Recent Work Investigating Acoustics of small Unmanned Aerial Systems (sUAS)

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VLHA motivation

Vertical Lift Hybrid Autonomy (VLHA) goal:

Show feasibility of applying current conceptual design tools to small vertical lift unmanned aerial vehicles (UAVs)

Acoustics discipline objectives:

- Assess current noise prediction tools and improve as necessary
- Apply tools to develop noise control solutions and quiet designs
- Assess human response through prediction-based auralizations

Current experimental research purpose:

- Provide experimental data from test stand and flight tests in support of noise predictions
- Record small UAV noise under a variety of conditions to provide test stimuli in support of human response assessment

Experimental Research Approach

Anechoic Chamber of the Structural Acoustics Loads and Transmission (SALT) Facility

Test Stand:

- Combined Experimental and Computational Aeroacoustic Analysis of an Isolated UAV-scale Propeller – **Nik Zawodny**

Indoor Flight Testing (Phantom 2):

- Controlled environment
- No background noise
- No wind
- Necessary instrumentation and equipment readily available
- No GPS-based autopilot and flight data acquisition system (FDAS)

Field Acoustic Flight Tests

- GPS guidance and control
- GPS time synchronization
- Background noise
- Changing wind speed and directions
- FDAS payload
- Portable equipment, instrumentation and power requirements

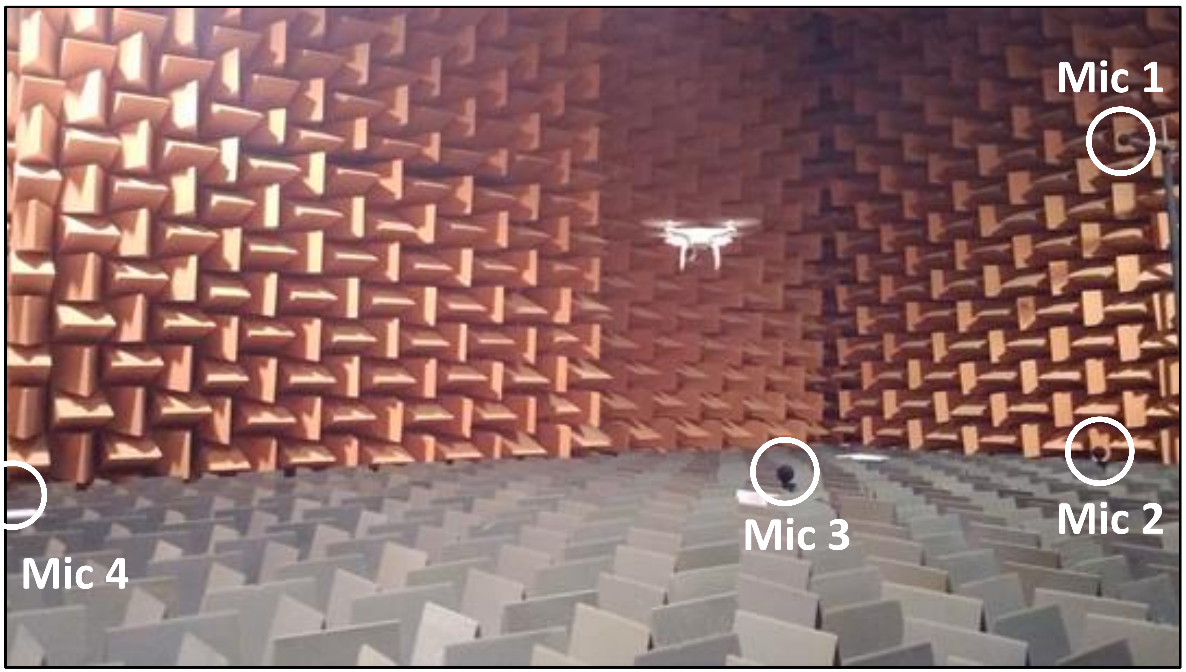
sUAS – Phantom 2

DJI Phantom 2	
sUAS Type	Multi-Copter, 4 Engine, Brushless Motors
Diagonal Length	13.8 in
Maximum Weight	2.9 lbs
Empty Weight	2.2 lbs
Speed	0 - 33.5 mph

sUAS acoustic tests - Phantom2

Anechoic Chamber of the Structural Acoustics Loads and Transmission (SALT)

