OVERVIEW OF AVIATION NOISE RESEARCH EFFORT SUPPORTED BY THE EUROPEAN UNION

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Establishment of 2020 Noise Goals and Associated Research Strategy

Over the last 15 years the European Union has been implementing a consistent research strategy aimed at addressing aviation noise issues on a problem-solving basis. This priority was first identified in the 2001 report of the Group of Personalities "European Aeronautics – a Vision for 2020+", which set the following goals:

- Reduce perceived noise to one-half of current average levels.
- Eliminate noise nuisance outside airport boundaries both day and night by using quieter aircraft, improving land use planning around airports, and systematic use of noise reduction procedures.

Following-up on these goals, the first edition (2002) of the Strategic Research Agenda (SRA) issued by the Advisory Council for Aeronautics Research in Europe (ACARE) promoted the development of an appropriate strategy encompassing:

- Development of technology development strategies aimed at a new generation of noise reduction means, including the adaptation of related research infrastructures (in particular, testing and computing facilities), and utilizing potential synergies at the national level.
- Implementation of an action plan designed to take advantage of technology advances in aircraft and air traffic systems that employ environmentally friendly operational practices such as noise abatement procedures (NAPs).
- Elaboration of a development plan for impact assessment tools and instruments designed to improve airport noise planning and environmental management practices.

The proposed approach for research clearly mirrored the ICAO Balanced Approach and was further substantiated by way of a quantified target addressing the first noise objective of Vision 2020. Translated into quantitative terms, that objective is an average reduction of 10 decibels per aircraft operation (departure or landing), resulting from technology improvements (source noise reduction), as well as operational improvements (noise abatement procedures).

The two contributors identified to achieve the -10 dB reduction target were further defined in terms of associated technical and operational solutions:

- Source Noise Reduction solutions: noise reduction technologies (NRT generation 1 and 2), novel aircraft and engine /power-plant architectures.
- Noise Abatement Procedures solutions: improved operating practices with current concepts, optimized operations with new technology, and ATM-ATC integration.

A phased approach, as shown in **Figure 1**, was then developed to meet an interim 2010 target of -5 dB. This was done with the help of more readily available solutions with a higher technology readiness level (TRL), paving the way for the technology breakthroughs needed to achieve the full target in 2020.

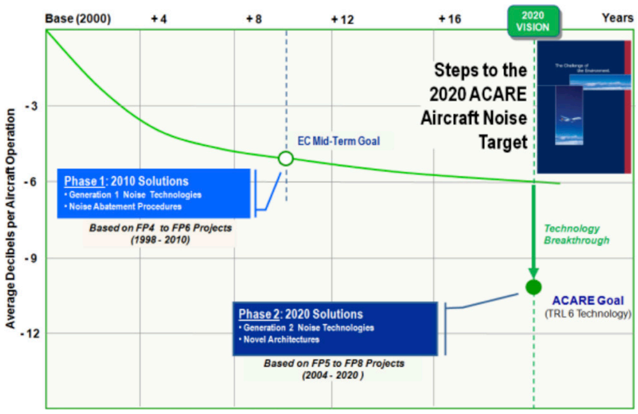

Figure 1. Steps to ACARE 2020 noise target.

A Coordinated European Aviation Noise Research Effort

The basic concept of the European Aviation Noise Research Network (X-NOISE) emerged about the same time as the ACARE SRA. Over the years, the concept of research "network" demonstrated its capacity to accommodate the evolution of the broader research context. It also helped in defining and implementing a robust research strategy with the aim to reduce the impact of noise from air transport. It established well-recognized dissemination and communication protocols and developed an active research community that covered the vast

