PROJECT FINAL REPORT

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Project acronym: CALAS

Project title: **C**omputational **A**ero-acoustic Analysis of **L**ow-Noise **A**irframe Devices with the Aid of **S**tochastic Method

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1 Executive Summary

The CALAS (**C**omputational **A**ero-acoustic Analysis of **L**ow-Noise **A**irframe Devices with the Aid of **S**tochastic Method) project comprises analysis, evaluation and assessment of aero-acoustic performance for high-lift and main landing gear configurations of regional aircraft. The project has been carried out within the Green Regional Aircraft (GRA) ITD of Clean Sky JU. The project consortium includes two partners, FOI (Swedish Defence Research Agency) and Chalmers University of Technology. The project duration is 21 months after a 3-month extension approved by CS JU. The project work has been conducted in close collaboration with CIRA (acting topic manager), and being supported by Alenia.

An important aspect in the project work has been to carry out Computational Aero-Acoustics (CAA) analysis and assessment for airframe configurations using a stochastic method based on steady RANS (Reynolds-Averaged Navier-Stokes equations) computations using CFD (Computational Fluid Dynamics) techniques. In the project work, the same stochastic method has thus been used to formulate the turbulent-flow-generated noise source, which was then incorporated into CAA analysis to predict far-field noise level for the assessment of aero-acoustic performance.

The project has been conducted in two technical work packages (WP 2 and WP 3), besides the project management and coordination dedicated in **WP 1**, which is also responsible for the project final summary report (**Deliverable 1.1).** In **WP 2** (Analysis of flap side-edge configurations), the stochastic method based on RANS solution was first tested and demonstrated in CAA analysis of the baseline Flap Side-Edge (FSE) double-flap wing configuration for wind-tunnel (WT) and flight conditions. The result was summarized in **Deliverable 2.1**. Using the same method, CAA analysis was then conducted for a low-noise FSE wing configuration with an add-on fence in comparison with the baseline configuration for the assessment and evaluation of aero-acoustic performance. The analysis was reported in **Deliverable 2.2**. In order to provide a reference for the aero-acoustic assessment, in addition, CAA analysis was further undertaken for the baseline FSE configuration of WT scale using different acoustic analogy methods based on a turbulence-resolving simulation obtained with a hybrid RANS-LES model. This part of work has been summarized in **Deliverable 2.3**. The work in WP 2 on the flap side-edge configuration revealed that, with the fence-on flap side-edge configuration, an overall far-field noise reduction of 3-7 dB has been achieved.

In **WP 3** (Analysis of landing-gear configurations), CAA analysis was first performed using the same stochastic method to formulate the noise source based on RANS solutions for the baseline main landing gear (MLG) configuration, which was reported in **Deliverable 3.1**. With the purpose of alleviating the noise-source generation in the flow due to vortex motions or damping surface pressure fluctuations, three other different low-noise concepts were analysed in comparison with the baseline MLG configuration. These include, Configuration 2 with a fairing over the LG strut, Configuration 3 with a shallow LG bay cavity, and Configuration 4 with acoustic liner patched on the bay-cavity rear wall. A summary of acoustic analysis and assessment for all MLG configurations conducted in WP 3 was provided in **Deliverable 3.2**. The CAA analysis has shown that the acoustic liner patched on the rear wall of the LG bay has enabled a noise reduction of about 1.8 dBA, while the other proposed concepts do not show desired noise reduction, as compared to the baseline configuration.

The project had its kick-off meeting (CIRA, Naples) on 21 June 2012. The project progress has been reported at the mid-term meeting on 24 May 2013 (CIRA, Naples) and at the final meeting in Brussels on 11 March 2014. In addition, two telephone meetings were arranged (taking place, respectively, on 21 November 2012 and 22 November 2013). CALAS participated also in the Workshop of LG technology, hosted by CIRA in Naples on 19 September 2013.

2 Description of project context and objectives

Reducing aircraft noise has been, and will remain, a major challenge confronting aeronautic industries. Airframe noise (AFN) is recognized as being a significant source contributing to the overall noise radiated by modern aircraft. For efficient industrial designs of low-noise (LN) airframe configurations using computational aero-acoustics (CAA), one of the most challenging aspects is the modelling of near-field noise generation. CAA analysis of AFN radiation requires detailed information of turbulent fluctuations and their correlations. Turbulence-resolving simulation is usually able to provide more reliable modelling of noise generation, yet is also time-consuming and often unaffordable for industrial applications. In recognition of the fact that RANS modelling remains the mainstay for industrial routine use, it is desirable in CAA analysis to benefit the favourite computational efficiency of RANS simulations in modelling turbulent-flow-generated noise sources based on a relevant stochastic method. By means of CAA analysis, the work conducted in the CALAS project concerns evaluation and assessment of acoustic performance of several LN concepts applied to high-lift and main landing-gear (MLG) configurations of regional aircraft.

