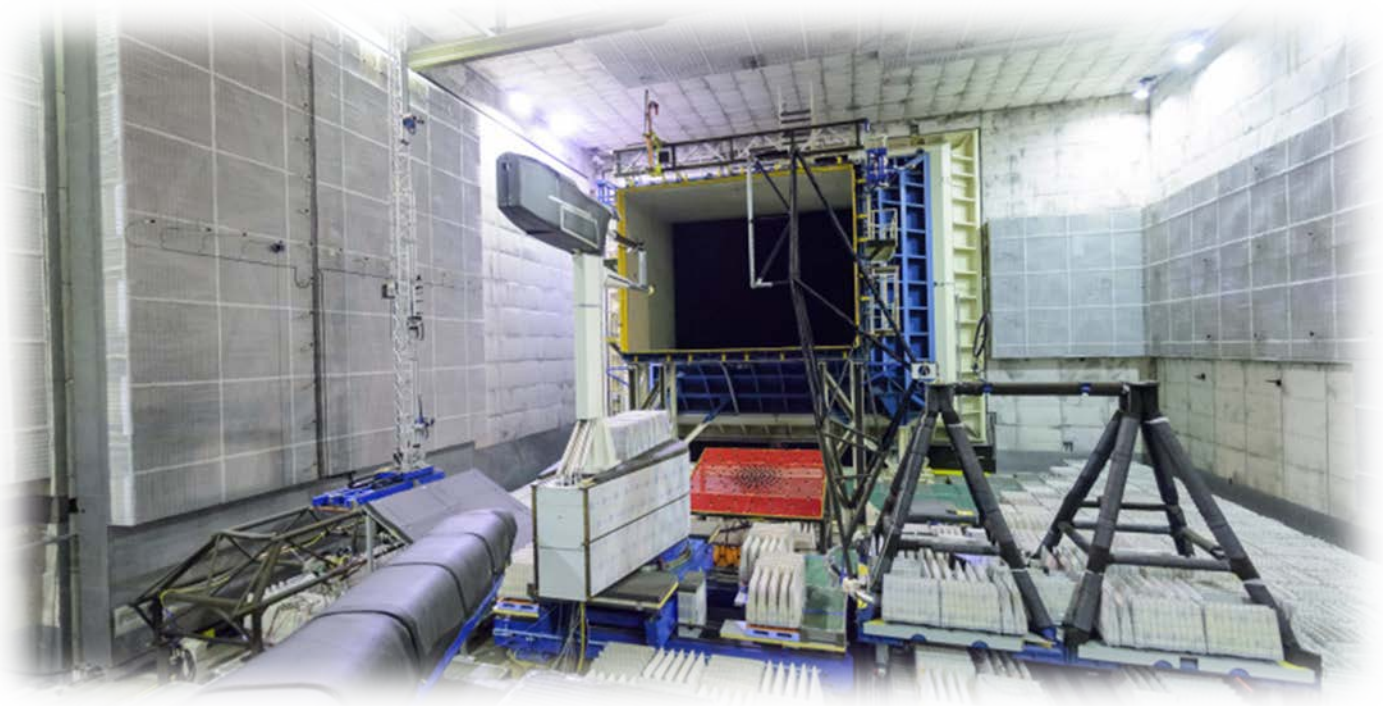


Acoustic testing at wind tunnel facilities of German-Dutch Wind Tunnels (DNW)

Hermann Holthusen, DNW Project Manager

German-Dutch Wind Tunnels

Contents

DNW sites and principle organization structure

Dutch Government

German Government

German-Dutch Wind Tunnels

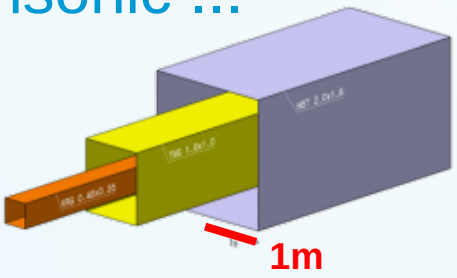
1.	Amsterdam	The Netherlands
2.	Marknesse	The Netherlands
3.	Braunschweig	Germany
4.	Göttingen	Germany
5.	Köln	Germany

German-Dutch Wind Tunnels

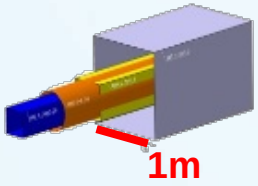
DNW wind tunnel facilities

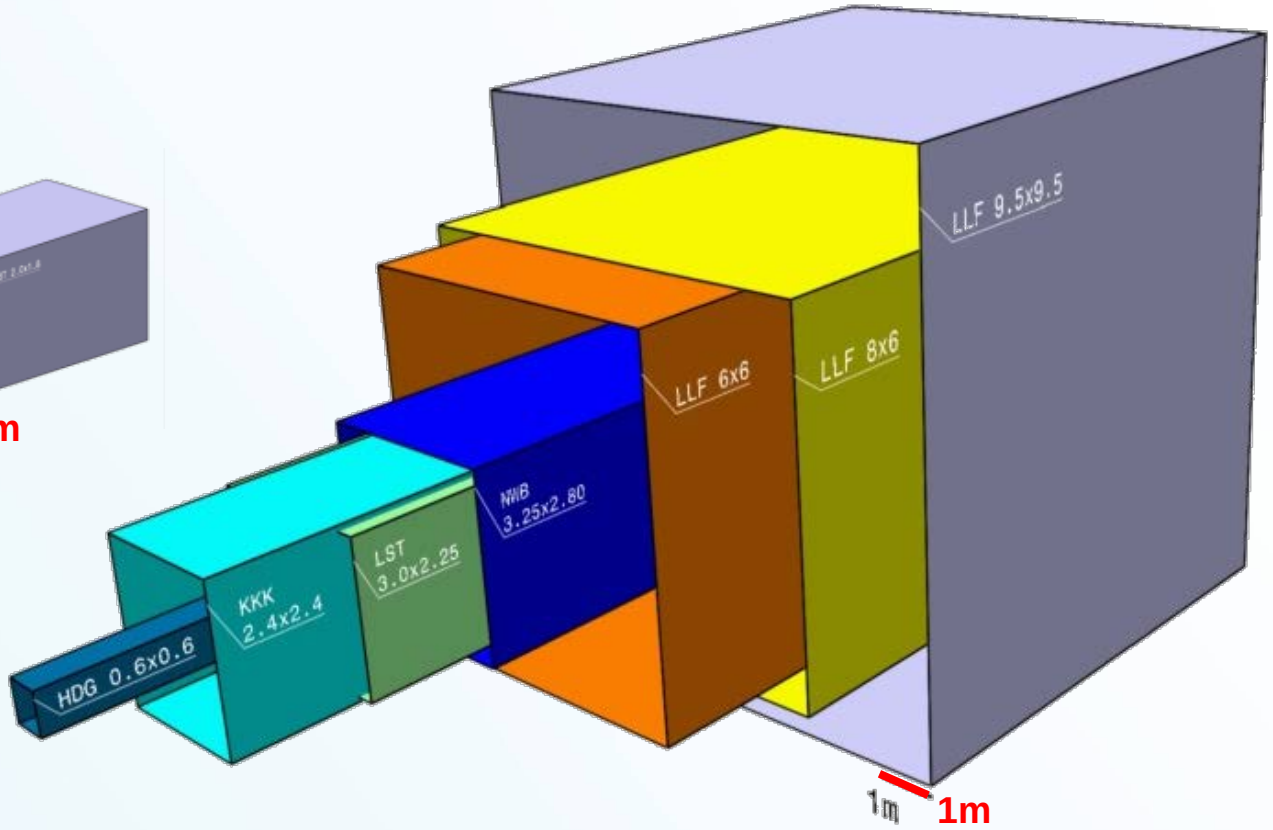
subsonic, ...

transonic ...



