“Aircraft Noise Reduction Technologies and Related Environmental Impact”

ARTEM

Project Overview and

Achievements at Month 36

Published 22.01.2021

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.

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

2. Activities and Achievements during the period M25-M36

The following paragraphs highlight some activities and achievements of ARTEM partners which have been finished or produced significant results during the stated period.

While the spread of the COVID-19 virus and the associated governmental measures as travel restrictions, lab closures, and shift from office to home-office have severely affected also the partners working in ARTEM, there has been made significant progress in several tasks. Test campaigns could be finished just before the first shutdown in March 2020, while others could be handled after the lab re-opening in the late summer season with remote partner support. Numerical simulations could in most cases handled like during regular office work. However, the direct exchange between all the involved persons could not be fully replaced by online venues and video calls and is missed greatly.

Novel Liner Concepts are Maturing

One of the great challenges for the air transport is the further improvement in energy (fuel) efficiency and the reduction of emissions. While in past years, the increase of engine size and bypass ratio has yielded significant positive contributions to both design goals, it involves a crucial noise issue too: larger engines emit low frequency noise (tones and broadband noise) while the well-established noise absorbing structures (liners) mounted in the inner duct of the engine nacelle are limited in their effectiveness due to limitation in size when trying to adjust to these changing requirements.

In ARTEM, several concepts are addressing this issue aiming for low frequency and broad-band absorption.

At Southampton university (SOTON), the colleagues are investigating liner structures which are adding additional degrees of freedom to the base structure by sophisticated inner structures of the basic liner cell. Additive manufacturing opens up new fields of complicated structures which have not been - technically and/or economically - possible before.
While the acoustic modelling and design of novel cell structures (as shown in Figure 2) is only the starting point, first measurements in Kundt tube have been made to further qualify the concept. The next step of the investigation involves specific wind tunnel tests at Southampton and the NLR grazing flow facility.
Further, the manufacturing process and the assessment of printing quality for the small

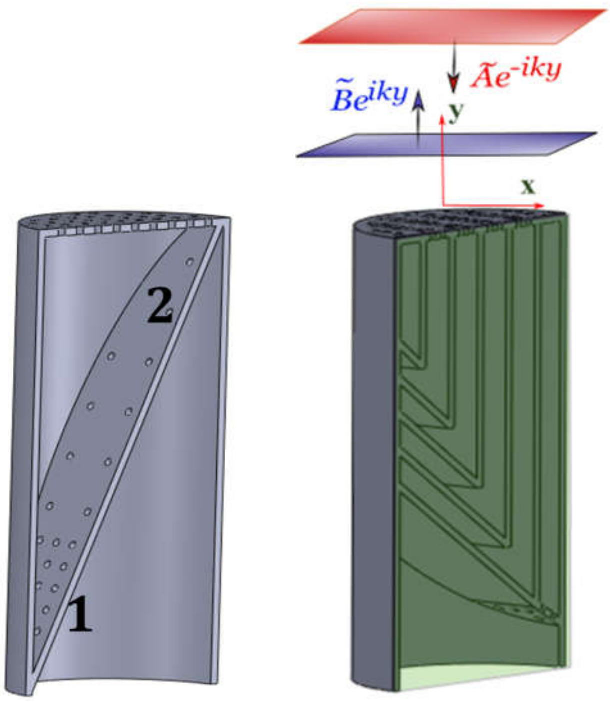

Figure 2: SOTON liner cell concepts for improved acoustic absorption. Left: Diagonal Septum Core, right: MultiFOCAL concept. ***(© SOTON 2019)***

structures and the covering perforate structure are of high relevance for the successful application and are being examined carefully by the involved partners NLR and SOTON.

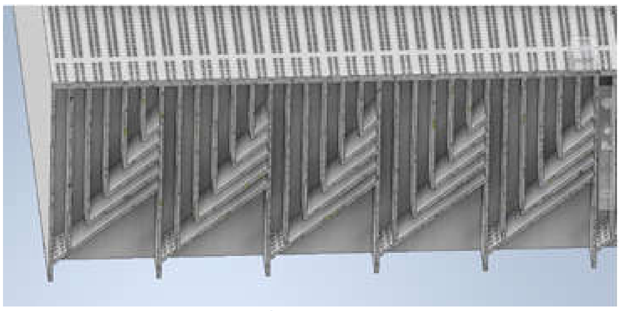

Figure 3: Four pieces of the 3D printed structure - based on SOTON cell design - yielding an overall length of 80cm will be finally installed in the NLR test duct. *(© SOTON/NLR 2020)*

In Figure 3, one of the liner structures that will be tested under flow conditions in the NLR grazing flow facility is shown. By testing different concepts in the same facility, the comparability of results of these concepts is greatly improved.

However, as the setup and operation of the grazing flow facility is rather complicated and expensive, initial development work has been performed by the respective partners using their own facilities allowing also for more flexible test-improvement-test cycles and in-depth analysis of certain phenomena.

The comparative testing of more-explorative and still lower TRL 2050 liner concepts has been started in the wind tunnel of LeMans University (CNRS). Here, the specific liner structures filled with different powders (COMOTI concept) yielding additional internal friction and energy dissipation were tested just recently in October 2020. Prior to this test campaign, the plasma-actuator based active liner structure developed by EPFL (supported by simulations of AEDS) was tested in the same facility (Figure 4 and Figure 5).

