



An Introduction to the UAM Noise Working Group (UNWG)

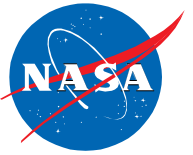
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Transformative Vertical Flight 2022
Aeromechanics for Advanced Vertical Flight Technical Meeting
9th Annual Electric VTOL Symposium
Cross Agency/Industry Working Groups

San Jose, CA
January 25-27, 2022

Outline



- What is the UAM Noise Working Group?
 - The Beginning
 - Organization
 - Meetings

- Scope

- Goals

- Progress Towards Recommendations of UNWG White Paper

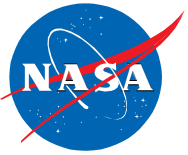
UAM Noise Exploratory Meeting (April '18)

- Positive interest in forming a focused working group to define and address noise goals for UAM vehicles.
- Participants included stakeholders across industry, government agencies, academia, and community groups.
- Focus efforts on reducing or eliminating the barriers associated with community noise.
- Key topics of interest include:
 - Tools & Technologies
 - Ground & Flight Testing
 - Human Response & Metrics
 - Regulation & Policy



~ 70 attendees at Exploratory Meeting

UNWG Organization



Leads: Brenda Henderson (NASA Glenn) and Stephen Rizzi (NASA Langley)

Subgroup 1: Tools and Technologies

Leads: Doug Boyd and Len Lopes (NASA Langley), Jeremy Bain (Joby)

Subgroup 2: Ground and Flight Testing

Leads: Kyle Pascioni (NASA Langley), Devin Boyle (NASA Glenn), Juliet Page (Blue Ridge Research)

Subgroup 3: Human Response and Metrics

Leads: Siddhartha Krishnamurthy (NASA Langley), David Josephson (Josephson Engineering)

Subgroup 4: Regulation and Policy

Leads: Bill He (FAA Office of Environment and Energy), Royce Snider (Bell Flight)

UNWG Meeting Recap

- Two face-to-face meetings per year held in conjunction with NASA Acoustics Technical Working Group meeting – Spring (LaRC), Fall (GRC)
- 1st Meeting – Focus on organization, defining the scope and setting of goals
 - October 2018 @ NASA Glenn
 - 95 attendees
- 2nd Meeting – Focus on white paper development
 - April 2019 @ NASA Langley
 - 125 attendees
- 3rd Meeting – Focus on experimental database and model validation
 - October 2019 @ NASA Glenn
 - 131 attendees



UNWG Meeting Recap

- 4th Meeting – Focus on community outreach
 - April 2020 @ Virtual – hosted by NASA Langley
 - 180 attendees
- 5th Meeting – Focus on human response and metrics
 - Nov 2020 @ Virtual – hosted by NASA Glenn
 - 250 registrants
- 6th Meeting – Focus on ground and flight testing
 - April 2021 @ Virtual – hosted by NASA Langley
 - 340 registrants
- 7th Meeting – Focus on external efforts of interest
 - Oct 2021 @ Virtual – hosted by NASA Glenn
 - 335 registrants



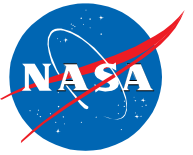
- 8th Meeting – Focus TBD
 - 14 April 2022
 - Expecting to be hybrid @ NASA Langley

UNWG Scope

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

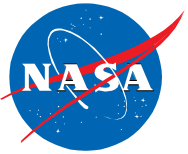




UNWG High Level Goals

- **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

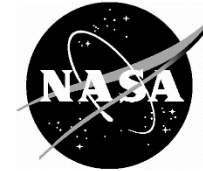


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<https://ntrs.nasa.gov/search?q=20205007433>

NASA/TP-2020-5007433



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

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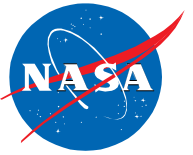
Hua (Bill) He, Federal Aviation Administration, District of Columbia

