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ENVIRONMENT

STATUS REPORT

A 3D rendering of a jet engine in a dark blue color, positioned on the left side of the cover. To its right, several concentric circles in shades of green, yellow, and red radiate outwards, representing sound waves. The background is a dark blue grid pattern.

# NOISE TECHNOLOGY RESEARCH FOR FIXED WING AIRCRAFT

November 2025

**Overview:**

Shows a portrait of current noise technology research initiatives worldwide.

# NOISE TECHNOLOGY RESEARCH FOR FIXED WING AIRCRAFT

## STATUS REPORT

NOVEMBER 2025

### **Contributors:**

*Committee on Aviation Environmental Protection (CAEP) Members:* China, United States - Federal Aviation Administration (FAA) and France - French Civil Aviation Authority (DGAC).

*International Coordinating Council of Aerospace Industries Associations (ICCAIA):* Airbus, Boeing, Bombardier, Collins, Dassault, DeHavilland, Embraer, GE, Pratt & Whitney, Pratt & Whitney Canada, Rolls Royce, Safran.

*Research:* CIAM, DLR, Georgia Tech, JAXA, NASA, Tsagi.

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## 1. SUMMARY

- 1.1 This report concludes the Committee on Aviation Environmental Protection (CAEP) Working Group 1 (Noise) 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 CAEP/13 cycle (2022-2024).
- 1.2 The situation of noise technology research initiatives worldwide is reviewed, and a summary of the research activities is provided for each region.

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## 3. INTRODUCTION - BACKGROUND

- 3.1 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.
- 3.2 The first noise technology workshop was held in São Paulo, Brazil, in December 2001, later the basis of a dedicated ICAO journal article. In the following cycle, IP/11 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, United States, as an introduction to the first Noise Technology Independent Expert Review (IER1). IP/26 to CAEP/8 documented the information presented at this occasion. Further updates on ongoing noise technology research programmes were subsequently provided at each CAEP meetings (IP/14 to CAEP/9, IP/10 to CAEP/10, IP/11 to CAEP/11 and WP/36 to CAEP/12).

- 3.3 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 supporting the technological side of the Balanced Approach.
- 3.4 As for similar previous reports, the paper will cover known national and regional noise technology research initiatives and aims at providing an up-to-date view of ongoing and planned efforts with respect to their technical scope as well as their set objectives.

#### 4. OVERVIEW OF TECHNOLOGY PROGRAMMES AND RESEARCH INITIATIVES

- 4.1 The situation of noise technology research initiatives worldwide as of May 2024 is summarized in Figure 1. It covers an 18-year period (2009-2029), providing an evolutionary perspective and clearly shows the last two decades of commitment of the States involved.

### International Noise Technology Research Programmes(2024)

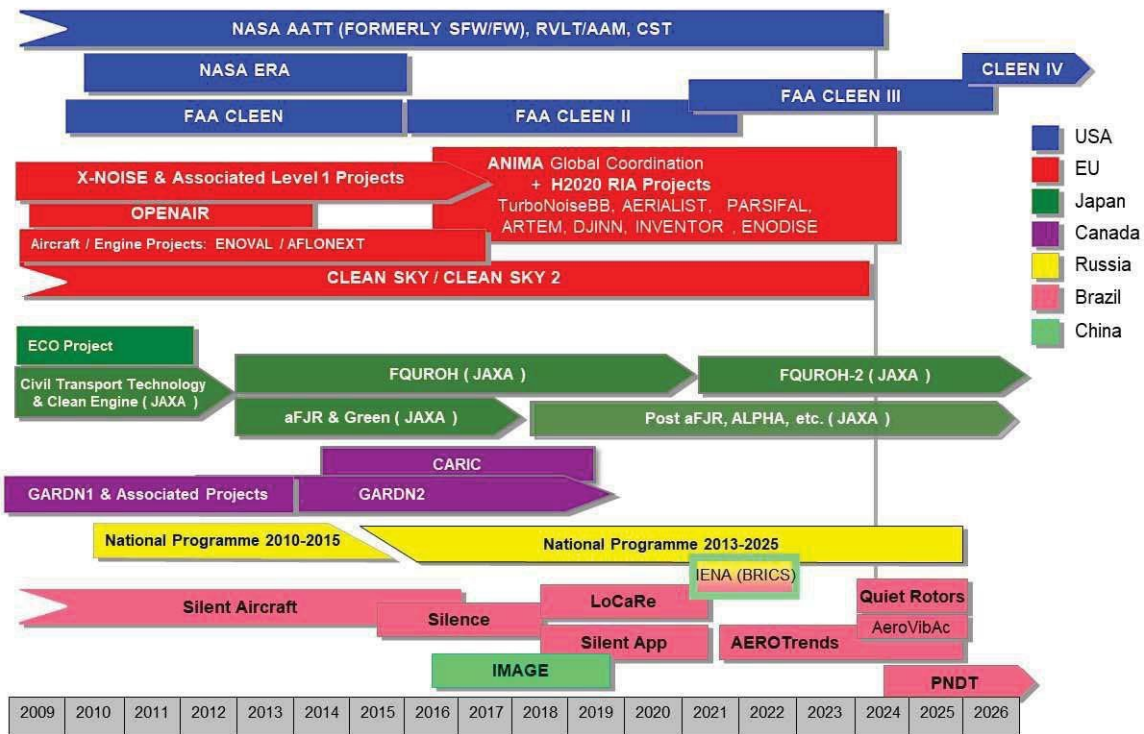


Figure 1 - Committed Major National / Regional Initiatives as of May 2024

- 4.2 In this light, it should be noticed that while the major initiatives reviewed in 2001 (United States (US), European Union (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 Brazil, Canada, Russian Federation and recently China, providing here the picture of a true worldwide effort. Specific National programmes also exist in France and the United Kingdom, examples of which can be found in Appendix B on the EU region.
- 4.3 Going across the various programmes, general observations can be made concerning research goals and emerging technology trends.
- 4.4 Research programmes set stretch goals (sometimes called aspirational) and consequently 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 TRL 6 (or below), not their successful implementation at industrial level (TRL 8).

- 4.5 As pointed out in previous reports, the general trend for large research initiatives has been to address a global environmental agenda, trade-offs and interdependence aspects being considered in scientific and technical work programmes. 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.
- 4.6 Highlights on emerging technologies are reported below:
- 4.6.1 Concerning Open Rotors, after running a full-scale Counter Rotating Open Rotor in Europe in 2016, studies continue within the European Clean Sky and Clean Aviation project to further explore the integration aspects and interdependencies of the Open Rotor engine architecture. Furthermore, CFM launched the RISE project in 2021, kicking off a large commitment to accelerate the maturation of the Open Rotor architecture. Elements of the RISE development are being supported by the US Federal Aviation Administration’s CLEEN Programme and NASA Aeronautics.
- 4.6.2 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.
- 4.6.3 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.
- 4.6.4 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; and
  - a renewed effort on acoustic liners technologies to accommodate future engine and nacelle integration constraints (low frequency sources, reduced available space, low weight requirements).
- 4.6.5 Concerning regional noise research programmes, it should be noted that since the late 2020s timeframe there is a significant priority change in both Canada and the EU: In Canada, after several years of successful noise research programmes under GARDN and CARIC, research on aviation noise is no longer supported in a large, dedicated programme. Similarly, the EU aviation environmental research focus has changed towards climate change, resulting in very limited funding options for noise research. The large CLEAN AVIATION research project, started in 2023, has only Climate and CO<sub>2</sub> related environmental objectives, no longer advocating quantified noise objectives, which were part of its predecessor project CLEAN SKY. However, for US research programmes, noise remains a priority and is balanced with climate and emissions objectives under CLEEN IV.
- 4.7 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

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maintain a steady funding support over a significant period of time.

- 4.8 Summaries and more details of each research initiative represented in Figure 1 are provided in the appendices.
- 4.8.1 US Noise Technology Research Programmes: An overview of the US Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix A.
- 4.8.2 EU Noise Technology Research Programmes: An overview of the EU Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix B.
- 4.8.3 Japanese Noise Technology Research Programmes: An overview of the Japanese Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix C.
- 4.8.4 Russian Noise Technology Research Programmes: An overview of the Russian Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix D.
- 4.8.5 Canadian Noise Technology Research Programmes: An overview of the Canadian Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix E.
- 4.8.6 Brazilian Noise Technology Research Programmes: An overview of the Brazilian Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix F.
- 4.8.7 Chinese Noise Technology Research Programmes: An overview of the Chinese Research Programmes dedicated to Aircraft Noise Reduction Technology is provided in Appendix G.