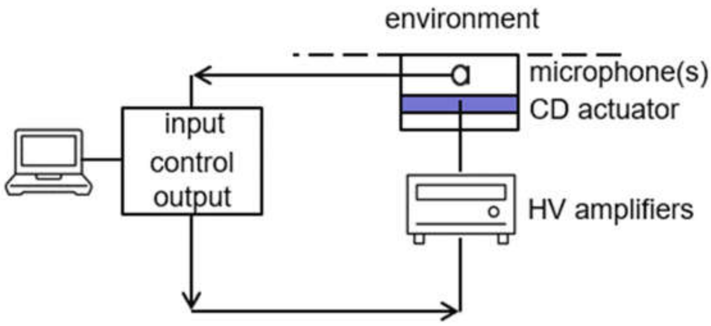

Figure 4: Actuator for the EPFL concept and control strategy *(© EPFL, 2020)*

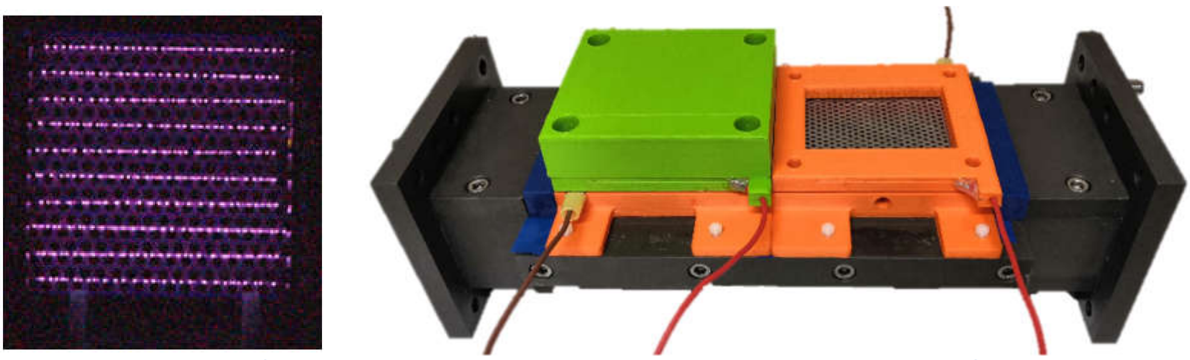

Figure 5: Plasma glow of the actuator and device mounted in the wind tunnel section *(© EPFL, 2020)*

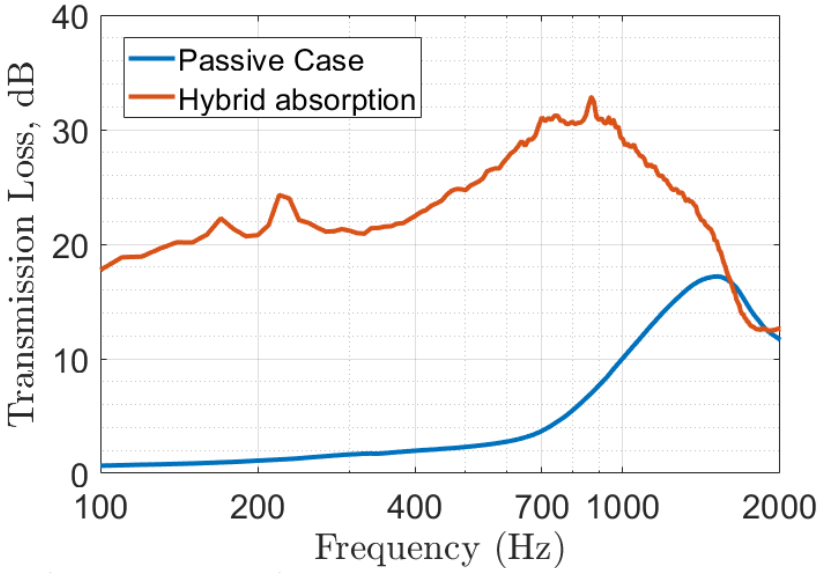

Figure 6: Comparison of transmission loss for the plasma actuator concept: no actuation applied (passive) and with actuation. No grazing flow.

The result of a transmission loss measurement for the plasma actuator is shown in Figure 6. The transmission loss is increased over a large frequency range (100-1500Hz) significantly (>20dB) compared to the passive case.
However, this impressive result is limited to the no flow case so far. The turbulent noise interfering with the actual signal on the control input microphone and the limited output power of the plasma actuator control decrease the performance for SPL>95dB. More details about the concept, the design, and the testing can be found in the publication of Stanislav Sergeev (see in the publication list at the end of this document).

A further concept to be tested in the same tunnel by the beginning of 2021 are small micro-deformable structures which are also actively controlled by electrostatic actuation. This concept is developed by CNRS.

Based on the results of the tests at LeMans facility and with the experience of all involved experts, the most promising candidate will be selected and also tested at the NLR grazing flow facility. This enables a direct comparison with the higher TRL concepts of SOTON and other partners (not presented here).

Predicting Noise from High-Lift Devices (HLD noise)

After the finalization of numerical benchmark activities, one focus was on the numerical simulation of noise generation mechanisms and associated reduction means for the high-lift system of the aircraft wing.

