Lärmminderung bei Modernen Flugtriebwerken

ICANA 2023

Leitthema: Aktiver Schallschutz an der Quelle

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Technology pathway to net zero

To achieve net zero carbon we must ensure that all of our products are compatible with net zero carbon operation by 2050, at the latest.

This will be achieved through further advancing the efficiency of our engine portfolio, ensuring our products can be used with alternative fuels and introducing new low or zero emission products, including fuel cells, microgrids, hybrid-electric and all-electric technologies.

Agenda

- Bestandsaufnahme zum Thema Fluglärm
  - Warum ist die Reduktion von Fluglärm so wichtig?
  - Was wurde bisher erreicht?
  - Schallquellen an einem Flugtriebwerk
- Der Beitrag von Rolls-Royce zur zukünftigen Lärmreduktion
  - Powering sustainable growth
- Die Forschungslandschaft in Deutschland
- Schlussfolgerungen

Bestandsaufnahme zum Thema Fluglärm

Schwerpunkt: Triebwerkslärm

ACARE Flightpath 2050 Objectives

ACARE

SRA - 2002, 2004 & 2008

SRIA - 2012 & 2017

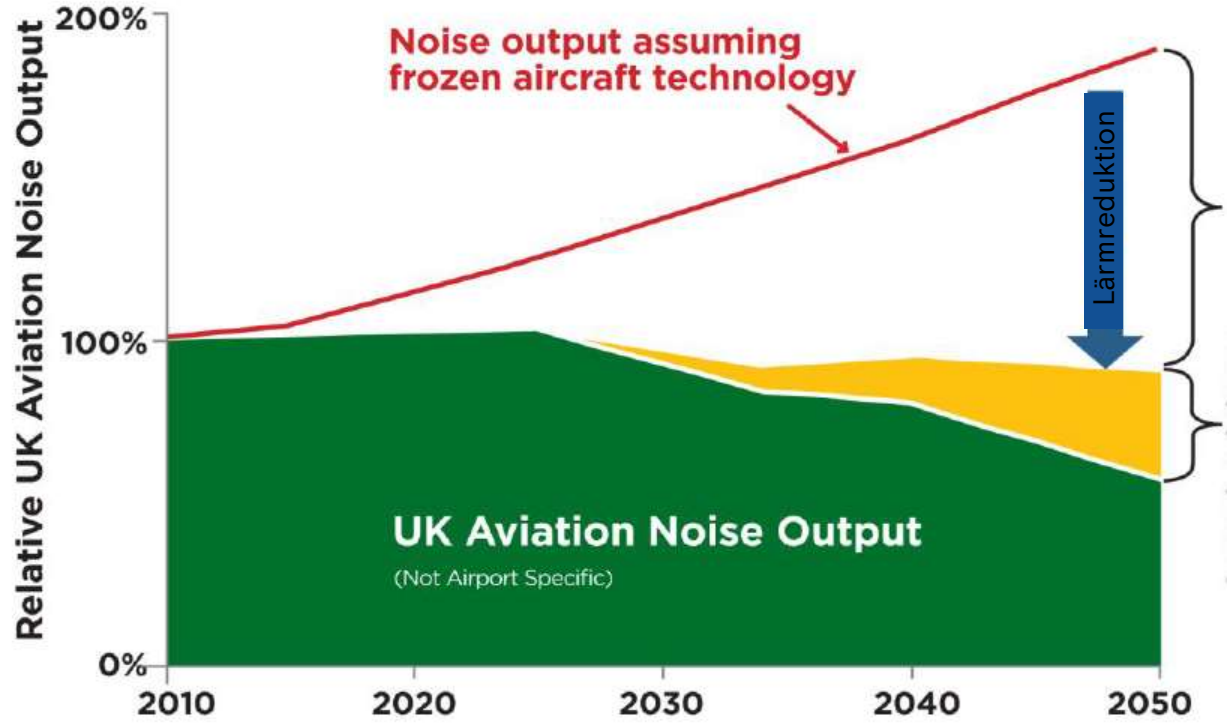
Environmental Objectives

CO_2	Noise	NOx
50%	50% -10 dB*	80%
2020 relative to 2000		
75%	65% -15 dB*	90%
2050 relative to 2000		

