AAM Ecosystem Aircraft Working Group: Urban Air Mobility Noise Working Group (UNWG) Update
## Agenda

**April 29, 2021**  
**3:00pm - 4:30pm ET**

<table>
<thead>
<tr>
<th>TIME (ET)</th>
<th>TOPIC</th>
<th>SPEAKER(S)</th>
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</thead>
<tbody>
<tr>
<td>3:00PM – 3:05PM</td>
<td>Welcome</td>
<td>Carl Russell, NASA</td>
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</table>
| 3:05PM – 3:15PM| Introduction to the Acoustic Technical Working Group | Brenda Henderson, NASA  
Stephen Rizzi, NASA |
| 3:35PM – 3:45PM| Subgroup 3 Update: Human Response and Metrics      | Siddhartha Krishnamurthy, NASA                  |
| 3:45PM – 3:55PM| Subgroup 4 Update: Regulation and Policy           | Royce Snider, Bell Flight  
Bill He, FAA                                             |
| 3:55PM – 4:25PM| Discussion with the Audience, including:           | All the Above                                  |
|                | - Active Participates: MS Teams chat and open microphone |                                                |
|                | - Listen Only Participants: [Conferences.io](#)    |                                                |
| 4:25PM – 4:30PM| Closing Remarks                                    | Carl Russell, NASA                              |
Platform and Discussion

• **Active Participants**
  – Platform: MS Teams
  – Discussion: MS Teams microphone, chat, and “Raise your hand” functions
    • Leave your cameras/webcams off to preserve WiFi bandwidth
    • Use your mute/unmute button (e.g., remain on mute unless you are speaking)
    • Enter comments/questions in the chat
    • Click the “Raise your hand” button if you wish to speak
    • Say your name and affiliation before you begin speaking

• **Listen Only Participants**
  – Platform: YouTube Live Stream
    • Go to [https://nari.arc.nasa.gov/aam-portal/](https://nari.arc.nasa.gov/aam-portal/) for the link
  – Discussion: Conferences.io
    • Enter [https://arc.cnf.io/sessions/gppq/#!/dashboard](https://arc.cnf.io/sessions/gppq/#!/dashboard) into your browser
    • Questions will be addressed *if times permits or at the facilitator’s discretion*
Presentations & Discussion
Urban Air Mobility Noise Working Group (UNWG) Update
(A Panel Session)

Stephen Rizzi (NASA Langley)
Brenda Henderson (NASA Glenn)

29 April 2021
AEWG Aircraft Working Group
UAM Noise Exploratory Meeting (April ’18)

• Positive interest in forming a focused working group to define and address noise goals for UAM vehicles.

• Participants should include 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 (Subgroup 1 – NASA led)
  Ground & Flight Testing (Subgroup 2 – NASA led)
  Human Response & Metrics (Subgroup 3 – NASA led)
  Regulation & Policy (Subgroup 4 – FAA led)
UNWG Organization

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

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 (Volpe)

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 Subgroups and the 5 Pillars

1. Design, manufacture, and system readiness of AAM vehicles
2. Individual Vehicle Management & Operations
3. Airspace System Design & Implementation
4. Airspace & Fleet Operations Management
5. Societal integration and acceptance of AAM operations

Operations and management of multiple vehicles within an AAM system that enable safe and efficient sharing of airspace and other system resources.

Operations and maintenance of a single AAM vehicle, independent of the sharing of airspace or other system resources.

Community Integration
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 with support from NARI
  • 180 registrants

• 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 15, 2021 @ Virtual – hosted by NASA Langley with support from NARI
  • 340 registrants
Scope of the 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.
Urban Air Mobility Noise: Current Practice, Gaps, and Recommendations

Stephen A. Bizi, Langley Research Center, Hampton, Virginia
Dennis L. Huff, Glenn Research Center, Cleveland, Ohio
D. Douglas Boyd, Jr., Langley Research Center, Hampton, Virginia
Paul Bent, Boeing R&T, St. Louis, Missouri
Brenda S. Henderson, Glenn Research Center, Cleveland, Ohio
Kyle A. Pascione, Langley Research Center, Hampton, Virginia
D. Caleb Sargent, Sikorsky Aircraft, Stratford, Connecticut
David L. Josephson, Josephson Engineering, Santa Cruz, California
Mehmet Mansan, Federal Aviation Administration, District of Columbia
Hua (Bill) He, Federal Aviation Administration, District of Columbia
Royce Snider, Bell Flight, Ft. Worth, Texas

