



Acoustic Flight Tests of small Unmanned Aerial Vehicles (sUAVs)

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Outline

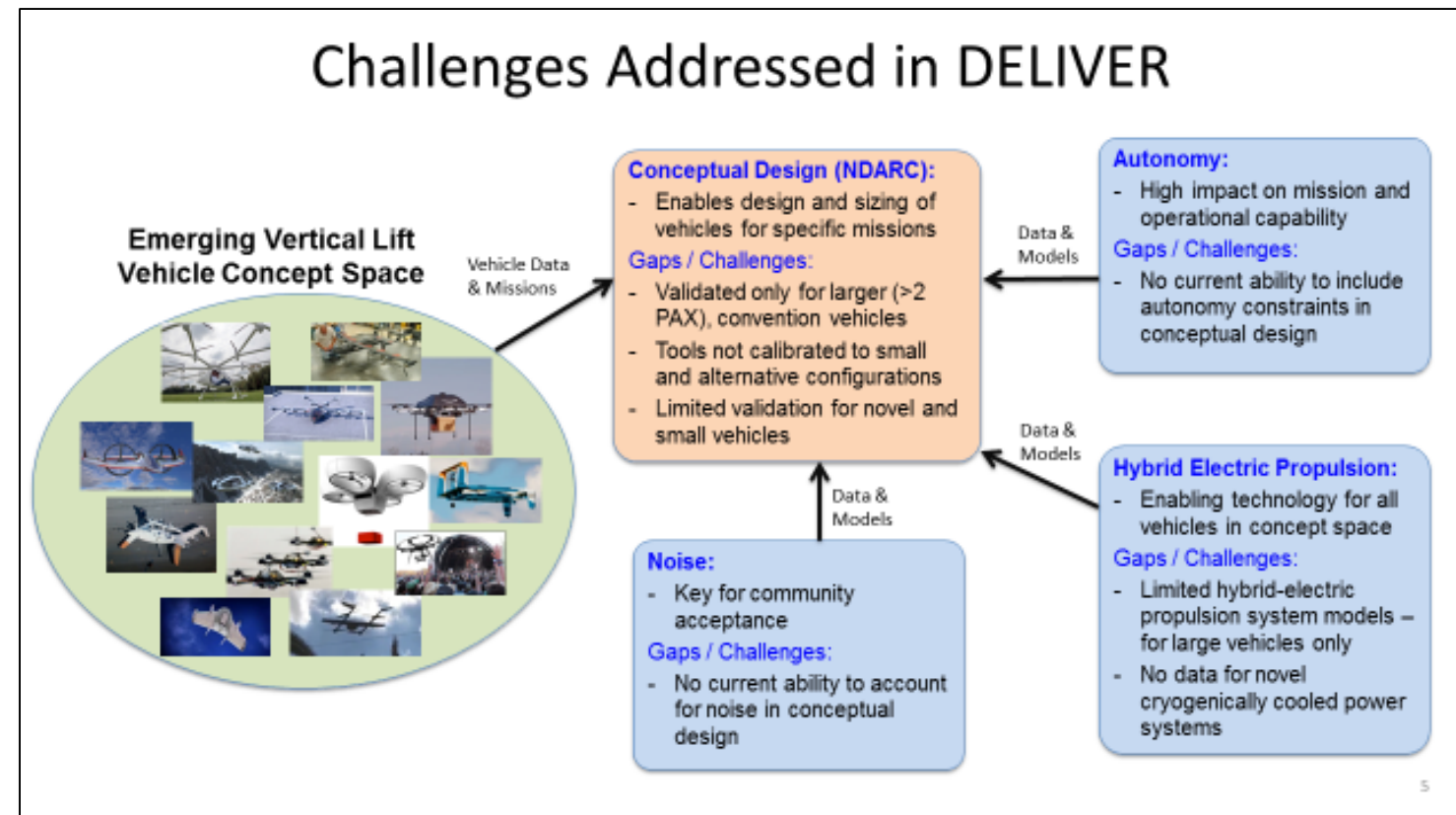


- Motivation
- Recent sUAV Flight Tests
- Basic sUAV Noise Characteristics
- Some acoustics metrics applied to sUAV noise
- Conclusions and Future Work

Motivation

Improve our understanding of sUAV noise to assess the feasibility of including acoustics in small UAV design. Flight measurements inform modeling and annoyance studies.

