“Aircraft Noise Reduction Technologies and Related Environmental Impact”

ARTEM

Project Overview and

Achievements at Month 18

Published 02.09.2019

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1. General information and project objectives

"ARTEM" – stands for **A**ircraft noise **R**eduction **T**echnologies and related **E**nvironmental i**M**pact

ARTEM is a four-year research project, started in December 2017, and is devoted to the development of novel noise reduction technologies for low-noise 2035 and 2050 aircraft configurations.

The project was set up in order to help closing the gap between noise reductions obtained by current technologies - as already applied or being matured in large EC technology projects such as OpenAir and CleanSky - and the long-term goals of ACARE, i.e. a noise reduction of 65% for each aircraft operation in year 2050 compared to the reference year 2000 value.

Therefore, ARTEM takes up innovative ideas and concepts for efficient noise reduction by novel liner concepts and investigates the potential of dissipative surfaces as encountered with the development of meta-materials. The aim is to develop those "Generation 3" noise reduction technologies (NRTs) to a technology readiness level (TRL) of 3 (experimental proof of concept) to 4 (technology validated in lab).

Within the project it is taken into account, that future aircrafts, anticipated to be introduced between 2035 and 2050, might have different configurations than the current tube-and-wing design with underwing–mounting of the engines. For 2035, the tube-and-wing layout could persist while the engine placement might differ, e.g. being semi-buried in the fuselage. For the 2050 time frame, blended wing-body aircrafts with very high bypass ratio (BPR≥16) may power long-range aircrafts, while regional aircrafts might exhibit hybrid propulsion systems or distributed electric propulsion system.

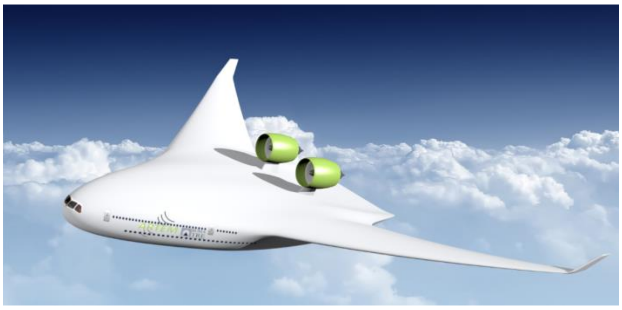

Figure 1: Left: *A possible candidate for 2035 air transport: ONERAs NOVA concept with semi-buried engine (© ONERA, 2015). Right: Initial layout of a blended wing body anticipated for 2050 operation, equipped with generic UHBR engines mounted on pylons on the top of the centerbody (© University RomaTre, 2018).*

The noise signature of the anticipated configurations will be strongly influenced by the interaction of several aircraft components: the interaction of airframe, high-lift-system, and propulsive jet of the engine(s), the interaction of airframe and engine inlet, the interaction of the landing gear with the airframe. These effects – which directly involve the noise generation - will be investigated in the ARTEM framework by dedicated experiments and high-fidelity numerical calculations.

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Reduce noise sources, reduce noise propagation, predict the impact of new aircrafts and their noise reduction

The first core topic of ARTEM is the development of innovative technologies for the reduction of aircraft noise at the source. The approach moves beyond the reduction of isolated noise 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 development work 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 auralizations.

Initiated by the Association of European Research Establishments in Aeronautics (EREA), ARTEM follows a holistic approach for noise reduction of future aircrafts and provides enablers for quiet air traffic of the future which is an important part of EREAs Future Sky initiative.

ARTEM brings together the expertise of a large and diverse consortium consisting of twenty-four (24) partners throughout Europe: national research centers for aviation research, universities, small-and medium-sized enterprises (SMEs), and major European aircraft industry companies.

Project Details

Project ID/Grant Agreement:	769350
Funded under:	Smart, Green and Integrated Transport
Start date:	2017-12-01,
End date:	2021-11-30
Total cost:	7.9 M€
EU contribution:	7.5 M€
Coordinated by:	DLR
Call Topic(s):	MG-1-2-2017 “Reducing aviation noise”
Funding scheme:	RIA – Research and Innovation action

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2. Activities and Achievements during the period M13-M18

Initial Development of Novel Liner Concepts

One of the objectives of ARTEM is the reduction of noise on its way propagating away from the noise sources. This activity is embedded in the first work package of the ARTEM project. Here, acoustically damping wall treatment, called liner, and shielding effects are in focus.
Liners are already found in inlets and on other places in aircraft engines. They reduce the engine noise. Shielding describes the effect, when the noise propagation path towards the person on the ground is changed by parts of the aircraft structure or dedicated devices – which also results in a noise reduction for the person on the ground.

During the first period of this project several liner concepts have been established and developed further. Starting from a selection of the most promising novel liner ideas, the objective is to derive an appropriate model description of the underlying mechanisms in order to allow a specific implementation in the design process of future aircraft configurations. This first stage of investigations is conducted experimentally and with numerical studies.

