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UAM Community Noise Impact Studies in Project PAULA

Session: Human Response to UAM Noise

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Abstract There is increasing interest in urban airspace mobility (UAM or AAM), which essentially refers to two- or four-seated, electrically driven air-taxis. Due to their expected operations, populated areas will experience this new and unfamiliar aircraft noise. Because of their novel design and operating concepts, their noise characteristics differ remarkably from those of a conventional aircraft. Therefore, aspects of noise impact on affected residents around vertiports and resulting community acceptance of air-taxis come into the focus of research. At the same time, most residents have little or no idea what air-taxi operations will look, or sound like in reality. Acceptance predictions based on acoustic metrics for single flight events, such as sound pressure levels perceived on the ground or equivalent sound pressure levels across a period of time, are speculative. This circumstance represents an uncertainty factor for developing the emerging UAM industry and must be addressed. One central part of the Bavarian State Ministry-funded project PAULA specifically addresses the question: How are air-taxi noise and scenarios across a certain number of operations at various observer points perceived and judged by the population? Laboratory studies using distributions of audio sequences of flyovers and fly-bys, synthetically made audible, can provide the answer to this question. This paper focuses on an overview of the project's methods, used in the noise impact studies.

Keywords: UAM community noise, UAM noise impact, UAM acceptance

1. INTRODUCTION

Using electric drives, urban air mobility (UAM) with its air-taxis will make a significant contribution to environmentally friendly and at the same time flexible and powerful urban aviation in the future. However, there are large gaps in knowledge regarding the perception and effects of the noise of these new types of aircraft. Due to the quiet drives, the noise emissions of air-taxis are reduced per-se, but they will remain clearly noticeable, both in the passenger cabin and on the ground, especially in the area around take-off and landing sites (vertiports) - as in the previous German nationally funded project ATEFA and Bavarian funded project LONI was shown. In addition, air-taxis may sound very unusual compared to conventional airplanes and helicopters. PAULA, the follow-on project of LONI, therefore, aims to use two sub-studies to examine in detail the effects of this novel aircraft noise on a) acoustic passenger comfort inside the aircraft and b) on the affected population residing near vertiports.

With a focus on the perception of noise, PAULA is dedicated to a central factor in the acceptance of the use and operation of air-taxis and the associated design of vertiports. The solution approaches and knowledge gained in the project are intended to accelerate the integration of air-taxis into urban and regional transport for goods and people.

Since the project started just in January 2024, this paper aims to provide a general overview over the objectives and approaches. The present paper focus on PAULA's principle approach to examine the impact related to UAM exterior noise in communities around vertiports.

2. PAULA – THE PROJECT

For a better understanding of the project, a short description of its structure and main objectives should be given first. Four full partner and one associated partner are sharing the work over the intended duration of 33 months. Figure 1 shows the project's structure which consists of 5 technical work packages.