The CALAS project responded to the CS JTI call in 2011, SP1-JTI-CS-2011-03, within the Green Regional Aircraft (GRA) ITD of Clean Sky JU with identification JTI-CS-2011-3-GRA-02-018. The project consortium consists of two partners, FOI (Swedish Defence Research Agency) in Stockholm and Chalmers University of Technology in Gothenburg. CIRA (Italian Aerospace Research Centre, Naples) has acted as the topic manager. The project duration is 21 months.

2.1 Main objectives

The CALAS project addresses airframe noise emitted from high-lift wing section and main landing gear configurations, aiming at numerical exploration and evaluation of low-noise airframe concepts, including double-flap wing section and MLG configurations, using stochastic source modelling method for noise generation of broadband type based on steady RANS solutions. In CAA analysis, the use and relevance of the adopted methodologies will be further examined and demonstrated in the project work.

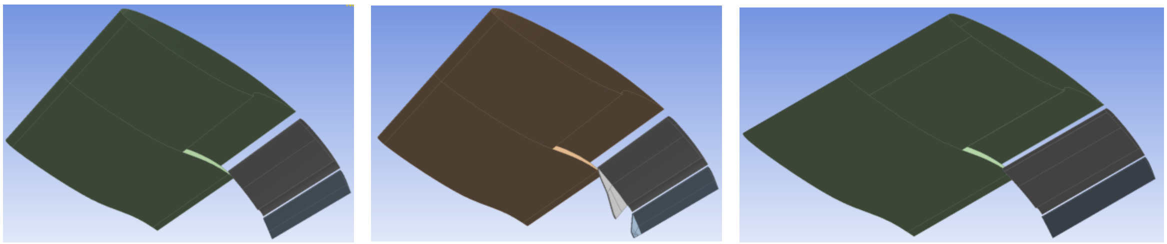
The main objectives of the CALAS project are twofold: (1) To explore and evaluate low-noise airframe concepts in comparison with the baseline airframe configuration by means of CAA analysis using RANS solutions with the aid of the SNGR method for noise-generation modelling; This will provide quantitative scales of noise reduction for industrial down-selection. (2) To explore and demonstrate the effectiveness and relevance (to industrial use) of the methodologies as employed in the project work, in particular, the stochastic noise-source modelling method.

2.2 Description of project context

The project work is divided into three work packages (WPs). A small effort was dedicated to the project coordination and management in WP 1. CAA analysis and assessment of double-flap wing-section configurations with flap side-edge have been carried out in WP 2 using a stochastic method for modelling the flow-generated noise source based on RANS solutions. In WP 3, the same methods and tools have been used for extensive CAA analysis of a variety of different main landing gear configurations of full scale, operating at flight Reynolds number. CAA evaluation and assessment have been conducted for several different low-noise concepts proposed by CIRA in discussion with CALAS and other involved GRA members.

WP 2 Flap side-edge configurations

CAA analysis and assessment of double-flap wing-section configurations with flap side-edge were carried out in WP 2 using a stochastic method for modelling the flow-generated noise source based on RANS solutions. Figure 1 shows the flap side-edge (FSE) configurations that have been explored and assessed in terms of their acoustic performance by means of CAA analysis. For the baseline FSE configuration, the analysis has been conducted for both wind-tunnel (WT) and full scales.



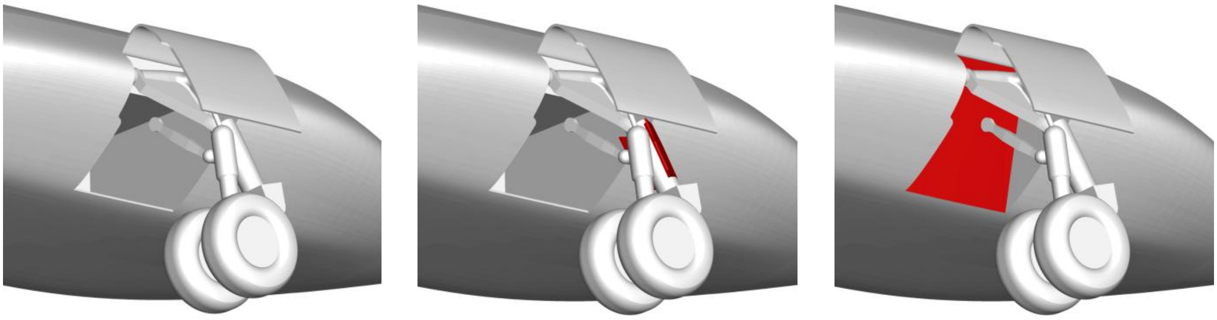
(a) (b) (c)

Figure 1: Three flap side-edge configurations. (a) Baseline configuration (full scale); (b) Fence-on configuration (full acsle); (c) Baseline-WT configuration (WT scale).

