ENTWICKLUNG, UMSETZUNG UND FLUGERPROBUNG VON MINDERUNGSTECHNOLOGIEN BEI SCHALLQUELLEN AM FLUGVERSUCHSTRÄGER ATRA DES DLR

DAGA VORKOLLOQUIUM, HAMBURG 06.03.-09.03.2023

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DLR - Institut für Aerodynamik & Strömungstechnik Braunschweig

Outline

- Low noise ATRA – Noise reduction by retro-fit measures
- Beyond LNATRA
  Reduction technologies for newly identified sources of sound
- Design of low noise aircraft
- Conclusion

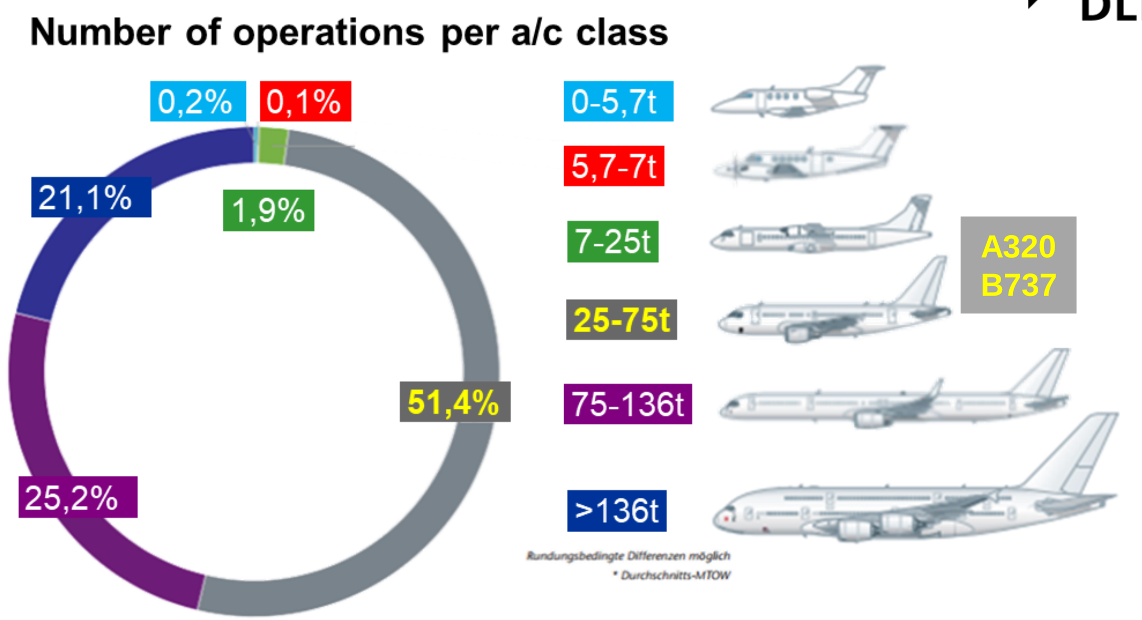
1. LN-ATRA

→ A DLR project to **demonstrate** the potential of **noise reduction technologies** (NRT) for current transport aircraft

→ Implementation/test of known airframe+jet NRTs on real a/c

Background & Motivation

- Social and political demands, e.g.
  EU Green Deal und Flightpath 2050
  - -50% (-10 EPNdB per op.) in 2020 (missed)
  - -53% (-11 EPNdB per op) in 2035 (questionable)
  - -65% (-15 EPNdB pro Ereignis) in 2050 & additional effects by means of NAPs
- World wide air traffic increase, DLR forecast:
  +3.7 % yearly in the upcoming 20 years

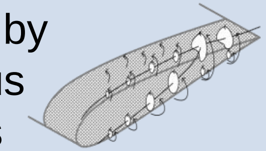
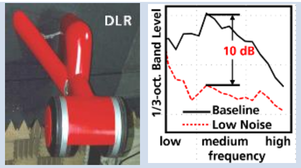


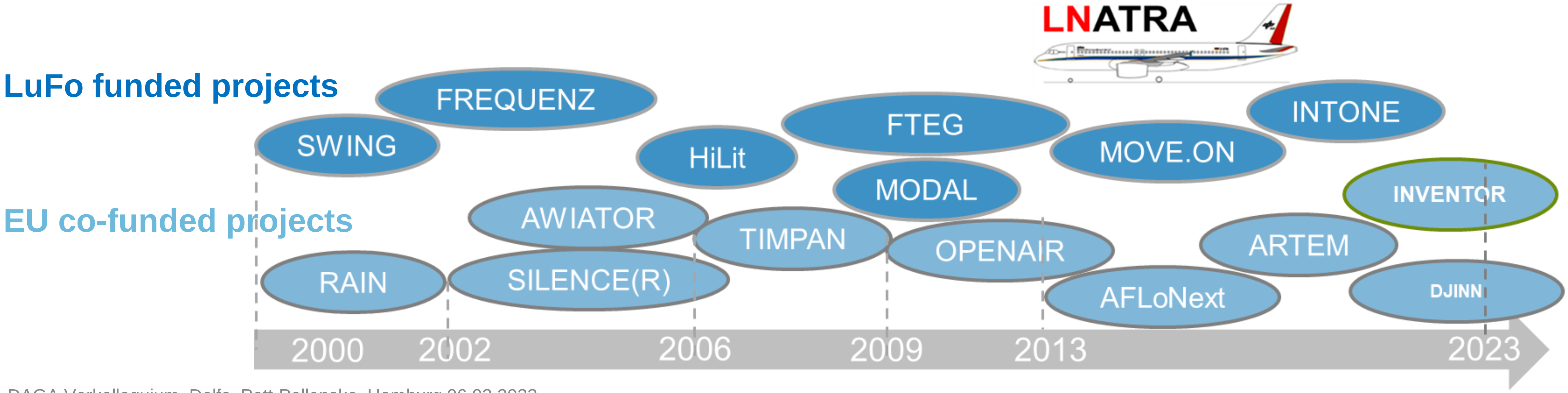
Source: Frankfurt Airport Luftverkehrsstatistik 2018, FRAPORT

Demonstrate the potential of noise reduction technologies (NRT) for current transport aircraft

- Preserve the acceptance of air traffic, especilly in close vicinity of airports
- Prepare concepts and provide technology for future aircraft
- Establish a database for the improvement of noise reduction prediction

High Lift System & Landing Gear – Position Fixing

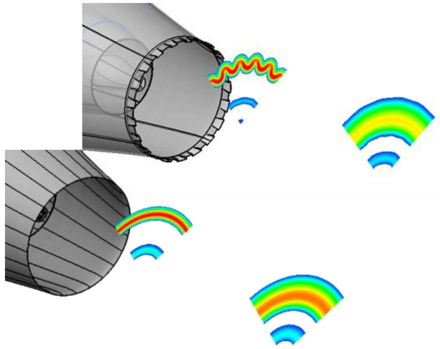
High Lift System / FlapSide Edge Noise			Landing Gear		
1980	Fink	Noise reduction by means of porous edge treatments 	1995 1996	Heller Dobrzynski	~10 dB mit full LG fairing 
2001	Dobrzynski	Proof of concept on full scale A320 wing (RAIN)	2000	Dobrzynski	-5 dB at 4-wheel LG by solid fairings (MLG and NLG)
2015	Reichenberger	TRL verification for flight tests (AFLoNext)	2009 2013	Dobrzynski	Use of mesh fairings (Timpan), application on A320 2-wheel landing gear (OPENAIR)



From Technology Concepts to Flightworth Aircraft Parts

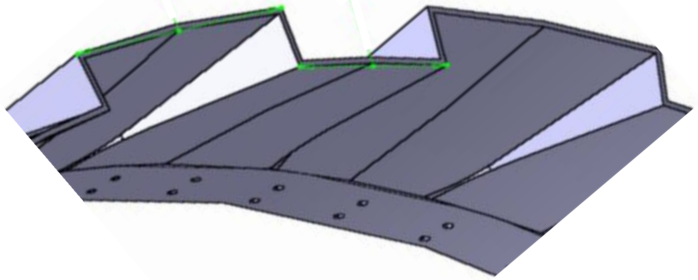
- Selection of appropriate concept → decision
- Decision for castellations due to higher TRL and maturation level
- Next steps
  1. Aerodynamic design: no adverse effects on engine operation and no power loss
  2. Mechanical design: reverse engineering of original nozzle shape and adaptation of the NRT to the original geometry
  3. Iteration loop: aerodynamic performance ⇔ geometry adaptation
  4. Qualification for flight test subcontracted to

Lufthansa Technik



CFD with DLR TAU code

Castellation concept

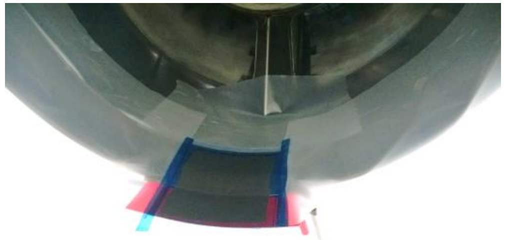


$$C_D = \frac{1}{A_8}\left[\left(\frac{\left(\dot{m}\cdot\frac{\sqrt{T_t}}{P_t}\right)}{Q_{ideal}}\right)_{Fan} + \left(\frac{\left(\dot{m}\cdot\frac{\sqrt{T_t}}{P_t}\right)}{Q_{ideal}}\right)_{Core}\right]$$

mass flow coefficient C_D

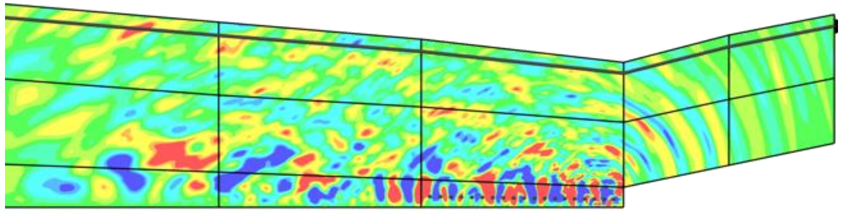
$$C_V = \frac{F_{Brutto.gemessen}}{(\dot{m}_{real}\cdot u_{ideal})_{Fan} + (\dot{m}_{real}\cdot u_{ideal})_{Core}}$$

thrust coefficient C_V



Negative molding of original type contour for CAD model

CAA based noise prediction, DLR PIANO



Prediction result:
Approx. -2 dB for polar radiation angles between 60° to 120°

Flight test for noise reduction technologies

LNATRA

Concept:

Test of all measures simultaneously at DLR **A**dvanced **T**echnology **R**esearch **A**ircraft

Programme:

- Reference test 2016
- 1. part test 2017 (co-operation with EU AFLoNext)
- 2. part test 2018 (5 years preparation)
- main test, 1. part 2019
- ~~main test, 2. part 202x~~ –prepared, not flown–

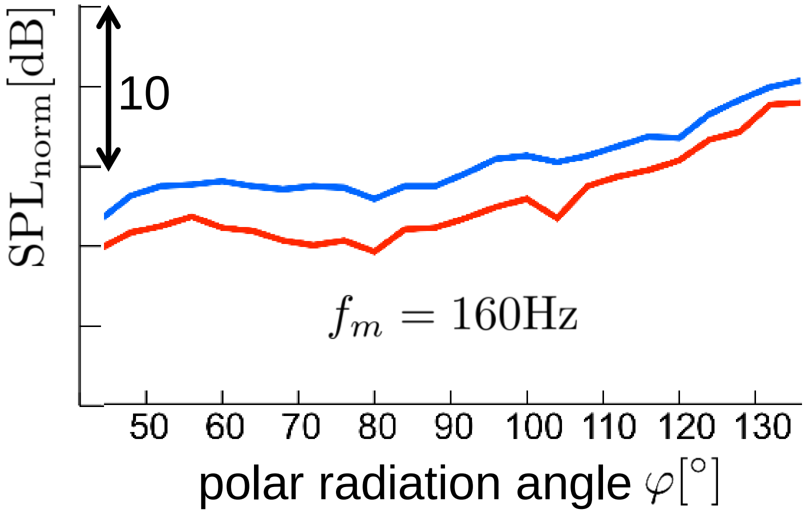
Partners:

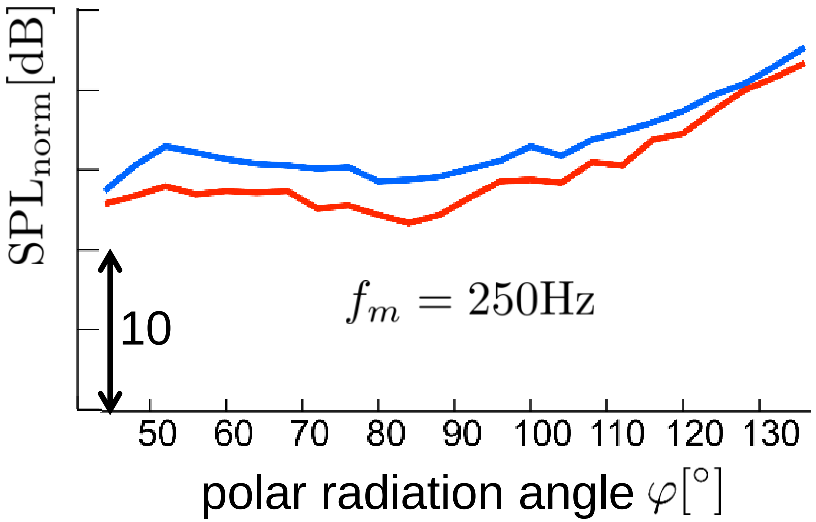
SAFRAN, Deharde, SPÖRL, AMAS technology, AIRBUS, Lufthansa Technik, asco, SONACA, Leichtwerk AG