National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23881-2199

October 2020
UNWG Contacts

Leads
Stephen Rizzi (stephen.a.rizzi@nasa.gov)
Brenda Henderson (brenda.s.henderson@nasa.gov)

Subgroup 1
Doug Boyd (d.d.boyd@nasa.gov)
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Devin Boyle (devin.k.boyle@nasa.gov)
Juliet Page (juliet.page@dot.gov)

Subgroup 3
Siddhartha Krishnamurthy (siddhartha.krishnamurthy@nasa.gov)
David Josephson (dlj@josephson.com)

Subgroup 4
Bill He (Hua.He@faa.gov)
Royce Snider (rsnider@bellflight.com)
1. System noise prediction tools be further developed for application to UAM vehicles and made available to the research and industrial communities.
   - Noise prediction framework updates, new capabilities and tools.

2. 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.
   - Noise prediction framework updates, new capabilities and tools.

3. 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).
   - Dissemination of geometry and acoustic measurement of nominal rotor design for participants to validate their tools, potential workshop.

4. 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.
   - Broadband noise prediction coupled into auralization framework
5. 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.

6. 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.
   - Additional tool development underway to evolve existing computational techniques and measurement data into reduced order model

7. 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.
   - Noise power distance (NPD) curve generation for UAM vehicles into integrated environment design tool (AEDT)
   - Advanced Acoustic Model (AAM) recent release with UAM vehicle updates to acoustic assessment evaluation

8. 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.
Aircraft Noise Prediction

- Ongoing tool development and distribution
  - ANOPP2 framework provides prediction platform
  - Component prediction and propagation capability
  - Tools for user interfaces and applications

Broadband self noise component prediction capability

Single broadband noise element

Discretization of rotor into elements

Available tools incorporating self noise

Comprehensive tools (AARON)

Fast blade element tools (ABEAT)

Proportional Band Spectrum (dB)

Center Band Frequency (Hz)
Reduced Order Models

- Computationally intensive predictions are prohibitive
  - Very prohibitive where several iterations are needed
- Neural nets allow ‘training’ a system of neurons to interpolate within a complex database
  - Training data can be measurement or prediction
  - Predictions can be low or high order
- ANOPP2’s Neural Network (ANNs) capability is under development
  - Training and applying neural networks
  - Coupled with array of prediction modules within ANOPP2
- Applied ANOPP PAS to train model using tapered rotor
  - 148 PAS computations were used to train neural network
  - Comparisons of neural network prediction to PAS computation show good agreement

(a) Tonal Noise Comparison. (b) Broadband Noise Comparison.
NAF Auralization Developments

- High fidelity loading and thickness (tonal) noise auralization for arbitrary vehicle maneuvers

\[ t = t_1 \quad \text{and} \quad t = t_2 \]

- Modulated broadband synthesis for auralization with self noise

F1A computation of sound pressures at each time step in simulated flyover

Simulated Bell 206B Pitch-Up Maneuver Tonal Noise at Ground Observer

![Simulation of Bell 206B Helicopter Pitch-Up](image)

![Graph showing pressure vs. time](image)
Source Noise Prediction

NPD Database Generation for Quadrotor and Lift+Cruise

Gen 1: Loading & Thickness Noise
Gen 2: Gen 1 + Broadband Selfnoise

Gen 1 Assessment of ATM-X Routes

600 Operations/Route of Quadrotor

Gen 2 SEL Data for Quadrotor

Construction of AEDT Study Using Fixed-Point Flight Profiles
• Government, industry, and academia all have their tools
  • Lack consistent set of validation data

• Dissemination challenges (including blade geometries)
  • Previously NASA used commercial blades because:
    • They were cost effective
    • They could be acquired quickly
    • They did not require design efforts
  • NASA promised efforts to create sharable database of nominal rotor design
    • Easy to define rotor properties
    • NASA fabricated several sets of blades with different materials
Ideally Twisted Rotor (ITR) Geometry

