Aviation Noise Impact Management

From ANIMA

Chapter 1

Understanding the Basics of Aviation Noise
by Denis Gély and Ferenc Márki

The past

Noise from aircraft has fallen by 90% since the 1960s. This was made possible thanks efforts which focused on reducing the aircraft noise at its source.

The present

Almost 3 million people in Europe are exposed to potentially annoying levels of aircraft noise above 55 dB Lden, which is the level where significant annoyance begins, according to the EU. This chapter of the report does not refer to the World Health Organisation's 2018 study which puts the figure lower, as do some of the recent studies from the UK, such as the SoNA Study. **It means 3 million will be an underestimate.**

For comparison, 125 million people are affected by noise levels from road traffic greater than 55 dB Lden, including more than 37 million exposed to noise levels above 65 dB Lden. However, people start to get annoyed by aircraft noise at lower levels than road or rail noise. The report includes a useful chart illustrating this.

The future

In Europe, the Advisory Council for Aeronautics Research in Europe (ACARE) has targeted a further 50% reduction by 2020 and 65% by 2050 of perceived noise, with 2000 as the reference year.

'Perceived' noise is the noise we hear. It is measured using EPNdB.

- A 10 decibel reduction in noise equals a halving of perceived noise.

So, in order to reach the EU goals:

- Noise from planes would need to have fallen by 10 decibels by 2020 from the level in 2000
- And by 15% by 2050 from the 200 levels

The chapter goes on to explain the technical side of how we perceive noise.

A number of factors influence the way we perceive noise:

- The volume

- The pitch, ranging from very high-frequency to low-frequency (like the roar of an aircraft engine)

When acousticians have to measure sound events as people hear them, they apply—most of the time—so-called A-weighting. This takes into account the characteristics of the ear, and therefore makes the measuring instruments “listen” more like humans by weighting low and high frequencies. The report says ‘the A-weighted sound level has been shown to correlate extremely well with a subjective response and is therefore widely used. This is the reason why you can often see dB(A) instead of dB’.

But there is another important factor which influences the way we perceive any particular noise.

- The background noise levels

The report describes it like this: ‘An interesting effect of human hearing is called masking. This describes the scenario when a quieter sound cannot be heard in the presence of a louder one. Sound sources can be natural, such as dogs barking, birds singing, wind, rain or even human voices, etc., but can also be artificially generated like traffic noise, industrial or construction noise, machine noise from gardening, music, etc.

Many of these sounds form together a more or less steady background noise. So when a specific sound event happens, it is either low enough to vanish in the background noise or it is high enough to be heard. Our brain is used to living in a noisy world and tries to suppress background noise, i.e. make it unperceived for us (but this activity certainly causes fatigue…).

The more a sound event emerges from the background, the more it attracts our attention. When the sound is welcomed, then we are happy (a nice bird, good music, etc.). If, on the other hand, it is unpleasant, then it causes annoyance. In the long term, if we hear the same sound several times, our brain learns it, and tries to suppress it but whether it succeeds depends highly on (1) how strongly it emerges from the background, (2) how fast it becomes audible (slowly or suddenly), (3) how long it lasts and (4) whether it is constant for a while or its loudness fluctuates.

Unfortunately, aircraft noise is hard to suppress, as it often reaches a significantly louder maximum loudness than the background noise, it lasts for a too-short time to get used to it, it is not constant, but at least it is not fast increasing/decreasing its level.
The most important negative aspect of this is how high the noise level is. In acoustics, this is called the maximum sound level and is denoted by Lmax. This is different from the average sound level called Leq. The use of Leq is reasonable for more or less constant noise sources, like traffic noise’. The report goes on to say it is not ideal for aircraft noise but argues ‘there is no obviously better metric to replace it.’ It says that the Lmax (the maximum noise level) should be used alongside the average.

The EU uses an average measurement called Lden. Lden (Day Evening Night Sound Level) is the average sound level over a 24 hour period. To take into account of the fact that background levels are usually in the evening and at night, a penalty of 5 dB is added for the evening period (usually from 19:00 to 23:00) and 10 dB for the night period (usually from 23:00 to 7:00). The Lden measurement is used for noise contour mapping around airports.

Another factor influences how we hear noise.

- The direction of the noise

In everyday life, we are used to teaching our children to turn towards us, when they talk to us. The report says: 'Directivity expresses how much sound is radiated into one or the other direction. If this wouldn't make our life complicated enough, we face the fact that directivity is most of the time also frequency-dependent. This means that for example, a source radiates the lower-pitched "parts" of the sound evenly into every direction, while the higher-pitched content of the sound is radiated strongly into one direction. So we hear low- and high-tuned sound components quieter than mid-tuned ones. **This means, in practice, if a directional source is directed towards us, we definitely hear it louder than a source that is turned away from us.**

And this could happen also with aircraft noise. Noise radiated from aircraft engines is strongly directionally, specifically the direction along the axis of their engines. When the aircraft takes off, the engines exhaust point towards the ground, causing higher sound levels there, generally, but these are also perceived to be as being even louder because of the higher mid-tone content. Additionally, when a taking-off aircraft turns, it rapidly draws a "trace" on the ground with strongly directed sound. For people living there, this means that the sound becomes louder more quickly, and it also reaches a higher maximum sound level than for people who are not affected by the directed part of the engine noise. **So let us keep in mind that the directional behaviour of engine noise also causes a measurable sound level difference at some locations, and the perceived noise is even higher'.**

However, the report says, the directional noise lasts for too short a time to be captured by average noise measurements. The report says 'annoyance cannot always be described by metrics and especially by time-average metrics'. **In order to capture both the duration and the tone of the noise of aircraft Effective Perceived Noise Level (EPNdB) is used.** 10 EPNdB re is generally the same as 10 decibel reduction in noise which is halving perceived loudness.