- Work is funded by NASA's DELIVER project
- “Small” UAVs refers to vehicles under 55 lbs.
- Current focus is COTS vehicles



Recent Flight Tests

Virginia Beach Airport (12/2014)

- Private grass airfield, 1500m x 60m
- 2 fixed-wing vehicles, 1 quadcopter, 1 tricopter (with co-axial rotors)
- 3 ground mics, 1 mic on 1.2m stand
- No on-site meteorological data



Fort A.P. Hill (8/2015)

- Paved 365m x 30m runway
- Piggy-backed on ERA-funded airframe noise test
- 1 fixed-wing vehicle and 1 hexcopter
- 4 ground mics; weather station ~4m off ground



Vehicles, pilots, & range safety provided by LaRC's UAS Ops. office and Aero. Systems Eng. Branch

Summary of Flight Events

Flight events judged to be acceptable, with minimal extraneous noise, good vehicle state data (pitch, roll, yaw, position), and acceptable trajectory:

Vehicle	Vehicle type	Power source	# flyovers	# hovers	Nominal height range
Carbon Cub	Fixed-wing	IC engine	3	-	10m
Edge 540	Fixed-wing	IC engine	12	-	20-100m
Prioria Hex	Hexcopter	Battery	14	10	1.5-32m
Phantom 2	Quadcopter	Battery	6	5	4-18m
3DR Y6	Hexcopter/tri	Battery	-	11	10-16m



Cub



Edge



Hex



Phantom

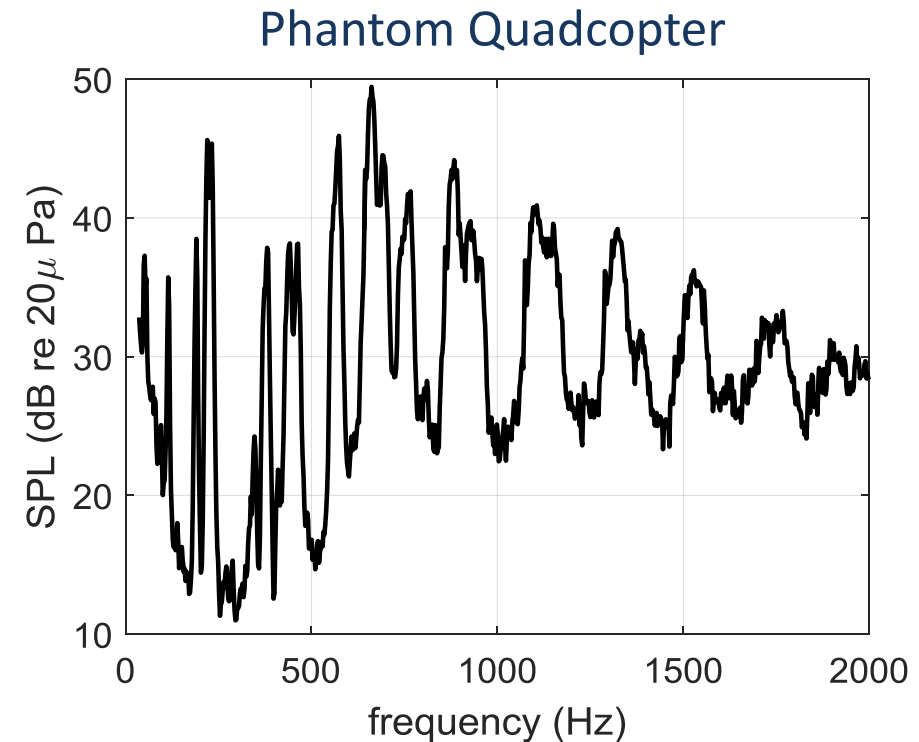
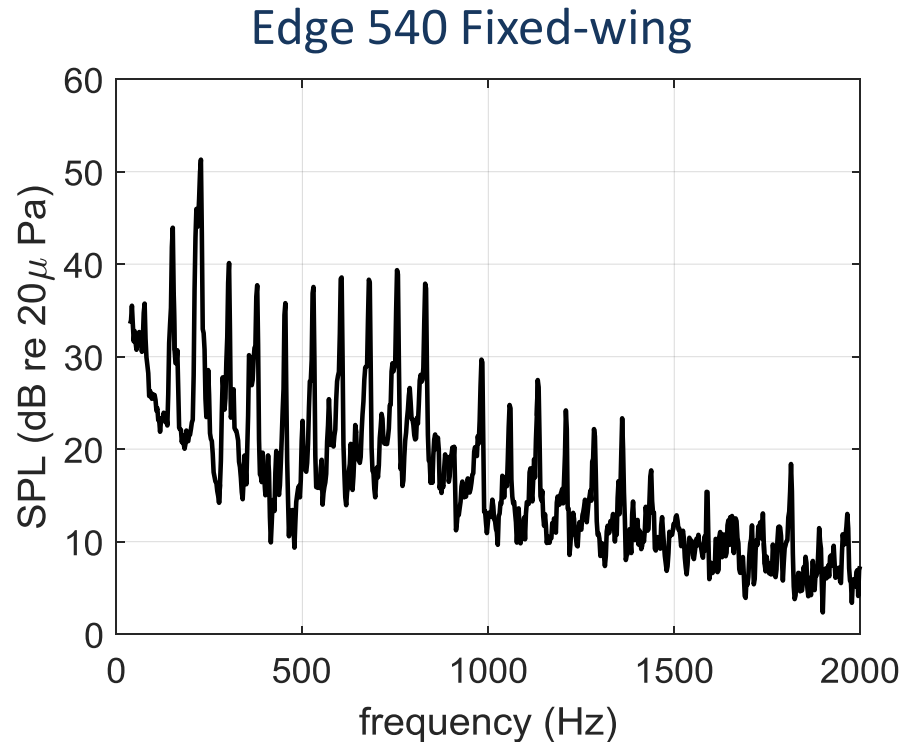