The use of the Stochastic Noise Generation and Radiation (SGNR) method was first demonstrated for the baseline FSE configuration in WP 2 using the commercial CAA package VNoise by NUMECA. Moreover, in order to set up a reference for the acoustic analysis based on the stochastic method, a more comprehensive CAA analysis was conducted using three different acoustic analogy methods, the Curle, the Kirchhoff and the FW-H method, based on a hybrid RANS-LES computation for the baseline FSE configuration. In order to explore possible effect of the integral-surface location on the acoustical analysis when using the Kirchhoff and the FW-H method, two integral surfaces were implemented (the inner one denoted SF1 and SF2 for the outer surface) and verified. The analysis indicated that both surfaces have been reasonably placed to enclose the most potent noise source for CAA analysis using the resolved instantaneous flow properties sampled on these surfaces.
Based on the hybrid RANS-LES computation for the baseline FSE configuration, it is revealed that, over the flap side-edge, intensive flow separation and vortex motions have been induced (cf. project Deliverable 2.3). This flow region has been identified as being the most potent noise-generating region. Using the acoustic analogy in CAA analysis based on this turbulence-resolving simulation, it is shown that the analysis is comparable to those obtained using the SNGR method.

WP 3 Main landing-gear configurations

In WP 3, the same methods and tools were used for extensive CAA analysis of a variety of different main landing gear configurations of full scale, operating at flight Reynolds number. With the purpose of alleviating the noise-source generation in the flow due to vortex motions or damping surface pressure fluctuations, several different low-noise concepts were proposed by CIRA in discussion with CALAS and other involved GRA members. These include, respectively, Configuration 2 with an additional fairing over the LG strut, Configuration 3 with reduced height of the LG bay cavity (shallow cavity), and Configuration 4 with acoustic liner patched on the bay-cavity rear wall. These configurations are highlighted in Figure 2 and Figure 3. The “fairing” in Configuration 2 and the “shallow cavity” in Configuration 3 are highlighted with red color. The fairing is installed in front of the strut in Configuration 2. The depth of the LG-bay cavity is reduced in Configuration 3 (shallow bay cavity). These LN concepts have been proposed by CIRA in discussion with GRA partners.



(a) (b) (c)

Figure 2: The MLG configurations. (a) Baseline configuration (Configuration 1) (b) Configuration 2 and (c) Configuration 3. The red parts indicate the low-noise setting of Configurations 2 (fairing) and 3 (bottom wall of bay cavity) compared to the baseline configuration.

Figure 3 illustrates the location of the acoustic liners for Configuration 4. This configuration invokes the acoustic liners patched on the cavity rear wall, which has the same geometry as the baseline configuration (or Configuration 1).

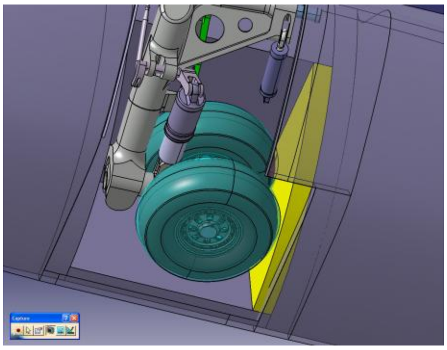


Figure 3: MLG Configuration 4 with acoustic liners (colored with yellow), placed on the rear wall of the LG bay cavity.

The proposed low-noise measures were concept-based by adding additional components or by a modification onto the baseline MLG configuration. The main objective of the work in WP 3 was to examine these low-noise concepts on their effectiveness of suppressing noise emission in comparison with the baseline MLG configuration (or Configuration 1).

In all the analysis, the bay-door of MLG is at the open position, since the door may impose noise-scattering impact. The baseline MLG configuration was first analyzed. With an identical platform in the analysis, the evaluation of the acoustic performance of the low-noise concepts has thus been carried out in comparison with the baseline configuration (Configuration 1). The four MLG configurations are further summarized in Table 1.

Table 1: Information of MLG configurations

Configurations	**Low-noise design**
Configuration 1 (Baseline)	N/A
Configuration 2	fairing over the strut
Configuration 3	shallow cavity of the LG bay
Configuration 4	acoustic liners on the bay rear wall

3 Main technical results

This part is a summary of the main technical results achieved in the CALAS project. It has thus to a large extent been an adaptation of the final deliverable D1.1 (Final summary report). More detailed description about the methods and tools invoked to conduct the project work, and the details of some results can be further referred to the project deliverables.

