FIRST WORKSHOP

Analysis of Acoustic Wind Tunnel Test in the NWB on Gear-wake Flap Interaction Noise

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2ND GENERATION ACTIVE WING

Delft, September 10, 2015

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ANALYSIS OF ACOUSTIC WIND TUNNEL TEST IN THE NWB ON GEAR-WAKE FLAP INTERACTION NOISE

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AFLoNext Workshop 2015, 10 September 2015, Delft, The Netherlands

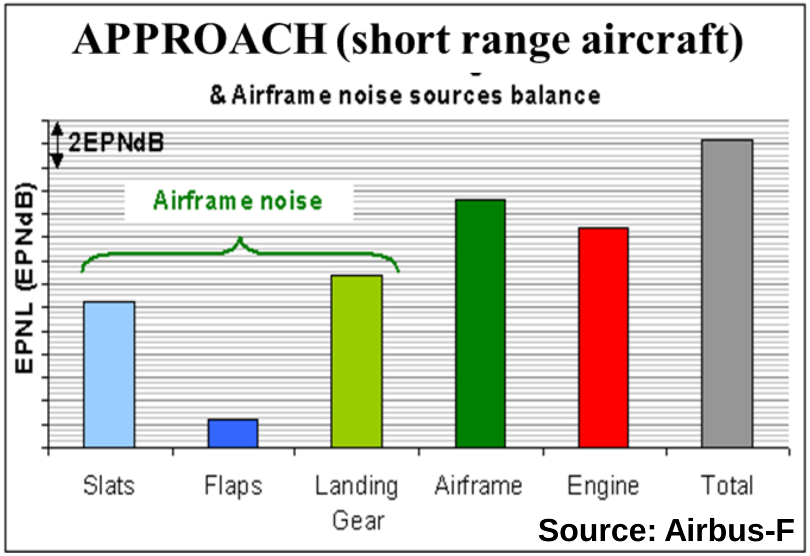
Outline

- Motivation
- High lift system and landing gear configurations
- Wind tunnel test setup
- Acoustic data analysis
- Summary and Conclusions

Motivation

Airframe noise is a major source of overall a/c noise in approach conditions

Former studies, e.g. conducted within SILENCE(R), revealed the importance of gear-wake / flap interaction noise



Objective in AFLoNext

\ **Identify and quantify gear-wake / flap interaction noise for a realistic 3-dimensional high lift system and landing gear**

High lift system and Landing Gear Configurations

4 High Lift Configurations A320

\ **Conf. 3   (flaps 20°)**

\ Conf. Full A (flaps 35°)

\ Conf. Full B (flaps 40°)