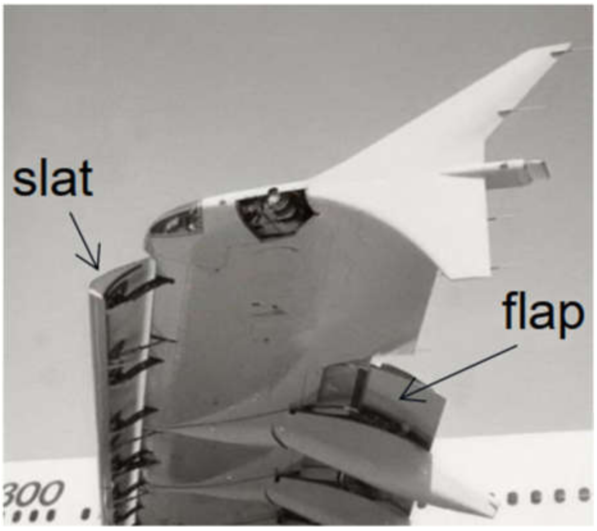

Figure 7: Left: Slat, main wing and flap of an A310-300 (from https://commons.wikimedia.org/wiki/File:Wing.slat.600pix.jpg, public domain)

Here, complex flow features are present and noise generation occurs through the interaction of several structures like slat, main wing, and flap. While future aircraft configurations might have a different overall shape (e.g. blended wing body), there is most likely still some kind of high-lift system required for take-off and approach.

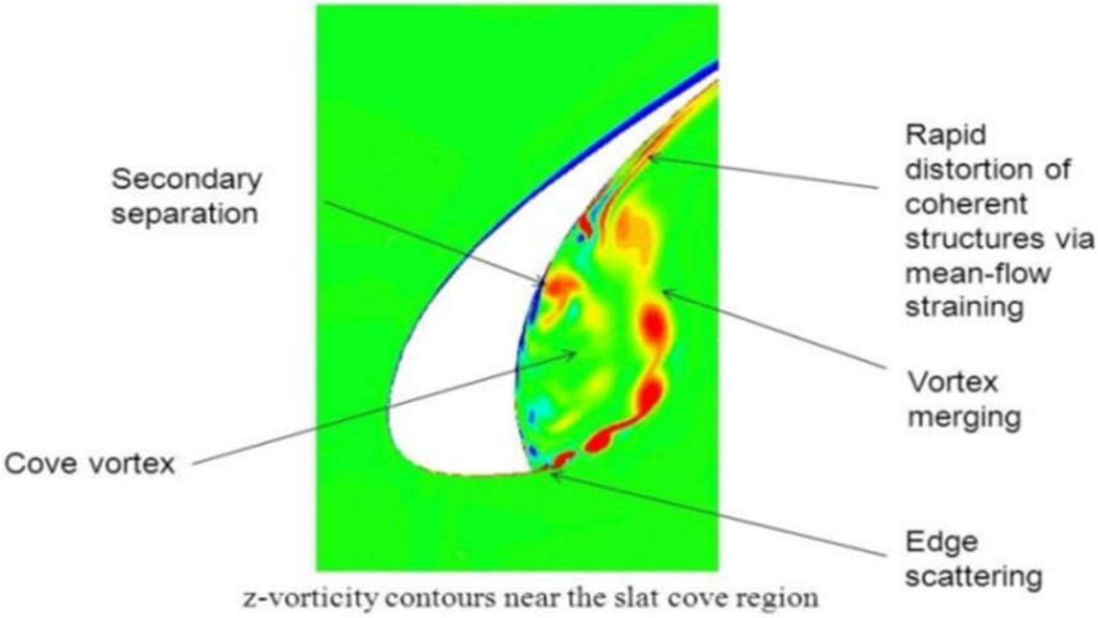

Figure 8: Complex flow phenomena at the slat cove are necessary to be accurately captured by aero-acoustic simulation in order to describe the noise generation and the effect of counter-measures *(© University Southampton, 2015).*

The complexity of the mechanical structures and the resulting flow features are one of the large challenges for aero-acoustic simulations (Figure 8).

ARTEM addresses this issue by applying different methods for fast and accurate prediction of the most important aero-acoustic features and the successful application and optimization of noise reduction devices.