The development of novel liner concepts within ARTEM is based on a detailed requirement analysis provided by RRD as one of the leading aero-engine manufactures. The resulting report covers a detailed set of acoustic requirements for the liner concept development at low TRL and a further set of non-acoustic integration requirements and constraints at a high level to allow a selection of the most viable and feasible concepts in an early stage.

For a passive damping systems, the friction-powder liner (COMOTI), already first sets of liner samples have been manufactured and successfully evaluated with an increased absorption coefficient in simple acoustic testing setups (Kundt-tube).

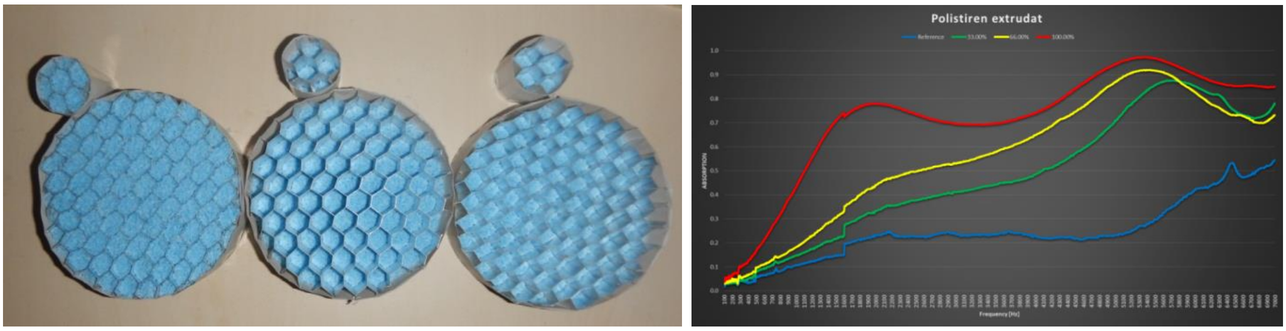

Figure 2: Friction-powder liner filed with blue extruded polystyrene (left). Acoustic absorption results from Kundt-tube measurements (right). (© COMOTI, 2019)

For the active liner system based on plasma actuators (investigated by EPFL/AEDS), different actuator types (DBD - dielectric barrier discharge and Corona type discharge) have been investigated experimentally and an initial acoustic assessment was carried out. For both discharge types numerical models have been developed and validated as the basis for a subsequent control strategy aiming at the aero-engine integration.

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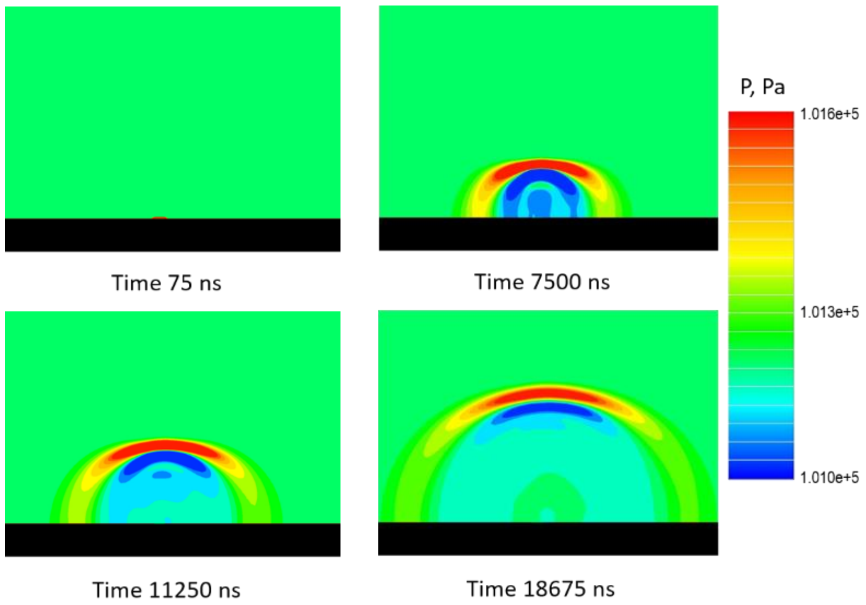

Figure 3: Plasma actuator liner: Numerical simulation of a pressure wave evolution (60 kJ/s energy impulse). (© AEDS, 2019)

For the Zero-Massflow-Liner concept (DLR), which aims at an enhanced broadband damping effect due to the interaction of the acoustic field with periodically excited synthetic jets at the liner face-sheet, it could be clearly identified that the additional damping mechanism is mainly related to the excited periodic velocity through the perforation. In a next step a proper model description of this influence will be derived.