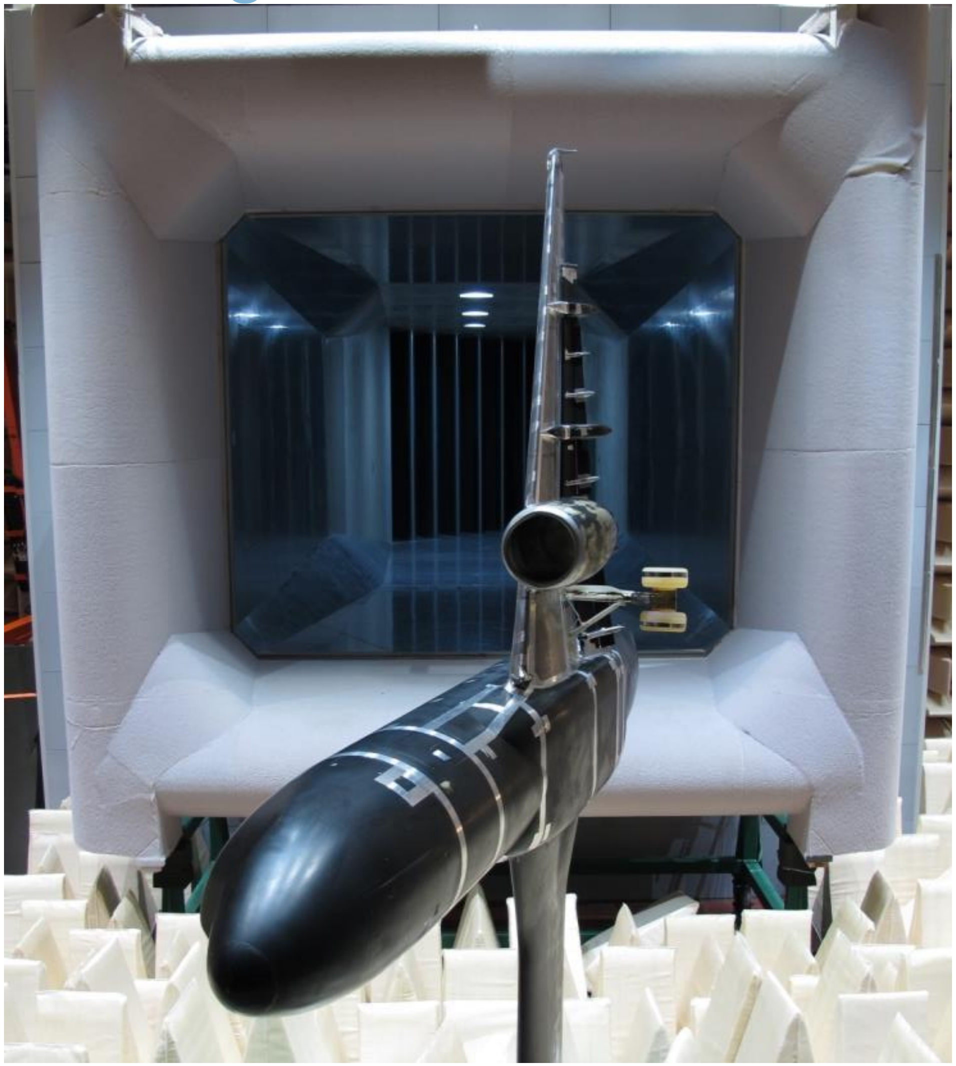
\ **Clean**

3 Standard Landing Gear Configurations

\ **No gear**

\ **Baseline landing gear**

\ Low noise landing gear



10ACOUS semi span model in DNW-NWB

Wind Tunnel Test Setup and Test Conditions

Aerodynamic hysteresis polar for every high lift configuration

\ Wind speeds: 50 and 63 m/s

\ AoA range: -5° ≤ α ≤ 15°, $\Delta\alpha$ = 1°

Aerodynamic polars for every HL/LG configuration

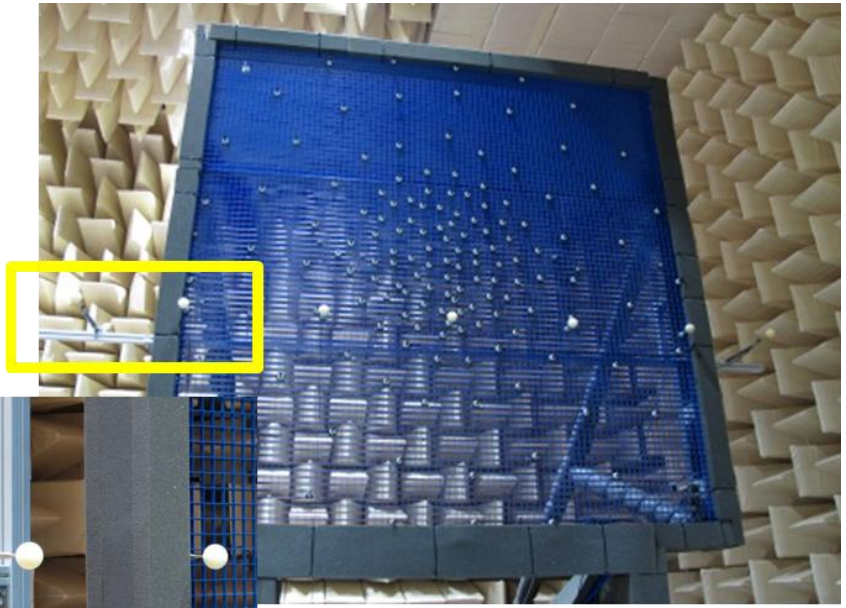
\ Wind speeds: 50, 57 and 63 m/s

\ AoA range: 3° ≤ α ≤ 13°, $\Delta\alpha$ = 2°

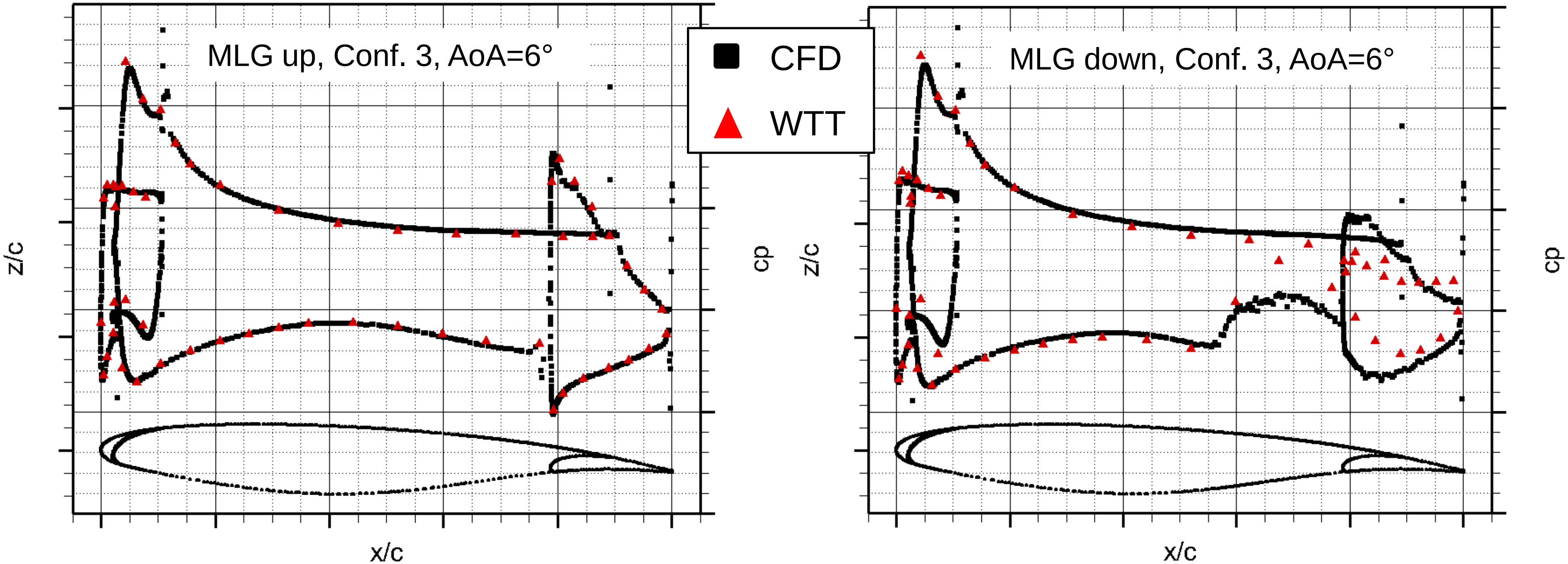
Acoustic measurements (array and single microphones)

