

IFAR 2025 PERSPECTIVES ON NOISE REDUCTION FOR EMERGING AND CONVENTIONAL AIR TRANSPORT

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Abstract

Aircraft noise remains a major constraint on the growth and societal acceptance of air transport, despite an overall reduction of about 75% in noise levels since the 1960s achieved mainly through successive generations of engines with increasing bypass ratio. This paper, developed from the discussions held during the 2025 IFAR (International Forum for Aviation Research) Summit, reviews technological and regulatory trends aimed at enabling “quieter aviation” for both large commercial aircraft and emerging operations such as Advanced Air Mobility (AAM) and future supersonic transport. The analysis brings together expert insights on propulsion and airframe noise-reduction technologies, advanced acoustic liner concepts, and morphing airframe concepts, alongside regulatory, operational, and economic measures designed to reduce noise immission around airports. More than forty senior researchers from twenty national research institutions across the IFAR network contributed to the discussions in Vienna in October 2025. Particular attention was devoted to the growing role of artificial intelligence (AI) in noise prediction, community response modelling, and trajectory optimization, as well as to the specific challenges associated with urban AAM noise and the acceptability of sonic booms. The paper concludes by outlining priority research needs and strategies that jointly address technological maturity, certification pathways, and the socio-political acceptance of future low-noise aviation systems.

Keywords: Aircraft noise mitigation, low noise aviation technologies, AI-based noise modelling, Noise regulation and societal acceptance, IFAR

1. Introduction

Aircraft noise at and around airports remains one of the main environmental constraints on air transport growth, despite substantial progress in engine and airframe technology over the last decades [1], [2]. Cumulative noise levels of typical commercial aircraft have been reduced by roughly 75% since the 1960s through successive generations of quieter aircraft such as A320neo-family, A350 and B787, yet International Civil Aviation Organization (ICAO) still identifies aircraft noise as the most significant cause of adverse community reaction and a key environmental issue [1], [3]. In parallel, emerging concepts such as AAM vehicles and a renewed interest in civil supersonic flight raise new questions on community noise exposure, public acceptance and regulatory responses. More than forty senior researchers from twenty national research institutions across the International Forum for Aviation Research (IFAR) network [4] contributed to the discussions in Vienna in October 2025. The following sections highlight the outcome of the expert discussion.

https://doi.org/10.71945/ica2026_0912

2. Noise Reduction Technologies for Large Aircraft

Large transport aircraft are central to the noise reduction challenge, since their operation dominates the noise footprint at major airports and they set the boundary conditions for certification standards and economic instruments. In the following, we present technology trends that address this challenge at the source. Many of such mitigation technologies and even novel aircraft concepts have been under investigation since many decades, at the large research institutions and universities. However, many of these technologies are not yet ready for application and market introduction due to a still low Technology Readiness Level (TRL) [5], [6], [7].

2.1 Propulsion and Airframe Technologies for Large Aircraft

For large commercial aircraft, future noise reductions at the source are expected from a combination of advanced propulsion architectures and low-noise vehicle designs [8]. As part of the European endeavor for silent aircraft, European project ARTEM has advanced the development of technologies for aircrafts expected to enter service between 2035 and 2050, [9]. On the propulsion side, ultra-high bypass ratio engines, open rotor concepts such as propellers and counter-rotating open rotors, as well as hybrid-electric architectures, are investigated for their potential to reduce fuel burn and noise, albeit with new challenges in terms of installation effects and wake interactions [8], [10].

Open-rotor solutions, in particular, tend to shift the noise spectrum towards lower frequencies while generating a new rotor structure interaction noise [11], which also requires dedicated mitigation strategies [12], [13]. Furthermore, the absence of ducted propulsors increases noise emission towards the ground and excludes the use of conventional noise reduction solutions through acoustic lining material. Liner technologies should adapt to this environment with new structural and installation constraints.

Airframe related measures target dominant contributors in approach and landing, notably high-lift systems and landing gear. Concerns raised about landing gear noise underline the need to develop low-noise landing gear geometries, fairings and other add-on devices, while morphing wing concepts and continuous molding surfaces aim to remove gaps and discontinuities that are strong airframe noise sources. Many of these mitigation concepts have been investigated in component experiment and even in dedicated wind tunnel [14], flight-tests of refurbished reference aircraft like DLR flight test [15], and JAXA flight test [16].

Meta-materials and advanced acoustic liners are identified as promising avenues to increase absorption efficiency in constrained nacelle volumes, enabling better attenuation of fan and core noise in future engine installations [17], [18], [19]. 3D printing and injection molding manufacturing techniques not only encourage creativity in advanced liners conception but also enable future integration of acoustic liners into aircraft. The next-generation acoustic liners should target both “low-frequency” tonal [20] and broadband components of fan and core noise while maintaining low weight, space, drag and structural integrity. Their integration into UHBR (Ultra High Bypass Ratio) and open-rotor nacelles, as well as into other parts of the airframe, will be a key determinant of the overall noise performance of future large aircraft [21].