## 5. CONCLUSION

- 5.1 This status report 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 CAEP cycle.
- 5.2 It is anticipated that the continuation of this activity will be supported as part of future work proposals, so that regular updates on research programmes keep being provided to CAEP, particularly during cycles where no noise technology review is planned.
-

## **Appendix A. US Noise Technology Research Programmes**

## Continuous Lower Energy, Emissions & Noise (CLEEN) Program

- FAA led public-private partnership with 1:1 cost matching 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	2021-2026
FAA Budget	~\$125M	~\$100M	~\$125M
Noise Reduction Goal	25 dB cumulative noise reduction cumulative to Stage 5 and/or reduces community noise exposure (new goal for Phase III)		
Fuel Burn Goal	33% reduction	40% reduction	-20% re: CAEP/10 Std.
NO <sub>x</sub> Emissions Reduction Goal	60% landing/take-off NO <sub>x</sub> emissions (re: CAEP/6)	75% landing/take-off NO <sub>x</sub> 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>



Federal Aviation Administration

## CLEEN Phase III Technologies

### Engine Core

- GE: Compact Core – Low Emissions Combustor
- GE: Advanced Thermal Management
- GE: Hybrid Electric Integrated Generation
- Honeywell: Efficient Green High Pressure Core
- Honeywell: Compact High Work High Lift Low Pressure Turbine (LPT)
- Pratt & Whitney: TALON X+ Combustor
- Rolls-Royce Axi-Cf Compressor Technologies

### Airframe

- Boeing: Quiet Landing Gear
- Boeing: Quiet High-Lift System

### Aircraft Systems

- GE: MESTANG III
- Boeing: Intelligent Operations

### Sustainable Aviation Fuels

- Boeing: Higher Blend SAF Qualification
- GE: Higher Blend SAF Qualification

### Nacelle, Fan, and Bypass

- America's Phenix: Erosion-Resistant Fan Blade Coating
- Boeing: Next Generation Inlet
- Collins: Large Cell Exhaust Acoustic Technology
- Collins: Titanium Inner Fixed Structure
- GE: Open Fan
- GE: Advanced Acoustics
- Honeywell: Highly Efficient Fan Module
- Pratt & Whitney: Ultra-Quiet Reduced-Loss Fan Stage
- Safran: Acoustic Air Inlet Lip Skin

Color Coded by Benefit Area:

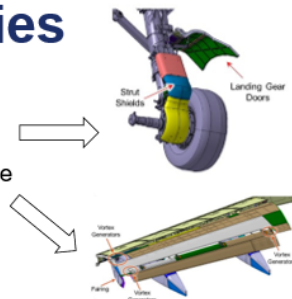
Noise  
Emissions  
Fuel



# CLEEN Phase III Noise Technologies

## Boeing

- Quiet Landing Gear: Up to 0.5 EPNdB cum. reduction from acoustically treated main gear doors and aerodynamic shields for gear struts
- Quiet High Lift System: Up to 0.5 EPNdB cum. reduction from outboard flap side edge fairings and flap vortex generators
- Next Generation Inlet: 1.5 EPNdB cum. reduction with expanded acoustic treatment area while enabling fuel burn reduction with shorter inlet length
- Intelligent Operations: 3-5 peak dBA reduction via flight path optimization

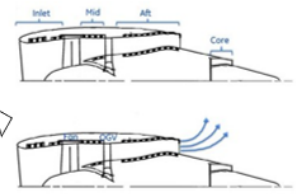


## Collins Aerospace

- Large cell acoustic exhaust technology: 0.9-1.5 EPNdB cum. Reduction

## General Electric

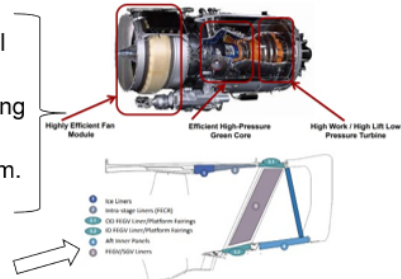
- Suite of CFM RISE technologies including open fan: 13 EPNdB cum. margin to Stage 5 for new engine architecture with 20+% fuel burn reduction vs. CFM LEAP engine
- Advanced acoustics: 2 EPNdB cum reduction from novel liners; 1 EPNdB cum. reduction from fan and OGV optimization for ducted fan configurations



# CLEEN Phase III Noise Technologies (contd.)

## Honeywell

- Highly Efficient Fan Module: 1.5 EPNdB cum. reduction while enabling fuel burn reduction
- Efficient Green High-Pressure Core: 3 EPNdB cum. reduction while enabling fuel burn, NOx and nvPM reductions
- Compact High Work High Lift Low Pressure Turbine (LPT): 0.5 EPNdB cum. reduction while enabling fuel burn reduction

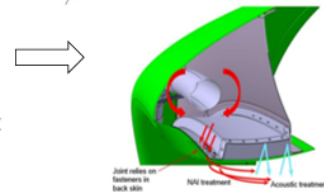


## Pratt & Whitney

- Ultra-Quiet Reduced-Loss fan stage and TALON X+ combustor: 3 EPNdB cum. noise reduction combined benefit

## Safran Nacelles

- Acoustic Air Inlet Lip Skin: Expanded acoustic treatment area on engine inlet lip, enabling short inlet designs



## ASCENT Technology Projects

- **Complementary venue for university-led research on aircraft technology research and development**
- **Advances the industry state-of-the-art and expands the technical knowledge base**
- **Cuts across development of individual technologies and models**
- **Technical Themes:**
  - Noise reduction technology modeling and development
  - System-level modeling and design considerations
  - Propulsion-airframe integration
  - Combustion
  - Turbomachinery
  - Supersonics
- **Overview of projects available on ASCENT website:**  
<https://ascent.aero/topic/Aircraft-Technology/>



## ASCENT Aircraft Noise Technology Projects

### Noise reduction technology modeling and development

- 075 - Improved Engine Fan Broadband Noise Prediction Capabilities
- 076 - Improved Open Rotor Noise Prediction Capabilities
- 079 - Novel Noise Liner Development Enabled by Advanced Manufacturing

### Supersonics

- 047 - Clean Sheet Supersonic Aircraft Engine Design and Performance
- 059 - Jet Noise Modeling to Support Low Noise Supersonic Aircraft Technology Development

Green = new projects pending award



The Sustainable Flight National Partnership (SFNP) has emerged as a primary focus for NASA subsonic transport aircraft research. The Transonic Truss-Braced Wing (TTBW) is the vehicle configuration for SFNP. While the stated goal of SFNP is a 30% fuel burn reduction for a 2030s EIS single aisle aircraft, noise and environmental compatibility are recognized as requirements for any aircraft system. The unique noise sources related to TTBW are being analysed as well as noise reduction for next generation propulsors, including Open Fans. FAA is a key partner in SFNP, and many technology synergies and collaborations exist between NASA and FAA.

As Advanced Air Mobility (AAM) missions emerge NASA has noise reduction and human response as primary components of the research effort which will be crucial in enabling this new market.

Other novel aircraft configurations such as Blended Wing Body (BWB), Boundary Layer Ingestion (BLI) concepts and Distributed Electric Propulsion continue to be studied as longer term configurations.

## Sustainable Flight National Partnership


Accelerating Toward NetZero Greenhouse Gas Emissions and Reduced NonCO<sub>2</sub> Climate Impact in the 2030s

**Small Core Gas Turbine** for 5%-10% fuel burn benefit

**Electrified Aircraft Propulsion** for ~5% fuel burn and maintenance benefit

**Sustainable Aviation Fuels** for reduced lifecycle carbon emissions

**Model-based Systems Analysis & Engineering** provides digital integration



**Transonic Truss-Braced Wing** for 5%-10% fuel burn benefit

**High-Rate Composites** for 4-6x manufacturing rate increase

**Integrated Trajectory Optimization** for 1%-2% reduction in fuel required and minimization of contrail formation


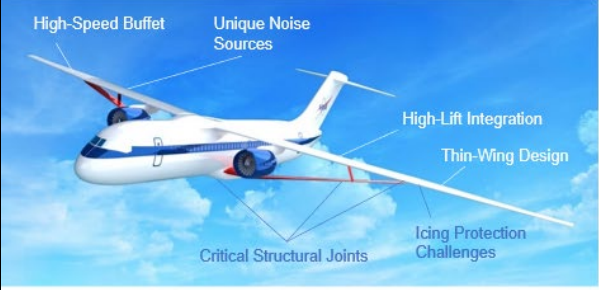
**Sustainable Flight Demonstrator** for Transonic Truss-Braced Wing and fully integrated associated technologies

Next-generation transports using up to 30% less fuel, current and future fleets flying optimal trajectories, engines burning sustainable aviation fuels for greater than 50% reduction in lifecycle greenhouse gas emissions

www.nasa.gov | 2

## Transonic Truss-Braced Wing Technology Maturation

Increase confidence in technology to be robustly integrated in the aircraft system

**Scope**

- Mature and reduce risk of Transonic Truss-Braced Wing technology, focused on:
  - Buffet boundary prediction
  - Stall characteristics
  - High-lift system integration
  - Acoustic assessment
  - Icing impact
  - Thin wing structural design
  - Unique structural joints

**Benefit**

- Achieve 5-10% reduction in fuel burn through reduced drag

**Approach**

- Concept studies through scale model testing
- Perform high-fidelity prediction, testing and validation to increase confidence in fuel burn benefit

Design/analysis studies and wind tunnel tests are underway. Completed high-speed buffet wind tunnel test in FY22.

www.nasa.gov | 3

## Efficient Quiet Integrated Propulsors (EQuIP) Tech Challenge

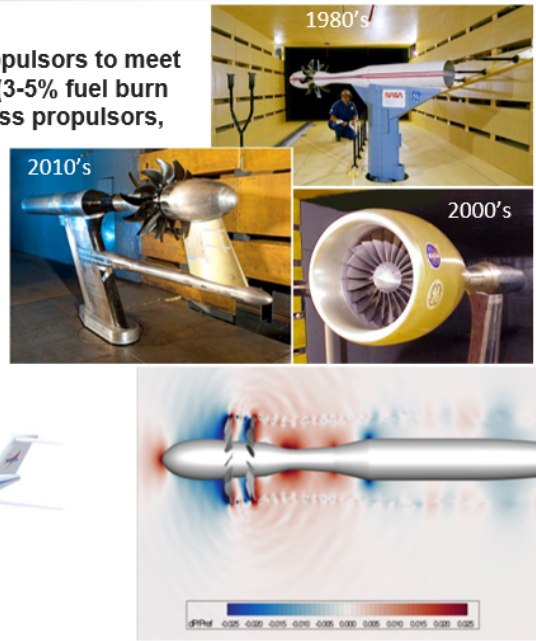


### Objective

Assess, model, and predict the ability for next-generation propulsors to meet market-driven goals for noise (4dB reduction) and efficiency (3-5% fuel burn reduction) *with integration effects*, relative to 2021 best in class propulsors, and reduce risk to a new single-aisle aircraft in the 2030's.

