"Aircraft Noise Reduction Technologies and Related Environmental Impact"

ARTEM

Project Overview and

Achievements at Month 12

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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.

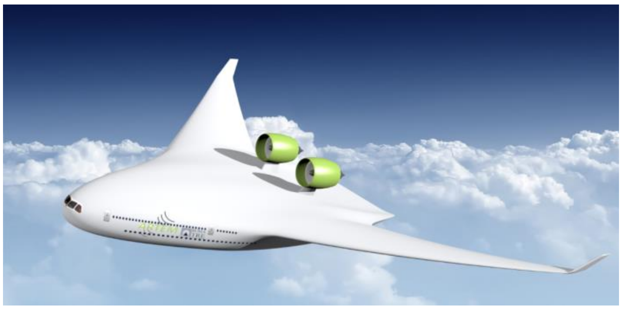



Figure 1: Left: ***A possible candidate for 2035 air transport: ONERAs NOVA concept with semi-buried engine (© ONERA, 2015). Right: Initial layout of a blended wing body anticipated for 2050 operation, equipped with generic UHBR engines mounted on pylons on the top of the centerbody (© University RomaTre,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

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 Europe (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 during the first year

Get it rolling

The project officially started on 01.12.2017. A kick-off event for all partners was organized on the 7th and 8th of December 2017 in Berlin, which provided information about partner's specific skills and knowledge, enabled a mutual exchange about project objectives and tasks, and supported the development of a team spirit right from the beginning of the project.

During the first months, an extensive exchange took place defining in detail the specifications for technology assessment and the data sets which will be generated during technology development. Subsequently, the generated data sets are required by other partners for the assessment of the technologies benefits when implemented in the novel aircraft configurations.
The results of these activities are documented in two reports "Specifications" (ARTEM deliverable 4.3) and the "Data Management Plan (DMP)" (ARTEM deliverable D4.4).

Determination of aircraft design parameters and airframe aerodynamic characteristics required for noise assessment

Within ARTEM, the development of noise reduction technologies shall be assessed with respect to aircraft configurations which are anticipated for the future with an entry-into-service by 2035 and 2050, respectively. These will have different configurations in order to reduce fuel-burn and emissions, and provide low-noise air transport.

In order to make best use of available resources and to be coherent with other on-going European Research efforts, the NOVA (NextGen ONERA Versatile Aircraft) was chosen as a possible candidate for 2035 scenario. Four configurations, mainly differentiated by their engine integration, have been designed by ONERA, from which two are considered in detail in ARTEM:

- the "baseline" configuration, with conventional under wing nacelles,
- the "BLI" (boundary layer ingestion) configuration, with lateral semi-buried turbofans on the aft fuselage. BLI technology is expected to provide efficiency benefits, but noise signature will be affected due to inflow distortion and engine interactions effects with the fuselage

These configurations are illustrated in Figure 2 , and details regarding their development may be found in [1] and [2].

Figure 2: NOVA configurations (©ONERA, 2015)

The “baseline” serves as a rather classical “tube and wing” reference, and the BLI, as an innovative aircraft considered for a mid-term time-frame of 2035 entry-into-service.

The geometry of the airframe and additional data was provided by ONERA to involved partners. Since not all configuration data could be shared with ARTEM project partners due to ongoing ONERA research activities and respective intellectual property rights, the NASA Source Diagnostic Test (SDT) engine was chosen for the respective configurations by TU Delft being responsible for the numerical assessment of the associated noise signature of the BLI configuration.

The SDT nacelle intake length has been increased to match the original NOVA intake and fan axial locations, and the whole engine has been scaled up to fit with the NOVA nacelle diameter. It has then been integrated on the NOVA fuselage to create the BLI configuration (Figure 3). In order to avoid strong blade and duct flow separation in the BLI case, four S-ducts geometry have been designed.