Y6

Basic Spectral Characteristics

Spectra dominated by propeller/rotor tones

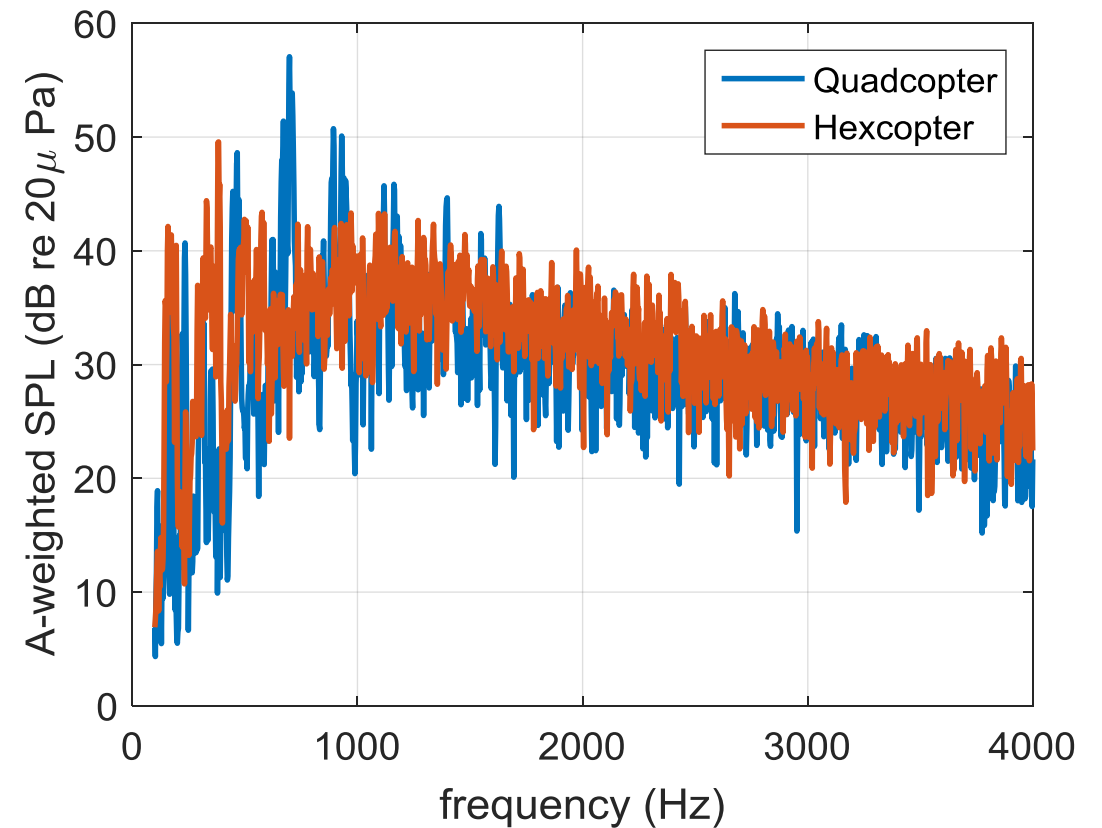
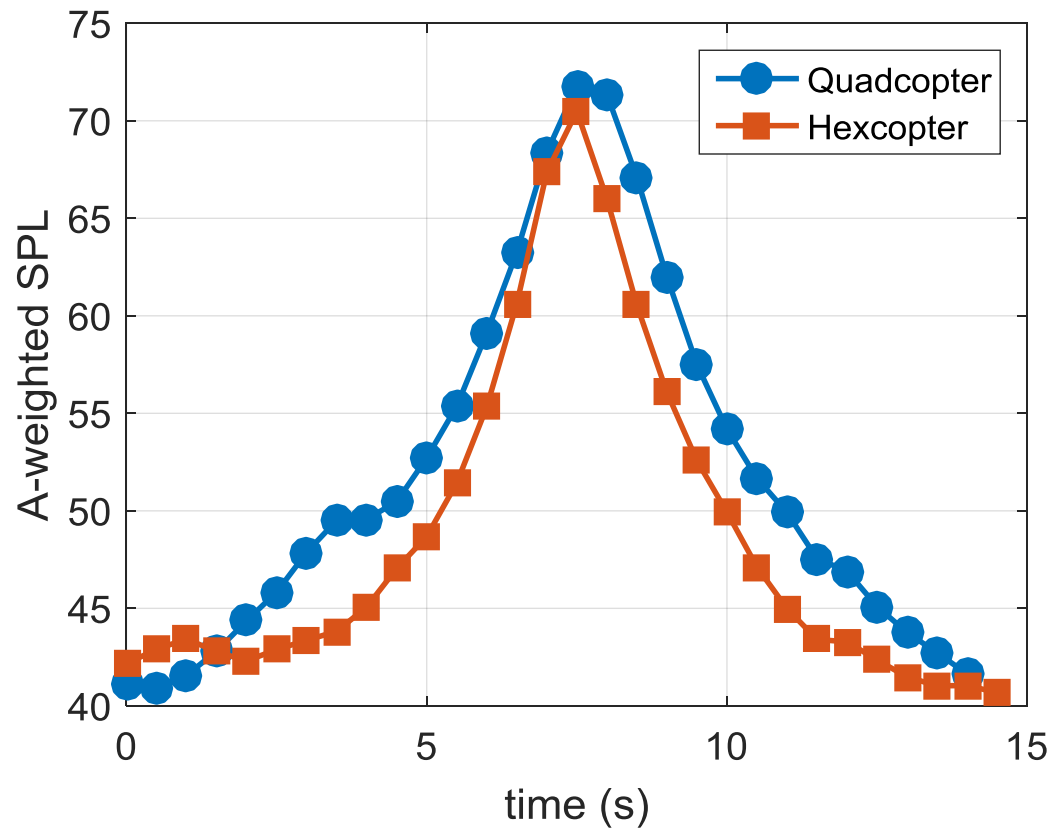
- tip Mach number ~ 0.2 for multicopters, ~ 0.5 for fixed-wing
- Multicopters use rotor rpm to control vehicle attitude



