

Aircraft Noise – Aeroacoustics: ICA2016-110**Civil aircraft noise reduction: Summary of recent research and overview of forthcoming efforts to promote new research within European context****Denis Gély ^(a), Laurent Leylekian ^(b)**^(a)ONERA, France, denis.gely@onera.fr^(b) ONERA, France, laurent.leylekian@onera.fr**Abstract**

Over the last decades, the noise by civil aircraft has been mitigated by more than 20 EPNdB. This success was made possible thanks to specific research efforts which focused on reducing the aircraft noise at its source, following the guidelines of International Civil Aviation Organization (ICAO) balanced approach for meeting the international regulations on aircraft noise. On another hand, Advisory Council for Aeronautics Research in Europe (ACARE) now targets a further 50% reduction by 2020 and 65% by 2050 of the perceived noise, with respect to a year 2000 reference. The present paper first recalls some of the research efforts that were deployed within a European context over the last decade and a half. Indeed, since 2000, many Research and Development (R&D) works were performed, which first focused on technological bricks and were then progressively replaced by larger Integrated Projects or Joint Research Initiatives aiming at maturing still more the Noise Reduction Technologies (NRTs) proposed, e.g. via a technological transfer from research initiatives to demonstrator platforms. Consequently, the European Research on Aircraft noise is now organized through large programs relying on specific demonstrators. New impetus is expected from mid- and long-term initiatives, such as the EREA recently proposed FutureSky program, which aims at deriving a comprehensive R&D approach that would allow the air traffic growth to meet ICAO and ACARE constraints on perceived aircraft noise. If granted, this European project shall allow strengthening various national efforts, as well as reinforcing specific cooperation with partners from outside the E.U. (e.g. United States, Russia and Japan).

Keywords: Aircraft Noise Reduction, European Projects, Future Sky

Civil Aircraft Noise Reduction: Summary of Recent Research and Overview of Forthcoming Efforts to Promote New Research within European Context

1 Introduction

Reducing aircraft noise is a major objective of the environmental policy weighting on air transportation. Over the last 30 years, aircraft noise has been drastically reduced, thanks to a combination of technological innovations and international regulations specifically devoted to aircraft noise. Since its “Chapter 3” of 1977 the International Civil Aviation Organization (ICAO) has enacted more stringent certification limits. The current Chapter 4 (enforced since 2006) involves a stringency of 10 EPNdB. A recent increase in stringency of 7 EPNdB for Chapter 14 (17 EPNdB cumulative with respect to Chapter 3) will be enforced for all aircraft submitted to certification after December 2017. These mandatory requirements come on the top of a more comprehensive policy effort devoted to aircraft noise reduction, such as the ICAO’s so-called “balanced approach” (adopted in October 2001) which includes 4 pillars: 1/ noise reduction at source, 2/ operational procedures, 3/ land use and planning management, 4/ aircraft operation restrictions [1], [2].