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October 2020

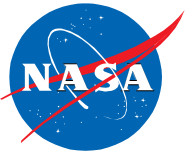


Recommendations – Tools & Technologies

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.**
 - The NASA 2nd generation Aircraft Noise Prediction Program 2 (ANOPP2), available at software.nasa.gov, has new capabilities for prediction of eVTOL noise.
 - NASA has developed and conducted workshops on tools to explore the noise and performance of multirotor UAM vehicles. Next workshop for US participants to be conducted in summer 2022.
- **Prediction models for the highest amplitude noise sources be validated with experimental data for isolated and installed configurations.**
 - NASA has identified several configurations for model validation over the next several years.
 - Data from isolated configurations have been made available with additional datasets possible.

Recommendations – Tools & Technologies (continued)

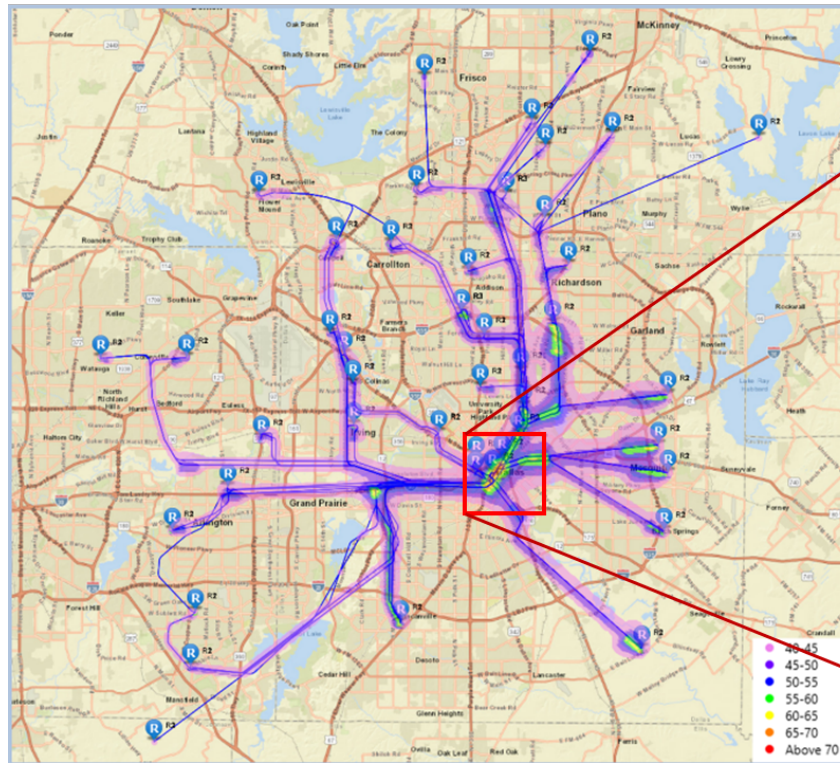


- **Continued development of auralization tools be performed to allow realization of flight operations (including takeoff, forward flight, landing, and transition) for a representative range of vehicle configurations.**
 - New capabilities for synthesis of loading and thickness noise and modulating broadband noise were recently added in the NASA Auralization Framework (NAF), available at software.nasa.gov.
- **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.**
 - Machine learning is being applied to ANOPP2 results to support surrogate model development.
 - Sensitivities are being added to ANOPP2 to support multidisciplinary design optimization.