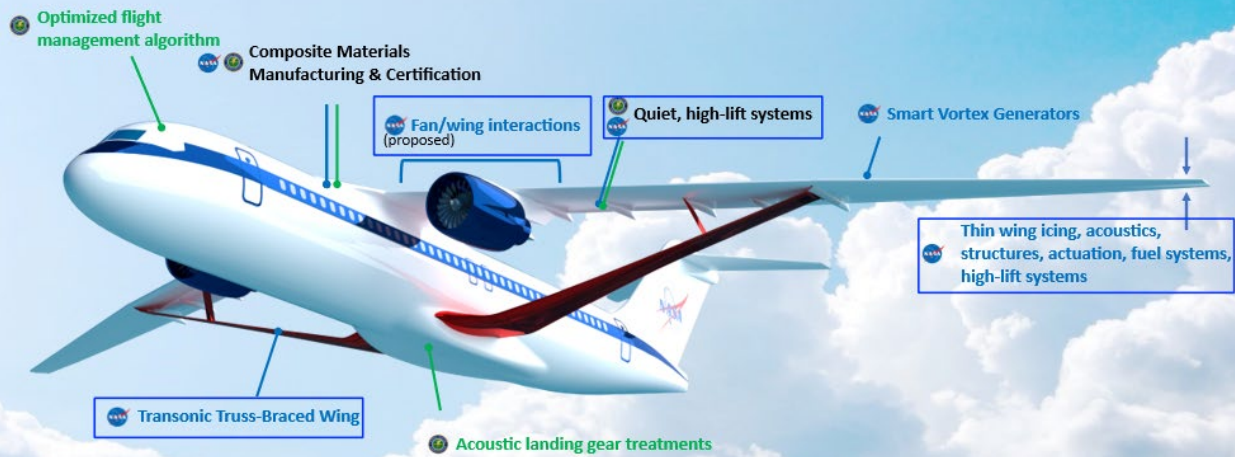
### Technical Areas and Motivation

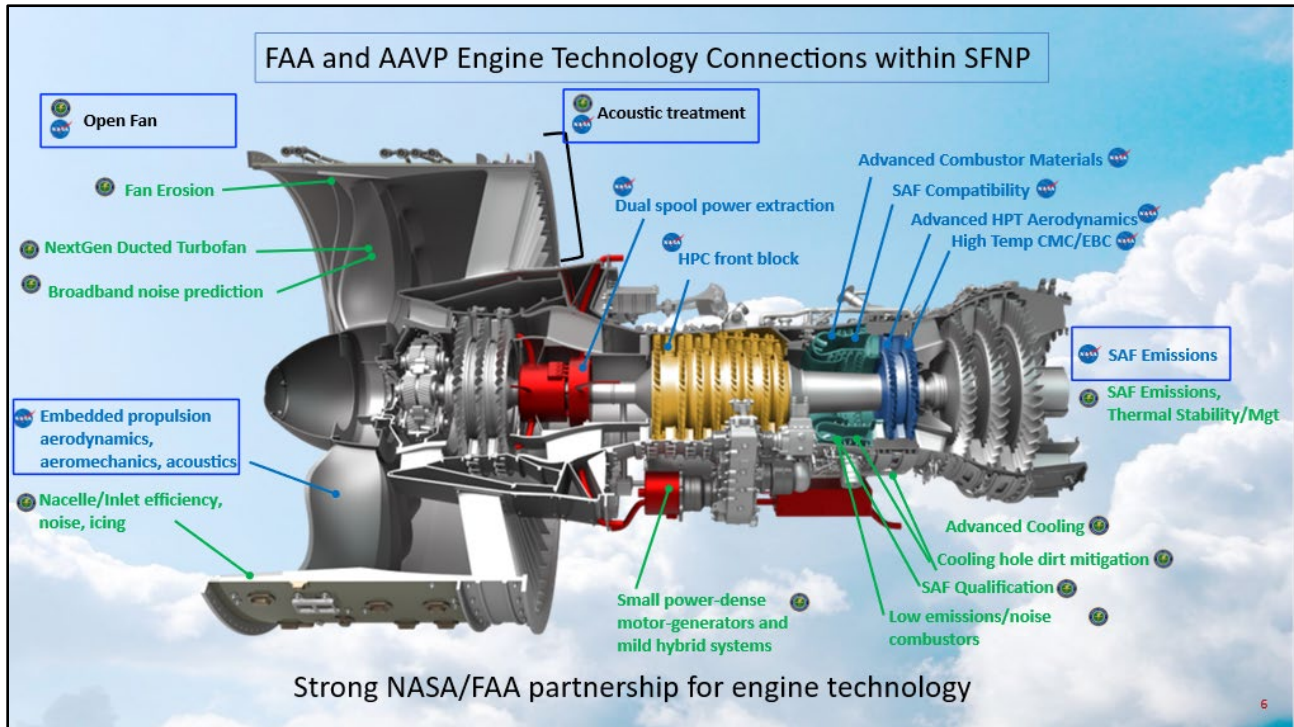
- Unducted propulsors are a potential step-change improvement
- Next-generation ducted propulsors with ultra-short nacelles offer evolutionary improvement in fuel burn and emissions at lower risk
- Next-generation ducted and unducted propulsors face challenges in **acoustics**, **aeromechanics**, **icing** and **airframe integration effects**
- NASA is uniquely positioned to address these challenges



