FAA’s Role in Progress towards Urban Air Mobility Acoustic Noise Models and Simulations

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Apr. 29, 2020
About Myself

- Education: B.S. Mechanical Engineering (Rowan University)
- Work Experience: Engineer with the FAA for past 10+ years
- Qualifications: UAS Pilot (ScanEagle, Solo, Parrot, Phantom, etc.), Private Pilot (ASEL)
- Hobbies: Racing (NASCAR/INDYCAR/F1), Philly Sports Fan, Guitarist, Outdoorsman,
My Role at the FAA

- Official Title: General Engineer
- Unofficial Titles: Part “Program Manager, Project Lead, Flight Test Engineer, Contracting Officer Representative, Purchase Cardholder, Inventory Delegate, UAS/GA Pilot, Simulator Instructor/Operator, Psychologist, etc.” (often serving in multiple capacities at the same time!)
FAA William J. Hughes Technical Center
Vertical Flight Safety Research at the FAA WJHTC

- Certification Standards (Wire Strike Avoidance, Bird Strike Avoidance, Flight Controls)
- Hazard Avoidance/Safety Risk Mitigation (Helicopter Flight Data Monitoring for ASIAS)
FAA’s S76-D Simulator

- Integrated with FAA’s WJHTC Simulation Labs
- Paired with Aviation Weather/Navigation Apps (i.e. Foreflight, etc.)
- Tailorable for various Weather Conditions
- Displays are configurable
- Eye-trackers/cameras
- HWD/HMD Integration
- SVS Integration
- EVS/CVS Integration Possible
FAA Experimental Helipad (HPM77)
UAM Noise

Community/Regulatory Noise Implementation Risk Factors
1. Community Sensitivities (surrounding additional noise sources)
2. Environmental Impacts
3. National Airspace System Impacts (on Air Traffic Control and other users)
4. Airspace Redesigns/Route Optimizations
5. e-VTOL Aircraft Designs for Low Noise
6. Terminal & EnRoute Noise Assessments
7. UAM Fly Neighborly Procedures

BOTTOM LINE: NOISE IS ONE OF THE TOP 5 CHALLENGES FOR UAM AND THE KEY TO A SUCCESSFUL UAM INDUSTRY! (Source: NASA UAM Market Study 2018)
Q: How do we build a framework for better UAM acoustic noise models?

A: Examine what has been done for Helicopters. This could enable a “straw man” UAM aircraft and transition of pre-existing aero-acoustic modelling tools (i.e. AEDT) to the UAM problem space as a "what-if concept".
Helicopter Acoustic Noise Measurements and Models Modelling

• Research Purpose
  – Characterize existing helicopter acoustic noise signatures and develop more accurate acoustic noise models and new noise abatement procedures for twin-engine helicopters

• Sponsors & Key Stakeholders
  – Office of Environment and Energy (AEE)
  – Dept. of Transportation VOLPE Center
  – NASA
  – Helicopter Association International (HAI): Fly Neighborly Program
  – United States Helicopter Safety Team (USHST)
  – International Helicopter Safety Foundation (IHSF)
Flight Test Objectives

• Primary Objectives
  – Better understanding of the physics regarding vertical lift acoustics
  – Development and validation of acoustic noise models and informing semiempirical models
  – Develop safe ways to fly quietly and examine safety aspects and limitations of procedures (i.e. Fly Neighborly Approaches for the following conditions)
    • Turning flight
    • Transient maneuvers
    • Effects of ambient conditions
    • Effects of trim changes
    • Validation of noise abatement techniques

• Secondary Objectives
  – Characterize vehicles’ noise signatures
  – Generate helicopter flight data for possible ASIAS noise metrics
  – Provide input data for mission / land-use planning models
Measurement Types

- Steady source noise characterization
- Ground noise footprint
- Transient maneuvers
- Hover
Steady Source Noise Characterization

• Vehicle maintains forward flight condition with constant operating state

• Data typically used for:
  – Source noise characterization
  – Empirical models (NPDs, noise spheres)
  – Model calibration (FRAME, AEDT)
  – Model validation
Transient Maneuvers

• Vehicle rapidly changes flight / acoustic state
• Data typically used for:
  – Gaining understanding of the underlying physics
  – Development of low noise procedures
  – Model validation
Ground Noise

• Collect data over wide area for a particular operation (i.e. steady or unsteady)

