Passenger Air Vehicles Noise Requirements

Yahia Ismail, Steven Morris, Martin Kearney-Fischer, and Nikola Baltadjiev
Aurora Flight Sciences
Cambridge, MA

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Overview

- Aurora Flight Sciences Passenger Air Vehicles (PAV)
- Current Noise Certification
- Design for Quieter PAV – Noise Simulation Tools
- Design for Quieter PAV – Model and Full Scale Validation
- Noise Metrics – Loudness vs Annoyance
- What Would be a Subjective Noise Metric for PAV?
- Summary

Current Noise Certification
FAA CFR

2016 CFR 14, Chapter 1, Part 36 Subpart F	2016 CFR 14, Chapter 1, Part 36 Subpart H	2016 CFR 14, Chapter 1, Part 36 Subpart K
Propeller Driven Small Airplanes and Propeller-Driven, Commuter Category Airplanes	Helicopters	Tiltrotors
36.501 Noise limits	36.801 Noise measurement 36.803 Noise evaluation and calculation 36.805 Noise limits	36.1101 Noise measurement and evaluation 36.1103 Noise limits

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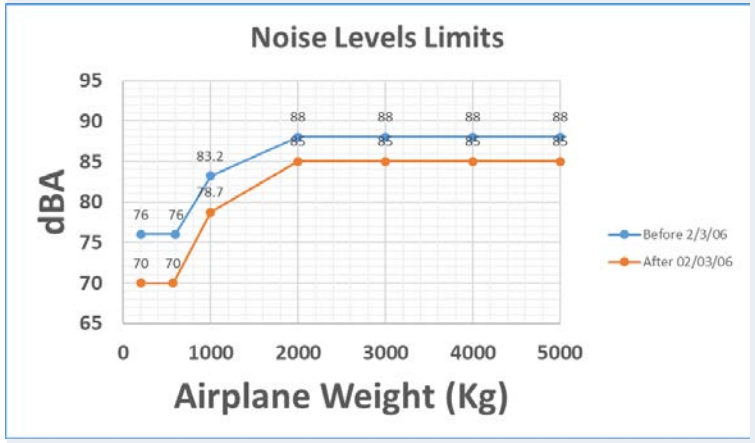
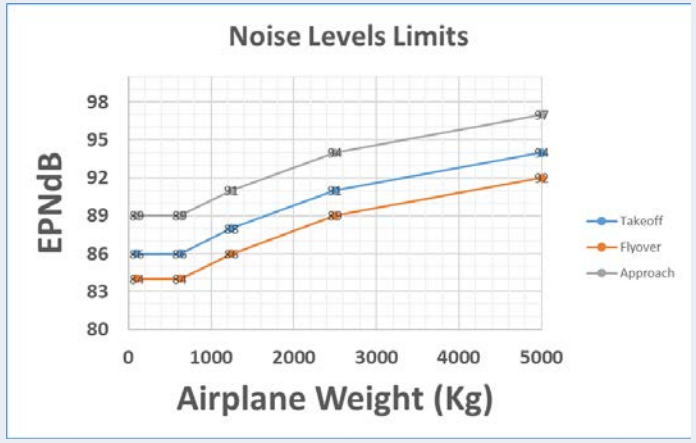
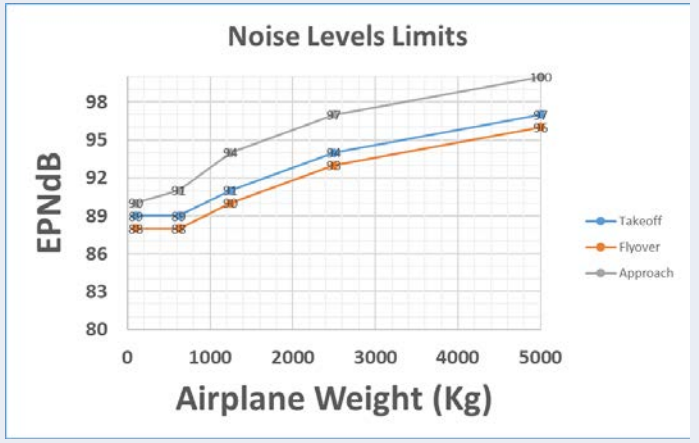
		