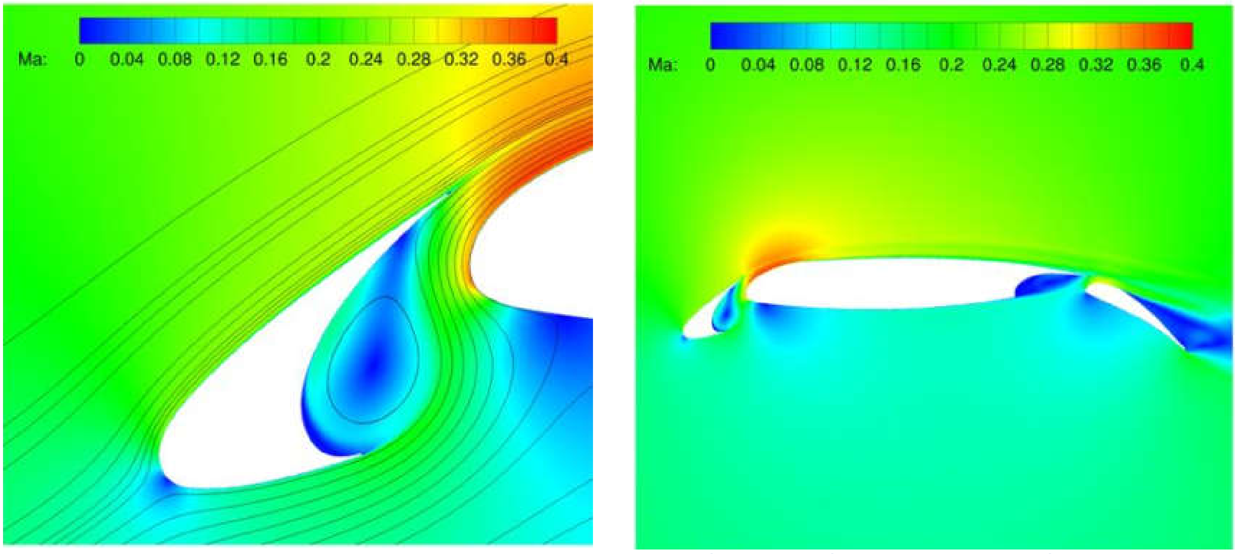

Figure 9: Mach number distribution around the slat and the full High lift system (F16 configuration, case 1). Results of a RANS simulation *(© DLR, 2020).*

Based on various simulation, the correct scaling for changing velocity (Mach number) and size (Reynolds number) were investigated.

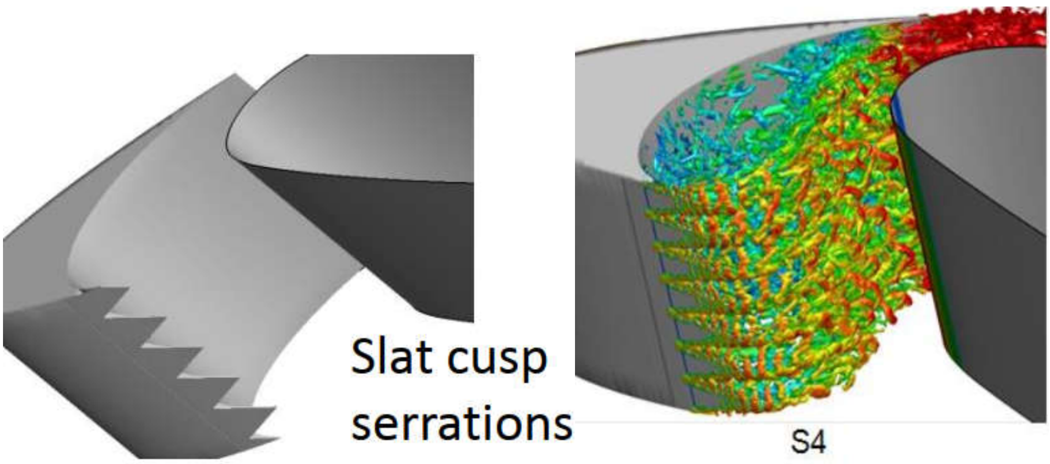

Figure 10: Serrations are one possibility to change the flow field between slat and main wing and thereby influence the noise generation. *(© ONERA, 2020).*

Involved partners in this activity are DLR (simulations), ONERA (simulations), Bristol (testing of finlets), TUBS (LES simulation of finlets).

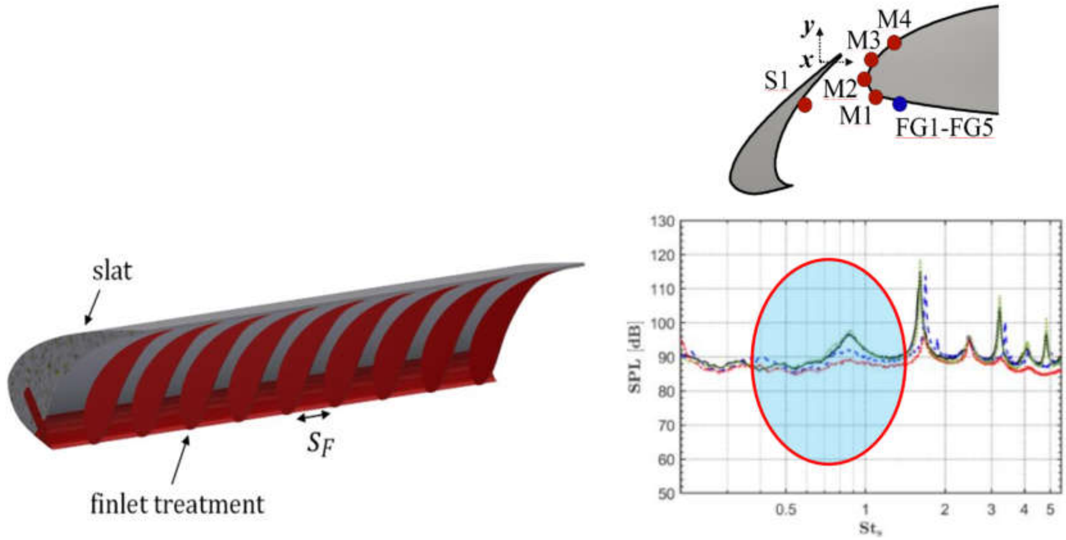

Figure 11: Finlets on the slat cove are investigated through numerical simulations and experiments. Right: Exemplary results from hydrodynamic near-field measurements (M4, angle 18°) *(© University Bristol, 2020).*

First Wind Tunnel Test of Distributed Electrical Propulsion (DEP)

Four ARTEM partners (Pipistrel Vertical Solutions – PVS, VKI, ONERA, INCAS) have worked closely to achieve the final assembly of the Distributed Electric Propulsion (DEP) mock-up, and have carried out several numerical activities that supported the final design.