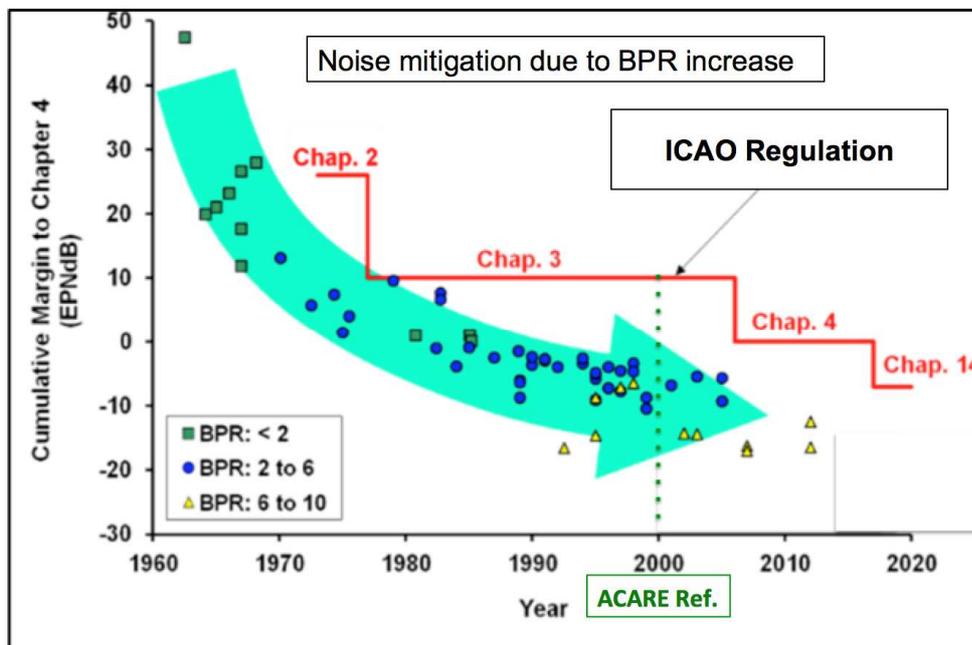


Figure 1: Evolution of the ICAO regulations for the noise emitted by large subsonic aircraft

On another hand, Europe’s vision for a quieter air transport is a further 50% reduction by 2020 and a 65% reduction by 2050 of the perceived noise by flying aircraft, relative to the year 2000 reference initially set by the Advisory Council for Aeronautics Research in Europe (ACARE) [3], [4]. These targets should be achieved by the means of more stringent noise standards for new aircraft, more efficient land use planning around airports, noise abatement procedures for a reduced noise print on the ground and operating restrictions (e.g. curfews).

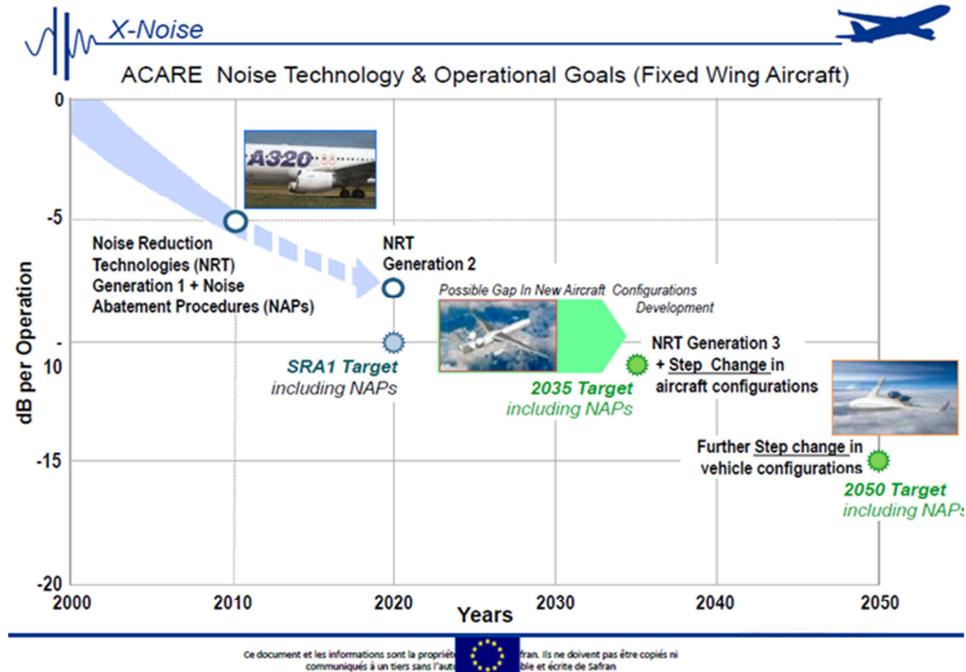


Figure 2: ACARE aircraft noise objectives

The present paper first aims at summarizing what were the research efforts deployed within a European context in terms of aircraft noise reduction. Indeed, since the eve of year 2000, many R&D works focused on “technological bricks”, thanks to the incentive of the European Commission and its R&D Framework Programmes. At this stage, it is worth noticing that these projects took direct benefit from already existing networks of experts on aircraft noise, such as the so-called “X-Noise” network at the European level [5], or its French national counterpart, the “Iroqua” board. These networks regularly hold dedicated workshops and meetings, which objectives are to enable and ease exchanges on Noise Reduction Technologies (NRTs) as well as to draft and update collaborative roadmaps focusing on “technological bricks”-oriented projects.

