



Urban Air Mobility Noise: Current Practice, Gaps, and Recommendations

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Scope of UAM Noise Working Group (UNWG)

The UNWG is focused on UAM vehicles and operations with attributes that include:

- 6 or fewer passengers (or equivalent cargo),
- a single pilot or autonomous control,
- approximately 100 nautical mile missions flown under 3000 feet above ground level,
- flight speeds of 200 knots or less,
- payloads ranging from 800 to 8000 pounds, and
- eVTOL with either all battery power or hybrid-electric propulsion

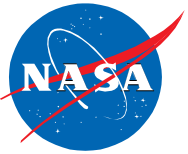




UNWG High Level Goals

- **Document noise reduction technologies available for UAM and identify knowledge gaps for each of the four areas of interest (UNWG subgroups).**
- Assess prediction capabilities for benchmark problems based on an open set of reference vehicle designs using available data.
- Define measurement methods/procedures to support noise regulations and assessment of community noise impact, and coordinate with UAM vehicle manufacturers on development of low noise approach and takeoff procedures for piloted and automated operations.
- Assess metrics for audibility and annoyance of single-event vehicle operations using available predicted and measured data.
- Examine fleet noise impacts through prediction and measurement, and characterize effectiveness of supplemental metrics for audibility and annoyance.
- Promote UAM integration into communities through mitigation of fleet noise impacts, and engagement with the public.

UAM Noise Working Group White Paper

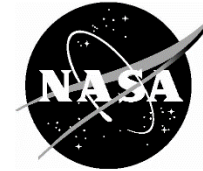


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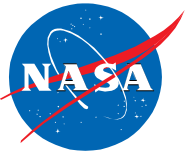


Recommendations – Tools & Technologies

Further development of validated noise prediction tools is required to support research and development of vehicles and their operations. It is recommended that:

- **System noise prediction tools be further developed for application to UAM vehicles and made available to the research and industrial communities.**
- Research be performed to develop conventions on how to handle control redundancies to obtain preferred low-noise trim conditions and to further develop the acoustic tools to handle aperiodic sources.
- **Prediction models for the highest amplitude noise sources be validated with experimental data for isolated and installed configurations**, and that flight test data be acquired to better understand variations under realistic operating conditions, particularly unsteady conditions (e.g., maneuvers and transition).
- **Continued development of auralization tools be performed to allow realization of flight operations (including takeoff, forward flight, landing, and transition) for a representative range of vehicle configurations.**

Recommendations – Tools & Technologies (continued)



It is recommended that:

- A dedicated technology maturation effort be performed on the most promising noise mitigation technologies and that opportunities be sought to evaluate their efficacy in flight.
- **Surrogate or other reduced order model methods be developed so that designers can quickly determine the effects of design changes on noise early in the design process, and that sensitivities be fully implemented to enable optimization of low-noise vehicle designs and operations.**
- **Research be conducted to more fully explore limitations in methods for assessing community noise impact of UAM vehicles in their operational environments,** and to generate a software development plan that addresses the limitations of current models over time.
- Manufacturers work with appropriate organizations to develop low noise guidance for piloted operations and automated low-noise procedures for autonomous operations that are specific to their products.



Recommendations – Ground & Flight Testing

Several practices commonly used across the aeronautics industry should be strongly considered for near-term testing or future standardization. It is recommended that:

- **Test environment constraints (e.g., ambient levels, benign meteorological conditions), similar to those in ICAO Annex 16 Vol. I and 14 CFR Part 36, be used for all tests conducted to measure UAM vehicle noise.**
- **Significant on-aircraft instrumentation and monitoring of the vehicle state be required due to varying levels of autonomy and potential increase in degrees-of-freedom of the flight envelope.**
- The “worst” case or the noisiest mode the vehicle will fly (under automatically controlled Variable Noise Reduction System provisions) be established. Additional work is recommended to define appropriate methods to evaluate acoustic dependence and variability with respect to the vehicle state.
- A full assessment of anticipated UAM aircraft flight performance and operational environments be performed to support the development of any future certification procedures and/or standards.



Recommendations – Ground & Flight Testing (cont.)

It is recommended that:

- **Stakeholders (including manufacturers, researchers, and certification authorities) closely collaborate in the development of new measurement approaches.**
- Noise measurements above the aircraft be investigated to understand the relative importance of noise directed along the horizon and above the aircraft.
- **Use of flush mounted or inverted microphones over a rigid ground plane be specified as part of any future noise certification procedures.**

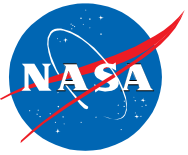


Recommendations – Human Response & Metrics

Further development of metrics and validated predictive models of human response is needed to inform decision making by UAM vehicle manufacturers and regulators. It is recommended that:

- **Efforts be made to acquire/generate measured and simulated vehicle acoustic data, and to make those data available to support subjective response studies for metric and predictive model development.**
- **Standardized processes for measuring and cataloging ambient noise be developed, and to make those data available to support subjective response studies for metric and predictive model development.**
- **Until early entrants are fielded, and community noise studies can be performed, laboratory studies be performed to help inform how different the annoyance to short-term exposure of UAM vehicle noise is from that of existing aircraft noise sources. Assessments can then be made to determine the sensitivity of noise exposure estimates to changes in the metric or to its level.**
- **Validated models for audibility, noticeability, and annoyance to UAM aircraft noise be developed to assess their utility for assessing community noise impact.**

Recommendations – Human Response & Metrics (cont.)



It is recommended that:

- The transmission of UAM vehicle noise through residential and commercial structures be quantified in order to evaluate the 20 dB loss assumed by current land use compatibility guidelines
- **Measures of human response be developed and used as constraints in perception-influenced design. Ideally, such measures would be easily calculated and include sensitivities.**
- Comprehensive evaluation of metrics that supplement the day-night average sound level be performed for communicating community noise impact of UAM vehicle noise.
- **A laboratory test campaign be used to explore differences in perception of UAM vehicle noise between communities, so that future policy decisions are based on data representing a wide range of environments.**



Recommendations – Regulation & Policy

It is recommended:

- **That at the national level, the FAA, in collaboration with other agencies and the industry, address certification, standards, and environmental reporting for UAM noise before these vehicles enter service.** This is needed so that local communities are not panicked into the establishment of ordinances that will both limit growth of the market and potentially create operationally restricted zones.
- That i) Industries be more proactive in approaching regulators to help them understand vehicle designs, noise characteristics, operating modes, etc., and to share relevant data, and ii) **Regulators help the industry to understand the regulation process and policies, and identify specific data needs to bridge gaps in standards and procedures.** R&D programs, technical committees, and workshops are some of the venues that such collaborations can take place, in addition to direct communications.
- **To collect more data in the field through R&D programs and to leverage data from manufacturers.** The data would not only help to support noise certification of UAM vehicles, but also to assist the development and validation of noise prediction capability for noise impact analyses and to identify approaches and best practices for quiet aircraft designs and for quiet flight operations.



Recommendations – Regulation & Policy (continued)

It is recommended:

- That regulators and policy makers work to clarify the boundaries of responsibilities in managing UAM noise, and support development of guidance for vertiport planning regarding both location identification and environmental assessment at the proposed locations.
- To develop a strategy and framework for community engagement before UAM noise concerns arise. Being prepared to address local community noise concerns early in the process will be critical to success for this market. Initial flight operations should not come as a surprise to the affected community. Modern tools such as virtual reality with auralization could provide effective ways to inform and engage the public.