2.2 Systemic and Implementation Aspects

Participants emphasize that noise reduction solutions must be designed from a system perspective, since improvements in one domain may negatively impact others, for example through mass, drag or efficiency penalties. It is of utmost importance to not limit an assessment to individual noise source effects but to capture the overall situation, i.e., from the noise source, the overall aircraft, to the final airport/airspace scenario. Snowball effects can be decisive and have to be accounted for, e.g., extraction of the landing gear will increase drag which typically results in higher thrust levels. Thereby, landing gear extraction will yield to increased engine noise contribution and has to be accounted for as a snowball effect. Furthermore, it can be demonstrated that no low-noise concept can be realized if noise is not a design objective from early conception stages on. Active noise control technologies are considered promising but face significant energy consumption requirements, which currently limit their feasibility for large transport aircraft. For example, liner architectures capable of adaptively modifying acoustic impedance have been considered in order to allow, in situ, adjustment of the acoustic absorption frequency range, using shape memory alloys, sliding perforated walls and

electromechanical Helmholtz resonators. But, as many of the most innovative concepts remain at low TRL, dedicated efforts are needed to mature them while maintaining a balanced view of acoustic, aerodynamic and economic performances.

3. Regulatory and Operational Measures for Reduced Immission

Beyond technology at the source, regulations and operations play a central role in limiting the noise actually experienced by communities, often referred to as immission. Noise reduction technologies as discussed in the previous section have to be assessed under consideration of regulations and operations to define their impact on a flying product.

3.1 Regulations and Operational Procedures

The development of tailored approach and departure procedures, such as steeper descents or dedicated approach paths that avoid densely populated areas, offers a way to reduce or dislocate noise exposure, provided that safety and operational constraints are respected. Closer collaboration between Air Traffic Control (ATC), aircraft manufacturers and regulators is needed to design and validate such procedures, and to revisit legacy ATC practices that may unnecessarily constrain noise optimized trajectories.

On the ground, land-use planning and building regulations in the vicinity of airports remain crucial instruments. Measures such as housing regulation around airports, and shielding strategies can significantly influence how much noise reaches people inside their homes, thereby affecting both measured exposure and perceived annoyance [22], [23]. Economic instruments, for example differentiated landing and take-off charges based on specific aircraft noise profiles, like the airport noise index developed for Zurich or Frankfurt airport [24], which are viewed as potential incentives for operators to deploy quieter aircraft and for manufacturers to integrate low-noise technologies [25].

3.2 Incentives, Barriers and OEM Decision-Making

The development and adoption of low noise technologies are constrained by high development costs, significant lead time, and the low Technology Readiness Level (TRL) of many emerging concepts.

Original Equipment Manufacturers (OEM) are primarily driven by return on investment and often face trade-offs between noise reduction and efficiency or operating cost, which can limit the prioritization of acoustically favorable but costly solutions in the absence of strong regulatory or market drivers.

Funding incentives and clear predictable regulatory frameworks are, therefore considered important to de-risk investments in low-noise technologies and accelerate their integration into future product lines. For example, assessments of the supersonic technology concept indicate that satisfying limits will require jet-noise reduction and optimized procedures [26], [27]. Some studies even include the investigations of inherent simulation uncertainties [28].

4. Role of Artificial Intelligence (AI) in Noise Prediction, Certification and Trajectory Optimization

Artificial intelligence is identified as a promising tool to complement physics-based models in aircraft noise prediction and in the analysis of community response. Beyond predicting sound levels, AI methods can help infer noise perception in society by combining acoustic data with large volumes of public feedback, complaint records and socio-demographic information, potentially enabling more targeted mitigation strategies. However, the use of AI in formal certification processes still lacks maturity due to still limited traceability, and sensitivity to training data.

4.1 AI for Prediction, Perception and Certification Support

To become credible tools in the certification process, AI approaches will require robust data collection, curation and management, as well as increased transparency, for example through physics-informed machine-learning frameworks that embed governing equations into the model structure. Acceptance by regulators, industry and the public will also be a key factor, particularly for safety-related applications where deterministic and traceable methods are currently preferred. In the near term, AI is seen as a way to accelerate preliminary noise analyses and to screen large design spaces, while high-fidelity physics-based simulations and measurements remain central for final validation.

Another promising application of AI as identified by the participants is the virtual assessment of noise impact. An AI supported system could enable the investigation of noise exposure on short-, medium, and long-term effects on virtual residents or communities. AI could support to identify more appropriate

noise descriptors to reflect the impact on humans. Standard descriptor LDEN (Level Day – Evening – Night) can only be associated with one third of the total annoyance whereas the remaining two thirds are associated with non-acoustic or unknown effects, respectively [29]. It can be expected that the correlation of acoustic effects can be improved if more appropriate noise descriptors are applied.

4.2 AI-assisted Trajectory Optimization and Operation

AI techniques can also contribute to noise reduction by optimizing flight trajectories and airport operations. Potential applications include AI-based tools that propose noise optimized trajectories to human controllers, support airport operations planning, and explore unconventional combinations of procedure parameters that might reduce noise without compromising safety. Nonetheless, human operators are still expected to retain decision authority for the foreseeable future.