- Ideally, radially constant induced inflow to minimize induced power.
- From blade element momentum theory (BEMT) in hover:

\[
\lambda(r) = \frac{\sigma Cl_\alpha}{16} \left( 1 + \frac{32}{\sigma Cl_\alpha} \theta r \right)^{1/2} - 1
\]

\[
\theta = \frac{\text{Constant}}{r}
\]

- Uniform inflow constraint

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<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Geometry</td>
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<tr>
<td>$c/R$</td>
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<td>$\Theta_{\text{tip}}$ (°)</td>
<td>6.9</td>
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<tr>
<td>$N_b$</td>
<td>4</td>
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<tr>
<td>$\sigma$</td>
<td>0.255</td>
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<table>
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<th>Operating Condition</th>
<th>Value</th>
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<tr>
<td>$C_T$</td>
<td>0.0137</td>
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<tr>
<td>$M_{\text{tip}}$</td>
<td>0.27</td>
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<tr>
<td>$\Omega_c$ (RPM)</td>
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</table>
ITR Example Data: Noise Trends

Acoustic spectra for smooth blade experiments at microphone 5 (-35 deg. below the plane of the rotor)

Spectral scaling
Strohal number \( (St = fH/U_{tip}) \) with bluntness thickness \( H \) as length scale
Tip Mach number to the 5th power as velocity scale
This represents work going on at NASA

There are, of course, other activities in government, industry, and academia

Any Questions?
Backup Slides
Breakout topics

• Current dataset dissemination
• Tool development and needs
• Potential validation datasets
• Recommended potential wind tunnel tests
“Acoustic and Performance Characteristics of an Ideally Twisted Rotor in Hover” – Pettingill, Zawodny, Thurman, and Lopes

- Various collective pitch angles to identify noise trends
- Tonal and broadband noise characteristics
- Identification of success and challenges

“Physics-Informed Broadband Noise Source Identification and Prediction of an Ideally Twisted Rotor” – Thurman, Zawodny, Pettingill, Lopes, and Baeder

- CFD based tonal and broadband noise prediction
- Source localization to identify if predictions match source identification
Ideally Twisted Rotor (ITR)

• Ideally, radially constant induced inflow to minimize induced power.

• From Blade Element Momentum Theory (BEMT) in hover:

\[
\lambda(r) = \frac{\sigma C_{\lambda}}{16} \left( 1 + \frac{32}{\sigma C_{\lambda}} \theta r \right)^{1/2} - 1
\]

• Uniform inflow constraint

\[
\theta = \frac{\text{Constant}}{r}
\]
Ideally Twisted Rotor (ITR) Images

Rotor in Small Hover Anechoic Chamber (SHAC) at NASA Langley Research Center
Experiment: Facility and Setup

**In-house Markforged blades**
- Onyx material: micro carbon fiber filled nylon plastic
- Aluminum ejector pin inserted span-wise to improve stiffness

**Protolabs SLA “smooth” blades**
- Accura Xtreme White 200 material: like injection molded resin (“ABS-like”)
- Manufactured via stereolithography (SLA)

**Protolabs SLS “rough” blades**
- PA 12 material: 25% mineral-filled nylon
- Manufactured via selective laser sintering (SLS)

**COTS varioPROP hub**
Experiment: Facility and Setup

Small Hover Anechoic Chamber (SHAC)*

- Room dimensions = [3.87 x 2.56 x 3.26] m
- Acoustically treated (cutoff down to 250 Hz)
- DAS: Brüel & Kjær (BK) LAN-XI DAQ and BK Connect Software
  - 6 B&K Type 4939 Free-Field microphones
  - Laser sensor tachometer
  - 6-Component AI-IA mini40 multiaxis load cell
- Scorpion Motor

Experiment Target Conditions

<table>
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<tr>
<th>Parameter Sweep</th>
<th>Ω (RPM)</th>
<th>θ_{fp} (°)</th>
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<tr>
<td>Rotation Rate (Ω)</td>
<td>3000⇒5800° †</td>
<td>6.9</td>
</tr>
<tr>
<td>Rotor Collective (A_{0})</td>
<td>5500° *</td>
<td>3.9, 6.9, 9.9</td>
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*Values are approximate.
†Tested in approximate increments of 500 RPM.
Performance Results