Multicopter Flyovers



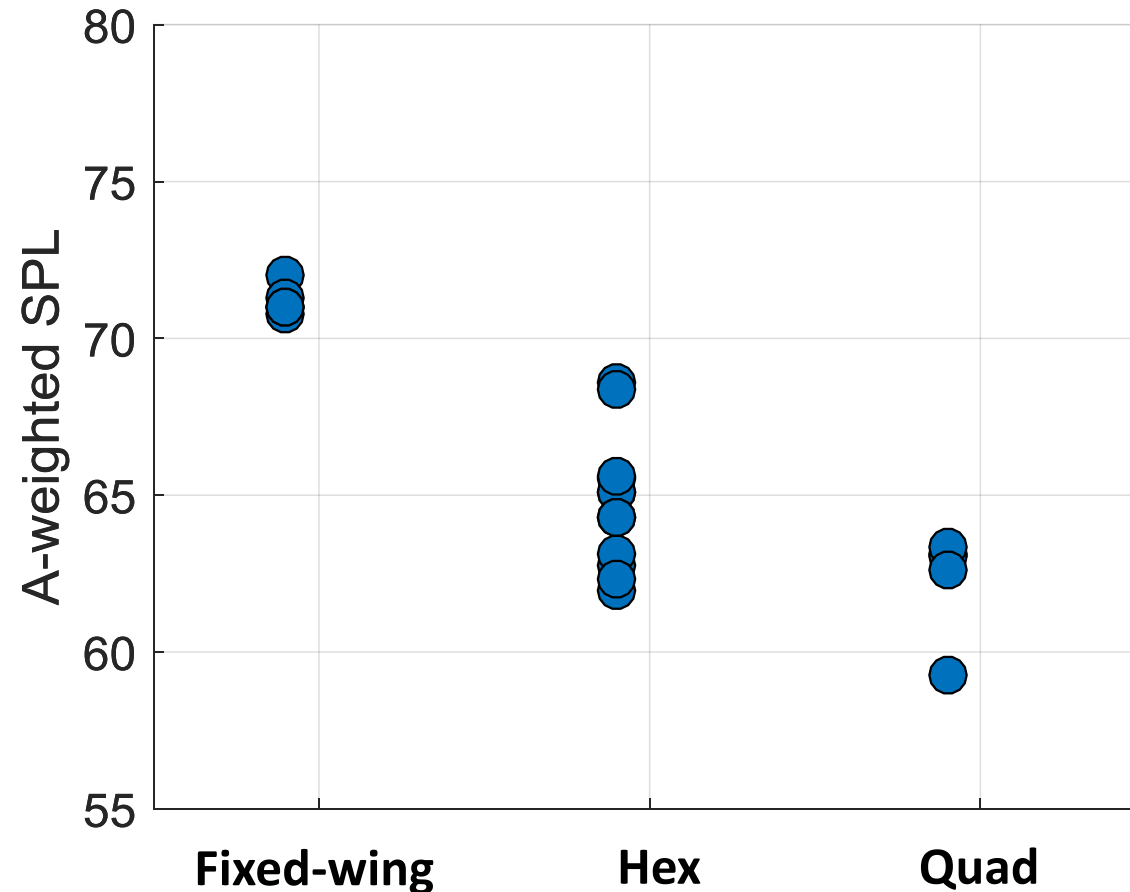
Time history of A-weighted SPL for flyovers ~5m above microphone