2030's

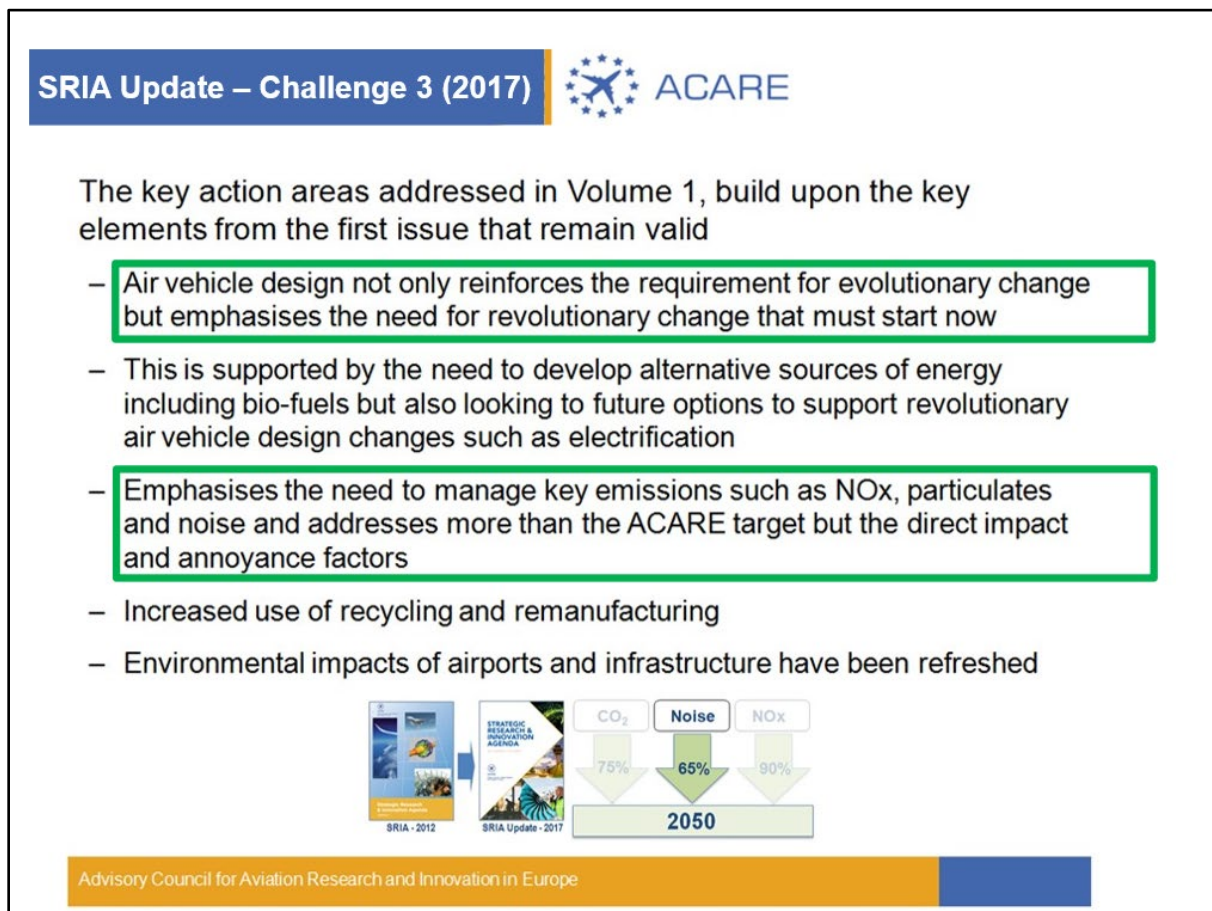
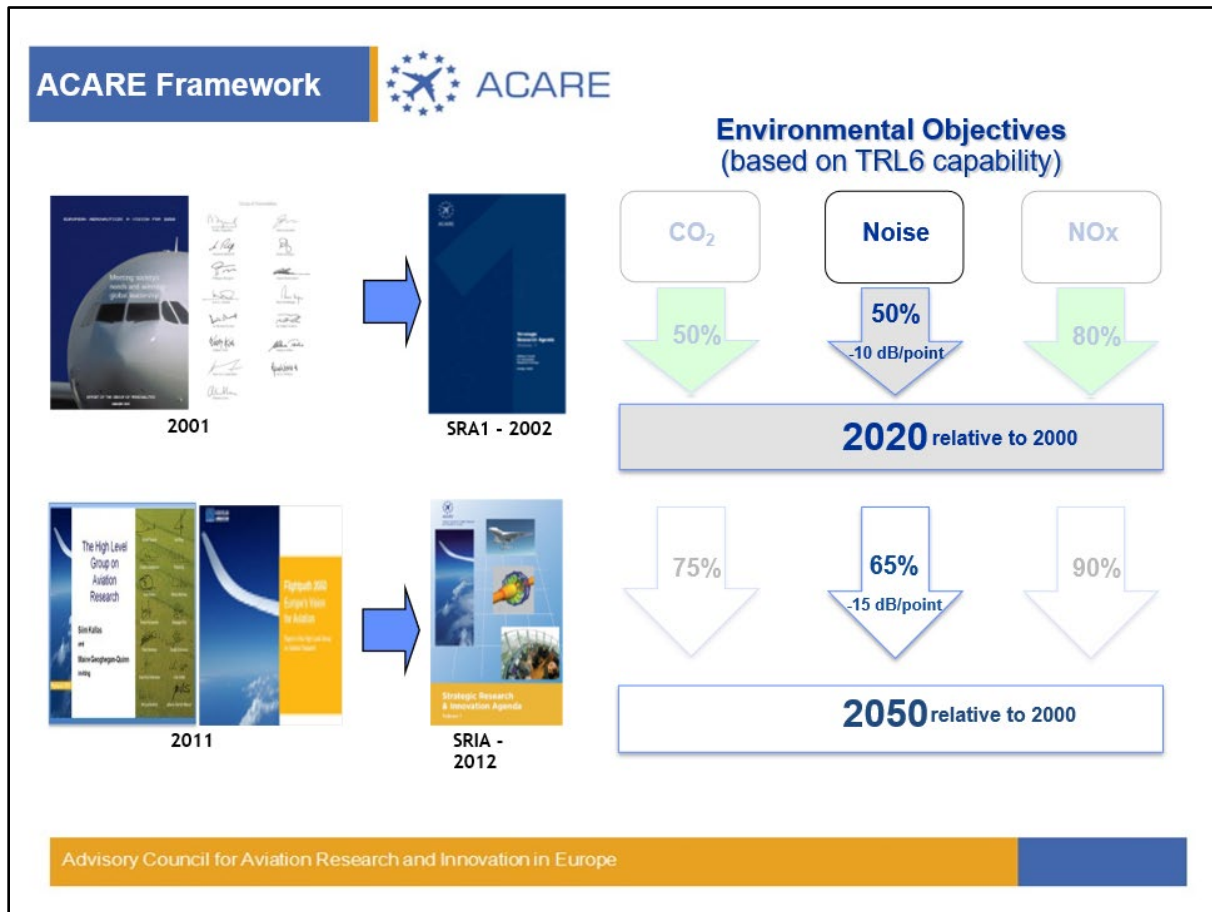
## FAA and AAVP Airframe Technology Connections within SFNP





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## **Appendix B. EU Noise Technology Research Programmes**



## Flightpath 2050 update (2021)



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

### Environmental commitment / Green Deal objectives

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

## EU Green Deal - Overarching Goals (2022)

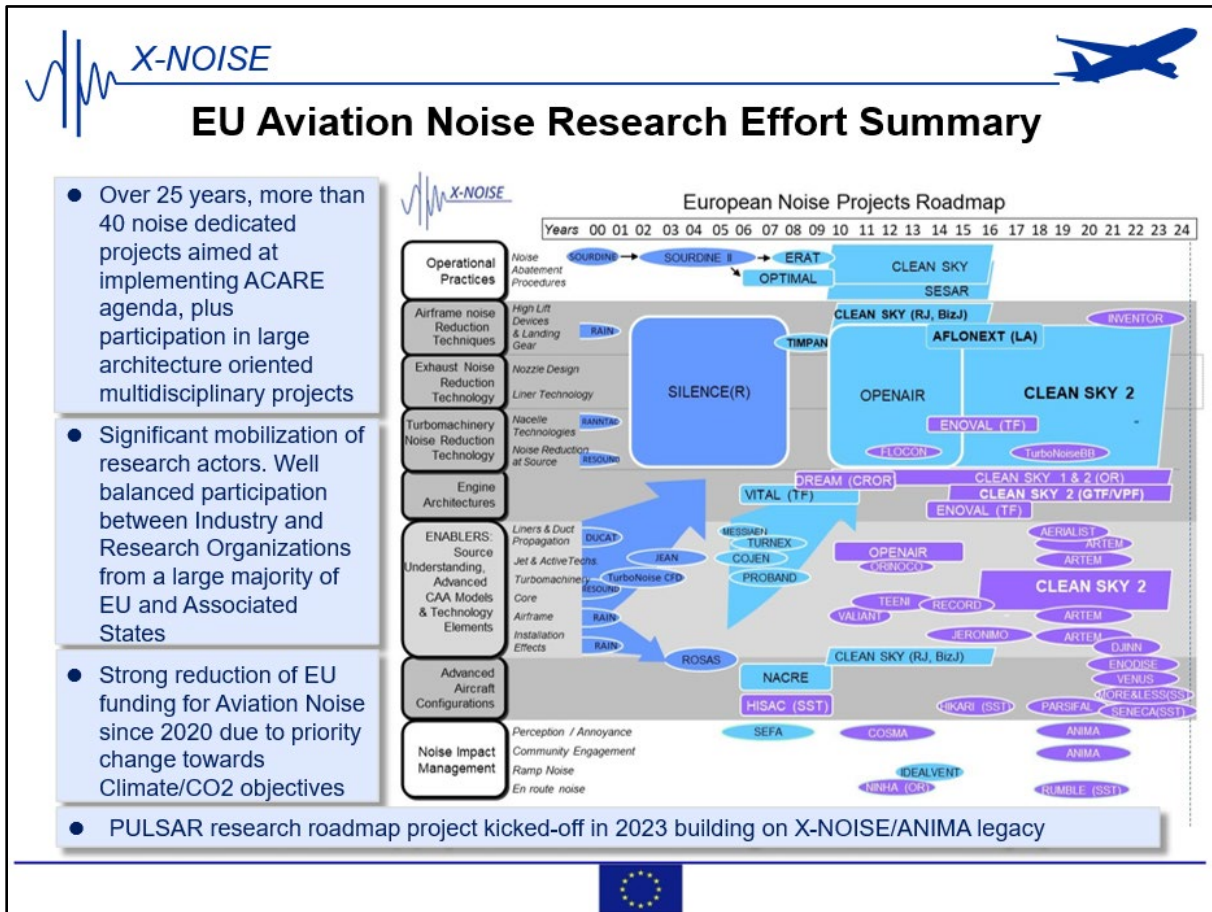


### Overarching Goals

- Achieving climate-neutral aviation by 2050
- Improving global leadership and competitiveness
- Putting the citizen at the centre, including
  - Stepped Noise goals derived from the ICAO Balanced Approach for 2030/2035/2050
    - Source Noise reduction (ref Flightpath 2050)
    - Operational Measures/ Continuous Decent Operation
    - Land Use Management

### Public Private Partnerships

- Clean Aviation (2023-2032)
  - Addresses only goal on « climate-neutral aviation »



## New Horizon2020 Research and Innovation (RIA) Projects

**DJINN**  
**New computational fluid dynamics methods make aircraft quieter**

Duration: June 2020 – November 2023  
 Funding: 5 M€



Main objective of DJINN project was to further develop and validate CFD/CAA tools for the prediction of the jet-wing interaction noise source on aircraft with engines under the wing and the prediction of acoustic loads due to the jet on aircraft with fuselage mounted engines. Different wind tunnel test campaigns were performed with different representative airframe/engine configurations and noise reduction concepts (scarfed and serrated nozzles). CFD/CAA tools were successfully validated against experimental data which paves the way for a more systemically use of CFD/CAA in aircraft noise mitigation at the early stages of development.