Figure 12: The DEP mock-up (3 tractor propellers) and the ARTEM T2.5 test team at the INCAS wind tunnel in March 2020 *(© INCAS, 2020).*

Just before the first lock-down in March 2020, the planned wind-tunnel tests could be performed at the INCAS wind tunnel in Bucharest/Romania.

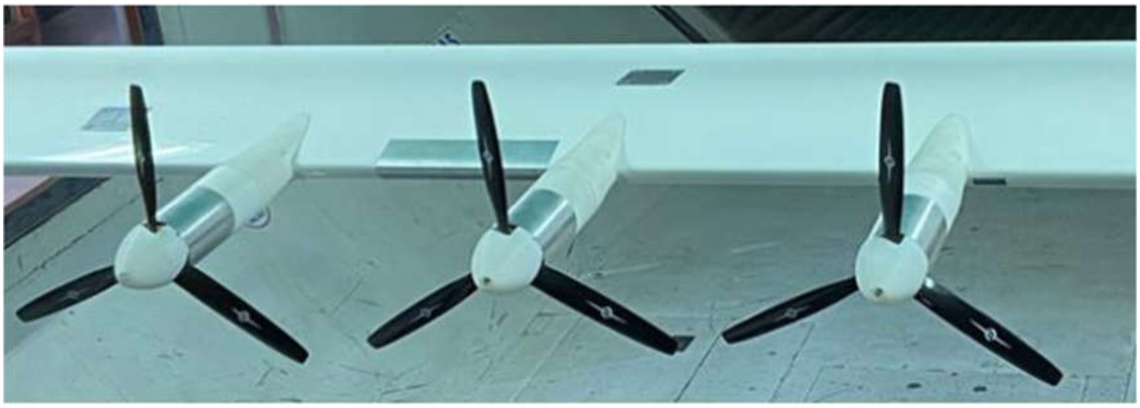

Figure 13: "Tractor" (or puller) configuration of the three propellers *(© INCAS, 2020).*

Beside balance measurements, pressure distribution measurements on the wing, and hot-wire measurements, the main emphasis was on the acoustic characterisation with a circular indoor array. A total of 58 aero acoustic test points have been measured in clean-wing, “tractor” (Figure 13) or “pusher” configuration (Figure 14). The detailed data processing is still ongoing- as there are several effects from rotor-self noise, rotor-wing (or support) structure interaction, and rotor-rotor interaction noise to be analysed and distinguished.

The parameters of the wind tunnel model are summarized in the following table:

Wing chord [m]	0.3
Freestream velocity [m/s]	30
Propeller diameter [m]	0.33
Propeller number of blades []	3
Propeller tip Mach number []	0.51
Wing Re []	0.6×10^6
Wing Mach []	0.09
Propeller RPM [/min]	10000

Figure 14: Pusher configuration *(© INCAS, 2020).*

Averaged spectra from the forward and rearward arc of the microphone array show the blade passing frequencies and broadband noise in the range from 2-20kHz for both, pusher and puller configurations compared to the clean wing configuration (Figure 15).

As the experiment is not in an anechoic environment (which is not possible in closed wind tunnel), there are currently simulations on-going in order to distinguish between direct noise sources and reflections from wind tunnel side walls and further improve the beam-forming results.