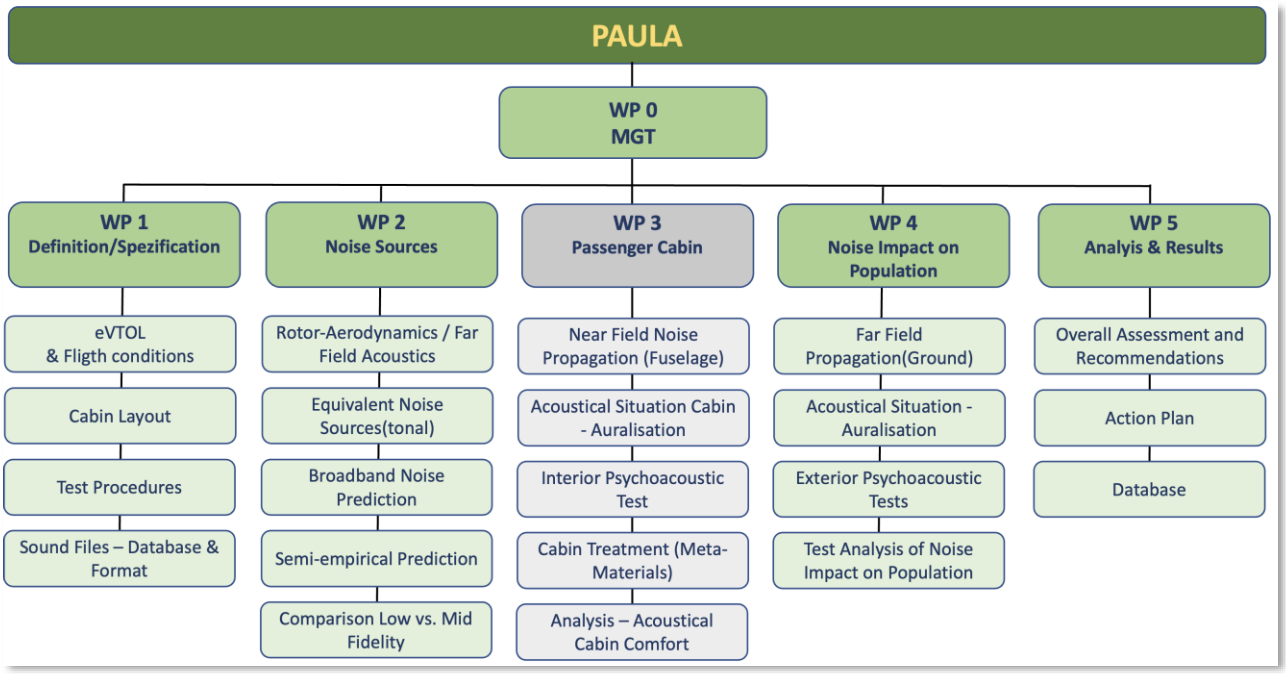

Figure 1: Project structure, embedding the noise impact research in WP4.

WP1 provides the requirements and definitions (e.g., the audio parameters), WP2 the noise sources, which are representing two different air-taxi systems under their typical operational conditions for realistic departure and approach at vertiport. The trajectories and operational parameters will be provided by the OEM partners in the project. While WP3 is focused on interior passenger comfort (not part of the present paper), WP4 is the central part of PAULA, dealing with the noise impact research, and will be described more detailed in the next sections of this paper. Finally, the assessment of all technical results will be done in WP5, as well as the establishing of an action plan, that aims to provide recommendations and guidelines for minimizing noise impact near vertiports in terms operational aspects (acceptable number and distribution of maneuvers) and criteria for land-use planning (distance to projected vertiport location from residential areas). Those guidelines could be used by government bodies and/or community administrations, but also for vertiport and air-taxi fleet operators. A publicly accessible database, which consists of selected audio files for specific flight situations will support the use of the action plan.

3. PAULA – NOISE IMPACT STUDIES FOR RESIDENTS LIVING NEAR A VERTIPORT

The principle of the activities which have to be performed before the actual noise impact studies can be started are shown in the diagram of Figure 2 and further explained in the following sections.