**INVENTOR**  
**INnoVative dEsign of iNstalled airframe componenTs for aircraft nOise Reduction**

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



INVENTOR aims at reducing airframe noise at landing for business jet and short-to-medium-range aircraft. Main landing gear noise and leading edge noise are addressed in particular. CFD/CAA approaches are carried-out to retrieve noise reduction levels of low-noise concepts (porous fairings) and to design acoustically optimal geometries. The numerical approaches are assessed against a variety of experimental databases with a wide range of complexity, from isolated single-device configurations to generic high fidelity airframe geometries, including one full-scale landing gear. Noise reduction levels are finally assessed at aircraft level with the objective to reduce noise by 1 EPNdB.

**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 suralization. Thereby, ARTEM constitutes a holistic approach for noise reduction for future aircrafts and provides enablers for the expected further increase of air traffic.

**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

## French National Projects

### AMBROSIA Project

AMELIORATION DU BRUIT DE PROPULSION DES AVIONS  
(Improvement of aircraft propulsion noise)

#### Main project objectives:

- **Ultra High By Pass Ratio (UHBR) aircraft fan noise**
  - Innovative nacelle treatment elaboration
  - ACTRAN-DGM software improvement for acoustic treatment optimization
- **Ultra High By Pass Ratio (UHBR) aircraft jet noise**
  - Characterization and reduction of installed jet noise risks by UHBR nozzles mock-up tests
  - Semi-empirical industrial methods improvement for learning, prediction and extraction on static bench. High fidelity simulation method improvement
- **Regional business planes jet noise**
  - Optimized Chevron Nozzles conception to minimize consumption and aerodynamic performance impact
  - Acoustic and aerodynamic tests validation
  - Improved drawing methodology, high fidelity noise and performance simulation for installed chevron nozzle

#### Partners:

Airbus, Safran Aircraft Engine, Ecole Centrale de Lyon, FFT + test prestation by ONERA

#### Timeframe:

Start: Q4 2019 – Q4 2024  
Duration: 60 months



### InPro Project

Integrated PROpeller design for low emission aircraft

#### Main project objectives:

- Be able to optimize and quantify the propeller/airframe integration, by capturing aerodynamic interactions between the propeller system and the airframe.
- **Non conventional propeller engine configuration**
  - Exploration and optimization of various overall A/C design configuration
  - Multi-disciplinary propeller design under the influence of airframe
- **Aero-acoustic simulation & design capabilities**
  - Numerical methods development to anticipate installation effects
  - Propeller aero-elastic characterization
  - Aerodynamic model for Aircraft behavior simulation
  - Anemo/climometry impact of propeller with aerodynamic model for optimized probe location
- **Mock-up testing**
  - Mock-up testing on the best solution coming from numerical studies
  - Low consumption target validation
  - Noise reduction target validation

Partners:  
Airbus, Safran AE, ONERA

Timeframe:  
Start: Q3 2021 – Q3 2025  
Duration: 50 months



### BALBUZARD Project

Building Advanced Lattice-Boltzmann multi-physics solver towards Zero-emissions Aircraft Research and Development

#### Main project objectives:

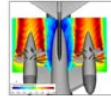
- **Zero-emissions new challenges**
  - Needs not covered by current tools/methodologies.
  - Needs on solid-mobiles
  - Complex geometries to be handled
- **Lattice-Boltzmann (LBM) methods maturation and extension**
  - LaB5 code Maturation on aerodynamic, acoustic & numerical methods
  - LaB5 code Extension with solid mobile capacities & huge improvement on precision
- **Physics / numerical understanding**
  - Immersed Navier-Stokes / Lattice-Boltzmann comparison
  - LBM turbulence modelization
  - LBM numerical stability on thermic & compressible

#### Partners:

AIRBUS, Ecole Centrale de Lyon, CS-Communication et Systèmes, CERFACS, Aix-Marseille Universités, ONERA, SAFRAN

#### Timeframe:

Start: Q2 2021 – Q2 2025  
Duration: 48 months



### CIGALE Project

Conciliation des études sur la Génie Aéroportuaire en Laboratoires et des Enquêtes de terrain  
(Conciliation of laboratorial and field Investigations on airport annoyance)

#### Main project objectives:

- **Development of new tools and methods to take into account interactions between acoustic and human factors in airport annoyance studies**
  - Innovative scientific method based on 3 observation levels of annoyance: on-line survey (1249 participants), 12 collective interviews, laboratory tests (281 participants)
  - Residents living close to Paris CDG and Toulouse Blagnac Airports
  - Identification of 6 different profiles of residents, negative and positive, and their expectations
- **Co-construction of new solutions to compensate or reduce airport annoyance**
  - Tools and methods to analyze annoyance situations and propose solutions to handle them
  - Organization of 2 workshops with Airports and authorities

#### Partners:

ONERA, CNRS MSH-ST

#### Timeframe:

Start: Q4 2018 – Q2 2023  
Duration: 56 months

#### Dissemination of the results toward the involved communities

- Communication in national and international workshops and congresses
- Organization of a final workshop with residents, industries, airports and authorities



## French National Projects

### MOTUS Project

Minimisation de l'impact acoustique Opérationnel des VTOLS en conditions Urbaines

#### Main project objectives:

- **Acoustic signatures and annoyance**
  - Laboratory tests on noticeability and annoyance
  - Long term annoyance based on dose-response curve correlated with on-site survey
- **Numerical predictions**
  - Development / improvement / evaluation of fast estimation tools to predict tonal and broadband components and installation effects
  - Evaluation of new high fidelity numerical methods such as LBM for new architecture of eVTOLs
- **Noise reduction**
  - Use of the development performed on numerical simulation to design optimized multi propeller eVTOL configuration
  - Design and test a liner for fenestron ("fan-in-fin")
  - Pre-study of a future low noise helicopter
  - Define and analyze Automatic Flight Control System (AFCS) for low noise flight procedure

#### Partners:

AIRBUS Helicopters, ONERA

#### Timeframe:

Start: Q3 2020 – Q3 2024  
Duration: 48 months

#### Technology bricks Portfolio



### OTTAWAN Project

Demonstration of a CS-23 hybrid aircraft with distributed propulsion

#### Objectives regarding noise:

- Design of a complete control system for the OTTAWAN demonstrator using distributed propulsion as an augmented means of control for flight qualities and noise reduction;
- The ability to correctly predict the acoustic characteristics of the aircraft due to the numerous interactions between the different noise sources (electric and thermal and wing and fuselage).

#### Expected outputs:

- Prediction methodology for distributed propulsion acoustic signature;
- Structure and principle of active noise control, demonstrated in flight;
- Good cross-checking quality with noise measurements (internal and external) in flight tests.

Partners:  
Daher, Airbus, Safran, Safran Helicopter Engines, Safran Electrical & Power, Safran Power Units

#### Timeframe:

Start: december 2019  
Duration: 60 months



## UK National Project

### FANTASIA (Future Noise Technologies And System Integration Analytics)

Duration: December 2020 – November 2025

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, CO<sub>2</sub> 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, CO<sub>2</sub> and emissions.

## Clean Sky Noise Related Projects

### CLEAN SKY2 / INNOSTAT

#### Innovative Stator

Duration: Oct 2019 – Dec 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 / SALUTE

#### Smart Acoustic Lining for UHBR Technologies Engines

Duration: Nov 2018 – June 2021  
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.

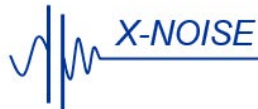
### CLEAN SKY2 / VENUS

#### Noise of Distributed Electric Propulsion

Duration: April 2020 – September 2023  
Funding: 2,3 M€



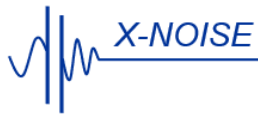
The EU-funded VENUS project contributed important knowledge on the aerodynamics and aeroacoustics performance of a wide range of DEP configurations through numerical simulations and experimental wind tunnel tests. The project's outcomes enhanced the future design of new regional aircraft.



## Pioneering Technology Evaluation / Progress Assessment

X-NOISE	2000 - First formulation of assessment methodology (ANTE) developed in Silence(R) proposal
X2-NOISE	2002 - SRA1 Noise Target Definition (2020)
X3-NOISE	2003 - Implementation of Annual Technology Status Report (Individual Techs vs TRL Scale)
	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
	2011 – X-NOISE / CLEAN SKY workshops to harmonize evaluation vs noise targets
X-NOISE EV	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





## 2020 Assessment of Progress towards the ACARE noise target

- An 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 to TRL6, 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.



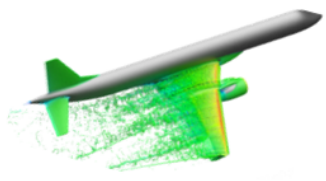
## **Appendix C. Japanese Noise Technology Research Programmes**

## Key technology projects (Airframe Noise)

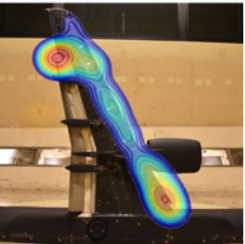
- After the flight demonstrations with JAXA's business jet-based research aircraft in the FQUROH<sup>\*1</sup> project, JAXA aims at phasing up the research and development of airframe noise reduction technology for larger aircraft. Studies targeting a regional jet have improved noise reduction concepts for high-lift devices and main landing gear.