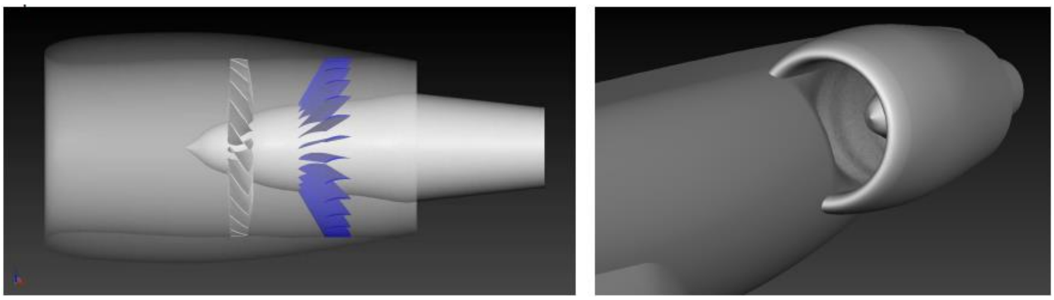


Figure 3: SDT low-noise fan stage with modified nacelle (left) and nacelle integration on NOVA fuselage with an s-duct (right) (© TU Delft, 2018)

Both isolated NASA/SDT with modified nacelle and BLI configurations have been simulated by PowerFLOW®. Aerodynamic and aeroacoustic analyses have been done, showing very different behaviour between both cases, and in particular an important cut-off effect in the S-duct that makes the BLI engine quieter than the isolated one in the front direction, while wave scattering at the nozzle makes it noisier in the rearward direction (Figure 4). Analyses are still on-going.

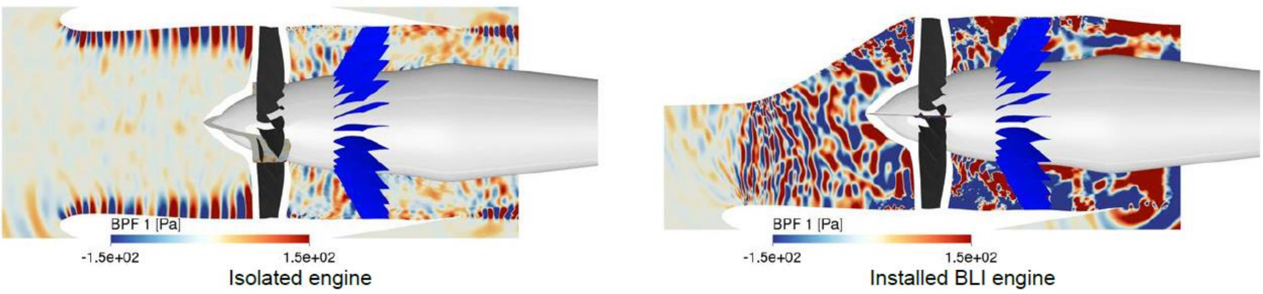


Figure 4: Band-pass filtered pressure around BPF from numerical simulations (© TU Delft, 2018)

Configuration analysis for 2050 candidates BOLT and REBEL

Two other aircraft configurations will be considered for the assessment of low-noise technologies in ARTEM for the 2050 time-frame. BOLT – a Blended wing body with Optimized Low-noise Technologies - is considered the best candidate, within skyline 2050, for long range commercial routes using conventional UHBR engines (BPR>16). The conceptual optimization is based on a

typical long haul mission profile, including the estimate of the noise emission using low and mid-accuracy noise models. The optimization will take into account the expected effect at aircraft level of those LNT for which noise reduction estimates are available. The analysis will include the influence of the uncertainties on the noise reduction actually achievable through the technological development of the LNT from the proof-of-concept to the production level, in order to guarantee the robustness of the design in the 2050 horizon.
In parallel, a design of a REBEL – a REgional Blended-wing-body ELectric-propelled – is considered as disruptive air concept, devoted to medium range commercial routes. In particular, the analysis of this new concept will take into account several parameters as: the hybrid-partially electric propulsion system, the size and the number of the propellers needed and the related distribution along the aircraft (REBEL-HEP). This kind of vehicle represents a different version of the "classical" Blended-Wing-Body (BWB) due the specific properties of the propulsion system. The baseline configurations equipped with conventional technologies and engines (REBEL-C) will be firstly analysed in terms of performance and noise based on low order models.

REBEL should carry 100 passengers on a range of 900 nm, the BOLT is a long haul concept sized for a 400 passengers payload.