\ Wind speeds: 50, 57 and **63 m/s**

\ AoA: **7°** and 8.7°



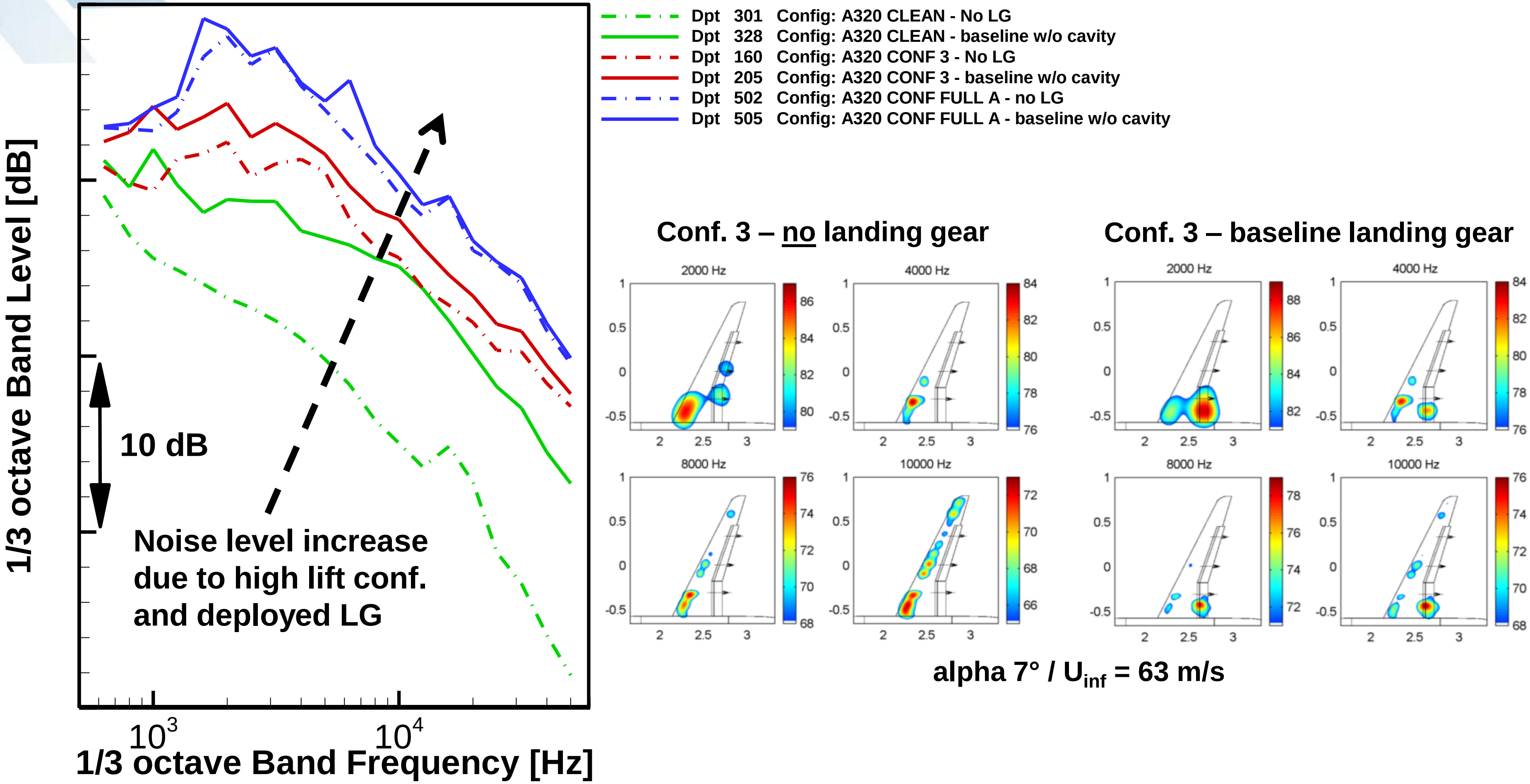
Global Aerodynamic Data Analysis



Inboard wing main section (fully installed with pressure taps)

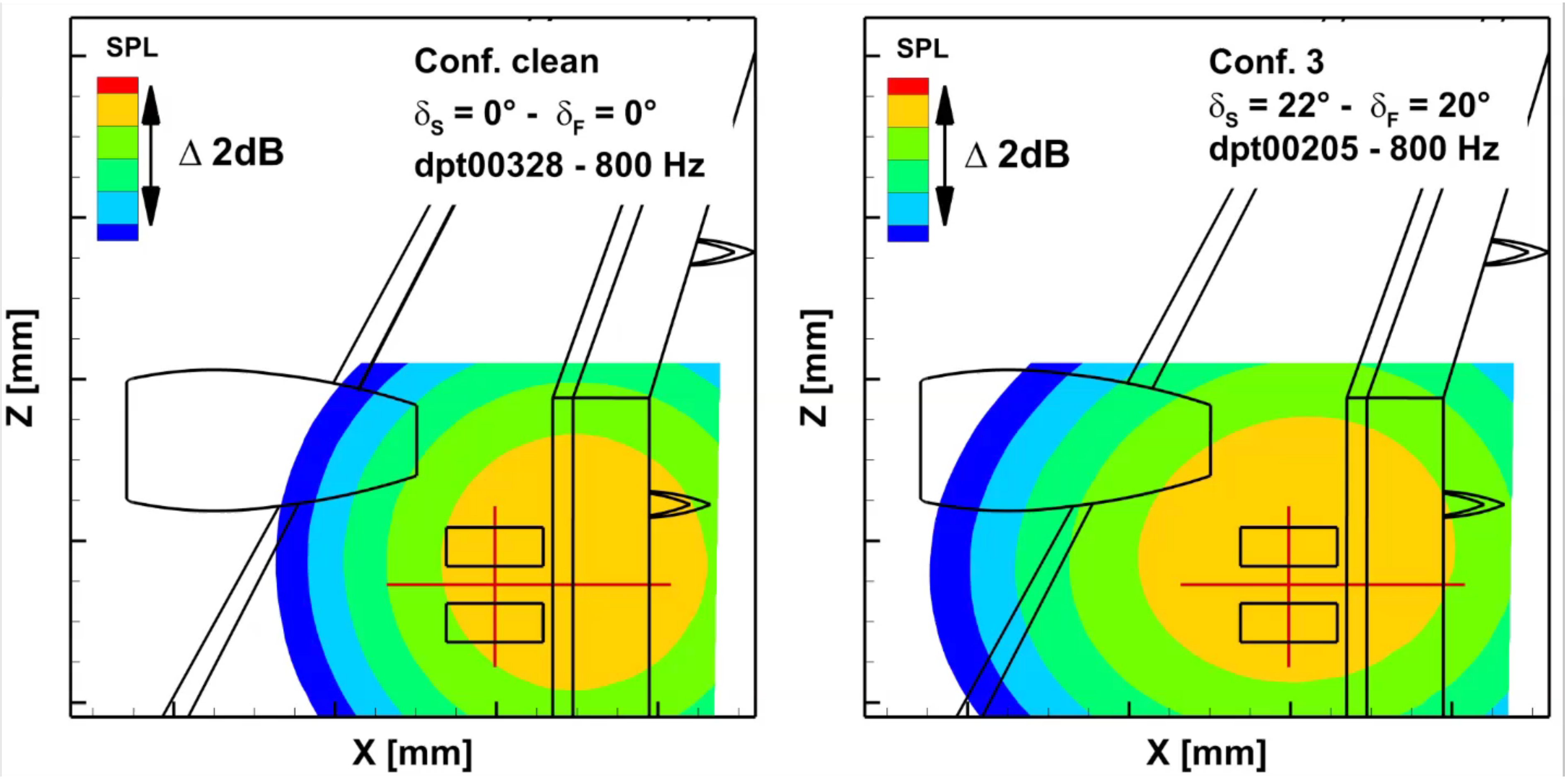
- Geometrical angle in WT set by adaptation to c_p distribution of CFD ($\Delta\alpha$=+3°)
- Excellent agreement on all components for MLG up case
- Clear lift loss on rear wing and flap due to MLG deployment
- Differences in flow separation on flap at least aided by Re effect