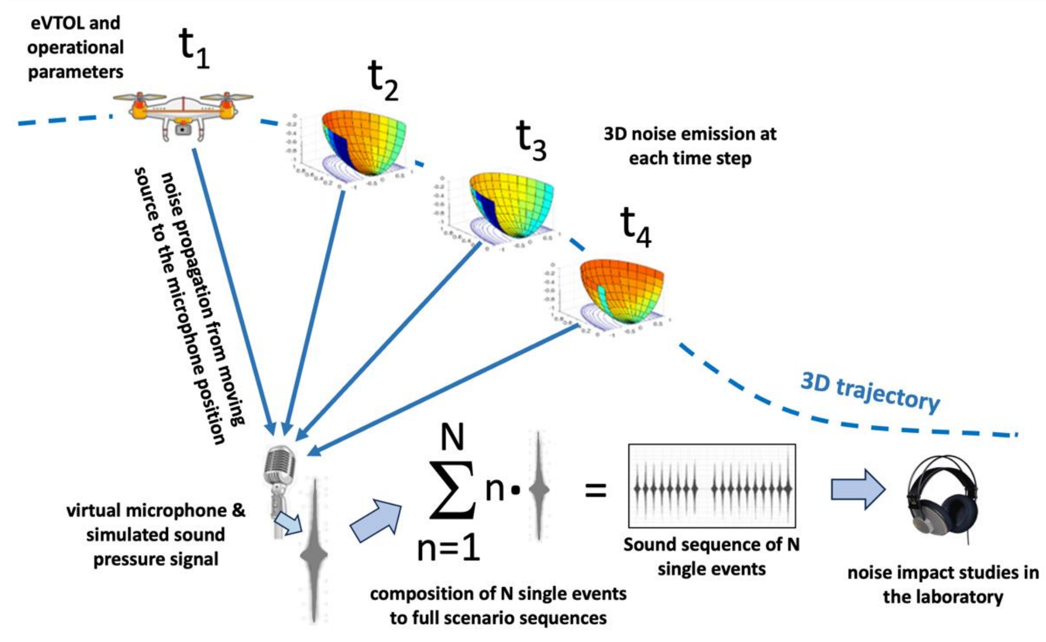

Figure 2: PAULA's principle from single noise source to audio sequences for Traffic scenarios

3.1 Air-taxi concepts and trajectories – WP1

The acoustic properties of the respective eVTOL depend largely on their technical properties and modes of operation. This also applies particularly to the audio files to be created later. The project will use eVTOL different in design, propulsion, and acoustic characteristics. The technical data will partially be used from the previously ended project LONI, which was dedicated to the community noise of a use-case vertiport. During the project PAULA, it is intended to compare two promising air-taxi concepts, both with vectorized thrust propulsion by using rotors/propellers and miniature fan/jet is distributed electric propulsion arrangement.

For a proper modelling of the sources' emission characteristics, these technical data of the air-taxis are required for take-off, landing, departure, approach, and transition, and will be made available from WP1 of the project.[1]

Project partner Kopter Germany will provide the eVTOL parameters for its operations and is coordinating the project.

3.2 eVTOL noise sources – WP2

For each type of air-taxi and each of the required flight conditions, the corresponding noise emissions from the main sound sources are determined according to relevant, validated semi-empirical methods. As a result, for each source (propeller, mini fan, etc.) the sound power spectrum (linear, unweighted) for the relevant frequency range 20 Hz to 20 kHz is

[1] The transition phase will describe the continuously change of engine/wing tilt angle before touch-down or short after take-off, which strongly influences the noise generation and radiation.

given in third-octave bandwidth, as well as the directivity (see Figure 3).

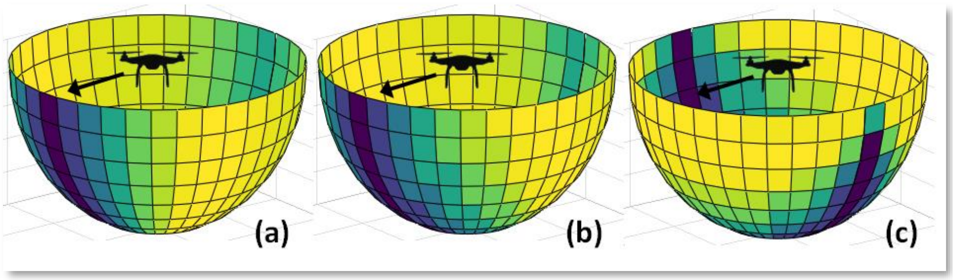

Figure 3: Different directivities for three typical air-taxis or their conditions (e.g., varying tilt angle). Bright areas indicate directions with higher sound radiation than darker areas.

With the noise emissions simulated in WP2, for each representative operational status of the eVTOL, together with the aircraft's position on the trajectory for approach or departure, the sound-pressure-spectrua as functions of time, at any desired observer/microphone position in the vicinity of the vertiport will be simulated for the aircraft, moving on its flightpath.

Project partner Munich Aeroacoustics will provide the noise sources, based on the eVTOL configuration.

3.3 Sound propagation and auralisation – WP4

The trajectory, the air-taxi's velocities and other flight-dynamics parameters in combination with the noise emission at each relevant point of its trajectory, the eVTOLs' perceived noise on the ground can be simulated for a single event operation on this trajectory. As explained previously, especially during take-off and approach, the noise characteristics are changing very strongly, thus, it will become essential to investigate the flyover noise on several observer locations in various distances from the take-off or touchdown position. Due to potentially strong directivity effects, it is also important to having virtual observers located on a sideline with no direct flyover situation. To support the selection of those sideline positions, a specific noise map for an area of 550 x 900 m², with a total number of 4.950 observer positions was already simulated (Figure 4), using the original trajectory, including transition in wing's tilt angle, but in a simplified procedure.