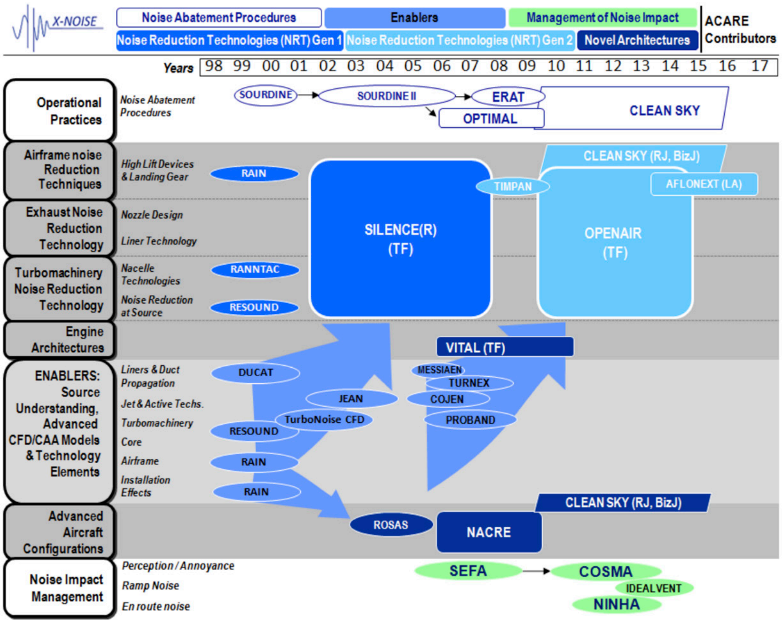

Figure 2. Roadmap of EU funded Aviation Noise Research Projects.

majority of EU Member States. Working with a common set of priorities and objectives, it led to more innovative upstream research developed at a national level, and evolving into larger European projects aimed at downstream research.

Effective strategy implementation is best depicted in the roadmap of European research projects contributing to the 2020 noise target achievement, as shown in **Figure 2**.

A key contributor to the achievement of the mid-term target was the SILENCE(R) project, funded under the EU 5th Framework Programme. Completed in 2007, the 6-year project involved a consortium of 51 partners. Research activities were carried out in various areas, such as engine source noise, nacelle technologies, and airframe source noise. More than 35 NRT Generation 1 prototypes were tested. The project involved two dedicated flight tests and a number of full-scale engine tests, and by the end, ten new technologies were validated from the noise reduction standpoint. They were considered mature enough for further work to address the design tradeoff issues that were identified during the technology evaluation process and through the industrial development work.

The initial research phase is now complete having met the mid-term objective of -5 dB per operation. In line with the described approach establishing operational improvements as an integral part of the solution, this result was achieved by combining the benefits provided by Generation 1 noise reduction technologies with those of the low noise operational procedures validated in the OPTIMAL project.

Initiating the next phase, a significant effort was dedicated to technology enablers throughout the 6th Framework Programme, This focused on advanced methods for predicting fan noise, jet noise, and nacelle liners efficiency, together with low TRL airframe noise reduction concepts. Further maturation of Generation 2 NRT solutions aimed at all significant noise sources was subsequently achieved in the 7th Framework Programme through the project OPENAIR (OPtimisation for low Environmental Noise impact).

Targeting the potential noise benefits expected from novel aircraft configurations, dedicated activity was initiated in ROSAS (Research On Silent Aircraft conceptS), then pursued in a multidisciplinary framework through NACRE (New Aircraft Concepts REsearch). In parallel, work on noise abatement procedures has progressed steadily beyond the initial validation performed in OPTIMAL, also addressing the aircraft systems aspects in CLEAN SKY, while the successive projects SEFA (Sound Engineering For Aircraft) and COSMA (Community Oriented Solutions to Minimise aircraft noise Annoyance) initiated a new approach on annoyance-related issues.

Assessment of Progress Relative to the ACARE 2020 Noise Targets

The methodology established for evaluating progress relative to the fixed-wing aircraft noise target of the SRA is primarily based on a dedicated technology evaluation process, which involves a predictive model that can roll up the benefits of individual technologies for a number of current and advanced aircraft engine configurations. This tool is being used to quantify the progress achieved relative to the ACARE targets, including operational aspects, when applied to operations at a typical airport in 2020. Initiated via the SILENCE(R) project, it has been implemented since 2001 through the string of major EU funded projects that deal with aircraft noise reduction.