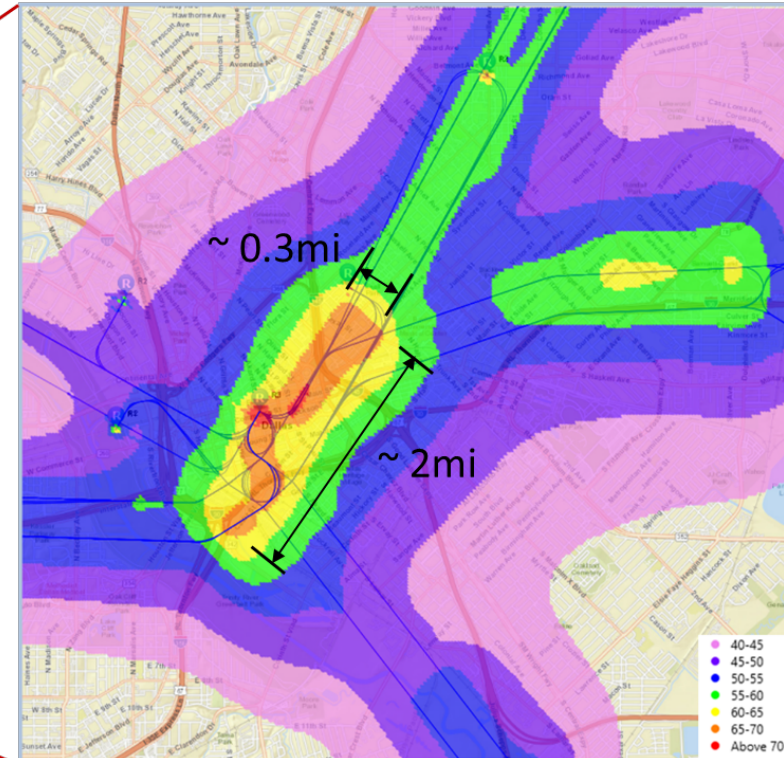
Recommendations – Tools & Technologies (continued)

- Research be conducted to more fully explore limitations in methods for assessing community noise impact of UAM vehicles in their operational environments.
 - Efforts underway to assess utilization of the FAA Aviation Environmental Design Tool for UAM vehicle operations.

Ldn (dB) – 1674 sq. nm study area



Ldn (dB) – 25 sq. nm study area near DF1



65 dB contour area ~ 60 city blocks



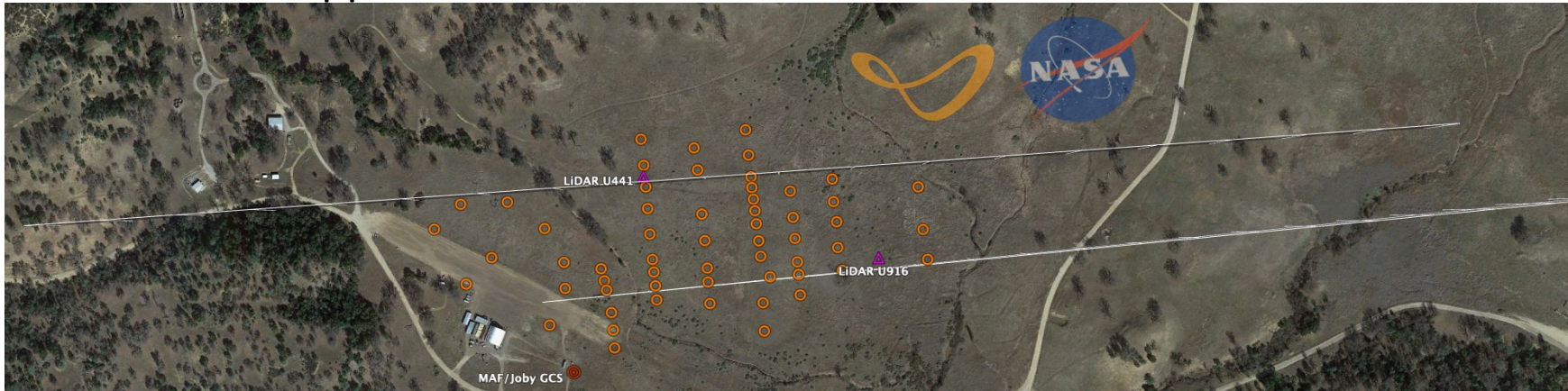
Recommendations – Ground & Flight Testing

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

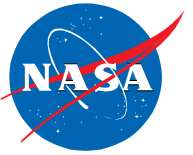
- **Test environment constraints (e.g., ambient levels, benign meteorological conditions), similar to those in ICAO Annex 16 Vol. I and 14 CFR Part 36, be used for all tests conducted to measure UAM vehicle noise.**
- **Use of flush mounted or inverted microphones over a rigid ground plane be specified as part of any future noise certification procedures.**
 - Subgroup 2 activity underway to develop a research measurement protocol or set of guidelines for quantifying community noise impact through creation of vehicle source noise spheres.
 - Draft document addressing environmental conditions, microphone position and orientation, data acquisition and signal conditioning, and other considerations will soon be available for review by other UNWG subgroups.

