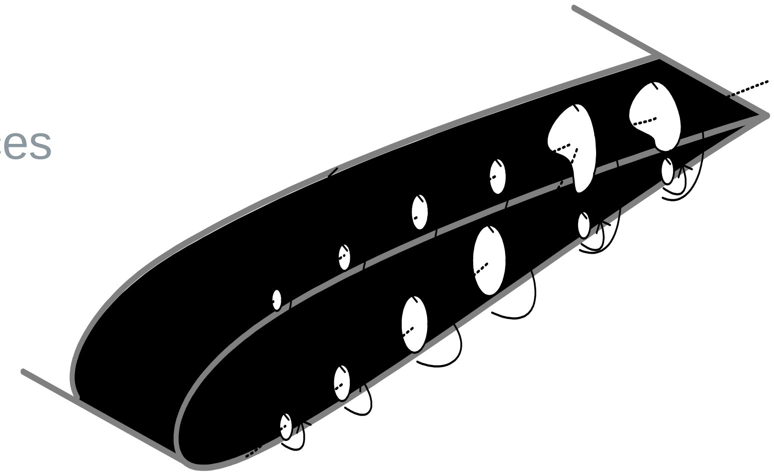
Flap Side Edge Noise Studies

Flap side edges (FSE) were identified as relevant noise source at approach and landing

\ mechanism of FSE noise is a mix of

\ sharp edges and corners generating vortices

\ cavities acting as Helmholtz resonators



In AFLoNext:

WTT on PFSE using realistic A320 flap geometry in AWB

\ model and design of very realistic A320 FSE WT model to provide representative reference

Airbus A320 FSE

FSE model (scale approx. 1:1.4)

Wind Tunnel Model

WTT on PFSE using realistic A320 flap geometry in AWB

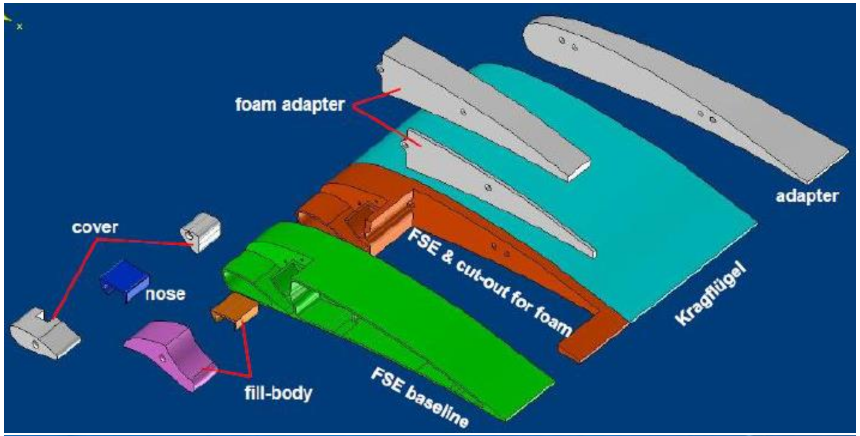
\ second FSE model provided to test low-noise technologies including porous material

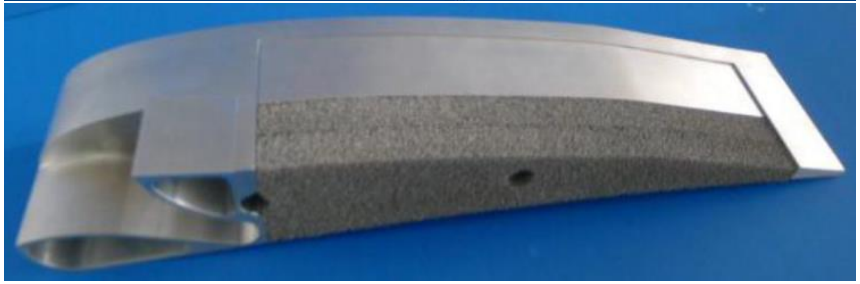
\ modular model design realised.

  \ to eliminate single noise sources separately

  \ to investigate spanwise extension of porous material (limitation given by flap structure).