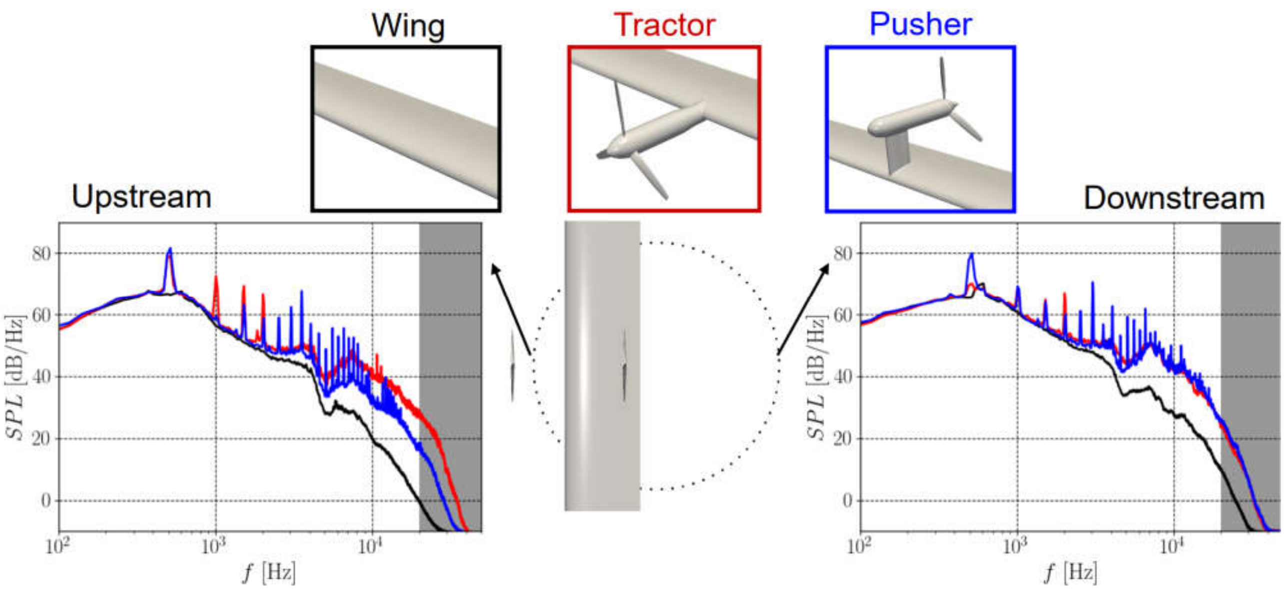

Figure 15: Averaged spectra from forward and rearward arc of the array *(© PVS, 2020).*

Noise Prediction for future aircraft configurations

The prediction of overall aircraft noise is very demanding due to the number of noise sources and their specific characteristic: changing amplitude, frequency content, and directivity depending on flight parameters. In addition, there are only very few models for noise sources which are new to other-than-conventional tube-and-wing configurations. Experimental data for validation of these models is obviously not existing so far.

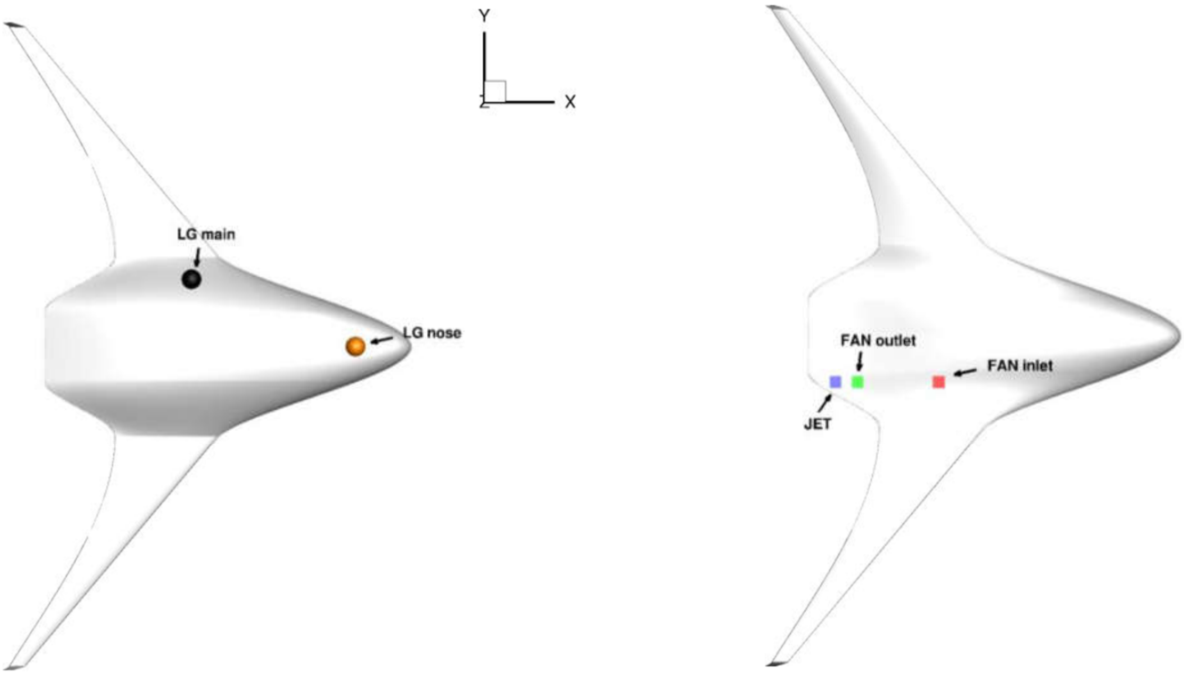

Figure 16: Generic noise sources for the tool benchmark for aircraft noise prediction *(© University RomaTre+ONERA, 2020).*

The starting point for the prediction process is therefore a tool benchmark with generic noise sources (Figure 16), which proves the full prediction chain for future work when more comprehensive noise source data is available. The benchmark of the tools of DLR, ONERA, and CIRA is nearly finished and will be reported in more detail in the next summary. A first result is shown below in Figure 17, showing reasonable agreement, but also some differences between the predictions of the three tools.