		BOLT	**REBEL**
Range	*nmi*	5500	900
Payload	*#pax*	400	100
Cruise altitude	*ft*	43000	25000
Cruise Mach number	-	0,84	0,50

The initial analysis was performed by UROMA3 using the in-house tool FRIDA (Framework for Innovative Design in Aeronautics), capable of multi-objective, multidisciplinary optimization of design and operations of innovative concepts under environmental constraints.

In order to account also for hybrid electric propulsion of REBEL (REBEL-HEP), a preliminary weight estimation procedure has been implemented in the tool, which accounts for conventional and hybrid propulsion systems. Secondly, the weights breakdown module has been adapted to enhance the estimation of the landing gear system and electrical components. The drag module has been modified to consider multi-patches geometry, as for the Blended-Wing-Body designed by three main patches. Finally, optimization objectives and constraints have been formulated based on the relevant variables.

Within 2018, the configuration definition and optimization of BOLT and REBEL has been achieved. Starting from the mission requirements, the preliminary weight estimation has been carried out in addition to the inner layout definition and the isolated wing structural analysis. The aerodynamic assessment has been performed using the zero-th order boundary element solution of the integral equation for quasi-potential flows. For all the configurations, the performance analysis ensured the flight correct properties in terms of attitudes for each mission phase, ground distances, as well as stall speeds.
Optimisation problems have been performed in order to obtain optimised layouts for BOLT, REBEL-C and REBEL-HEP: objectives are related to aircraft performances (glide ratio and weight), whereas the constraints pertain both geometrical characteristics and aerodynamics.
It has been noted that a unique compromise solution for both REBEL configuration could be picked, as the approximated Pareto frontiers, in the design space, turn out to be close to each other.

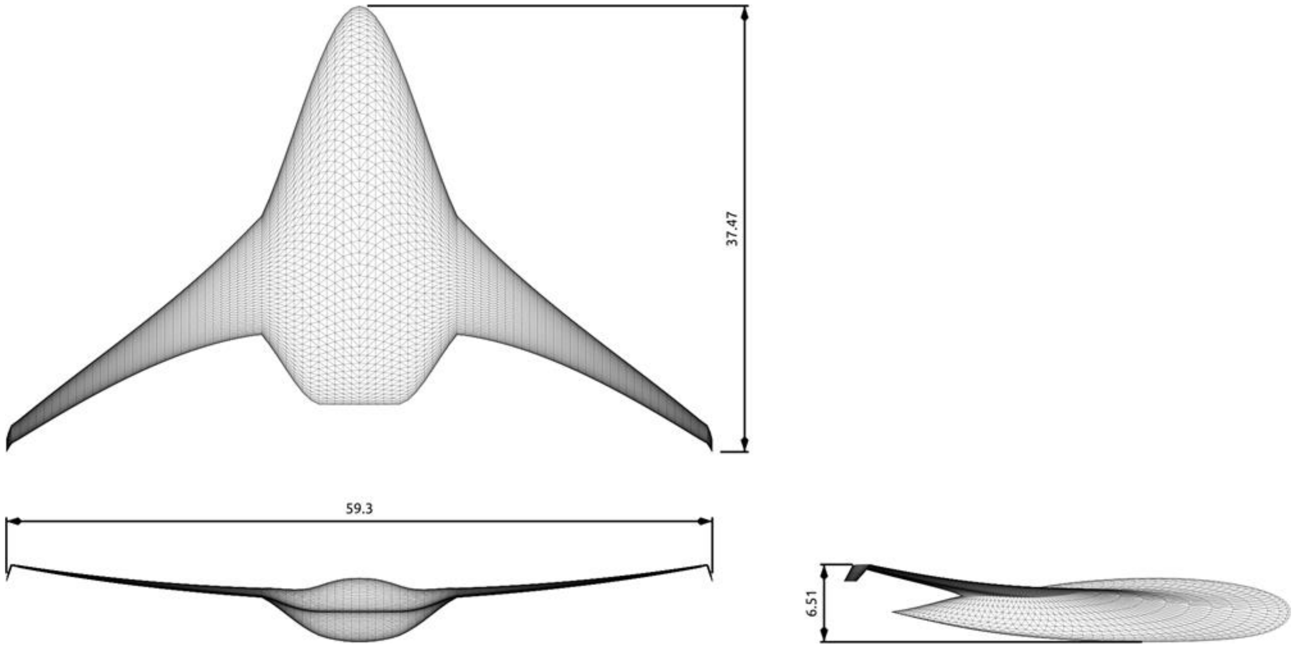


Figure 5: BOLT - optimized layout and main performance characteristics (©UNIROMA3, 2018)