* Total average reduction per operation re. year 2000

Eugene Kors and Dominique Collin: Perspective on 25 Years of European Aircraft Noise Reduction Technology Efforts and Shift Towards Global Research Aimed at Quieter Air Transport in: L. Leylekian et al. (eds.), *Aviation Noise Impact Management*, https://doi.org/10.1007/978-3-030-91194-2_4

Less noise despite a growth of +2% p.a. is possible!
Data from 2010 - Update expected soon!



New technologies

Potential further improvement in noise

SUSTAINABLE AVIATION
Cleaner. Quieter. Smarter.

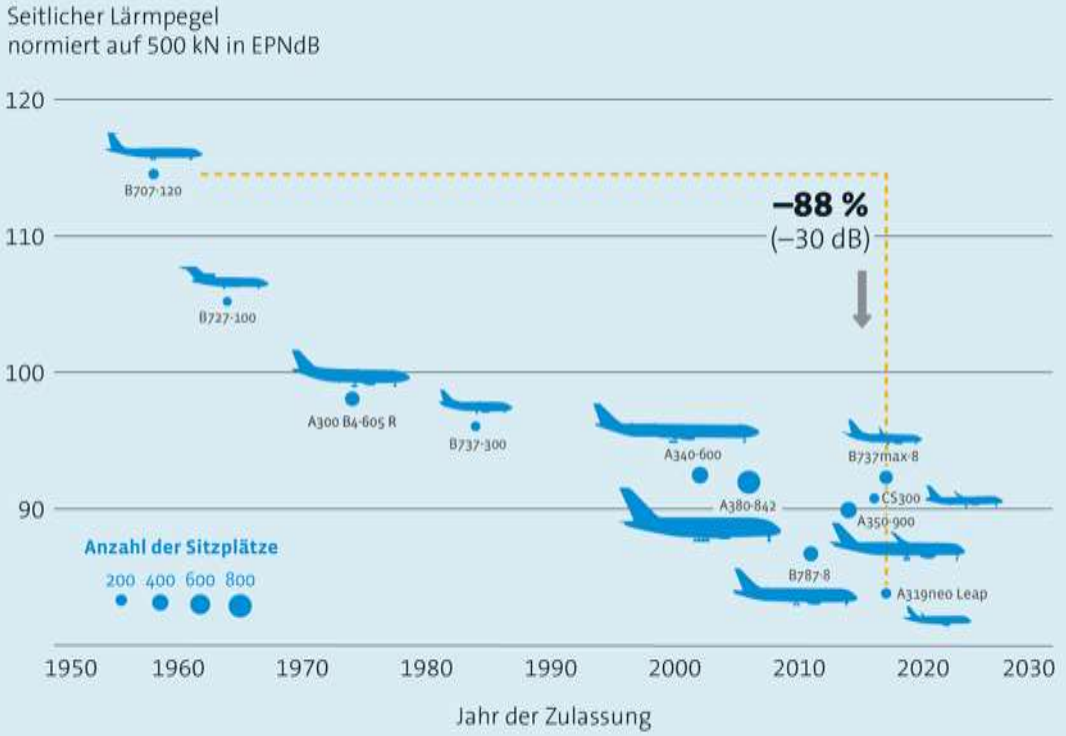
Source: "The SA Noise Road-Map" link: www.sustainableaviation.co.uk

Historische Entwicklung der Zertifizierungswerte für den seitlichen Zertifizierungspunkt