The Stochastic Noise Generation and Radiation (SNGR) approach has been used in the CALAS project for modelling flow-generated noise sources, using the RANS computation as the basis of the analysis. From the modelled turbulent quantities, e.g., the turbulent kinetic energy, K, and its dissipation rate, ε, or the specific dissipation rate, ω, stochastic fluctuations are approximated and incorporated consequently into the modelling of flow-generated acoustic sources. The resulting noise sources are then taken as inputs in the prediction of far-field noise levels to assess several airframe configurations selected by the GRA members with the purpose of supporting industrial design of low-noise concepts. The main technical results are briefly summarized here.

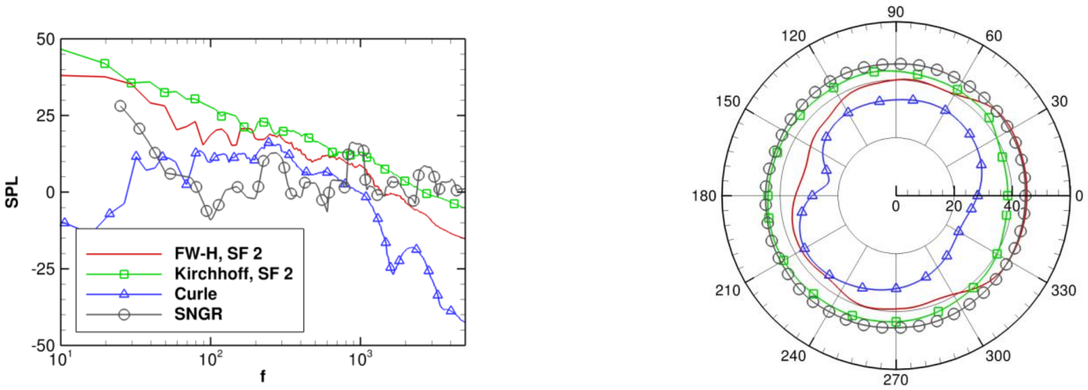
The project work has been conducted in close collaboration with CIRA, and being supported by Alenia. Except the mentioned RANS solutions for the baseline flap side-edge configurations, the RANS solutions for the airframe configurations adopted in CAA analysis of WP 2 and WP 3 have been provided by CIRA according to the work plan. It should be noted that, in the request of the GRA member and in agreement with the topic manager and project partners, the project DoW was amended in terms of the project start date and duration, as well as some planned technical work. The amendment has been approved by Clean Sky JU.

3.1 WP 2: Flap Side-Edge Configurations

CAA analysis and assessment of double-flap wing-section configurations with flap side-edge were carried out in WP 2 using a stochastic method for modelling the flow-generated noise source based on RANS solutions. The use of the Stochastic Noise Generation and Radiation (SGNR) method was first demonstrated for the baseline FSE configuration in WP 2 using the commercial CAA package Vnoise by NUMECA. Moreover, in order to set up a reference for the acoustic analysis based on the stochastic method, a more comprehensive CAA analysis was conducted using three different acoustic analogy methods, the Curle, the Kirchhoff and the FW-H method, based on a hybrid RANS-LES computation for the baseline FSE configuration. In order to explore possible effect of the integral-surface location on the acoustical analysis when using the Kirchhoff and the FW-H method, two integral surfaces were implemented (the inner one denoted SF1 and SF2 for the outer surface). The analysis indicated that both surfaces have been reasonably placed to enclose the most potent noise source for CAA analysis using the resolved instantaneous flow properties sampled on these surfaces. Finally, the analysis and assessment of the fence-on FSE configuration was carried out in comparison with the baseline FSE configuration.

Based on the hybrid RANS-LES computation for the baseline FSE configuration, it is revealed that, over the flap side-edge, intensive flow separation and vortex motions have been induced (cf. project Deliverable 2.3). This flow region has been identified as being the most potent noise-generating region. Using the acoustic analogy in CAA analysis based on this turbulence-resolving simulation, it is shown that the analysis is comparable to those obtained using the SNGR method.

In Figure 4(a), the SPLs predicted at a microphone located below the wing configuration at a distance of 120.125 m are compared due to different methods, also compared in Figure 4(b) is the OASPL. The noise level computed with the SNGR method is more comparable with the Curle method for relatively low frequencies, and with the Kirchhoff and the FW-H method at high frequencies. Moreover, the SNGR method gives a distribution of SPL showing hardly any decaying trend at large frequencies. On the other hand, the Kirchhoff method gives similar magnitudes of OASPL towards the upstream side, as compared to the SNGR method. The results are coincident between the FW-H method and the SNGR method in the downstream direction. In addition, it is noted that the OASPL obtained by the FW-H method is lower than the Kirchhoff method and the SNGR method, which have declared high noise levels at high frequencies above 1500 Hz.