... and supersonic wind tunnels





- 2 Test facilities for industrial customers: LLF & HST
- **2 Test facilities for aeroacoustics: LLF & NWB**
- 1 Facility for non-aeronautical tests: LST
- 6 Facilities for R&D wind tunnel tests: NWB, KKK, TWG, HDG, KRG, RWG

DNW

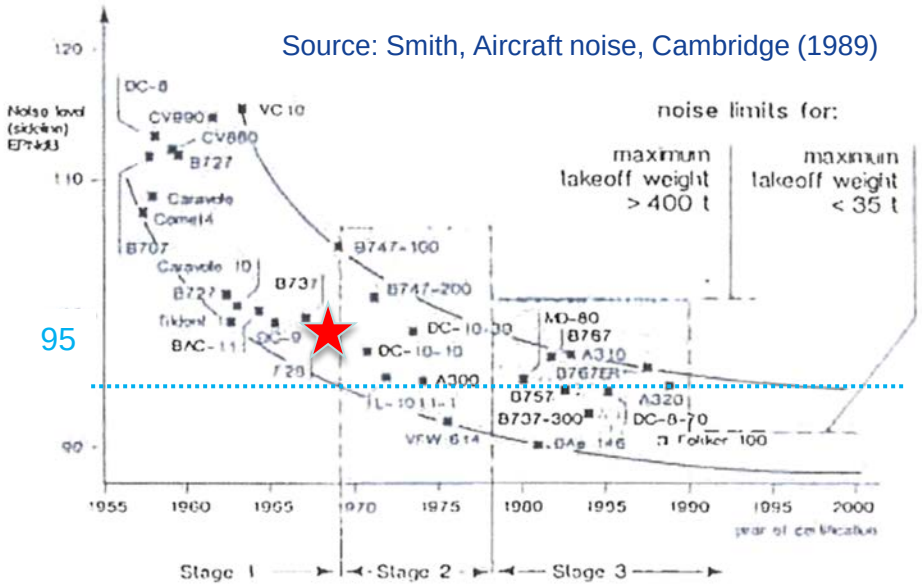
German-Dutch Wind Tunnels

- DNW organization
  - Sites & facilities
- DNW Large Low speed Facility LLF
  - Initial design
  - Acoustic upgrade
- Measurement techniques & capabilities
  - Acoustic measurement techniques
  - Examples of acoustic test capabilities at LLF
- Conclusions

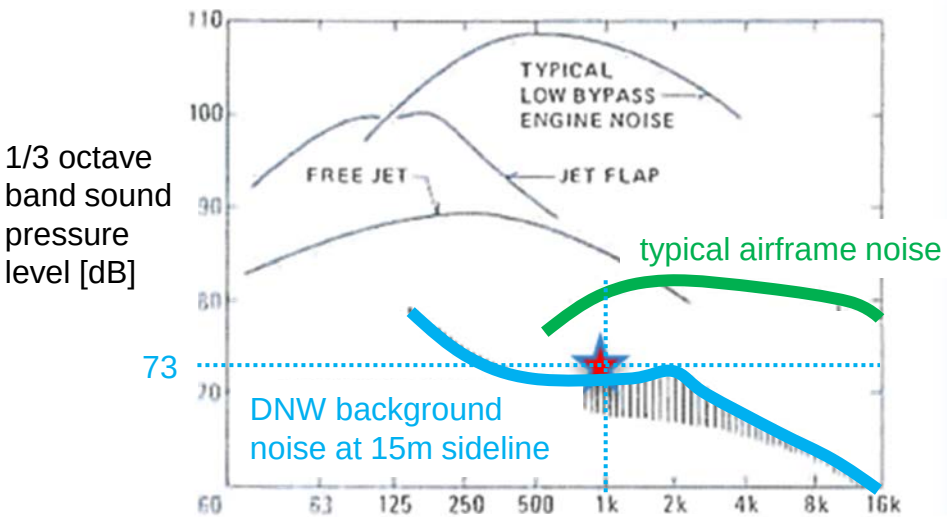
DNW-LLF original background noise (BGN) level design target (1979)

- Early 70ties initial background noise design point based on Fokker F-28
- Aim for **95 EPNdB** to account for future more stringent A/C noise requirements
- DNW-LLF design phase target set to **73 dB** out-of-flow (1/3 octave band @ 1 kHz, 80 m/s, 15 m tunnel side line)
- Realized BGN in 1980: **70 dB** (1/3 octave band @ 1 kHz, 78 m/s, 15 m tunnel side line)

Source: Smith, Aircraft noise, Cambridge (1989)



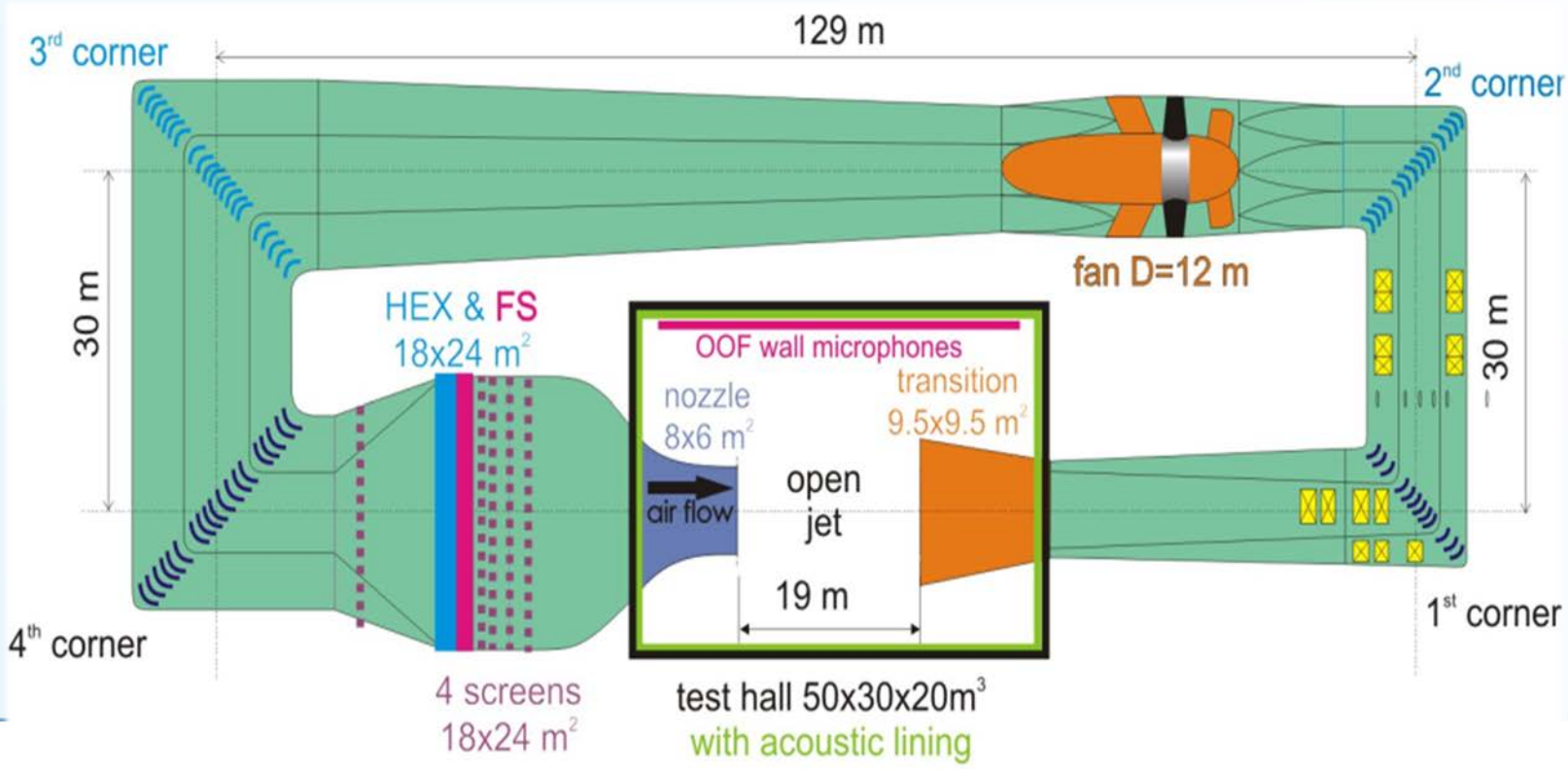
DNW background noise, wind speed 80 m/s



Acoustic upgrades of LLF

After 30 Years of operation ….. reduction of background noise:

- 2010: Modifications of Nozzle and Transition
  - Successful reduction of several (mainly tonal) noise sources
- 2010: Investigation of potential noise reduction by fan modifications
- 2011: Major upgrade by acoustic lining of turning corners 2 & 3
  - Successful broadband noise reduction up to 6 dB