PAV Could be Certified Under Subpart F, H, K or a new Category

Design for Quieter PAV

Meet Noise Requirements

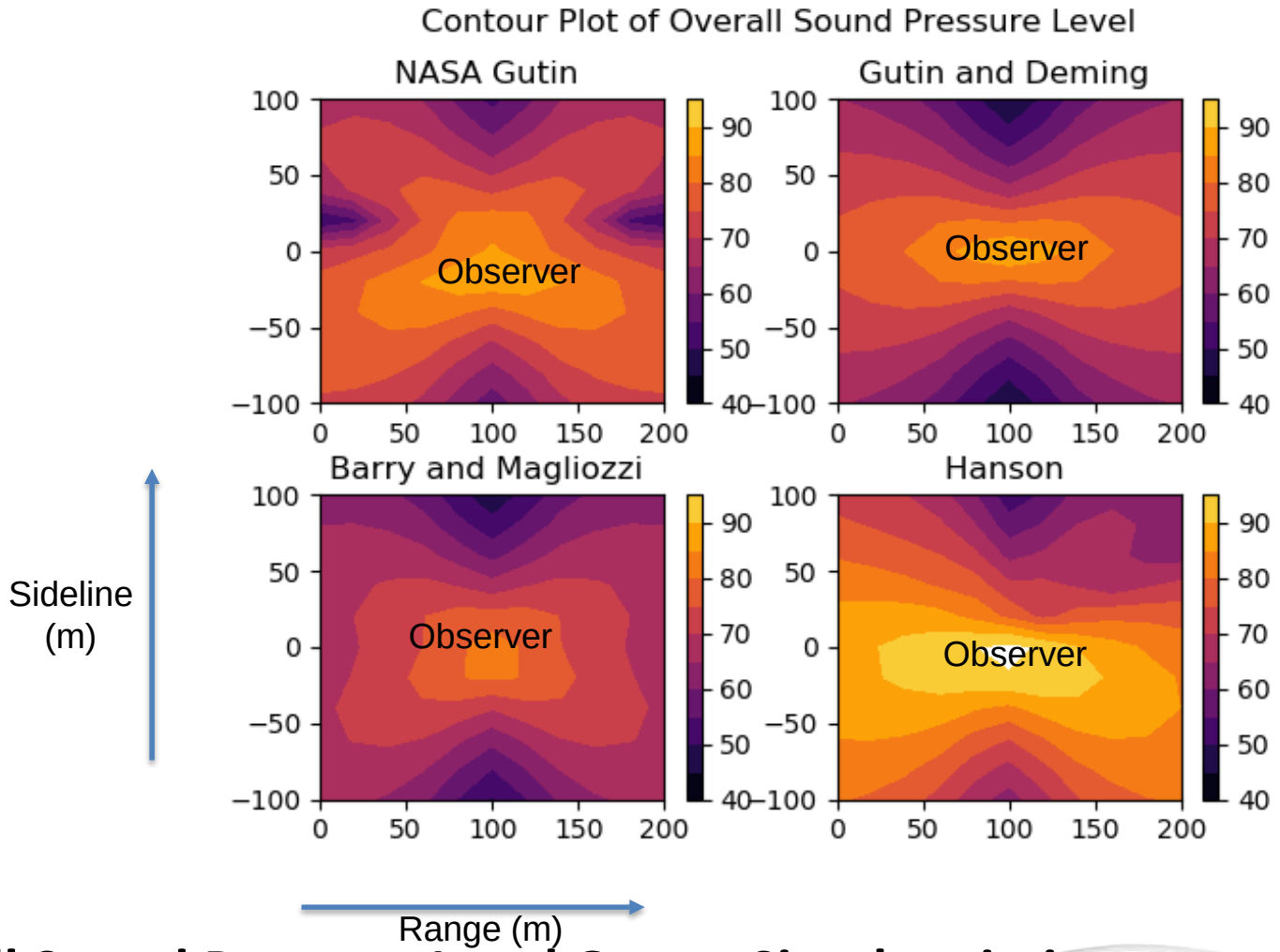
- Conceptual Design – Preliminary Tools
- High Fidelity Simulation CFD/CAA
- Propeller Stand and Wind Tunnel Testing
- Full Scale Flight Test Validation