Building a data base for shielding models – a contribution of the Russian partner TsAGI

During M1-M18 period, two experimental campaigns were conducted in Anechoic Chamber AC-2 of TsAGI in order to obtain data for future validation of tools for shielding effect prediction.
The first experimental study was devoted to the jet noise shielding by a rigid flat plate (Figure 4). Experiments were carried out for various jet operating conditions for two different nozzles. Typical results for jet operating conditions corresponding to the nozzle pressure ratio NPR=1.2 are shown in Figure 5.

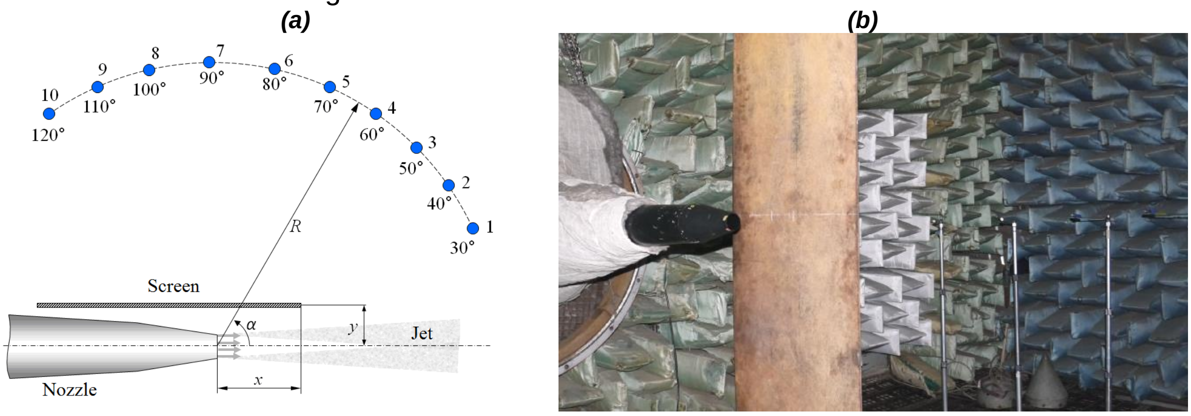

Figure 4:Jet shielding investigation: (a) – sketch of the experimental setup; (b) – actual setup in the anechoic test-chamber AC2 of TsAGI (view from the nozzle side), (© TSGAI, 2019).

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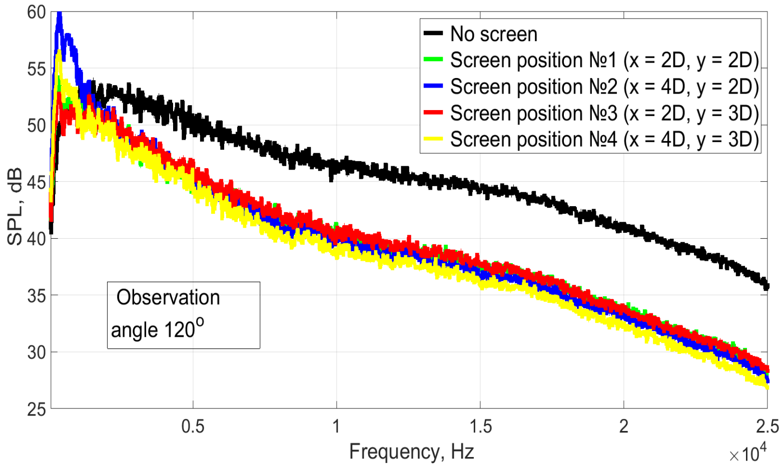

Figure 5: Effectiveness of shielding: Spectra for the observation angle 120°, NPR=1.2 (© TSGAI, 2019)

In general, the analysis of the experimental data on the jet noise shielding effect reveals the following main trends:

(1) – the effectiveness of jet noise shielding efficiency is higher for higher frequencies and its increases when the plate moves downstream (x coordinate increases);

(2) – the same effect is observed when the plate approaches the jet (y coordinate decreases), this tendency is somewhat weaker than the first one;

(3) – at low frequencies, when the plate is close enough to the jet, noise amplification symmetric relative to the plate is observed.

The first two tendencies can be qualitatively explained by the fact that with such plate movements the observer shifts deeper into the geometric shadow zone. Quantitative description of the effect will be developed in the next phases of this project.
The third observation is associated with scattering of hydrodynamic (subsonic) disturbances of the jet near field at the trailing (i.e. the rear) edge of the plate. In addition, there is a high-frequency effect associated with the diffraction of acoustic waves, emitted by the jet, on the plate edges. These effects might be of great importance for future aircraft configuration taking into account, that the frequencies of the observed phenomena could shift from 10 kHz as observed on model scale to about 1kHz for full scale configurations.
Another part of the experimental campaign is related to the shielding effect on fan noise radiated from the inlet. Here, a specific setup was used which is capable to generate acoustic modes (i.e. a spatial and temporal distribution of the acoustic pressure) which is comparable to the acoustic field at a real aircraft engine.