- Performance data for three blade sets compared
  - Thrust coefficient ($C_T$) expected to be constant if only rotation rate is varied
  - In-house blades showed high variance in $C_T$
- Protolabs smooth blades chosen to be tested for additional tip pitch conditions
  - Produced 9.26% less thrust than design thrust of 11.12 N

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<tr>
<th>Blade</th>
<th>Tip Pitch</th>
<th>$\Delta C_T/1000 \Delta \Omega$</th>
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<tbody>
<tr>
<td>In-house 3D Print</td>
<td>7 deg.</td>
<td>1.029e-3</td>
</tr>
<tr>
<td>Protolabs Smooth</td>
<td>4 deg.</td>
<td>3.713e-4</td>
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<tr>
<td>Protolabs Smooth</td>
<td>7 deg.</td>
<td>3.874e-4</td>
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<td>Protolabs Smooth</td>
<td>10 deg.</td>
<td>2.392e-4</td>
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<tr>
<td>Protolabs Rough</td>
<td>7 deg.</td>
<td>n/a</td>
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In-house Markforged blades

Protolabs SLS “smooth” blades

Protolabs SLS “rough” blades

\[ \text{Thrust (N)} \]

\[ \text{Torque (N-m)} \]
Acoustic spectra for smooth blade experiments at microphone 5 (-35 deg. below the plane of the rotor)

Spectral scaling
Strouhal number \((St = \frac{f H}{U_{tip}})\) with bluntness thickness \(H\) as length scale
Tip Mach number to the 5\(^{th}\) power as velocity scale
What NASA is Providing to Participants
CAD Drawing and Raw Measurement Data

- CAD Drawing
- Raw measurement data from all microphones all entries
- Raw data from figures in publications (measurement and predictions)
  - Approximately 1.8 GB of raw data
What NASA is Providing to Participants

Test Matrix

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<tr>
<th>Blade Set Name</th>
<th>Theta_tip (Deg.)</th>
<th>Omega_mech (RPM)</th>
<th>Omega_c (RPM)</th>
<th>T (N)</th>
<th>Q (N-m)</th>
<th>M_tip</th>
<th>CT</th>
<th>CP</th>
<th>CA (m/s)</th>
<th>PRESS (Pa)</th>
<th>TEMP (K)</th>
<th>RHD (kg/m²-3)</th>
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<tr>
<td>In-house Markforged</td>
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<td>Onyx Blades</td>
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<td>Protolabs SLA ABS</td>
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In-house Markforged Onyx Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades

Protolabs SLA ABS-like Smooth Blades
### Frequency Data (Dozens)

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<th>Frequency (Hz)</th>
<th>SPL_bb (dB)</th>
<th>Frequency (Hz)</th>
<th>SPL_bb_pr (dB)</th>
<th>Frequency (Hz)</th>
<th>Motor Noise (dB)</th>
<th>Frequency (Hz)</th>
<th>Facility Noise (dB)</th>
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**What NASA is Providing to Participants**

- **Figure Data (Dozens)**
- **Slide 37**
Expectations of Participants

• Download dataset from NASA server, including CAD and measurements
• Perform predictions of various flight conditions with your tools
  • NASA tools also available for download (US and International Distributions)
• Compare performance and noise metrics with measurement data
• Communicate on discoveries (positive and negative)
• Suggestion for future experiments
Future Datasets That May Be Possible

• Ideally Twisted Rotor:
  • Place rotor in Low Speed Aeroacoustic Wind Tunnel (LSAWT) (Date: TBD)
  • Forward flight configurations
  • Rotor angles of attack
  • Installation effects

• Other Rotors/Propellers
  • Suggestions?
Open Floor Discussion
Aircraft Working Group Meeting
Unmanned Noise Working Group (UNWG)
Subgroup 2: Ground & Flight Testing

29 April 2021
Virtual Meeting

Group Leads:
Devin Boyle (NASA, GRC), Juliet Page (Volpe, US DOT), Kyle Pascioni (NASA, LaRC)
Goal: Ground & Flight Testing Subgroup Goal