Stand: 2018

Quelle:
https://www.bdl.aero/de/publikation/fluglaermreport/

Entwicklung der Lärmemissionen bei Flugzeugen

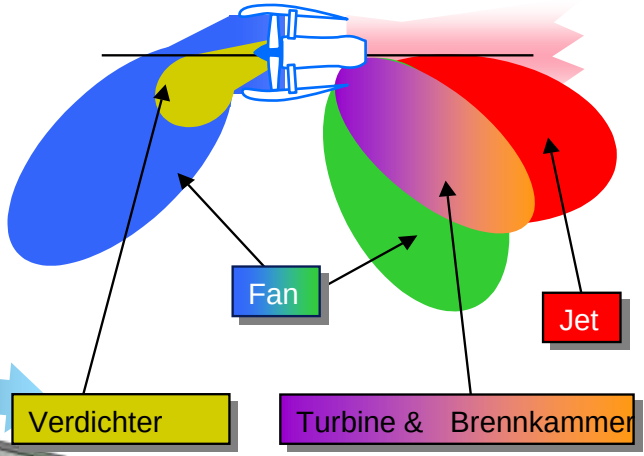


* EPNdB: Effective Perceived Noise in Decibels
Quelle: CFD-Software E+F GmbH Berlin

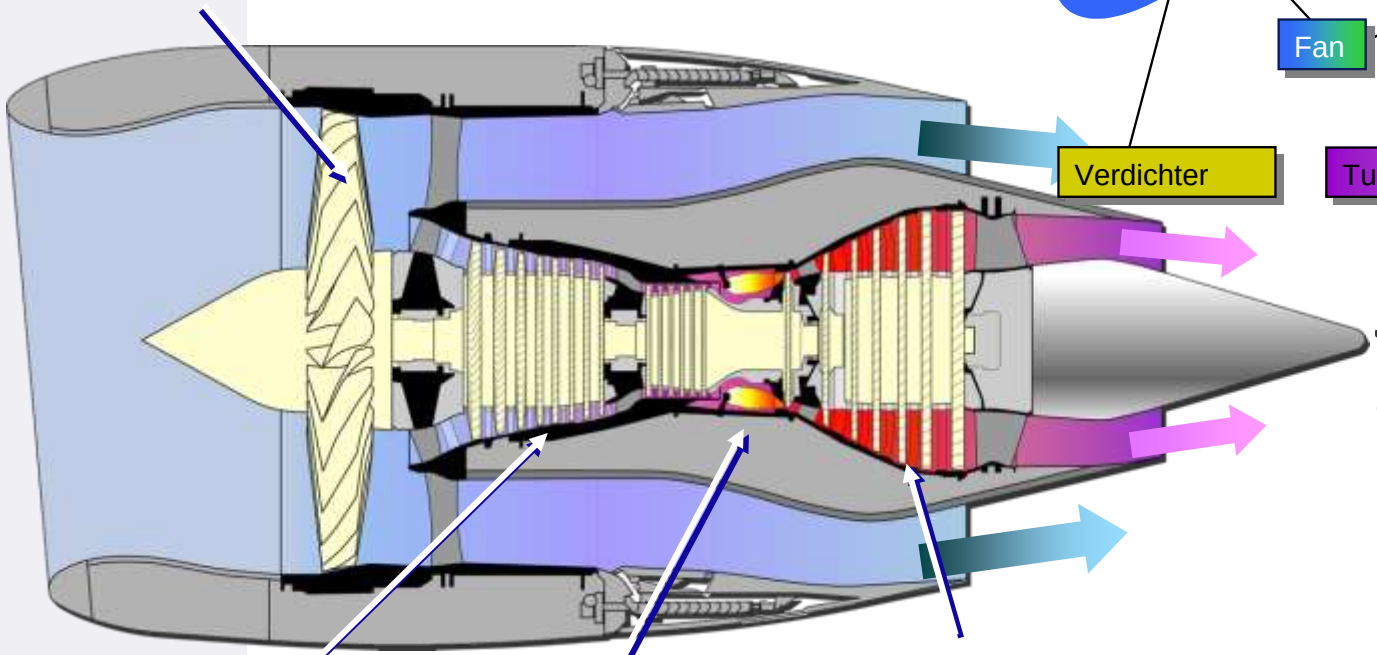
www.bdl.aero

Schallquellen an einem Flugtriebwerk

Lärmquellen eines Triebwerkes



Fan – System



Jet - Strahlärm

Verdichter

Brennkammer

Turbine

Mathematical/ Physical Models

Lighthill, Farassat and Ffowcs-Williams

- From Navier Stokes follows by some manipulations the Lighthill Equation:

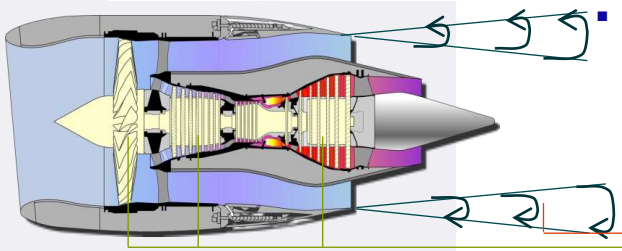
$$\frac{\partial^2 \rho}{\partial t^2} - c_0^2 \nabla^2 \rho = \frac{\partial^2 T_{ij}}{\partial x_i \partial x_j}, \quad (*)$$

where

$$T_{ij} = \rho v_i v_j - \sigma_{ij} + (p - c_0^2 \rho)\delta_{ij},$$

- This can be rewritten using an arbitrary control surface in motion to the Ffowcs-Williams Hawkings Equation:

$$\Box^2 p' = \frac{\partial}{\partial t}[\rho_0 v_n \delta(f)] - \frac{\partial}{\partial x_i}[p n_i \delta(f)] + \frac{\partial^2}{\partial x_i \partial x_j}[H(f) T_{ij}]$$



- Sources: „Thickness Noise“ – „Loading Noise“ + „Turbulent mixing noise“ (Lärm durch Verdrängung – Kraft + Turbulente Mischung)

$$\frac{\partial}{\partial t}[\rho_0 v_n \delta(f)] - \frac{\partial}{\partial x_i}[p n_i \delta(f)] + \frac{\partial^2}{\partial x_i \partial x_j}[H(f) T_{ij}]$$

- Jet noise as example of turbulent mixing noise goes with Ma^8 , whereas thrust efficiency increases the slower the jet is to a first order approximation.
  → Reducing noise and maintain efficiency is possible.
  → Increasing tip speed, drag and weight are limiting factors for Bypass ratio.
- Jet noise reductions leave other noise sources exposed, such as Fan.

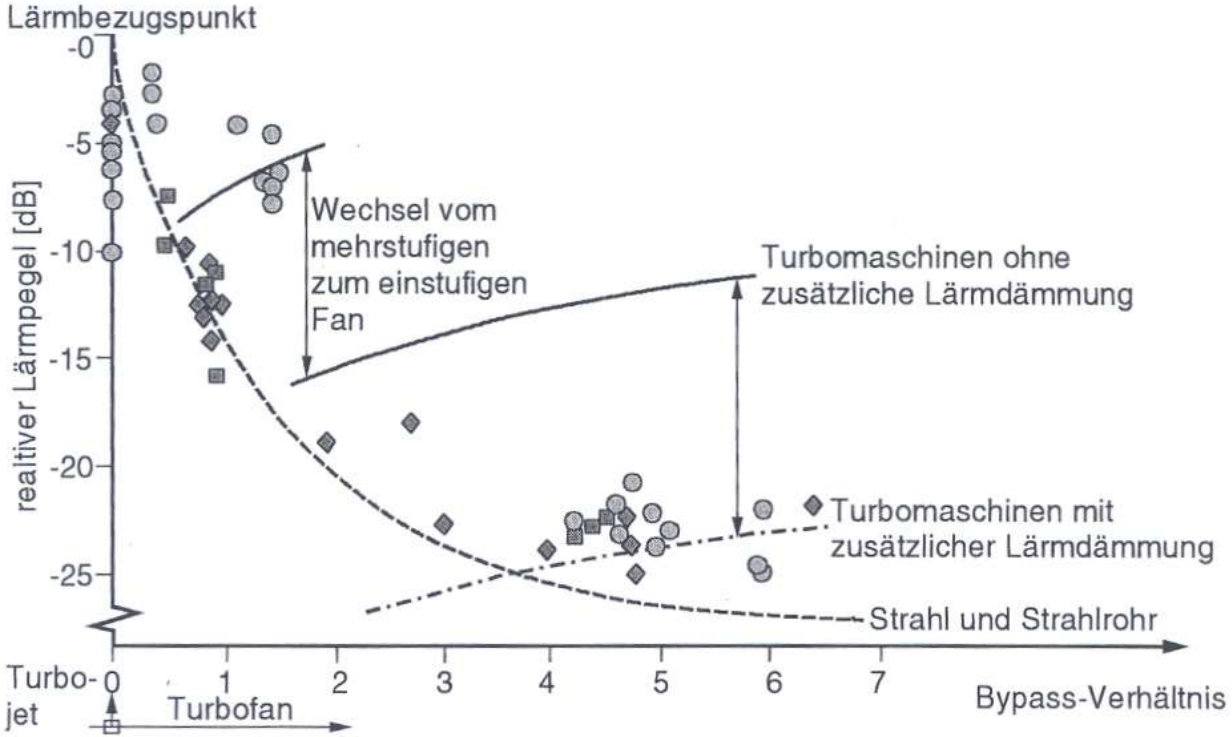
Strahllärm-Minderung allein reicht schon lange nicht mehr! Es müssen alle Schallquellen am Flugzeug beachtet werden!