Full Use of Noise Simulation and Testing to Achieve Noise Objectives

Conceptual Design Tools

Open Rotor Noise Footprint

- Use preliminary noise models to make a quick assessment of noise footprint
- Different levels of fidelity based on where we are in the design phase
- Different noise metrics can be estimated for a given mission and vehicle



Contour Plot of Overall Sound Pressure Level Over a Simple mission using four different levels of fidelity

High Fidelity Simulation

Rotor Design, Vehicle Interaction, Full Vehicle Noise

SOURCE PREDICTION - Star-CCM+/PowerFLOW

- URANS/DES/LBM CFD – Source Prediction (high computational cost simulation)

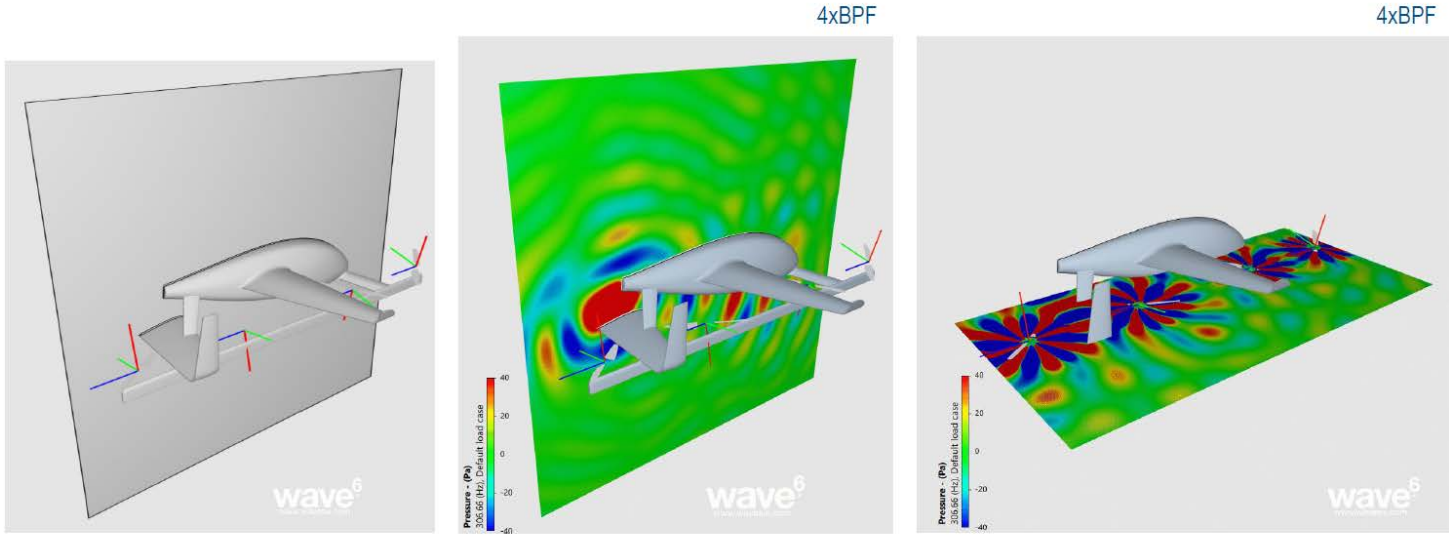
ACOUSTIC PROPAGATION - Wave6

- Ffowcs Williams - Hawkings Model
- Acoustic Finite Element Analysis
- Statistical Energy Analysis