Define measurements suitable for the creation of acoustic spheres

- Ensure sufficient data gathered to support quantifying community noise impacts
- Activities coupled with all the other SGs: Tools/Technologies, Metrics, Regulation & Policy
- Taking steps towards a standard or set of guidelines
  - Define a prioritized list of all possible measurements that would fully define the acoustic environment for the community – potentially perform an extensive test (possibly multiple tests)
  - Define a subset of measurements and requirements for a standard – this will likely require analysis (from multiple groups) of the data from an extensive measurement campaign
  - Starting small and developing group input on specifying best practices/requirements

Develop a research measurement standard or set of guidelines which can be used to adequately quantify community noise impact
Empirical Data Processing

- Connection with other Subgroups

- Process ground-based acoustic measurements of steady flight conditions to provide input to Subgroups 1 and 3

Subgroup 2

Measure –
- Acoustic pressure time histories
- Vehicle position

Determine relationship between source and reception time

DeDopplerize (optional)

Segment time series and determine emission angles

Assess SNR

Depropagate –
- Atmospheric attenuation
- Ground losses
- Spherical spreading

Subgroup 1 -
- High quality time series (for tonal), harmonically averaged
- High quality spectra (for broadband)

Subgroup 3 -
- to compute metrics
- use for auralization
Review current research, existing standards, certification procedures and guidelines. Discuss interrelated items and develop SG consensus on testing topics, including confidence level needs.

- **Environment:**
  - Temperature profiles
  - Wind Profiles
  - Humidity
  - Ground Impedance
  - Terrain / Obstructions
  - Background Noise

- **Time Synchronization:**
  - Acoustics & Flight Vehicle

- **Signal Acquisition and Processing:**
  - Frequency Range
  - Dynamic Range
  - Spectral Resolution

- **Acoustic Measurements:**
  - Microphone orientation
  - Ground board material / geometry
  - Microphone location / array layout
## Progress Towards the Standard

<table>
<thead>
<tr>
<th>Topic</th>
<th>Part 36-H</th>
<th>ANSI S12.75</th>
<th>UNWG Subgroup 2 Decision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolved frequencies</td>
<td>50Hz – 10 kHz</td>
<td>5 Hz to 20 kHz (Central Recording Systems)</td>
<td>Upper range at least 10 kHz and potentially up to 20 kHz Lower range 20 Hz or half of the BPF, whichever is lower</td>
</tr>
<tr>
<td>Temperature</td>
<td>14 – 95 F</td>
<td>36 – 95 F</td>
<td>1) Adopt Part 36 Wording – “There may be no temperature inversion or anomalous wind conditions that would significantly alter the noise level of the airplane when the noise is recorded at the required measuring point.” 2) Measure at 2 altitude 3) Measurement location will depend on aircraft altitude</td>
</tr>
<tr>
<td>Pressure</td>
<td>Measurement required</td>
<td>Measurement required</td>
<td>1) Measure at 2 altitude 2) Measurement location will depend on aircraft altitude</td>
</tr>
<tr>
<td>Humidity</td>
<td>1) Between 20-95%</td>
<td>1) Between 10-95%, 20-95% preferred</td>
<td>1) Should be frequency dependent 2) Specification should be based on predicted impact</td>
</tr>
<tr>
<td></td>
<td>2) 8kHz 1/3 octave band no greater than 12 dB/100 meters</td>
<td>2) Measure @ 5ft AGL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3) Measure within 30 min of test @ 44ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wind Speed</td>
<td>&lt; 10 kt</td>
<td>1) &lt; 8 kt sustained 2) 8 – 12 kt discretion of director</td>
<td>1) Should be aircraft weight based</td>
</tr>
<tr>
<td>Background Noise</td>
<td>1) SNR &gt; 3 dB for each 1/3 octave band, else corrected “Last Good Band” 2) measure 30s average, 1/3 octave band</td>
<td>1) SNR &gt; 10 dB for each 1/3 octave band, else toss 2) Measure 30s average, 1/3 octave from 20 – 12.5 kHz</td>
<td>1) get away from 1/3 octave, use 1/12 octave or narrowband</td>
</tr>
</tbody>
</table>
SG2 Activities

- Co-Leadership:
  - Devin Boyle (NASA, GRC)
  - Juliet Page (Volpe, US DOT)
  - Kyle Pascioni (NASA, LaRC)