Considering further steps towards the -10 dB target (NRT Generation 2, Novel Architectures), the 2015 assessment exercise benefited from the achievements of the OPENAIR project, as depicted in **Figure 3**, as well as from the interim results from CLEAN SKY in specific areas related to business jets and regional aircraft. Generation 2 noise reduction technology activity dedicated to engine noise reduction was mostly performed in the OPENAIR project and includes noise suppression techniques addressing the key sources of fan and jet noise. Through OPENAIR, CLEAN SKY and AFLONEXT, technologies are also being developed to reduce the noise of landing gears and high lift devices. While CLEAN SKY focused on solutions aimed at regional aircraft, OPENAIR and AFLONEXT investigated techniques for larger commercial models. Overall, more than 15 technologies were successfully matured to TRL 4. At last, although not yet quantified, the combined CLEAN SKY-SESAR effort on low noise abatement procedures is expected to provide further consolidation of the benefits registered at TRL 6 by 2010.

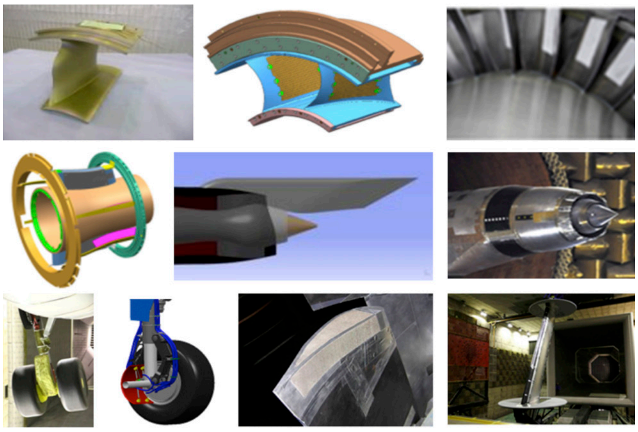

Figure 3. Scope of technologies matured in the OPENAIR project.

Relative to the ACARE noise target of -10 dB per operation, the aircraft noise research effort can be considered generally on track to meet its objective, but it will require significant support in the few years remaining before 2020. Critical actions needed for the ultimate success of the comprehensive overall approach initiated around 2000 can be summarised in the following recommendations:

1. Bring the most promising Generation 2 noise reduction technology to TRL 6, through an appropriately funded full-scale validation effort.
2. Significantly increase the effort dedicated to low noise aircraft configurations.
3. Consolidate wider implementation of low noise operational procedures.

While a significant effort was made towards the achievement of the -10 dB per operation target, a second noise objective defined by the ACARE SRA aims to ensure that benefits from technology and operational solutions effectively lead to reduced noise impacts on people outside airport boundaries, pending appropriate practices and policies are in place. Pan-European research activities have been subsequently initiated in the area related to management of noise impacts.

Supported by a well-balanced partnership, the COSMA project established a unique approach to aviation noise research, by targeting significant progress in the understanding of community noise impacts while consolidating the relationship between the technology optimization process and how the resulting aircraft sound is perceived. COSMA's scientific concept led to innovative ways of combining sound engineering and noise effects analysis to generate low noise impact design recommendations for future aircraft. Extensive field studies around European airports, combined with psychometric laboratory studies formed the basis to establish optimal aircraft noise characteristics regarding lower annoyance levels. Specific sound synthesis techniques re-created a realistic simulation of global airport operations and were then applied to the optimization of flight procedures, when associated with anticipated technology benefits.

Beyond its scientific results, COSMA also left a legacy of harmonized test protocols and innovative simulation tools for future projects to use. In the process, the Annoyance Task Group established within the X-NOISE network proposed a 6-point roadmap for future action, as follows:

1. Review of available aircraft noise annoyance studies in order to update and validate existing dose-response curves.
2. Extended scope of airport community studies.
3. Combined annoyance and sound prediction models.
4. Analysis of complaints due to aircraft noise and development of a standardized noise complaint handling system.
5. Improved dialogue between communities and airports with respect to technical aircraft noise issues.
6. Relevance of non-acoustic variables.

It was also recommended that wider international cooperation be sought in such areas, where knowledge development does not have competitive and industrial property implications.