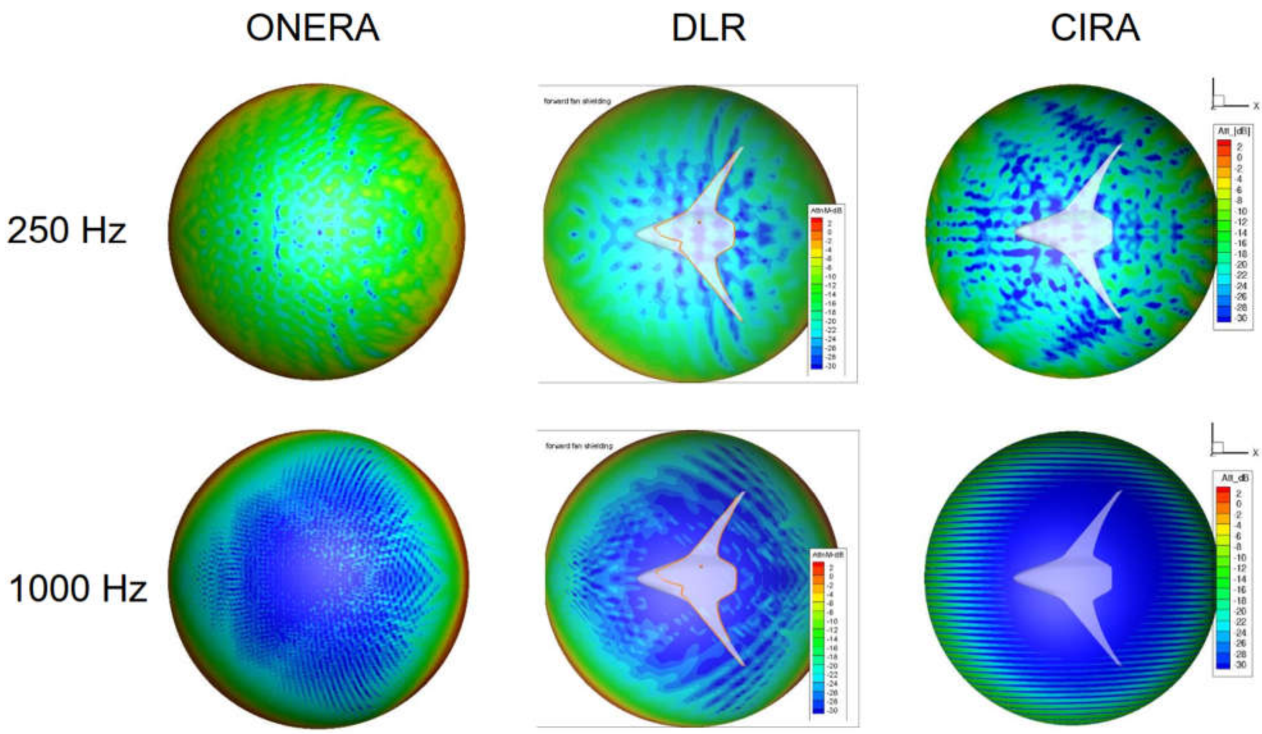

Figure 17: Comparison of the shielding prediction results of three tools (ONERA, DLR, CIRA) for the "Fan Inlet" noise source *(© DLR, ONERA, CIRA, 2020).*

The simulation network FRIDA developed and deployed by University RomaTre has been further extended and modularized. It was used within ARTEM to generate (physically reasonable) configurations BOLT and REBEL, the latter in a classical version with UHBR engines (REBEL-C) and a hybrid version (REBEL-H), which uses electrically driven propellers for the propulsion (see e.g. D4.5 publishable summary at M12 for some more details).

A model of the REBEL-H has been recently implemented in the free flight simulation environment JSBSim thanks to the work of Marco Stefanini, MSc student in Aeronautical Engineering at Roma Tre. The response of the aircraft to the pilot's inputs is calculated using FRIDA and saved in the specific .xml format.