Stall speed	**Take-off**	*m/s*	73,1
	Mid-cruise	*m/s*	152,3
	Landing	*m/s*	55,8
Average cruise efficiency		-	21,8
Mid-cruise wing load		*kg/m²*	306
Mid-cruise thrust to weight ratio			0,046

Design of experiments, setup of simulations, definition of configurations

In the other work packages concerned with individual noise reduction technologies, several activities have taken place defining configurations and geometries that will be considered. Test rigs and numerical simulations have been set-up.

WP1 activities include (limited selection):

- Improvement of liner test facility of NLR, including high SPL low frequency sound source
- Construction, manufacturing and initial test of wind-tunnel extension for novel liner concept at DLR (see Figure 6)
- Preparation of preliminary experiments for future liner concepts (COMOTI, CNRS/LAUM)
- Preparation of test facility (CNRS/LAUM)
- Assessment of meta-material surface properties for aero-acoustic application, specifically for change of reflection directivity for aero-engine inlets (CIRA/UNIROMA3)
- Model experiments on jet noise shielding (TSAGI)

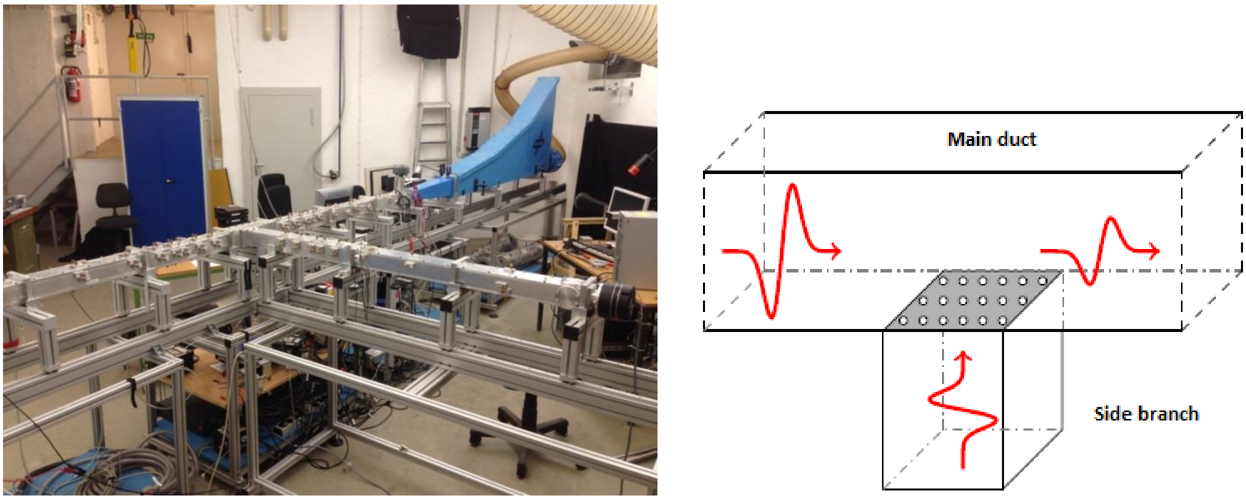
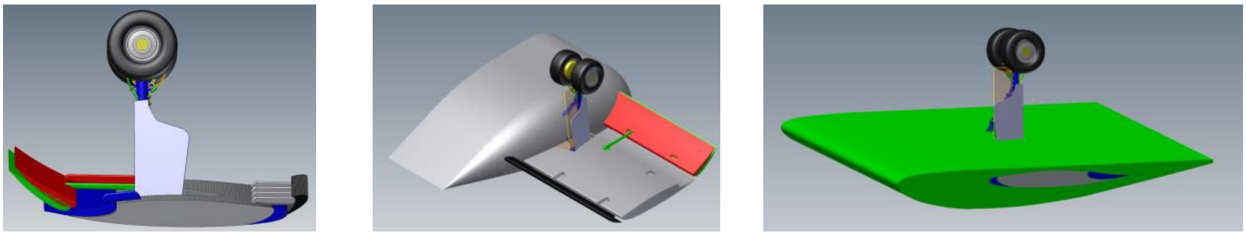