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

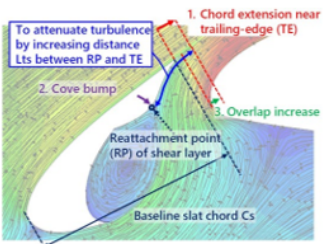
### Noise reduction design for high-lift devices



Unsteady CFD result for the 3D full-config with slats and flaps deployed



Wind tunnel test result for a baseline config without noise reduction devices



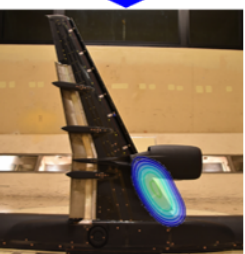
To attenuate turbulence by increasing distance Lts between RP and TE

1. Chord extension near trailing-edge (TE)
2. Cove bump
3. Overlap increase

Reattachment point (RP) of shear layer  
Baseline slat chord Cs

Noise reduction concepts for slat

M. Murayama et al., AIAA 2022-2955



Config with noise reduction devices for slats and flaps

### Noise reduction design for main landing gear

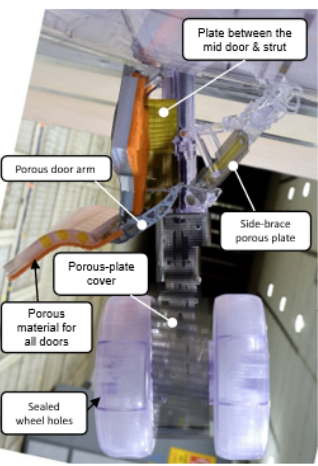
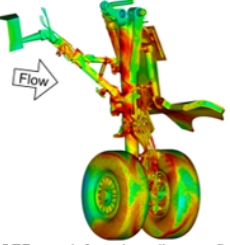


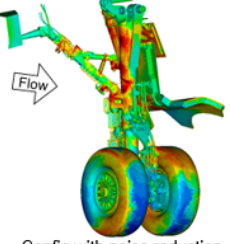
Plate between the mid door & strut  
Porous door arm  
Side-brace porous plate  
Porous-plate cover  
Porous material for all doors  
Sealed wheel holes

Wind tunnel model and noise reduction concepts

Y. Ito et al., AIAA 2022-2846



CFD result for a baseline config without noise reduction devices




Config with noise reduction devices

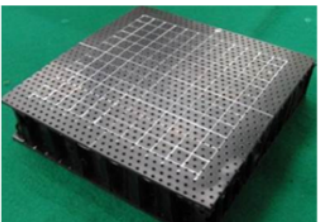
## Key technology projects (Engine Noise)

- 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. The engine demonstration on the turbofan testbed, F7, was conducted in 2020. Noise reduction capability and durability was successfully demonstrated.
- Noise reduction R&D has been conducted for future aircraft propulsion system. Present and future acoustic programs are coupled with the low / zero carbon emission requirements.

### Light-weight acoustic liner panel ( post-aFJR )




Present application




Resin-based liner panel

Thermoplastic resin facesheet & honeycomb

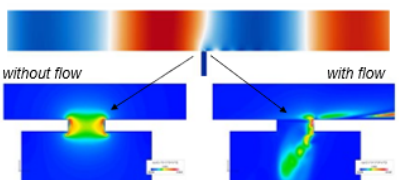


Resin-based liner panel for engine demonstration  
Internoise 2023 91603-1611




F7 turbofan engine testbed

### Noise reduction on future aircraft engine



without flow      with flow

CFD results of acoustic liner w/w/o grazing flow  
AIAA 2023-3636

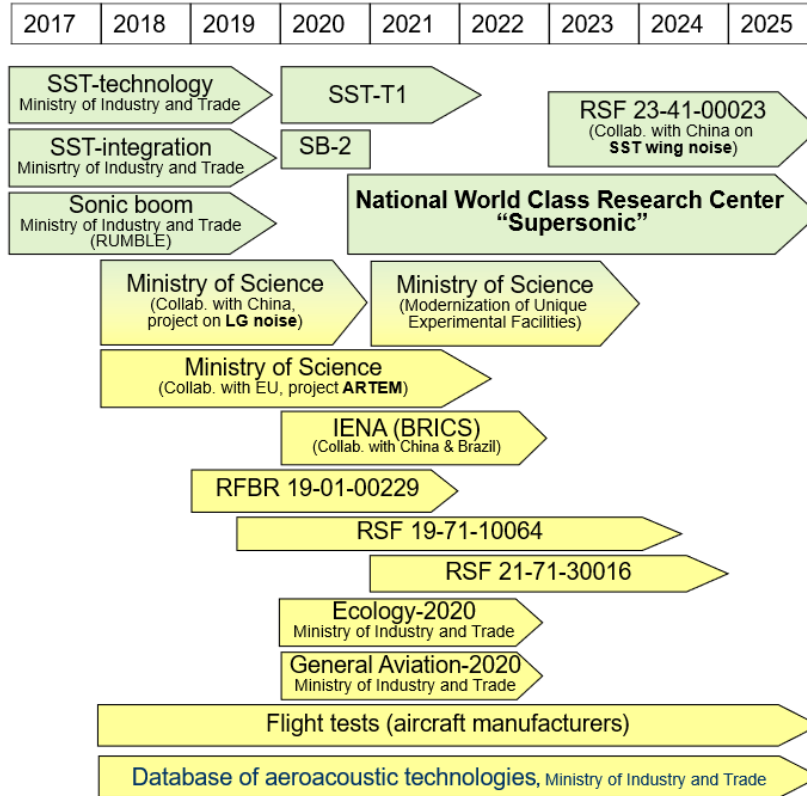


An acoustic liner for better sound absorption



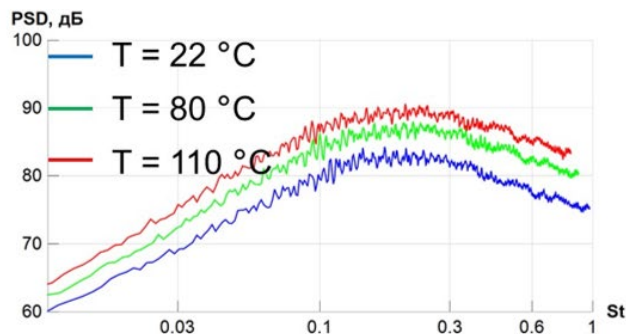
## **Appendix D. Russian Noise Technology Research Programmes**

## Aeroacoustics projects in Russia



### Project on modernization of unique experimental facility "Anechoic chamber with flow AC-2 TsAGI" (2021-2023)

funded by the Ministry of Science and Higher Education of the Russian Federation



#### Project results:

The experimental facility "Anechoic chamber AC-2 TsAGI" has been modernized to enable investigation of aeroacoustic of heated jets, including jets in coflow.

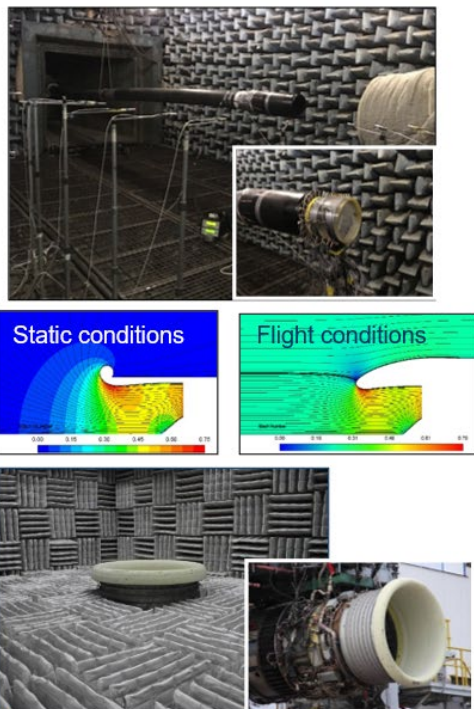
Preliminary measurements of single heated jets have been performed, and validation of the obtained data have been carried out.

### Determination of the range of parameters in which measurements in the AC-2 TsAGI can be used for technologies development, 2013-2023 (Funded by Ministry of Science, Ministry of Industry and Trade, ESWIRP, TsAGI-CAE, TsAGI-CARDC, TsAGI-DNW)



### Development and validation of mathematical models and computational algorithms in aeroacoustics (2021-2024)

funded by Russian Science Foundation for Labs development (RSF 21-71-30016)



#### Project description:

The project is aimed at developing new models of aerodynamic noise sources (analytical, numerical, half-empirical), creating corresponding computational algorithms and validating the developed computational methods.

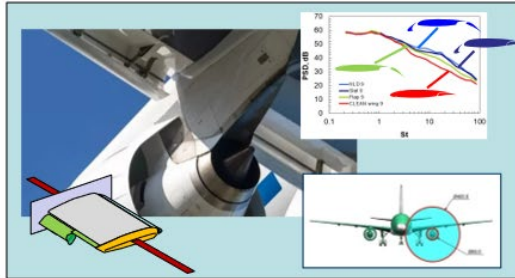
Within the framework of this approach, the project considers eight areas of aeroacoustics associated with the solution of individual problems related to the aircraft as a whole:

- Jet noise;
- Jet-wing interaction noise;
- Engine noise diffraction by the airframe;
- Airframe noise;
- Noise propagation inside ducts and acoustic liners;
- Interior noise;
- Noise of helicopter rotors;
- Noise of propellers.