~1990ies view on the optimum Fan diameter.

Geared Fans today reach Bypass ratio >10 and with UltraFan® Bypass ratios may reach 15.

Each generation of technologies pushes the limit further.

Architectural changes in each generation enable further noise reduction.



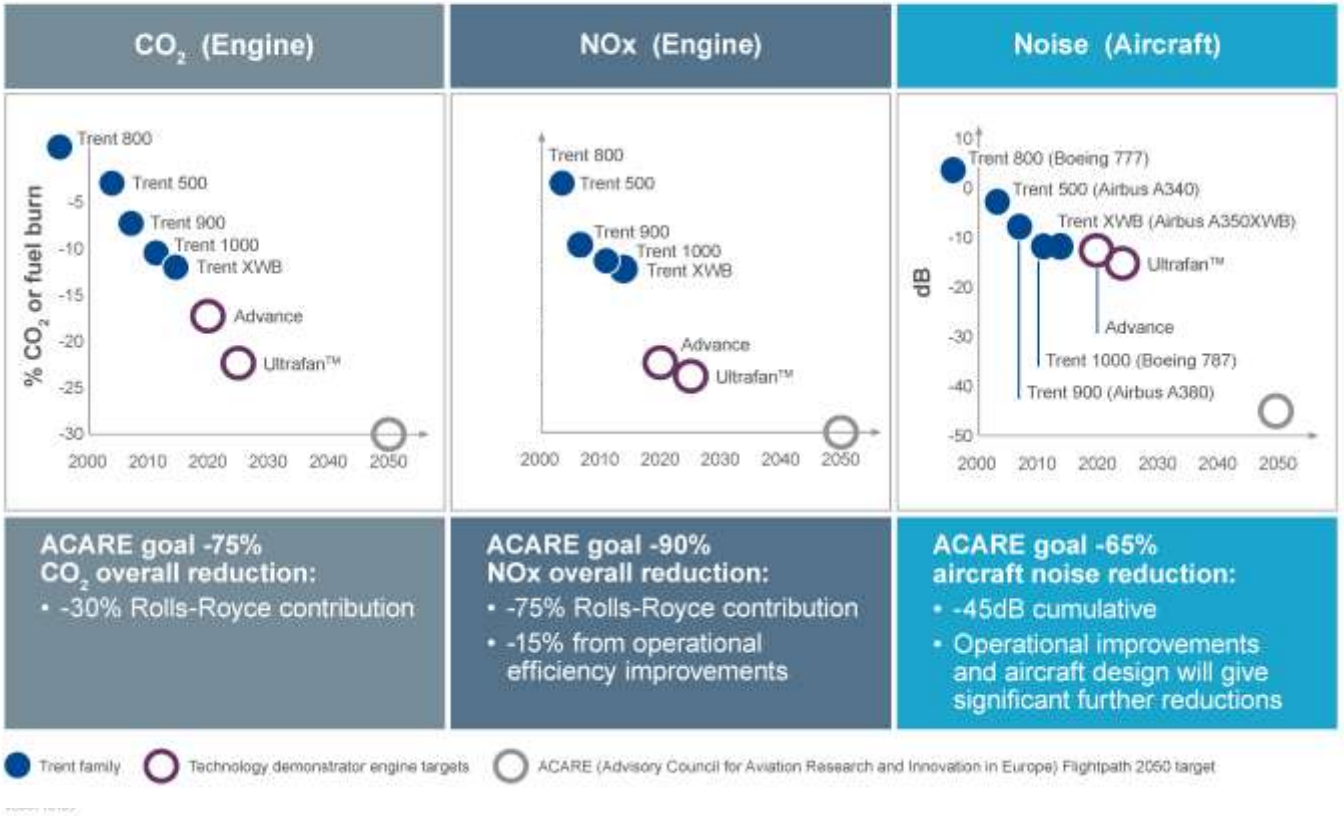
Verringerung des Lärmpegels nach Smith (1989) – “Aircraft Noise”
aus: Projektarbeit von Mark Endesfelder and der HAW Hamburg 2005
https://www.fzt.haw-hamburg.de/pers/Scholz/arbeiten/TextEndesfelder.pdf