Effect of Landing Gear on Farfield Radiated Noise



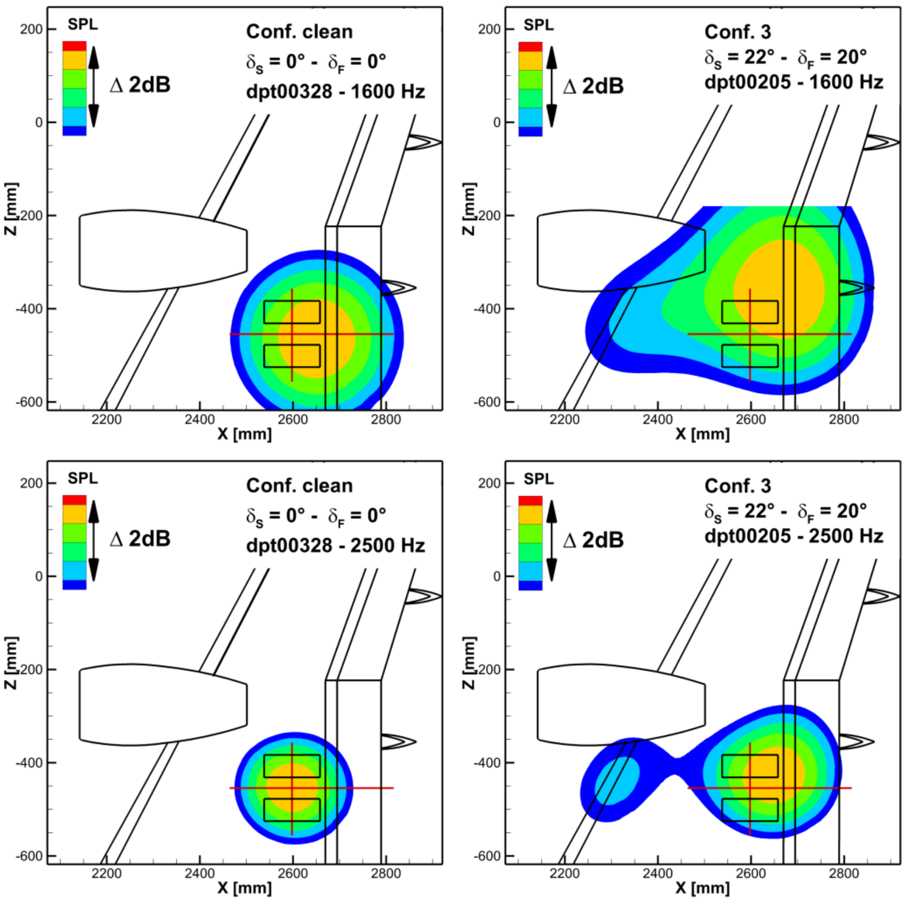
- Landing gear noise exceeds high lift noise
- Difference diminishes from Conf. clean to Conf. full