Chapter 2

Noise Burden in Europe
Ana Garcia Sainz Pardo and Fiona Rajé

The consequences of noise on the health of the population, as well as the policies and measures that can be adopted to minimise the problem, are a growing concern in Europe.

The chapter outlines what member states are required to do to provide information about noise exposure.

The Directive 2002/49/EC, also known as the Environmental Noise Directive (END), aims to "define a common approach intended to avoid, prevent or reduce on a prioritised basis, the harmful effects, including annoyance, due to exposure to environmental noise".

To this end, Member States must develop strategic noise maps in order to estimate the level of the population's and/or buildings' exposure to environmental noise using harmonised noise indicators Lden and Lnight. These maps and data are used to estimate the number of people annoyed and sleep-disturbed respectively throughout Europe.

The Directive requires the Member States to prepare and publish, every 5 years, the strategic noise maps (SNM) and noise management action plans (NAP) for major airports (i.e. those with more than

50.000 movements a year) and for airports (major and not-major) affecting population agglomerations with more than 100,000 inhabitants.

There have been 3 rounds of SNM thus far: 2007 (showing the noise situation in 2006), 2012 (showing 2011) and 2017 (showing 2016), and 3 NAP rounds in 2008, 2013 and 2018.

The next round (round 4) of SNM has to be delivered by the Member States in 2022, illustrating the situation in 2021. In this round, some changes are expected because of two new directives: Directive (EU) 2015/996 establishing common noise assessment methods, to provide complete and homogeneous content to Annex II of the END; and the Directive (EU) 2020/367 establishment of assessment methods for harmful effects of environmental noise.

Some countries have been late filing the data. In some cases after 15 years there is no data.

Page 17 of the report (page 31 of the pdf) has a useful chart showing how much data each country has provided.

Page 20 of the report (page 34 of the pdf) has a useful chart showing the number of people exposed to noise in the different countries.

The report points out two caveats to the figures:

- All the countries have nor provided a full set of data

- The health impacts were estimated using the number of people exposed to levels of noise starting at 55 dB Lden and 50 dB Lnight, as reported under the Environmental Noise Directive (END). The report says the numbers would have been higher if the World Health Organisation figures of 45 dB Lden and 40 dB Lnight had been used.

The report outlines the health impacts of aircraft noise:

- Annoyance
- Sleep disturbance
- Ischaemic heart disease
- Reading and oral comprehension in children -cognitive impairment
- Premature mortality

Finally, it makes the case for better, more consistent collection of data and good communication of it.

Chapter 3

Balanced Approach to Aircraft Noise Management

Oleksandr Zaporozhets

This chapter is about the Balanced Approach, set out by ICAO (the International Civil Aviation Organisation). All member states and all airports must follow the balanced approach when managing or seeking to reduce aircraft noise or exposure to it.

There are four elements to the balanced approach which are expected to be followed, in this order:

1. reduction of aircraft noise at source;
2. noise zoning, land-use planning and management;
3. noise abatement procedures for aircraft operation;
4. restrictions for aircraft operation.

The last two should be implemented on a basis of a cost–benefit analysis.

Reduction of Aircraft Noise at Source

Pages 37 – 41 (49 – 53 in the pdf) focus on why planes are noisy, how that noise can be reduced and the progress that has been made.

Land-Use Planning

'Land-use planning and management is a necessary means to ensure that the human activities nearby airports are consistent with aviation activities. Its main goal is to minimise the population, usually the residents in vicinity of the airport, affected by aircraft noise by introducing specific land-use zoning around airports'.

Pages 42- 45 (54 – 57 in the pdf) indicate how that can be done.

Aircraft Operational Measures for Noise Reduction

'Local airport rules can include noise limits, curfews and penalties on excessive noise levels. These measures are considered mostly as constraints, they may limit the operational capacity of airports (for example, by restrictions for flights during night) and they may affect the economics of air transportation by limiting the takeoff weight, payload and consequently reducing the economic benefit of specific flight. When analysing operational measures to arrive at an optimum result, it is important to involve all the stakeholders to ensure that interdependencies between the various aspects are fully identified and that any unintended consequences are avoided or minimised to the extent possible. This subchapter discusses the use of aircraft operational measures as a noise reduction method, one of the elements of ICAO's Balanced Approach. It presents a discussion of aircraft procedures for both departures and arrivals/approaches, and their potential effect on noise levels'.

Pages 46 – 50 (58 – 62 in the pdf) shows how this can be done. It includes some useful charts and diagrams.