Powering sustainable growth

Rolls-Royce UltraFan Concept allows to achieve all three environmental targets at the same time.

UltraFan® will be
25 % more fuel efficient
40% less NOx
35% lower noise

>50 MW,
3.56 m (140”) fan diameter



Our capability

We create industrial technologies using expertise acquired over many years. We combine distinct engineering disciplines to deliver highly complex power and propulsion solutions in the air, at sea and on land.

Rolls-Royce's Spirit of Innovation, the world's fastest all-electric vehicle

- No increase of bypass ratio - limited by drag
- Main Noise source is Jet noise during departures.
- Fan and core contributions

Complex Scarfed Mixer

© DLR HALO research AC (CC-BY-NC-ND 3.0)

NGE – AIAA2021-2160 (DLR ATRA)

Decarbonising complex, critical systems at the heart of global society

We believe in the positive, transforming potential of technology. To combat the climate crisis, we know that power must be made compatible with net zero carbon emissions.

New technologies represent a significant commercial opportunity for Rolls-Royce. By 2030, all our new products will be able to support net zero operation.

To decarbonise complex, critical systems we must continue to act across three areas:

Pioneering new low and zero carbon technologies and sustainable solutions

Accelerating the availability and affordability of sustainable fuels

Continuing to improve engine efficiency and environmental performance

Powering the Race to NetZero

End 2021, Speed record for fully electrical powered aircraft set by RR Spirit of Innovation

End 2022 RR demonstrated the first engine running on 100% hydrogen (RR @Twitter and BBC)

The competition of concepts

- Aircraft:
  Tube & Wings [or BWB]
  …and New Markets
- Drive:
  Advanced GT with PGB
  (Hybrid-)electrical
- Propulsor:
  Large & fast – Advanced Fan with SAF
  Small & slow – (hybrid-)electrical Prop.
- Energy storage:
  Battery, Hydrogen or SAF
- Energy conversion:
  Fuel cells vs. Direct burn

UltraFan December 2022 | Flickr

Lots of options including hybrid electrical ones, are not automatically more silent.
Roadmaps need update to align the noise and emissions targets with Net Zero.
Newly launched EU project PULSAR will generate a technology inventory and develop roadmaps for a European research strategy on noise and emissions.