Combining live aircraft data with AI can provide “noise radar” type information to the public, allowing residents to access real-time noise levels and possibly contributing feedback that can be integrated into route optimization. Such concepts would tie together technical optimization and participatory approaches, potentially improving transparency and trust in noise-management strategies.

5. Emerging Mobility Solutions: Advanced Air Mobility (AAM) and Supersonic Flights

5.1 AAM challenges and AI opportunities

In urban environments, AAM operations introduce distinct noise challenges due to proximity to people and the acoustic signatures of multi-rotor configurations. IFAR experts had identified noise as one of the prominent challenges to overcome when implementing AAM, especially in urban environments (then also called Urban Air Mobility), see also [30]. Multiple open rotors can generate high overall noise levels, and the associated distinctive sound is expected to be even more annoying than conventional helicopters with inherent very low acceptance rates among exposed communities. It can be expected that noise annoyance will become significant for any novel AAM concept due to the inherent design and operational concept [30]. AAM noise will be especially problematic due to the underlying business model, i.e., bringing AAM operation closer to populated areas or to regions that have not been exposed to aviation related noise before. The situation will be particularly worsened in otherwise quiet areas or at night. The cumulative effect of many AAM vehicles operating simultaneously is a key concern.

Design choices such as lined or rigid ducted versus open rotors, propellers with synchrophasing, flight profiles and vertiport location are therefore critical for public acceptance. AI-driven acoustic models are proposed as tools to support both design and operations, for example by combining measured noise data with complaint maps to adjust routing or scheduling, and by helping manage increasingly dense urban airspace that would be difficult for humans alone to handle. At the same time, there are notable differences in AI adoption across world regions, with some regions being more open to AI-based tools than others. there was a shared consensus that AI is not yet considered ready for safety-critical decision-making in this context.

5.2 Supersonic Flights

For future civil supersonic aircraft, sonic boom and community noise remain central obstacles to widespread adoption. From a regulatory perspective, novel certification regulations are discussed and introduced by ICAO [31] although supersonic transport is currently not a high priority in Europe, it appears more prominent in the USA, Japan and Singapore. The deployment of supersonic services raises important questions about their overall public benefit, as the gains in speed may accrue mainly to a small segment of high-income travelers while the associated noise and environmental impacts are borne by the broader population.

5.3 Socio-political Aspects of Emerging Mobility Solutions

More broadly, the socio-political impact of noise-minimizing measures for AAM and supersonic aircraft hinges on perceived fairness, safety and the distribution of benefits. Issues include who is exposed to additional noise, how flight routes and vertiport locations are chosen, and whether early use cases such as medical and emergency services can build public acceptance by demonstrating clear societal benefits. Early and continuous engagement with communities during the design and deployment of new operations is considered essential to avoid presenting a “finished product” that does not align with local expectations and values.

https://doi.org/10.71945/ica2026_0912

6. Conclusion

This paper, derived from the expert exchanges held during the IFAR Summit, has highlighted that further progress towards quieter aviation will depend on a coordinated combination of technological innovation, regulatory evolution and societal engagement rather than on isolated advances in any single domain. It can be demonstrated that the full potential of noise reduction measures can only be exploited if all aspects mentioned in sections 2 – 5 are accounted for simultaneously. Furthermore, measures have to be applied and assessed as early as possible within the design process of novel aircraft. Otherwise, the full potential cannot be exploited and will therefore yield non-optimal solutions. Focus and limitation to individual aspects might not result in any improvement. For large aircraft, promising source-noise reductions can be achieved through advanced propulsion architectures, such as ultra-high bypass ratio, and through low-noise aircraft concepts. Additional modifications to selected components on board could comprise morphing wings, optimized landing gear and next-generation acoustic liners, provided that multidisciplinary trade-offs with efficiency, mass and cost are properly managed. At the same time, regulatory and operational measures, including tailored approach and departure procedures, noise-differentiated charges, and robust land-use planning, remain essential to translate these technological gains into reduced immission experienced by communities or related noise dislocation effects.

From the IFAR experts' discussions, artificial intelligence emerges as a powerful enabler to support noise prediction, community-response modelling and trajectory optimization, but its use in certification and safety-critical applications is still constrained by questions like the lack of transparent internal logic, traceability, and data quality. In the context of advanced air mobility and prospective supersonic transport, noise management is tightly coupled with broader socio-political issues such as fairness, perceived safety, distribution of benefits and early community involvement in decisions on vertiport siting and routing. Addressing these intertwined challenges calls for closer collaboration between industry, research institutions, regulators and affected communities, as well as for integrated research programmes that jointly tackle low TRL technology maturation, simulation-based certification methods and participatory approaches to noise governance. With such holistic strategy, quieter and socially accepted airspace for both conventional and emerging aviation segments becomes a credible objective for the coming decades.

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https://doi.org/10.71945/ica2026_0912