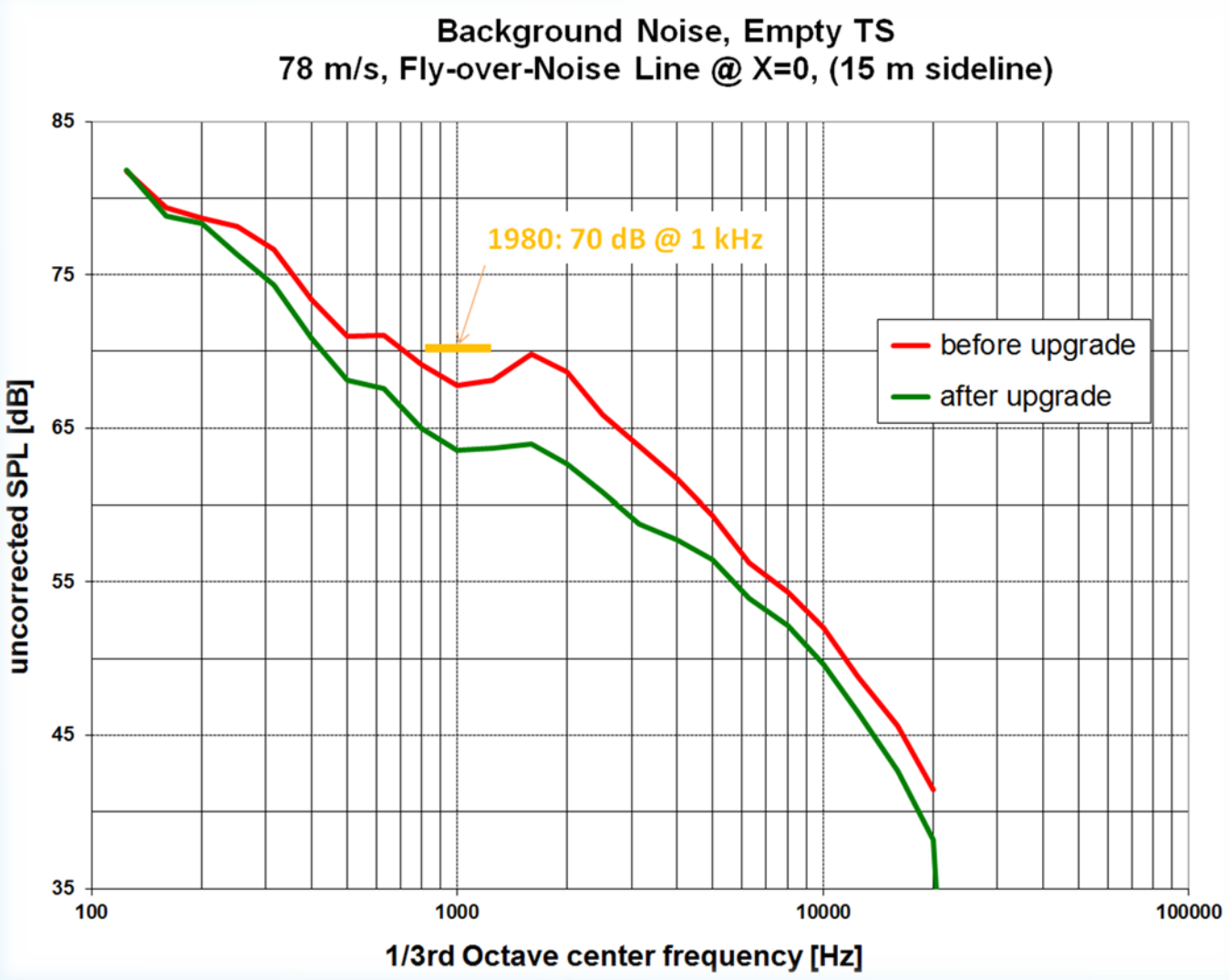


Acoustic upgrade turning vanes

Impressions from construction work in the 3rd corner upstream side

German-Dutch Wind Tunnels

Acoustic upgrade turning vanes: lower BGN



some serious investments and 11 weeks of downtime required to lower the BGN by a few dB ….

But that is normal in aeroacoustics …

….the last dBs cost the most!

German-Dutch Wind Tunnels

- DNW organization
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Acoustic measurement techniques at DNW

Single Microphones

- ~80x ½” free-field condenser microphones (B&K and GRAS) (LLF & NWB)
  - for use inflow and/or out-of-flow
- ~160x free-field (pre-polarized type) microphones
  - for use at out-of-flow measurement positions for monitoring tasks

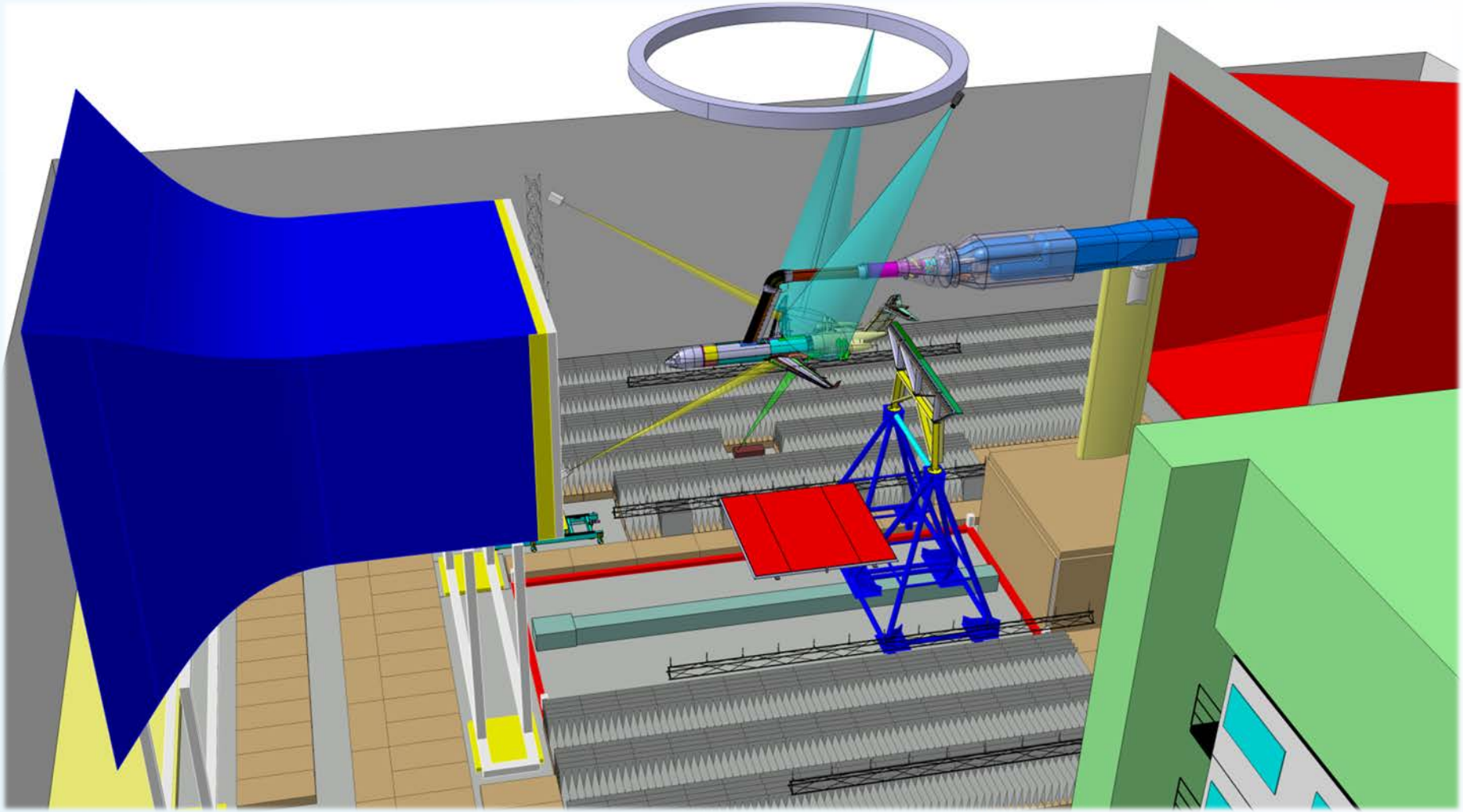
Phased Microphone Arrays

- 4x out-of-flow phased microphone arrays (LLF & NWB)
  - For application in open test sections
  - aperture **4m*4m** and **3m*3m**, 140 pre-polarized microphones each (total ~560)
- 2x inflow phased microphone wall arrays
  - for application in closed test sections
  - aperture **1m*1m**, 144 pre-polarized microphones each (total 288)

Data Acquisition Systems

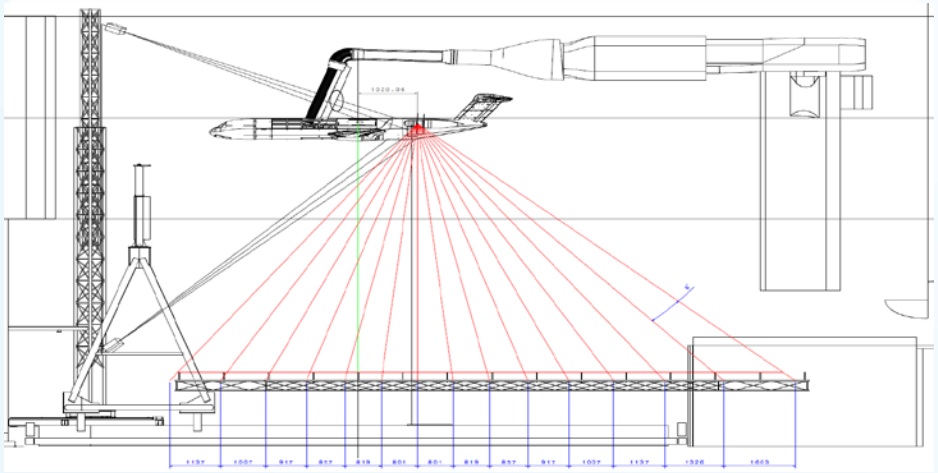
- 9x GBM Viper 16bit data acquisition systems (LLF & NWB)
  - 48 channels each (total **432**)
- 3x GBM Viper 24 bit data acquisition systems
  - 64 channels each (total **192**)