  \ to assess noise reduction wrt. the flush FSE (elimination of cavities only)

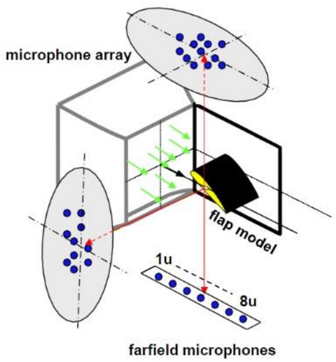




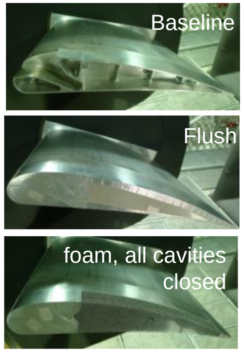
\ target is best noise reduction at minimum modification level of A/C flap

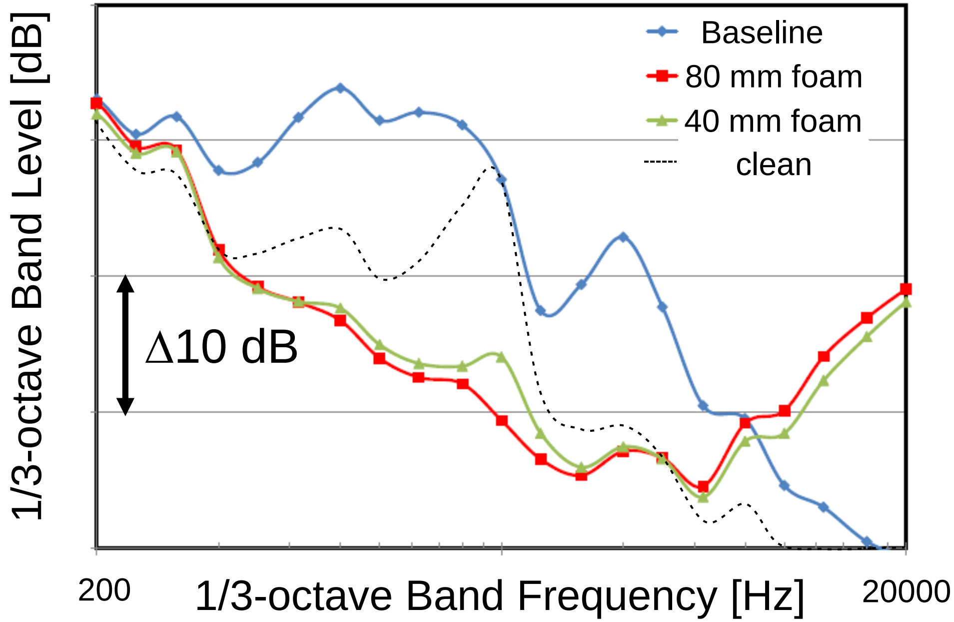
Wind Tunnel Test Data

AWB Test Setup



Test configurations





WTT on FSE noise in the Acoustic Windtunnel Braunschweig (AWB)

- Flap side edge noise was localized and quantified for numerous configurations
- Significant noise reduction is already achieved for clean FSE
- Thickness of porous material can be limited to 40 mm

Preparation for Flight Test

Transfer from Lab to Reality

\ Parts mounted into flap end rip

\ Outer holes of solid parts closed with cover discs

\ Design selected to allow mounting and de-mounting of all parts also on flap installed to aircraft

Required documentation for FT preparation

\ Complete documentation

\ Stress report(s)

\ Assessment of

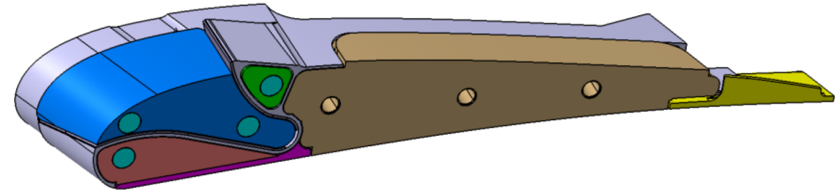
  \ System integration

  \ Aerodynamic performance

  \ Maintenance

  \ etc.

