Periodic Reporting for period 2 - CONCERTO (Computation of cOmpouNd rotorCraft latEral RoTor nOise)

**Reporting period:** 2019-09-01 to 2021-09-30

**Summary of the context and overall objectives of the project**

In the framework of the European Clean Sky 2 (CS2) project, the Fast Rotorcraft Platform aims at demonstrating that compound rotorcrafts implementing cutting-edge technologies open up to new mobility roles that neither conventional helicopters nor fixed wing aircraft can currently cover in a
sustainable way. One of the resulting rotorcraft proposed by Airbus Helicopters (AH) and named RACER, will take advantage of two lateral rotors placed under the main rotor with wings. This configuration brings several benefits (high cruise speed, low fuel consumption...). However, the noise issue remains a major challenge and is one of the most important factors to be considered to ensure that this rotorcraft can be used in urbanized areas to address new mobility roles.

Many progresses were made during the last decades concerning the prediction and the definition of Low Noise Procedures (LNP) on classical helicopters. Nevertheless, due to the specific architecture of the RACER, lessons from past studies could not directly be applied. New LNP have to be defined and a novel approach is needed to predict the noise emitted by this rotorcraft.

The main objective of the CONCERTO project (Computation of cOmpouNd rotorCraft latEral RoTor nOise), involving ONERA and DLR, was to develop a computational tool enabling, in multiple operating conditions, the noise prediction of lateral rotors installed on the RACER demonstrator, and equip Airbus Helicopters with this necessary tool to significantly improve the noise performance of this rotorcraft.

At the end of the project, AH is now able to perform independently aeroacoustic computation of RACER lateral rotors in a large variety of conditions taking into account numerous physical effects thanks to a dedicated computational chain composed of several tools allowing fast and high fidelity simulations. The overall tool has been validated and applied to a subset of the RACER flight domain. This project went beyond the state of the art and has fully addressed user needs. A comparison of the achievements versus the topic leader requirements expressed in the Call for Partners shows that all requirements have been mostly fulfilled without any major missing items.

Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far

The main achievements obtained at the end of this reporting period corresponding to the end of the project are given here after.

A simulation platform including several codes has been set up in order to be easily handled by the user and updated with new components. This computation chain has been installed at Airbus Helicopters premises and a user support has been provided during the project. It allows aeroacoustic computations of RACER lateral rotors in a large variety of conditions taking into account numerous physical effects. Several strategies have been developed and are proposed to the user in terms of noise source computations thanks to aerodynamic simulation:

• the DLR’s Tau code (CFD) for high fidelity.
• the ONERA’s PUMA code (lifting line) for fast prediction.

With the latest, new methodologies have been implemented in order to take into account interaction effects with the wings and the main rotor (analytical model, CFD Reduced Order Models (ROM), two-step procedure with time interpolation).

Also, a demonstration of maneuver flight aeroacoustic computation has been made.

In all cases, the noise propagation in free field is done thanks to the Flowcs-Williams and Hawkings solver KIM using different kind of noise source surfaces. It can be coupled with the code SURVOL in order to efficiently achieve fly-over simulations.

Two solutions are provided to the user in order to take into account the noise scattering effect of the rotorcraft. It can be either a fast prediction method using a Kirchhoff approximation or a Boundary
Element Method (BEM).

In the absence of available experimental data, the validation process has been based on comparison with high fidelity simulations. Globally a good agreement has been obtained, although differences caused by the different modelling approaches were noticed.

Finally, the CONCERTO chain has been applied on a large number of cases, providing valuable information on the noise emission of the RACER in those conditions.

Those results have been presented to the 77th Vertical Flight Society Annual Forum in 2021. By exploiting synergies of the CONCERTO achievements, the CONCERTO chain has been used in the CS2 NACOR project, also dedicated to the RACER, in order to compute the noise signature of the rotorcraft in many conditions and configurations. It has also been used in the optimization process of the eVTOL propeller blade in the framework of an AH direct contract to ONERA. Very promising perspectives in terms of exploitation can also be highlighted since the computation chain can be easily updated. It is already planned to be used in other projects at ONERA and at AH on eVTOLs development and in projects between DLR and Airbus.

Progress beyond the state of the art and expected potential impact
(including the socio-economic impact and the wider societal implications of the project so far)

The state of art at the beginning of the CONCERTO project regarding the noise prediction of the RACER’s lateral rotors corresponds to what has been proposed in the CS2 NACOR project. The methodology proposed by ONERA, which is the basis for the activities in CONCERTO to predict lateral rotors noise, is the following:

- the aerodynamic code PUMA computes the noise source by taking into account interactions with the main rotor’s downwash and the wings’ wake using a perturbation field computed separately by a CFD code,
- using those noise sources, the direct acoustic field is computed by the KIM code,
- the acoustic field scattered by the RACER’s fuselage is obtained thanks to a BEM code.

The CONCERTO project has gone beyond this approach. First of all, the methodology is now fully integrated in a computational chain, allowing easier and faster predictions. Also, DLR has developed a Reduced Order Model (ROM) strategy to provide perturbation fields derived from CFD. Using CFD simulations for a few, carefully selected, flight conditions, the ROM provides perturbation data for PUMA for a wide range of flight conditions without additional time consuming CFD simulations. Other improvements are listed here after:

- noise predictions during a maneuver,
- inclusion of the main rotor in the PUMA simulations,
- development of analytical models to capture propeller interactions with wings and main rotor in PUMA calculations,
- fast predictions of the acoustic scattered field using simplified approaches.

Several impacts have been identified, at the environmental, industrial and societal levels by:

- mitigating the noise footprint of a compound helicopter,
- strengthening the European Competitiveness of the aeronautical industry,
- increasing the range and speed for rescue, emergency and passenger transport.

These impacts are related to the fact that this project has provided AH with the tools for designing the
best possible compound rotorcraft in terms of noise emission in a shorter period of time. This is actually the case, since AH’ engineers are now able to perform their own noise prediction using the CONCERTO chain. Another expected impact is the enhancement of research and innovation capacity. Compound helicopters, like the RACER, are an actual challenge for the aeronautical research community. The improvements achieved in the CONCERTO project will definitely help in the prediction of aerodynamics and acoustics installation effects of next generation aircraft.

Noise levels on hemispheres placed under the propeller considering several computational options of
DLR's TAU aerodynamic simulation of the a RACER's lateral rotor

Noise levels on hemispheres placed under the propeller without (direct) or with (total) installation
Airbus Helicopters RACER as presented at the Paris Air Show 2017

DLR's TAU aerodynamic simulation of the RACER in take-off condition
Near acoustic field of the RACER right lateral rotor predicted by the CONCERTO chain