NOISE TECHNOLOGY RESEARCH
FOR FIXED WING AIRCRAFT

STATUS REPORT

September 2021

Contributors:
Members: USA FAA, France DGAC
ICCAIA: Airbus, Bombardier, GE, Dassault, Rolls Royce, Boeing, Embraer, Pratt & Whitney, Kopter, Safran.
Research: JAXA, CIAM, Tsagi, NASA, Civil Aviation University of China.

Content

SUMMARY

This working paper concludes Task N04 "*Monitor and report on the various national and international research programme goals and milestones. Review data on emerging technologies as it becomes available*" for the present CAEP12 cycle (2019-2021).

The situation of noise technology research initiatives worldwide is reviewed and a summary of the research activities is provided for each region.

1. INTRODUCTION - BACKGROUND

1.1 The task of monitoring noise technology research programmes has been active since the CAEP/6 cycle. This has been the opportunity to develop a broader view of the research activity worldwide and place in perspective the aspirational goals established for the wider initiatives.

The first noise technology workshop was held in Sao Paulo in December 2001, later the basis of a dedicated ICAO journal article. In the following cycle, IP11 to CAEP/7 reported in detail on the research situation as of 2006. A second noise technology workshop was held in September 2008 in Seattle, as an introduction to the first Noise Technology Independent Expert Review (IER1). IP26 to CAEP/8 documented the information presented at this occasion. Further updates on on-going noise technology research programs were subsequently provided at each CAEP meetings (IP 14 to CAEP/9, IP 10 to CAEP/10), IP 11 to CAEP/11.

1.2 More generally, these reports to CAEP aim at complementing the technology review process implemented at less regular intervals (2008, 2011, 2017), while providing information from a different angle, representative of joint Government / Industry efforts in implementing research initiatives. As such, it provides a good indication of the worldwide commitment to continuously support the technology side of the Balanced Approach.

1.3 As for similar previous reports, it will covers known national and regional noise technology research initiatives and aims at providing an up-to-date view of on-going and planned efforts with respect to their technical scope as well as their set objectives.

2. OVERVIEW OF TECHNOLOGY PROGRAMS AND RESEARCH INITIATIVES

2.1 The situation of noise technology research initiatives worldwide is summarized in Figure 1 as of May 2021. It covers a 18 year period (2006-2023), providing an evolutionary perspective since the original noise technology workshop (2001) and clearly shows the renewed commitment of the countries involved.

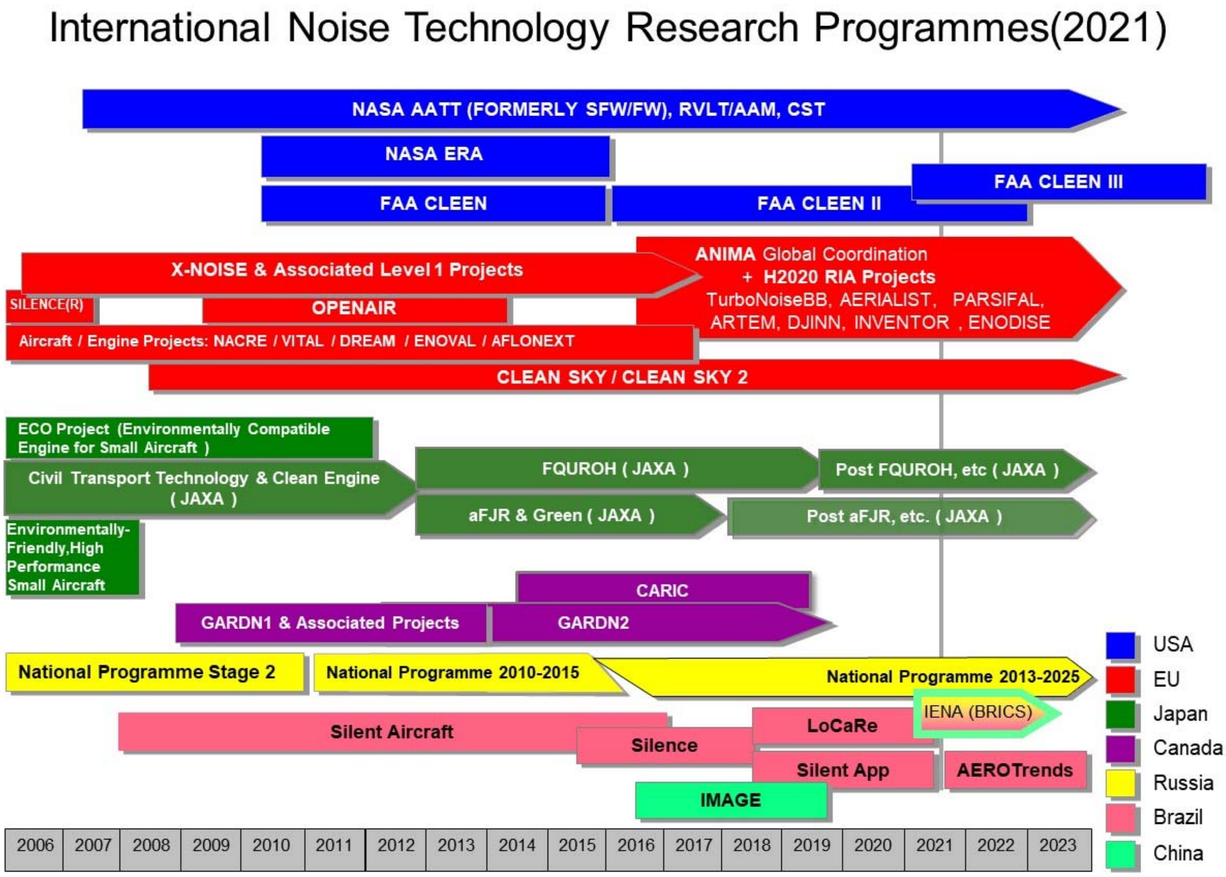

Figure 1 – Committed Major National / Regional Initiatives as of May 2021

In this light, it should be noticed that while the major initiatives reviewed in 2001 (US, EU, Japan) at the occasion of the first noise technology workshop have been sustained and generally expanded, new significant efforts have been initiated over the years in Canada, the Russian Federation, Brazil and recently China providing here the picture of a true worldwide effort.

Going across the various programs, general observations can be made concerning research goals and emerging technology trends.

Research programs set stretch goals (sometimes called aspirational), and as a consequence exhibit steeper progress slopes than supported by historical trends (which already includes several steps of technology breakthrough). Typically, no explicit level of uncertainty is taken into consideration, being somewhat built-in the “stretch” nature of the goal. From a timeframe perspective, research goals also tend to consider the availability of validated novel technologies at TRL6 (or below), not their successful implementation at industrial level (TRL 8).

As pointed out in previous reports, the general trend for large research initiatives has been to address a global environmental agenda, tradeoffs and interdependencies aspects being considered in scientific and technical work programs. It is also interesting to notice that innovative approaches investigating how an improved understanding of annoyance factors could better inform technology development efforts have recently emerged, widening the scope of technology related research even further.

Highlights on emerging technologies are reported below:

- Concerning Open Rotors, after running a full scale Counter Rotating Open Rotor in Europe in 2016, studies are continuing within the European Clean Sky project to further explore the integration aspects and interdependencies of the Open Rotor engine architecture.

- Concerning Advanced Propulsor Configurations, efforts within the US have focused on propulsion technologies that would be mature for the proposed single aisle replacement aircraft in the early 2030s.

- Concerning novel aircraft configurations, research performed by NASA is focused on the Transonic Truss Braced Wing (TTBW) configuration as a potential advanced contender for the single aisle replacement. Other configurations such as the Hybrid Wing Body (HWB) or Boundary Layer Ingesting (BLI) concepts continue to be studied as longer term configurations.

- Concerning Noise Reduction Technologies (NRT), it is worth emphasizing:
  - the important efforts carried out across all research programmes to provide airframe noise reduction solutions, in order to go along with forecast engine noise reductions. This is consistent with the now very significant weight of airframe noise sources observed in approach conditions.
  - a renewed effort on acoustic liners technologies to accommodate future engine and nacelle integration constraints (low frequency sources, reduced available space, low weight requirements).

- Concerning regional noise research programmes, it should be noted that there is a significant focus change in both Canada and Europe: In Canada, after several year of successful noise research programmes under GARDN and CARIC, no nationally lead research programme on aviation noise is supported at this time. Similarly, in Europe, the EU aviation environmental research focus has changed towards “climate change”, resulting in very limited funding options for “noise” research.

It should at last be reminded that, beyond research goals, anticipated progress trends will remain conditioned by several success factors such as the capability to ensure viable industrial application for promising technology breakthroughs as well as the commitment to maintain a steady funding support over a significant period of time.

2.2 Summaries of each research initiative represented in Figure 1 are provided in this paper appendices..

2.2.1 US Noise Technology Research Programs
An overview of the US Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix A.

2.2.2 EU Noise Technology Research Programs
An overview of the EU Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix B.

2.2.3 Japanese Noise Technology Research Programs
An overview of the Japanese Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix C.

2.2.4 Canadian Technology Research Programs
An overview of the Canadian Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix D

2.2.5 Russian Technology Research Programs
An overview of the Russian Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix E.

2.2.6 Brazilian Technology Research Programs
An overview of the Brazilian Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix F.

2.2.7 Chinese Technology Research Programs
An overview of the Chinese Research Programs dedicated to Aircraft Noise Reduction Technology is provided in Appendix G.

3. CONCLUSIONS

This information paper concludes Task N04 “Monitor and report on the various national and international research program goals and milestones. Review data on emerging technologies as it becomes available” for the present CAEP cycle.

It is anticipated that the continuation of this activity will be supported as part of future work proposals, so that regular update on research programs keep being provided to CAEP, particularly during cycles where no noise technology review is planned.

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Appendix A

US Noise Technology Research Programs

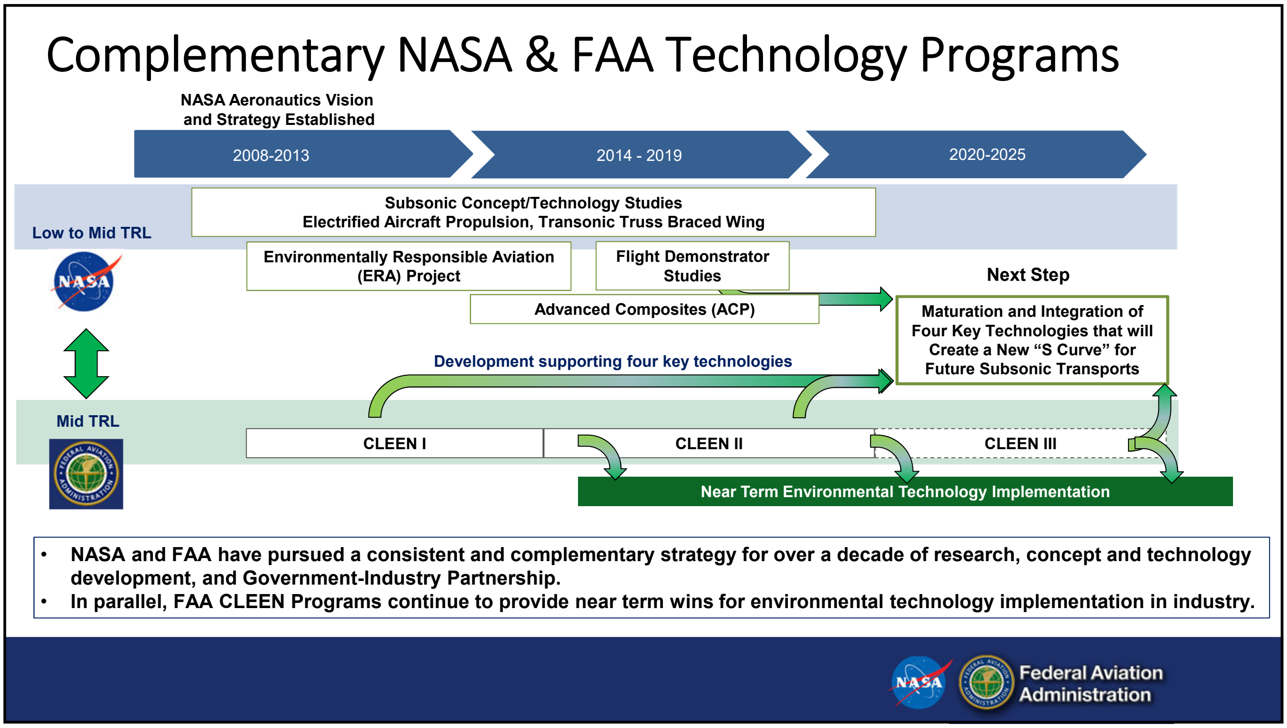
US Aircraft Noise Research Effort

Aviation Environmental Protection:

- US aircraft noise research covers a broad range of applications.
- Investing in applicable technologies to reduce noise impact on communities.
- Mature and demonstrate technologies for broad implementation into the fleet in the near term, mid term and far term timeframes.