Noise Sources at Gear and Flap Position – View on max. Level Noise Sources

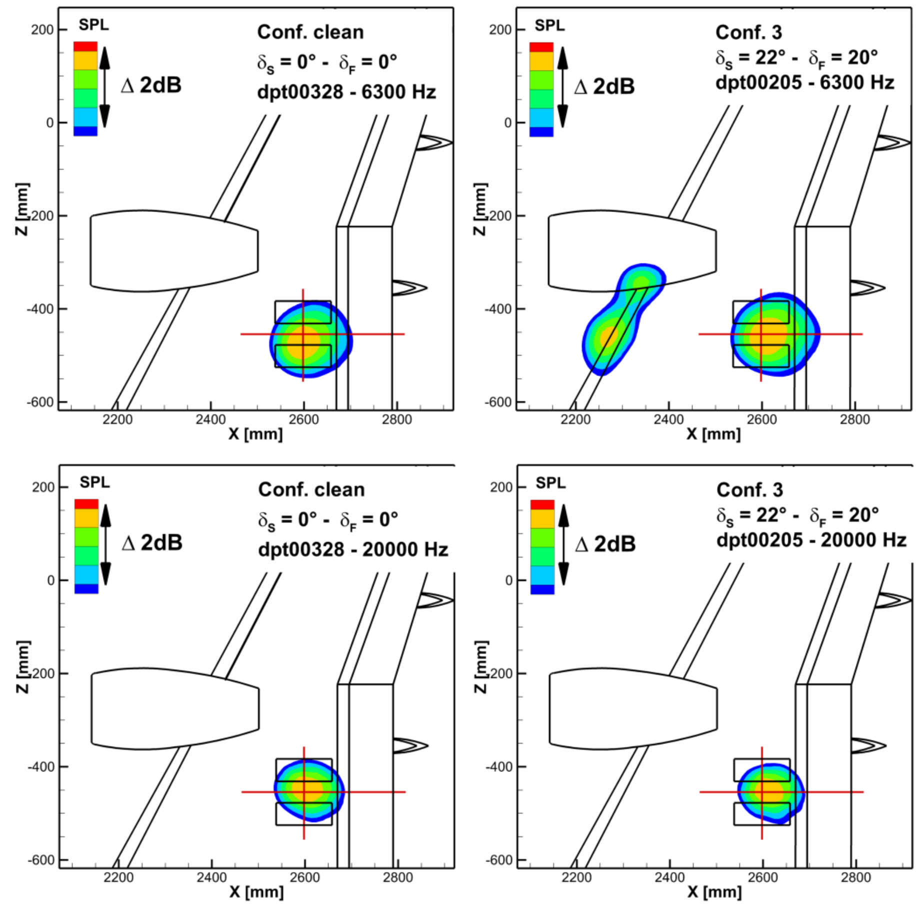


Noise Source Distribution Analysis for 0° and 20° Flap Deployment Angle

<u>Low to medium frequencies</u>:
Extended source area including flap leading edge for Conf. 3 (δ_F=20°)



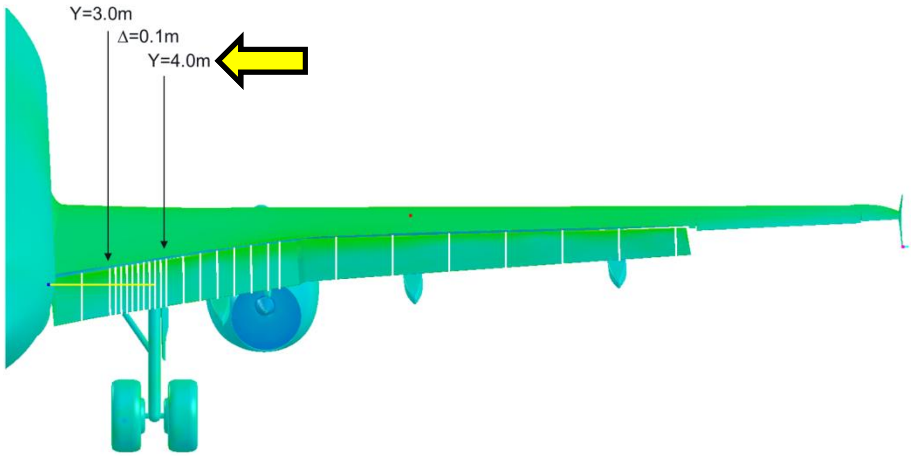
<u>Medium to high frequencies:</u>
Mainly landing gear noise, negligible effects on slat and flap



Correlation of Acoustic and CFD Data

Acoustic findings:

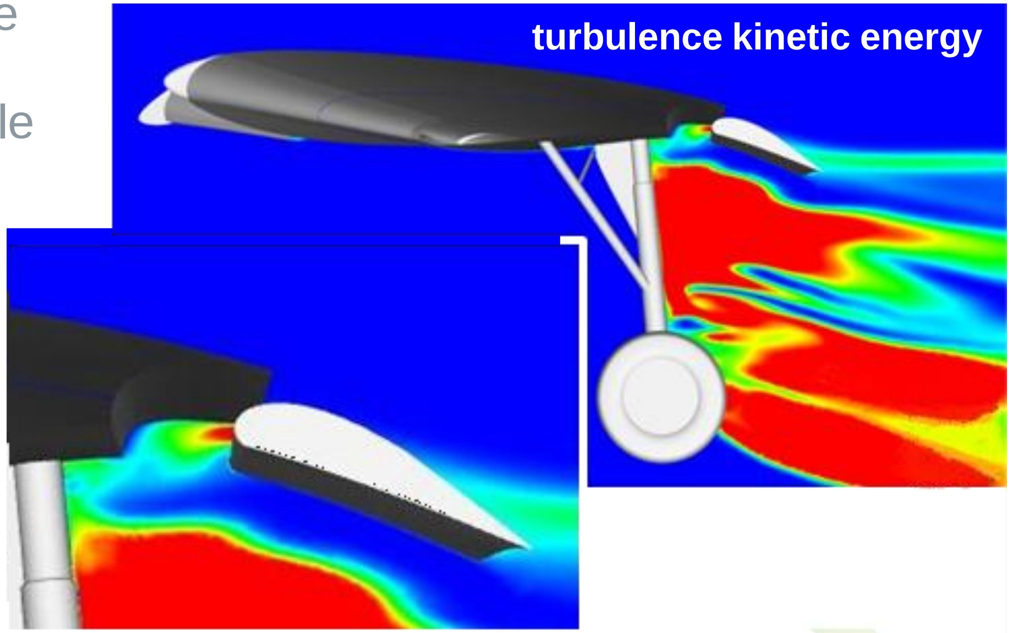
- Noise sources at gear and flap leading edge were identified for Conf. 3 (δ_F = 20°)
  - Frequency range: 1250 Hz to 4000 Hz
  - Position of flap related noise source is slightly outboard of the landing gear centre position



- For higher frequencies maximum noise levels show up at gear position only
- No dependence on flap deflection angle

CFD results:

- Strong TKE production downstream of gear door
- TKE spot at flap leading edge
- Most likely important noise source