• Data typically used for:
  – Characterizing noise of slowly varying operations (i.e. approach to landing)
  – Evaluation of noise abatement procedures
  – Validation of empirical models
Flight Test Platforms
(Leonardo AW139, Piper Archer, Sikorsky S76)
Mobile Acoustic Facility (2.0)

Transport, field maintenance, control, and operation of:
- Wireless Acoustic Measurement System (WAMS)
- DGPS survey system (cm accurate)
- UTVs
- Weather instrumentation
- Aircraft instrumentation
- Air-to-Ground, Ground-to-Ground voice and data communications
- Externally powered or quiet generators
"Joint NASA/FAA/VOLPE Acoustic Test – 2019" Location – Coyle Field (NJ20)
Wireless Acoustic Measurement Systems (WAMS)

- One channel per box
- LEMO and CC microphones supported
  - GRAS 67AX
  - B&K 4964
- On board data storage
- Real time health monitoring
- GPS provides time code as well as position
- Near-simultaneous sampling across units
- Up to 50 mile range
- Battery operation w/solar power augmentation
## Next Generation WAMS II

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<th>WAMS I</th>
<th>WAMS II</th>
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<td>Size</td>
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<tr>
<td>Weight</td>
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<td>Depth</td>
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<tr>
<td>Power Draw</td>
<td>6 W</td>
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<tr>
<td>Accuracy – DAQ</td>
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<td>24 bit</td>
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<tr>
<td>Accuracy – GPS (Timing)</td>
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<td>10 nanoseconds</td>
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<tr>
<td>Temperature Range</td>
<td>32°F to 122°F</td>
<td>-40°F to 176°F</td>
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<tr>
<td># Of Units</td>
<td>36</td>
<td>80 in production (26 complete)</td>
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Aircraft Instrumentation

Aircraft Navigation Tracking System (ANTS)
- Powered by Lithium Ion Battery
- 6 DoF INU measurements
- GPS
- Records on SD card
- 50 Hz sample rate
- 6” x 3.75” x 2.2”
- 2.5 pounds

Stratus 3
- Portable ADS-B Receiver
- AHRS
- Flight Recording via Foreflight

BadElf GPS Pro
- GPS (Position and Altitude)
- Groundspeed

GoPro Hero 5 Black/Axis Cameras
- Video of Flight Instruments
- Video of Outside View
- Cockpit/ATC Audio
Ground Instrumentation

ZephIR 300 LIDAR
- 11 selectable heights from 30 to 900 feet AGL
- 1 sample/second/height (11 second full profile)
- Battery/solar panel

Davis Weather Station
- Winds (Speed and Direction)
- Barometric Pressure

Precision Approach Path Indicator System (PAPI)
- Angles remotely set
- Battery operated
## Sample Flight Test Card

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<tr>
<th>Noise Abatement Approaches</th>
<th>Code</th>
<th>Entry Speed</th>
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</table>
Helicopter Acoustic Noise Modelling Video of Flight Trial
Acoustic Re-Propagation Technique

- Helicopter maintains steady flight condition throughout measurement
- Observation angles of microphones shift during flyover
- Single “compact” source of emission assumed (typically main rotor hub)
- Measurements resolved to surface of hemisphere
Empirical Noise Modeling

1. Divide flight track into linear segments
2. Determine steady flight condition for each segment
3. Select measured hemisphere from database
4. Propagate from hemispheres to ground along each segment
Test Results

- Rapid maneuvers lead to sudden increase in noise due to BVI
- Multiple interactions activated during maneuver
- Individual interactions correspond to those seen in steady-flight
- Directivity changes with orientation of helicopter
Example Test Measurement (USCG MH-65 Dauphin)
Model-Based Approach

Fundamental Rotorcraft Acoustic Modeling from Experiments (FRAME)

Model Calibration

Experimental Data

Modeling

Generalization

Acoustic Transformation

Parameter Identification

Noise Source Separation

Analytical Modeling $f(\mu, \Lambda, C, M_0)$
Other Considerations for UAM Noise

- Applicable Regulatory, Policy, and Guidance Material
  - 49 USC 44715
  - 14 CFR Part 36 (and Part 34 – don’t forget emissions!)
  - 14 CFR Part 150
  - FAA Order 1050.1f
  - Advisory Circulars (AC 91-36D & AC 36-4C)
- Noise Metrics (DNL, EPNdB, SEL, etc.)
- Analysis Methodologies
Thank You!