Typical aircraft-engine noise setup in OTS
Open Rotor engine; CAD pre-test design



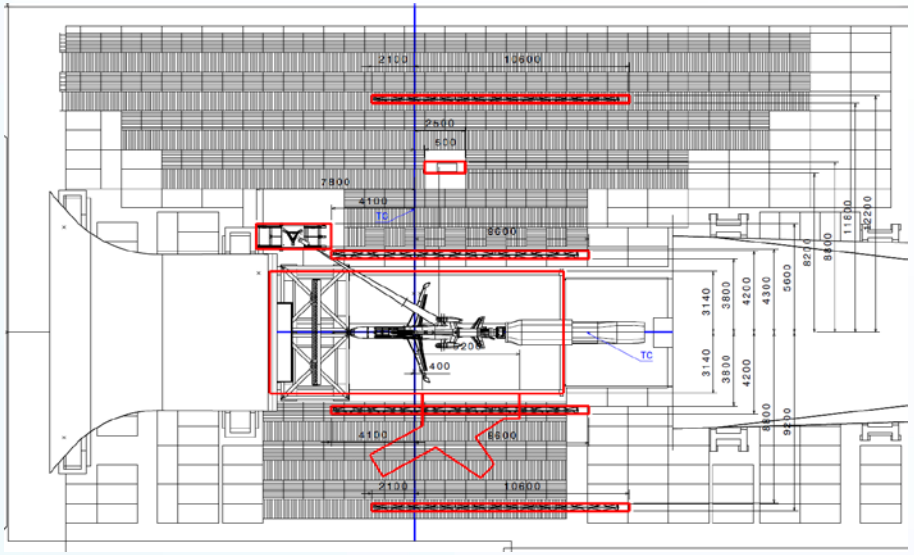
Typical aircraft-engine noise setup in OTS CAD: layout for microphone observer lines

Side-View

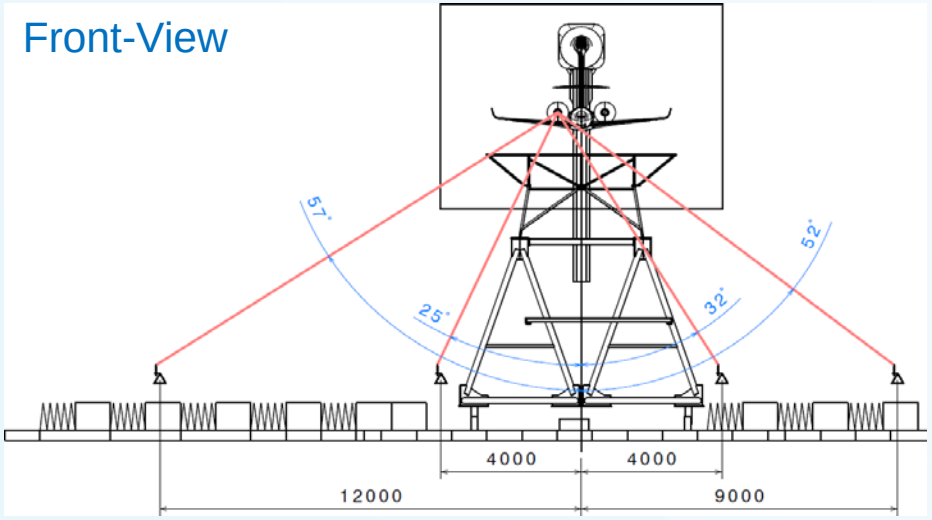


Fly-over noise observer line

Top-View



Front-View



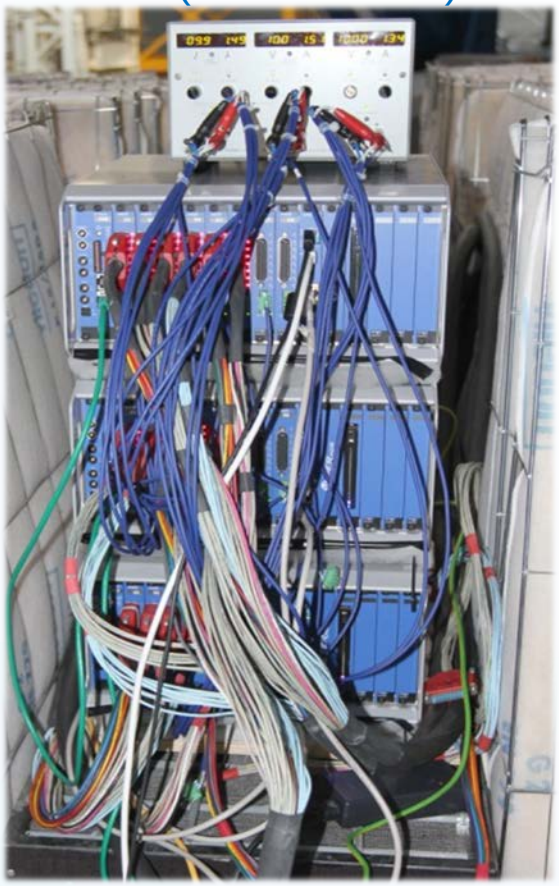
Side-line noise observer lines

German-Dutch Wind Tunnels

Typical aircraft noise testing at DNW acoustic data acquisition systems

6x 16bit Viper systems
(288 channels)

3x 24bit Viper systems
(192 channels)



Typical setup of acoustic measurement channels

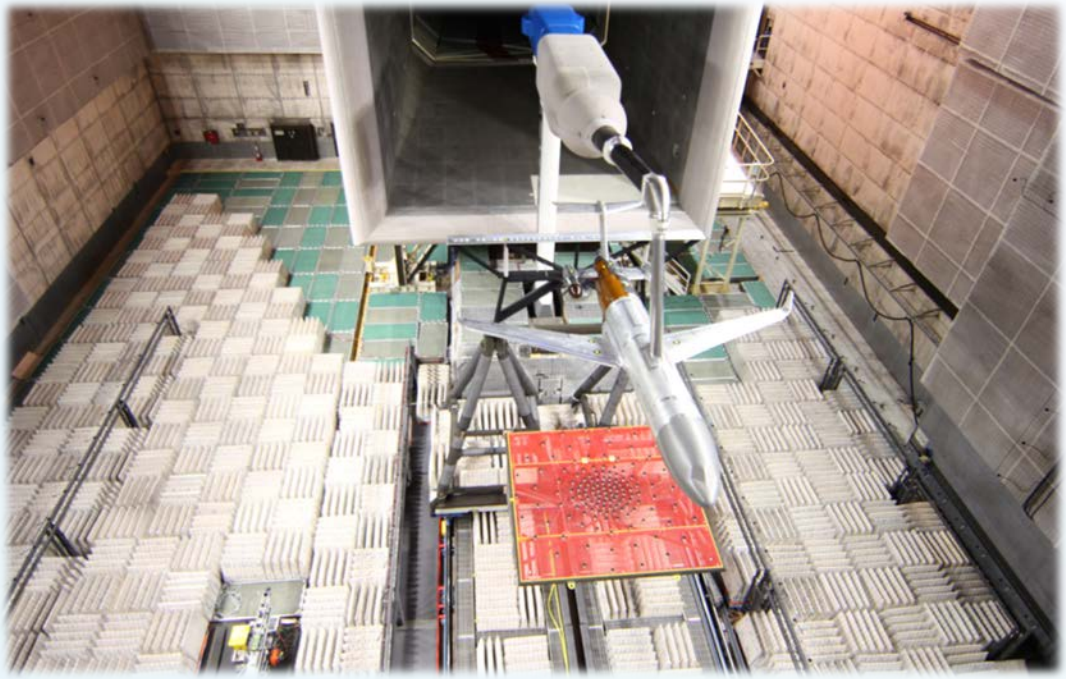
- ~10-60 channels for traversing inflow microphones
- 140-288 channels for phased microphone arrays
- ~10-60 channels for out-of-flow microphone lines
- ~10-100 channels for out-of-flow monitor microphones
- ~10-100 channels for unsteady pressure sensors in model

German-Dutch Wind Tunnels

Typical aircraft noise testing in OTS

From preparation….