Detailed CAD model



Flap Side Edge prepared for installation

Flap Side Edge prepared for flight tests

2. LANDING GEAR

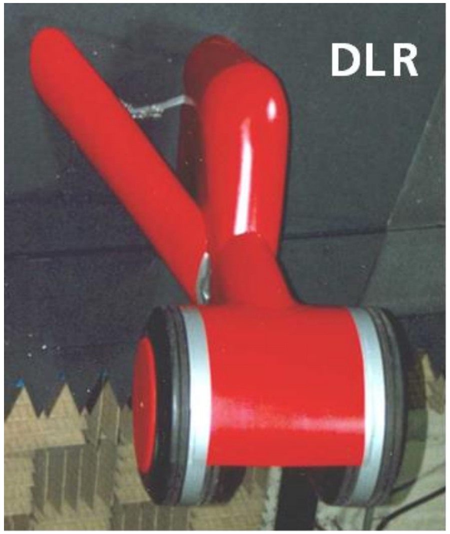
Landing Gear Noise Studies

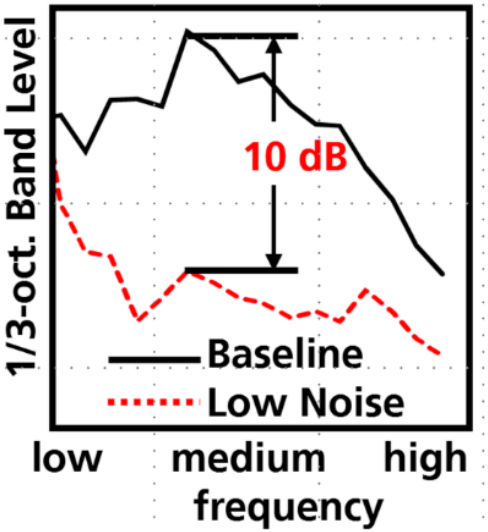
European highlight on full scale landing gear research

Demonstration of streamlined full landing gear fairings (2-wheels)

\ Dobrzynski W, Buchholz H. Full-Scale A320 Landing Gear Airframe Noise Characteristics. DLR Report IB129-96/43, Braunschweig, November 1996

\ Heller H, Dobrzynski W. Sound radiation from aircraft wheel-well/landing gear configurations. Proceedings of Inter-Noise 95 (10–12 July 1995), pp. 203-206.