Subsonic Noise Technology Research for:

- Transport fixed wing aircraft
- Rotary wing aircraft
- Landing and Take Off (LTO) noise reduction technology of supersonic airplanes


Complementary NASA & FAA Technology Programs
NASA Aeronautics Vision and Strategy Established
2008-2013
2014 - 2019
2020-2025
Low to Mid TRL
Subsonic Concept/Technology Studies
Electrified Aircraft Propulsion, Transonic Truss Braced Wing
Environmentally Responsible Aviation (ERA) Project
Flight Demonstrator Studies
Advanced Composites (ACP)
Next Step
Maturation and Integration of Four Key Technologies that will Create a New "S Curve" for Future Subsonic Transports
Development supporting four key technologies
Mid TRL
CLEEN I
CLEEN II
CLEEN III
Near Term Environmental Technology Implementation
• NASA and FAA have pursued a consistent and complementary strategy for over a decade of research, concept and technology development, and Government-Industry Partnership.
• In parallel, FAA CLEEN Programs continue to provide near term wins for environmental technology implementation in industry.
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NASA/FAA Sustainable Flight National Partnership (SFNP)
Critical to establish the new "S Curve" for the next 50 years of transports
Demonstrate a 'step change reduction' in GHG emissions relative to best in class aircraft
Transonic Truss-Braced Wing
5-10% fuel burn benefit
Small Core Gas Turbine
5-10% fuel burn benefit
Electrified Aircraft Propulsion
~5% fuel burn and maintenance benefit
High-Rate Composite Manufacturing
4x-6x manufacturing rate increase
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Common Research Model – Quiet High Lift Technical Challenge completing in 2021

Objective

Reduce fan (lateral and flyover) and high-lift system (approach) noise on a component basis by 4 dB with minimal impact on weight and performance (TRL 5, FY22)

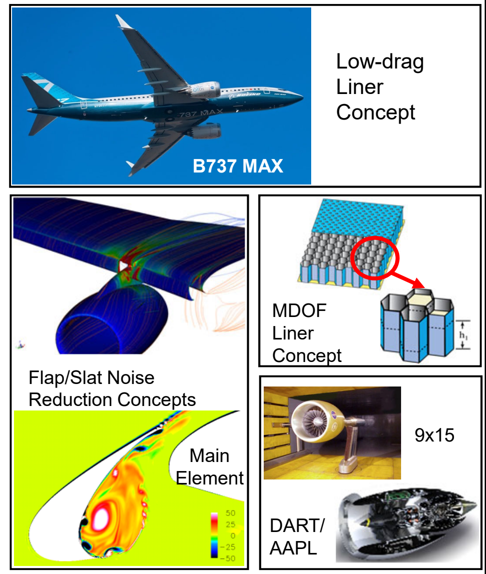
Technical Areas and Approaches

Airframe Noise
- Flap and slat noise reduction concepts
  - CRM-QHL 14x22 Test (complete in 2021)

Acoustic Liners and Duct Propagation
- Multi-degree-of-freedom low-drag liners
  - 9x15 Honeywell/DART Tests (TRL 5)
  - B737 MAX Flight Test (TRL 7)

Benefit/Payoff

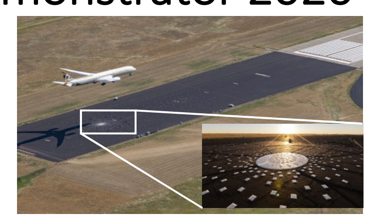
Component noise reduction with minimal impact on weight and performance
- 12 dB cum noise reduction
- Liner and high-lift system technology have early insertion potential



Images: NASA

Propulsion Airframe Aeroacoustics and Aircraft System Noise Flight Test on the B787 eco-Demonstrator 2020

- First ever NASA flight test for vehicle system-level acoustic objectives to research:
  - Full scale, full fidelity individual noise sources
  - PAA integration effects
  - Total aircraft system noise
  - Shielding and reflection PAA effects
  - Highly-relevant aircraft representative of future designs
- Data collection exceeded success criteria:
  - Six flight days (8/25 – 9/1), 20 flight hours
  - 50 unique test conditions
- Most highly instrumented NASA acoustic flight test to date:
  - 960 microphone phased array
  - 214 on-aircraft microphones in four distinct arrays
  - 31 far field microphones
- Analysis of the very large dataset is underway



Ground phased array

On-aircraft arrays

Provides years of valuable aircraft systems noise research data

Images: Boeing, used with permission.

Low-Noise Common Research Model – Quiet High Lift Pre-test Predictions

Problem

Predictions of the low-noise designs for the CRM-HL are needed in order to make assessments of upcoming test results

Approach

Use simulations to evaluate the acoustic benefit and potential aerodynamic penalties of candidate low-noise configurations to increase efficiency of 14x22 test

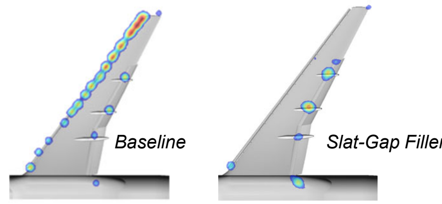
Results

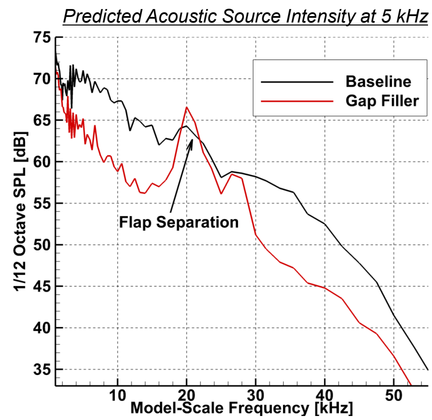
- PowerFLOW® was used to evaluate numerous configurations and refine the designs
- Simulations predict that the slat gap filler and slat cove filler reduce slat noise by more than 4 dB over a large frequency range

Significance

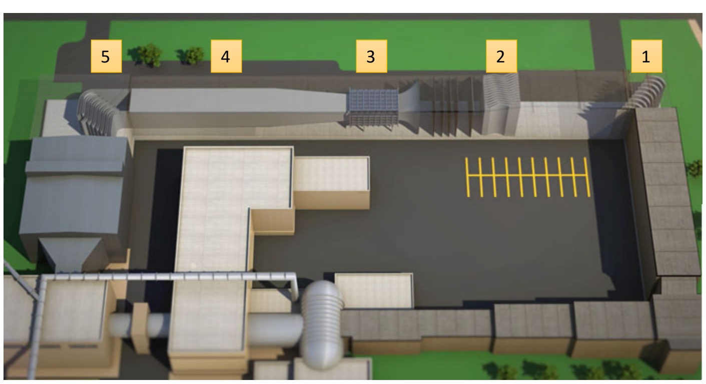
- Simulations provided guidance on structural loads, the placement of instrumentation, and aided test matrix development
- Minimized the number of test configurations while still maintaining a high probability of success

Acoustic benefit of low-noise concepts predicted with simulations





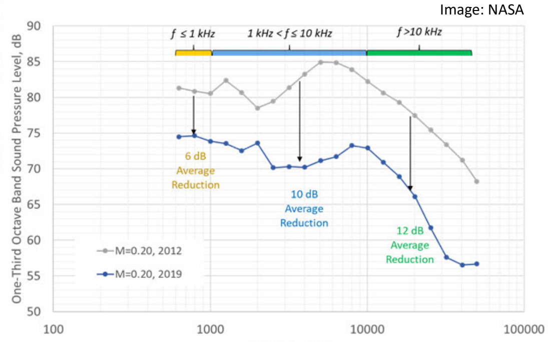
NASA 9x15 Wind Tunnel Improvement Project



1. Upstream acoustic turning vanes
2. Acoustic baffles
3. New test section, uniform deep lining
4. Reshape diffuser and add acoustic treatment
5. Downstream acoustic turning vanes

New Test Section
(looking upstream)

Image: NASA



Continuous Lower Energy, Emissions & Noise (CLEEN)

- FAA led public-private partnership with 100% cost share from industry
- Reducing fuel burn, emissions and noise via aircraft and engine technologies and alternative jet fuels
- Conducting ground and/or flight test demonstrations to accelerate maturation of certifiable aircraft and engine technologies

	Phase I	Phase II	Phase III
Time Frame	2010-2015	2016-2020	2021-2025
FAA Budget	~$125M	~$100M	TBD
Noise Reduction Goal	**25 dB cumulative noise reduction cumulative to Stage 5 (42 dB cum noise reduction to Stage 3)** ***and/or reduces community noise exposure (new goal for Phase III)***		
Fuel Burn Goal	33% reduction	40% reduction	-20% re: CAEP/10 Std.
NO_X Emissions Reduction Goal	60% landing/take-off NO_X emissions	75% landing/take-off NO_X emissions (-70% re: CAEP/8)	
Particulate Matter Reduction Goal			Reduction relative to CAEP/11 Std
Entry into Service	2018	2026	2031

For more information on CLEEN program: http://www.faa.gov/go/cleen
CLEEN III Industry Day: https://faaco.faa.gov/index.cfm/announcement/view/32134
CLEEN III Solicitation: https://faaco.faa.gov/index.cfm/announcement/view/31885

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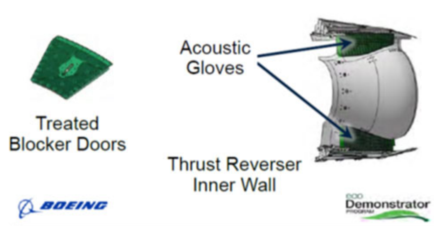
Compact Nacelle (CN) – Aft Fan Duct Acoustics



Anticipated Benefits:

- *0.4 to 1.2 EPNdB for future applications to UHB-configured aircraft entering service in the 2025 time frame*
- *0.2 to 0.6 EPNdB as retrofit potential for some existing models.*

Objectives:

- *Develop acoustic treatment concepts for aft duct of compact nacelle architectures*
- *Validate design concepts through flight demonstration for transition to new and existing products*

Work Statement:

- *Develop prototype TR hardware*
- *Conduct flight demonstration on the Boeing 737 Max 9 ecoDemonstrator*

http://www.faa.gov/go/cleen

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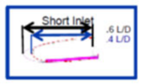
CLEEN II Consortium Meeting October 2020 – Collins

TECHNOLOGIES – SHORT INLET

Short Inlet



Anticipated Benefits:
- -0.5% fuel burn

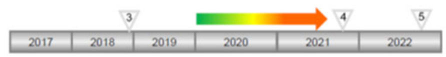
Risks/Mitigations:
- Perforations requirements to produce attenuation may not be well understood
  - Develop perforation model
- Scale-up fabrication issues may not be well understood
  - Perform experimentation on large-scale equipment
- COVID-19 impact on schedule delay

Objectives:
- Develop and demonstrate a low-cost, structural bond panel with DDOF acoustic performance

Work Statement:
- Develop concepts & down-select technologies
- Test prototypes to confirm attenuation
- Confirm producibility & cost
- Test fabricated panels in relevant environment