…to testing



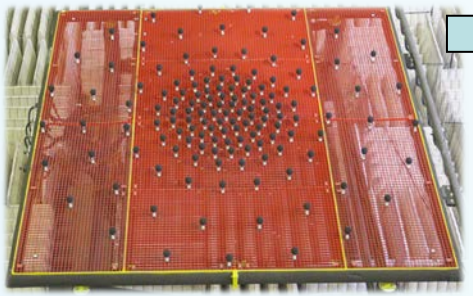
German-Dutch Wind Tunnels

Typical aircraft-engine noise testing in OTS realized test-setup

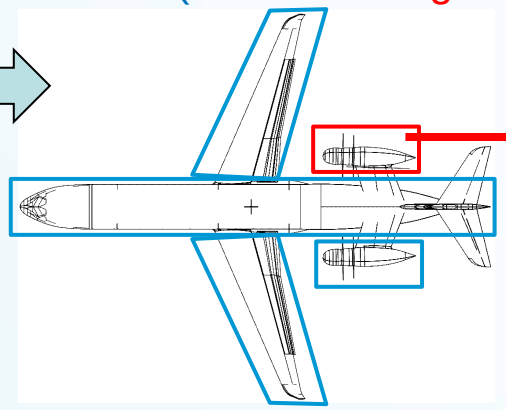
German-Dutch Wind Tunnels

Phased microphone technique at DNW

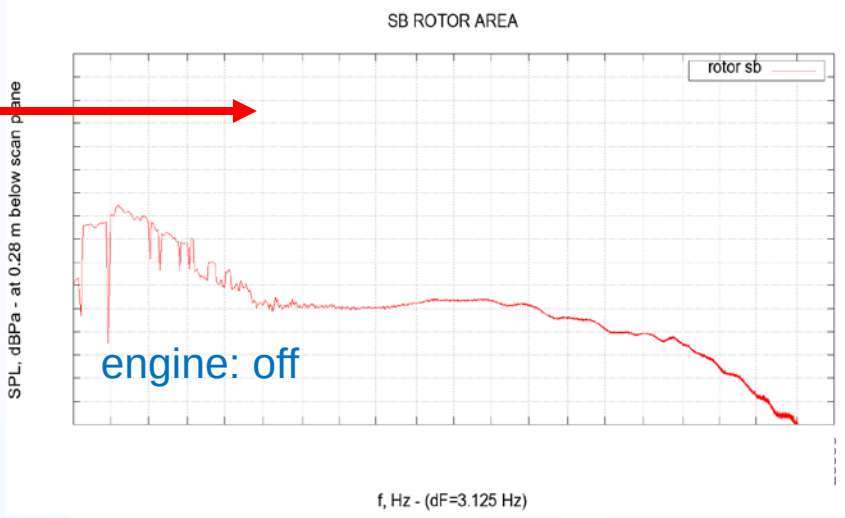
Array measurement

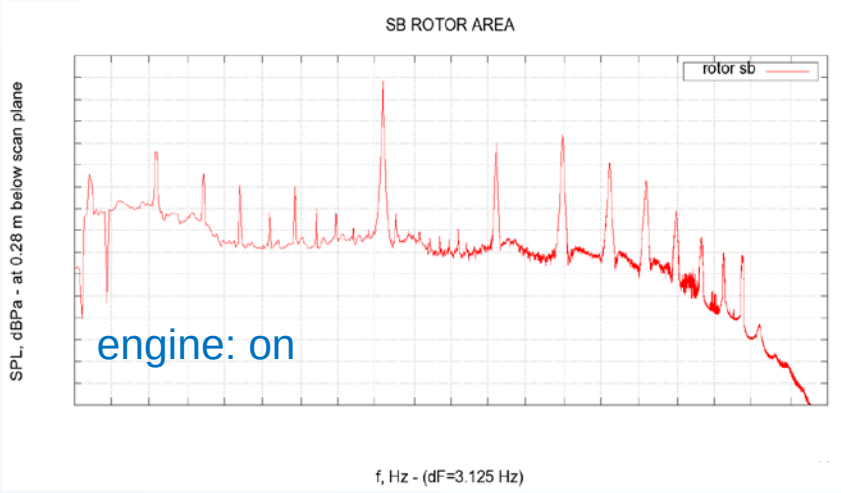


Scan areas (starboard engine)