Jet noise

Nozzle modification

take-off – flaps 2: 22°/20° - gear up



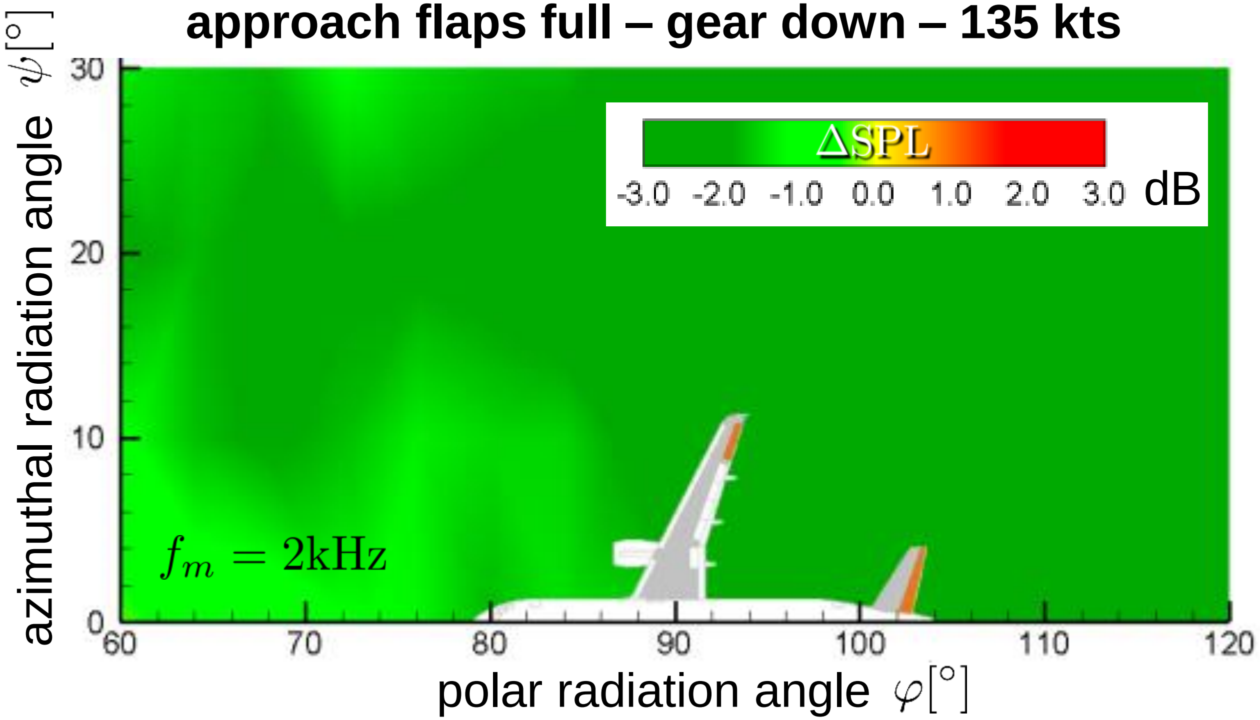


standard nozzle (2016)
modified nozzle (2019)

- significant reduction at low frequencies, slight increase (~1dB) at high frequencies

Landing gear noise

Nose/Main LG modification



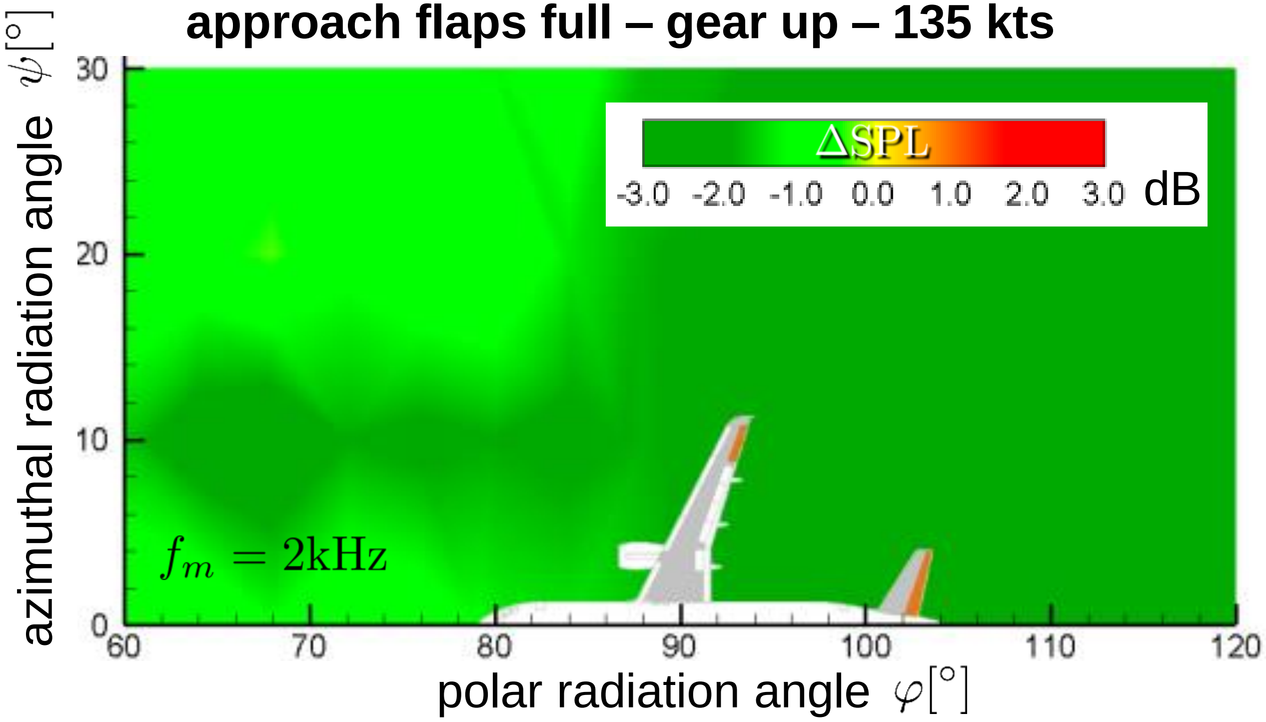
- wide area broadband noise reduction ~ 2-3dB (single mics!)

High Lift noise

HLD side edge modification

aluminum foam

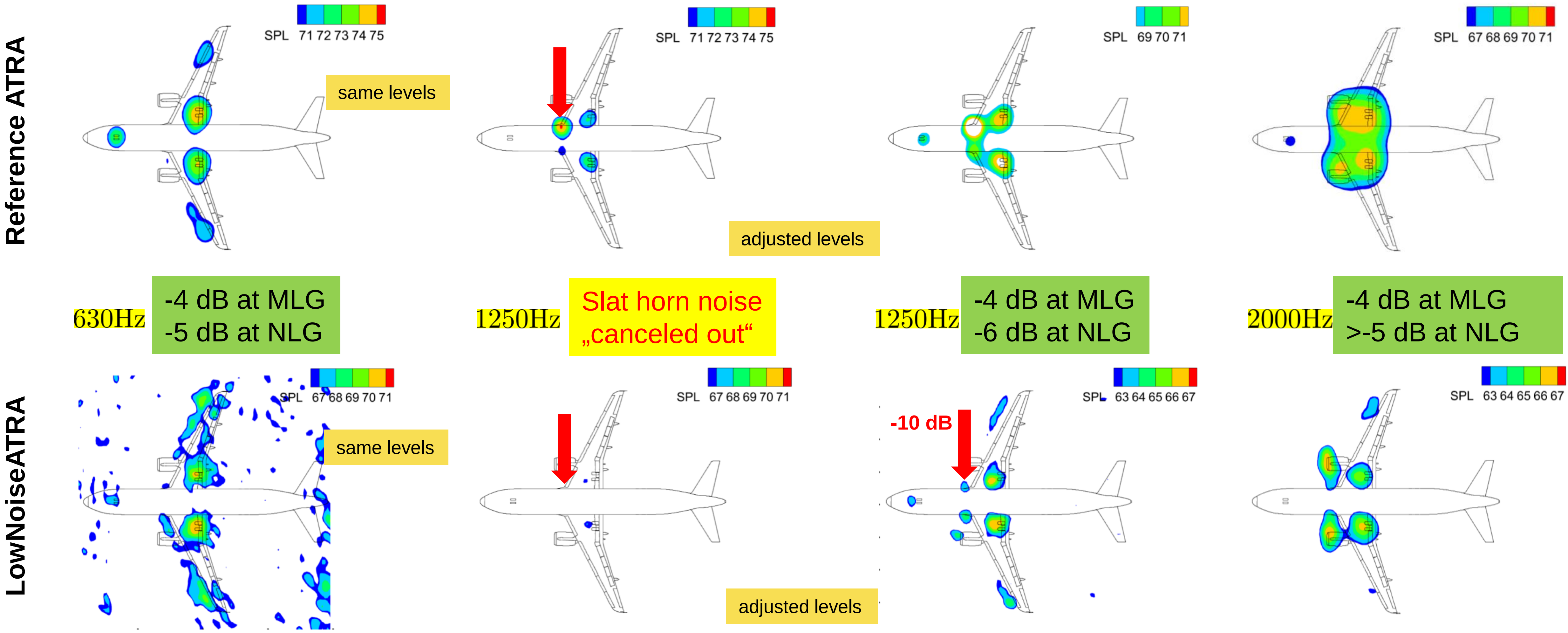
open cell urethane foam



- wide area broadband noise reduction ~ 2-3dB (single mics!)

Detailed Noise Source Analysis

flaps full – gear down -170kts $\varphi_x = 60^\circ$

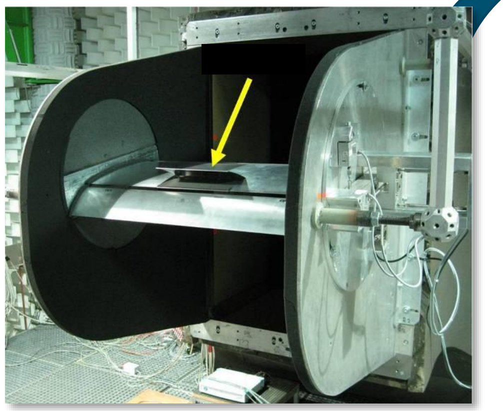


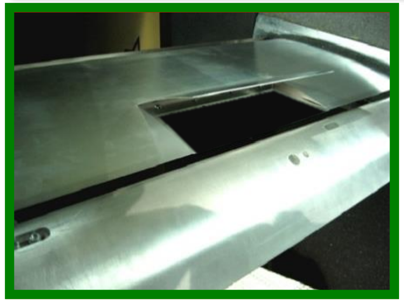
Array data: Siller, H., Schumacher T.:“Low Noise ATRA - Phased Array Measurements of Jet Noise in Flight”, 27th AIAA/CEAS Conf. 2021, https://doi.org/10.2514/6.2021-2160