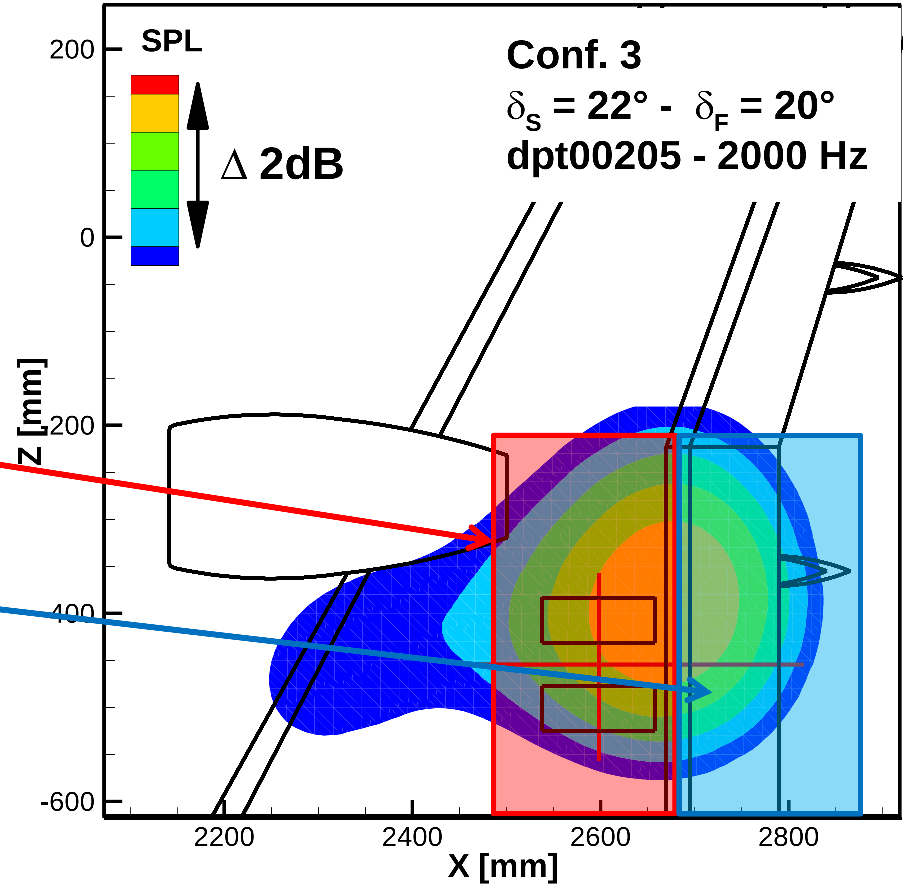
Separation of Gear and Gear-wake Flap Interaction Noise (I)

Definition of two scan grids

- Identical size and scan point distribution
- Computation of integrated spectra on each scan grid

- red grid: landing gear

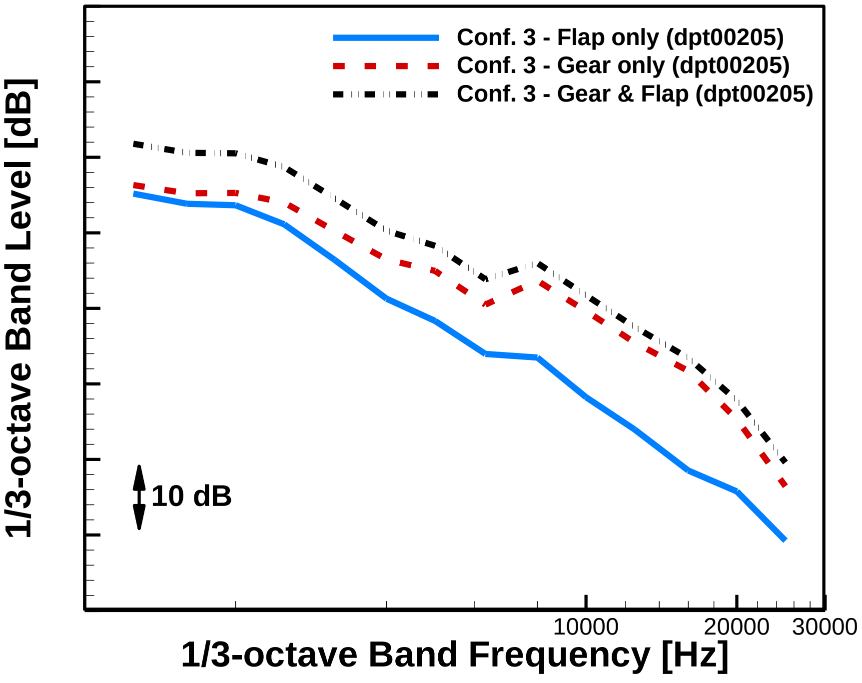
- blue grid: flap



Separation of Gear and Gear-wake Flap Interaction Noise (II)

Result of the noise source breakdown for Conf. 3 (δ_F = 20°):

- Interaction Noise and pure landing gear noise show sound pressure levels of similar magnitude for low frequencies
- Summation leads to about +3 dB in this frequency domain
- Interaction noise spectrum shows more rapid level decay towards high frequencies
- Reduced influence on overall sound pressure levels
- Sound pressure levels at medium to high frequecy range are dominated by landing gear noise