Figure 6: Photography of the acoustic test rig and schematic description of measurement setup at DLR

WP2 activities include (limited selection):

- Setup of wind-tunnel test incl. model preparation for aero-acoustic measurements on flat plates with and without surface treatments (U Bristol)
- Numerical simulations of LEISA2 high-lift-device setup (DLR, ONERA)
- Numerical (DLR) and experimental work (TSAGI) on installation effects of jet noise
- Definition of landing gear (LG) configuration to be considered for model testing, numerical simulations and low-noise optimization (DLR, Airbus, U Southampton), see Figure 7
- Definition of the setup for wind-tunnel experiments on clocking and other interaction effects of several model propellers (VKI, Pipistrel, INCAS)



Classical high-lift wing	Closed-coupling with belly fairing	Blended wing body

Figure 7: Sketches of wind tunnel models for landing-gear installation noise

Activities listed here only in short bullet points will be introduced in more depth in future issues of the projects publishable summaries.

3. Dissemination activities

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 ocassions:

- 7th EASN International Conference on Innovation in European Aeronautics Research (26.-28.09.2017)
- Aerospace Europe CEAS 2017 Conference, Bucharest/Romania (16.-20.10.2017)
- ”EU Aviation Research Policy on Noise” workshop (16.01.2018)
- Full Network-Meeting of “European Aviation Noise Research Network” supported by ANIMA global coordination task, Amsterdam/The Netherlands, 5.09.2018

Scientific publications:

- Pieren, R., Bertsch, L., Blinstrub, J., Schäffer,B., & Wunderli, J.M. (2018). Simulation process for perception-based noise optimization of conventional and novel aircraft concepts. In *2018 AIAA Aerospace Sciences Meeting* (p. 0266).
- 22nd CEAS work shop ``Future Aircraft Design and Noise Impact'', Amsterdam/The Netherlands 6.-7.09.2018 (only ARTEM related presentations):
  - Keynote presentation by L. Bertsch (DLR) – 10 years of joint research at DLR and TU Braunschweig toward low-noise aircraft design – what did we achieve
  - U. Iemma (UniRomaTre) – Metamodels based on deterministic and stochastic radial basis functions for engine noise shielding of innovative aircraft
  - G. Romani (TU Delft) – Simulation of Boundary Layer Ingestion Fan Noise for NOVA Aircraft Configuration
  - L. Rego (TU Delft) – Lattice-Boltzmann Computations of Jet-Installation Noise
- Centracchio, F., Rossetti, M. and Iemma, U., “Approach to the Weight Estimation in the Conceptual Design of Hybrid-Electric-Powered Unconventional Regional Aircraft” Hindawi, Journal of Advanced Transportation, Volume 2018, Article ID 6320197, https://doi.org/10.1155/2018/6320197

Further publications are in preparation and have been submitted for review to 25th AIAA/CEAS Aeroacoustics Conference (Aeroacoustics 2019) to be held in May 2019 in Delft/The Netherlands and national events (e.g. DAGA 2019 - Jahrestagung für Akustik in Rostock/Germany)

Other publications:

- The project and its objectives were introduced in “Aircraft noise: an emerging environmental issue”, PLATINUM magazine, New business media, Milano/Italy, issue 31, July 2018

4. Online ressources

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

- 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

5. Contact for further information

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

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

7. Further References

[1] Wiart L., Atinault O., Paluch B., Hue D., Grenon R., Development of NOVA Aircraft Configurations for Large Engine Integration Studies, AIAA Aviation, June 2015, Dallas, TX, AIAA 2015-2254

[2] Wiart L., Atinault O., Boniface J.C., Barrier R., Aeropropulsive Performance Analysis of the NOVA Configurations, ICAS, September 2016, Daejeon, Korea