Aircraft Operating Restrictions to Reduce Noise Exposure

The Balanced Approach sees this as a last resort.

"An operating restriction is defined in ICAO's Balanced Approach guidance [13], as "any noise-related action that limits or reduces an aircraft's access to an airport". The guidance recommends to avoid applying any operating constraints as a first measure to eliminate noise exposure, but after considering the exposure reduction to be obtained from the other three BA elements. If the total efficiency of the first three is not enough to reduce noise at any location in the vicinity of an airport, operating restrictions may be implemented, even to exclude it at all".

Pages 50 - 53 (62 – 65 in the pdf) outlines what can be done.

Chapter 5

Perspective on 25 Years of European Aircraft Noise Reduction Technology Efforts and Shift Towards Global Research Aimed at Quieter Air Transport

By Eugene Kors and Dominique Collin

This is a very long chapter - pages 57 – 116 (69 – 128 in the pdf). It details the technical work which has been done in past years to make planes quieter. It also details what different organizations have done and the objectives and targets they have set to achieve noise reduction. But is a look back. It is what has happened in the past. I have not tried to summarise it because I suspect UECNA is more interested in plans for the future.

Chapter 6

Future Aircraft and the Future of Aircraft Noise

By Karsten Knobloch, Eric Manoha, Olivier Atinault, Raphaël Barrier, Cyril Polacsek, Mathieu Lorteau, Damiano Casalino, Daniele Ragni, Gianluca Romani, Francesco Centracchio, Monica Rossetti, Ilaria Cioffi, Umberto Iemma, Vittorio Cipolla, Aldo Frediani, Robert Jaron, and Lars Enghardt

It is clear that "significant improvements in all connected disciplines are required to counterbalance the expected growth and beyond: to decrease the footprint of aviation in terms of use of resources, emissions, and noise exposure. This includes the development of novel aircraft configurations and associated technologies which are anticipated to bring significant improvements for fuel burn, gaseous and noise emissions compared to the current state and the current evolutionary development. Several research projects all over the world have been investigating specific technologies to address these goals individually, or novel—sometimes also called "disruptive" —aircraft concepts as a whole. The chapter provides a small glimpse on these activities—mainly from a point of view of recent European funded research activities like Horizon2020 projects ARTEM, PARSIFAL, and SENECA, being by no-way complete or exhaustive. The focus of this collection is on noise implications as this is one of the most complicated and least addressed topics in the assessment of aircraft configurations in an early design stage.

The selected activities are based on recent and on-going EC funded research activities. In particular, following four topics are addressed in this chapter:

- **A new propulsion concept using embedded engines** (BLI) on an otherwise nearly conventional tube-and-wing aircraft design is described, and its implications on noise, is assessed.

• **A Multidisciplinary Conceptual Robust Design Optimisation (MCRDO) framework is described** which gives a good impression of the complexity and interactions of the individual disciplines in an aircraft design process. An application of this framework for the design of two novel aircraft blended wing aircraft configurations is described as well.

• **The box-wing concept** – aiming at an improved aerodynamic performance – as explored within the recent H2020 project PARSIFAL is presented briefly and major project results are described.

• Finally, a further spotlight is shed on developments for **super-sonic civil air transport** – which is expected to resume in the near future. The latter does not imply the expectation for positive contributions of supersonic transport to the desired reduction in noise and resource consumption, but shall provide a short overview of current worldwide activities which are expected to influence the air transport sector and aircraft noise of the future.

The chapter explores each of these concepts in some detail.

It concludes:

- **Generally speaking, the research and development costs for future improvements are expected to be rather high.**

- **With current engine technology having reached a high level of maturity and complexity,** the further increase in bypass ratio will be somehow limited by detrimental effects like drag, weight, (under wing) installation space etc.

- **Geared turbofans** have made a significant contribution by reducing the rotational speed of the fan at the cost of increased weight and cost for the gear itself.

- **Future engine installations with bypass ratios** of 16 or beyond will face integration issues and interaction effects as can be seen from inflow distortion effects for the BLI concept.

- **Open rotors** instead of nacelle-mounted turbofan engines are another option for increased efficiency, but inhibit again the different noise characteristics demanding for adapted noise reduction technologies.

- **The distributed propulsion** – being driven by small turbo-prop engines or electric motors – are currently being considered at least for short-range aircraft.

- **Electric driven propulsors** are not necessarily “quiet” a priori, as the well-known fan noise sources and interactions are present as well. Moreover there are unknown effects of mutual interactions in the case of multiple propulsors.

- **For the introduction of disruptive configurations like the blended wing body**, rather drastic changes are likely being required for current airport facilities, maintenance procedures, but also for design and manufacturing routines. So far, there is a certain lack of data and therefore in reliability of all predictions with respect to performance, aerodynamics, but especially also noise emissions of these configurations.

- **All those technological improvements have to be ultimately accepted by the market**, i.e. the development and introduction are strongly dependent on regulations, and on the overall competitive advantage they may provide (where also noise reduction translates back to earned or saved money).

The other chapters are:

I haven't summarized them as the English is a lot easier to understand.