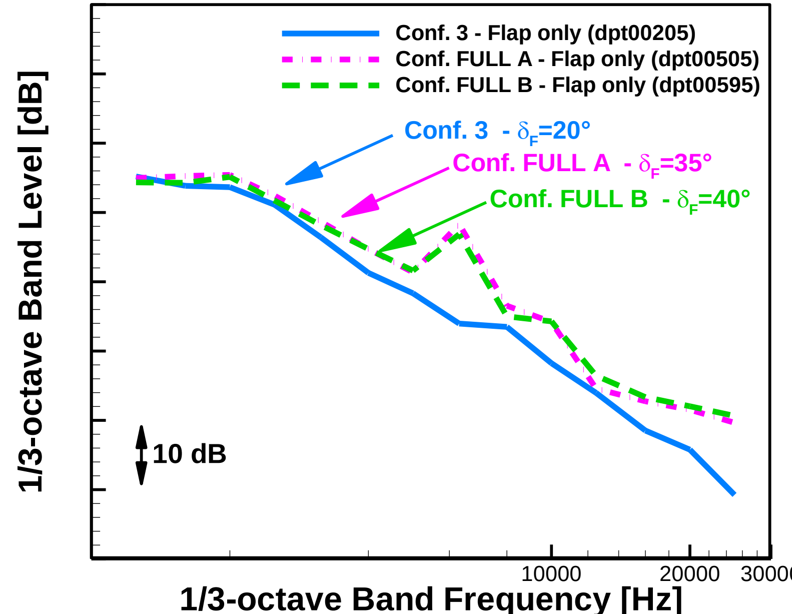


Characteristic of Gear-Wake Flap Interaction Noise

Effect of flap deflection angle

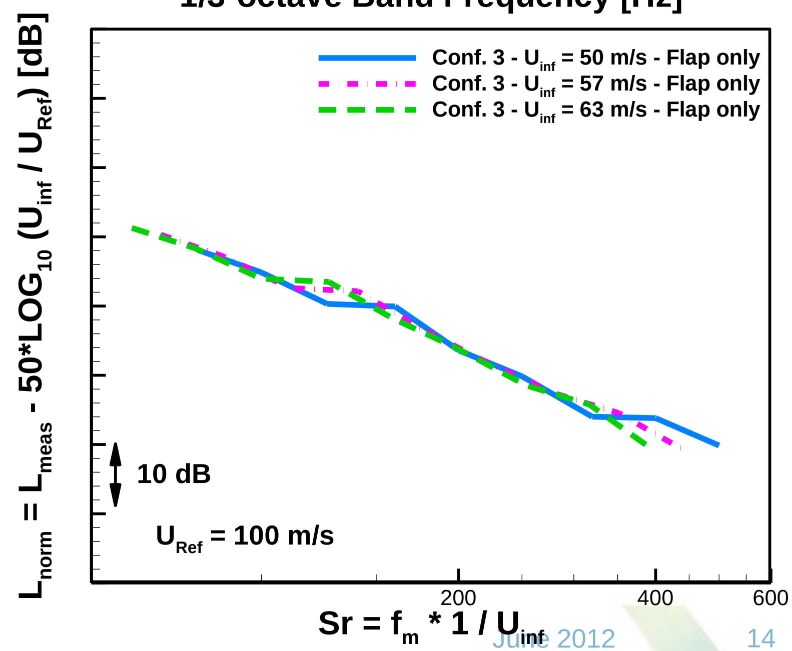
- A doubling of the flap deflection angle leads to a high frequency noise level increase
- Maximum levels at low frequencies are not affected

→ Flap deflection angle is only minor driver for gear-wake flap interaction noise



Effect of flow velocity

- Data were normalized with the free stream velocity
- A U^5 scaling provides the best data collapse
- Scaling is different from LG noise (usually $p'^2 \sim U^6$)



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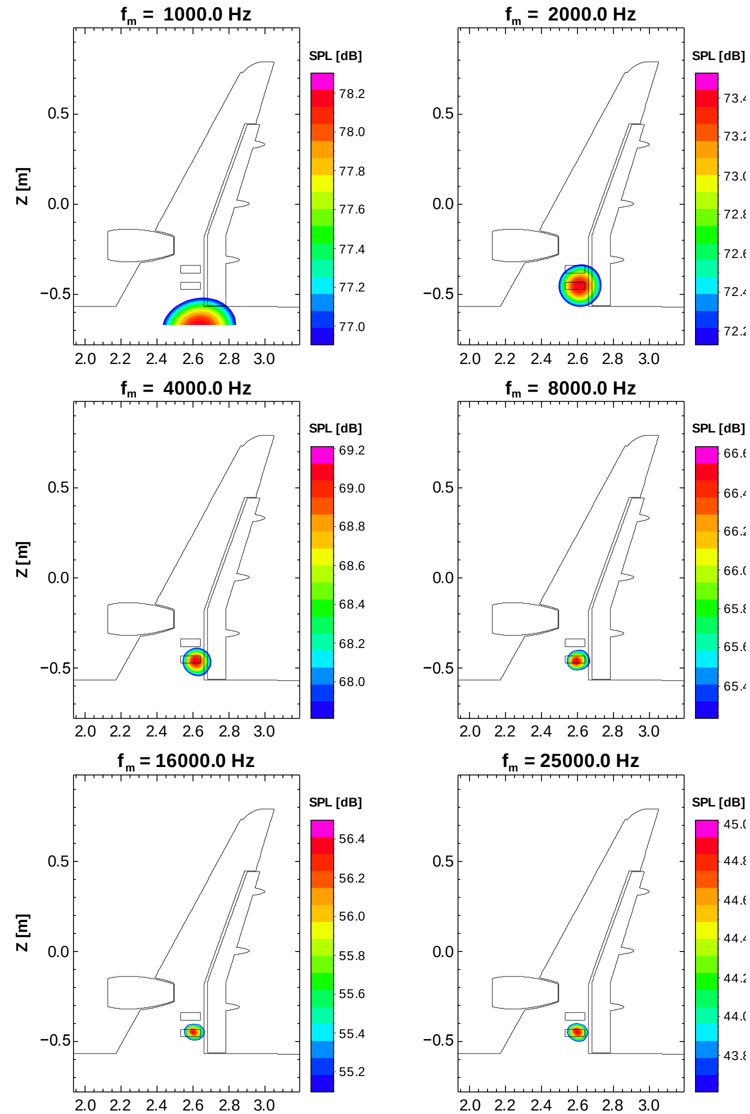
Spectral Representation of Gear-wake Flap Interaction Noise in the Acoustic Farfield

Database: single microphone sound pressure level data as measured for Conf. CLEAN and Conf. 3