FULL VEHICLE NOISE PERFORMANCE

- High Fidelity Rotor Geometry Design
- Multirotor Interaction Effects
- Rotor-Vehicle Interaction Effects
- Interior Noise

Example multirotor source interaction analysis from Wave6



Use State of the Art Noise Simulation to Predict Noise with Accuracy

Component and Wind Tunnel Testing

- Prop Stand to perform full scale propeller performance and acoustics testing
- Array of microphones to measure rotor noise at several observer locations
- Use of Boeing noise laboratory anechoic chamber for propeller performance and acoustics testing

Acquired five new class 1 sound level meters that can acquire +/- 1 dB accuracy, narrowband frequency resolution up to ~20 kHz

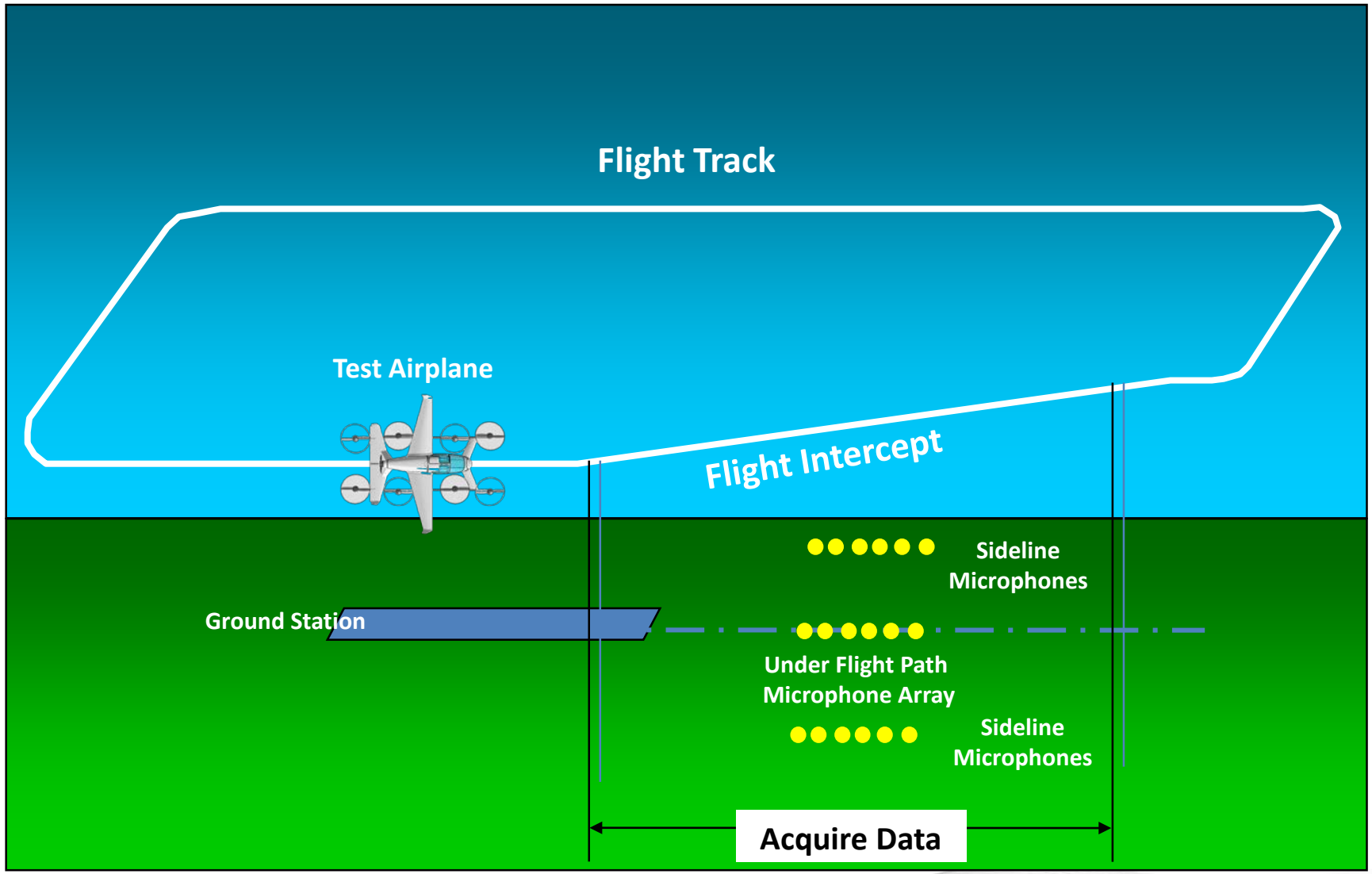
Boeing Anechoic Chamber

Wind Tunnel and Propeller Stand Testing To Verify Design

Full Scale Validation and Certification

- Full scale noise validation will be conducted using an array of microphones to verify vehicle noise levels for a given background
- The microphone array will comply with CFR 14 measurement locations
- All measured data will be corrected for performance and weather reference conditions