- Monthly Team meetings:
  - Third Thursday of the month, 12-1pm ET
  - Appx. 20-30 in attendance at meetings
  - Appx. 45 on distribution

- Actively developing a working document identifying measurement guidelines

- File sharing of documents via OneDrive
  - Eric Greenwood (PSU) provided a collection of empirical noise model literature
  - PSU is hosting the shared drive

- The following topics were briefed:
  - Anthony Martinez, Rory Nicholls, University of Salford (UK) – Data exchange / measurements for human response testing
  - David Read (Volpe) – Unconventional Aircraft Measurements - Choctaw Nation
  - Robert Downs (Volpe) – “Some considerations for fractional octave band spectrum calculations”
Ground and Flight Testing SG Data Status and Requests

• Datasets with sharing potential for advancing procedure development via analysis:
  • FAA UAS National Airspace Integration Pilot Program – Measurements of Unconventional Aircraft - Chocktaw Nation of Oklahoma, Daisy Ranch
    • 4 UAVs: three multicopters (5-45 lbs) and one fixed-wing vehicle (span ~7 ft)
  • PSU/FAA multirotor UAS, Beta Technologies vehicle (to be acquired soon)
  • NASA/FAA civil helicopter data (limited set of R44 flyovers)

• Request to the UAM community:
  • Vehicles for acoustic measurements
    • Would provide crucial data!
    • Would provide you with quality acoustic measurements and a better understanding of potential community impact

• Request to other UNWG subgroups:
  • Input from tools group on what outcomes from measurements may be useful
  • Input from metrics group on any specific attributes of importance
• Please reach out to Leadership to join UNWG SG2
  • Devin Boyle  devin.k.boyle@nasa.gov
  • Juliet Page  juliet.page@dot.gov
  • Kyle Pascioni  kyle.a.pascioni@nasa.gov
Aircraft Working Group: Urban Air Mobility Noise Working Group Update
Subgroup 3: Metrics

29 April 2021
Virtual Meeting

Group Leads:
Siddhartha Krishnamurthy (NASA), David Josephson (Josephson/Joby)
• Activities addressing UNWG White Paper recommendations regarding Human Response and Metrics
  • Data Acquisition
  • Ambient Noise
  • Human Response Models
  • Perception Influenced Design

• UNWG Subgroup 3 (SG3) primary focus: cooperative psychoacoustic test to gather human response to UAM vehicle noise
Data Acquisition

- UNWG White Paper Recommendation: Acquire/generate measured and simulated vehicle acoustic data and make those data available to support subjective response studies for metric and predictive model development.

NASA’s MAF can measure UAM sounds from NASA National Campaign.

Auralizations: simulated UAM flyover sounds.

![Mobile Acoustics Facility (MAF)](image)

![NASA's MAF can measure UAM sounds from NASA National Campaign](image)

![Auralizations: simulated UAM flyover sounds](image)
Ambient Noise

• UNWG White Paper Recommendation: Develop standardized processes for measuring and cataloging ambient noise and make data available to support subjective response studies for metric and predictive model development

• Durand Begault (NASA Ames) writing technical memorandum suggesting metadata structure to address UNWG white paper recommendation

• Metadata categories for ambient noise:
  - **Sound file identifiers** (unique information for identifying a particular recording)
    • Examples: File name, recording type
  - **Sound file detail** (information on the digital sound file format and duration)
    • Examples: Sample rate, bit depth, calibration method
  - **Instrumentation** (details regarding the microphones and set up used, ancillary video information)
    • Examples: Recorder name, microphone information
  - **Measurement notes**
    • Examples: Maps, weather, photos, notes on personally identifiable information
  - **Recording locale and time (UTC)**
    Examples: Address, date
Human Response Models

- UNWG White Paper Recommendation: Develop validated models for audibility, noticeability, and annoyance to UAM aircraft noise and evaluate their utility for assessing community noise impact.
- Models being developed by multiple organizations.
- From Andy Christian, January 25th Transportation Research Board Annual Meeting:
  - Predict how likely it was that a listener heard a signal in the presence of a masker.
  - Inaudible signal is fully masked.
  - Relate to annoyance.