Integrated spectra for specific areas





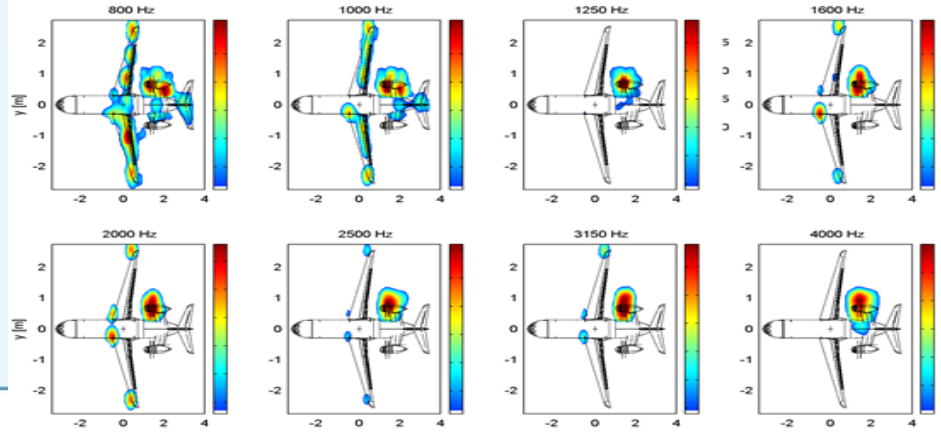
Noise source maps for complete model

German-Dutch Wind Tunnels

Clean Sky

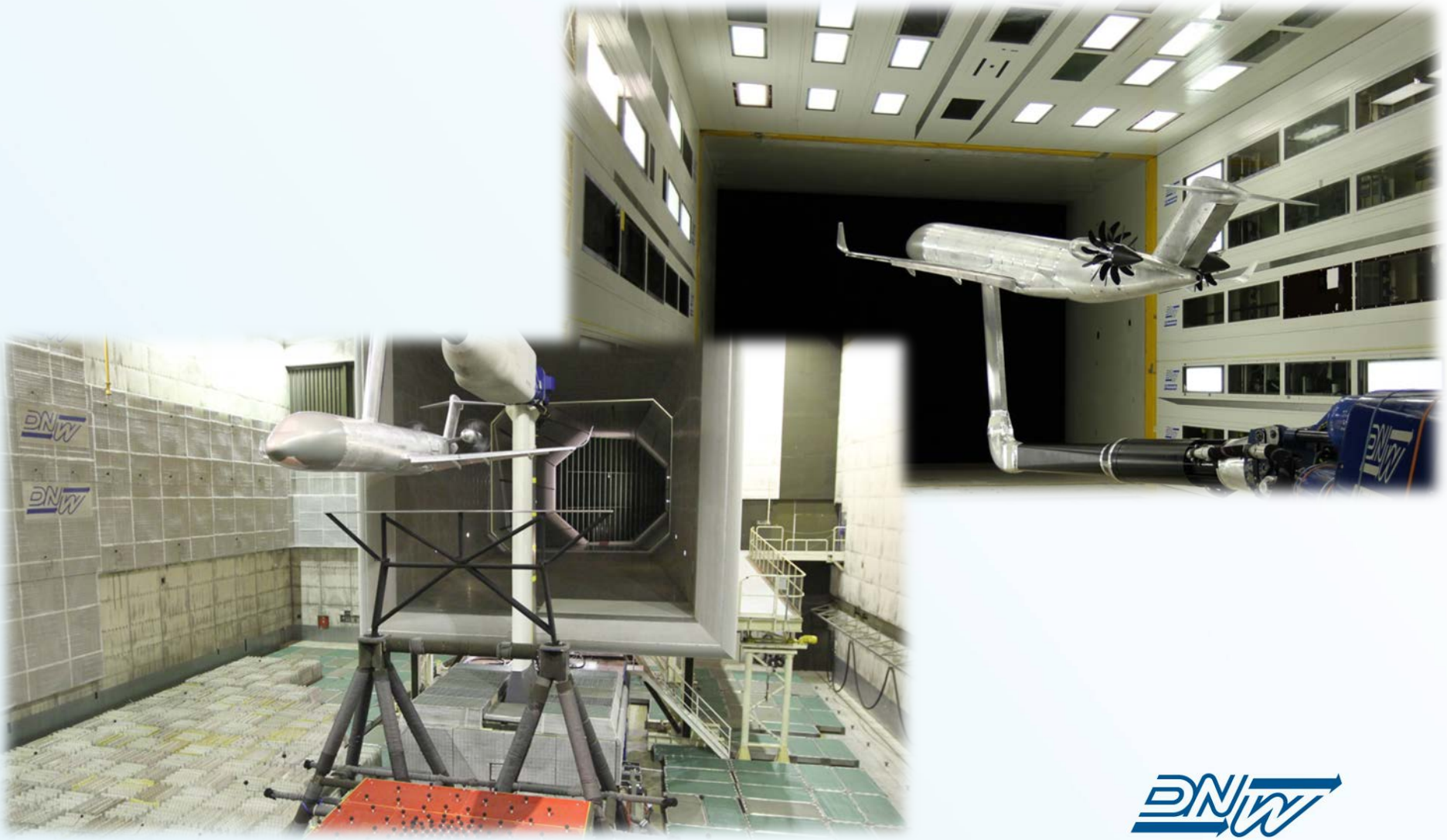
TA161457-161541 - Z08 / ARRAY

DNW-RUN	: 057	VELOCITY (m/s)	: 62.4
DNW-POL	: 0142	MA (-)	: 0.180
DNW-DPN	: 02945	ALPHA (deg)	: 7.8
		X-ROTOR (m)	: 1.089
TRAVERSE-X (m)	: 4.000	Z-ROTOR (m)	: -0.125
SCAN AREA	: Full Z08 Overview	RPM.SF (rpm)	:
PROCESSING	: A-CSC.20kHz-32k	RPM.PF (rpm)	:
Final	: CSC-POWINT	CONFIG	:



German-Dutch Wind Tunnels

Counter Rotating Open Rotor (CROR) Engine Integration: noise and performance



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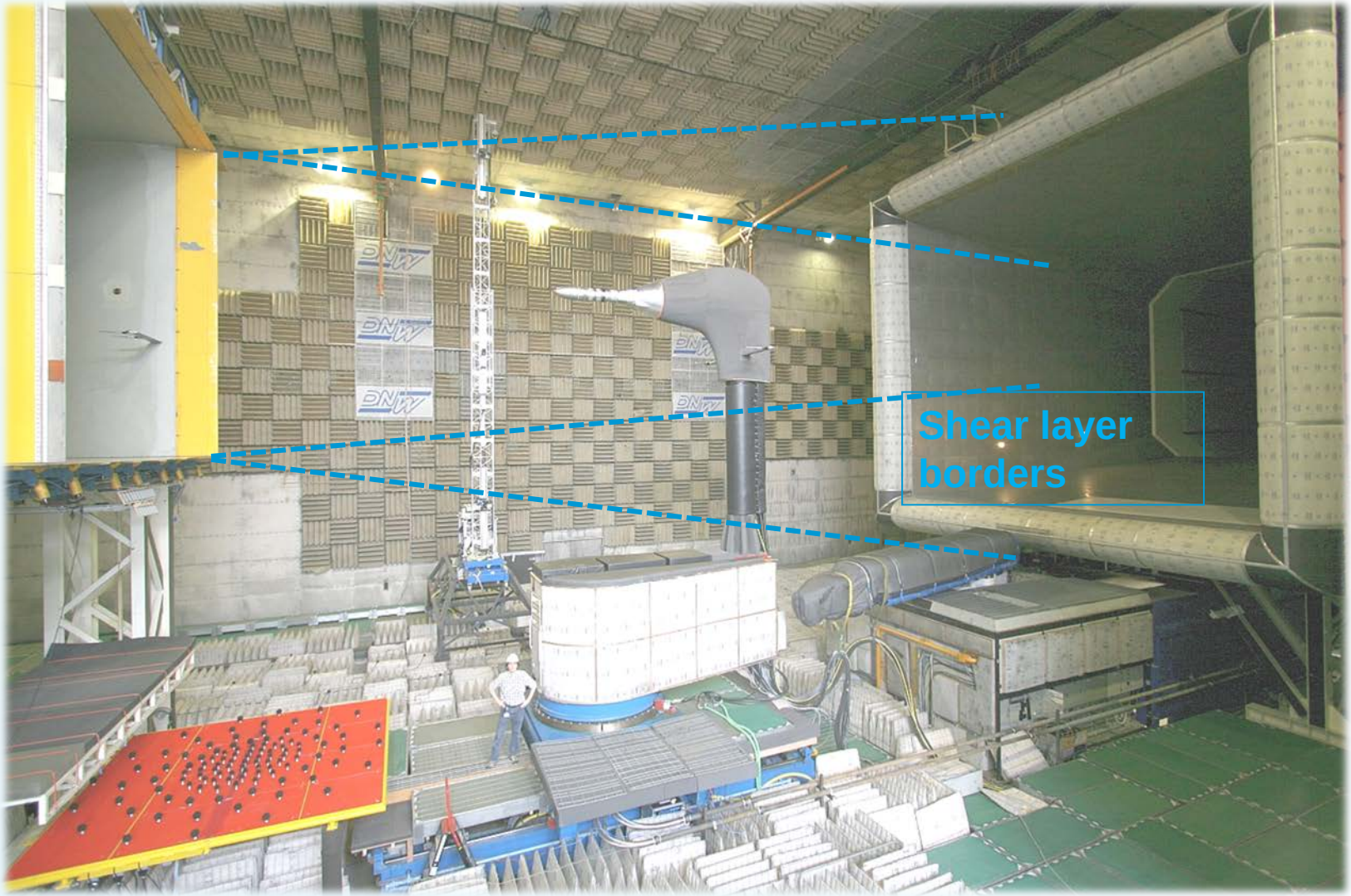
Acoustics on Isolated CROR Engine (CleanSky)



German-Dutch Wind Tunnels

Acoustics on Isolated CROR Engine (CleanSky)

German-Dutch Wind Tunnels

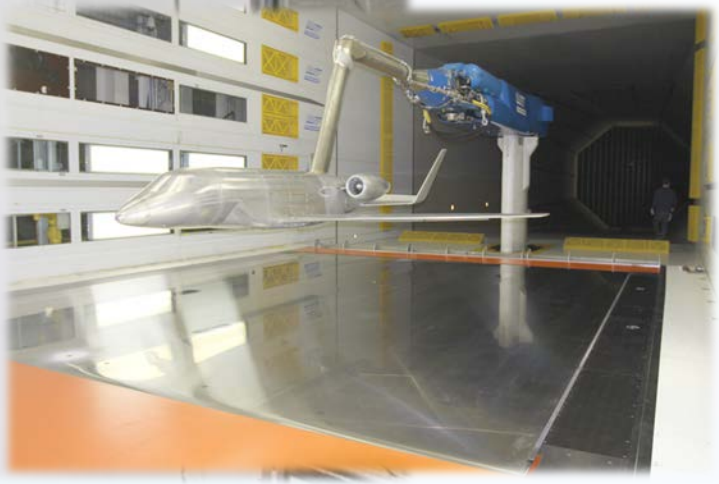
Acoustics with Isolated Engine (CleanSky)