Progress Update:
- Design concepts developed (Complete)
- Initial prototypes fabricated (Complete)
- Efforts stopped for 2020 will restart in 2021

TRL Schedule:
- COVID-19 Impact
- Collins Aerospace will continue efforts outside CLEEN II



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Collins Aerospace

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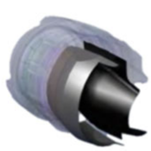
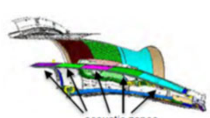
CLEEN II Consortium Meeting October 2020 – Collins

Acoustic Ground Test Clean Fan Duct for HBR Engines





Anticipated Benefits:
- -2.0 EPNdB noise

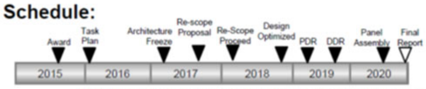
Risks/Mitigation Plans:
- Acoustic performance/subscale tests, acoustic optimization models
- Manufacturing tooling and assembly
- Test stand integration/work with P&W
- COVID-19 impact on ground test postponement

Objectives:
- Achieve TRL6 for Clean Fan Duct acoustics
- Validate anticipated benefits

Work Statement:
- Develop ground test demonstrator
- Do subscale acoustic tests to validate models
- Perform full-scale engine ground test
- Use test data & validated analyses to project aircraft-level benefits

Progress Update:
- Ground test TR passed DDR in Sep '19
- IFS RH bond panel fabrication complete
- TRL6 achieved for two technologies
- All other builds on hold including ground test
- Contract extended 3 months to Dec 2020
- Final Report in work

Schedule:



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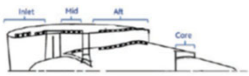
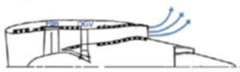
CLEEN II Consortium Meeting October 2020 – GE

Project Technology:

Novel Liners



Fan Source Strength Reduction



Anticipated Benefits:

- Improved Acoustic liner benefit re: Single degree freedom Liners,
- Target ~ 2EPNdB Cum, Neutral Performance.

- Improved Fan Noise Source Strength Reduction re: LEAP.
- Target ~ 1 EPNdB Cum, Neutral Performance.

Objectives:

- To Develop Novel Acoustic Liners.
- To Develop Fan Source Strength Reduction Concepts.

Work Statement:

Design, Develop, Fabricate and Test Novel Acoustic Liner.

Aeroacoustic Design and Testing of Fan noise source strength reduction concepts.

Accomplishments/ Milestones:

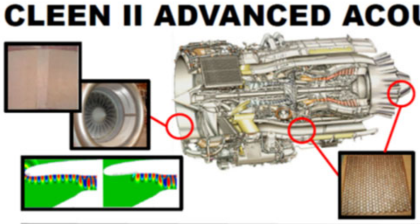
- Developed several novel liner cores
- Tested several liners with at NASA's Grazing Flow Impedance Tube facility
- Downselected to a specific liner design
- Completed large demo panel

Fan Noise Source Reduction

- Completed Fan Source Strength Reduction design reviews
- Started manufacture of subscale hardware to validate acoustic benefit and performance.

CLEEN II Consortium Meeting October 2020 – Honeywell

CLEEN II ADVANCED ACOUSTIC FAN AND LINER



Benefits

- Reduce noise by 2.5 EPNdB
- Reduce fuel burn by 1.5%

Risks/Mitigations

- Fan Noise Improvement – Fan Rig Test to validate noise generating mechanisms
- Acoustic Liner Acoustic Benefit – Manufacturing trials and acoustic test
- Acoustic Liner Durability – Endurance Engine Test

Objectives

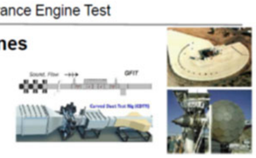
- Design a light-weight fan that reduces rotor noise
- Design acoustic liners that reduce tonal and broad band noise.
- Design bypass/center-body acoustic liners to reduce tonal and broadband noise

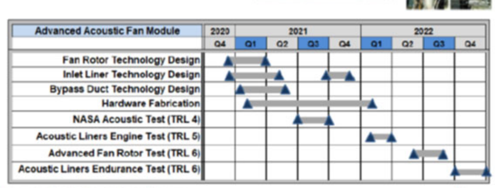
Work Statement

- Design fan rotor (In process)
- Fan rig test
- Design acoustic liners (In process)
- Acoustic rig test
- Acoustic engine test

Accomplishments/Milestones

- Fan rotor design Q1 2021
- Inlet Liner design Q1 2021
- Bypass duct liner Q2 2021





FAA ASCENT Center of Excellence Technology Projects

- **Continue execution of the environmental technology research portfolio in our Center of Excellence**
- **Provides complementary venue for University-led research to advance industry state-of-the-art and expand knowledge broadly**
- **Themes:**
  - Noise reduction technology modeling and development
  - System-level modeling and design considerations
  - Propulsion-airframe integration
  - Combustion
  - Turbomachinery
  - Supersonics (covered in separate session on supersonics)
- **Overview of projects now available on ASCENT website:**

https://ascent.aero/topic/Aircraft-Technology/

Appendix B

EU Noise Technology Research Programs

European Aircraft Noise Reduction Technology Effort

ACARE Framework

ACARE

2001

SRA1 - 2002

2011

SRIA - 2012

Environmental Objectives
(based on TRL6 capability)

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

Advisory Council for Aviation Research and Innovation in Europe

SRIA update – Challenge 3 (2017)

ACARE

The key action areas addressed in Volume 1, build upon the key elements from the first issue that remain valid

- Air vehicle design not only reinforces the requirement for evolutionary change but emphasises the need for revolutionary change that must start now
- This is supported by the need to develop alternative sources of energy including bio-fuels but also looking to future options to support revolutionary air vehicle design changes such as electrification
- Emphasises the need to manage key emissions such as NOx, particulates and noise and addresses more than the ACARE target but the direct impact and annoyance factors
- Increased use of recycling and remanufacturing
- Environmental impacts of airports and infrastructure have been refreshed

Advisory Council for Aviation Research and Innovation in Europe

Flightpath 2050 update (2021)

ACARE

ACARE **Time for change** The need to rethink Europe's FlightPath 2050

Environmental commitment / Green Deal objectives

Societal expectations on CO_2 mitigation have strongly increased, especially in the field of aviation. Aviation has been pinpointed as a potential major contributor to CO_2 emissions and global warming, although it is currently estimated that the aviation industry represents only approximately 2% of global human-induced CO_2 emissions.

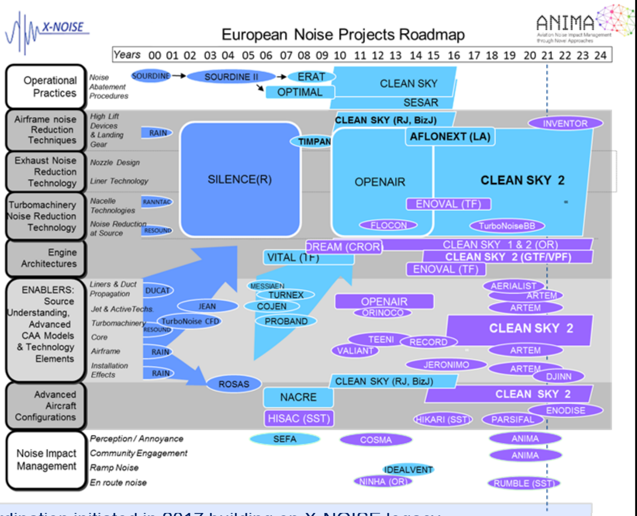
The ratified Green Deal objectives demand that the European aviation sector achieves drastically reduced emissions by 2030 and climate neutral aviation by 2050. These targets include emissions, air quality and noise around airports, and ECO-design and end-of-life recycling.

This societal change demands disruptive technological solutions; conventional technologies are not enough. New energy sources need researching, integrating, and deploying as new generation aircraft types enter airline fleets.

X-NOISE

EU Aviation Noise Research Effort Summary

- Over 20 years, more than 40 noise dedicated projects aimed at implementing ACARE agenda, plus participation in large architecture oriented multidisciplinary projects
- Complementary effort on noise impacts initiated
- Significant mobilization of research actors. Well balanced participation between Industry and Research Organizations from a large majority of EU and Associated States
- As of FP6, international participation in proposed projects from Russia, Brazil, China, Canada, US



- A new phase in research coordination initiated in 2017 building on X-NOISE legacy

Clean Sky Noise Related Projects (1)

Clean Sky2 : LPA PROPMAT

Project Title : Support to Future CROR and UHBR Propulsion System Maturation
Project Consortium : *NLR*
Topic Manager : *AIRBUS*
Project start / end date : *01/01/16 – 31/12/21*
EU funding : 2,751,000 EUR

Project Context & Objectives:

- *Context :* In the framework of the Large Passenger Aircraft ITD of Clean Sky 2, the PROPMAT project contributes to maturation & demonstration of the CROR and UHBR low fuel burn propulsion concepts to TRL6. The project builds upon the scientific work performed in Clean Sky's Smart Fixed Wing Aircraft especially wrt the CROR.
- The project activities comprise:
  - CROR&UHBR numerical aero-acoustic characterisation
  - CROR blade aero-elastic deformation
  - Innovative acoustic measurement techniques
  - Acoustic chase aircraft flight testing,
  - Blade impact numerical simulation

Pictures courtesy of NLR

Some Results:

http://www.nlr.org/news/measuring-aircraft-noise-in-an-innovative-way/
https://www.youtube.com/watch?v=Jlx-Jr3bg2E

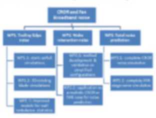
European Commission

Clean Sky2 : LPA SCONE

Project Title : Simulations of CrOr and fan broadband NoisE with reduced order modelling
Project Consortium : *CERFACS, ISAE, Ecole Centrale de Lyon*
Topic Manager : *AIRBUS*
Project start / end date : *01/09/17 – 31/12/20*
EU funding : 600,000 EUR

Project Context & Objectives:

- *Context :* In the framework of the Large Passenger Aircraft ITD of Clean Sky 2, the SCONE project contributes to improve the CROR and UHBR Fan broadband noise prediction by using high-fidelity Large-Eddy Simulation (LES).
- The project objectives are to:
  - Build improved turbulence statistics data to feed the semi-analytic models by the use of high fidelity CFD Innovative acoustic measurement techniques
  - Provide validated high-fidelity methods for direct broadband noise computation
  - Improve existing semi-analytic models



European Commission

CLEAN SKY2 / SALUTE

Smart Acoustic Lining for UHBR Technologies Engines

SALUTE

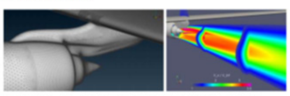
Duration: Nov 2018 – April 2022
Funding: 2,4 M€

SALUTE aims to deliver excellent sound absorption at low frequencies while remaining sufficiently small to fit into thin nacelle geometries. This development will be carried out on three different concepts. The SALUTE test 3D prototypes with a geometry corresponding to a small-scale fan at the PHARE test facility. This is required to reach TRL4, but will present specific challenges in terms of manufacturing. Secondly, gaining more insight into the physical interaction between the transducers, the control system and the high-speed flow will be necessary. This will be achieved through multi-physics simulations coupling all these sub-systems.

INSPIRE

Industrialisation of Jet Noise Prediction Methods

- Reducing expensive experimental testing by using computational methods and achieving methods for low noise design, in order to remain in advance of ever tighter emissions targets.
- This will involve developing reliable Detached Eddy Simulation plus Ffowcs-Williams and Hawkings (DES/FWH) methods aiming to enhance jet noise predictions and consequently improving confidence in numerical methods and best practices.
- The research will be applied to 3D nozzle designs optimized for specific styles of integration, e.g. various under-wing configurations targeted to lower jet-flap interaction noise emissions.



INSPIRE (398k€ EU funding) CFD SOFTWARE - ENTWICKLUNGS- UND FORSCHUNGSGESELLSCHAFT MBH, 36 Months.