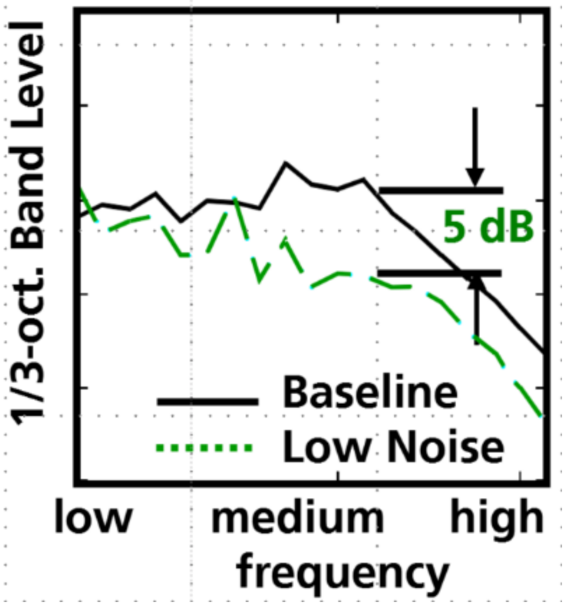


Landing Gear Noise Studies

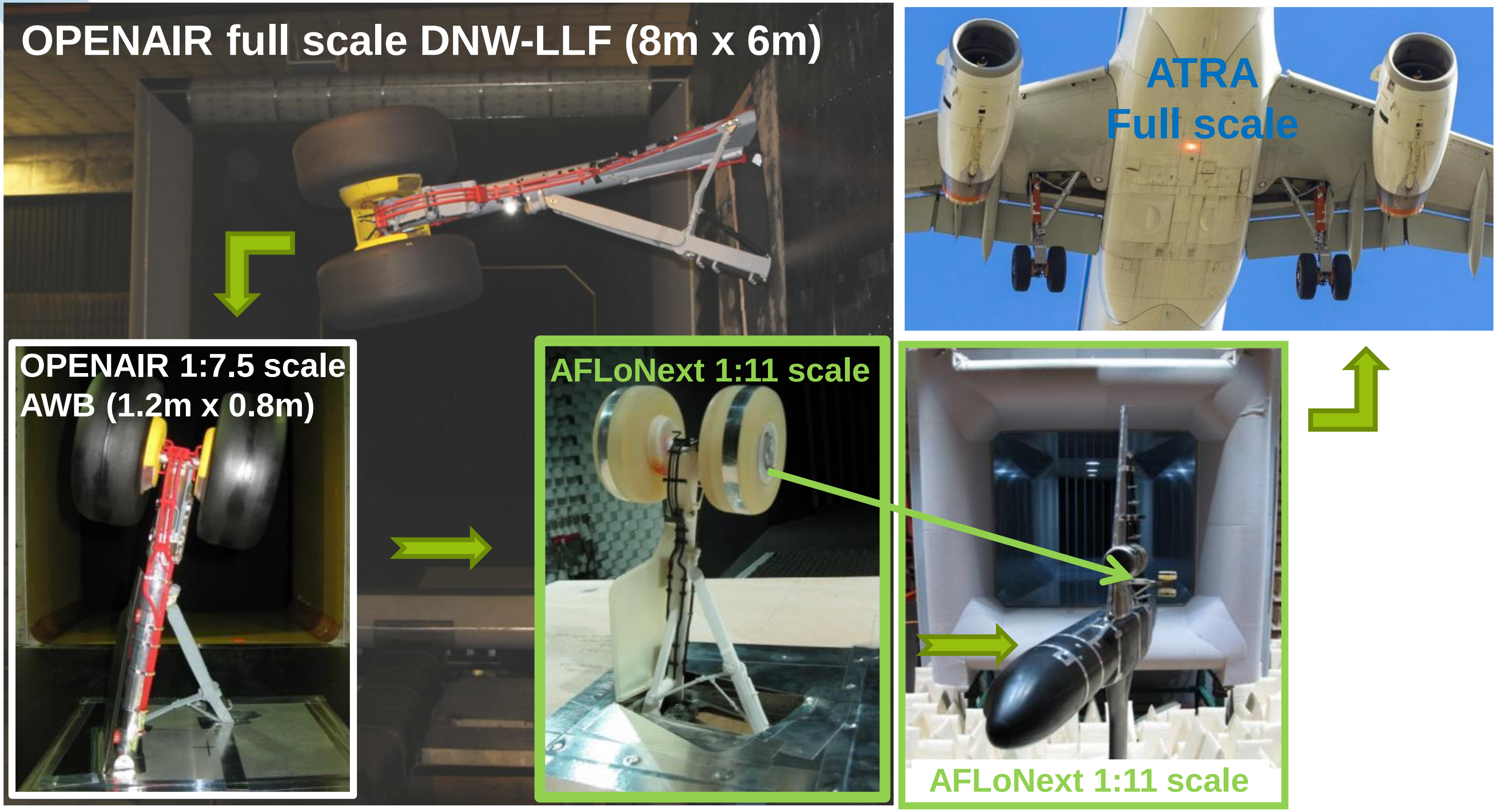
RAIN project: Reduction of Airframe and Installation Noise

\ Dobrzynski, W., Gehlhar, B., Buchholz, H., Holthusen, H., A340 Main landing gear noise reduction study, RAIN-TR-02.2-03-R3/DLR/1, 2000