These areas are at different levels of development of computational algorithms; therefore, they are considered in the project separately, on the one hand, in order to trace the universality of this approach and, on the other hand, wherever working validated programs may appear, try to bring them to the engineering level, with purpose of use in industry.

## Development and validation of mathematical models and computational algorithms in aeroacoustics (2021-2024)

funded by Russian Science Foundation for Labs development (RSF 21-71-30016)



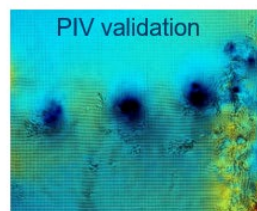
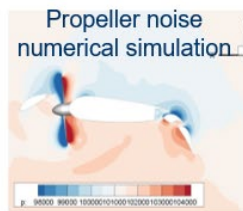
### Project description:

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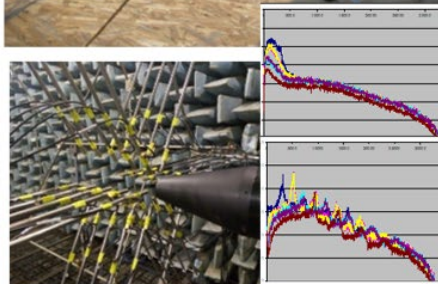
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- Jet noise;
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- Airframe noise;
- Noise propagation inside ducts and acoustic liners;
- Interior noise;
- Noise of helicopter rotors;
- Noise of propellers.

These areas are at different levels of development of computational algorithms; therefore, they are considered in the project separately, on the one hand, in order to trace the universality of this approach and, on the other hand, wherever working validated programs may appear, try to bring them to the engineering level, with purpose of use in industry.



## Development of multichannel measurement techniques in aeroacoustics in application to the diagnostics of the main sources of noise of advanced aircraft (2021-2024) funded by Russian Science Foundation (RSF 19-71-10064)



### Project description:

The project aims to address the following main tasks:

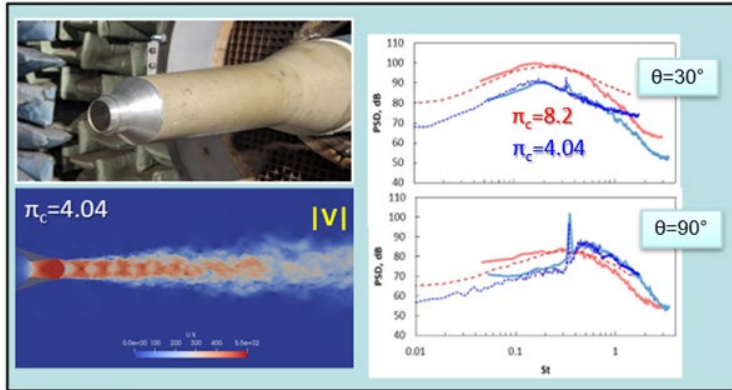
- development of methods for measuring the sound field structure and characterizing the sources of noise generated by free turbulent flows (noise of jet of complex geometry), interaction of turbulent flows with solid bodies (airframe noise, jet/airframe interaction noise) using planar, polyhedral and cylindrical multi-microphone arrays;

- development of methods for measuring the structure of the sound field in ducts with different cross-sectional shapes in the presence and absence of a pylon, taking into account the average flow in the cross-section;

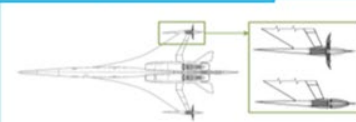
- development of methods for measuring the field radiated from the open end of the duct, using hybrid linear-azimuthal multi-microphone arrays for further selection optimal acoustic liners;

- development of methods for analyzing the structure of turbulent flows, based on the processing of multi-channel measurement data or numerical simulation results, in order to identify the radiating part of turbulence.

**The program for the creation and development of  
National World Class Research Center “Supersonic” (2020-2025)**  
funded by the Ministry of Science and Higher Education of the Russian Federation



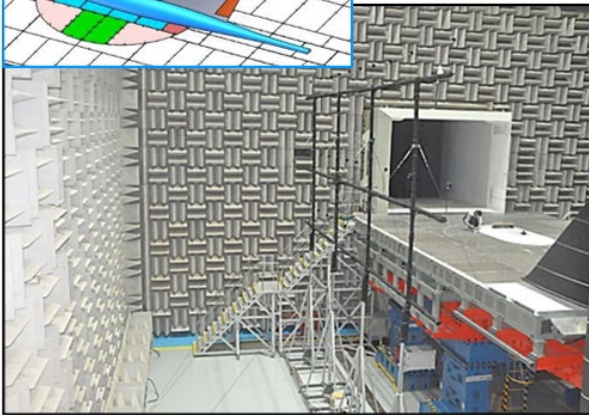
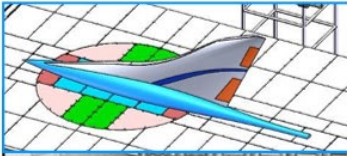
New concept to meet ICAO Chapter 15 stringency rules



**Areas of research:**

1. Modeling and reduction of jet noise for nozzle geometries considered for SST
2. Modeling and reduction of noise radiated from non-circular inlets considered for SST
3. Modeling and reduction of airframe noise for SST geometries (landing gears and SST wing with flaps)
4. Measurement and modeling of sound propagation through composite structures of SST fuselage.
5. Modeling of sonic boom levels and vibrations inside buildings under the effect of SST sonic boom.

**Investigation of the aerodynamic noise and methods of its reduction for the wing of the future supersonic civil vehicle (NOISE), 2023-2025, Joint RSF-NSFC, funded by Russian Science Foundation (RSF 23-41-00023)**



**Project objectives:**

The project aims to improve the understanding, prediction and control of SST wing noise.

Its objectives include:

- developing an advanced measurement technique for wing noise in the aeroacoustic wind tunnel;
- developing a high-resolution numerical approach for modeling of HLD noise sources;
- developing an effective aeroacoustic prediction model based on the small-scaled and large-scale tests data, as well as on semi-empirical equations;
- investigating noise reduction methods based on structured porous trailing edges and fences, with an optimization approach to maximize the noise reduction effects.

The project will provide unique and extremely valuable data for SST airframe noise. Its results and conclusions can lay a firm foundation for the noise control of SST, and will contribute to the development of next generation aircraft made by China and Russia.

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## **Appendix E. Canadian Noise Technology Research Programmes**

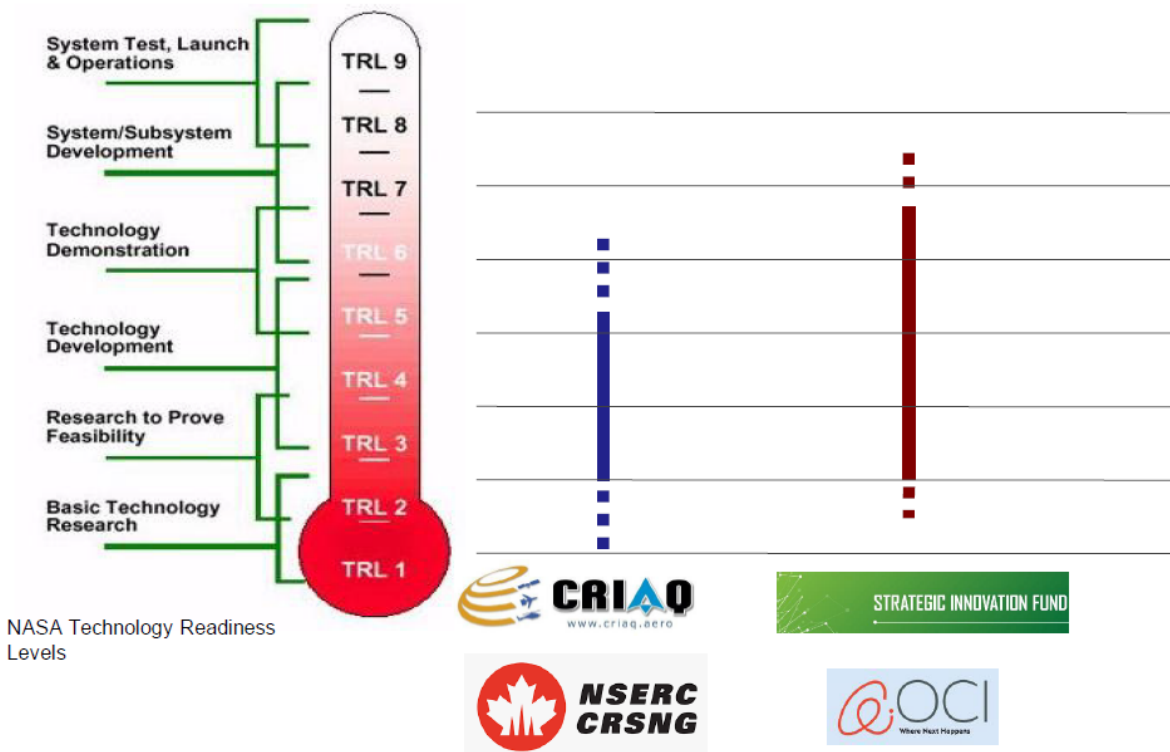
CANADA



4<sup>th</sup> CAEP Noise Technology  
Independent Experts  
Goals Review

- Currently, no nationally lead noise research programs
- 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