Clean Sky

Clean Sky Noise Related Projects (2)

CLEAN SKY2 / INNOSTAT

Innovative Stator

Duration: Oct 2019 – Sept 2023
Funding: 2,8 M€

INNOSTAT targets rearward radiated fan noise through innovative OGV design. The project's objectives are

- to define 5 novel low noise stator concept designs, to develop and test them on prototype level TRL2 to TRL3,
- to select and develop 3 novel stator concepts for further advanced design, characterisation and full 3D stator stage large scale testing to TRL4,
- to define, design and manufacture 2 demonstrator OGV at TRL3 on full scale.

CLEAN SKY2 / CIRRUS

Core noIse Reduction foR Uhbr engineS

Duration: July 2020 – Dec 2023
Funding: 3,6 M€

The overall goals of CIRRUS are to:

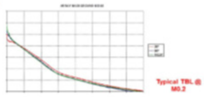
- Improve numerical methods to predict the noise source mechanisms and the acoustic core noise radiation,
- Improve experimental methods to measure the contribution of core noise on real engines,
- Develop, test and integration of new generations of noise reduction acoustic liners made of Ceramic Matrix Composites (CMC),
- Investigate on future UHBR 2030+ architectures the influence on the core noise sources by comparing various configurations of turbines by reducing the number of stages.

Clean Sky2 : LPA ADAPT

Project Title : ADvanced Aeroacoustic Processing Techniques
Project Consortium : Micro DB, Ecole Centrale de Lyon, CNRS, INSA Lyon, Pieter Sijtsma Advanced Aeroacoustics
Topic Manager : AIRBUS
Project start / end date : 01/09/17 – 31/08/20
EU funding : 363,497 EUR

Project Context & Objectives:

- *Context :* In the framework of the Large Passenger Aircraft ITD of Clean Sky 2, the ADAPT project aims at developing new techniques for aircraft noise separation & identification.
- The ADAPT consortium will improve and optimize the ability of identifying sources emitted by aircraft components (airframe ; tonal & broadband noise of the engine) by developing three approaches:
  - Aeroacoustic source separation
  - De-noising techniques based on cyclostationarity
  - Aeroacoustic sources localization



European Commission

Clean Sky 2 – AIRFRAME ITD
Aeroacoustics liner concept for laminar nacelle

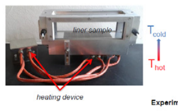
Fuel burn reduction can be achieved thanks to :

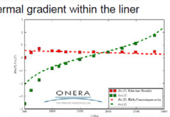
- New engines with Higher Bypass ratio (UHBR/UHPE)
- Laminar Nacelle concepts

→ Lower frequency fan noise
→ Shorter and thinner Nacelle

→New liner for lower frequency range near hot engine part

- ❑ Acoustic tests of different liner concepts with and without grazing flow
- ❑ Effect of thermal gradient on acoustic liner characteristics
- ❑ Effect of acoustics on the thermal gradient within the liner





Experiments vs Model Impedance Sample #6, M=0,0, ΔT=150K

Méry et al. , Experimental Assessment of the Effect of Temperature Gradient Across an Aeroacoustic Liner
Journal of Aircraft, 2019,56:5, pp. 1809–1821

New Horizon2020 Research and Innovation (RIA) Projects

DJINN

New computational fluid dynamics methods make aircraft quieter

Duration: June 2020 –May 2023

Funding: 5 M€

DJINN project will develop a new generation of reliable computational fluid dynamics (CFD) methods to assess promising noise-reduction technologies for future integrated propulsion aircraft. It is suggested to achieve 5 dB reduction of the jet-airframe interaction noise peak level at low frequencies. According to DJINN, understanding, modelling and predicting jet-airframe noise is the key to conceiving efficient noise-reduction technologies. Improved CFD methods for multi-physics modelling utilizing high-performance computing are expected to reduce design times and costs by around 25% compared to large-scale testing.

ARTEM

Aircraft noise Reduction Technologies and related Environmental iMpact

Project ID: 769350
From 2017-12-01 **to** 2021-11-30, ongoing project
Topic(s): MG-1-2-2017 - Reducing aviation noise
Call for proposal: H2020-MG-2017-SingleStage-INEA
Funding scheme: RIA

Objective

With ARTEM (Aircraft noise Reduction Technologies and related Environmental iMpact), seven EREA members and strategic partners have teamed up with leading European universities and major entities of the European aerospace industry in order to address the technology challenges raised in the call MG-1-2-2017 "Reducing aviation noise". ARTEM aims at the maturing of promising novel concepts and methods which are directly coupled to new low noise and disruptive 2035 and 2050 aircraft configurations. A core topic of ARTEM is the development of innovative technologies for the reduction of aircraft noise at the source. The approach chosen moves beyond the reduction of isolated sources as pure fan or landing gear noise and addresses the interaction of various components and sources - which often contributes significantly to the overall noise emission of the aircraft. Secondly, ARTEM addresses innovative concepts for the efficient damping of engine noise and other sources by the investigation of dissipative surface materials and liners. The chosen technology concepts offer the chance to overcome shortcomings (as the narrow band absorption peak or poor low-frequency performance) of current devices. The tasks proposed will mature, and subsequently down select these technologies by comparative testing in a single relevant test setup. Furthermore, noise shielding potential for future aircraft configurations will be investigated. The noise reduction technologies will be coupled to the modelling of future aircraft configurations as the blended wing body (BWB) and other innovative concepts with integrated engines and distributed electrical propulsion. The impact of those new configurations with low noise technology will be assessed in several ways including industry tools, airport scenario predictions, and auralization.
Thereby, ARTEM constitutes a holistic approach for noise reduction for future aircrafts and provides enablers for the expected further increase of air traffic.

INVENTOR

INnoVative dEsign of iNstalled airframe componenTs for aircraft nOise Reduction

Duration: May 2020 – April 2024
Funding: 5,1 M€

Aircraft are noisy during approach; landing gears and high-lift devices are the main noise sources. The EU-funded INVENTOR project will study the physics of noise generated by landing gears and high-lift devices at landing/approach. INVENTOR's main goal is to develop innovative low-noise installed landing gear, high-lift device components and noise reduction technologies, in order to lower external noise from business jet and short-to-medium-range transport aircraft.

ENODISE

ENabling Optimized DISruptivE Airframe-Propulsion Integration Concepts

Duration: June 2020 – May 2024
Funding: 5 M€

ENODISE aims at reducing aircraft gaseous and noise emissions by improving the integration of the propulsion system with the airframe. ENODISE will investigate the main propulsion-airframe integration issues at low TRL.
ENODISE will investigate the existence of local/global integration optima via an innovative experimental methodology combined with reduced order modelling and machine learning strategies. Selected configurations will be simulated using methods ranging from low-CPU to high-fidelity. The low-CPU techniques will be employed to verify if the experimentally observed optima can be obtained numerically, and the high-fidelity methods will contribute to the detailed investigation of the aeroacoustic mechanisms in addition to permitting a fine-tuning of the low-cost methods. The work being carried out on relatively low-cost generic configurations, this project will permit spanning a broad parameter space and testing optimization-based robust design methods

New Horizon2020 Research and Innovation (RIA) Projects

ANIMA

Aviation Noise Impact Management through Novel Approaches

Duration: Oct 2017 – Dec 2021
Funding: 7,6 M€

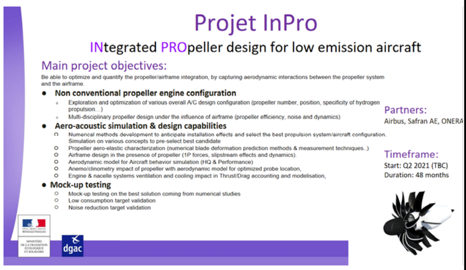
ANIMA aims to develop new methodologies and tools to manage and mitigate the impact of aviation noise, improving the quality of life near airports while facilitating airports growth and competitiveness of the EU aviation sector within the environmental limits, also considering 24/7 operations. ANIMA carries out critical review and assessment of noise impacts and existing management practices to establish best practices' guidelines for an effective management of annoyance beyond ICAO Balanced Approach; develops a better understanding of annoyance, sleep disturbance and improve quality of life; develops a 24/7 Noise Management Toolset; to empower non-specialists with decision support capability and a 24/7 Design Toolset for researchers; supports the coordination of national and EU research activities, establishing a common strategic research roadmap for aviation noise.

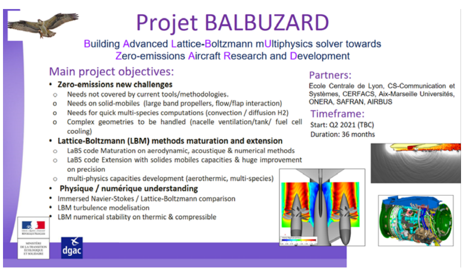
UK National Project

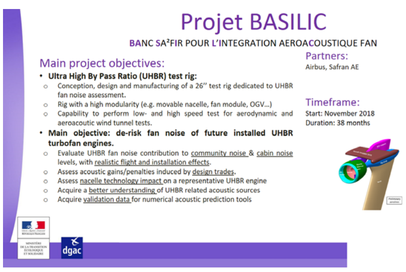
FANTASIA (Future Noise Technologies And System Integration Analytics)
Duration: December 2020 – November 2024

Partners: Rolls-Royce, University of Southampton
Objective: Develop, model and validate noise technologies for integrated propulsion systems, that achieve the required noise level for a novel UHBR engine architecture as well as hybrid electrical propulsion systems. Multi-disciplinary optimisation techniques will be developed for design for the optimal noise, CO2 and emissions. Computational fluid dynamics as well as advanced measurement and source separation techniques will be applied in the project to replace test and provide an early assessment of the noise. The multidisciplinary approach and the contributions of UK based industry and Universities ensures state of the art as well as emerging technologies are considered, which are required to achieve the required interim progress towards the ACARE 2050 targets with a propulsion system optimised for noise, CO2 and emissions.

French National Projects







ICAO CAEP support and Aviation Research activities by Germany

The Federal Republic of Germany is highly engaged in aviation research, including on noise reduction, through many programs and projects supported by various ministries and organizations.

Germany supports the work of ICAO's Committee on Aviation Environmental Protection (CAEP).

Research program LuFo (Luftfahrtforschungsprogramm)

LuFo is a perennial program with a planning horizon of 4-5 years

Funding of research projects on aviation noise reduction since 1994

- Target groups: Industry, SME, Research establishments, Universities
- Objectives:
  - Support program for enhancing innovation through collaboration between industry, supply chain and academia
  - Efficient use of national resources

Scope of LuFo aviation noise reduction funding in 2020:

Projects funded with 18 Mio € in 2020 with direct reference to noise reduction.