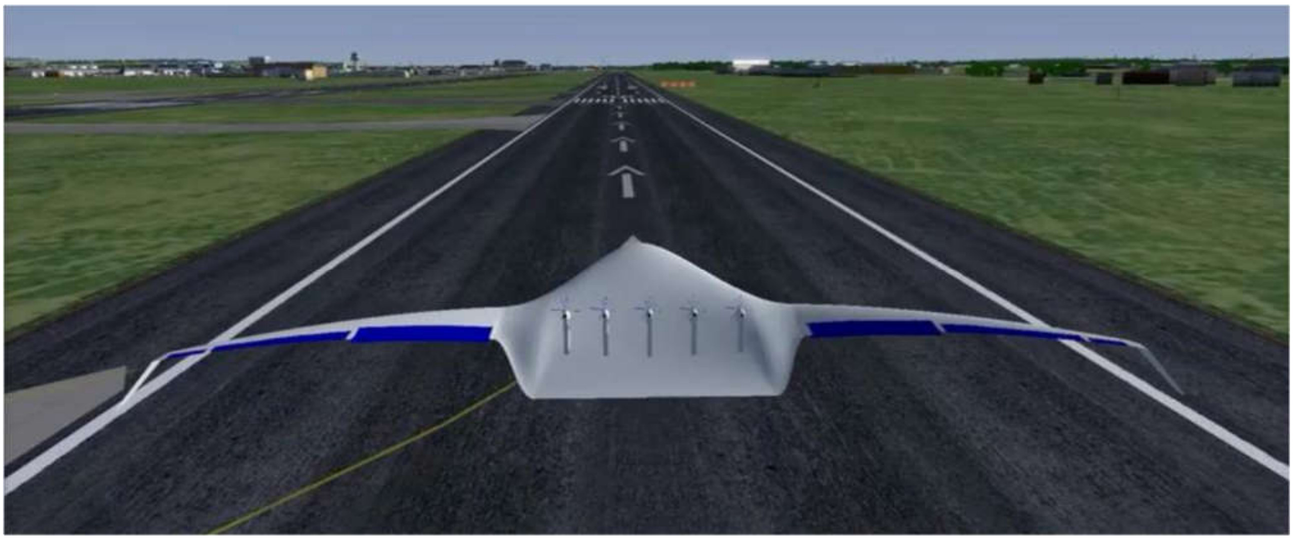

Figure 18: REBEL-H simulated in JSBSim using the aircraft configuration developed by FRIDA *(© University RomaTre, 2020).*

Management Issues:

As the COVID-19 situation does have obviously an impact also on the mutual work in ARTEM, certain tasks have encountered delays due to lab closures and limited resources during the last months. Therefore, the consortium decided to apply for a 6 months project extension which is currently under negotiation with the managing agency INEA which acts on behalf of the European Commission.

3. Dissemination activities (M25-M36 only)

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

- DEVELOPING "GENERATION 3" NOISE REDUCTION TECHNOLOGIES, Poster at Aerospace Europe Conference AEC2020, Bordeaux, France 25.-28.02.2020
- Full Network-Meeting of "European Aviation Noise Research Network" supported by ANIMA global coordination task, online venue, 2.10.2020

Scientific publications:

- Sergeev, S., Development of a plasma electroacoustic actuator for active noise control, Journal of Physics D: Applied Physics Vol.53, Number 49
  https://iopscience.iop.org/article/10.1088/1361-6463/abafde
  OpenAccess: after 12M embargo period
- Bychkov, O., Localization of Dipole Noise Sources Using Planar Microphone Arrays https://doi.org/10.1134/S1063771019050063, English version of Akusticheskii Zhurnal, 2019, Vol. 65, No. 5, pp. 675–687
  Open Access: will be added soon
- Romani, G., Numerical Analysis of Fan Noise for the NOVA Boundary-Layer Ingestion Configuration, Aerospace Science and Technology Aerospace Science and Technology 96 (2020) 105532, https://doi.org/10.1016/j.ast.2019.105532
  Open Access: https://repository.tudelft.nl/islandora/object/uuid%3A5562b95c-42bd-476c-9956-2b8d87c7fa26?collection=research
- Gstrein, F., A Parametric Study on the Application of Finlets for Trailing Edge Noise Reduction of a Flat Plate, 26th AIAA/CEAS Aeroacoustics Conference (part of AVIATION 2020), 15.-19.06.2020, Reno/USA
  Open Access: https://research-information.bris.ac.uk/en/publications/a-parametric-study-on-the-application-of-finlets-for-trailing-edg
- Gstrein, F., Application of Finlets for Trailing Edge Noise Reduction of a NACA 0012, 26th AIAA/CEAS Aeroacoustics Conference (part of AVIATION 2020), 15.-19.06.2020, Reno/USA
  Open Access: https://research-information.bris.ac.uk/en/publications/application-of-finlets-for-trailing-edge-noise-reduction-of-a-nac
- Kopiev, V., Assessment of Shielding Effect Effiency for BWB with UHBR, Aerospace Europe Conference AEC2020 (25-28 February 2020, Bordeaux)
- Bernicke, P., Hybrid Overset-LES Simulations of Noise Reduction Concepts of Loaded Airfoils, ISROMAC 18, Honolulu, initial venue: 19.-23.04.2020, Hawai, USA shifted to online venue 23.-26.11.2020

3 papers have been submitted for the 27th AIAA Aeroacosutics Conference 2021 and 3 further submission are currently under review for journal publication.

Online resources

The **ARTEM website** is accessible at: www.dlr.de/ARTEM

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

4. The ARTEM Consortium

Advanced Engineering Design Solutions SARL (AEDS)

Airbus Operations SAS (Airbus)

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)

Swiss Federal Laboratories for Material Science and Technology (EMPA)

National Institute for Aerospace Research Elie Carafoli (INCAS)

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

Office National D'Etudes et de Recherches Aerospatiales (ONERA), French Aerospace Lab

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)

Cergy Paris Université (UCP)

Universita' Degli Studi Roma Tre (URoma3)

The von Karman Institute for Fluid Dynamics (VKI)

5. Contact for further information

The project is coordinated by the German Aerospace Center (DLR), Dept. Engine Acoustics.

Inquiries should be directed to

Dr.-Ing. Karsten Knobloch
German Aerospace Center (DLR)
Institute of Propulsion Technology | Engine Acoustics
Mueller-Breslau-Str. 8 | 10623 Berlin | Germany

Mail to: artem@dlr.de

Project supervision at the European Commission:

Innovation and Networks Executive Agency (INEA)
Chaussée de Wavre 910
W910 03/60
B-1049 Brussels, Belgium

6. Acknowledgements

This project has received funding from the European Union‘s Horizon 2020 research and innovation programme under grant No 769 350.

ARTEM and other projects within the MG1-2-2017 call “Reducing Aviation Noise” were initiated by the EREA “Future Sky” initiative.