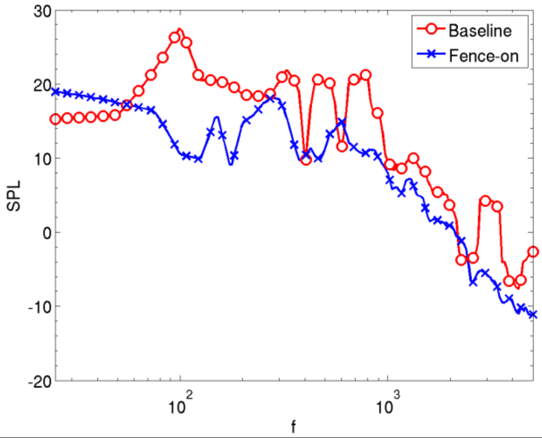


(a) (b)

Figure 4: Comparisons of CAA analyses using the SNGR method based on RANS solution and the acoustic analogies based on hybrid RANS-LES simulation, for the baseline FSE configuration of wind-tunnel (WT) scale at a distance of 120.135 m. (a) SPLs at microphone located below the wing configuration. (b) Directivity of OASPLs (flow direction aligned with $\theta = 180^o$).

In spite of the discrepancies observed in the numerical results, the RANS-based SNGR method and the acoustic analogy methods present generally consistent properties of noise source and tendency of noise spectra. The SGNR method models the noise source based on synthetic turbulent fluctuations generated with assumed energy spectra of isotropic turbulence. It is recognized that, while the SNGR method is able to give reasonable acoustic analysis of broadband noise, it cannot provide an accurate estimation of the tonal noise. However, the SNGR method has been proved effective for industrial applications aiming at assessment of acoustic performance of airframe configurations in which broadband noise is the major concern. In the CALAS project, this method has thus been adopted, as required by the GRA program. It was demonstrated that it is justifiable and effective to use the stochastic method for comparative assessment of airframe configurations based on the RANS solution with consistent computational settings.

In WP 2, the analysis and assessment have been undertaken for a low-noise FSE configuration with a fence attached on the flap side edge in comparison with the baseline FSE configuration (with no fence). As shown in Figure 5, the directivities reflected by the OASPLs are commonly similar, being of a monopole type. The noise induced by the fence-on configuration is overall lower than the baseline configuration. The difference in the OASPLs due to the two configurations is about (3-7) dB at a distance of 500m. At the near-field microphones, the disparities in OASPL vary between 6 dB and 8 dB (cf Deliverable 2.3). This suggests that the attached fence has indeed supressed the noise emission in all the directions by, particularly, alleviating the intensity of vortex motions induced by the flap side-edge. The most sensible noise reduction occurs in the downstream direction where the presence of the fence has damped significantly the intensive of the vortex motions in the trailing wake (and thus corresponding noise generation).



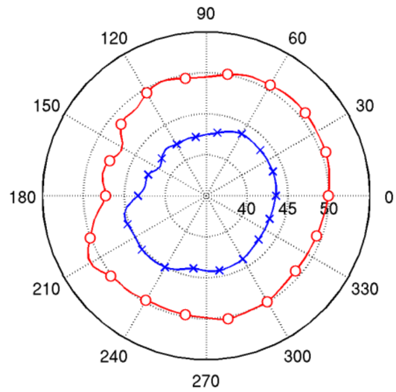
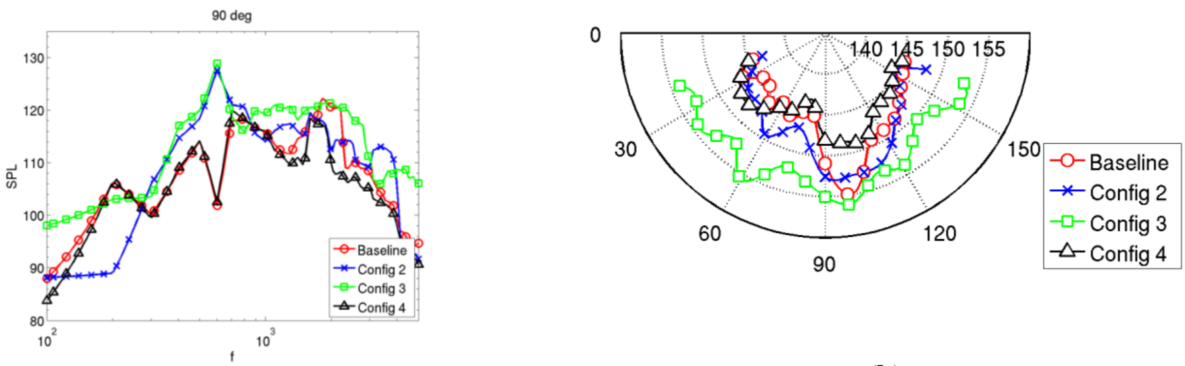


Figure 5: CAA assessment of FSE configurations of full-scale at a distance of 500 m. (a) SPLs at microphone located below the wing configuration. (b) Directivity of OASPLs (flow direction aligned with θ = 180°).