Although still pursued at the present date, the R&D projects devoted to technological bricks are now progressively replaced by larger collaborative efforts, such as the so-called Integrated Projects (IP) or the more recent Joint Research Initiatives (JRI). Such evolution naturally results from the need of both maturing still more the NRTs (e.g. high TRL) whereas transferring them from research stages to demonstrator platforms. This, however, paradoxically diminishes the research efforts to be devoted to

more fundamental aspects of aircraft noise, which are mandatory for better understanding the noise physics and/or addressing its issues through experimental/numerical means.

2 European Civil Aviation Noise Research Effort

Since 2000, several “technological brick”-oriented European projects (Level 1) addressed technological challenges related to aircraft noise reduction, with the view of enhancing the Technological Readiness Level (TRL) of emergent technologies, as well as to achieve a better understanding of the noise physics. For example, one can mention the COJEN, FLOCON, RECORD, TEENI or TIMPAN European projects [6], [7], [8], [9], [10], which focused on jet noise, fan noise and flow control, combustion noise, turboshaft engine exhaust noise and landing gear noise, respectively. In addition, these European research efforts were completed by various national projects, such as the French LAGOON project devoted to landing gear noise, for instance.

An assessment of these projects and of their subsequent progress was regularly made by the X-Noise network [xx], which then classified the proposed Noise Reduction Technologies (NRT) into two main classes, namely of first and second generation (NRT1 and NRT2, respectively), depending on if they might reach a TRL 6 before 2010, or between 2010 and 2020. As was said, and although still supported, these kind of NRT-oriented projects have been superseded by larger Integrated Programs (IP) and demonstration platforms (such as SILENCER, OPENAIR [11] and, more recently, CLEANSKY 1 and 2 [12]), which aim at gathering and assessing altogether the outcomes made on individual components.

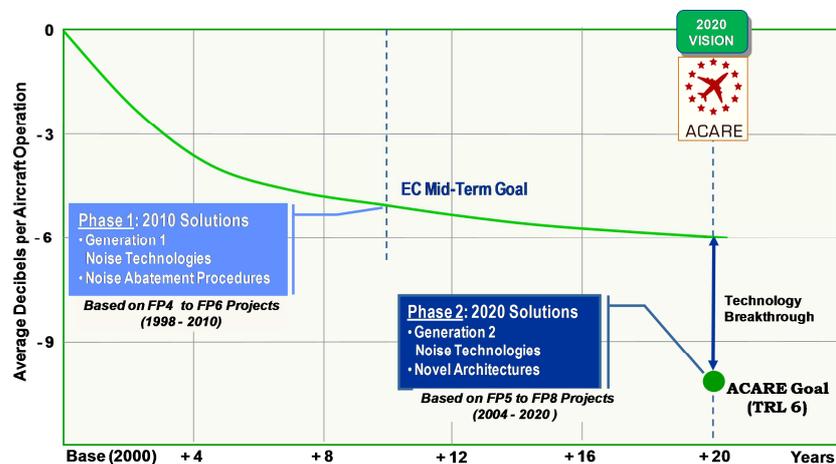


Figure 3: Expected noise reduction with NRT1, NRT2 and abatement procedures

At this point, it can be observed that a cumulative benefit of 5dB is already gained from the various NRT1. A typical 2.5 dB additional benefit can be expected from the NRT2s, provided that the associated technologies are further matured up to TRL6 through static and flight demonstrations by 2020. These expectations are based on the noise mitigation coming from classic turbofan engines and classic aircraft configurations.

Novel engine architectures, such as the so-called Counter Rotating Open Rotor (CROR), could provide a large benefit in fuel consumption. However, such CROR-based engine concepts come with higher noise issues, which led the EC commission to dedicate several European projects (e.g. NACRE, DREAM, CLEANSKY) to CROR-oriented noise reduction technologies. As a result, one may now expect that, by the 2025-2030 timeframe, the CROR-originated noise levels shall be similar to those produced by the classical turbofans currently under development.