A variety of other projects with a funding volume of 12 Mio € in LuFo in 2020 also refer to noise reduction (e.g. hybrid-electric flying, efficient flight guidance, innovative structures)

DLR Project Management Agency for Aeronautics Research

Excerpt of academic aircraft noise research in Germany

HAW Hamburg
- Automotive and Aeronautical: Flow Acoustics

University of Oldenburg
- Hearing Research/Auralization

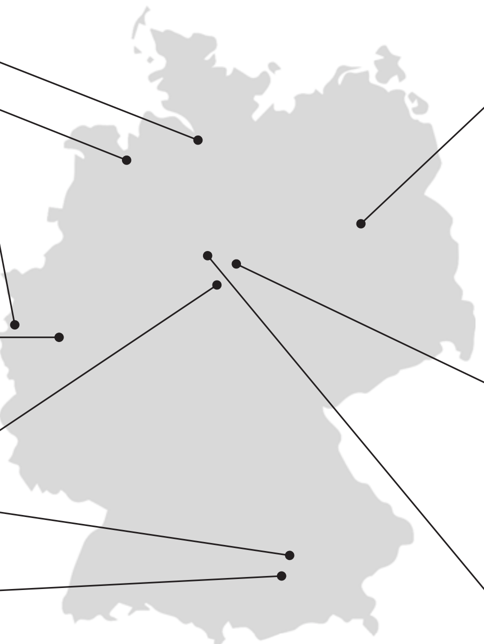
RWTH Aachen University
- Institute of Jet Propulsion and Turbomachinery
- Institute of Aerospace Systems: Impact Research, Start-up e.SAT
- Institute of Transport Science: Airport scenarios

DLR Cologne
- Institute of Aerospace Medicine: Noise Effects Research

DLR Göttingen
- Institute of Aerodynamics and Flow Technology: Measurement Technology, Simulation and noise prediction, low-noise aircraft design, interdisciplinary aircraft noise research

TU Munich
- Institute of Aircraft Design: Noise prediction and airport scenarios

DLR Oberpfaffenhofen
- Institute of Atmospheric Physics: Noise and Sound Propagation



DLR Berlin
- Institute of Propulsion Technology/Department Engine Acoustics: Sound sources in turbomachines and Aero-Engines, Aircraft noise measurement, low-noise engine design

TU Berlin
- Institute of Fluid Mechanics and Engineering Acoustics: Aero- and Psychoacoustics

TU Braunschweig
- Institute for Acoustics Cluster of Excellence SE²A – Sustainable and Energy-Efficient Aviation, incl. Cabin noise, airport scenarios, psychoacoustics
- Institute of Jet Propulsion and Turbo Machinery

DLR Braunschweig
- Institute of Aerodynamics and Flow Technology/ Department Technical Acoustics: Acoustics windtunnel, directional characteristics and noise-driven aircraft configuration, Aircraft noise measurement
- Institute of Flight Systems: low-noise flight procedures
- Institute of Flight Guidance: Flight path planning

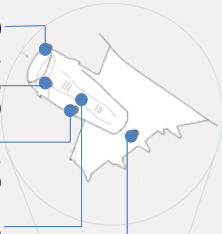
Leibniz University Hannover
- Institute of Turbomachinery and Fluid Dynamics: Aeroacoustic Wind Tunnel, core engine noise, acoustic transport mechanisms in turbomachines

DLR Project Management Agency for Aeronautics Research

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

LuFo research projects in 2020 (excerpt) with direct reference to aviation noise reduction potential

… in jet engines:



Low-Noise engine installation (INTONE)

Sound-absorbing engine lining (ERADOT).

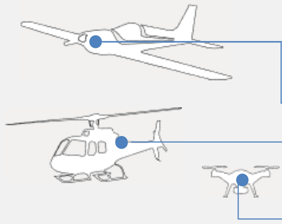
Determination of noise generation at propulsors (SiVaIT)

Methods for low-noise design, optimization and acoustic measurement of engine components (MUTE)

Sound-absorbing engine lining, active stator, mistuned blade/vance combinations (MAMUT)

Low-noise nozzle and aircraft configurations (PAKO)

… in propeller aircraft, helicopters and UAS:



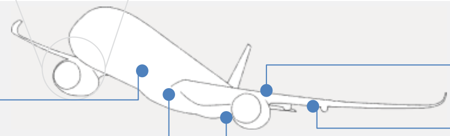
Optimization of electric propeller engines in drive- or recuperation-mode (E-DARIT)

Aeroacustic simulation of low-noise propeller and turboprop engines (FusionProp)

Predictive capabilities of noise radiation (eVolve)

UAS noise analysis (ATEFA)

… in wings, flaps, cavities and landing gear:



Measurement of pressure fluctuation on aircraft skins (FlexMEMS)

Virtual development environment for noise reducing measures at NEO aircrafts (FLIGHT-LAB)

Acoustic interaction between UHBR engines and high-lift devices (INTONE)

Determination of noise generation at high-lift devices (LoCaRe)

Excitation of fuelage and cabin acoustics (UHBR2Noise)

.. in operational measures :

Efficient planning of flight operations with Industry 4.0 (EffFlug)

DLR Project Management Agency for Aeronautics Research

LuFo Noise related projects (excerpt)

DLR Project Management Agency for Aeronautics Research

Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

FusionProp

Enabling the Next Generation of Quieter Turboprops

The FUSIONProp project began in 2018 under the German LuFo programme to advance the state of the art in turboprop acoustics. As part of this collaborative effort between GE Aviation Munich and DLR, flight tests were successfully carried out in 2019 with two different aircraft, providing important insights into installed turboprop noise. Unique amongst the measurements performed was acoustic source localization, carried out for the first time synchronously using a fuselage array mounted on DLR's Do228 research aircraft and a ground microphone array. The results from these tests will help better understand the complexities of installed propeller noise and improve modelling and predictive capabilities for different installations that will enable future efficient and low noise aircraft.

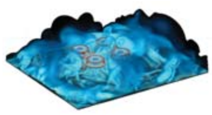
DLR's Dornier 228 research aircraft during flight testing in Germany (Credit: DLR (CC-BY 3.0))

Contact:
Dr. Davide Giacche
Davide.Giacche@ge.com

eVolve

enhanced VTOL aeromechanics – a system level approach

The research project eVolve is dedicated to advanced prediction capabilities and technologies concerning aeromechanics of classical helicopters and novel vehicle architectures.
In a dedicated sub work package on aeroacoustics the partners are striving to enable first acoustic assessments for new VTOL architectures already in a conceptual design phase. To that purpose acoustic design databases are pre-calculated with established fast freewake and CAA methodologies that are complemented with and validated by BEM simulations and higher sophisticated simulation tools. Based on these results, surrogate models for sound emissions are derived and implemented into mission management methodologies for ground noise impact assessments.



Contact:
Rainer Heger
rainer.heger@airbus.com

AIRBUS · Universität Stuttgart · TUM · DLR

MUTE

Methods and Technologies for Prediction and Reduction of Aeroengine Noise

Within the German national joint research project MUTE, funded by the Ministry of Economics, RRD, MTU, DLR and CFDB have partnered with the objective to develop methods and technologies for prediction and further noise reduction in modern environmentally friendly aero-engines. RRD leads a task to develop and validate methods for low noise design and advanced noise measurements, with partner contributions from DLR and CFDB. MTU leads tasks with DLR for modeling and analysis of turbomachinery noise, in particular transmission and modal analysis in the interstage region and the propulsor noise source prediction. Last but not least RRD and MTU develop and validate models for spectral broadening of tones based on wind tunnel tests and simulations under in a joint task, which is led by DLR.

CFD Software E+F GmbH

Contact:
Dr. Christoph Richter
Christoph.Richter@Rolls-Royce.com

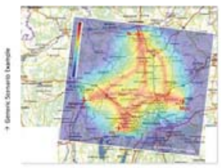
ATEFA

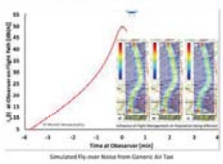
Air Taxis: First Operational Noise Assessment

ATEFA investigates, models and evaluates the noise generated by projected air taxi (eVTOL) traffic in urban environments. The models incorporates key factors such as number of vertiports, flight paths, number of movements and predicted noise signatures of various generic eVTOL types to determine the noise impact at airfields, vertiports and along flight paths. The project allows a direct noise comparison between different platforms (e.g., conventional helicopters and eVTOLs) and shall give first estimation for annoyances produced by new air vehicles.

Main Objectives in ATEFA:

- Description of noise sources for new a/c concepts
- Creation of generic noise maps ("Land Use Planning")
- Certification values according to ICAO Chapter 8 and 11 as a basis for comparison
- Raise TRL from 3 to 6





Contact:
Daniel Redmann
daniel.redmann@koptergroup.de

kopter · ILR · RWTH Aachen University · Munich Aeroacoustics

X-NOISE

Pioneering Technology Evaluation / Progress Assessment

X-NOISE	2000 - First formulation of assessment methodology (ANTE) developped in Silence(R) proposal
	2002 - SRA1 Noise Target Definition (2020)
X2-NOISE	2003 - Implementation of Annual Technology Status Report (Invidual Techs vs TRL Scale)
X3-NOISE	2007 – Completion of Silence(R) Technology Evaluation Exercise
	2008 – Formulation of improved ANTE tool for OPENAIR
	2010 – Noise Reduction Progress Assessment in Support of AGAPE
X-NOISE EV	2011 – X-NOISE / CLEAN SKY workshops to harmonize evaluation vs noise targets
	2012 - SRIA Noise Target Definition (2035-2050)
	2013 - Noise Reduction Progress Assessment in Support of OPTI
	2014 – Completion of OPENAIR Technology Evaluation Exercise
	2015 - Noise Reduction Progress Assessment in Support of ACARE WG3
	2020 – Noise Reduction Progress Assessment in Support of ACARE WG3

X-NOISE

2020 Assessment of Progress towards the ACARE noise target

- A new assessment by experts in 2020 estimated that the progress made towards the ACARE 2020 goals (-10 dB) is 6,4 dB (at TRL 6).
- Relative to the ACARE 2050 noise target of -15dB per operation, this performance underlines that significant improvement are still needed to recover to reach the objective.

Success Conditions

- Bring most promising Generation 2 noise reduction technology toTRL6, through appropriate full scale validation effort across the board (engines, nacelles, landing gears, airframes).
- Very significantly increase the effort dedicated to Low Noise Aircraft configurations
- Take advantage of the sustained effort on low noise operational procedures to consolidate wider implementation capability.

Appendix C

Japanese Noise Technology Research Programs

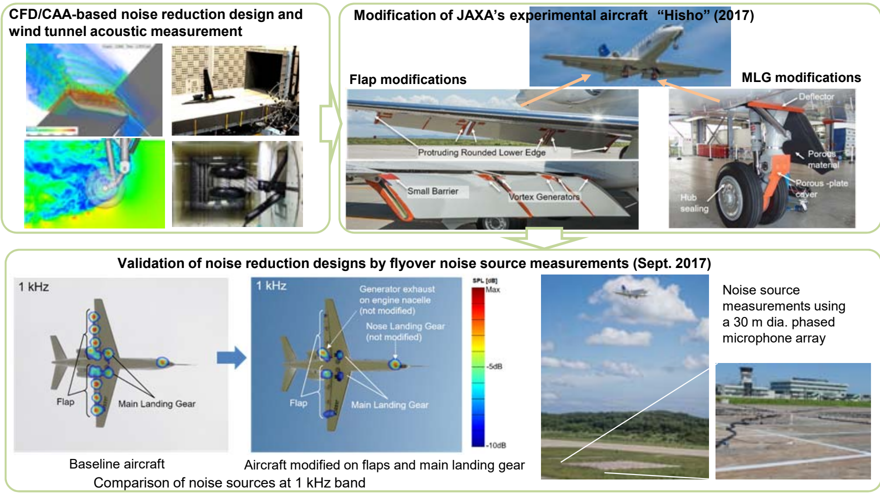
CAEP/WG1

Status of research programs worldwide (JAPAN)

Key technology projects (Airframe Noise)

- JAXA's FQUROH[*1] project aims at establishing technologies for airframe noise reduction. Noise reduction concepts for flap side-edges and main landing gear were applied to JAXA's experimental aircraft "Hisho" which is based on a Cessna Citation Sovereign. The 2nd flight test campaign was conducted in Sept. 2017 to validate the noise reduction designs, and successfully showed flap and MLG noise reductions of 3 to 4 dB[A].