Spoiler noise

Spoiler modification

WTT





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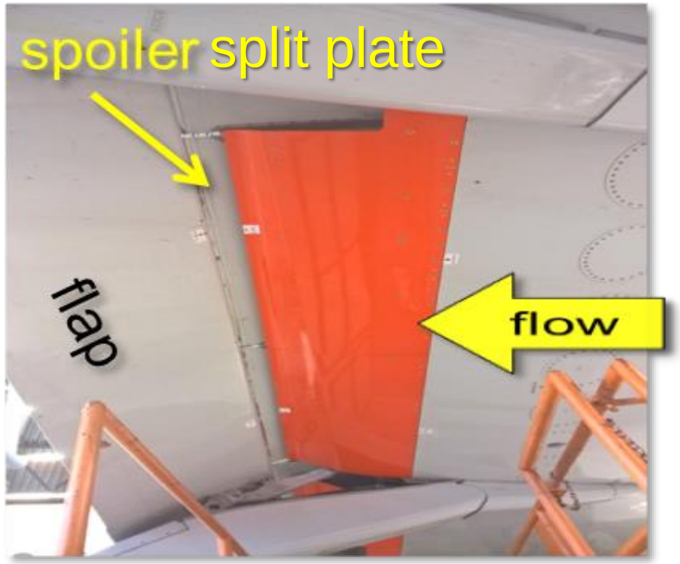
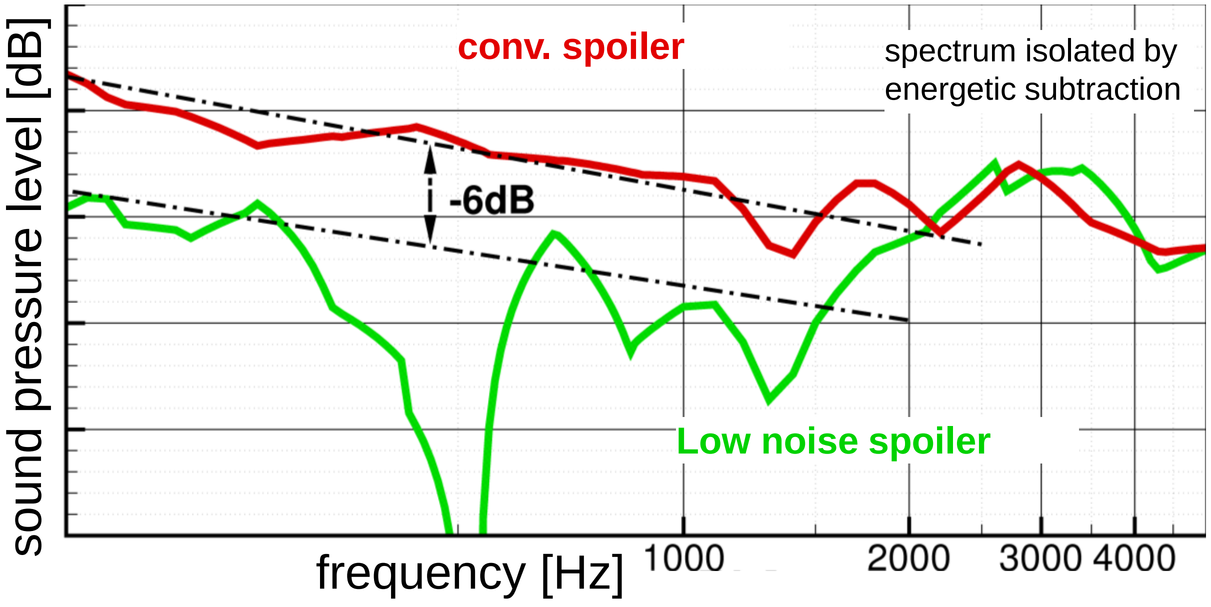
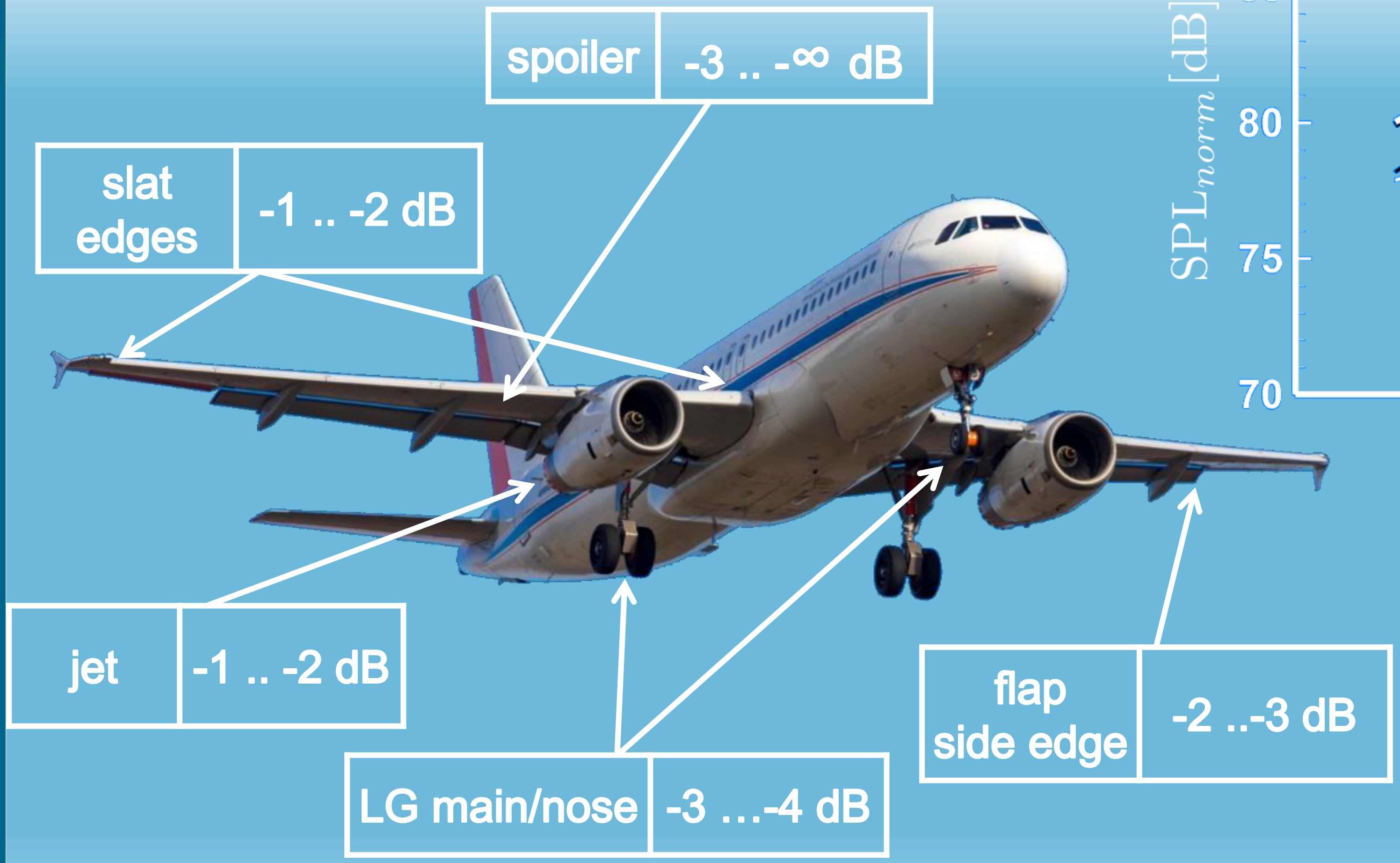
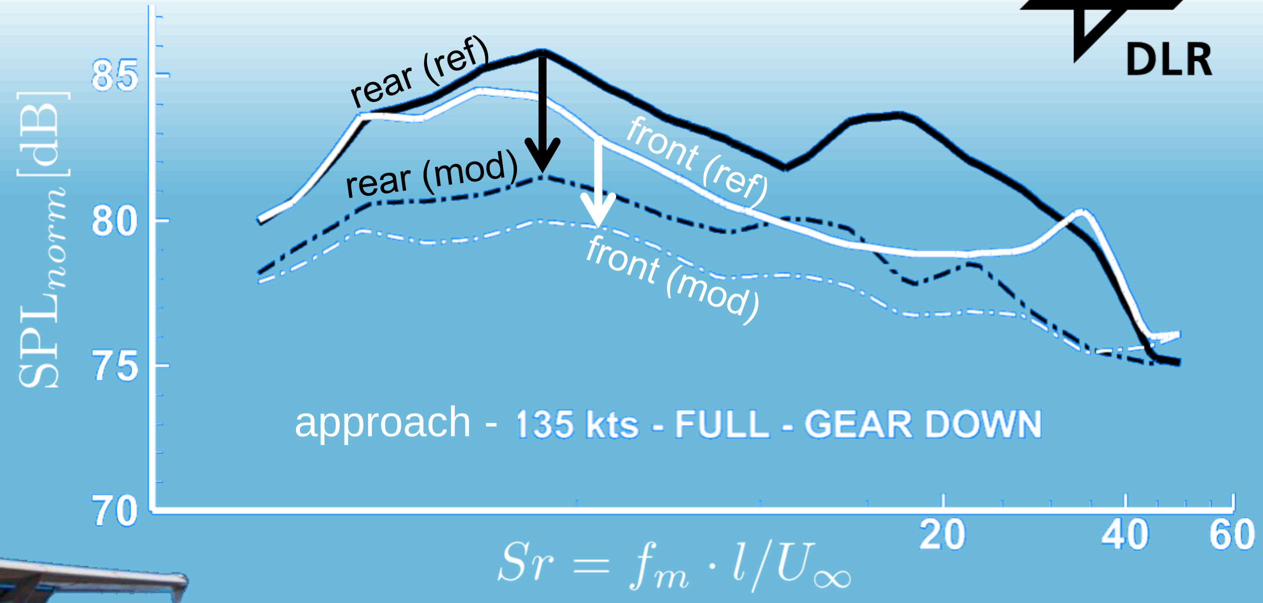




- massive reduction for frequencies 500-2000Hz, largest effect laterally
- enables steep approaches w/o excess source noise

Low noise ATRA - synopsis





- ✓ broadband reduction 3 – 4 dB for standard approaches
- ✓ spoiler noise eliminated
- ✓ 1 – 2 dB reduction at departure

- up to **5dB reduction** at approach (if including slat modification)

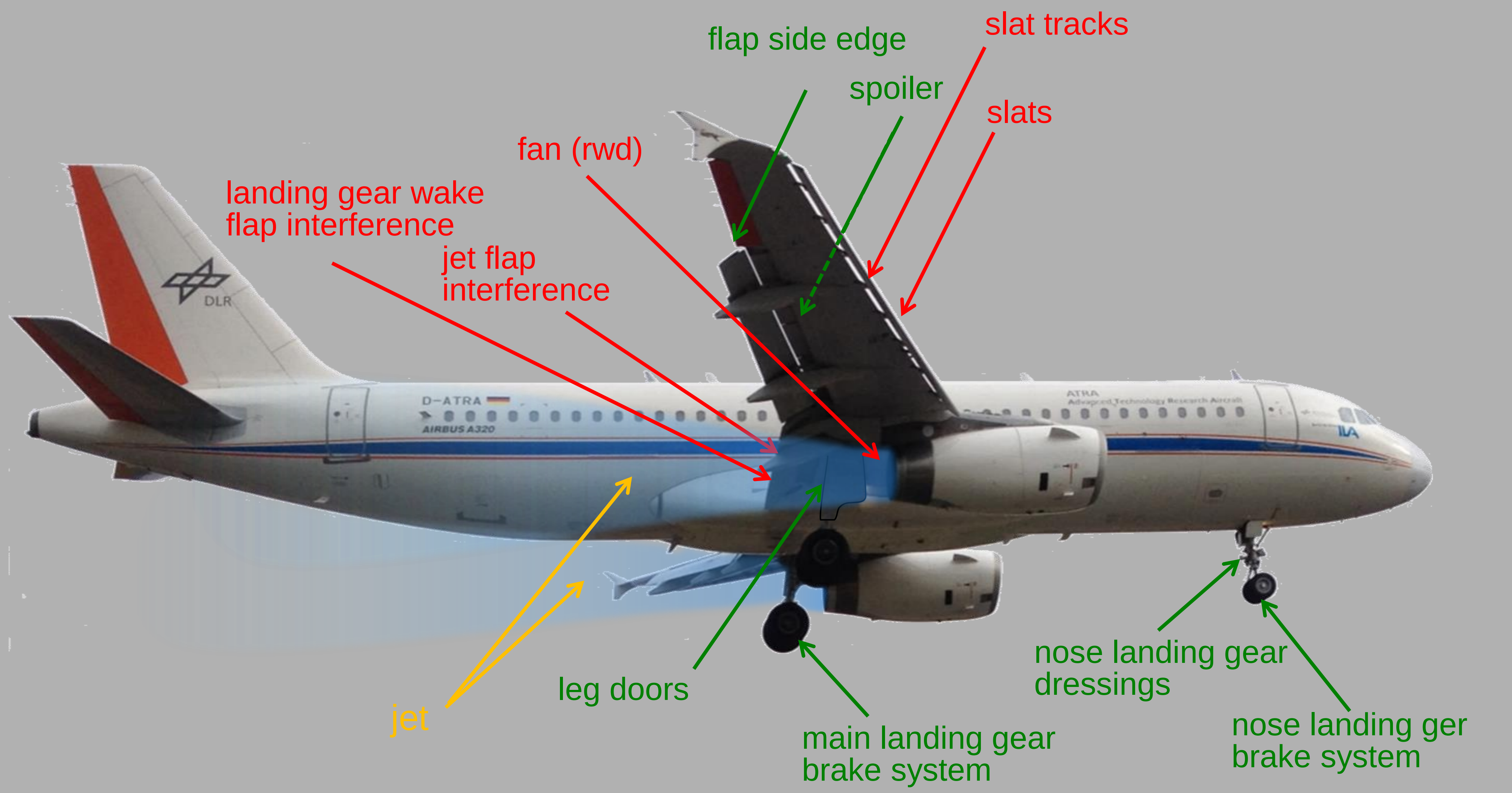
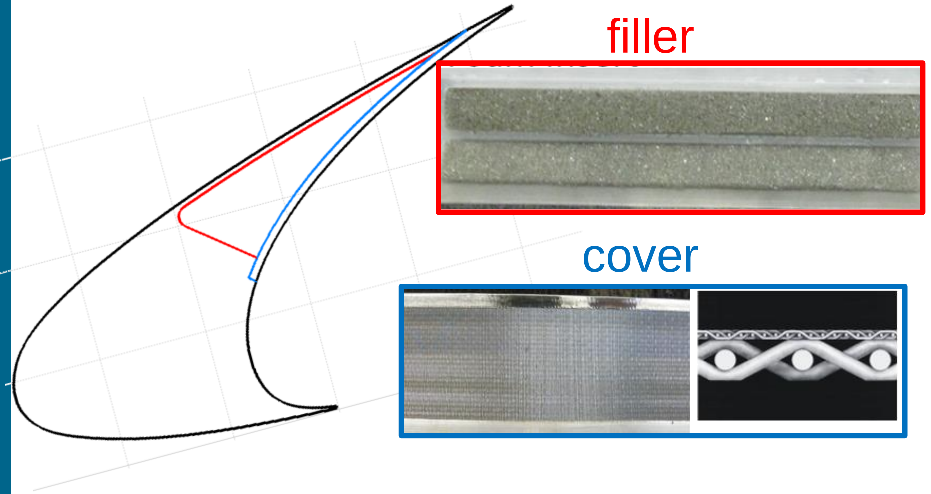


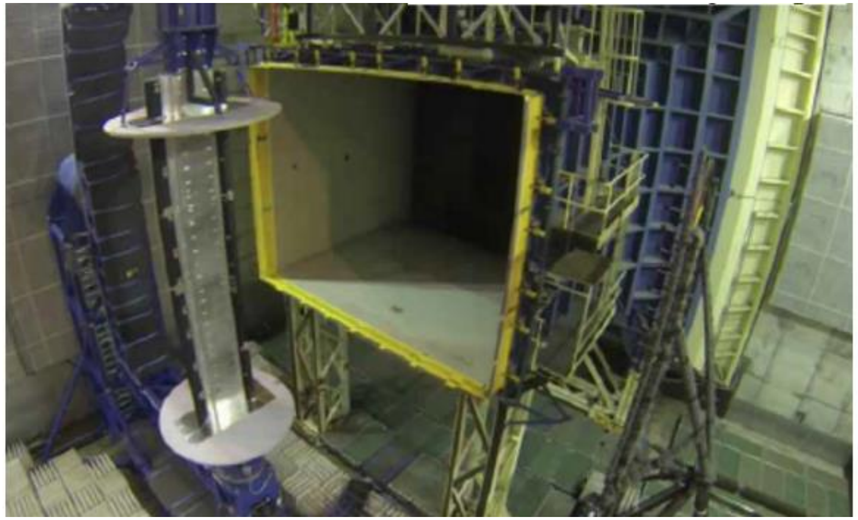
Photo: H. Siller

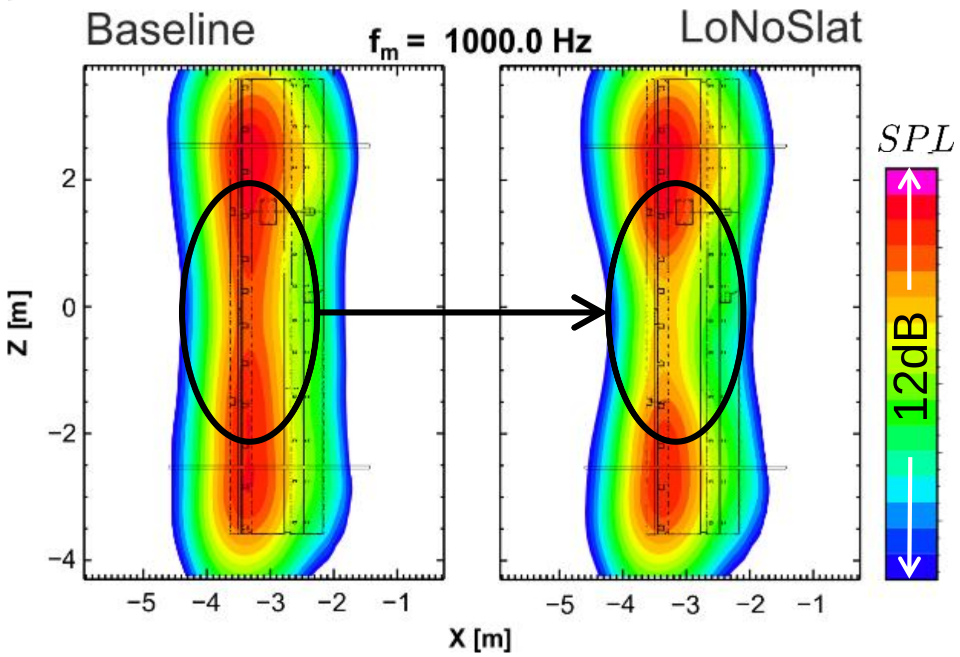
2. BEYOND LNATRA → Further research on sources of sound and respective noise reduction technology