Reference setup as base for installed test with source shielding

German-Dutch Wind Tunnels

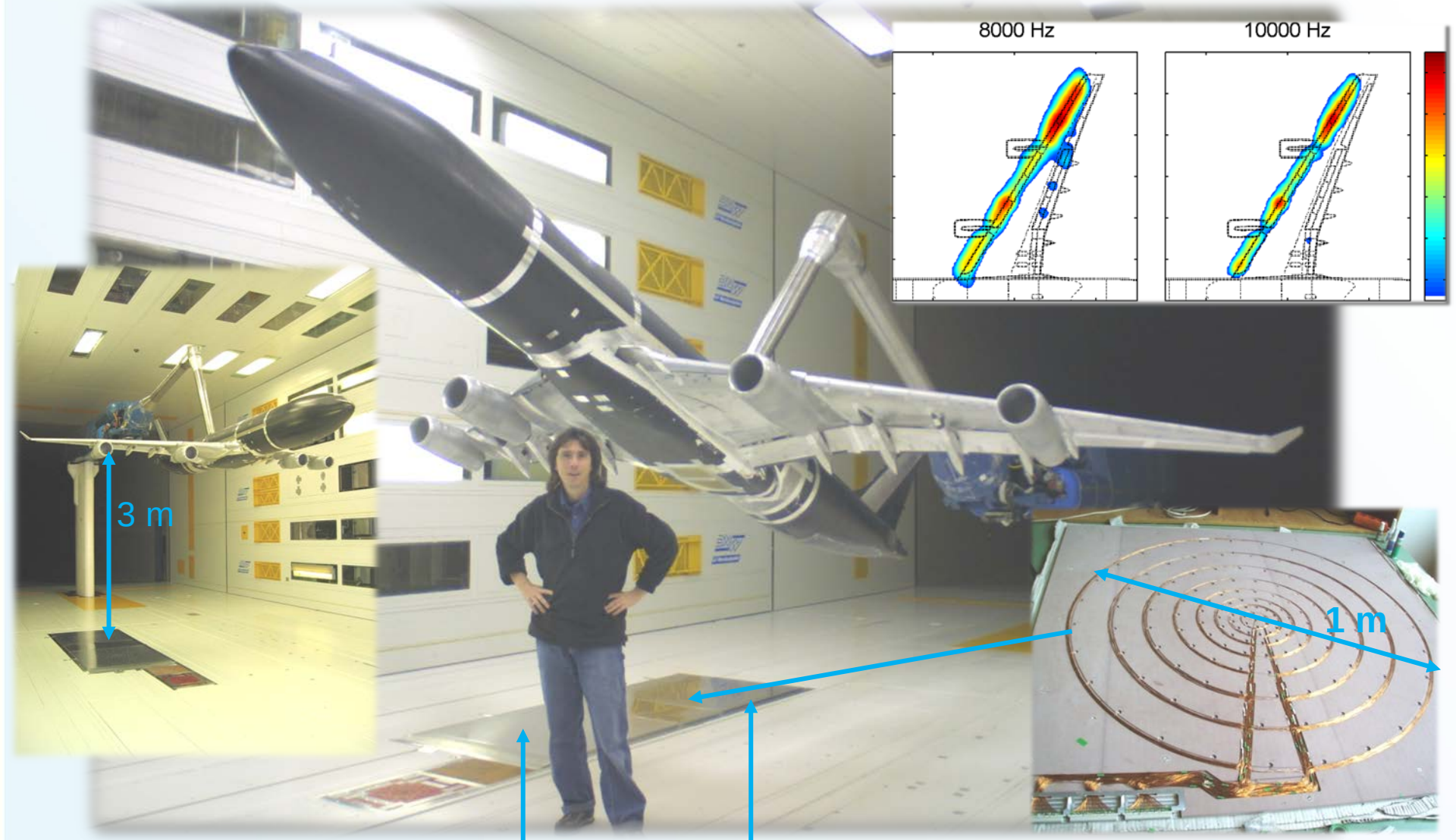
Acoustics with Installed Engine (CleanSky)

Comparison setup to evaluate effect of different noise shielding techniques



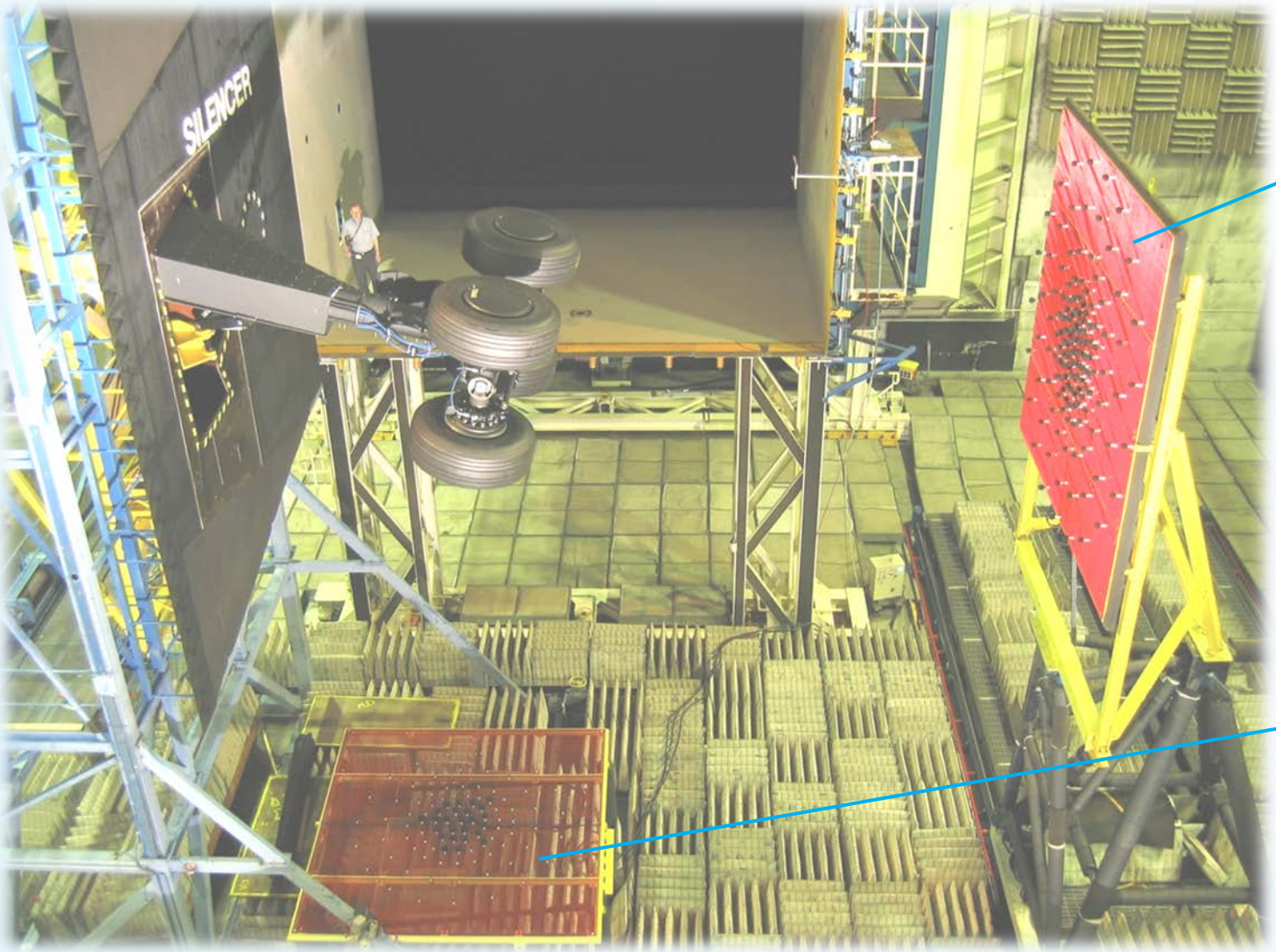
German-Dutch Wind Tunnels

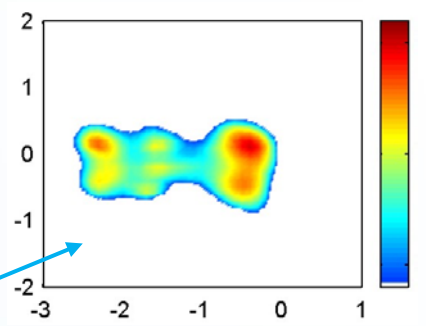
Airframe Noise measured with Wall arrays



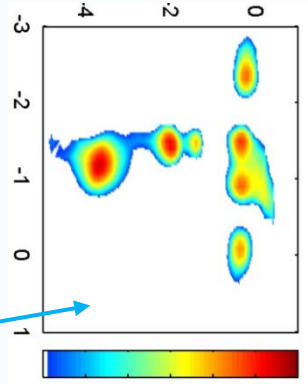
German-Dutch Wind Tunnels

Acoustics on Full-Scale A340 Landing Gear (EU)