[*1] Flight Demonstration of Quiet Technology to Reduce Noise from High-lift Configurations; "owl" in Japanese

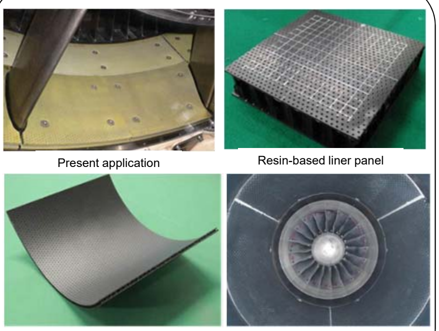


Comparison of noise sources at 1 kHz band

Key technology projects (Engine Noise)

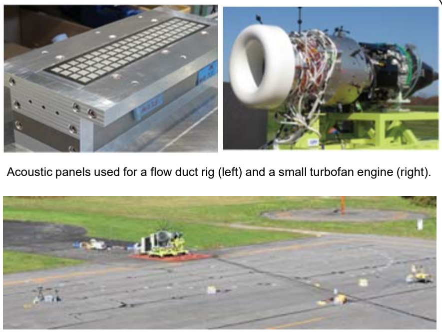
- A light-weight acoustic liner panel, made from resin-based material, has been developed in JAXA's aFJR (advanced Fan Jet Research) project. Noise reduction compatible to the conventional liner panel was obtained through fan rig tests. JAXA and IHI corporation plans to install this panel on new demonstration engine, F7, to confirm the durability of the panel under harsh conditions.
- Research associated with the shorter nacelle configuration has been conducted for the higher bypass ratio engines. As well as prediction of inlet distortion in the nacelle, improving the acoustic and aerodynamic performances of the acoustic liner panels under grazing conditions has been by computational and experimental approaches.

Light-weight acoustic liner panel (post-aFJR)



Present application | Resin-based liner panel | Curved liner panel | Fan rig application

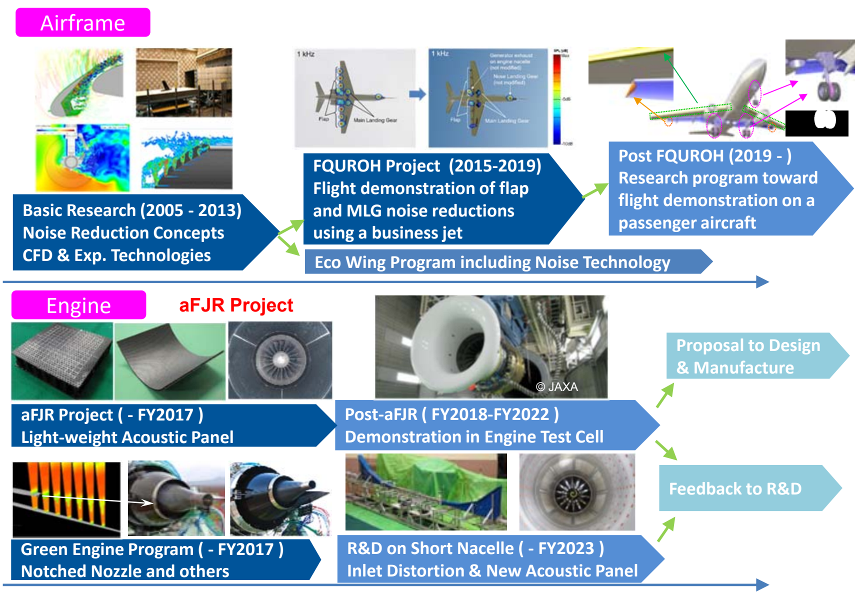
Noise reduction studies on short nacelle



Acoustic panels used for a flow duct rig (left) and a small turbofan engine (right).

Noise test with a small turbofan engine in an open test site.

Progress towards the goals



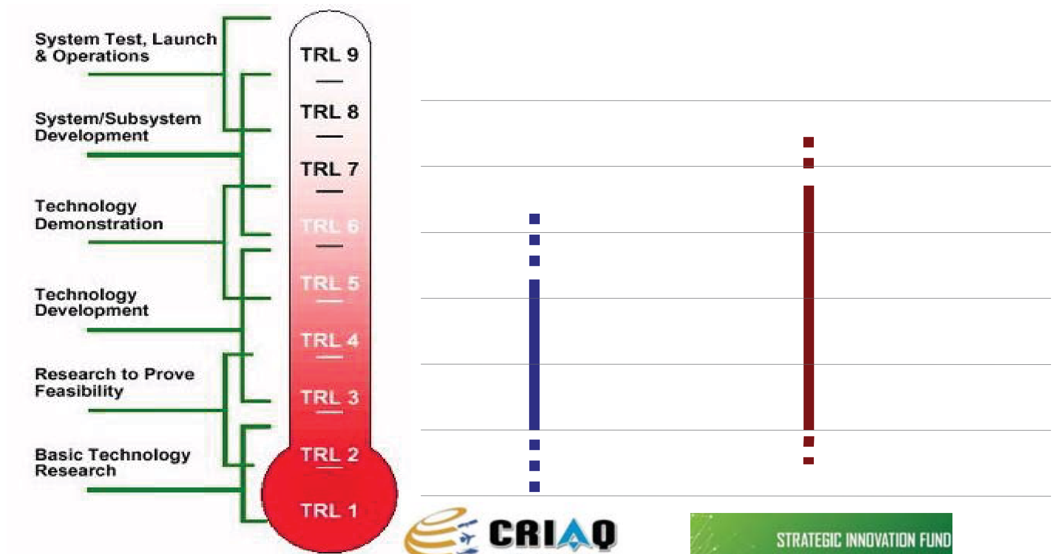
Appendix D

Canadian Technology Research Programs

CANADA

- **Currently, no nationally lead noise research programs**
  - **GARDN has closed**
  - **New program options are being studied**
- **Funding opportunities for noise research projects exist**
  - **Aerospace focused**
    - **CRIAQ (Quebec)**
  - **Generic funding opportunities**
    - **NSERC, Strategic Innovation Fund, OCI (Ontario)**
- **Canadian companies are currently leveraging these to support noise reduction research**
  - **Airframe noise, Tail rotor noise, Engine noise**

Canadian Aviation Research Funding Opportunities



NASA Technology Readiness Levels

Appendix E

Russian Technology Research Programs

Aeroacoustics projects in Russia on subsonic aircraft

2017	2018	2019	2020	2021	2022	2023	2024	2025

- Ministry of Science (Collab. with EU, APTEM)
- Ministry of Science (Collab. with China)
- IENA (Science foundation) (BRICS)
- RFBR (Science foundation)
- RSF (Science foundation)
- Flight tests (aircraft manufacturers)
- Ecology-2020 Minisrtry of Industry and Trade
- General Aviation-2020 Minisrtry of Industry and Trade

Ministry of Science **MSHE №14.628.21.0011**. **Collaborative Russian-EU project ARTEM** "Aircraft Noise Reduction Technologies and related Environmental Impact" (Russian part)

ARTEM

Shielding

Development of innovative technologies of reduction using shielding effect.
Iinvestigation the effect of non-compactness of aviation noise sources on airframe shielding and to develop the Geometry Theory of Diffraction (GTD) and the Uniform Theory of Diffraction (UTD) for the prediction of shielding efficiency.

$$P_{total} = P_G + P_D$$

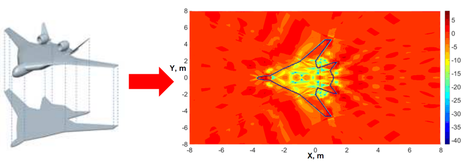
$$P_G = A\frac{\exp(ikR_{obs})}{4\pi R_{obs}}\Theta(R_{obs})$$

$$P_D = A\frac{\exp(ik(R_{sc}+R_d))}{4\pi R_{sc}}\cdot\sqrt{\frac{R_{sc}}{R_d(R_{sc}+R_d)}}\cdot D_{coeff}$$

$$D_{coeff} = \frac{-\exp\left(i\frac{\pi}{4}\right)}{2\cdot\sin(\beta_0)\sqrt{2\pi k}}\left(\sum_{m=1}^{4}F(p_m)\cdot ctg(\theta_m)\right)$$

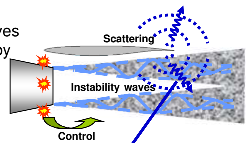
$$F(p_m) = 2i\sqrt{p_m}\exp(ip_m)\int_{\sqrt{p_m}}^{\infty}\exp\left(i\frac{\pi}{2}u^2\right)du,$$

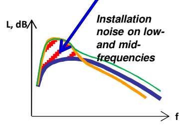
$$p_m = \frac{2kR_sR_d}{R_s+R_d}\sin^2(\beta_0)\cdot\cos^2(\chi_m),$$

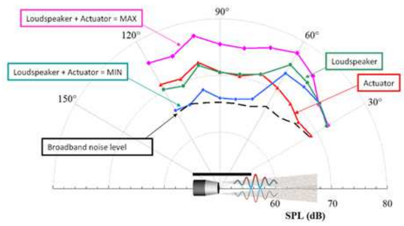


Plasma actuators for jet-flap interaction noise control

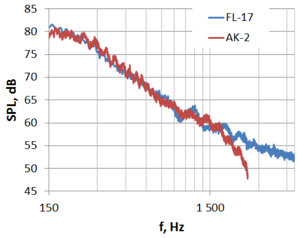
Active control of the hydrodynamic instability waves to reduce installation noise by means of HF DBD plasma actuators

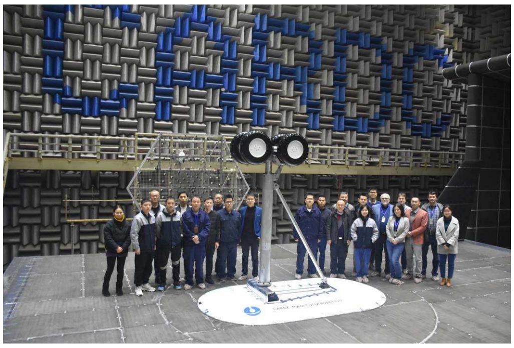


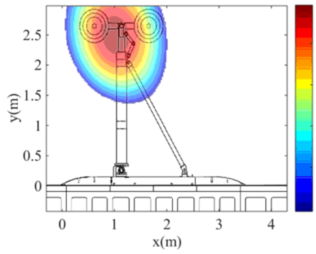




Ministry of Science (**MSHE #14.627.21.0004) "Joint Russian-Chinese project on landing gear noise**" (funded by Russian Ministry of Science and Higher Education and by National Key R&D Program of China)



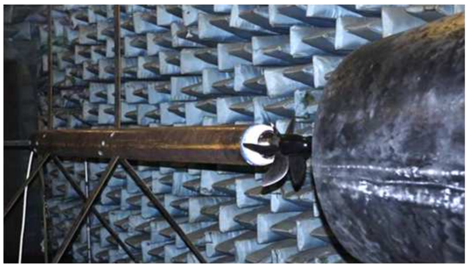


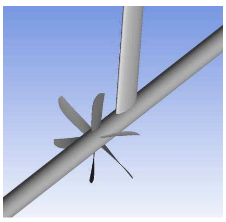


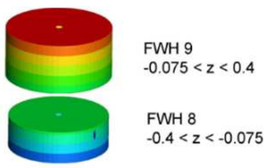
Parametric study on the effect of different geometric parameters for landing gear noise. Comparison of small-scale and large-scale landing gear noise results.

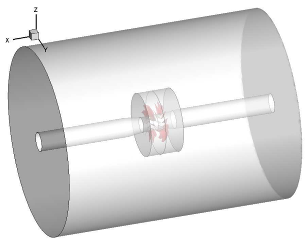
General aviation (MA19-20, Ministry of Industry and Trade)
"Development of numerical methods and parallel software for aerodynamics and aeroacoustics of regional aviation propellers"

Development and validation of in-house fully parallel unstructured-mesh solver to model propeller and rotor noise.



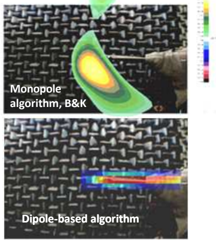






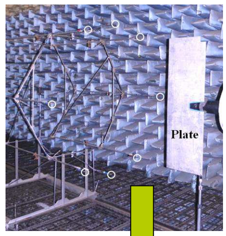
RFBR for BRICS cooperation project (Brazil, China, and Russia)
IENA (Installed Engine Noise Attenuation)

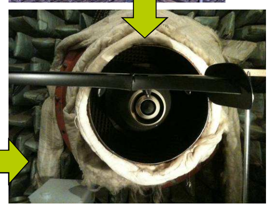
The project focuses on the development of **methods for measurement and localization** of installed engine noise, investigation of the installation effect on engine noise (relative position of wing/fan and jet/flap on noise), and development of recommendations for installed engine noise attenuation.