Max A-weighted SPL for Flyovers

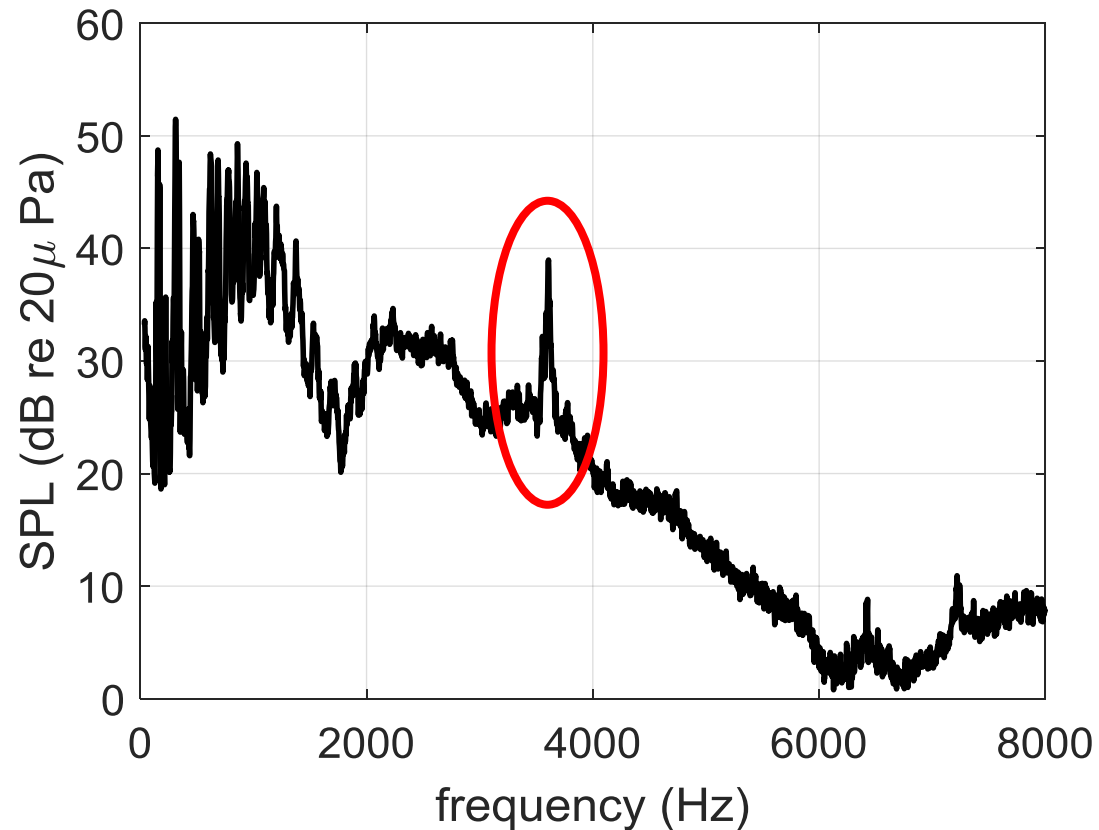
L_{Amax} levels adjusted as if flyover were 15m above microphone (assuming spherical spreading only)