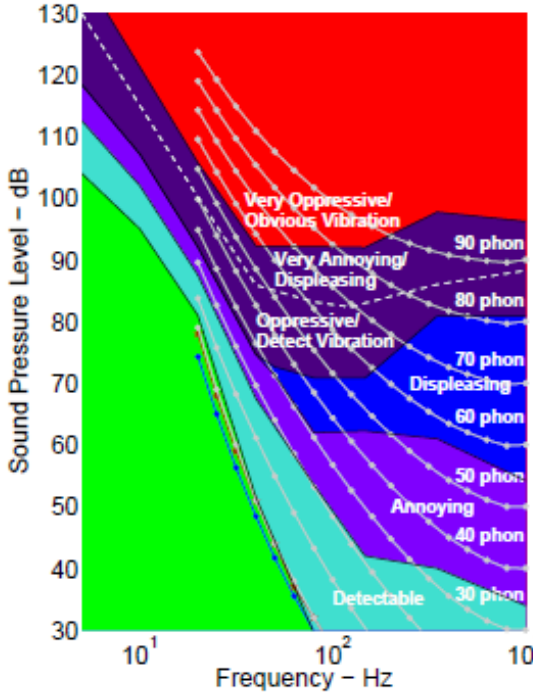
Race track for flyover

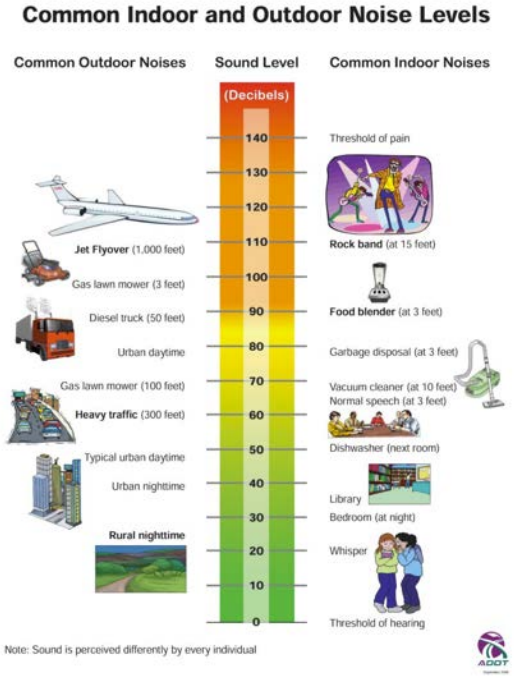


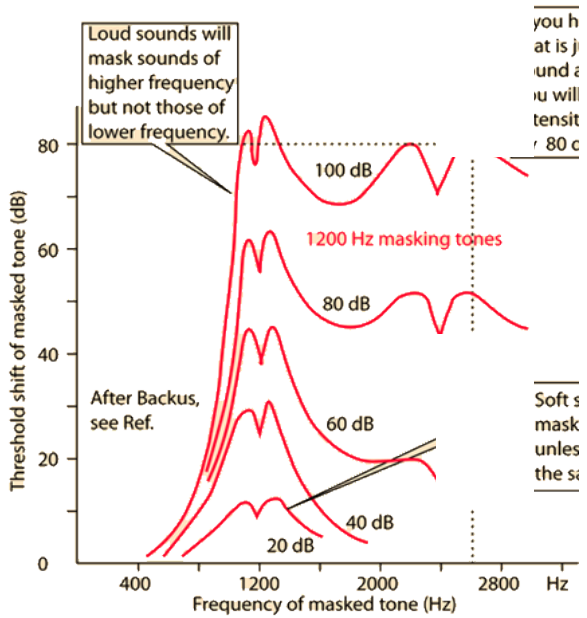
What Would be a Subjective Noise Metric for PAV or Similar Vehicles?

Noise Perception

- Perceived loudness depends on frequency content of noise source
- Noise deltas are more important than absolutes