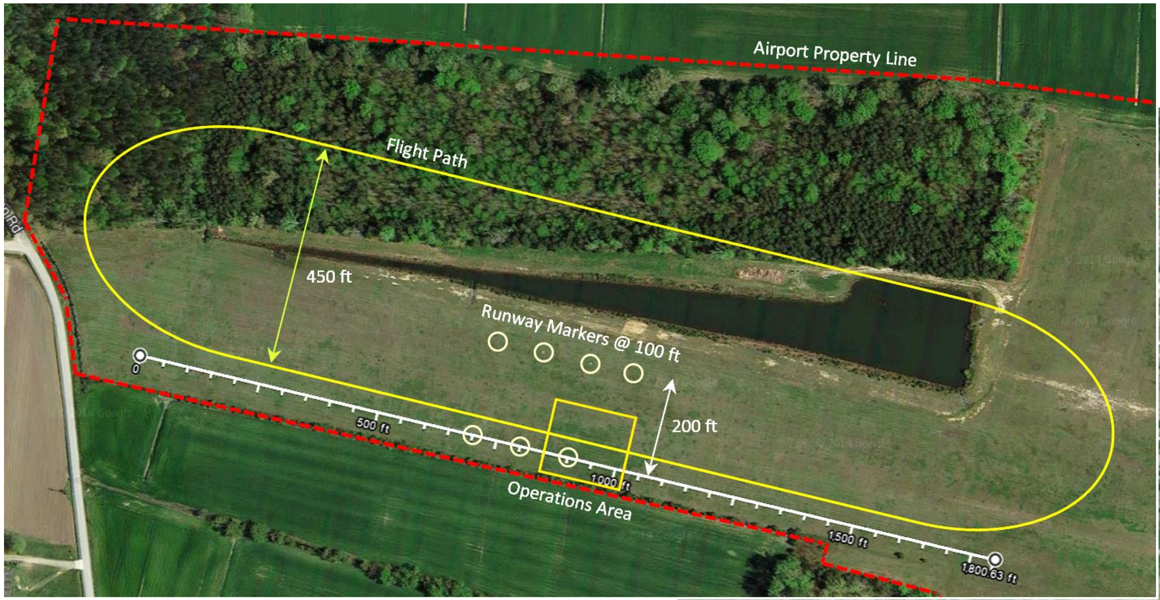
- 4 microphones
- Hover at 2, 4, 8 and 12 ft over 3 microphone locations
- 12 microphone flyovers along 2 chamber diagonals
- 8 circles around center microphone