Die Forschungslandschaft in Deutschland

Technologien aus R&T Projekten => lärmarmes Design

LUFO Projekte

- Lärm- und Leistungsoptmierter Mischer
- LEXMOS
- FREQUENZ
- OPAL
- OPTITHECK
- MASSIF
- LEILA
- LIST
- SYSTUGEN
- FUNKTUGEN
- …

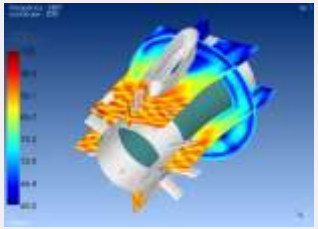
Förderung der Zusammenarbeit mit kompetenten Partnern wie CFDB, MTU, AIRBUS und DLR

Internationale Kooperation mit dem UTC in Southampton.

EU Projekte

…nächste Seite

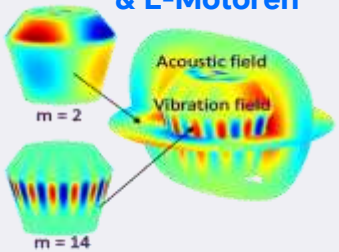
Lärmoptimierter Cycle, Einlauf & Bypass Duct



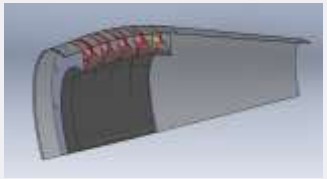
Lärmarme Design: Fan-, Kompressor- & Turbinensysteme