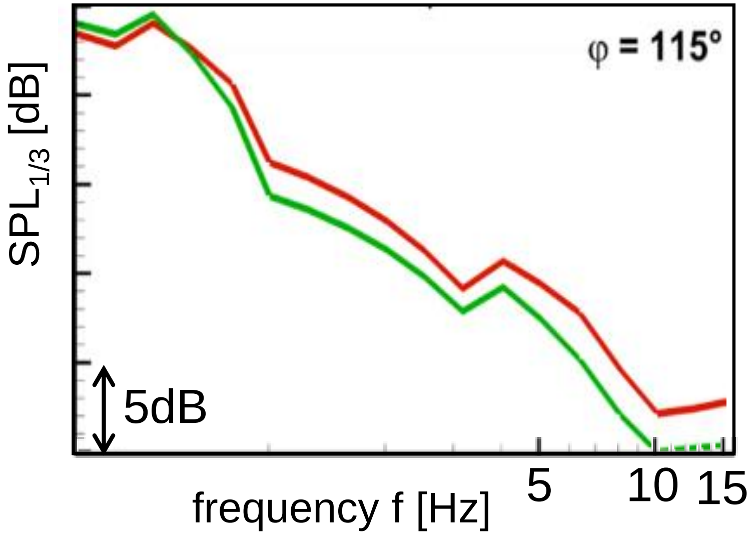
SLAT - noise reduction by slat cove liner



F15LS (4:1 sister of F16)
1200 mm chord,
Re ~ 4 Mio.@ 55 m/s





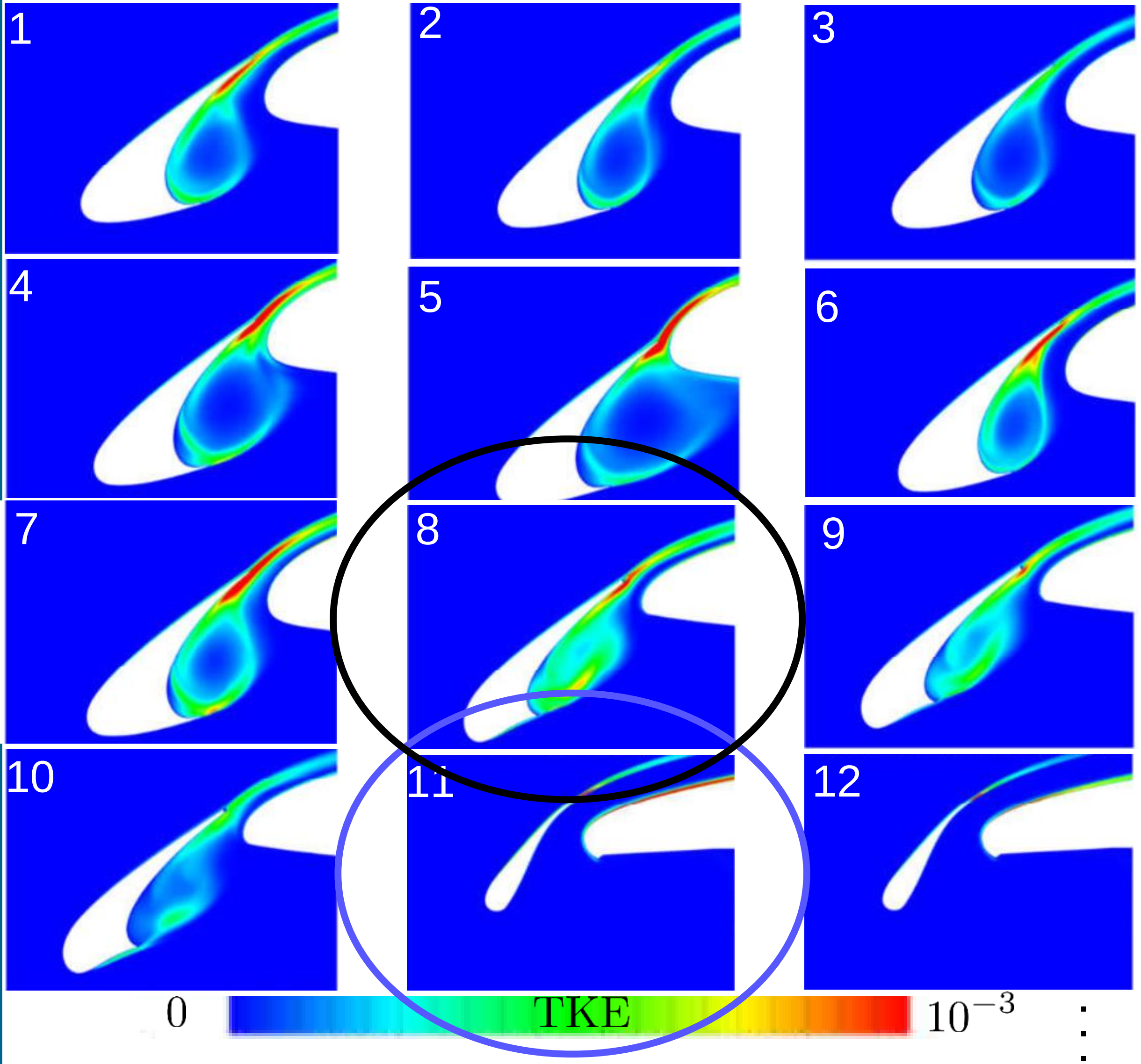


- 2-3 dB reduction broadband
- no lift penalty

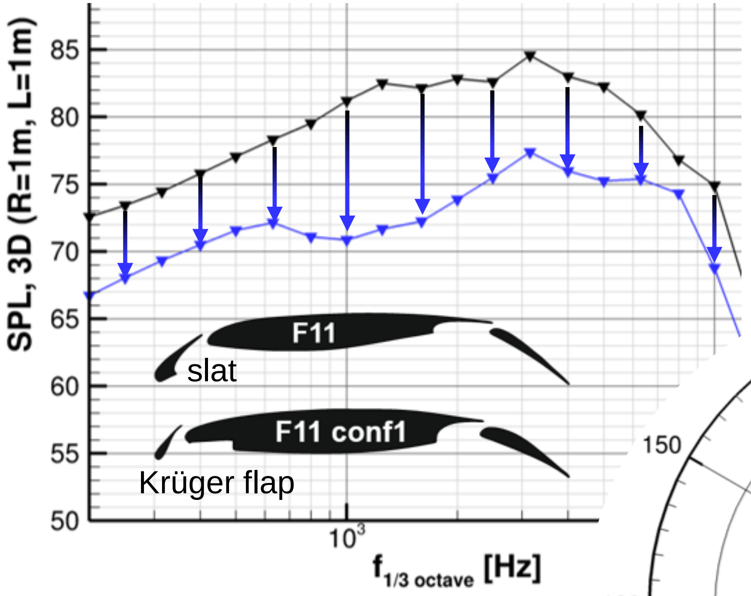
Lufo MOVE.ON

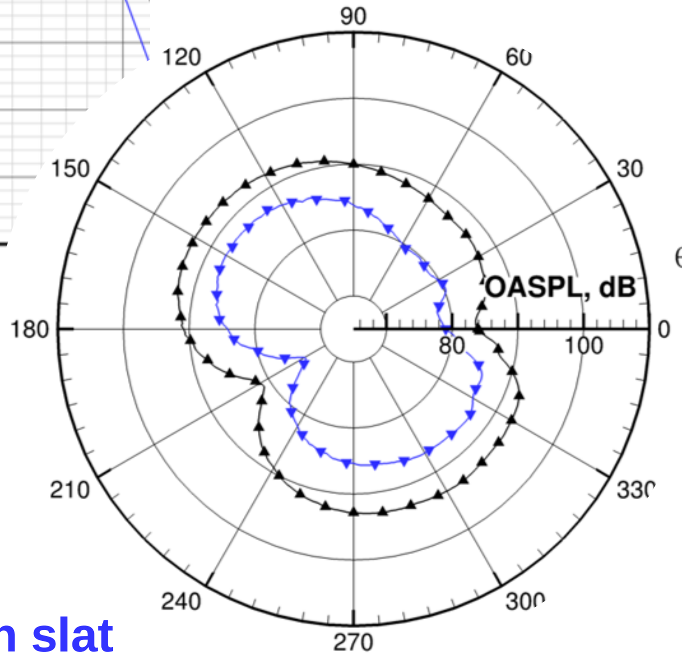
M. Pott-Pollenske, AIAA 2021-2114

LEADING EDGE DEVICES – Systematic CAA design study



GeometryName	clean chord (m)	AoA (deg)	U (m/s)	Slat GAP (-)	Slat OL (-)	Cl
F11	0,3	6	61,5	1	1	2.5
F11 conf1	0,3	10	61,5	1	1	2.63