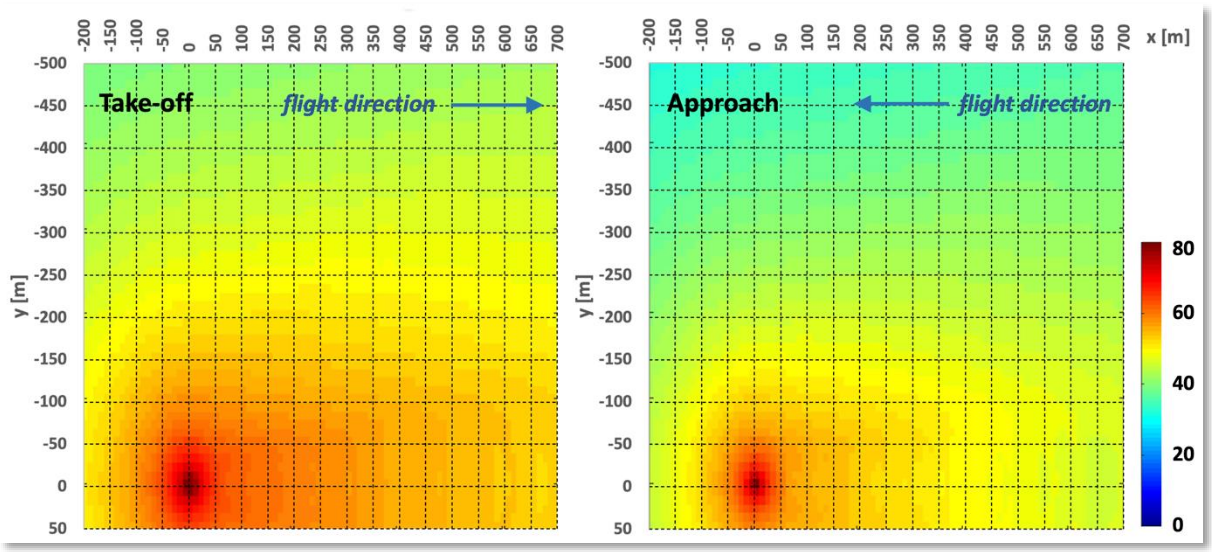

Figure 4: Community noise map for an eVTOL for a vertiport (at x = y = 0.0 m), displaying the A-weighted maximum sound pressure level L_{max} , simulated for a single event (take-off / approach).

Finally, auralisation will be performed by using the sound pressure spectra on the ground, which will have to be produced at certain timesteps. The correct setup, together with sound quality checks, will be decided after first audio files have been generated by simulating a realistic aircraft operation. This step is necessary to ensure that especially the transitions are correctly covered and that the synthesized sounds for all aircraft positions are recognized to be “realistic”. Only after this important step, all audio files for the laboratory tests (Section 3.4) will be generated. The audio parameters (e.g., sample rate, filters, etc.) were specified earlier in WP1. Project partner Munich Aeroacoustics will provide the synthesized audio files.

One important fact that has to be mentioned here is that PAULA will be one, if not the first, project to auralise the in-flight transition phase, during which the propulsion system or the complete wing are being tilted, e.g., by 90 degrees, in a relatively short time of typically 40 to 50 seconds. This procedure may create very specific “sound effects”, which has to be included in the impact studies. So far, no auralised transitions have been investigated and/or published.