- Noise backgrounds and interactions can result in complex perception pattern







Annoyance can be highly subjective, including cognitive bias.

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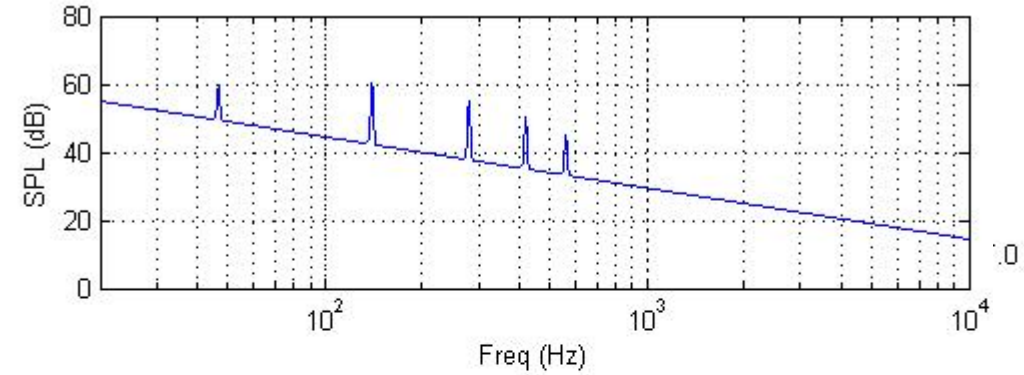
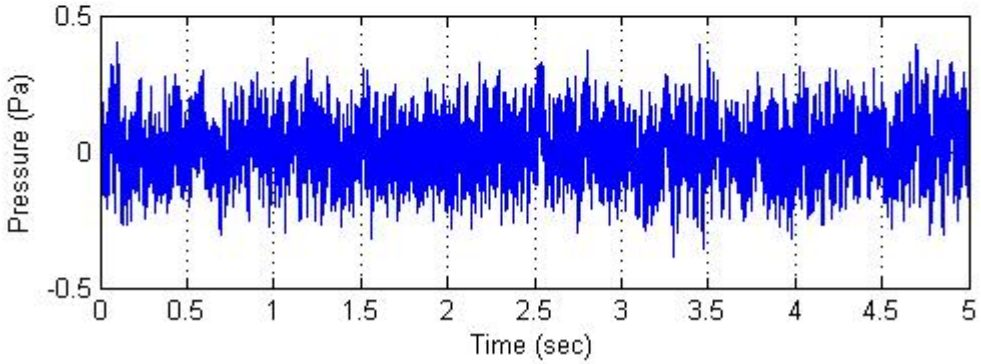
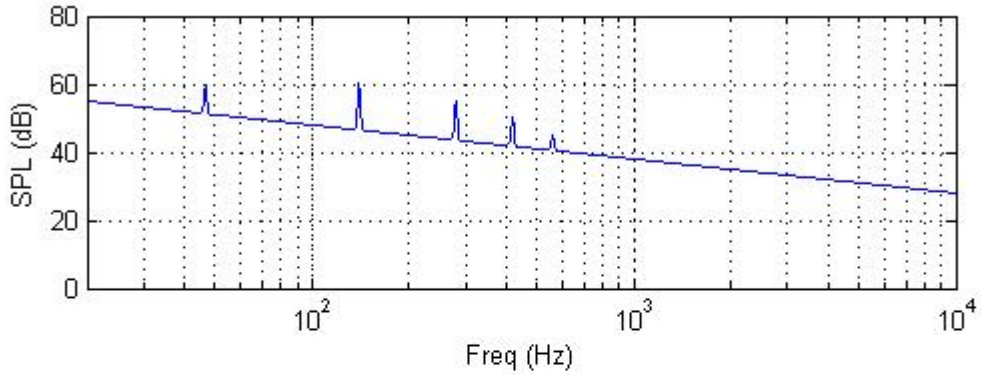
Rural Vs Urban Areas