Details of the experiments are contained in a project internal report “Experimental database from model test”. These results will be used on the next stages of the project for validation of theoretical/numerical methods of shielding effect prediction.

TsAGI is a project partner from Russia, which contributes to the objectives of ARTEM without direct funding of the European Commission (EC). TsAGI receives his funding from Russian Ministries based on a cooperation agreement between the EC and Russia. With TsAGIs expertise

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and experience and their unique facilities for aero-acoustic research, they significantly contribute to the success of ARTEM and other European research projects.

Landing Gear – a major noise source during approach

For current aircrafts, the engines dominate the overall aircraft noise at take-off. However, during the approach to the airport – not much power (thrust) is needed and the engines are less noisy. Here, other noise sources as the high-lift system (generating enough lift force also during slower flight speeds) and the landing gear are significant contributors to the overall noise emission of the aircraft. In addition, there are interactions between jet and high-lift system, between landing gear and fuselage and others which generate noise too.

Also for future aircrafts - no matter which specific configuration it will be (tube-and-wing, blended-wing-body,…) - there will be landing gears which have complex mechanical structures and generate noise.

One of the tasks in ARTEM is the investigation of different landing gear concepts, which are suitable for the novel aircraft configurations (NOVA, BOLT, and REBEL). Model scale experiments of different landing gear concepts and associated means of noise reductions (e.g. shape design, deflectors, shields, etc…) are tested in aero-acoustic wind-tunnels in order to generate validation data for numerical tools, which are used for the actual design of landing gear systems. During the last months, a first test campaign was successfully performed.

The acoustic wind tunnel test was prepared and conducted by DLR in close collaboration with Airbus and University of Southampton (SOTON) at the Aeroacoustic Wind Tunnel in Braunschweig (AWB).

The test was based on DLR's generic AWB high lift system equipped with a full span slat and a full span flap. The high lift system was tested in the following three slat/flap configurations:

- CLEAN: slat and flap retracted
- INTERMEDIATE: δ_{slat} = 26°, δ_{flap}=30°
- FULL: δ_{slat} = 26°, δ_{flap}=34°

The selected landing gear model was scaled 1:11 and mounted in a cavity which was closed for nearly all test points. The second tested configuration was the "fuselage and belly fairing" variant. The high lift system settings are similar to the ones already mentioned. The BWB aircraft configuration was simulated by using a Clark-Y profile with installed landing gear. All three configurations are presented in Figure 6 from left to right.

Figure 6: ARTEM test configurations in AWB . (© DLR, 2019)

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Acoustic measurements were conducted for wind speeds of 40, 50 and 60 m/s. The aerodynamic investigations were conducted at 60 m/s only as Reynolds-number dependent effects were not expected within the operational speed range. Including the background noise test a total number of 21 configurations were tested.

The following measurement techniques were applied during the test.

Aerodynamic measurements:

- Wind tunnel balance for high lift system and Clark-Y model
- Static pressure taps on the fuselage and belly configuration for comparison against CFD
- 6 static pressure taps on the flaps in order to determine local flow speeds
- 36 unsteady pressure sensors on the flap in order to identify footprint of impinging turbulence

Acoustic measurements:

- Microphone array with aperture of ~1m and 96 microphones to localize and identify noise sources for later rank ordering
- 8 single farfield microphones in order to assess farfield radiated noise in terms of absolute levels and the radiation characteristic

First acoustic data is presented here for the fuselage and belly configuration. The following Figure 7 shows the increase of far-field noise levels in the mid to high frequency noise regions due to the landing gear installation. The blue curve represents the measurement with installed landing gear, while the red curve shows the same configuration without landing gear.
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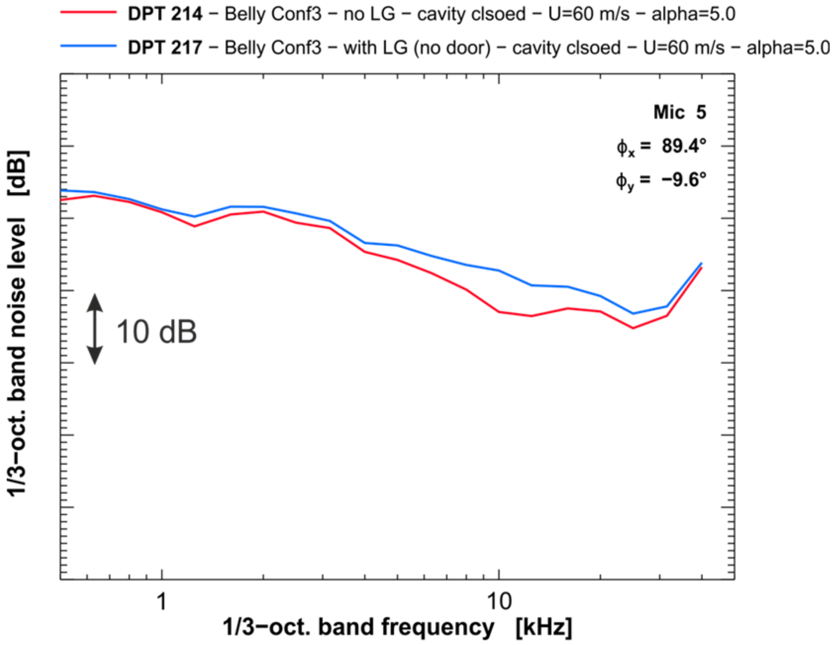