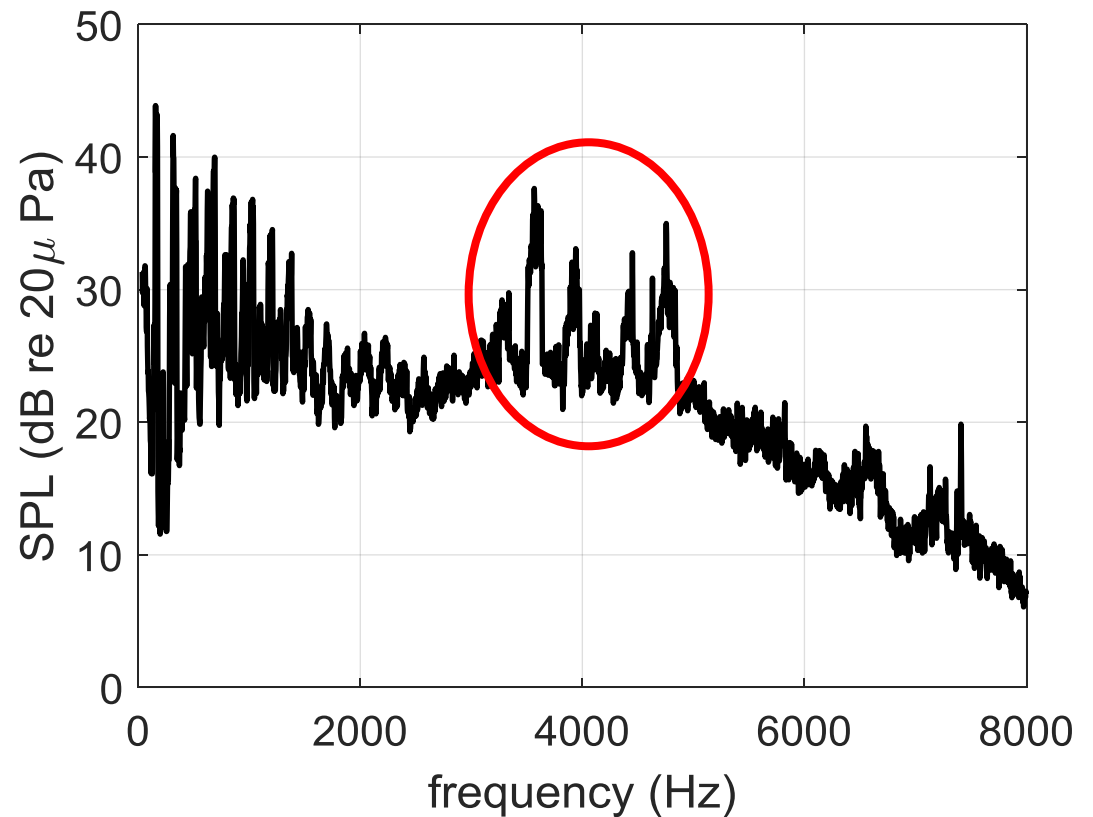
Electric Motor Noise: Y6 Tricopter

Vehicle hovering ~8m above ground level (AGL)