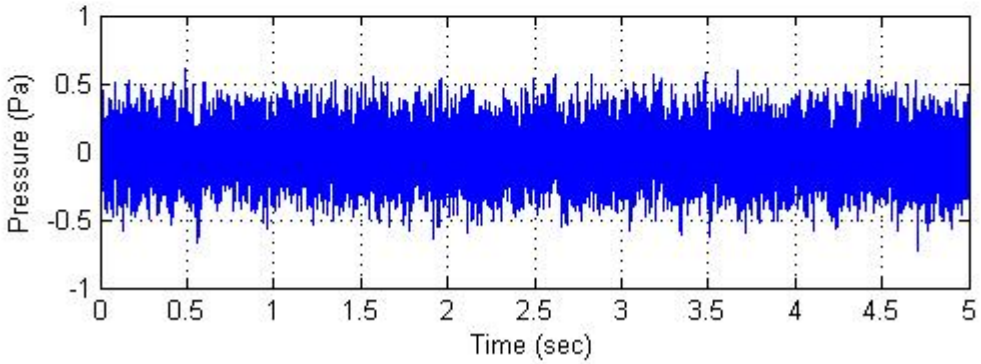
- In Quieter Rural and Suburban areas, tone levels will be distinguished
- In Urban area many of the tones will be masked by the background