Figure 7: Increase in far-field noise levels for the fuselage and belly configuration. Blue curve: LG installed, red curve: no LG installed (© DLR, 2019)

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The respective noise source maps – obtained by the microphone array – highlight regions of different sound generation (Figure 8). The noise generated directly at the landing gear is dominating. The elongated source region could be considered a landing gear installation effect.

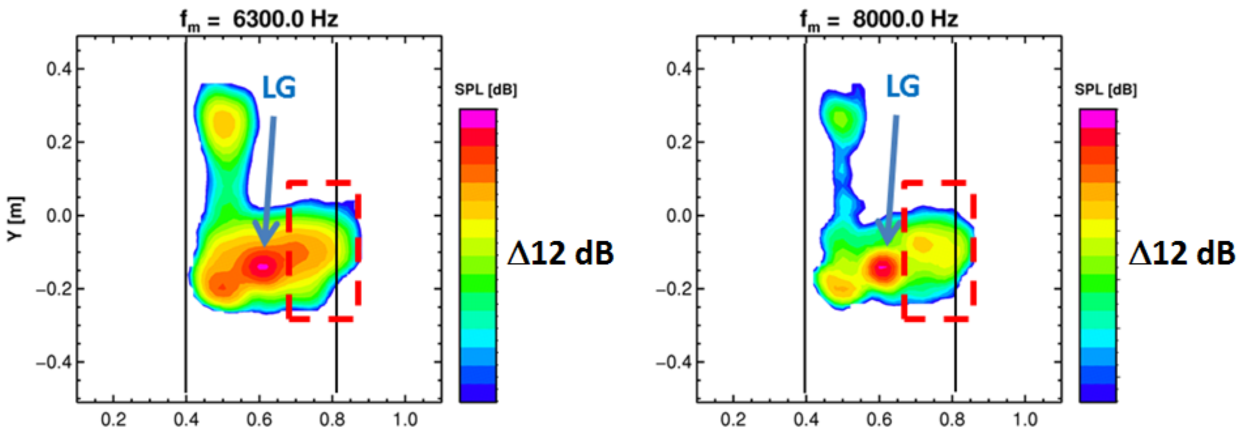

Figure 8: Effect of installed landing gear on far-field radiated and source noise levels. The colour bar covers a range of 12dB (© DLR, 2019)

The aerodynamic and aero-acoustic data collected during the test series is currently under further analysis and will serve as basis for experimental work of noise reduction technologies and associated numerical investigations.

First aero-acoustic simulation of a BLI configuration achieved

From an aerodynamic point of view – there is a significant reduction of fuel consumption expected, if the main engines are not placed in an underwing configuration but are (partly) embedded in the fuselage of the aircraft. This configuration is called Boundary Layer Ingestion (BLI, see Figure 9).