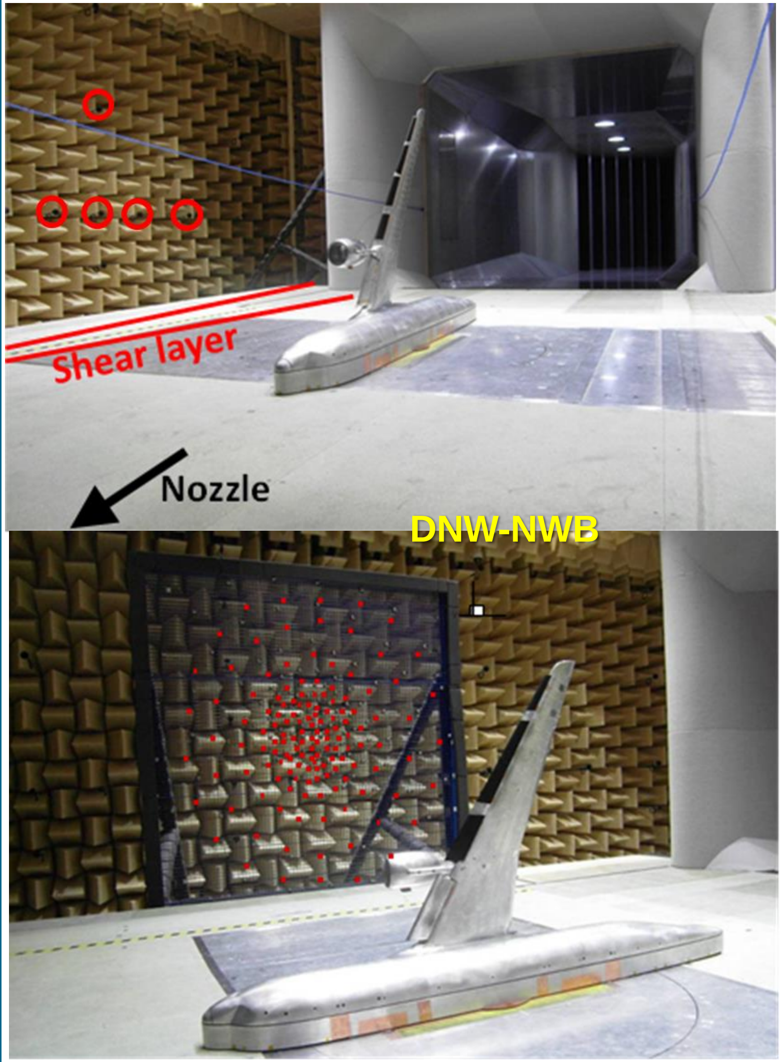


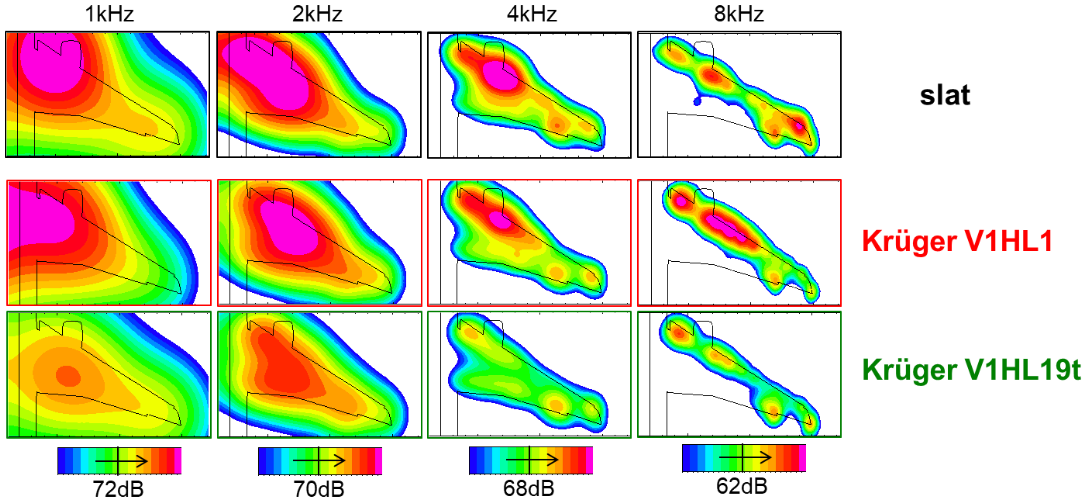


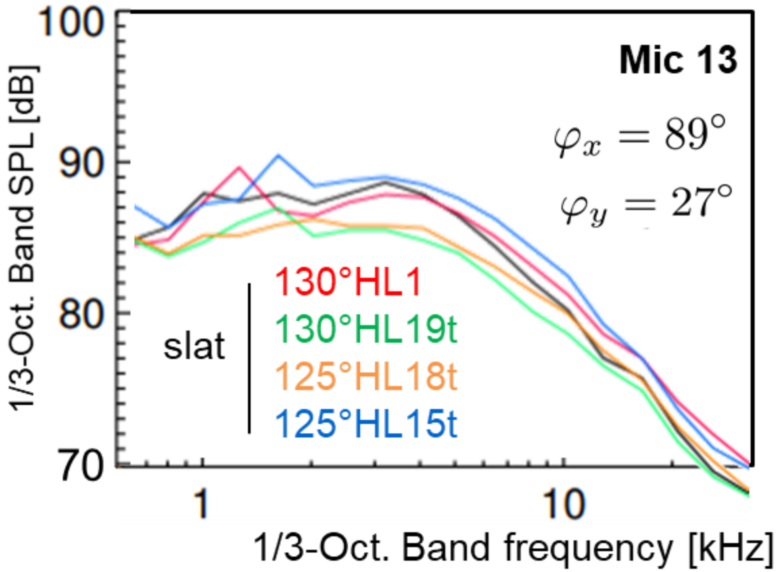
→ Krüger more silent than slat

D. Heitmann, R. Ewert / Lufo-INTONE 2021

KRÜGER vs. SLAT - noise study at complete wing / FNG



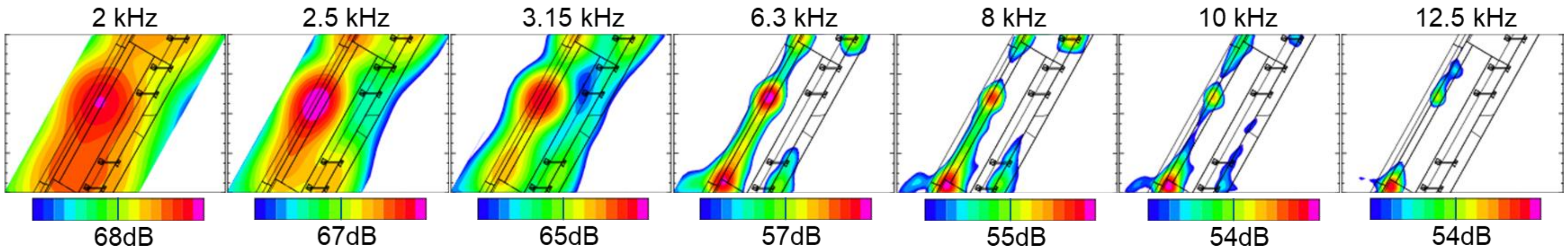


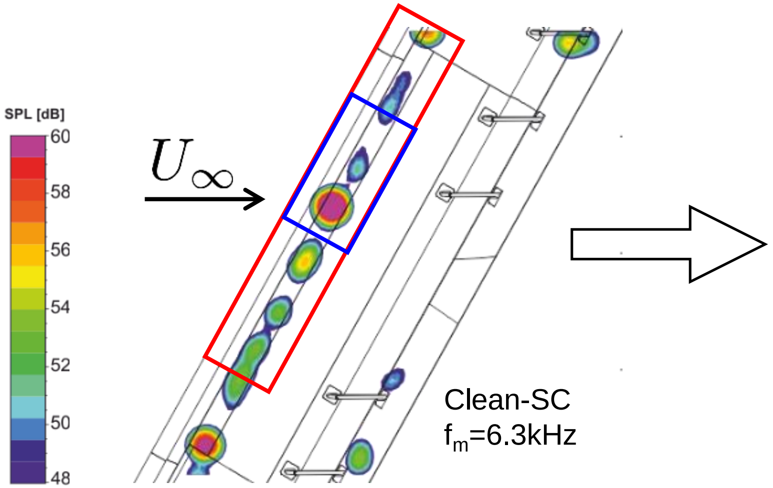


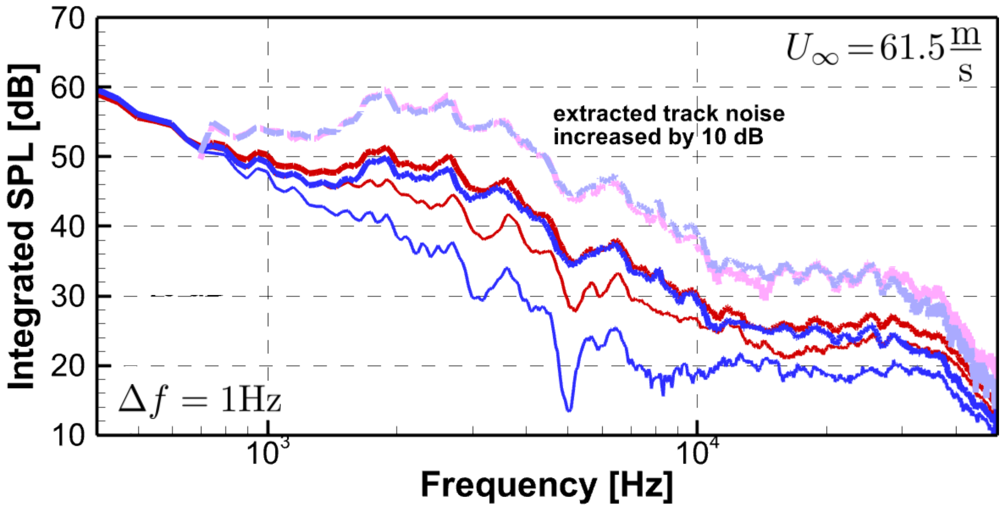
→ **3D proof of low noise potential of Krüger flaps**

M. Pott-Pollenske, A. Büscher / Lufo-INTONE 2021

Importance of **SLAT TRACK** noise







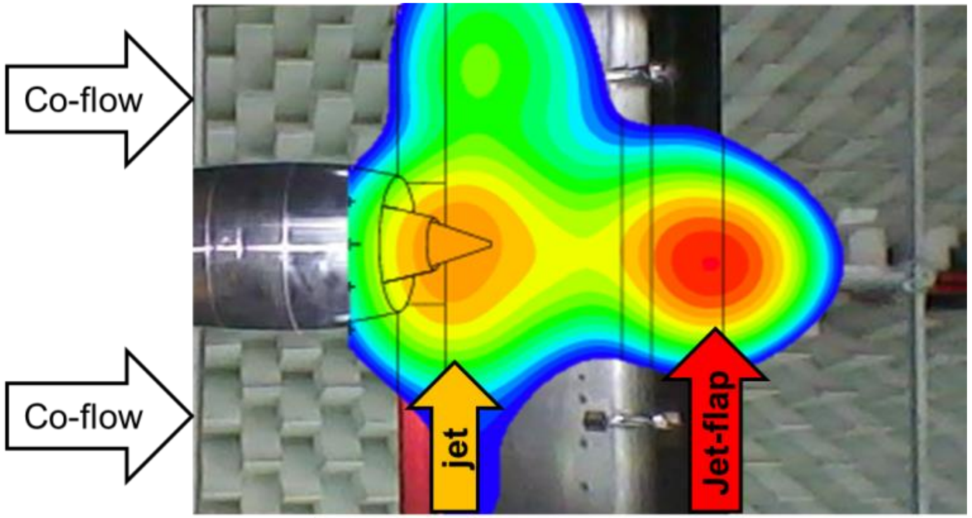
- **track noise may dominate spectrum in wide frequency range**
- **first empirical track noise model derived**

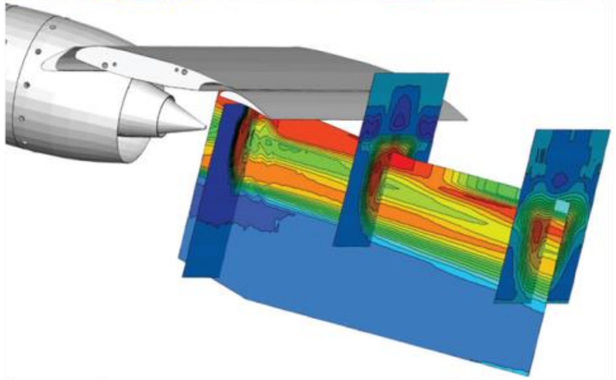
Lufo 5-3 INTONE

Pott-Pollenske, Jansen, AIAA 2002-2807

JET-FLAP INTERFERENCE noise

Measurement of JFI noise dual stream nozzle in DLR-AWB (F16 High lift)

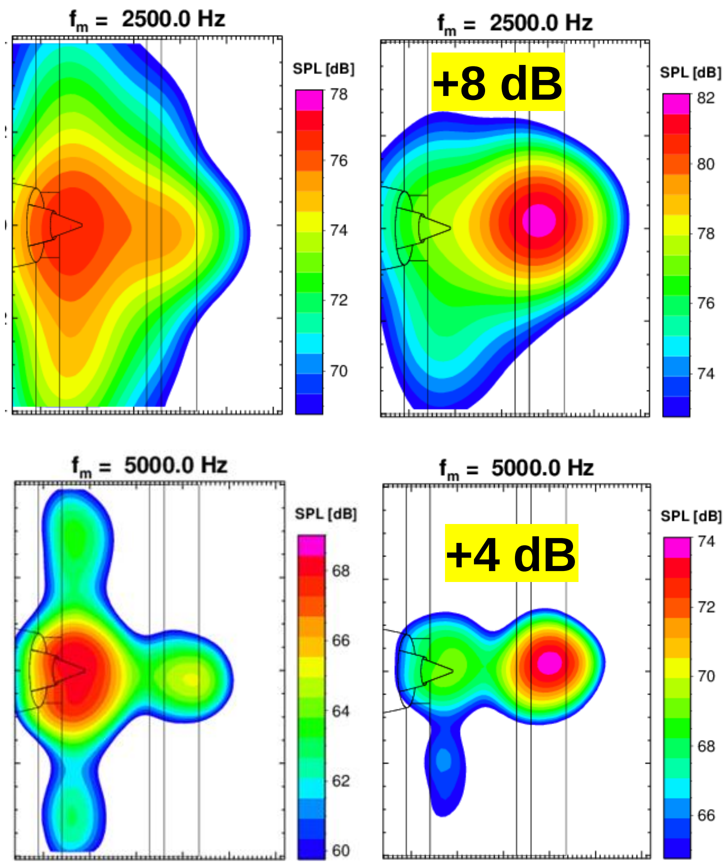




U_{Fan} = 129 m/s U_{Core} = 108 m/s

flap setting

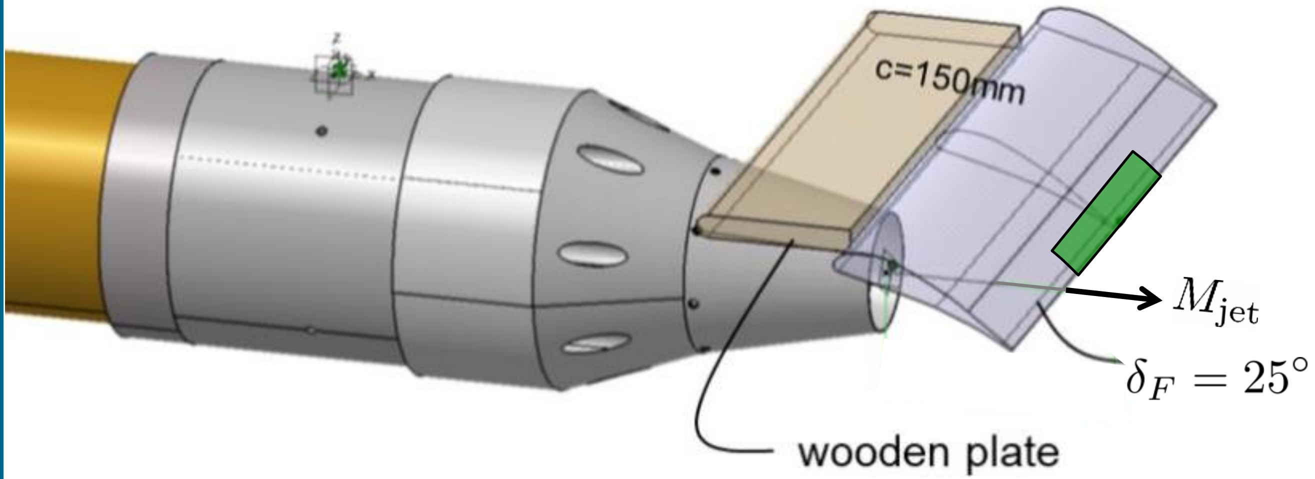
δ_F=25° δ_F=35°

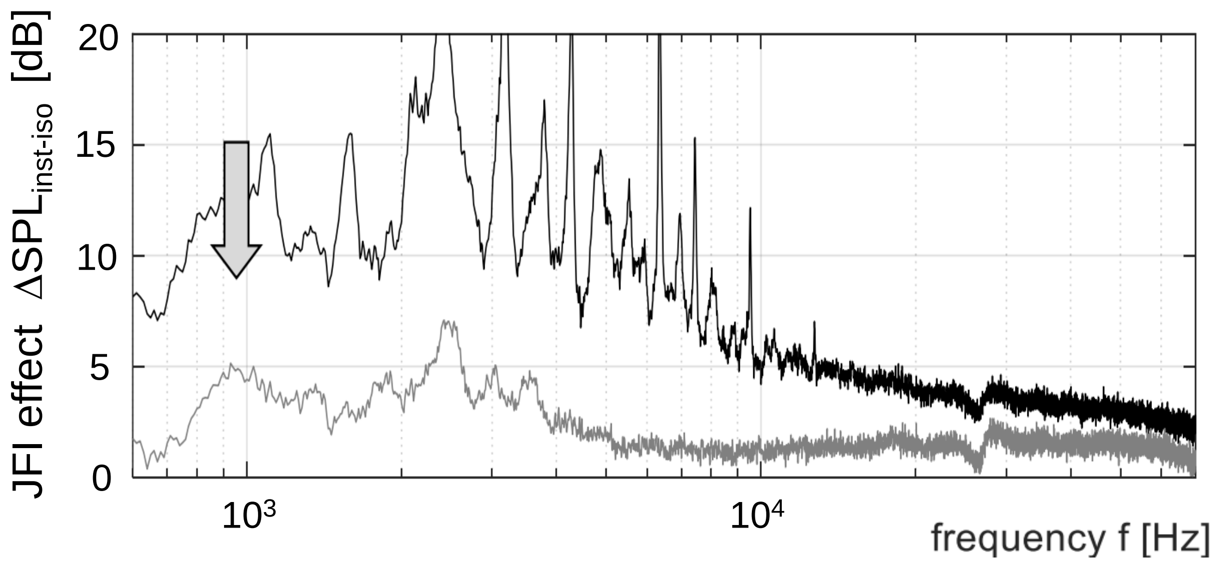


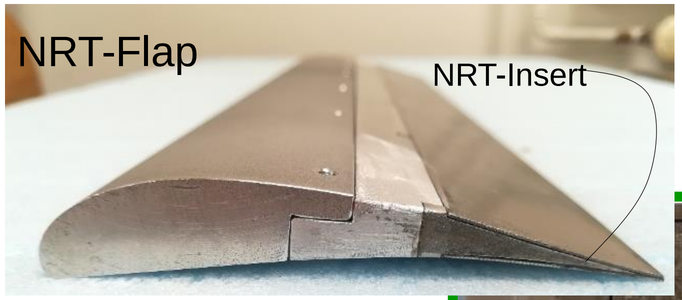
M. Pott-Pollenske, R. Meier, Lufo Power25