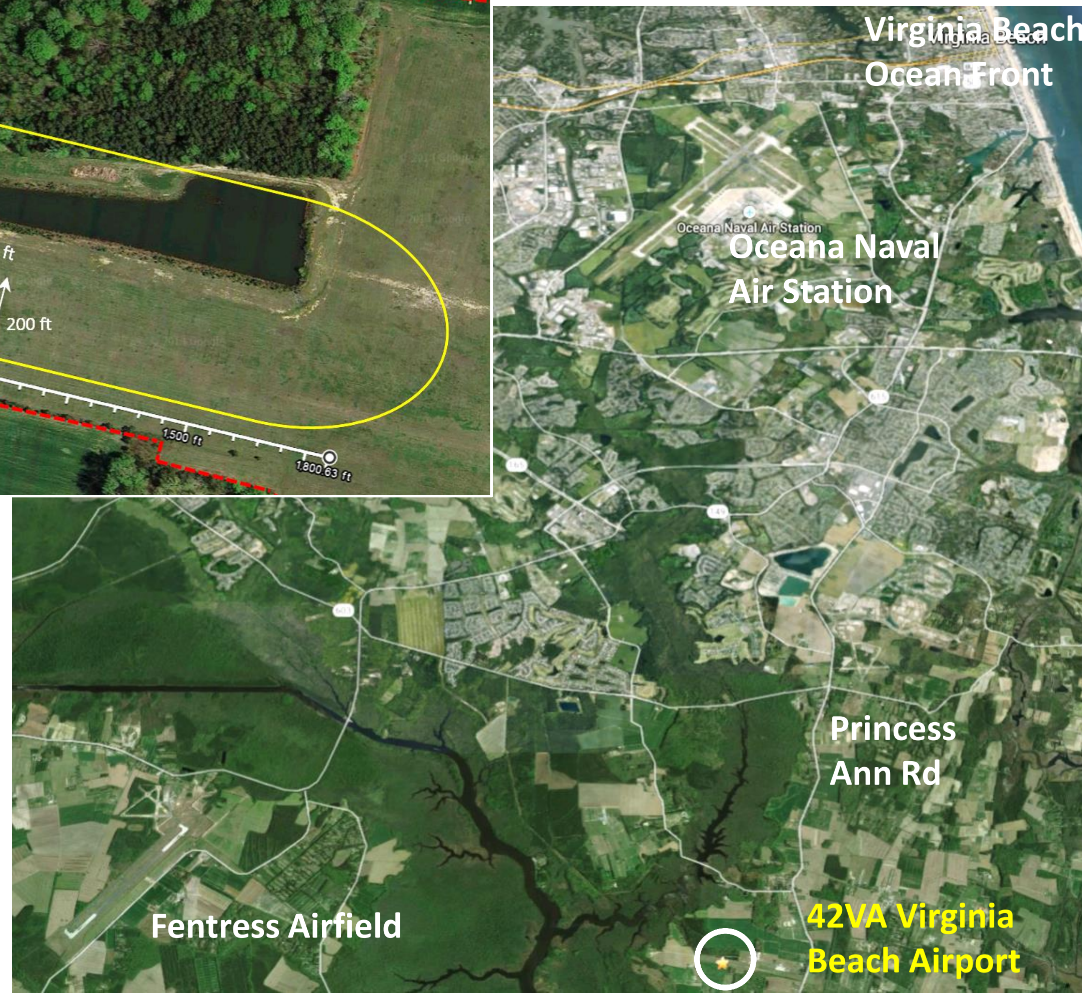


Purpose:

- Eliminate wind and background noise factors
- Acoustic analysis in support of isolated rotor tests
- Prediction validation tests
- High-quality recordings for response tests

42VA – Virginia Beach Airport (Private)





- 10 miles South of Oceana Naval Air Station; 5 miles East of Fentress Field
- Active runway 11/29 – 4845 x 190 ft
- Surface: turf; Elevation 10/9 ft
- Targeted flight path ~ 2000 x 450 ft
- Runway markers both sides @ 100 ft
- Prevailing winds NNE at 10 ft/s