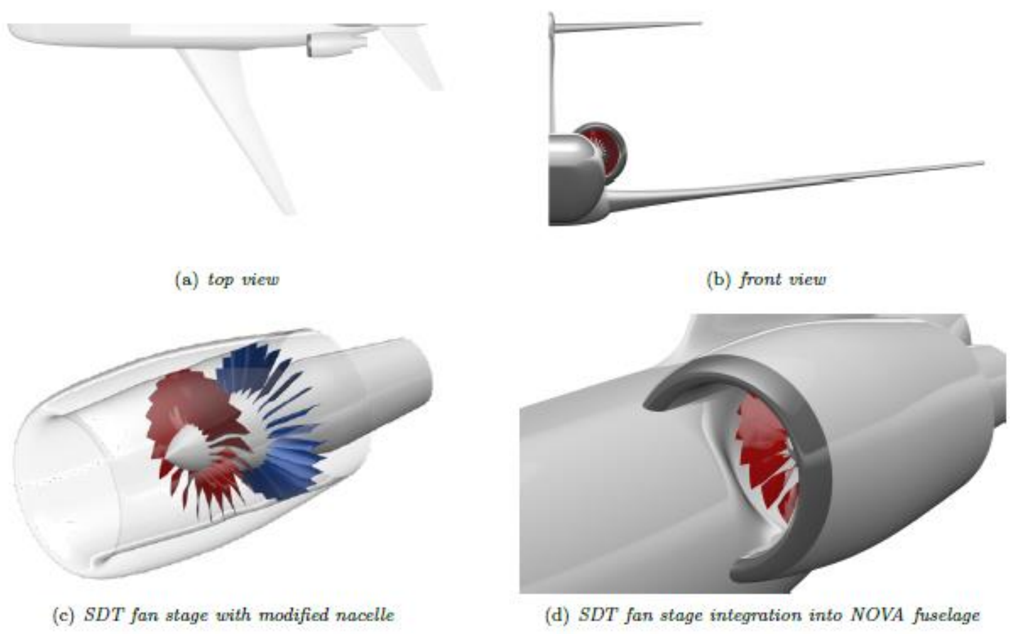

Figure 9: NOVA aircraft equipped with the redesigned BLI engine nacelle accomodating the adapted SDT fan stage (©TU Delft, 2019)

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However, from an aero-acoustic point of view, the distortion of the incoming flow field will generate additional noise when interacting with the rotor-stator stage. TU Delft has performed a first numerical simulation of this configuration in full-scale for low-speed conditions (as encountered during take-off) obtaining aerodynamic (Figure 10) and aero-acoustic information.

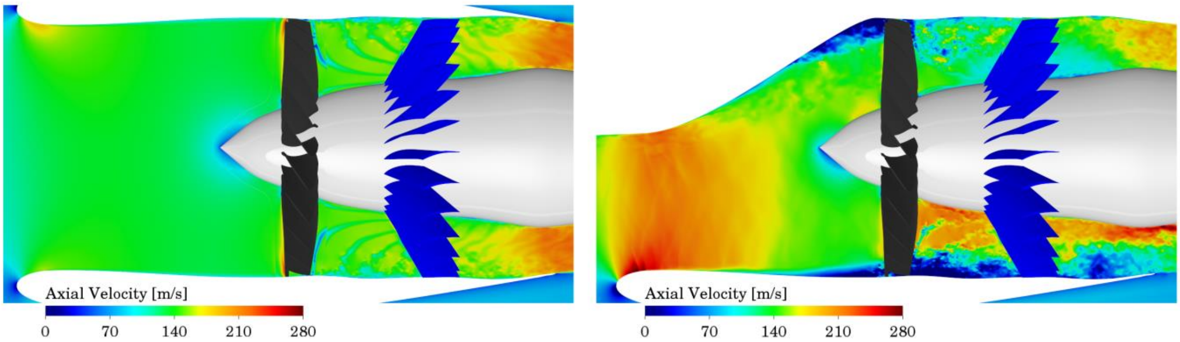

Figure 10: Instantaneous axial velocity field on a plane normal to the fuselage surface and passing through the engine axis: isolated engine (left) and BLI engine (right), (©TU Delft, 2019)

Far-field noise directivity predictions revealed that the noise is radiated most efficiently downstream the engine for the BLI layout, as also observed for the isolated engine (Figure 11). While acoustic tones are clearly present for the isolated fan stage, the BLI configuration is almost completely dominated by broadband noise – which is a result of the distorted inflow and strong turbulence interactions with rotor and stator.

Overall, the BLI configuration showed from 10 to 20 dB higher broadband levels in the far-field compared to those related to the isolated configuration, for most of the frequencies and directivity angles considered. The BLI layout resulted to be as noisy as the isolated one, or quieter by 5-10 dB only for directions nearly perpendicular to the engine axis and for frequencies higher than BPF-2 due to some fuselage noise shielding.

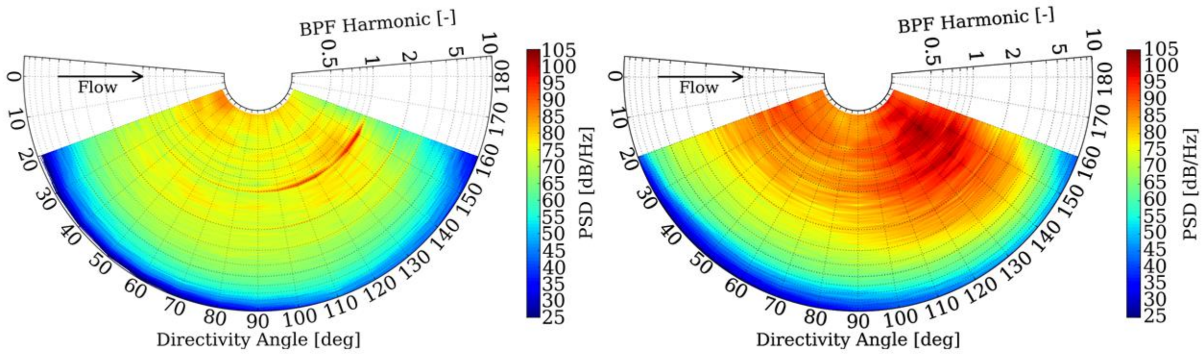

Figure 11: Far-field noise directivity on a circular array of 10 m radius centered around the fan and located below it: isolated engine (left) and BLI engine (right), (©TU Delft, 2019)