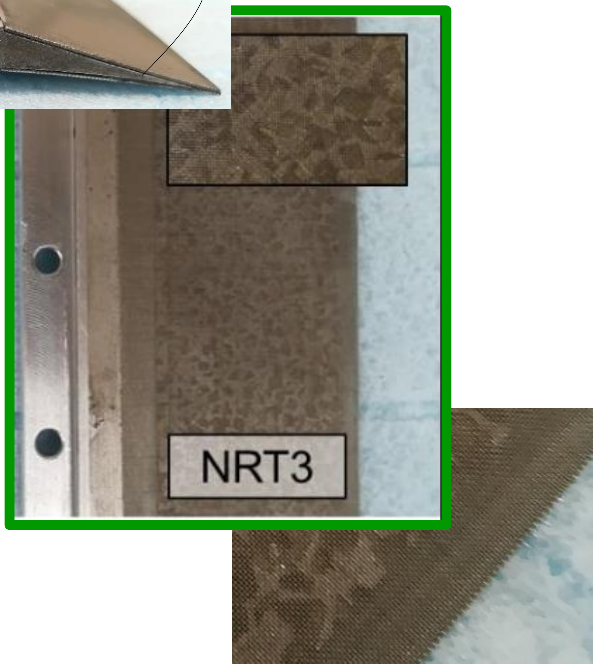
JET-FLAP INTERFERENCE noise reduction

Test of single stream jet combined with F16 flap / effect of porous flap inserts



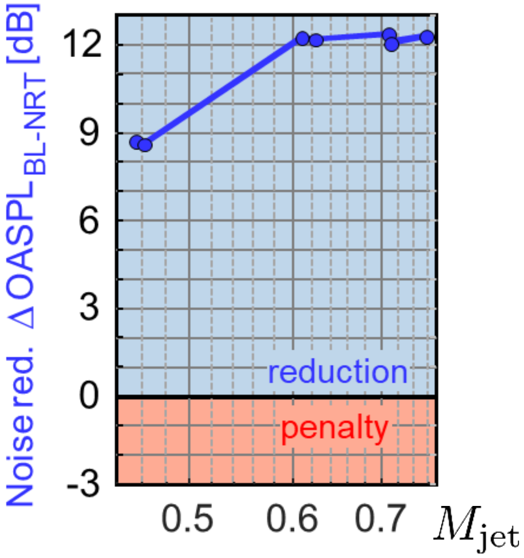






best variant:

coarse porous metal
+ mesh cover

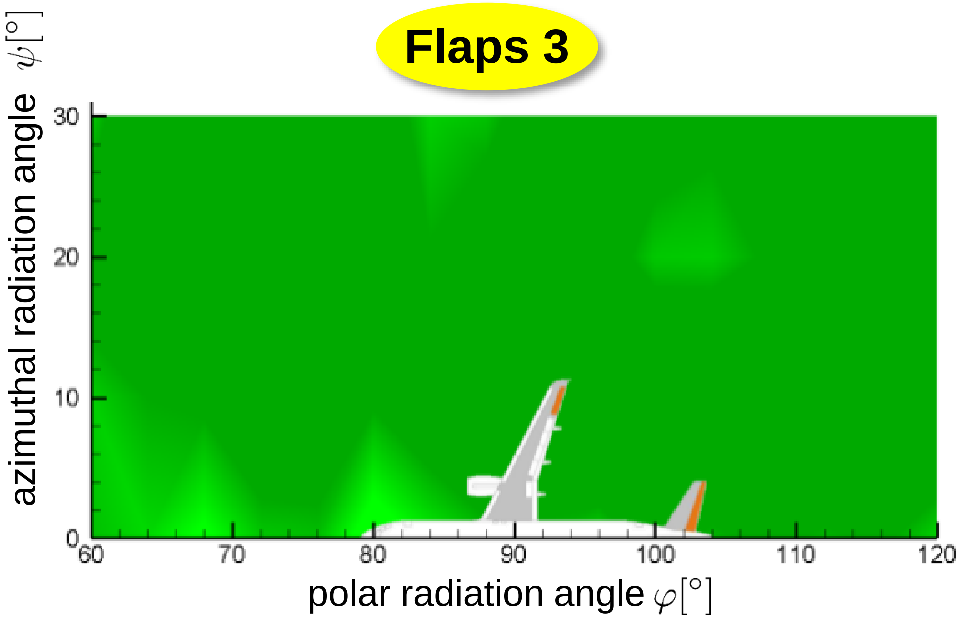


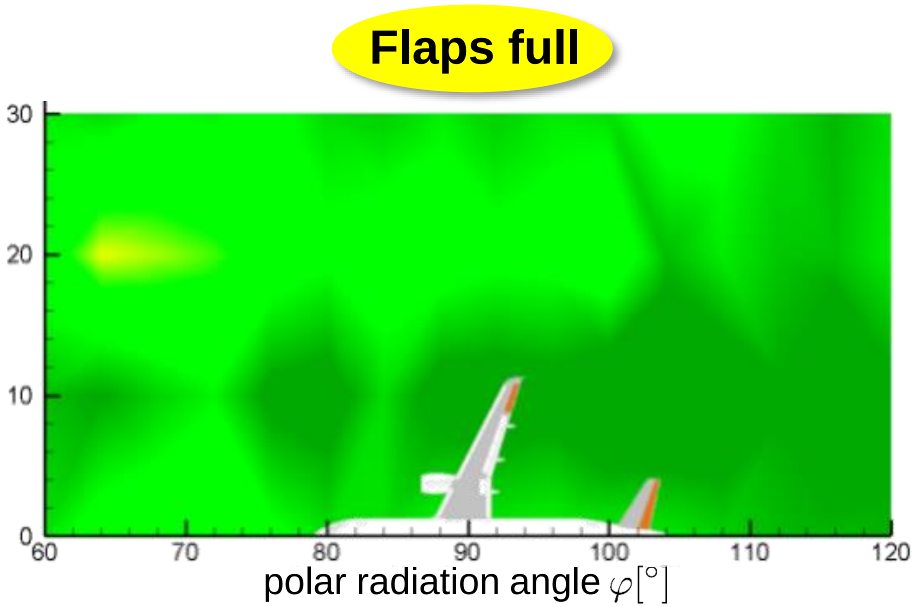
→ **appropriate materials extremely effective**

Chr. Jente, J. Schmidt, J. Delfs, M. Pott-Pollenske, H. Siller AIAA 2022-3040

LANDING GEAR – FLAP INTERFERENCE noise

approach– gear down – 135 kts



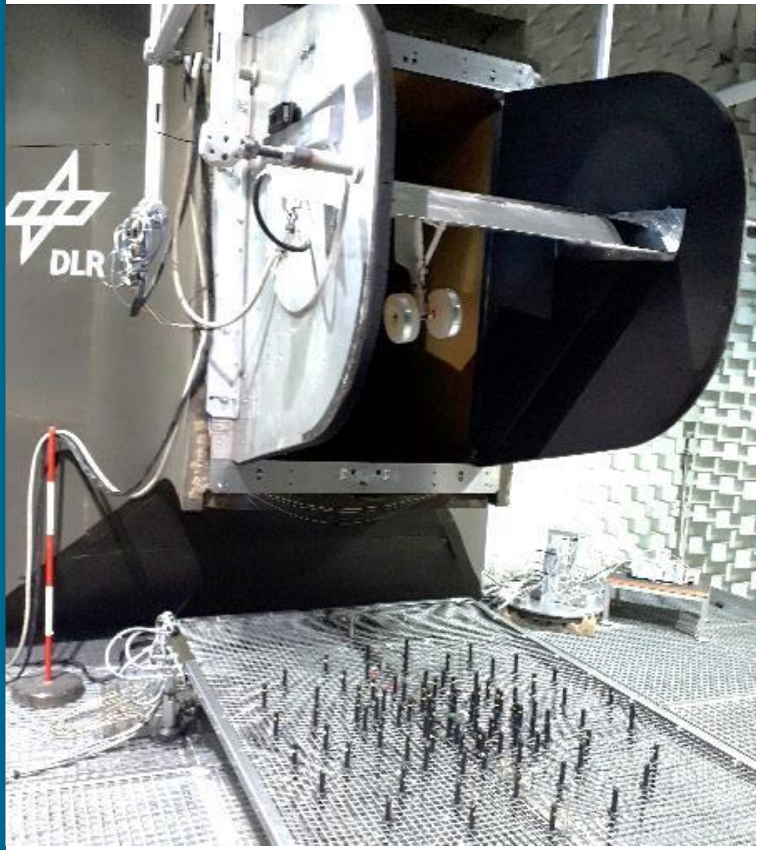


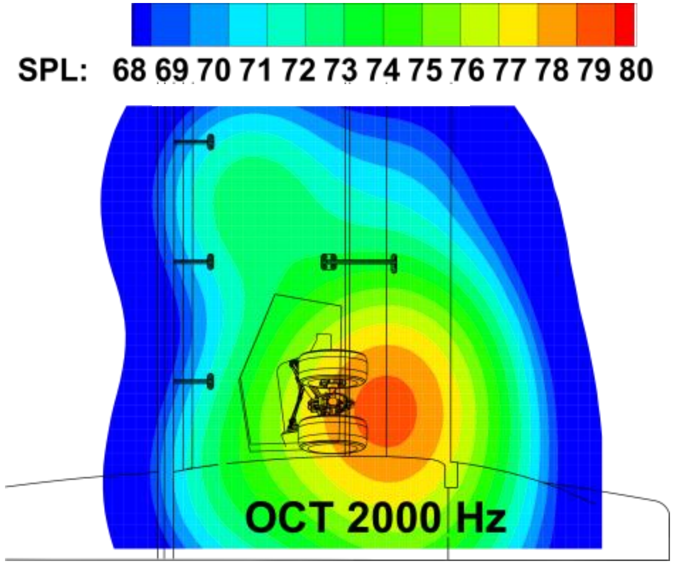
→ at large deployment angle installation excess noise increased

M. Pott-Pollenske et al., DLR-LNATRA 2021

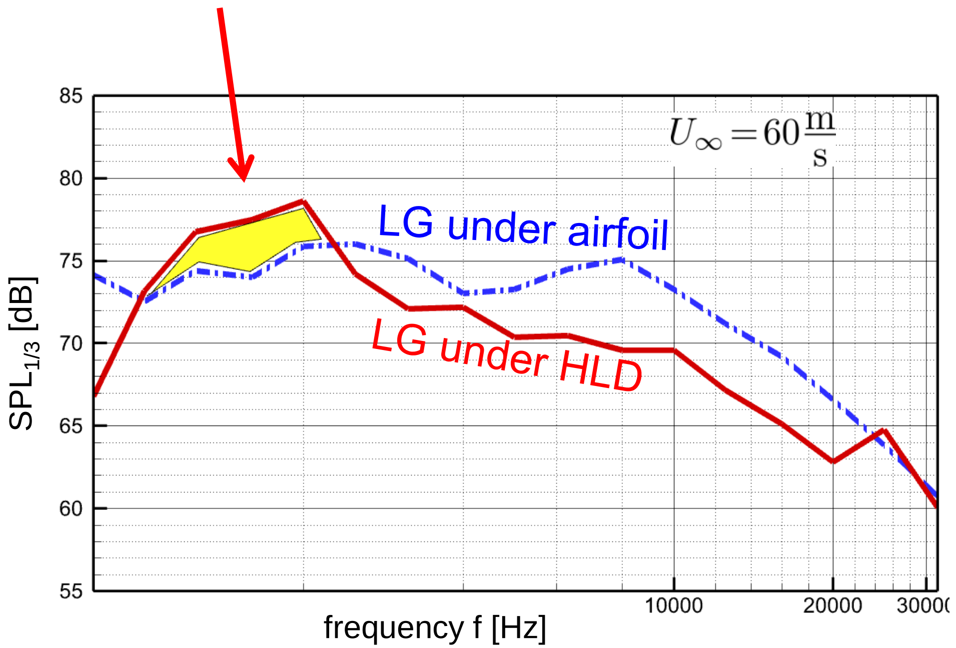
LANDING GEAR – FLAP INTERFERENCE noise

Acoustic Windtunnel studies AWB





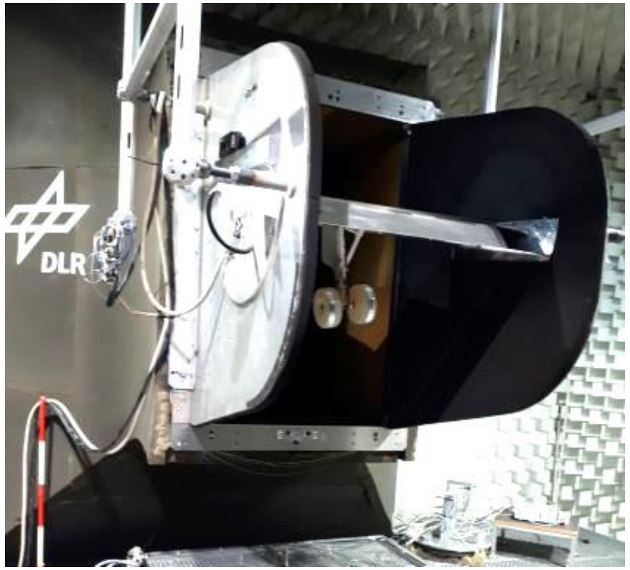
Gear wake / flap interaction noise

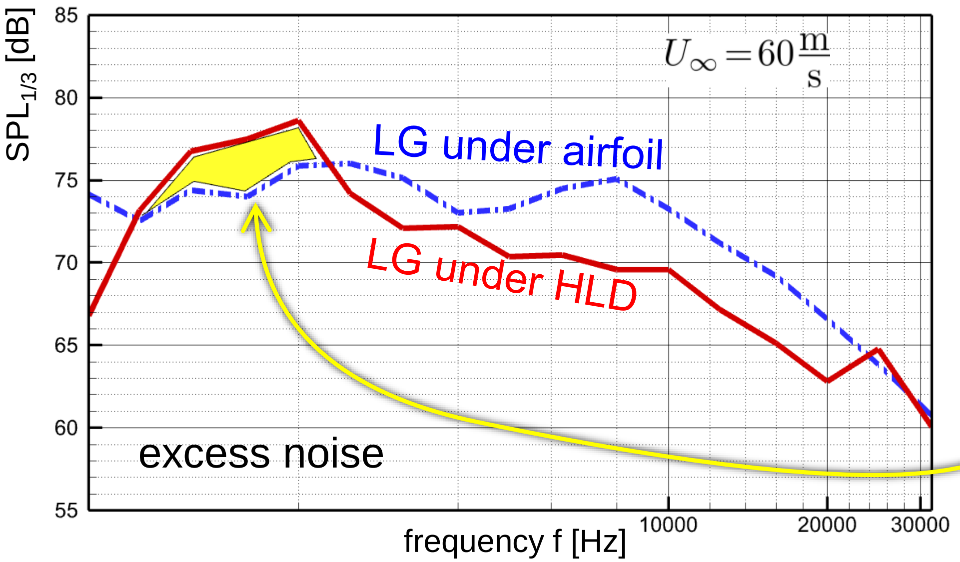


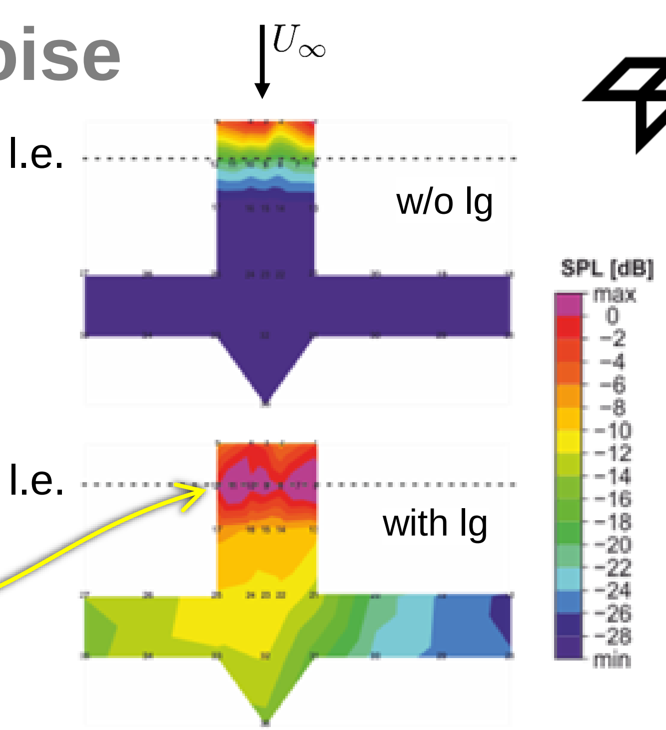
→ significant low frequency noise source at flap leading edge