3.2 WP 3 Main Landing-Gear Configurations

In WP 3, the same methods and tools were used for extensive CAA analysis of a variety of different main landing gear configurations of full scale, operating at flight Reynolds number. With the purpose of alleviating the noise-source generation in the flow due to vortex motions or damping surface pressure fluctuations, several different low-noise concepts were proposed by CIRA in discussion with CALAS and other involved GRA members. These include, respectively, Configuration 2 with an additional fairing over the LG strut, Configuration 3 with reduced height of the LG bay cavity (shallow cavity), and Configuration 4 with acoustic liner patched on the bay-cavity rear wall. The proposed low-noise measures were concept-based by adding additional components or by a modification onto the baseline MLG configuration. The main objective of the work in WP 3 was to examine these low-noise concepts on their effectiveness of suppressing noise emission in comparison with the baseline MLG configuration (or Configuration 1). The four MLG configurations have been given in Table 1 in Section 2.2.

As a typical example, Figure 6(a) displays a comparison of the SPLs for the configurations, predicted at the microphone below the configuration. The SPL was estimated at some selected microphones between 20° and 160° at a distance of 150 ft, required by the down-selection criteria. It is shown that the proposed concept in Configuration 2 (with a fairing over the LG strut) and in Configuration 3 (with a reduced depth of the bay cavity) does not lead to any desirable noise reduction, but having even enhanced the far-field noise level. The acoustic liner patched on the bay-cavity rear wall (Configuration 4) has enabled a reduction of OASPL, however, as shown in Figure 6(b). This has been achieved by damping the SPL at high frequencies. The averaged OASPLA indicates that Configuration 4 has led to a noise reduction of 1.817 dBA, as compared with the baseline configuration.



(a) **(b)**

Figure 6: CAA assessment of MLG configurations of full-scale at a distance of 150 ft. (a) SPLs at microphone located below the MLG configuration. (b) Directivity of A-weighted OASPLs (flow direction aligned with θ = 0°).

3.3 Summary and Conclusions

In summary, the CALAS project has been successful and has given new insights and justification concerning aero-acoustic performance of high-lift and landing-gear airframe configurations with a variety of proposed low-noise concepts and, furthermore, gained experiences, as well as contributed to the data base, in CAA analysis and assessment of these airframe configurations aiming at noise reduction and using the stochastic method for flow-generated noise-source modelling.

In addition to the project management and coordination in WP 1, the project consists of two technical work packages, WP 2 and WP 3, addressing respectively the aero-acoustic performance of a double-flap wing section with flap side-edge (FSE) and of a main landing gear (MLG) configuration, as well as of conceptual low-noise measures added on these configurations aiming at noise reduction. In recognition of the fact that, for its favored computational efficiency, RANS modelling remains the mainstay in industrial aeronautic applications, the CAA analysis in evaluating the FSE and the MLG configurations has been carried out on the basis of RANS computations with the aid of a stochastic method for modelling the noise sources.

With the commercial package, VNoise, the use of the SNGR method was thus first introduced and demonstrated in CAA analysis for the baseline FSE configuration based on RANS computations. It is shown that the stochastic method is effective to model the flow-generated noise source of broadband type for predicting far-field noise radiation. The same method incorporated in the VNoise package has formed the major tool for CAA analysis in the CALAS project.

To provide a reference, an additional acoustic analysis was carried out using different acoustic analogies based on a turbulence-resolving simulation with a hybrid RANS-LES model. The analysis was conducted for the baseline-WT FSE configuration. It is shown that the flap side-edge has induced flow separation generating extensive aerodynamic fluctuations and vortex motions. The region around wing-flap junction and the flap side edge is the most significant area of generating noise. The acoustic performance of the baseline-WT configuration was then investigated using, in addition to the SNGR method, acoustic analogy methods, including the Kirchhoff, the FW-H, and the Curle method. It is shown that the Kirchhoff and FW-H methods predict higher noise levels comparing with the SNGR method in the frequency band of 40 Hz and 800 Hz. This may suggest that, for the baseline FSE configuration, the anisotropic and inhomogeneous flow dynamics in association to noise generation has happened at relatively low frequencies. In this frequency band, nonetheless, the noise level computed with the Curle method is more comparable with the SNGR method. The SPL predicted with the SNGR method hardly decays with respect to increasing frequencies, with magnitudes consistent and comparable with those obtained with acoustic analogy methods at high frequencies. The OASPL predicted using the SNGR method is comparable to the level obtained with the Kirchhoff towards the upstream side, on the downstream side with the FW-H method. It suggests that the SNGR method is able to provide a reasonable estimation for the broad-band noise, and thus for relevant assessment of airframe configuration with the major concern of broadband noise.