Noise reduction potential with solid fairings on a 4-wheel landing gear

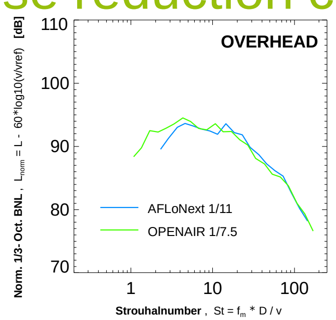


Development and Test of Noise Reduction Concepts



Development of landing gear noise reduction concepts to be tested in flight

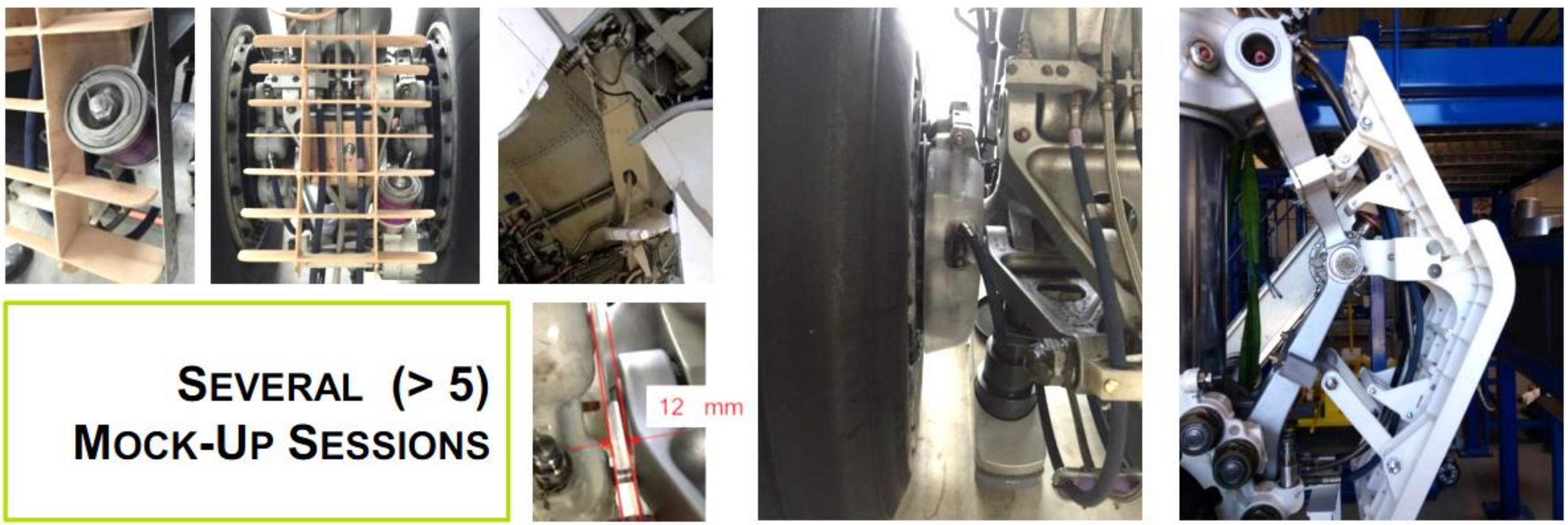
- Brake cover
- Torque link fairing
- Leg door fairing