## **Appendix F. Brazilian Noise Technology Research Programmes**

## Summary

- AERO-Trends Consortium (2021-25)
- PDNT é Platform for New Aeronautics Technologies Development (2024-2027)
- Experimental and numerical evaluation of the aerovibroacoustic characteristics of propellers for electric propulsion aircraft (2024-2025)
- Silent rotors (2024-2025)



## AERO-Trends

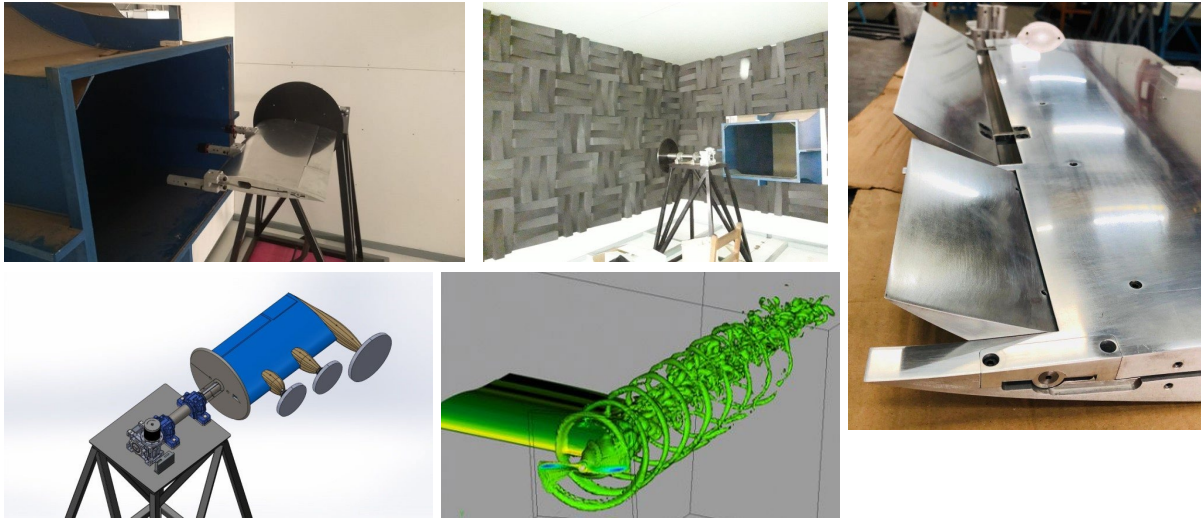
### TOPICS:

- 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.

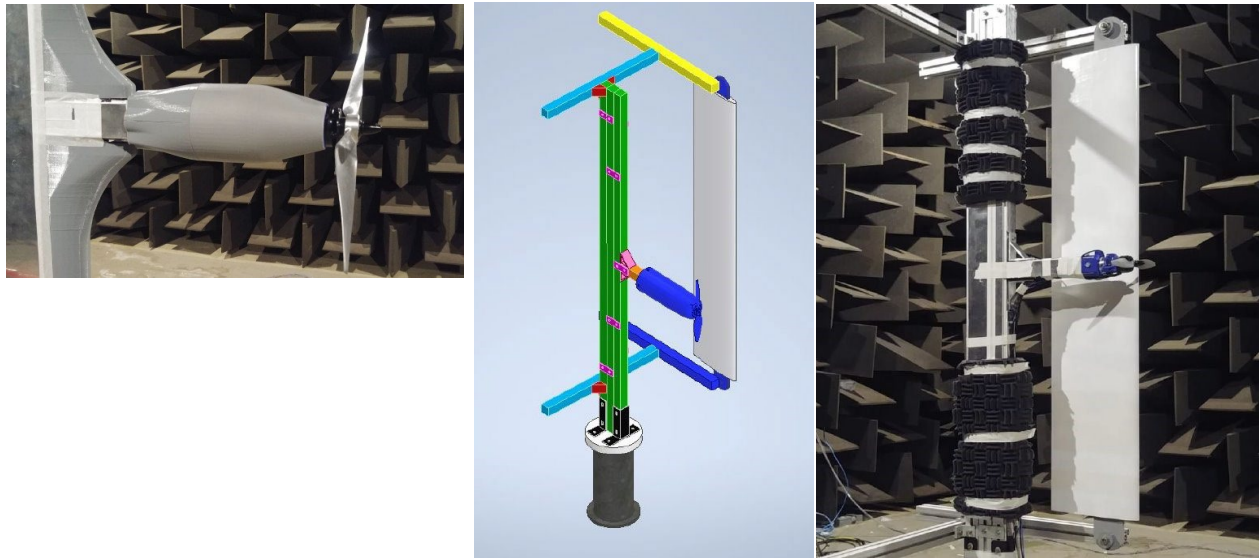
### BRAZILIAN PARTNERS

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

## Distributed Propulsion Rig (USP-EESC)



## Propeller Noise Stationary Rig (UFSC)



## PDNT

Large initiative for demonstrating new aeronautic technologies, with several partners in Brazil. Noise is within the scope.

### TOPICS

- Design, construction and operation of an open section wind tunnel for aeroacoustic measurements.
- Analytical/numerical noise trade-offs for a distributed propulsion propeller aircraft concept.
- Wind tunnel-to-flight corrections.

### BRAZILIAN PARTNERS

- FINEP – Financiadora de Estudos e Projetos (Brazilian Government Agency)
- EMBRAER
- University of São Paulo, São Carlos (USP-EESC)

Experimental and numerical evaluation of the aerovibroacoustic characteristics of propellers for electric propulsion aircraft

### TOPICS

- Numerical and experimental investigation of noise generated by installed propellers.
- Induced vibration associated with distributed electric propulsion systems.

### BRAZILIAN PARTNERS

- Federal University of Santa Catarina, Florianópolis (UFSC)
- CNPq (Brazilian Government Agency)

# Silent Rotors

## TOPICS:

- Comparative noise analysis of isolated rotor designs based on aeroacoustic measurements on closed section wind tunnels.
- Closed vs open section wind tunnel corrections for aeroacoustic measurements of isolated rotors

## BRAZILIAN PARTNERS

- Technological Institute of Aeronautics (ITA), Sflo JosÂdos Campos
- CNPq (Brazilian Government Agency)

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## **Appendix G. Chinese Noise Technology Research Programmes**

### Installed Engine Noise Attenuation project (IENA, MOST No.2018YFE0184000, China, Russia, Brazil)



#### Partners:

- China: AVIC Aerodynamics Research Institute(ARI)
- Russia: Central Aerohydrodynamic Institute named after Professor N.E. Zhukovsky (TsAGI)
- Brazil: Federal University of Santa Catarina(UFSC)

#### Research target:

The project aims at development of measurement techniques for 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.

#### Research content:

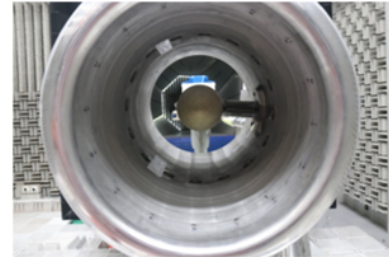
- WP1: Jet/airframe interaction noise
- WP2: Fan/airframe interaction noise
- WP3: Liner/fan optimize design

#### Duration:

Jan 2020~Dec 2022



Detailed view of fan simulator



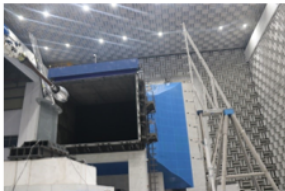
Detailed view of fan noise simulator

### Installed Engine Noise Attenuation project (IENA, MOST No.2018YFE0184000, China, Russia, Brazil)

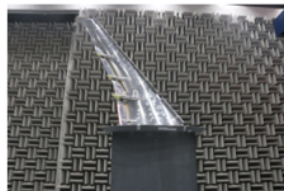


#### Fan/Airframe installed noise experiment:

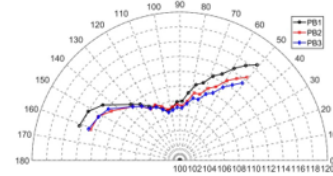
The fan/airframe installed noise experiment was carried out in FL-10 wind tunnel to study the influence of fan/airframe relative position. In general, 11 positions were designed and experimentally measured, the influence of fan/airframe relative position on far field noise was summarized by comparing single airframe, single fan and installed fan/airframe.



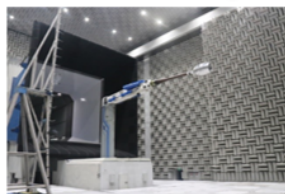
The measurement array



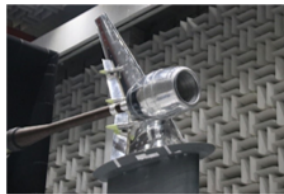
Airframe noise experiment



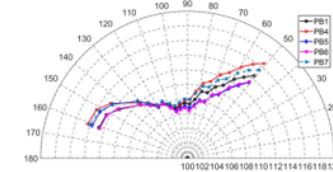
Influence of nacelle movement in streamwise direction



Fan noise experiment



Fan/airframe installed noise experiment



Influence of nacelle movement in vertical direction