Allotted with an overall budget of 1.6 Billion euros, the CLEANSKY1 initiative gathers a total of 86 entities which, coming from 16 different countries, are composed of major industry companies, research centers, universities and SMEs. It is made up of 6 Integrated Technology Demonstrators, 3 of them targeting more specifically noise issues, namely the Smart Fixed Wing Aircraft, the Green Regional Aircraft and the Green Rotorcraft. The subsequent CLEANSKY2 program will address still more the noise challenges coming from all categories of aircraft. As an example, efforts will focus on Ultra-High Bypass Ratio engines (UHBR) coexisting with CROR, adaptive wings, new aircraft architecture, cabin noise, and so on.

Midterm assessments of the progresses achieved so far (2010) showed that the existing NRTs alone will not be sufficient for meeting the ACARE 2020 noise goals. Actually, assessments projects such as AGAPE or OPTI clearly indicated that ACARE goals will be met only through both the enforcement of Noise Abatement Procedures (NAPs) and the development of innovative aircraft architectures. Therefore, it appears that there is a crude need for some renewed research initiatives to reach the still more ambitious objectives of ACARE 2050.

This explains why the research on aircraft noise at the European level is now organized through new prospects: short-term needs (up to 2020) are being tackled through several demonstrator programmes that are led within CLEANSKY and CLEANSKY 2 [12]. In the same time, new impetus is expected to be given on NRTs of 3rd generation and on innovative low noise aircraft architectures. In this regard, the Association of European Research Establishments in Aeronautics (EREA) recently proposed the Future Sky, a comprehensive initiative that seeks at enabling the air traffic growth in Europe. One of the Future Sky programme is the Quiet Air Transport project, which is currently set-up by ONERA with the view of shaping the long term research on aircraft noise - including perception and annoyance aspects. Such effort will be coordinated in line with the various research performed at national levels.

3 A Comprehensive Approach : Future Sky

Generally speaking, large research programs are industry-oriented and encompass far more issues than just aircraft noise. As a matter of fact, CLEANSKY aims at pushing several technologies beyond TRL 6 (i.e. beyond pure research) by proving the values of developed concepts on actual aircraft platforms. Though noise reduction is of course considered, it is not the main focus of the CLEANSKY program. Similarly, SESAR program addresses core air traffic concerns such as full integration of airport operations, trajectory management and system-wide information

management rather than noise. It is significant that, regarding environmental issues, SESAR is deprived of any noise Key Performance Indicator (KPI).

In contrast with these short-term (so-called “N+1”) programmes, the EU recently felt the need for more prospective projects, which explains why the European Commission is now calling upon renewed research within the so-called H2020, which constitutes its main research framework programme for the 2014-2020 period. In order to answer these new needs from EU aircraft research, as well as to strengthen the exchanges between aircraft noise experts, the Association of European Research Establishments in Aeronautics (EREA) recently launched an ambitious programme named Future Sky; this Future Sky initiative is a 4-pillars oriented program, each one of them addressing some specific challenges that are deemed to potentially hinder the future development of air transport in Europe. The horizon of Future Sky is rather a “N+2” one, and in terms of technologies, it typically intends to bring laboratory concepts to TRL 5. The 1st of these four pillar-associated projects focused on safety issues, and it actually started in 2015. The second project, which is devoted to noise issues and is branded Quiet Air Transport – QUIET(R), will apply to the 2017 EC call for proposals.

Like the three other Future Sky programs, QUIET(R) is being led by one of the EREA members (in the present case, ONERA), but it is widely open to third parties, whether they are aircraft leading industries, Research Centers, Universities or SME’s. The work programme of QUIET(R) is not fully defined yet, and shall be achieved by the end of 2016. However, it clearly intends to fit the EC research requirements on aircraft noise within three successive “skylines” (i.e. timescale): 2020, 2035 and 2050. These skylines were set in coherence with the corresponding ACARE targets (e.g. a minus 10 dB per operation by 2020, and 15 dB per operation by 2050 – reference: 2000).