Overhead



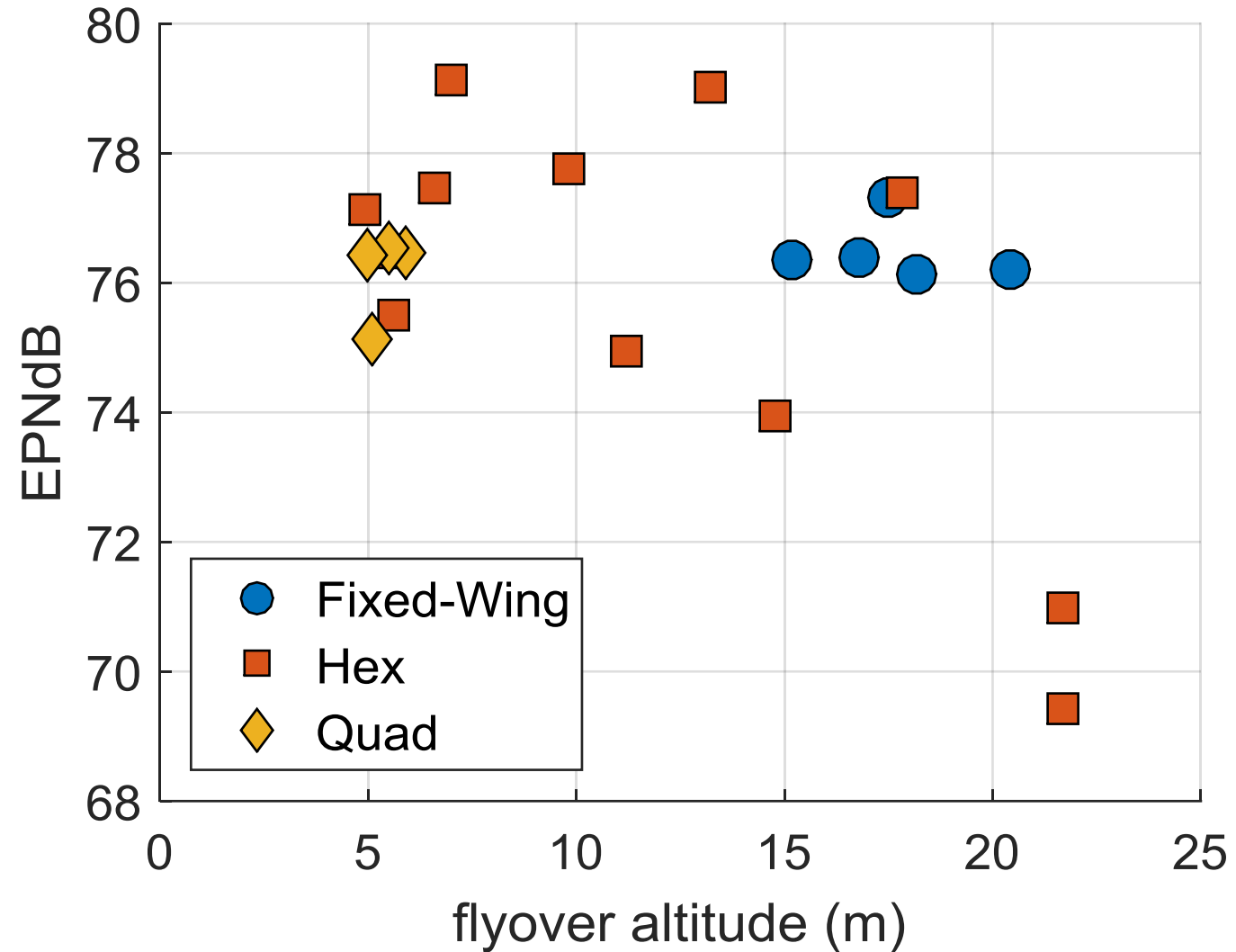
45° observer angle



EPNL of Flyovers

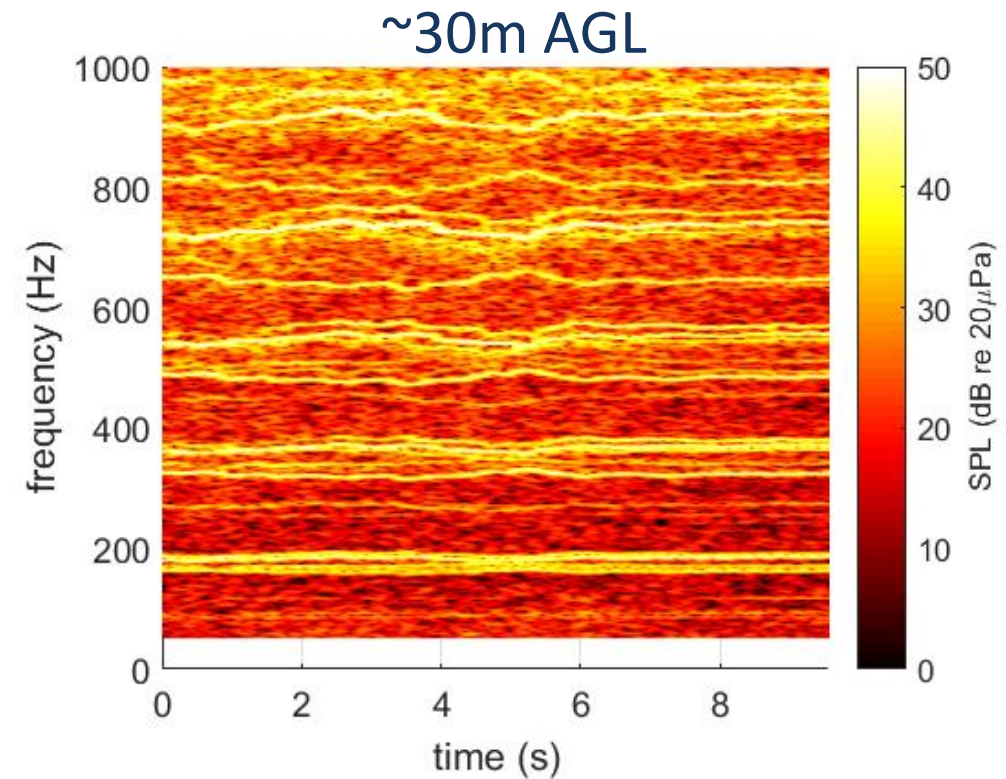
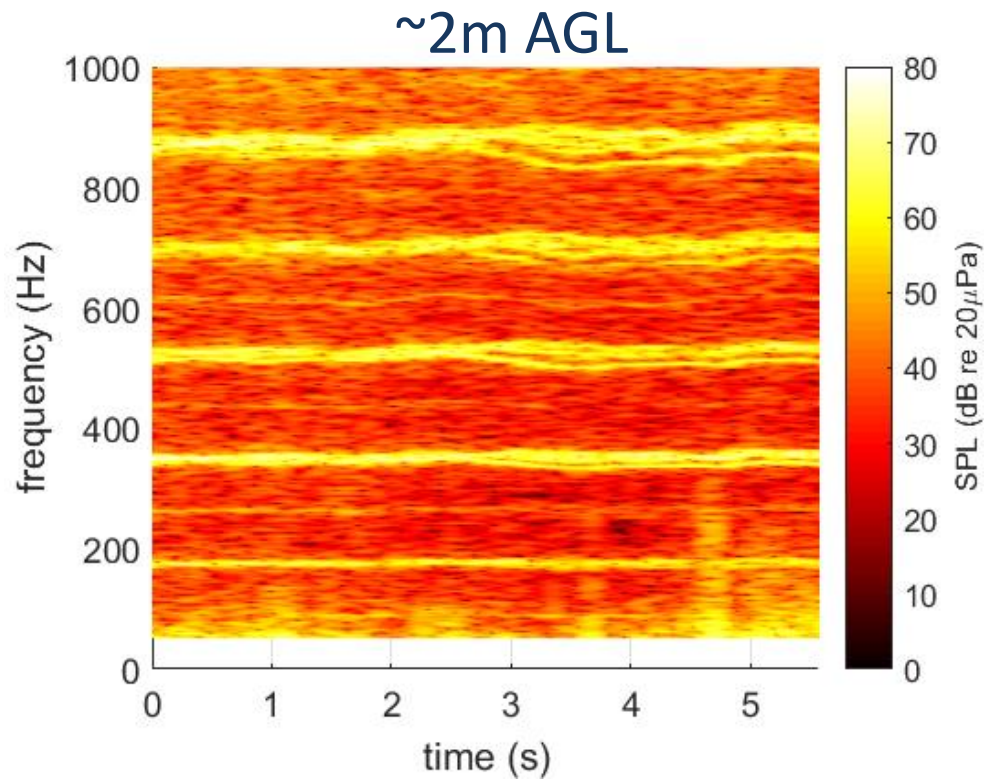