Fly-over-line-view array

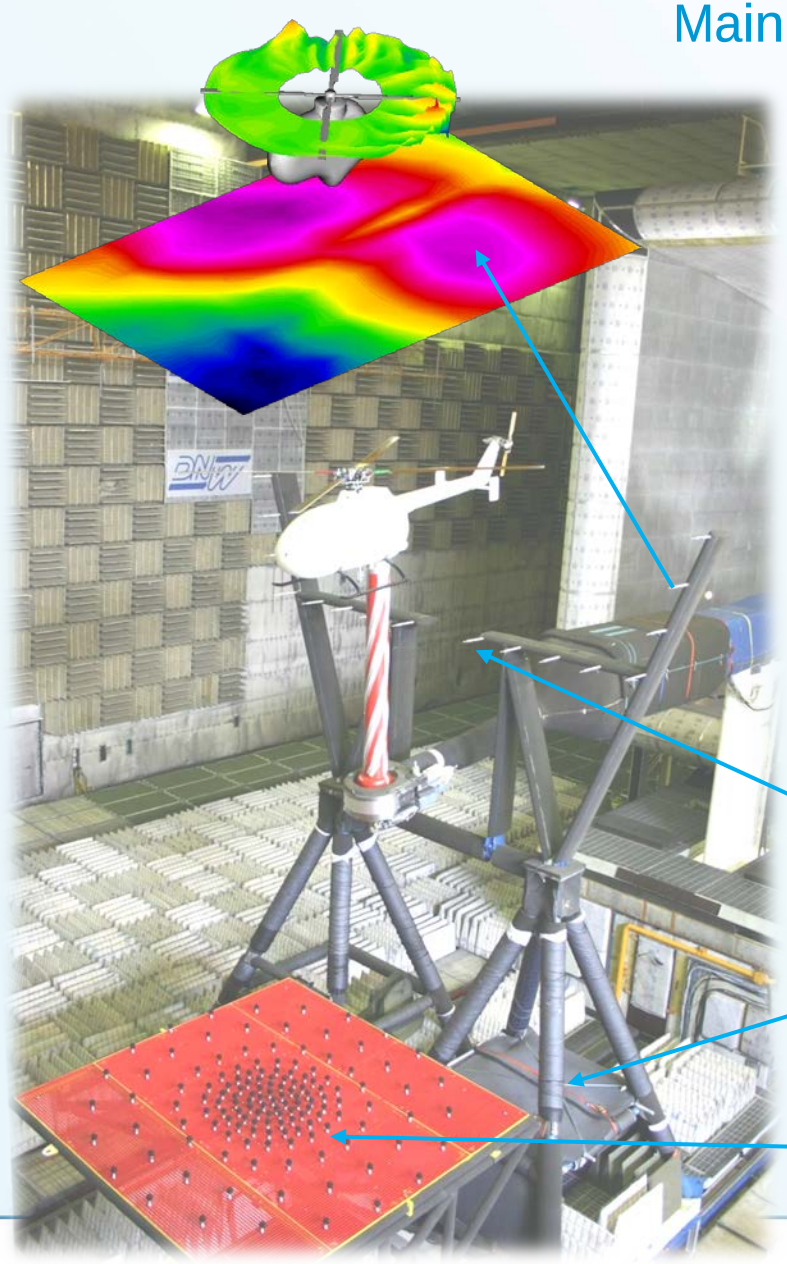


Sideline-view array

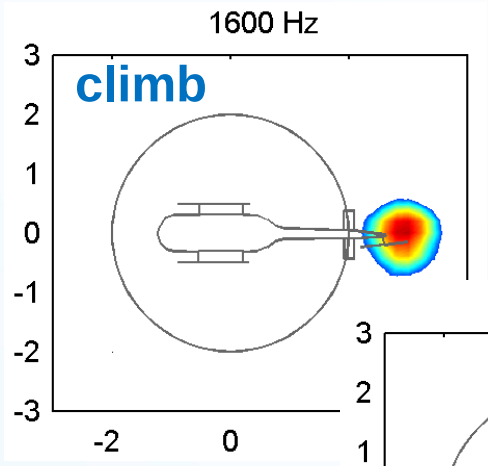
German-Dutch Wind Tunnels

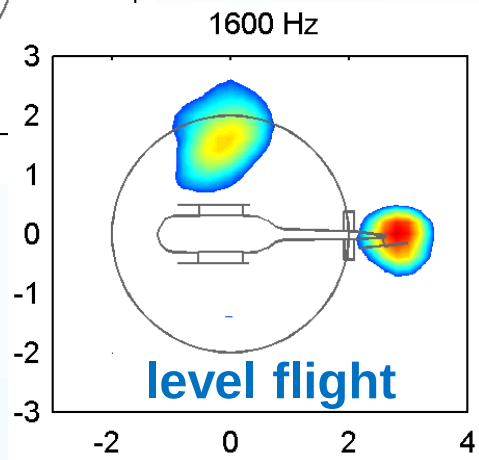
Acoustics on 1:4 Scale Helicopter (R&D)

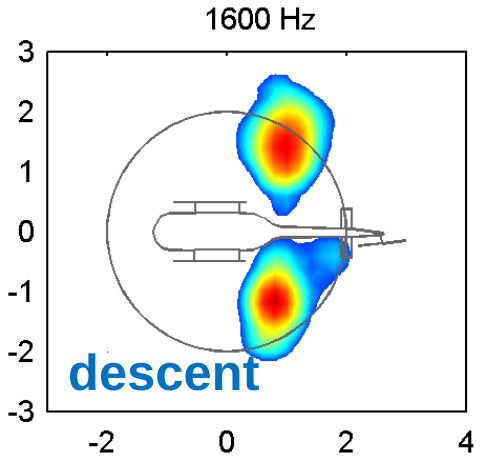
Main & Tail Rotor



Array source plots

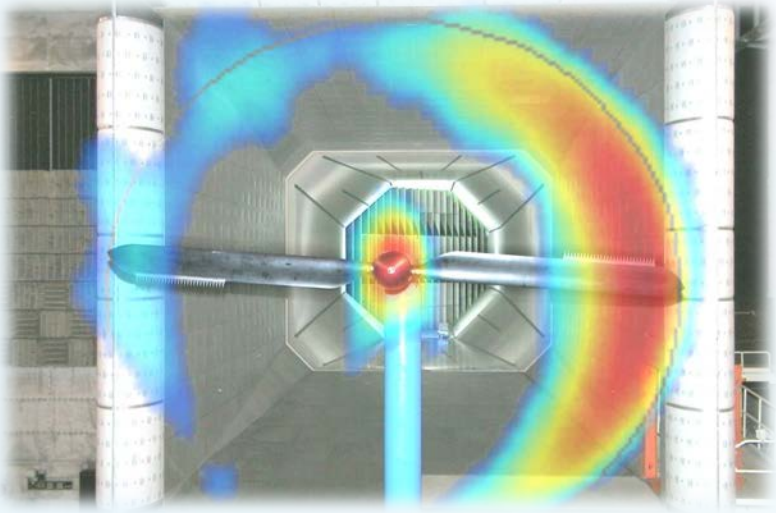




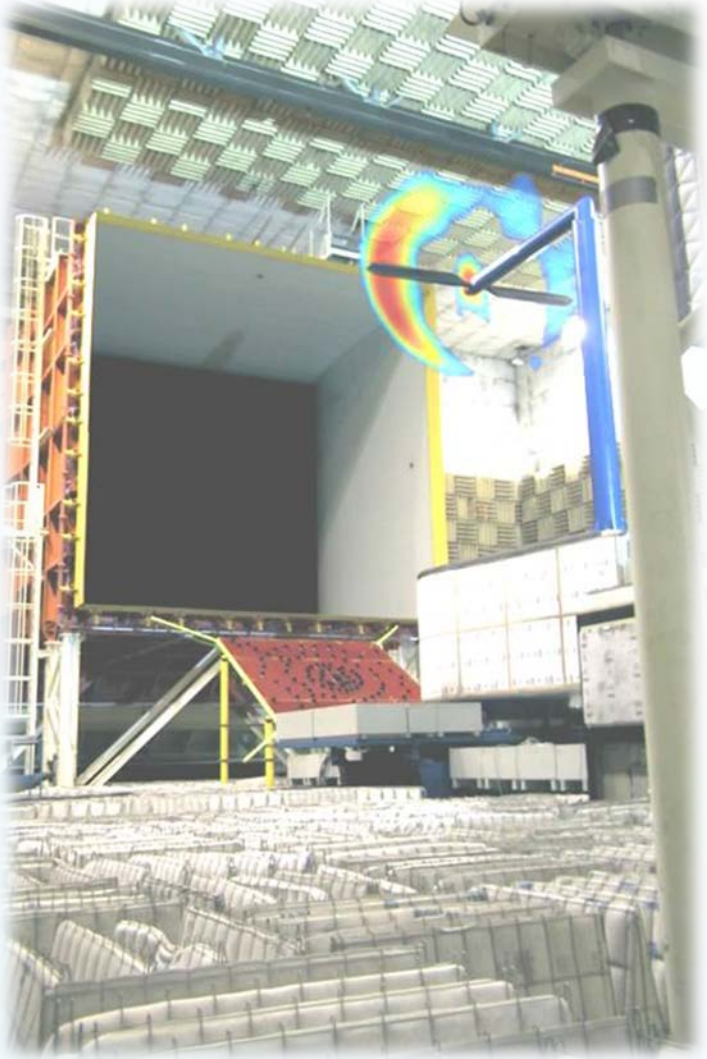


Acoustics on Scaled Wind Turbines (Industry)

Noise sources identification in rotor plane



Noise sources identification for individual rotor blades



German-Dutch Wind Tunnels

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Conclusions

- DNW facilities (especially LLF and NWB) are used extensively for aero acoustic testing by European and non-EU research and industries
- Versatile acoustic technologies as part of wind tunnel infrastructure, with focus on aircraft airframe and engine noise
- Engine noise and engine integration is the main focus of wind tunnel research for the near future

Time for questions ...?