Skyline 2020 will focus on operational research, coping with the short-terms needs expressed by the EC. On one hand, it is planned to review the existing aircraft noise regulations and associated land-use planning policies across Europe (including the associated administrative stacking), in order to deliver some EC-endorsed guidelines of good practices for authorities and airport planners. On the other hand it is also planned to provide decision-makers with handy versions of professional tools, in order to enable a higher level of effectiveness in scenario-analysis and decision-support capabilities, whilst allowing heightened proficiency for use by non-specialists. In this framework, it is also intended to develop some mobile applications for general audience with respect to two different purposes: the first objective shall be to establish a direct communication channel with communities through social media, whereas the second one shall be to associate noise records patterns with annoyance situations and social characteristics of people expressing annoyance. The last step of this work shall thus be to try refining our understanding of annoyance criteria, with a special focus put on noise-assigned annoyances due to non-acoustical factors. This task shall be performed with the help of big data analyses, and achieved through the previously developed mobile applications.

Skyline 2035 will be twofold; with respect to technology, it will focus on the so-called NRT3 (noise reduction technologies of 3rd generation) that are to be implemented on classical tube wings architectures by 2035. The objective there will be to push new NRTs up to TRL 5 within the QUIET(R) timeframe, the chosen technologies being selected by mid-2016. For more efficiency, the focus shall be put on landing scenarios rather than on take-off ones, for most of the past works were devoted to engine (especially isolated jet noise and fan noise) issues rather than to airframe noise ones. This shall allow addressing some noise sources and associated reduction technologies for which few progresses were achieved up to now (e.g. high-lift devices, installation effects). Moreover, in this Skyline, it is also scheduled to assess noise annoyance due to acoustical factors. The basic idea here is to perform hearing tests upon given scenarios, comparing baseline aircraft to improved ones. Selected scenarios could help assessing the effects of various noise patterns (such as emergence, slopes of noise increases or frequency effects due to atmospheric modulations). Resulting improvements could lead to improve some of the NRTs locally implemented on given components, as well as a more global modification of aircraft architectures (for instance, by shifting the engines position in order to take benefit of noise shielding by the airframe).

Within this skyline too, a substantial effort shall be devoted to validate numerical simulation tools. Indeed, it has been deemed that current simulation techniques and underlying methods need to be further assessed and/or improved, whether it is for increasing the fidelity level of noise predictions made on aircraft components or for allowing a more global assessment of noise signatures by full aircraft. In this last regard, it is noticeable that the current methods could be soon unable to efficiently match the capacity of the most recent High Performance Computers (HPC). QUIET(R) programme will seek at addressing this point more specifically.

Last but not least, Skyline 2050 shall address novel aircraft architectures from the noise perspective, so that the EU efforts previously made (e.g. NACRE program) are further continued. In this regard, some configurations previously proposed by Airbus, ONERA or DLR may serve as reference configurations.

Beside this technical content, it must be emphasized that QUIET(R) shall help strengthening the pan European cooperation on aircraft noise: on one hand, QUIET(R) shall allow maintaining the coordination efforts previously made through the X-Noise network. Such coordination is necessary for regularly updating the European roadmaps on aircraft noise reduction technologies and annoyances. On the other hand, as an EREA-driven program, QUIET(R) shall also help enhancing the synergies between the noise research programs led by the various European research agencies. In this regard, a dedicated roadmap specific to low TRL noise research projects might be carved out. This will complement industry views and provide the European Research Community with a comprehensive view on current developments, expectations/needs, and on gaps to fill out.

4 Conclusions

With respect to the overall problem of aircraft noise mitigation, the present paper recalled the research dynamics that was deployed within a European context over the last decade and a half. It then summarized what are the actual trends of such research dynamics, whether it is in terms of final objectives (e.g. OACI and ACARE targets of aircraft noise reduction) or means of implementation (e.g. large research programs). Finally, the latter were exemplified through a dedicated project which is currently set-up by ONERA on behalf EREA, and shall answer specific needs on the matter, if granted by the EC within its H2020 framework program.

Acknowledgments

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