M. Pott-Pollenske 2020 EU ARTEM

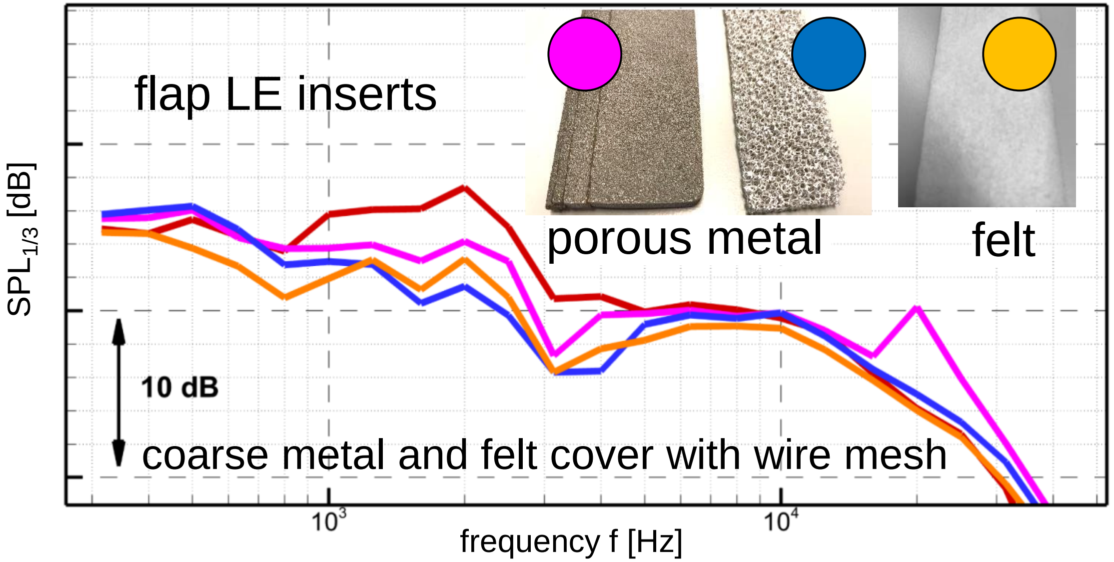
LANDING GEAR – FLAP INTERFERENCE noise





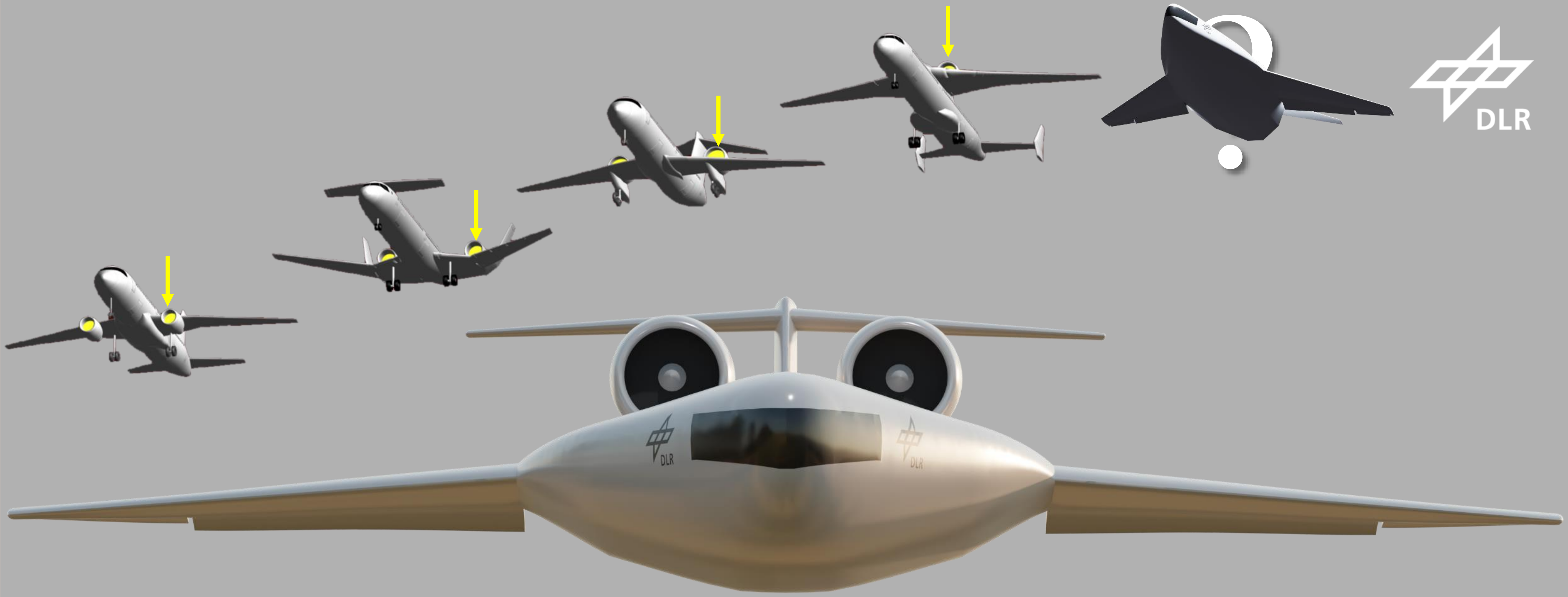


flap surface pressures



→ **proof of noise reduction potential of porous metal**

M. Pott-Pollenske 2021 EU ARTEM

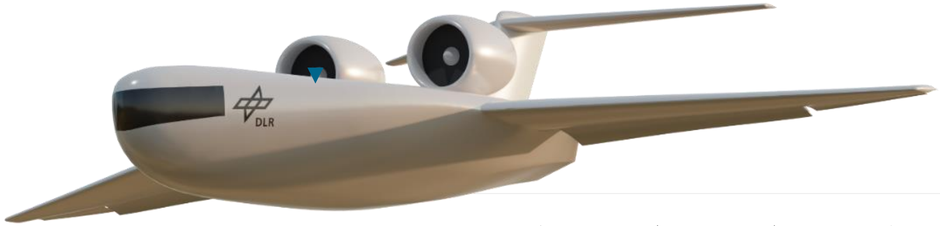


3 - SIAM

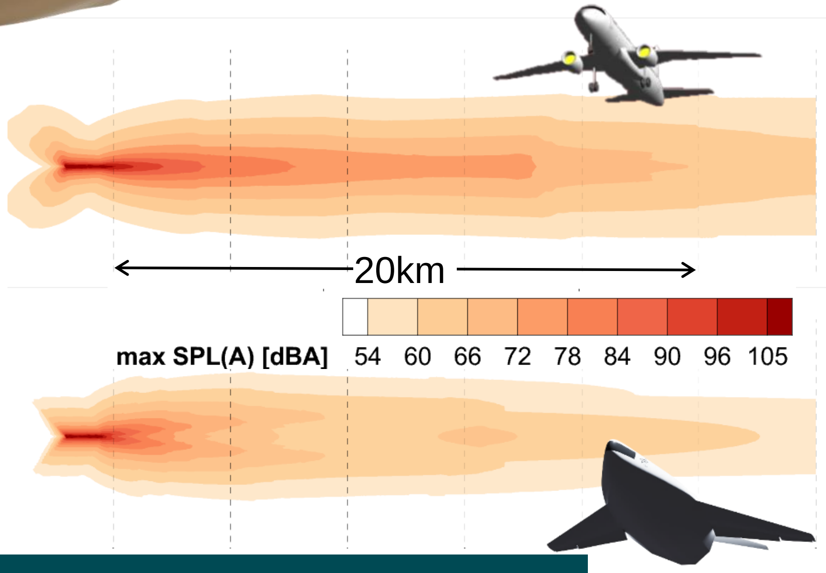
→ A DLR project to **design** a mid range a/c from scratch to be **most silent**
→ A high fidelity final design is aimed at to enable a **comparative** and **fair** aircraft **assessment** w.r.t. a typical A320 mission

SIAM - **S**chall**I**mmssions**A**rmes **M**ittelstreckenflugzeug
(mid range a/c with low noise impact)

Silent by design



- Hybrid Wing Body (HWB) concept
- Extreme shielding of propulsion noise
- Slotless flap system, noise reduction technos
- Very silent UHBR GTF turbofan propulsors



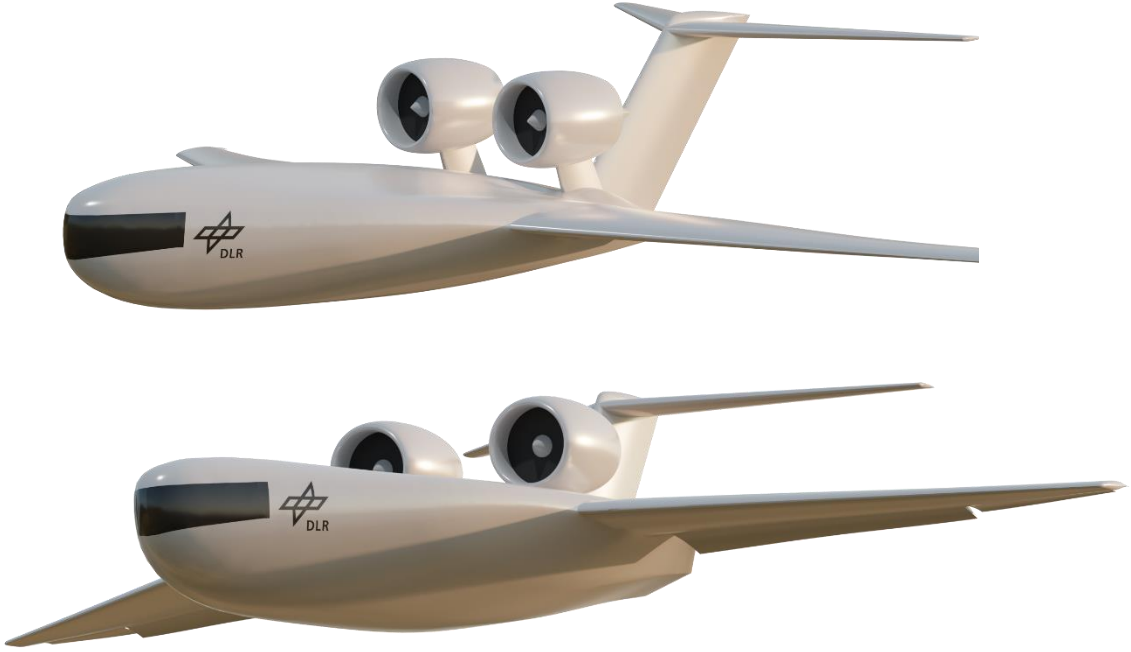
- **15dB/ 5dB/ 18dB*** reduction @ certification points w.r.t. A320ceo (2000)
- → close to visionary ACARE FlightPath 2050 noise objective!
  (15dB reduction per op.)

*) EPNdB flyover/sideline/approach

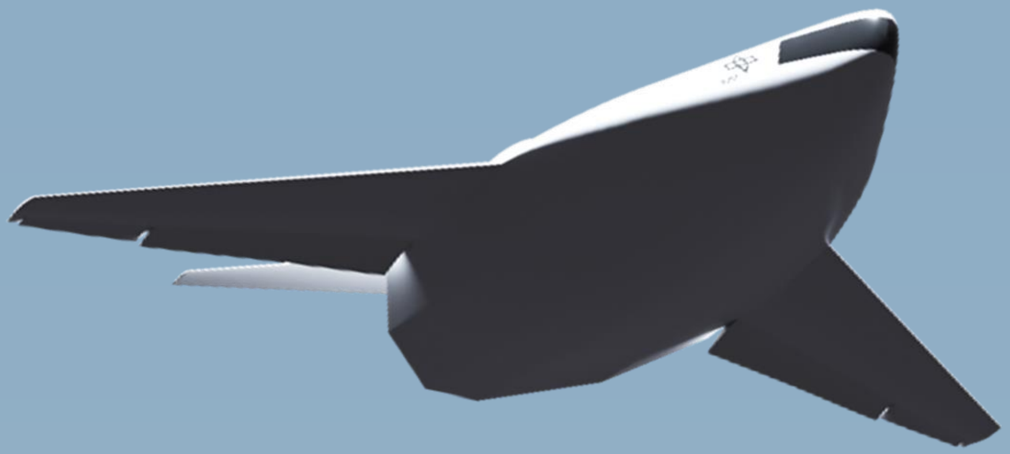
SIAM - SchallImmssionsArmes Mittelstreckenflugzeug (mid range a/c with low noise impact)

HiFi design reveals

- Increased drag from propulsor integration
- Increased mass from T-tail (necessary for stability)
- Although most silent, too inefficient (even for further local optimisation)



- SIAM shows massive potential of a/c design in terms of noise reduction
- → future research will focus on balance between **noise vs. efficiency**

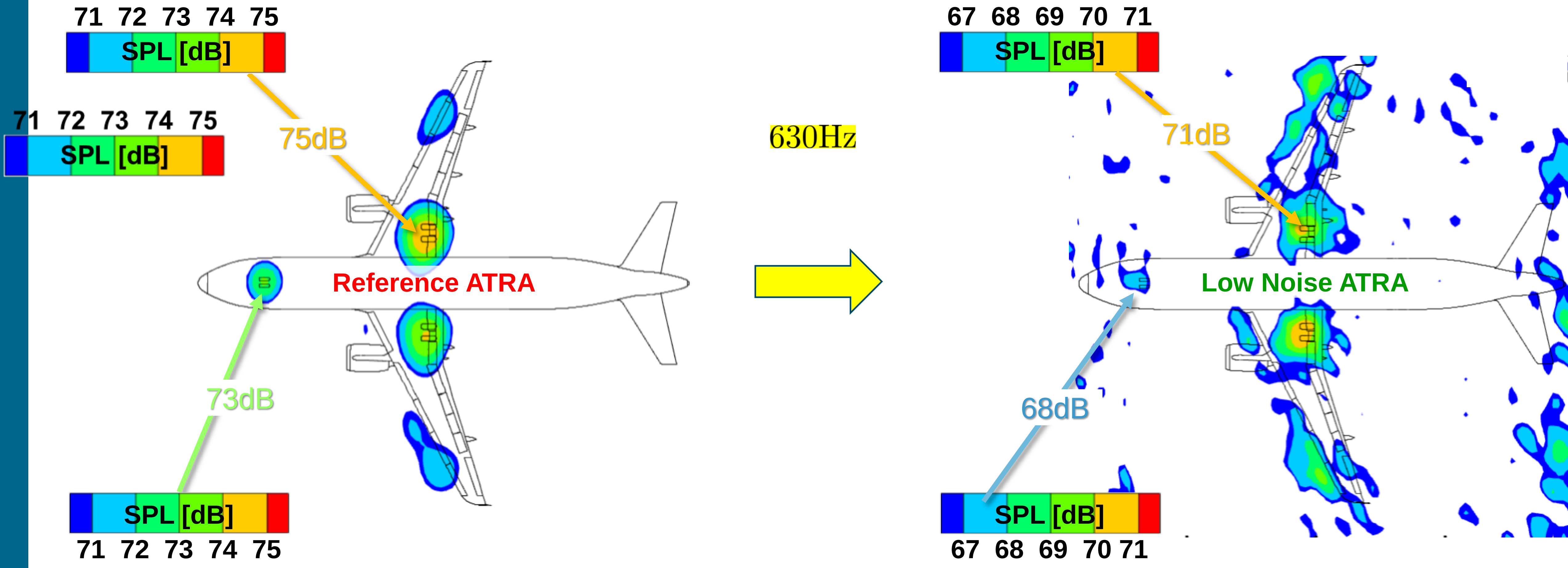


- First time NRT-demonstration at midrange a/c successful
- Additional sources identified – NRT developed
- Drastic noise reduction (only) possible by low noise design

  caution: noise vs. efficiency?