Development and Test of Noise Reduction Concepts

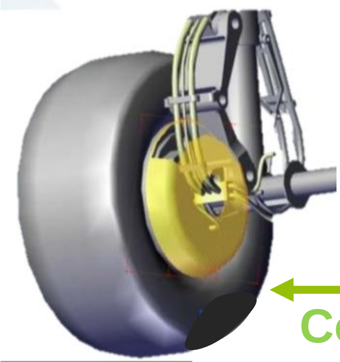
Facing constraints to integrate devices on a existing leg which is optimized for other functions

- Brake temperature – evaluation of the impact of covers on brakes
- Available space, clearances and attachments
- Keep design acoustically friendly



Overview of Final Parts Installed on Aircraft

Brake Cover

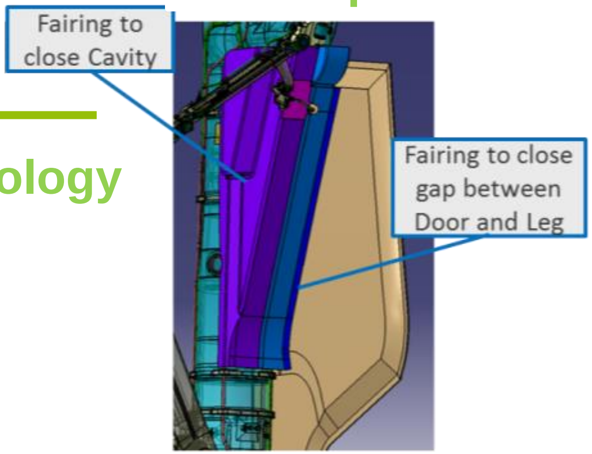


Concept

Technology

Leg-Door-Cover

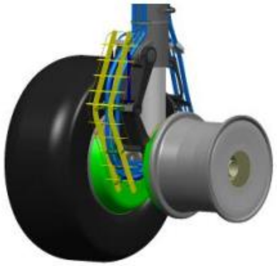
Concept



Technology

Torque Link Mesh Fairing

Concept



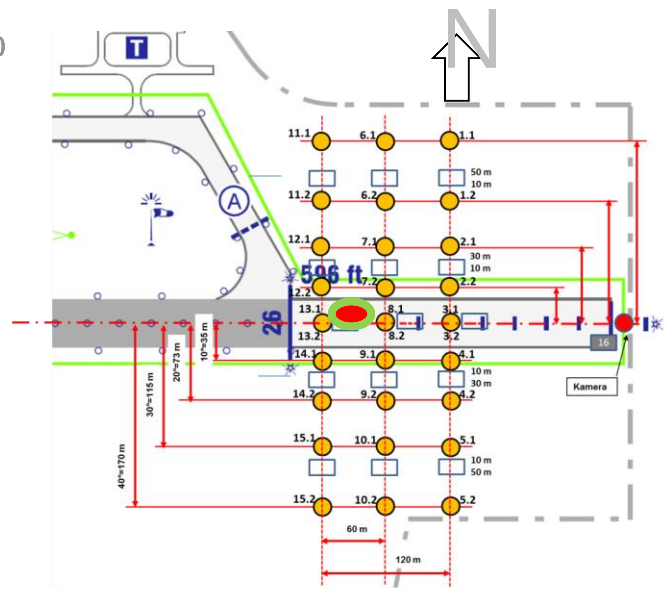
Technology

3. FLIGHT TEST

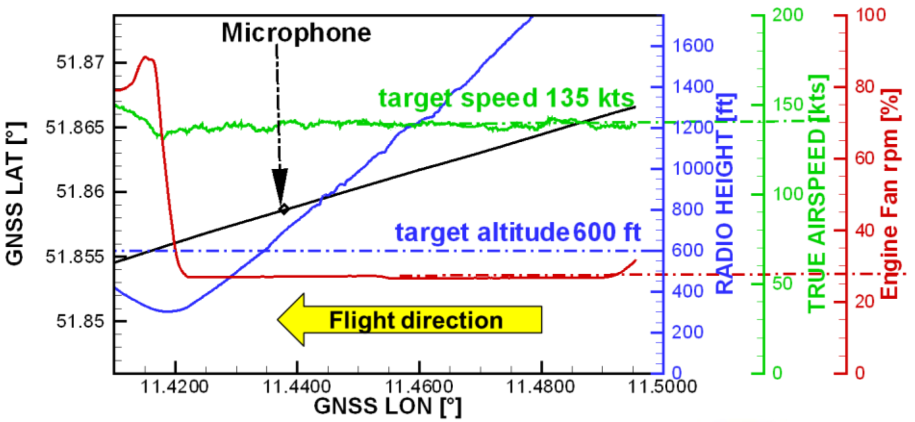
Aircraft Configuration and Flight Procedure

Flyover noise source identification and quantification

- Engine power: flight idle, equivalent to N1 ~ 29%
- V_{CAS} 130 and 175 kts
- Target altitude: 600 ft
- Lateral deviation ±10°
- V_{Wind} < 12 kts
- 60 t > A/C weight > 54 t
- No precipation, no inversion or other anomalous meteorological conditions



- 31 condenser microphones on 120m x 340m area
- 250 mics. phased array
- $50° < \varphi_x < 140°$, $\varphi_y=\pm 40°$
- data acquisition synchronized on basis of GPS time



Data Processing and Analysis

Target: Derrive noise source characteristics for a source at rest for comparison to wind tunnel test data

Methodology:

Source: DLR/Lindner

Synchronisation
- acoustic data
- trajectory data
- a/c attitude
- a/c operation

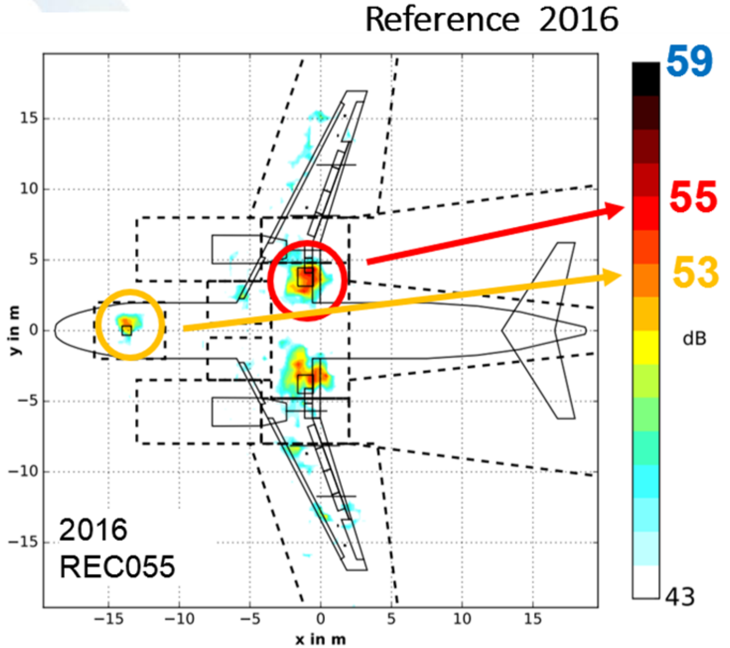
Validity check
- excess noise
- check on trajectories
- specialties

Processing
- De-Doppler
- technical corrections
- Propagation effects and source effects