![Diagram](https://via.placeholder.com/150)

- Statistical Measure of Audibility (d’)
- Signal
- Audibility Prediction
- Masker
Perception-Influenced Design

- UNWG White Paper Recommendation: Develop measures of human response and use as constraints in perception-influenced design. Ideally, such measures would be easily calculated and include sensitivities.

- Design optimization involving backwards differentiation:

  - Update Design With Gradient
  - Design Step 1, (ex. Blade Shape)
  - Design Step 2 (ex. CFD)
  - Design Step 3 (ex. Calculate Metrics)

  - Backwards Differentiation Step 1 (ex. df/dMetrics)
  - Backwards Differentiation Step 2 (ex. df/dCFD)
  - Backwards Differentiation Step 3 (ex. df/dBlade Shape)

  - Converged?
  - Yes
  - No

  - Optimized Design

- Work planned at NASA to incorporate human response metrics (e.g., sound quality metrics, annoyance models) into optimization process (red highlighted boxes)
UNWG White Paper Recommended Laboratory Studies

1. Until early entrants are fielded and community noise studies can be performed, laboratory studies should be used to understand differences in annoyance responses to UAM vehicles and existing aircraft noise sources.

2. A laboratory test campaign can 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 communities.

- Studies being planned and pursued by NASA and other organizations.
- Cooperative psychoacoustic test by UNWG member organizations is one such activity.
Cooperative Psychoacoustic Test

(The UNWG Human Response Study)

Conduct large psychoacoustic test on UAM vehicle noise using testing facilities around the world

Goals:

1. Assemble a wide range of recorded and auralized UAM vehicle sounds through cooperation between multiple agencies and organizations for use in human response studies
2. Provide insights into community response of UAM vehicle noise that would be challenging for any single agency or organization to acquire
3. Create a rich database of community response to UAM vehicle noise that can be used for subsequent novel analyses
UNWG Human Response Study Phases

• **Phase I: Feasibility Study**  
  - Human response to short-term exposure to noise of different aircraft  
  - UNWG Metrics Subgroup members provided feedback on HMMH and Arup jumpstart activity reports (discussed at Fall 2020 ATWG/UNWG meeting)

• **Phase II: UAM Vehicle Noise Perception**  
  - Human response to UAM vehicle noise in different urban soundscapes
Human Response Study Feasibility Phase: Requirements

- Primary goal: collect annoyance responses to short-term exposure to different aircraft
- Subjects will be asked a single question on annoyance response
  - Test subjects come from UNWG member organizations
  - Remote testing platform will be used
  - Test will include introduction video, practice session with video, and post-test survey
Human Response Study Feasibility Phase: Remote Testing Platform

• Remote testing platform will allow subjects to use their own headphones and laptops
• Platform will provide means for sound calibration

• Platform development and execution of psychoacoustic test currently being pursued by NASA
Current/Upcoming Activities

• Pre-test activities:
  • Stimuli generation
  • Test question discussion
• Limited discussion on post-test activities (agreement on criteria to remove outliers in data)
• David Bowen (ACEN TECH) will give talk on Design for Sound Quality at May 12, 2021, subgroup meeting
Questions?
Image References

- Slide 3:
  - AAM Concept art from: https://www.nasa.gov/sites/default/files/thumbnails/image/aam-design4-new-image-2-24-2021-3.jpg
  - Spectrogram generated by presenter.

- Slide 5:

- Slide 6:
  - Flowchart generated by presenter.

- Slide 9:

- Slide 10:
Aircraft Working Group: Acoustics
Technical Working Group Update

Subgroup 4: Regulation and Policy

Group Leads:
Bill He (FAA), Royce Snider (BellTextron)
UAS noise certification via Rules of Particular Applicability (RPA)

- FAA presented RPA concept/examples at the recent SG4 and NASA Acoustic Technical Working Group Meeting
- Noise (type) certification to address innovative aircraft designs that can’t fit into existing part 36 noise testing procedures/standards
  - RPA case-by-case in nature, G-3 Issue paper process (FAA Order 8110.112A) used
  - FAA will issue a Federal Register Noise on the first RPA soon
  - RPA is an interim approach, opportunity for gaining experiences
  - Research is ongoing to inform future regulations (general applicability)
- SG4 discussed this with great interests as elements may be relevant for UAM/AAM

