Abstract
Challenges in Innovative Air Mobility Noise Prediction

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Innovative Air Mobility (IAM) covers a variety of applications and air vehicles. The field of IAM ranges from microdrones up to large helicopters, from unmanned to manned vehicles, and from urban to regional air mobility. The smallest vehicles perform reconnaissance missions in urban spaces, while the largest vehicles transport people within urban or regional areas. Most vehicles have in common that they feature vertical take-off and landing (VTOL) or at least short take-off and landing (STOL) capabilities. Moreover, most concepts use distributed propulsion, which is closely linked to the electrification of air mobility [1, 2].

All these types of vehicles and missions are restricted by noise emissions [3]. The propulsion and lift systems are the major contributors to the overall noise, as conventional engines are mostly replaced by electric motors, which produce significantly lower noise emissions.

Due to the variety of vehicles and missions, different kinds of propulsion systems are applied, and each propulsion system comes with its own challenges in noise prediction. As the propulsion system is often also used for VTOL operations, it not only overcomes drag during cruise conditions but also lifts the aircraft. Since the size of the vehicles differs, the type of propulsor ranges from small propellers to large helicopter rotors. The propulsors can be used for both horizontal flight and VTOL, or only for one mode of operation. They can be enclosed in ducts, shrouds, or wings, or they can be exposed. However, they all have in common that they use an electrically driven propeller or fan for thrust production.

One possible way to classify the type of thruster is through the analysis of disk loading (DL) [4, 5]. DL is defined as the ratio of thrust to the total disk area, as shown in eq. (1). The disk area (A_P) is typically the sum of all rotor or propeller disk areas that contribute to the overall thrust (T).

$$DL = \frac{T}{A_P} \tag{1}$$

The DL is a measure of hover efficiency, but it also limits the maximum cruise speed of the vehicle. In addition, the disk area can be used to assess dominant noise sources, as higher DL values typically lead to increased tonal noise components from the thrusters.

The presentation highlights the challenges of IAM noise prediction depending on the mission profile and vehicle configuration. Therefore, relationships between disk loading and noise sources are derived and presented.

Noise predictions for different DL values at a constant thrust requirement under hover conditions are presented in detail. For this purpose, a blade element momentum theory is coupled with an acoustic model to predict tonal and broadband noise emissions. The acoustic model combines Farassat's formulation 1A [6] for tonal noise and the Brooks, Pope, and Marcolini [7] (BPM) model for broadband noise. For each DL, a propeller is designed according to the minimum induced loss condition derived by Betz [8]. The models are implemented in the simulation tool PropCODE – "Propeller Comprehensive Optimisation and Design Environment" – and have been validated in Ref. [9, 10].

Finally, the paper presents the relationships between DL, achievable cruise speed, and noise emissions. These findings support the categorization of noise emissions based on vehicle configuration.

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Biography

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Completed Bachelor's and Master's degrees at FH Aachen University of Applied Sciences in 2019. From 2019 to 2025, pursued a cooperative PhD between FH Aachen and RWTH Aachen, focusing on the aeroacoustic design of propellers for Advanced Air Mobility (AAM) systems. Since June 2025, working at DLR in the field of AAM aeroacoustics.