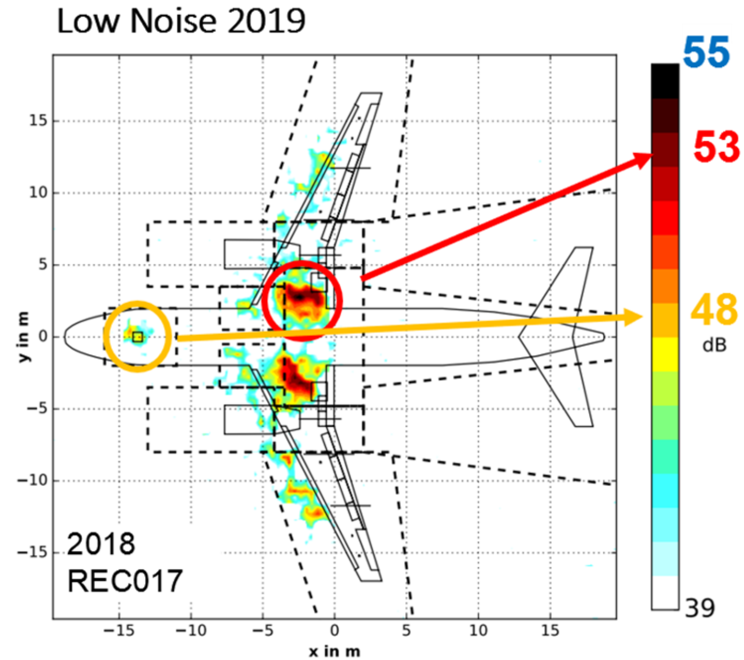
Acoustic analysis
- SPL spectra
- Interated OASPL ($L_{A,max}$, $L_{AX,}$, SEL)

Acoustic Assessment
- **1:1 comparison of measured data → qualitative assessment**
- Energetic subtraction of SPL spectra to isolate sources → quantification of NRT effects
- Analysis of environmental noise, e.g.approach noise
- Certification noise level determination

Test Results – Landing Gear Sources



H ~ 550 ft
CAS ~ 175 kts
φ_x = 60°
f_m = 1000 Hz



Array data proof noise reduction at the main landing gear

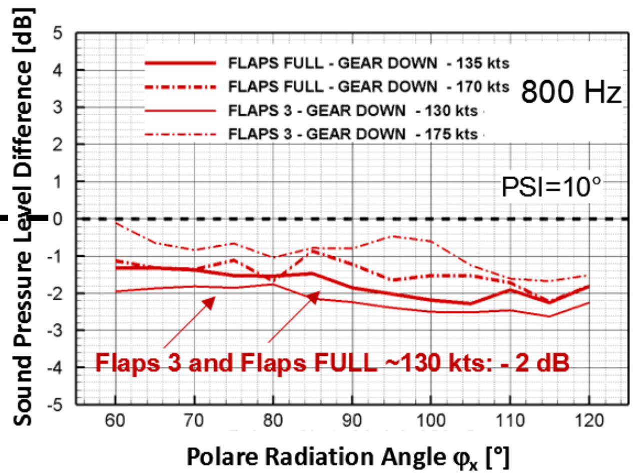
Noise landing gear contributes less to farfield noise

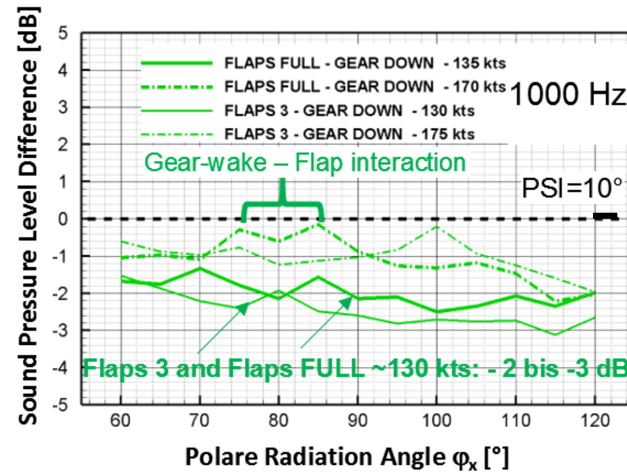
→ Single microphone measured sound pressure level data represent mainly mainly landing gear related noise