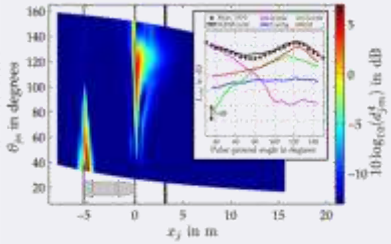
Strahllärm, NGE & Complex Scarfed Mixer

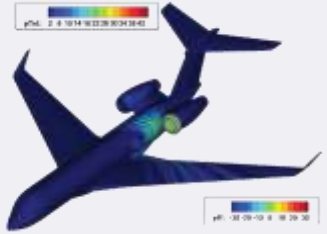
Lärmarme Getriebe & E-Motoren



Neuartige Akustische Absorber







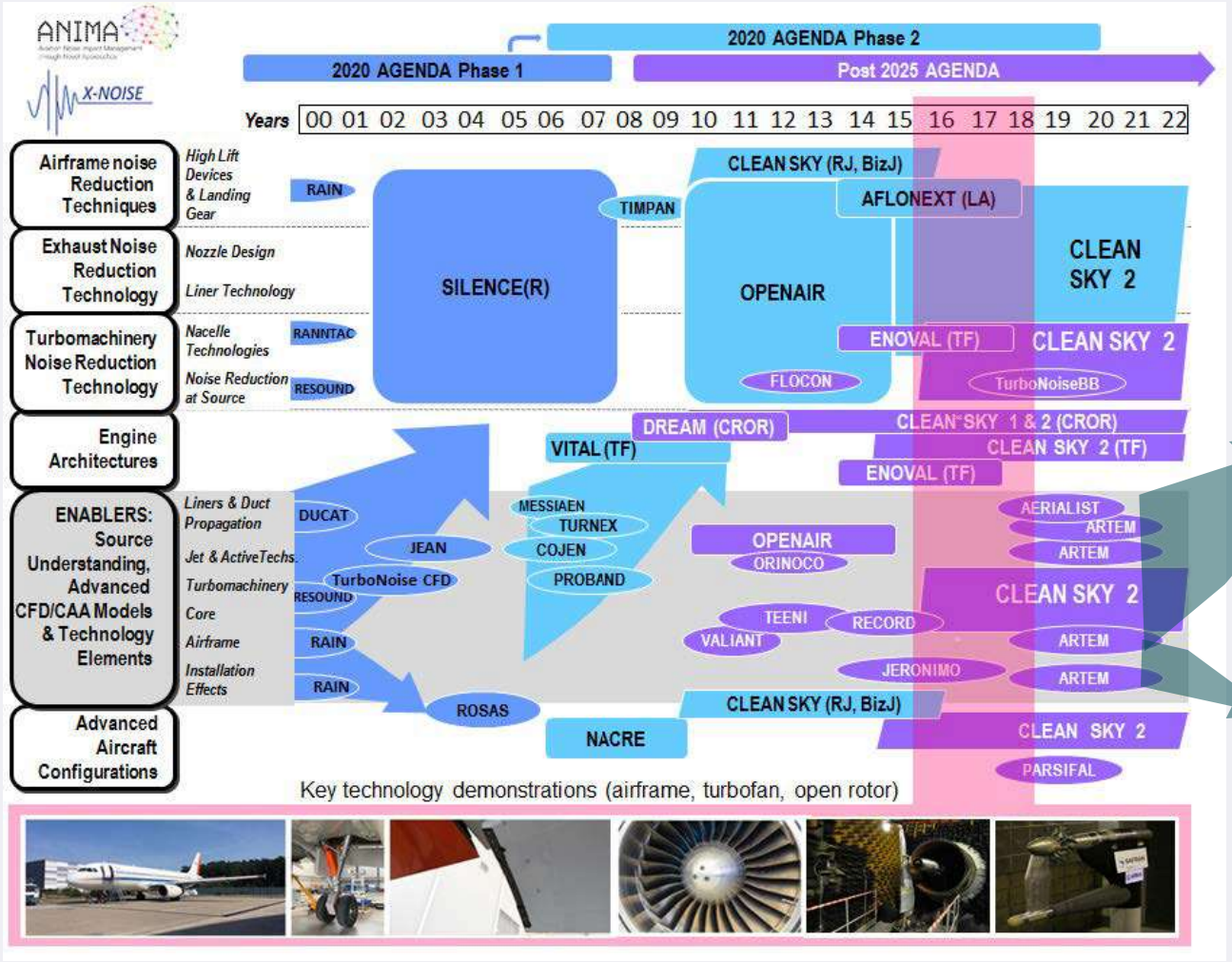
Neue Messtechniken

Schallquellenortung

Optimierte Installation

European Noise research

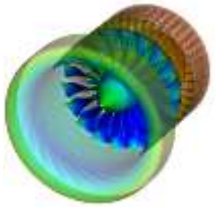
- The Horizon Europe EU project PULSAR will support generation of Roadmaps for Noise and emission research
- These will be based on Expert review of technologies developed in national and European projects.
- More work will be needed to integrate noise into the European Green Deal projects (Horizon Europe and Clean Aviation)



https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2019/ENVReport2019_pg72-80.pdf

Schlussfolgerungen

Conclusions



- Progress achieved:
  - Continuous increase of bypass ratio has lowered jet noise
  - Supplementary optimisation of turbomachinery and installation using high fidelity CFD/CAA methods and low order method enabled further noise reduction
  - Significant contribution of nacelle improvement for efficiency and noise
  - Validation by component and engine noise measurements is still needed
- Next Steps:
  - The UltraFan architecture will enable Rolls-Royce and our customers to deliver the required improvement along all three ACARE Flightpath 2050 targets
  - New technologies, which are introduced to protect the climate, come with risks and opportunities for noise
    - Rolls-Royce considers these in the technology development noting that from a sustainability perspective, aircrafts should be used for a long time (typ. 30 years)
    - All new RR engines are designed for 100% SAF
      → CO_2 can be improved after EIS without modification of the engine.
    - Improvement of Noise after EIS is limited and often increases weight and drag
      → Increase CO_2.
  - Operational Procedures
    - Consider capability of the aircraft and implication on noise
    - Similar to other noise aspects, integration of OP in the engine and aircraft design could allow further optimisation.
- This results in following generic research requirements applicable to design for all new low CO_2 aircraft types (incl. Electrical aircraft):
  - Avoid late noise mitigation
  - Consider and optimisation of noise aspects in the aircraft and engine cycle design
  - Interdisciplinary use of High-fidelity CFD/CAA methods in the design optimisation process
  - Use advanced noise measurements for development and design optimisation
  - Optimise integration of engine and aircraft considering operational procedures

Acknowledgement

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Vielen Dank für Ihre Aufmerksamkeit!