Addressing the Longer-Term Objectives – Noise and the ACARE SRIA

In 2011, the report "Flightpath 2050 - Europe's Vision for Aviation" issued by the High Level Group on Aviation Research set a new target for 2050, stating that by then "the perceived noise emission of flying aircraft is reduced by 65% relative to the capabilities of typical new aircraft in 2000".

To address the targets set by Flightpath 2050, the 2012 ACARE Strategic Research and Innovation Agenda (SRIA)[1] was developed to cover the 2035 to 2050 timeframe. A complete set of recommendations identified solutions that were capable of reducing noise at departure and arrival by 15 dB per operation by 2050, relative to Year 2000. In addition to expected 2020 achievements, anticipated solutions would involve the development of a 3rd Generation of Noise Reduction Technologies (NRT), relying in particular on active and/or adaptive techniques to reduce the noise of engines, landing gears and high-lift devices. The emergence of novel aircraft configurations was considered an essential factor. In the shorter-term, masking effects from advanced tube and wing concepts associated with ultra-high by-pass ratio propulsion concepts should provide an anticipated 2 dB contribution to the ACARE target. In the longer-term, wider options associated with blended-wing body concepts such as embedded nacelles or distributed propulsion systems should also significantly contribute to further noise reduction.

Moreover, in order to exploit new technology and low noise operations developments, and to enable integrated impact mitigation solutions, it was considered of utmost importance to:

- Improve and continuously update the understanding of how noise from air transport operations affects people, with a significant focus on the influence of non-acoustic factors. **Figure 4** provides a rough survey of the most important non-acoustic variables for long-term annoyance and for annoyance at night.
- Provide the technical support for the successful implementation of planning policies compatible with traffic growth for the long-term benefit of the communities. This will require specific thematic research aimed at better integration of land use planning (LUP) in decision making.

Consistent with this comprehensive strategy, a number of "Enabling Factors" are foreseen as key contributors to the 2050 noise goal achievement, namely:

- Improved numerical simulation capabilities, together with test facilities incorporating advanced measurement techniques, in order to support further noise reduction at source level, and the implementation of multi-disciplinary optimization techniques and aircraft/engine integrated design practices that contribute to lower noise through efficient integration of noise reduction solutions, reduced weight, decreased drag, improved power-plant efficiency, and enhanced flight path design.
- Stimulated advances in related technology areas, such as materials and electronics, to allow the introduction of novel low noise technologies, including active/adaptive techniques.
- Updated, and internationally recognized, annoyance and sleep disturbance models, that take into account the evolution of aircraft noise signatures and traffic conditions (multiple events), and that consider airport specificities.
- Improved tools to support transparent communication policies that cover relevant indices, online forecast and tracking flight path operations, and comprehensive assessment of environmental interdependencies, and the monetization of impacts.

The ACARE SRIA confirmed the importance of addressing the impacts aspects as part of a coordinated research strategy, stating that the targeted 65% noise reduction relative to the 2000 baseline "should be achieved through a significant and balanced research programme aimed at developing novel technologies and enhanced low noise operational procedures, complemented by a coordinated effort providing industry, airports and authorities with better knowledge and impact assessment tools to ensure that the benefits are effectively perceived by the communities exposed to noise from air transport activities".

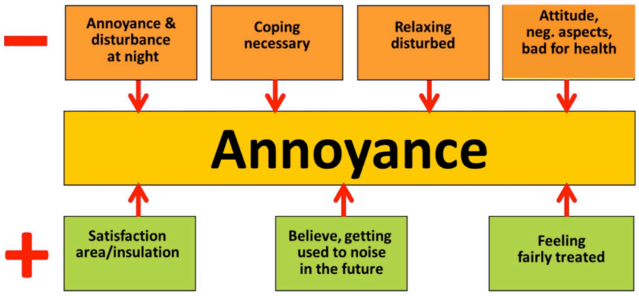

Figure 4. Overview of most important non-acoustic factors contributing to aircraft noise annoyance.

References

1. Advisory Council for Aeronautics Research in Europe (ACARE), Strategic Research and Innovation Agenda (SRIA), Available at http://www.acare4europe.com/sria