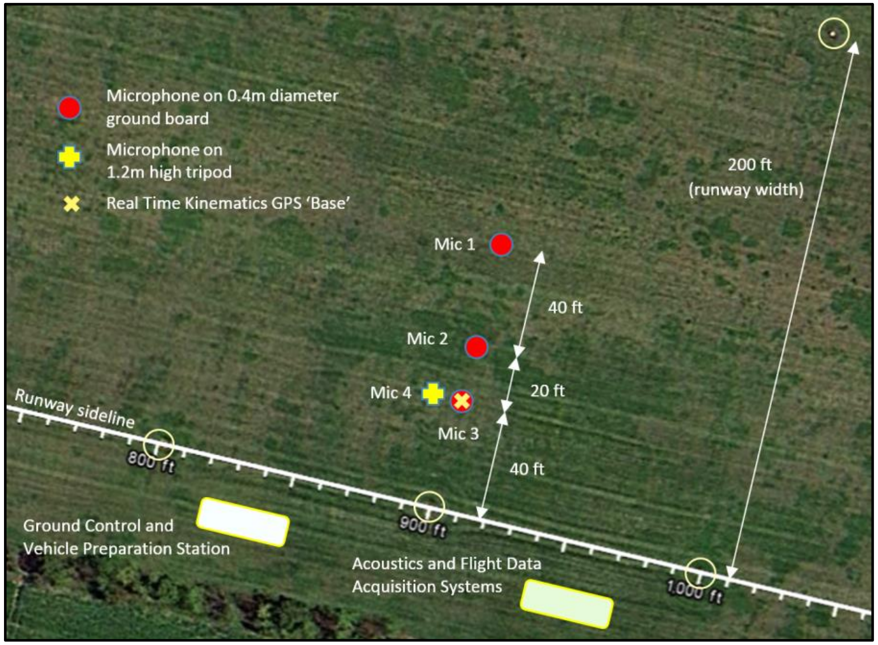
42VA Operations Area and Equipment

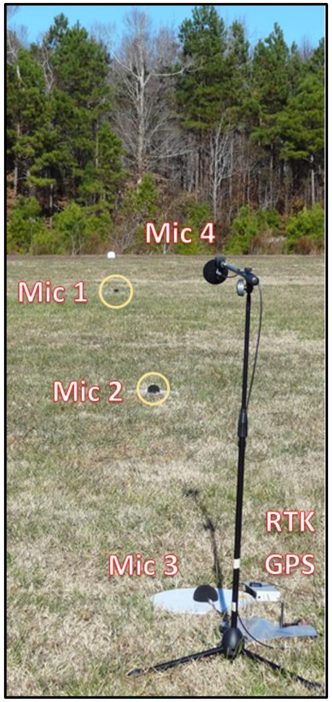
Acoustics Data Acquisition System

- Three ground-based and one tripod-mounted (4 ft) G.R.A.S. ½-inch microphones
- National Instruments NI USB-4431 24-bit 4-channel dynamic signal acquisition module
- Two laptop computers with Matlab data acquisition, analysis and post-processing software

Flight Data Acquisition System (FDAS)

- Real Time Kinematics (RTK) GPS system with centimeter accuracy
- FDAS collects vehicle in-flight parameters





Other

- Weatherstation
- Ultrasonic wind sensor
- Portable Synchronized Time Code Generator
- Video cameras/tablets
- Battery pack power management system
- Volpe photo-scaling system
- All time metrics were converted to Coordinated Universal Time (UTC)

sUAS – Test Vehicles

DJI Phantom 2	
sUAS Type	Multi-Copter, 4 Engine, Brushless Motor
Diagonal Length	13.8 in
Maximum Weight	2.9 lbs
Empty Weight	2.2 lbs
Speed	0 - 33.5 mph

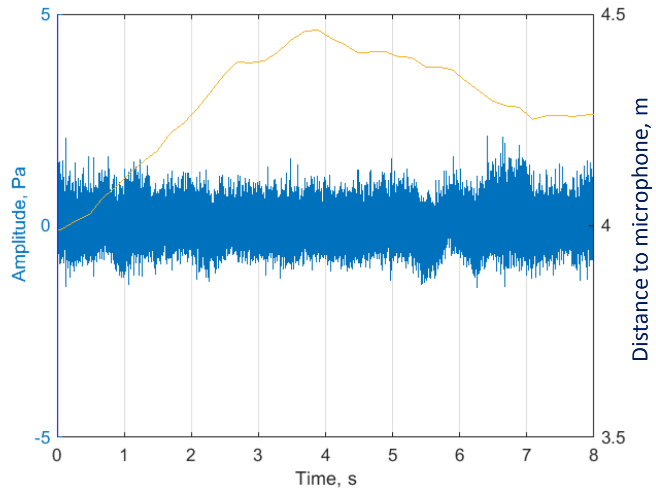
3DR Y6 RTF	
sUAS Type	Multi-Copter, 6 Engine, Brushless Motor
Diagonal Length	20 in
Maximum Weight	5.5 lbs
Empty Weight	4.2 lbs
Speed	0 - 33.5 mph