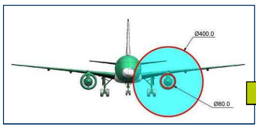
Beamforming

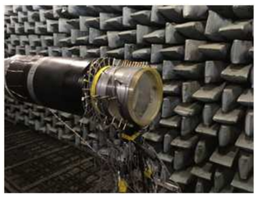
Azimuthal modes of jet/wing interaction noise

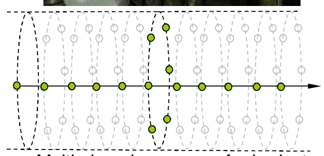




Russia's part:
1) To localize sound sources for jet/wing interaction based on a modified beamforming method.
2) To investigate modal structure of noise in the farfield for installed engines (with realistic configuration of airframe).
3) To investigate modal structure of sound field in ducts by nonuniform microphone arrays.





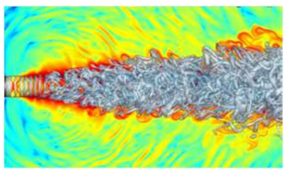


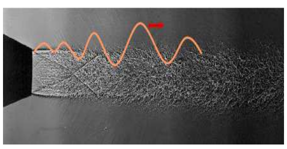
Multimicrophone array for in-duct mode measurements

RFBR №19-01-00229 "Development of low-order models for noise generation mechanisms in coaxial jets based on the correlation theory of noise sources in turbulent flows"

At present, there is no consensus on the mechanism of sound generation in turbulent flow. There are a number of directions in which different processes are selected as sources of noise:

1. Linear perturbations of the meanflow
   - Instability waves
   - Global linear models
2. Linear perturbations of non-radiating large eddies
   - Eigen-oscillations of vortex rings in jets and traces
3. Non-linear sources of sound
   - Correlation models of sound

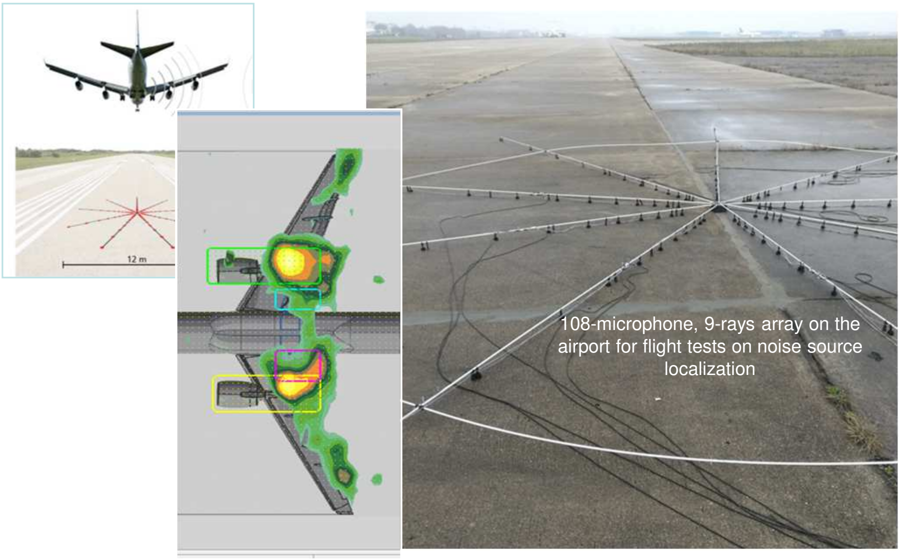




The topical task is the development of unified ideas about the mechanism of sound generation by turbulent flows based on the creation of predictive low-order models of sound-emitting pulsations

Programs of Flight tests (Contracts with aircraft manufactures)

In flight tests, unique results on localization and ranking of aircraft noise sources were obtained with the help of 108-microphone array, which are aimed at development of airframe noise reduction technologies

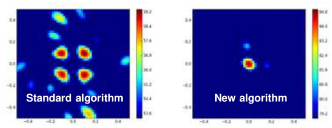


Russian Science Foundation (RSF № 19-71-10064) «Development of methods of multichannel measurements in aeroacoustics in application to the diagnostics of the major noise source for prospective aircraft»

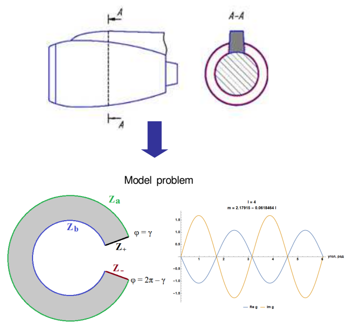
The project is aimed at solving the following problems:

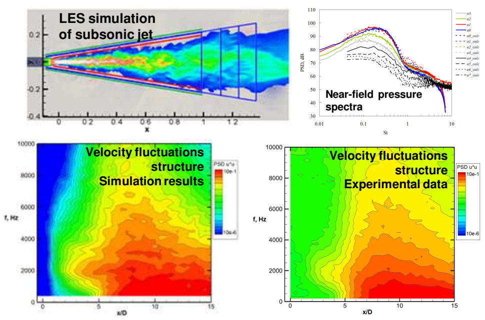
- Development of measurement methods for sound field structure and determination of characteristics of noise sources produced by turbulent flows;
- Development of measurement methods for sound field structure in ducts with the account for nonhomogeneity of the mean flow, as well as methods for sound field radiated from the open end of the duct;
- Development of the methods for the analysis of turbulent flow field structure, based on post-processing of the data of multi-channel measurements and LES numerical results, with the aim to identify the sound-radiating part of turbulence.

Localization of quadrupole sound source



Acoustic liners in a turbofan fan duct





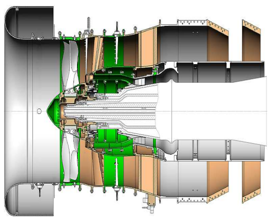
ECOLOGY-2020

DESIGN AND EXPERIMENTAL STUDY OF THE ADVANCED FAN MODEL C194-2 WITH INCREASED PERFORMANCES

Main feature - the technology of manufacturing fan blades from polymer composite materials.

The rotor blades of the geared fan model were manufactured of domestic composite materials. The C194-2 fan model with the bypass ratio BPR = 13-14 and the designed fan tip speed U_f ~ 320 m/s.

Rotor of the fan model C194-2 with composite blades



Experimental fan model C194-2 adapted to the C-3A test facility (CIAM)

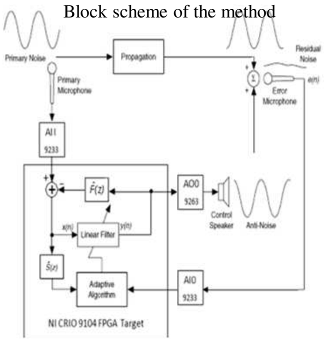
FAN MODEL C179-2 WITH THREE-ROW SLOT TYPE CASING TREATMENT

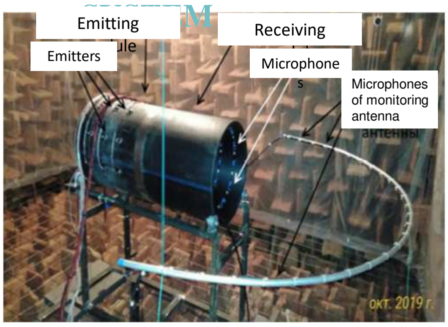
Pilot study aimed to increase the fan pressure ratio, efficiency and surge margins in operating modes n = 60% -100%

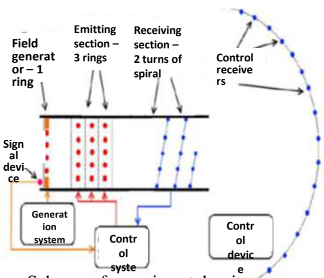
ECOLOGY-2020

ACTIVE FAN NOISE CONTROL SYSTEM

Block scheme of the method

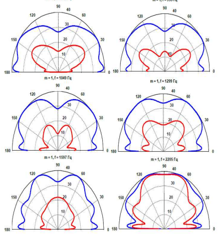


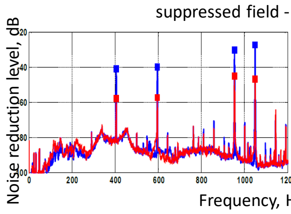




Scheme of experimental unit

Directivity diagrams of sound radiation and sound spectra: initial field - blue, suppressed field - red





Realization of ANC method (TRL=4) on fan model is expected by 2022

Appendix F

Brazilian Technology Research Programs

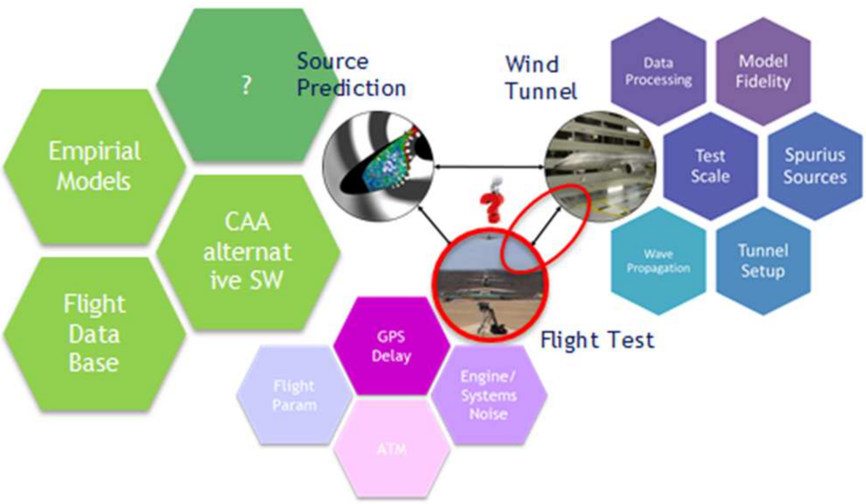
BRAZILIAN AIRCRAFT NOISE RESEARCH PROGRAMS

Summary

- Brazilian Silent Aircraft Consortium Phases 1 and 2 (2007-16)
- SILENCE consortium (2015-18)
- Silent Approach Brazilian-Dutch Consortium (2018-21)
- LoCaRe Brazilian-German Consortium (2018-21)
- AERO-Trends Consortium (2021-23)

SILENT APPROACH AND LOCARE PRELIMINARY

Airframe Noise Uncertainties puzzle mind map



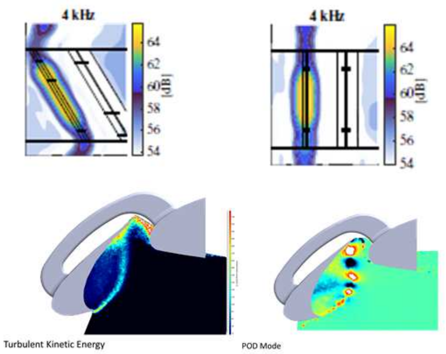
EMBRAER | CHALLENGE. CREATE. OUTPERFORM.