1.6kg quadcopter
has similar EPNL to
7.3kg hexcopter



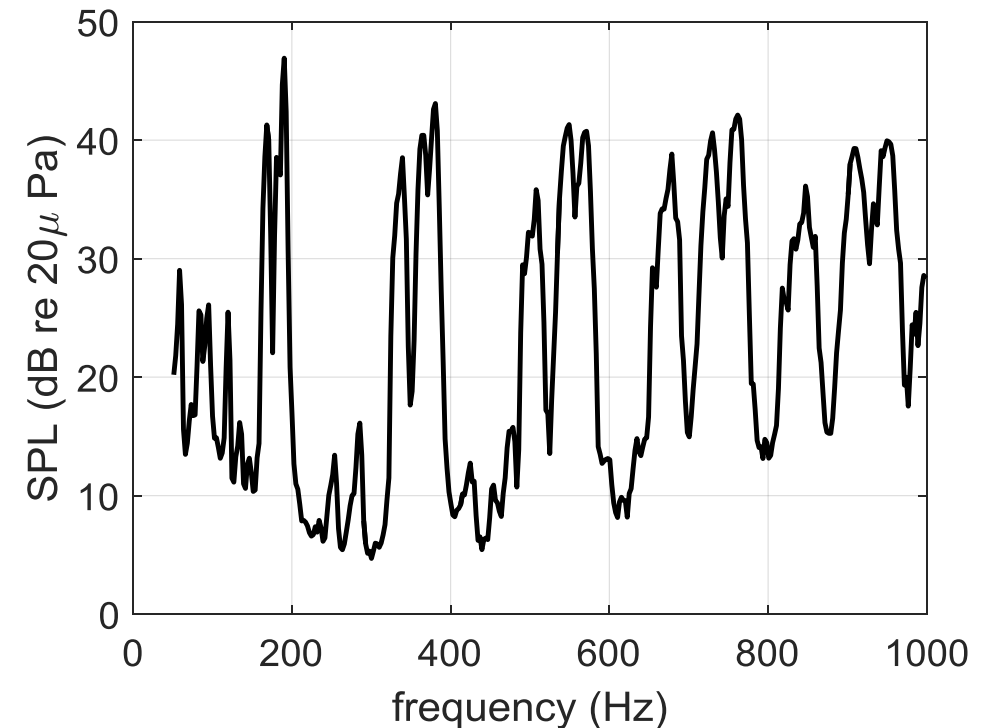
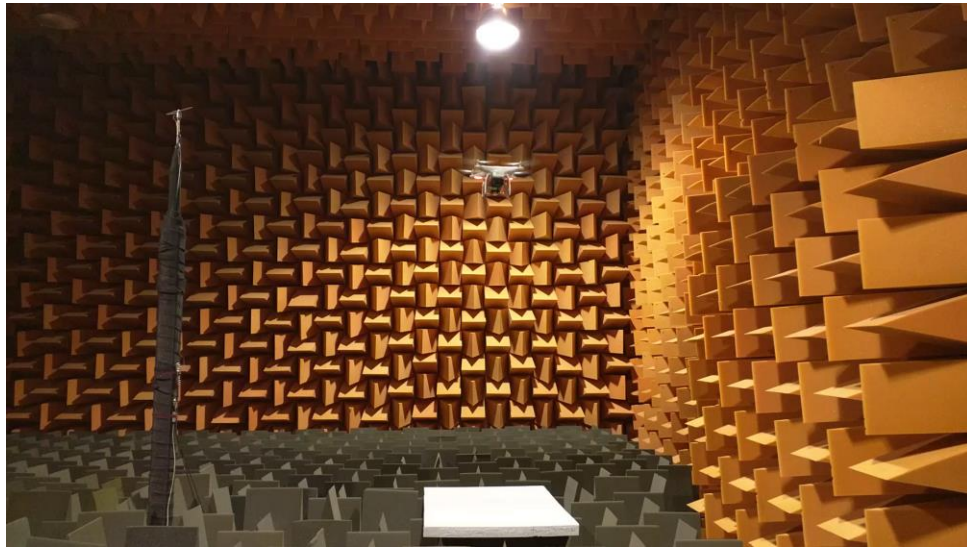
Hexcopter Spectrograms

Spectral characteristics are time varying



Indoor Flight Measurements

Indoor measurements of hovering quadcopter show amplitudes of higher BPF harmonics do not roll off, which suggests importance of unsteady inflow due to rotor-rotor, rotor-fuselage interactions





Conclusions and Future Work

- Multicopter noise is complex and time varying
 - Higher BPF harmonics can affect A-weighted levels
 - Electric motor noise is audible
 - Vehicle position information important when propagation distances are small
- Plans:
 - Continue indoor component and system testing (N. Zawodny's presentation)
 - Measure noise from pitch-controlled quadcopter (uniform rotor rpm)
 - Measure noise from autopiloted vehicles - reduce variability due to human pilot