Recommendations – Ground & Flight Testing (cont.)

- **Stakeholders (including manufacturers, researchers, and certification authorities) closely collaborate in the development of new measurement approaches.**
 - NASA Advanced Air Mobility National Campaign Developmental Test (NC-DT) acquired nearly 100 test points on Joby's S4 2.0 vehicle spanning all phases of flight including hover, departure, cruise, and approach.



- NASA and other UNWG participants are also making acoustic measurements on other vehicles apart from the National Campaign.
- **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.**

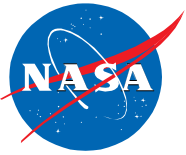


Recommendations – Human Response & Metrics

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:

- **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.**
 - NASA TM on “Methods for Recording and Documenting Ambient Environmental Sound for use in Listening Tests,” Durand Begault, just released (https://hsi.arc.nasa.gov/publications/NASA_TM_20210017504.pdf)
- **Validated models for audibility, noticeability, and annoyance to UAM aircraft noise be developed to assess their utility for assessing community noise impact.**
 - Three psychoacoustic tests at NASA investigating effect of sound quality, duration, and audibility on annoyance to UAM noise over course of next 18 months.
 - Psychoacoustic tests being conducted by other UNWG members including Royal Netherlands Aerospace Center (NLR) and University of Salford.

Recommendations – Human Response & Metrics (cont.)



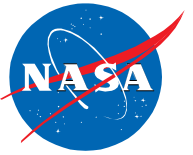
- **Measures of human response be developed and used as constraints in perception-influenced design. Ideally, such measures would be easily calculated and include sensitivities.**
 - Sensitivities of sound quality metrics to design parameters are being computed within ANOPP2 and NAF to allow multidisciplinary design incorporating human response.
- **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.**
- **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.**
 - Subgroup 3 cooperative human response study being conducted using a remote test platform.
 - Phase 1 uses existing aircraft sounds to assess ability to replicate results from a prior lab study and investigates influence of context on subject responses.
 - Phase 2 will assess annoyance to a range of UAM vehicle sounds.



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.**
- **Regulators help the industry to understand the regulation process and policies, and identify specific data needs to bridge gaps in standards and procedures.**
 - Several presentations have been made by FAA Office of Environment and Energy (AEE) leaders at UNWG meetings.
 - FAA is collaborating with NASA on the National Campaign and other activities, e.g., Research Transition Teams.
 - Not explicitly stated is one underlying need/recommendation to harmonize noise measurement procedures and standards at the international level. ICAO Committee on Aviation Environmental Protection (CAEP) WG1 has been tracking noise development of new entrants such as UAS, electric aircraft, air taxis, etc.



Recommendations – Regulation & Policy

- **To collect more data in the field through R&D programs and to leverage data from manufacturers.**
 - Data not only helps support noise certification of UAM vehicles, but also assists the development and validation of noise prediction capability for noise impact analyses (SG1).
 - Data helps identify approaches and best practices for quiet aircraft designs and for quiet flight operations (SG2).
- **To develop a strategy and framework for community engagement before UAM noise concerns arise.**
 - Modern tools such as virtual reality with auralization could provide effective ways to inform and engage the public (SG3).
 - There has been some discussion on development of talking points to inform public on what they might expect with introduction of UAM vehicle operations.
 - Plan to share thoughts on possible community response testing at the April UNWG meeting.



Thank You

Questions?