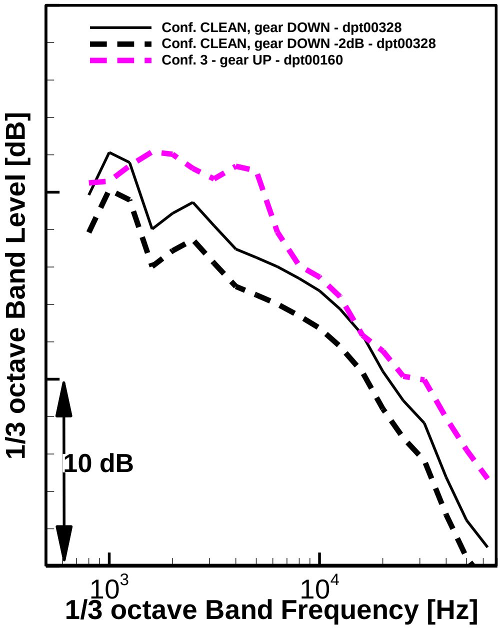
Approach:

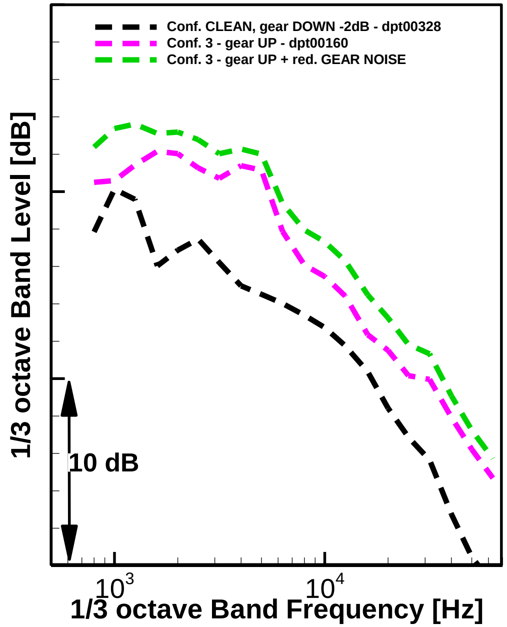
- Circulation around high lift wing increases due to flap deployment
- Local flow speed decrease upstream of LG is approx. 7%
- Assumption: $p'^2 \sim U^6$ velocity law for landing gear noise is valid.
- Result: -2 dB noise level reduction for pure landing gear noise in Conf. 3 wrt. Conf. CLEAN

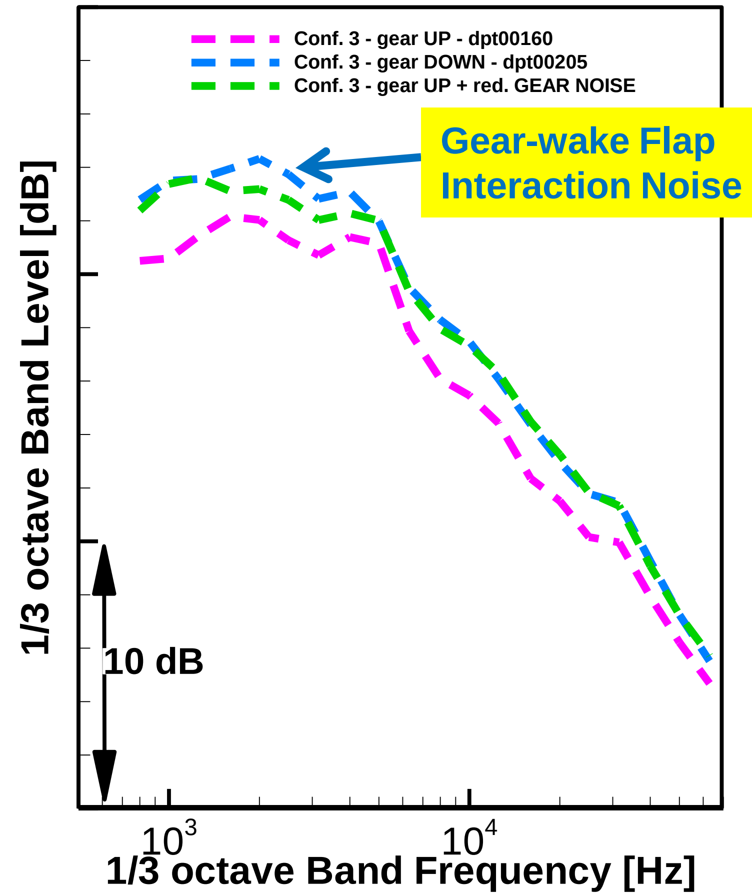
- Step by Step:
  1. Evaluate landing gear noise for config. CLEAN + LG
  2. Substract 2 dB and add up resulting spectrum to Config. 3 (high lift system only, no LG)
  3. Compare to measured data for Conf. 3 with LG deployed



Spectral Representation of Gear-wake Flap Interaction Noise in the Farfield







Gear-wake flap interaction noise can be identified in farfield noise data

- Low frequency phenomenon
- About 2 dB noise level increase wrt. pure LG noise
- No impact at high frequencies

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Summary and Conclusions

Study on gear-wake flap interaction noise was conducted with a 3-dimensional semi span model

On basis of array measurements interaction noise effect were identified and later on isolated in terms of sound pressure level spectra. The characteristics are

- Highest sound pressure levels at low frequencies and of similar magnitude as landing gear noise levels
- Presence of gear-wake flap interaction noise leads to about 2 dB higher noise levels at low frequencies
- Rapid level roll off towards high frequencies, no influence on airframe noise radiation
- Flap deflection angle and angle of attack have negligible influence on gear-wake flap interaction noise
- Present data show U^5 power law, which is in contrast to the SILENCE(R) results (U^6). Probably a Re-number effect.

Noise generation most likely induced by main leg / door wake

- Wake from upper landing gear area (main leg an leg door) leads to stong turbulent kinetic energy spot on flap leading edge

Gear-wake flap interaction noise is a high level airframe noise source.

In order to achieve an overall airframe noise reduction it is inevitable to either

- investigate means to reduce gear wake flap interaction noise or
- change the LG architecture and develop suitable body mounted landing gears.

Thank you !

For more information:

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