3.4 Scenario building and impact studies – WP4

Based on the auralised air-taxi sounds for departures and approaches, and several observer points, in WP4 noise scenarios are compiled to evaluate them in terms of their annoyance and disturbance in a systematic multi-stage laboratory experiment. Scenarios are built in variation of the factors described in Table 1. The noise scenarios differ regarding the number of movements. Per session, that is limited to a duration of approximately 30 min, one to seven movements are presented. Examination will be repeated for nine different observer points. Departures and approaches are tested separately. In half of the scenarios, continuous background noises from distance urban road noise and nature sounds are added to the air-taxi sounds in order to evaluate the potential of masking air-taxis sounds by ambient noise and its effect on annoyance and disturbance. In sum, combinations of the mentioned factors result in 144 different scenarios. In a repeated measurement design, we plan to distribute these scenarios among 48 participants running through six randomly selected scenarios each. All examinations will be conducted at the DLR Institute of Aerospace Medicine in Cologne.

The air-taxi scenarios will be presented via headphones in a sound insulated laboratory furnished like a living room. Annoyance will be assessed by a question referring to the home environment. Participants will be instructed to imagine that they are sitting in a/their garden and are hearing the presented scenarios – a modification of a question proposed by Schäffer and colleagues (2016). Annoyance can be rated on numerical 11-point scale according to the ISO 15666:2021 recommendations (ISO, 2021) reaching from 0 = “not at all annoyed” to 10 = “extremely annoyed”.

Table 1: Factors to be considered in the study design and the definition of the air-taxi scenarios

Factor	Description	Nature of factor	Number of factor levels
Operation type	Departure and approach	within-subject	2
Movements	Number of movements during the test period (as categorical factor)	within-subject	4
Distance to vertiport	Observer points under the center line and in lateral position parallel to the center line	within-subject	up to 9
Background noise	No background noise vs. urban ambient sounds	between-subject	2

In addition, a focused listening test is planned, i.e. each of the sounds that were auralised for the nine observer positions in for departure and approach in WP2 will be rated regarding their single-event annoyance, again via an adaptation of the question and scale as mentioned above (ISO, 2021; Schäffer et al., 2016). Acoustic metrics suitable to describe the sound pressure level of these single events (e.g. SEL, $L_{As,max}$) will be derived. Exposure-response models will describe the association between the sound level and annoyance and serve as basis for the comparison to other results on single-event annoyance of UAM sounds (e.g. Krishnamurthy et al., 2023).

3.5 D&E plan for the results

The results from PAULA are expected to be valuable for the future assessment of UAM noise impact. Of course, the specific situation depends on vertiport positioning, flight path selection, traffic management and aircraft type and its operations. But the principle effects of a flying air-taxi will still be audible from the various sound files, produced during the project. The variety of selected observer positions, which are exposed to different aircraft settings (e.g., wing or engine tilt angles during transition from take-off to cruise), will allow to receive a general impression of "what it is like to live in the vicinity of a vertiport". This will be enabled by providing a publicly accessible database, which consists of different flyover or fly-by situations. Community administrations, future vertiport operators, but also common citizens will then be able to listen at flying air-taxis, which may be discussed or already planned for some future operations. This could enhance the transparency and finally the acceptance regarding this novel transportation mode.

While the database is probably more of public interest, PAULA will deliver an action plan, which will address the requirements, needs, and potential pitfalls for administrations, vertiport and air-taxi fleet operators. The results from WP4 are going to be analysed according to latest standards of noise impact research and will be translated into a set of general requirements (e.g. in terms of land-use planning and operational recommendation). Those requirements shall reduce the risk of a public reluctance against UAM plannings in their community. Thus, it can increase the planning certainty on the side of administrations and industry.

Project partner Munich Aeroacoustics will be responsible for the database and coordinate the establishment of the action plan.

4. SUMMARY

The research project PAULA is focused on the noise impact research regarding UAM air traffic noise. Starting from realistic aircraft operational parameters and eVTOL's trajectories towards and from a vertiport, audio sequences will be auralised at several positions inside the community surrounding the vertiport. The synthesized sounds will be used in laboratory tests to assess how they do affect individuals who are exposed to the UAM traffic noise. For the first time, not only single sounds but scenarios will be evaluated. A systematic evaluation will lead to a general understanding, e.g., how many movements per hour may be critical, but will also being exploited in a final action plan, which shall support administrators and operators who have to deal with this new means of air transportation. Most of the auralised sounds and will be collected in database, which is accessible by the public after the project's end. This kind of audio database will be the first to be known in the context of UAM air traffic noise.

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