From (CTS) wind tunnel data to noise impact assessment

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Introduction

Current best practice:
• Aerodynamic test in Closed test sections (CTS)
• Acoustic tests in open test sections (OTS)

Preferable to use acoustic results obtained in CTS
• Scaling effects
• Geometric near field effects

Measurements only available at limited number of radiation angles

Desired are EPNL and noise impact assessment
Approach

• Public domain semi-empirical noise radiation models
  – calibrated against the CTS data
• We have limited ourselves to airframe noise
  – Flap side edge noise
  – Slat noise
  – Trailing edge noise
  – Landing gear noise

• Reconstruction of aircraft noise directivity by ad-hoc calibrations
• EPNL and assessment of environmental impact
4-step approach

Acoustic wind tunnel measurement
Isolation of sound sources
Acoustic wind tunnel measurements

- The sound strength from different sound sources on the model are obtained with phased microphone measurements.
- Diagonal removal is employed to remove boundary layer noise.
- Measurements in CTS are performed in geometric near field:
  - Every source
    - is located at a different distance
    - emits with a different angle to the array
Calibration of sound modules

- Sound source modules are calibrated at the local emission angle
  1) Local axis system at the centre of the sound source
  2) Transformation to inertial system
  3) Calculation of virtual sound source position
## Sound source modules

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<th>Source model</th>
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<td>Landing gear noise</td>
<td>Guo</td>
<td>- <strong>Empirical prediction of aircraft landing gear noise, NASA 2005</strong></td>
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<td>• Separate description for</td>
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<td>- <strong>Effects of a local flow variation on landing gear noise prediction</strong></td>
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<td>nose and main LG</td>
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<td>and analysis, JOA 2010</td>
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<td>• Local flow correction</td>
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<td>- Aircraft slat noise modelling and prediction, AIAA 2010</td>
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<td>- Component-based empirical model for high-lift system noise prediction, JOA 2003</td>
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<td>Aircraft flap side edge noise modelling and prediction AIAA 2011</td>
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<td>Brooks, Pope</td>
<td>Airfoil self-noise and prediction, NASA 1989</td>
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<td>and Marcolini</td>
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Calibration of noise modules

Landing gear noise

Flap noise

SPL (dB)

20 dB

Frequency (Hz)

10^2  10^3  10^4

Mach=0.13 ENOISE
Mach=0.16 ENOISE
Mach=0.2 ENOISE
Mach=0.25 ENOISE

SPL (dB)

20 dB

Frequency (Hz)

10^2  10^3  10^4

Mach=0.13 ENOISE
Mach=0.16 ENOISE
Mach=0.2 ENOISE
Mach=0.25 ENOISE
Calibration of noise modules

• Measured noise levels in WT can be reproduced

• Sound levels for different observer positions and conditions can be determined.
Full scale aircraft sound

- Full scale predictions by changing to full scale input
  - Strouhal scaling of frequency
  - Correction of levels to account for larger source region
  - Reynolds dependent scaling is used for high lift devices
    (Flap side edge noise and slat noise)
EPNL for noise impact assessment

• To assess the noise impact at certification points, levels need to be translated from source to an observer on the ground.

• Propagation effects
  – Spreading losses
  – Atmospheric attenuation
  – Ground reflection

• Doppler frequency shift
Prediction of fly-over data

![Graph showing prediction of fly-over data with SPL (dB) vs. Frequency (Hz) for different configurations: Slat + flap + LG noise, $\theta = 60^0$ and Slat + flap + LG noise, $\theta = 120^0$. The graph includes a label indicating a 20 dB difference.](image-url)
Footprints full scale aircraft prediction
Conclusions

• Models from the public domain are used to describe the behaviour of different acoustic sources.
• Acoustic sources are treated separately to correct for: Different distances, emission angles in the CTS and scaling effects
• Translation of acoustic CTS measurements to:
  – Emission footprints for full scale airplane and airplane parts
  – Effective Perceived noise levels for noise impact assessment
  – For different flight conditions

  – Good trend between translated CTS data and fly-over data.
Fully engaged
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