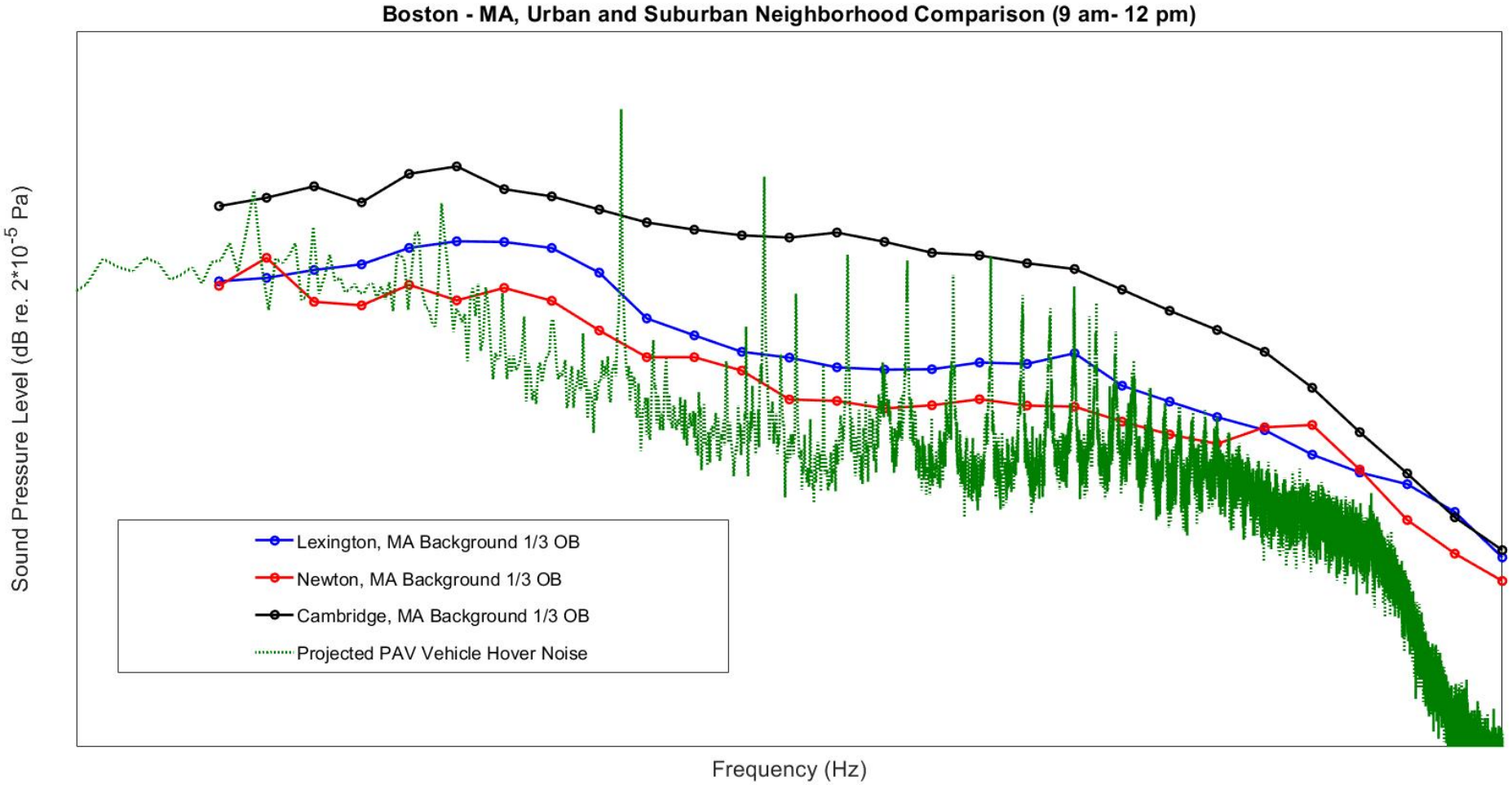
Rural Areas





Urban/Suburban Areas

Current Projected Open Rotor Performance Against Urban Background



Spectral Irregularity and Background Noise Has Significant Impact on Perceived Noise

Noise Requirements for PAV

- Based on Urban and Suburban background noise, a conventional metric may not be sufficient for the PAV

- Whether we use dBA, SEL or EPNdB, background noise has to be considered

Summary

- Aurora Flight Sciences Successfully Completed its First Flight Testing of a Passenger Air Vehicle (PAV) at a test site in Manassas, VA
- Different Noise Certification Categories (Small Airplane driven propellers, Helicopters and Tiltrotors) that may fit the new Passenger Air Vehicles
- Advanced Noise Simulation Tools from Conceptual to Detailed design Tools, Model Scale Wind Tunnel, Component and Full Scale Noise Validation Flight Testing are used to Design a Quieter Vehicle
- Background Noise of Different Urban Areas will have significant impact on the Noise Limits Definition for the new Vehicle
- Noise requirements or metrics based on Loudness (EPNL) or Annoyance (SEL) need to be defined for the PAV Category

Questions?