The noise penalty as found in these calculations is a kind of worst-case scenario. The shape of the inlet duct (S-duct) could not be optimized to a sufficient degree to fully avoid flow separation. Latter effect causes additional aerodynamic losses and excess noise. Thereby it becomes clear, that one of the most efficient noise reduction means for a BLI configuration is an optimal design of the inlet duct – preferably in combination with a homogenization device for the incoming flow.

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Further activities during the recent period:

- U Bristol: Test setups have been designed and manufactured for the examination of the fundamental physics of trailing edge noise reduction using 3D surface treatments (finlets), including a long, heavily instrumented flat plate and two aerofoils. Measurements were performed for several surface treatments applied at various positions on the surface of the plate and aerofoils. A dataset has been produced from the first phase of the flow and noise measurements, which is currently being post-processed.
  This data serves for the selection of optimal finlet geometry and as validation data for the LES simulations of TUBS.

- Comparative calculations of slat noise generation using different numerical tools. This task used a reference test case for the comparison of the different tools. Calculations have been finished. The comparison of results and conclusions will be highlighted in the next publishable report (M24).

- Model-scale experiments to obtain far-field pressure data of nozzle-bullet combination as simulation for engine configurations have been performed (SOTON).

- First model-tests of plasma actuators for instability control of the jet-surface interaction (TsAGI)

- Design of wind-tunnel test setup for the investigation of the interaction of distributed propellers including accompanying numerical simulations (PVS).
  The model will be made in approximately 1:3 scale and will consist of a wing featuring 17% thick airfoil and three propellers positioned either in front (tractor configuration) or above (pusher configuration) the wing, as depicted in Figure 12:

a) b)

Figure 12: DEP wing: a) configuration with three tractor propeller units, b) configuration with three pusher propeller units. (©PVS, 2019)

Management Activities:

The month 18 meeting was held at the premises of CIRA in Capua, Italy on the 13th and 14th of May 2019. The review of the project status with the project officer of the funding agency occurred on June 5th, 2019 in Brussels.

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3. Dissemination activities (M13-M18 only)

Project progress and results are frequently published in order to inform the scientific community and partners from aerospace industry about the project progress.

The project has been introduced to **aerospace and aircraft noise community** at following occasions:

- "Noise Reduction Technologies for Future Aircraft Concepts – first results of the H2020 project ARTEM", Karsten Knobloch, tandem Aerodays 2019, 27.-30.05.2019, Bucharest, Romania
- "Activity of TsAGI in ARTEM", Victor Kopiev, tandem Aerodays 2019, 27.-30.5.2019, Bucharest/Romania
- A poster of European Aeroacoustic Research projects, including ARTEM, was presented at 25th AIAA/CEAS Aeroacoustics Conference 2019, 20.-24.05.2019 in Delft/The Netherlands

Scientific publications:

- "Fan Noise Boundary-Layer Ingestion Installation Effects for NOVA Aircraft Configuration", G. Romani, 25th AIAA/CEAS Aeroacoustics Conference 2019, 20.-24.05.2019, Delft/ The Netherlands
- "Radial Basis Functions for Stochastic Metamodels Tailored to Aeroacoustic Applications", Umberto Iemma, 25th AIAA/CEAS Aeroacoustics Conference 2019, 20.-24.05.2019 Delft/ The Netherlands
- "Plasma-based active closed-loop control of instability waves in unexcited turbulent jet. Part 2. Installed jet", Oleg Bychkov, 25th AIAA/CEAS Aeroacoustics Conference 2019, 20.-24.05.2019, Delft, The Netherlands
- "Mitigation of jet-wing interaction noise by plasma actuators", O. Bychkov, European Drag Reduction and Flow Control Meeting – EDRFCM 2019 26.–29.3.2019, Bad Herrenalb, Germany
- "Dissipationseigenschaften periodisch durchströmter Liner bei streifendem Schalleinfall", Ralf Burgmayer, DAGA 2019 - 45. Jahrestagung für Akustik, 18. - 21.03.2019 Rostock, Germany (published in German)