As compared to the CAA analysis using acoustic analogy based on a turbulence-resolving simulation, the RANS-based CAA analysis using the SNGR method is more computationally efficient and able to produce comparable trend in the SPL spectrum. The turbulent flow taken as the noise sources are synthetically constructed using the stochastic method. The SNGR method cannot thus provide an accurate estimation of the tonal noise. However, the CALAS work has demonstrated that the SNGR method is effective for predicting broadband noise in industrial applications.

The acoustic assessment for the full-scale fence-on FSE configuration was undertaken in comparison with the baseline configuration (with no add-on fence). It is found that the add-on fence attached on the flap side-edge has enabled effective reduction of noise emission at frequencies between 55 Hz and 5000 Hz. The add-on fence has led to an overall noise reduction of 5-7 dB in the far-field and up to 6-8 dB in the near-field. Furthermore, it is shown that the noise radiates with a directivity of a nearly monopole pattern. It suggests that the noise source in the wake has been represented by monopole type as a whole with synthetic turbulence based on a RANS solution, which fails to distinguish quadruple and dipole sources that would have otherwise been reflected in the directivity of noise radiation obtained with turbulence-resolving simulations. The downstream noise is more intensive than in the upstream direction, due to the noise source embedded in the trailing wake of the wing section.

In the acoustic analysis of the Main Landing Gear (MLG) configurations in WP 3, the configurations are all of full scale. The door of the bay is at the “open” position to investigate the scattering effect of the bay-door on the noise radiation and to mimic the landing or takeoff situations.

The CAA analysis of all four MLG configurations has shown that relatively high noise levels have occurred in the range of frequencies between 300Hz to 3000Hz. Moreover, for all the configurations assessed, the directivity presents in general a peak in OASPLA at a polar angle of about 100^{o} in relation to the after-LG wake with significant generation of turbulent kinetic energy (and thus intensive modelled noise sources). The noise-scattering effect of the open-door is significant, mainly at the frequencies higher than 1600 Hz at the flight condition considered. For the baseline configuration (Configuration 1), Configuration 2, Configuration 3 and Configuration 4, respectively, the RANS-based CAA analysis has predicted an averaged A-weighted OASPL (OASPLA) of 148.355 dBA, 149.239 dBA, 153.582 dBA and 146.538 dBA. This suggests that Configuration 2 (with a fairing attached in front of the LG strut) and Configuration 3 (with a shallow LG-bay cavity) are not effective to introduce noise reduction, as compared to the baseline configuration. However, the acoustic liner installed in the bay rear wall (Configuration 4) has effectively led to noise level. The averaged OASPLA with Configuration 4 is about 1.82 dBA lower than with the baseline configuration. It is further revealed that, with Configuration 4, the most efficient noise reduction presents in the downward arc from 90 to 115 degree, which is in the range of interest in industry designs. It would be interesting to further investigate the proposed concepts introduced in Configurations 2 and 3 to explore their possible impacts on suppressing noise sources of tonal type, since the noise-source modelling using the SNGR method has been based on a steady RANS solution and focusing on noise sources of broadband type.

In close collaboration among the project partners (FOI and Chalmers) and with the topic manager (CIRA), the CALAS project has been successfully completed and has achieved its objectives in line with the project work plan and with the requirement of GRA program. The project consortium has extensively analyzed and evaluated the double-flap wing-section configurations and the main landing gear configurations with a variety of proposed concepts aiming at airframe noise reduction, specified by the topic manager in collaboration with CALAS and with involved JTI GRA members. By the completion of this final summary report, along with all the submitted project deliverables, the project has reported all the technical work conducted.

4 Impact, Dissemination and Exploitation

4.1 Potential impact

The CALAS project has mainly addressed airframe noise (AFN) emitted from high-lift wing section and landing gears, aiming at a numerical exploration and evaluation of low-noise airframe concepts, including a flap side-edge wing section (of double flaps) and landing-gear configurations, using stochastic source modelling method for broadband noise generation based on steady RANS solutions. The effectiveness of methodologies used, including, in particular, the stochastic noise-source modelling method and the liner boundary condition have been well demonstrated in numerical acoustic analysis. It was shown that, with a major concern of broadband noise, the stochastic method for noise-source modelling is effective for industrial use in order to make efficient assessment of low-noise airframe concepts at the design stage on a comparative basis by referring to a baseline airframe configuration. This should impose impact on aeronautic industries to shorten the cycle of low-noise airframe designs by cost-efficient CAA analysis of aero-acoustic performance.