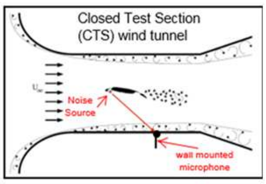
Silent Approach

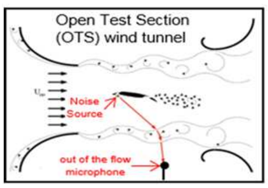
TOPICS:
- Closed vs Open Test Section Assessments in Aero-acoustic Wind Tunnel Tests
- Dedicated aero-acoustic wind tunnel tests in small and industrial scale
- Flight test vs wind tunnel data comparison
- Tunnel setup and test model spurious effects modeling

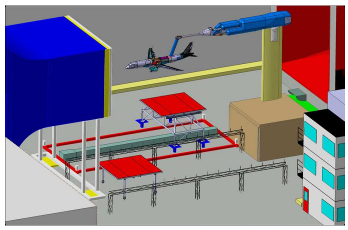
PARTNERS
- University of Twente, Netherlands (UTwente)
- German Dutch Wind Tunnels, Netherlands (DNW)
- Royal Dutch Aeospace Institute, Netherlands (NLR)

Silent Approach: preliminar achievements









LoCaRe

TOPICS:
- High Reynolds effects investigations on airframe noise
- Dedicated pressurized criogenic wind tunnel test
- Advanced acoustic processing algorithms
- Crio PIV vs Farfield Acoustic data correlation

PARTNERS
- German Aeroscpace Institute, Germany (DLR)
- European transonic Wind Tunnels, Germany (ETW)

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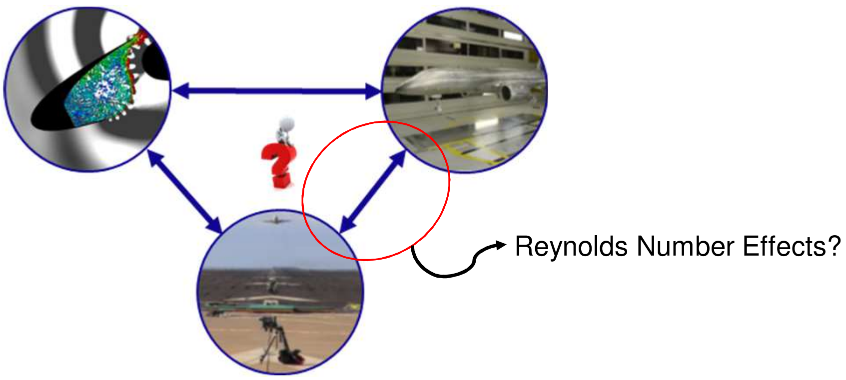
LoCaRe: motivation diagram



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AERO-TRENDS INITIATIVE

AERO-Trends

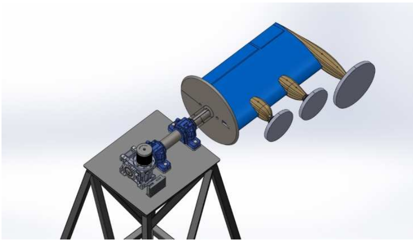
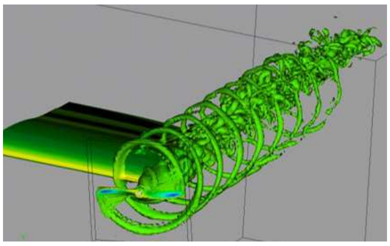
TOPICS:
- Noise Evaluation of Distributed Propulsion Concepts.
- Rotative Acoustics Sources Modeling.
- Assessment of Installation and In-flight Effects of Multiple Propeller configurations.
- Noise Module for Early Design Trade Offs and Multidisciplinary Optimization.

BRAZILIAN PARTNERS
- University of São Paulo, São Carlos Campus (USP-EESC)
- Federal University of Santa Catarina, Florianópolis (UFSC-Florianópolis)

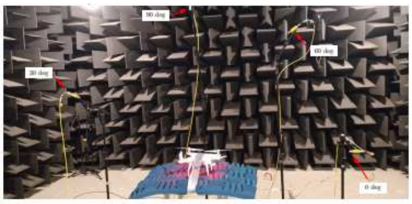
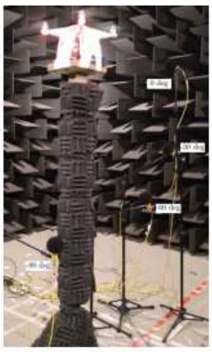
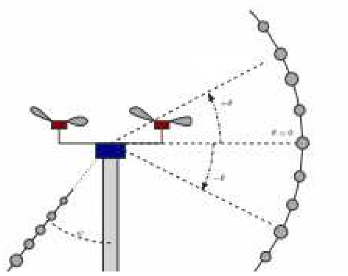
EMBRAER | CHALLENGE. CREATE. OUTPERFORM.

Distributed Propulsion Rig (USP-EESC)



Propeller Noise Stationary Rig (UFSC)

Appendix G

Chinese Technology Research Programs

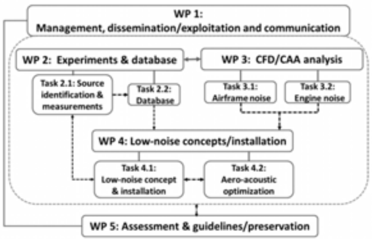
EU-China Innovative Methodologies and technologies for reducing Aircraft noise Generation and Emission (IMAGE) program (1 April 2016 to 30 June 2019)

➢Objectives

CH-EU project IMAGE targets to investigate innovative control technologies and strategies that could effectively manipulate aircraft noise in terms of suppression of noise generation and propagation with minimum penalty for aerodynamic performance, weight and cost.

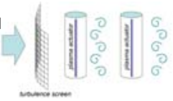
CN Consortium : ASRI, THU, NPU, ACAE, BUAA, iMech, ARI, FAI and BASTRI

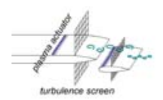
EU Consortium : Chalmers, KTH, VKI, ONERA, CIMNE, CFDB, NLR, NUMECA, RWTH, TU-K, UPM, AGI

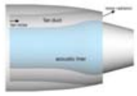


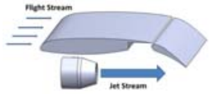
➢Simplified Configurations

In order to unveil and model the physical mechanisms permitting the control of airframe and engine noise, detailed knowledge was obtained in IMAGE by studying simplified but representative configurations. Four specific basic configurations are selected.


Tandem cylinders


Simplified wing mock-up


Engine-fan duct


Installation effects

Significant Noise Sources	Approaching stage	Engine far-field propagation
Applications	landing gears and high-lift devices (airframe)	Engine fan and engine-jet/wing (engine)
Simplified Configurations	tandem cylinders, simplified wing mock-up	engine-fan duct, installation effects

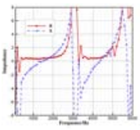
➢Impedance Eduction (IFAR ./w NASA)

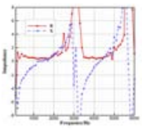
Impedance duct test rig was design and constructed in term of the eduction method validation under various flow and acoustic conditions .

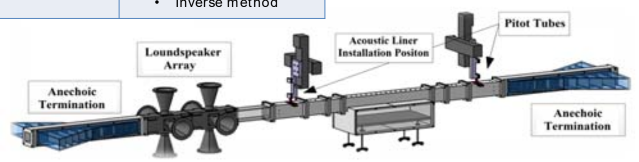
Tasks	Impedance and Transmission loss
Velocity	0Ma - 0.6Ma
Frequency	100Hz - 6000Hz
SPL	>140dB
Methd	• In-situ • Prony method • Inverse method


Uniformed Liner


Segmented Liner


R & X (Uniformed)

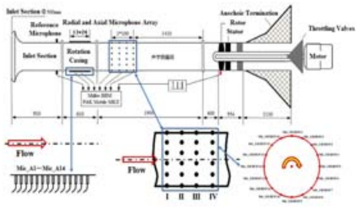

R & X (Segmented)

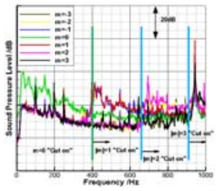


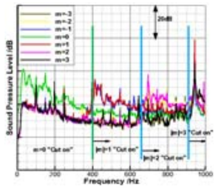
➢Mode Decomposition Method (./w NPU)

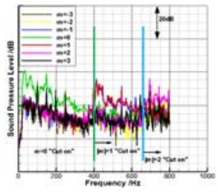
Mode decomposition method was further studied and expanded to broadband noise mode decomposition:

Three microphone array configurations were carried out for mode decomposition at multiple perspectives such as dimensional, transmission directional and rotational with flow pattern influences.


Microphone Array Configurations

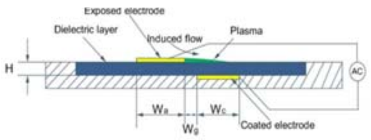

Instant-MDM

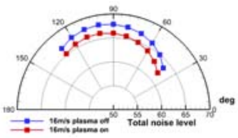

CC-MDM

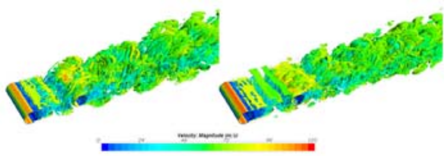

RC-MDM

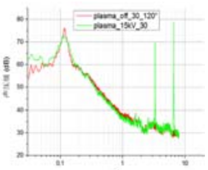
➢Noise Reduction with Plasma Actuation (./w Chalmers)

Plasma actuator for noise reduction for both tandem cylinders and wing mockup was numerically and experimentally studied, where promising noise reduction performance were observed.



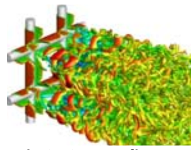


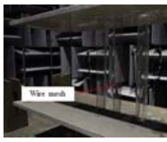

Instant velocities with/without plasma

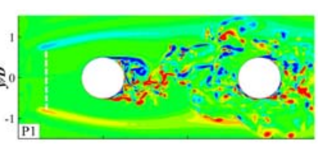

SPL vs. St via Plasma

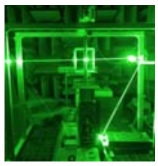
➢Noise Reduction with Turbulence Screen(./w ONERA)

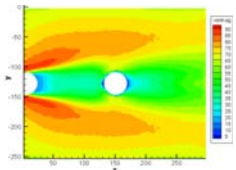
Small scale vortices pattern and noise generation for turbulence screen were observed by numerical and experimental method, effective noise reduction observed.

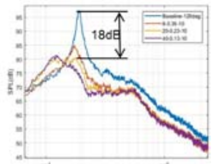

Instantaneous flow


Experimental setup


Turbulence screen on tandem cylinder


PIV test setup

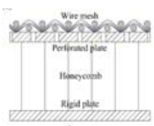

PIV result



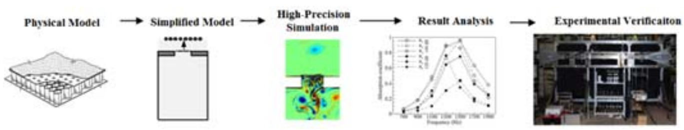
SPL vs. St via wiremesh

➢Wiremesh Liner

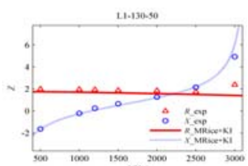
- Effective in acoustic resistance enhancement.
- Comprehensive impedance model of metallic wire mesh liner was developed.

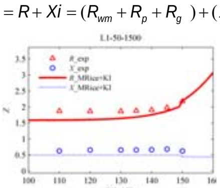


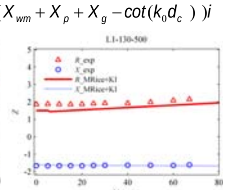
structures



$$Z = R + Xi = (R_{wm} + R_p + R_g) + (X_{wm} + X_p + X_g - cot(k_0 d_c))i$$

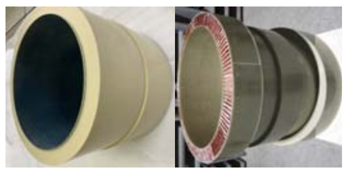

Z vs. Frequency

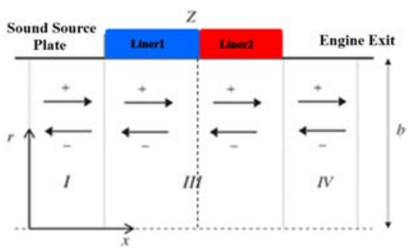

Z vs. SPL


Z vs. Velocity

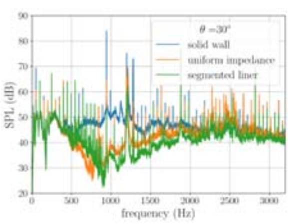
➢Segmented Liners (./w CFDB)

- Segmented liners with improved noise reduction performance were studied.
- Modal reflection and dispersion at impedance boundary between each stage of liners were improved.


Segmented liners



Mode reflection and dispersion illustration


SPL vs. Frequency