Small UAS 14 CFR Part 107 Operations Over People Rule

- This rule was published on 15 January 2021 allowing UAS no more than 55lbs to fly at night and over people under certain conditions
- Even though noise certification is not currently required for UAS operating under Part 107, the FAA continues to seek and collect available noise data on unmanned aircraft models

FAA released draft AC 150/5390-2D, Heliport Design, for comments in early 2021
• This advisory circular (AC) provides standards for the planning, design and construction of heliports serving helicopters
• Incorporates policies and procedures for considering environmental impacts, including noise
• “The guidance provided in this AC is limited to heliports and helicopter operations. This guidance does not address landing areas for or operations by vertical takeoff and landing (VTOL) aircraft or unmanned aircraft.”
• Comment period closed

FAA released Neighborhood Environmental Survey results for public comments in early 2021
• FAA conducted a nationwide survey regarding annoyance related to aircraft noise
• Results and more research are expected to inform future noise policy
• Comments period closed. FAA is currently reviewing 4000+ comments received. https://www.faa.gov/regulations_policies/policy_guidance/noise/survey/
Community Engagement

- VFS Infrastructure for UAM Workshop discussion panels held 2-4 March
  - Infrastructure Policy Challenges, Industry and Local Perspectives
  - State & Municipality Strategic Considerations
    - Provided an overview of lessons learned as it applies to local policy, community outreach, and engagement strategies
  - Advancing Technology Through Policy
    - Community Engagement and Unlocking Scaled Advanced Air Mobility
    - Vertiport Infrastructure: A Case Study – Practical and Legal Considerations

Noise is a top community concern, behind only safety

Private heliports that receive no federal funding are regulated by States and/or local jurisdictions, not the FAA

3,000+ county jurisdictions in the US

~20,000 incorporated jurisdictions in the US

Standardization is key
SG4 Actions on White Paper Recommendations (1 of 2):

1. 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.

   ➢ Subject to Applicant data availability, need being monitored

2. 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.

   ➢ Item i) Coordination with SG1 activities, FAA ASCENT Project 49 (Modeling of UAM Noise); Item ii) SG4 activities (slide 3), VFS NAWG, FAA ASCENT Project 61 (Noise Certification Streamlining), GAMA EPIC/eVTOL/AIA

3. 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.

   ➢ US DOT Volpe “certification-compatible” noise research measurements of unconventional aircraft, coordination with SG1, SG2, SG3 activities, NASA / FAA AAM National Campaign to include noise footprint, FAA ASCENT Project 77 (Measurements to Support Noise Certification for UAS/UAM)
4. 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.

- FAA considering industry comments to draft AC 150/5390-2D, Heliport Design (slide 3)

5. 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.

- VFS Infrastructure for UAM Workshop (slide 6), UNWG community engagement resource site (under consideration), coordination with SG3 to leverage Human Response Study results and other activities

- Engage AAM Announcement of Collaborative Partnership Opportunities, section 2.3 AAM Community Planning and Integration
UNWG Contacts

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**Subgroup 4**
Bill He (Hua.He@faa.gov)
Royce Snider (rsnider@bellflight.com)
Upcoming Aircraft WG Meetings

Typically, the Aircraft Working Group holds their meetings on the last Thursday of every month from 3:00PM - 4:30PM ET (12:00PM - 1:30PM PT).

- May 27, 2021: Topic: Autonomy
- June 24, 2021: Topic: eSTOL
- July 29, 2021: Topic: “Pilots Perspective”

– POCs: Carl Russell: carl.r.russell@nasa.gov & Anna Cavolowsky: anna.e.cavolowsky@nasa.gov
Upcoming AAM Working Group Meetings

• **Airspace Working Group: TBD**
  – **DATE:** Tuesday, May 18, 2021
  – **TIME:** 1:30PM – 3:00PM ET (10:30AM – 12:00PM PT)

• **Crosscutting Working Group: Assurance of Autonomy**
  – **DATE:** Tuesday, May 25, 2021
  – **TIME:** 11:30AM – 1:00PM ET (8:30AM – 10:00AM PT)
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Thank You for Joining!