The project objective has been directly related to the reduction of aircraft AFN, and is therefore to the quality of future silencer regional aircraft design. The impact of CALAS should be potentially reflected in the procedure of a comparative evaluation of low-noise concepts. The evaluation of low-noise AF concepts will serve the aeronautic industry in high-lift and landing-gear designs towards effective noise reduction. More specifically, the CALAS project has shown that an attached fence on the flap side-edge is able to lead to noise reduction for a double-flap wing section, and further the use of acoustic liner patched on rear wall of the LG bay cavity may also contribute to noise reduction generated in the deployment of the MLG.

CALAS has dedicated to the general objective of the industrial development of a European green regional aircraft. The assessment and analysis offered by the project in terms of improved AF system with reduced noise emissions should facilitate industrial consideration in future aircraft design and testing of improved low-noise AF concepts and advanced CAA methods based on the analysis conducted in the project. Hence, CALAS will influence and encourage future research programs to focus more on multiple disciplines not only in the analysis of the AF performance but also in the development of new innovative concepts, as well as effective methods for industry use. CALAS may thus provide a favourable impact on the European aeronautic research and industry.

The CALAS project has had an impact within the Green Regional Aircraft (GRA) program demonstrating that a relevant stochastic method can be used at an initial design stage in the CAA assessment of low-noise AFN configurations based on cost-effective RANS solutions. The analysis of several different configurations has also revealed potential noise reduction of a reduced number of low-noise AF concepts for further evaluation. It suggests that the current baseline AF configuration is not the optimal design.

The limited success of the proposed low-noise MLG concepts in noise reduction has, on the other hand, highlighted a necessary condition for future AF system designs: the method should be able to effectively suppress turbulence generation in relation to interaction of vortices generated by different AF components.

4.2 Dissemination and exploitation of project results

Dissemination of project results

The outcome and results of CALAS has been disseminated within GRA. CALAS participated in the Clean Sky GRA ITD workshop on "Landing-Gear Technologies", organized by CIRA in Naples on 19 September 2013. A presentation was delivered with a title: "CAA evaluation of low-noise airframe concepts".

CALAS has contributed to the following two conference papers, coordinated by CIRA.

M. Barbarino , I. Dimino, A. Carozza, C. Nae, C. Stoica, V. Pricop, S.-H. Peng, P. Eliasson, O. Grundestam, L. Tysell, L. Davidson, L.-E. Eriksson, H.-D. Yao, S. Ben Khelil, F. Moens, T. Le Garrec, D.-C. Mincu, F. Simon, E. Manoha, J.-L. Godard, M. A. Averardo: *Airframe Noise Reduction Technologies applied to High-Lift Devices of Future Green Regional Aircraft*. 3AF/CEAS Greener Aviation 2014, Brussels, 12-14 March 2014.

G. Mingione, G. Rapicano, M.A. Averardo, M. Di Giulio, T. Rougier, P. Brandstaett, S.-H. Peng, L. Davidson, H. Yao and M. Mesbah: *Landing gear noise reduction technology development within JTI-GRA project*. 3AF/CEAS Greener Aviation 2014, Brussels, 12-14 March 2014.

Plan of after-project dissemination

Moreover, based on the project deliverables and further in collaboration with CIRA, after-project dissemination is planned in terms of, respectively, "*CAA evaluation of flap side-edge high-lift configurations*" (based on D2.2 and D2.3) and "*Acoustic assessment of MLG concepts towards noise reduction*" (based on D3.2).

Exploitation of project results

The analysis and assessment of MLG configurations have been used for the down-selection in the GRA program. The results and experience gained from CALAS will be further exploited in several ways by FOI and Chalmers in future research activities in the same or similar fields. These may, for example, include optimization of low-noise concepts for AFN reduction, noise control, as well as the methods in assessment of aero-acoustic performance of aircraft.

The exploration on the use of the SNGR method will be potentially exploited in future collaborative work between the CALAS partners, as well as with CIRA and Numeca. The latter is a SME and the developer of the VNoise software that has been used in CALAS.

CALAS has brought FOI, Chalmers and CIRA in close interaction and collaboration. The experience gained has stimulated new proposed project work on noise control.

Some lessons learned and experience gained through the project work that can be further exploited in future collaborative research activities, including, e.g.,

- Close interaction with related experimental partners for comprehensive synthesis of the collaborative work.
- Well-defined configurations and inputs at an early stage for effective process of follow-up investigation.

Section A

Template A1: List of all scientific publications relating to the foreground

No journal publication has been produced from the project work.

Template A2: List of all dissemination activities

Inputs have been provided to the reporting system based on the following description.

Section B

No patents, trademarks, registered designs etc. have been produced.

5 Report on societal implications

Replies to the following questions will assist the Commission to obtain statistics and indicators on societal and socio-economic issues addressed by projects. The questions are arranged in a number of key themes. As well as producing certain statistics, the replies will also help identify those projects that have shown a real engagement with wider societal issues, and thereby identify interesting approaches to these issues and best practices. The replies for individual projects will not be made public.

Inputs have been provided via reporting system