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4. Online ressources

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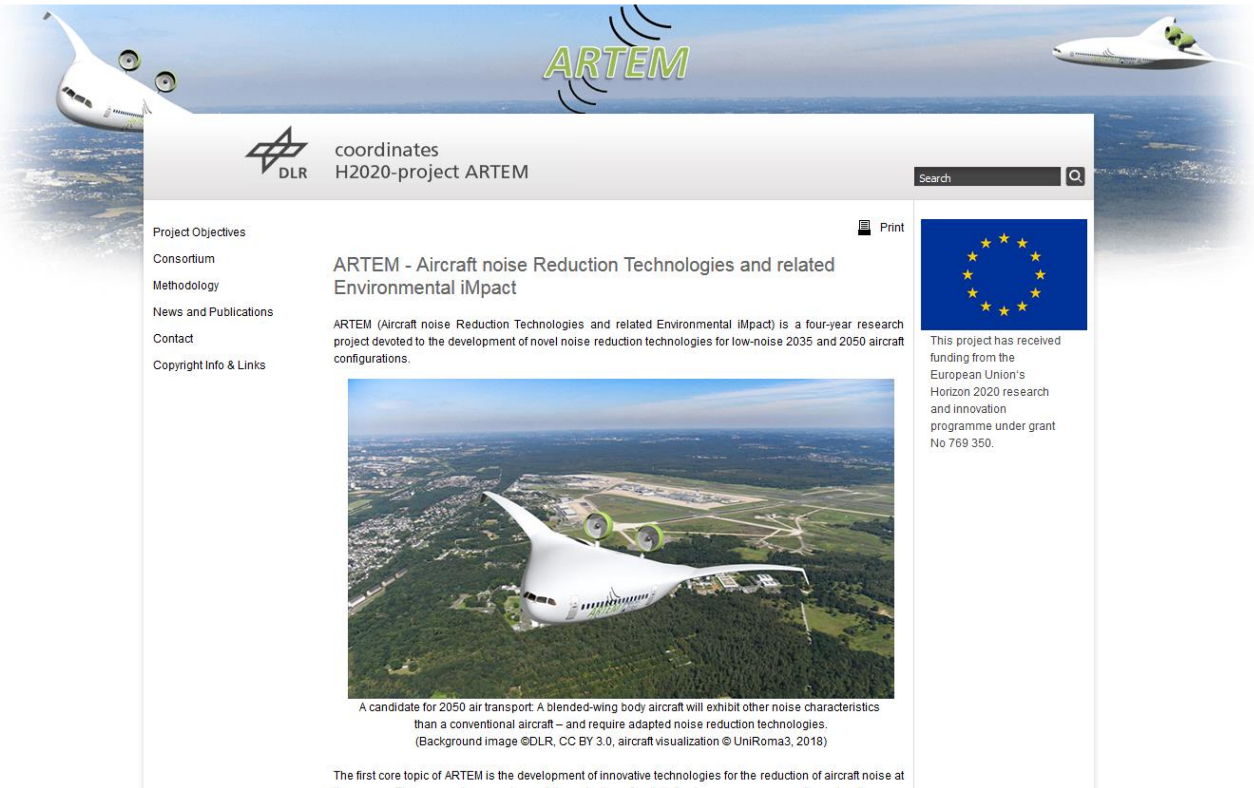

A project flyer and the publishable summaries are available for download at the ARTEM website.

- ARTEM at the EC information site (CORDIS):
  https://cordis.europa.eu/project/rcn/212367/en

- Project fiche of ARTEM at the INEA site:
  https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/aviation/artem

LINKS:

- Coordination Action for European Noise Research within H2020 project ANIMA:
  https://anima-project.eu/what-does-anima-do/global-co-ordination/

- Future Sky initiative of EREA:
  http://www.futuresky.eu/projects/quiet-air-transport

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5. The ARTEM Consortium

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Centro Italiano Ricerche Aerospaziali (Italian Aerospace Research Center CIRA)

Le Centre National de la Recherche Scientifique (CNRS)

COMOTI, Romanian Research & Development Institute for Gas Turbines

Dassault Aviation SA (DASSAV)

Deutsches Zentrum für Luft- und Raumfahrt (DLR), German Aerospace Center

Ecole Central de Lyon (ECL)

École Polytechnique Fédéral de Lausanne (EPFL)

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National Institute for Aerospace Research Elie Carafoli (INCAS)

Stichting Nationaal Lucht- en Ruimtevaartlaboratorium (NLR), Netherlands Aerospace Centre

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PIPISTREL VERTICAL SOLUTIONS d.o.o. (PVS)

Rolls-Royce Deutschland Ltd & Co KG (RRD)

Safran Aircraft Engines (SAE)

University of Southampton (home of the Airbus Noise Technology Centre and the Rolls-Royce University Technology Centre in Noise) (SOTON)

Central Aerohydrodynamic Institute (TsAGI)

Technische Universität Braunschweig (TUBS)

Delft University of Technology (TUDelft)

University of Bristol (U Bristol)

Université de Cergy-Pontoise (UCP)

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The von Karman Institute for Fluid Dynamics (VKI)

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6. Contact for further information

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