Test Results – Landing Gear Farfield Noise

increase

reduction





2 to 3 dB

Porous fairing,
40% open area

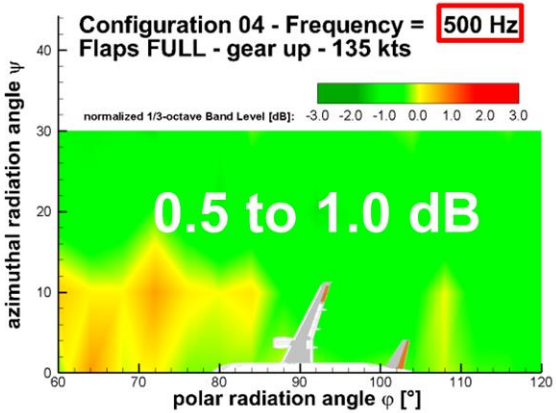
Reduce local
flow speed
$p'^2 \sim u^6$

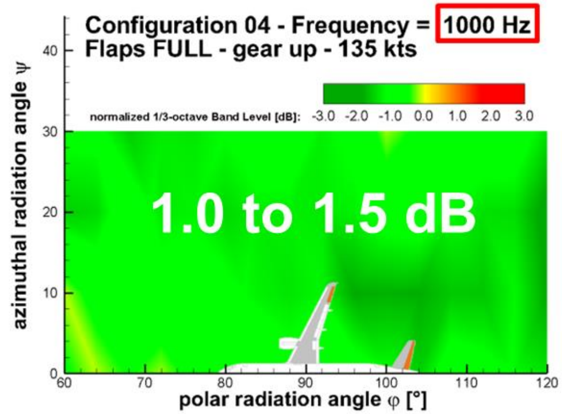
solid fairings

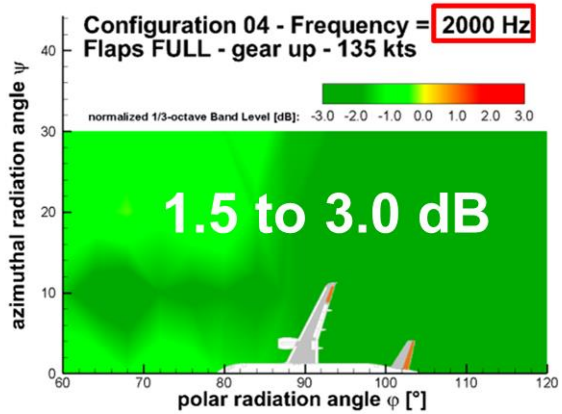
deflect flow,
protect parts

An up to 3 dB noise reduction was achieved by means of the LG fairings.

Test Results - Flap Side Edge



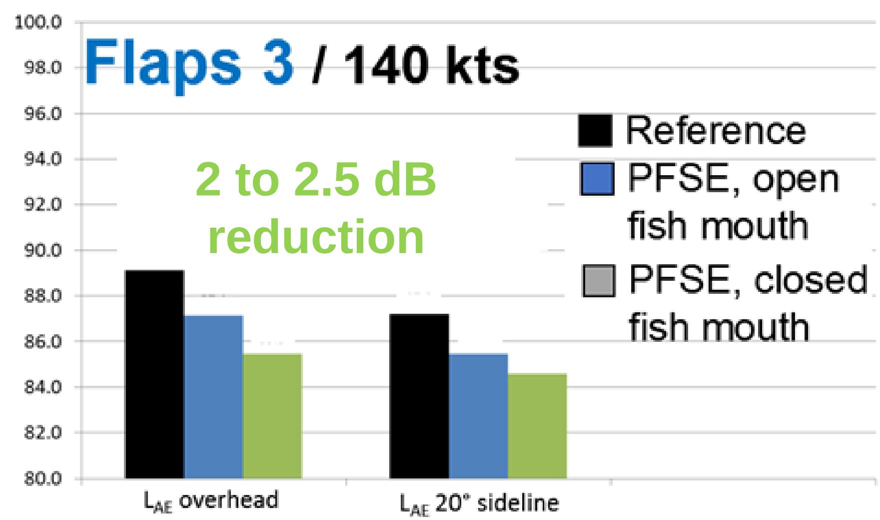




- Farfield noise reduction, especially for rear arc radiation direction

$$SEL_{korr} = L_{A,max} + \frac{t_{10}}{2} + 12.5 * log_{10}\left({}^{D}/_{D_{Ref}}\right) - 40.0 * log_{10}\left({}^{V}/_{V_{Ref}}\right)$$

- Evaluation of the single event noise level shows even an effect for the fish mouth closure



AFLoNext

4. CONCLUSIONS

Summary and Conclusions

Summary

\ Noise reduction concepts to mitigate landing gear and flap side edge noise were matured and flight tested

\ Both concets showed a significant noise reduction

\ The achieved noise reductions compared well to expactations based on wind tunnel test data and respective predictions.

Conclusions

\ The flight tests showed part of the potential of retro fitting the actual fleet to achieve thenoise reductions demanded e.g. by the actual European strategic research agenda Flightpath 2050

\ All tested parts are prototypes with limitations regarding daily operation. Further development is necessary to reach full airworthiness for normal airline operation.

Acknowledgements

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