CONCLUSION

Detailed Noise Source Analysis



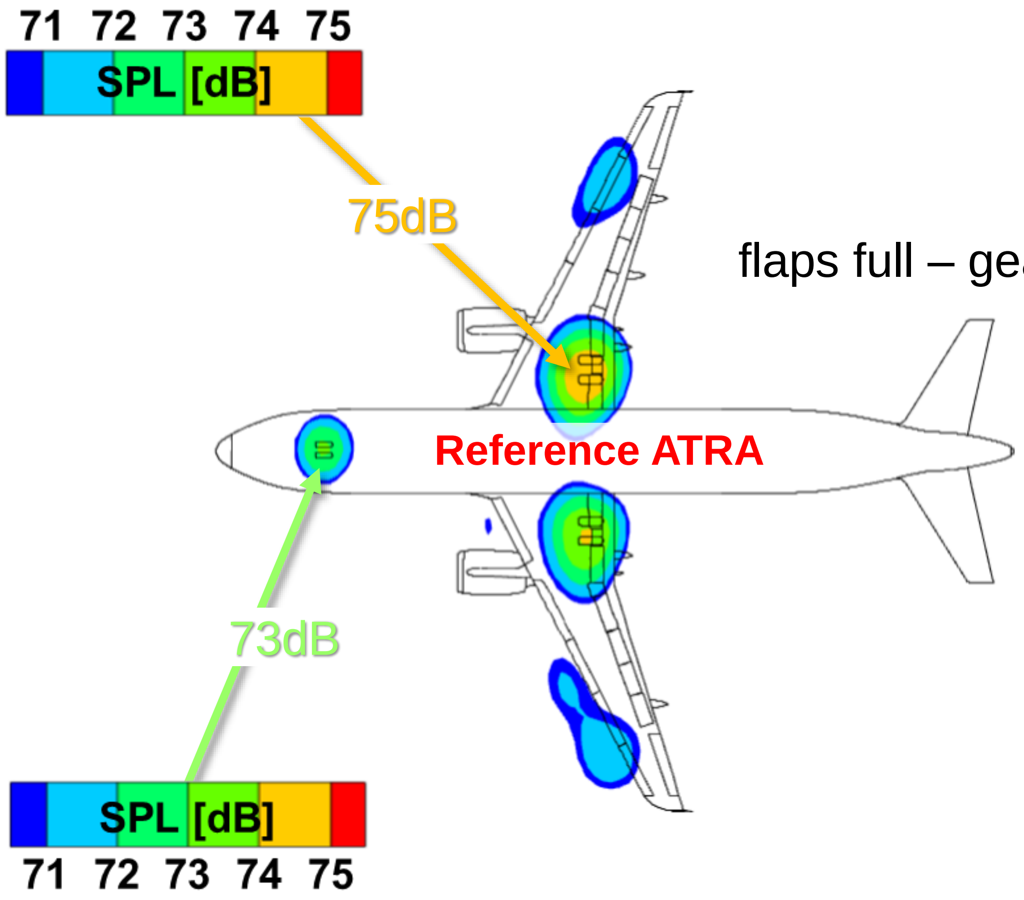
- -4-5 dB at MainLG
- -5-6 dB at NoseLG

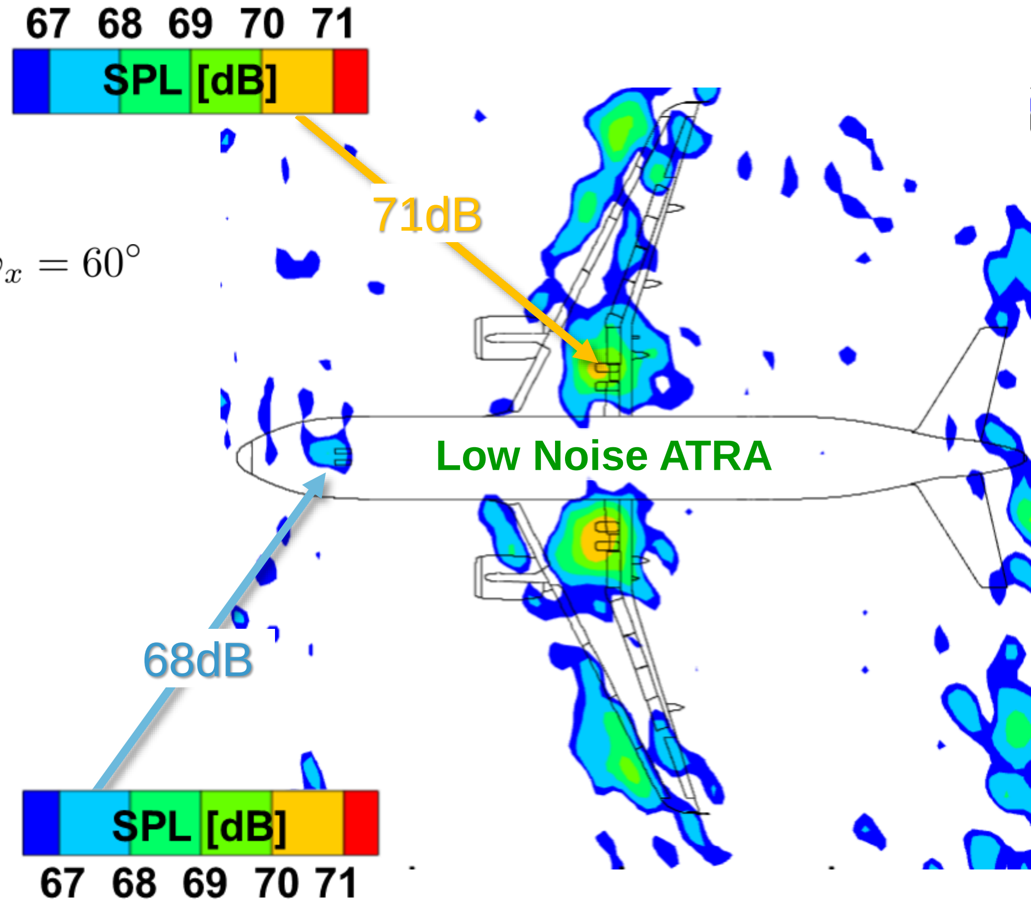
Array data: Siller, H., Schumacher T.: AIAA Paper 2021-2160

Detailed Noise Source Analysis

630Hz

flaps full – gear down -170kts $\varphi_x = 60^\circ$

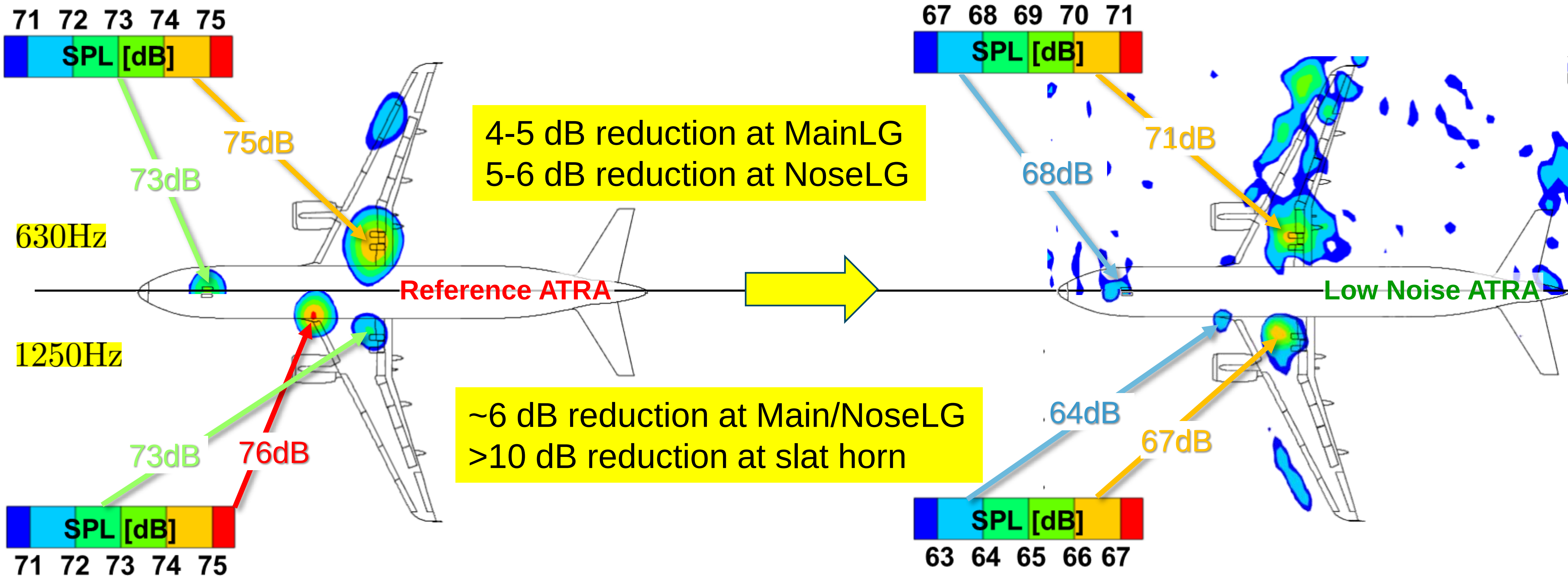




- 4-5 dB reduction at MainLG
- 5-6 dB reduction at NoseLG

Array data: Siller, H., Schumacher T.: AIAA Paper 2021-2160

Detailed Noise Source Analysis

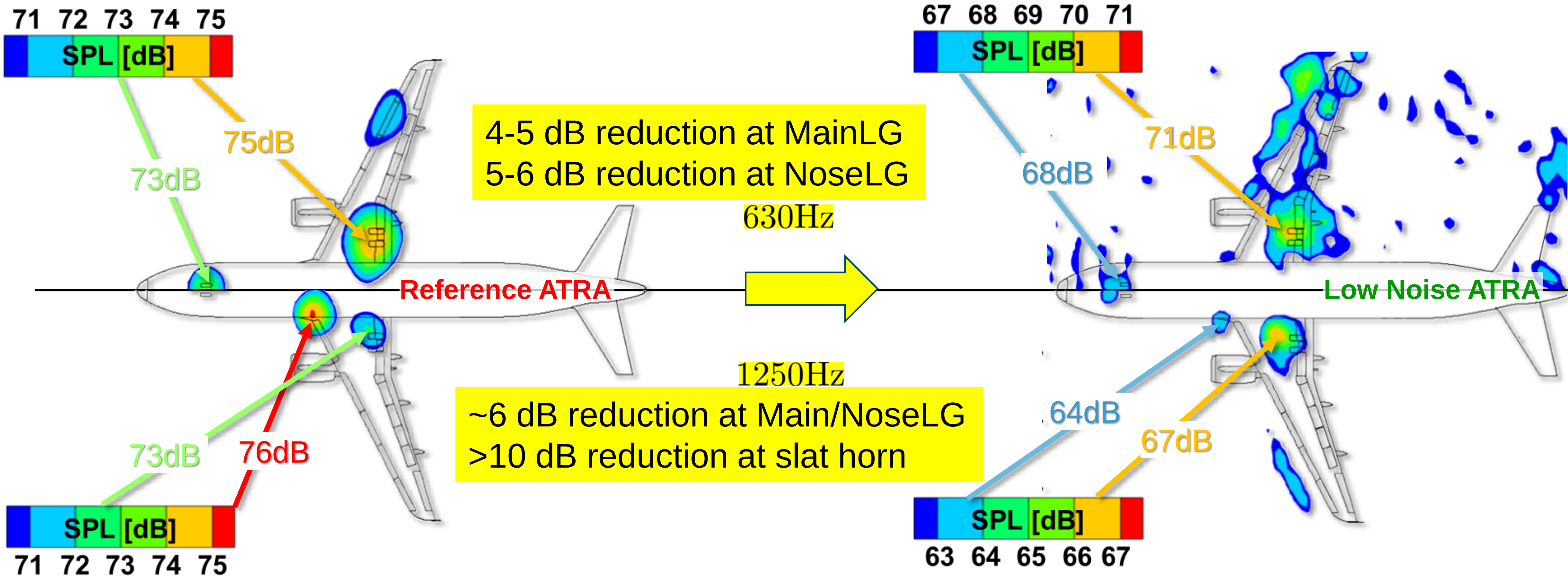


flaps full – gear down -170kts $\varphi_x = 60^\circ$

Array data: Siller, H., Schumacher T.: AIAA Paper 2021-2160

Detailed Noise Source Analysis

flaps full – gear down -170kts, polar angle $\varphi_x = 60^\circ$



Array data: Siller, H., Schumacher T.: AIAA Paper 2021-2160