Edge 540 NO.22	
sUAS Type	Fixed-Wing, 1 Engine, Piston
Wingspan	68.1 in
Length	71 in
Empty Weight	10.6 lbs
Speed	0 - 60 mph

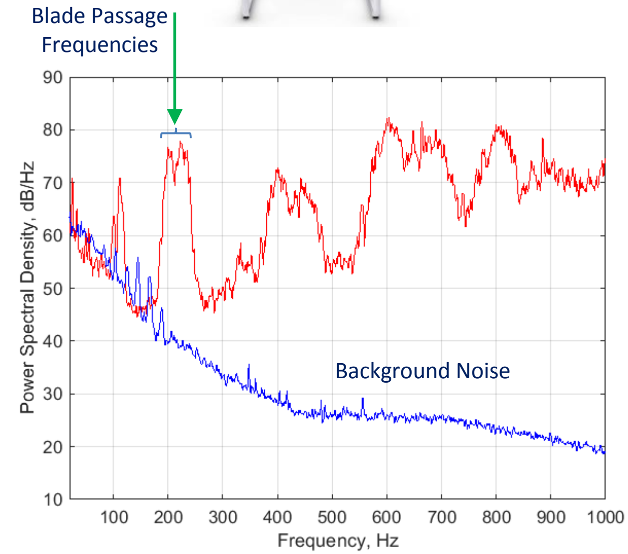
FQM-117B MigLH	
sUAS Type	Fixed-Wing, 1 Engine, Brushless Motor
Wingspan	68 in
Length	70 in
Empty Weight	15.1 lbs
Speed	0 - 60 mph

Phantom 2 – Hover over Microphone

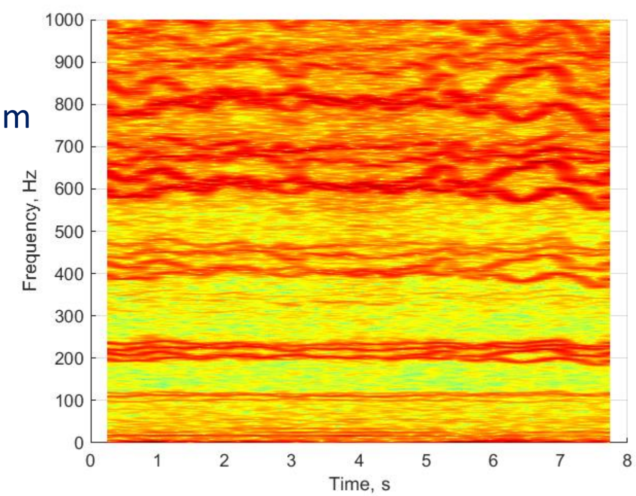
Amplitude Time History



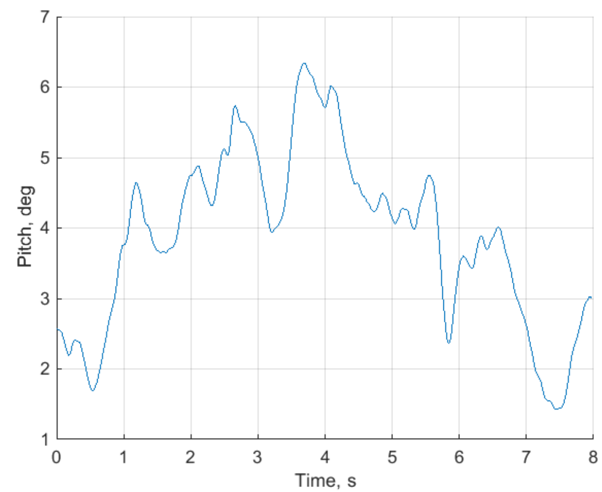
Power Spectral Density



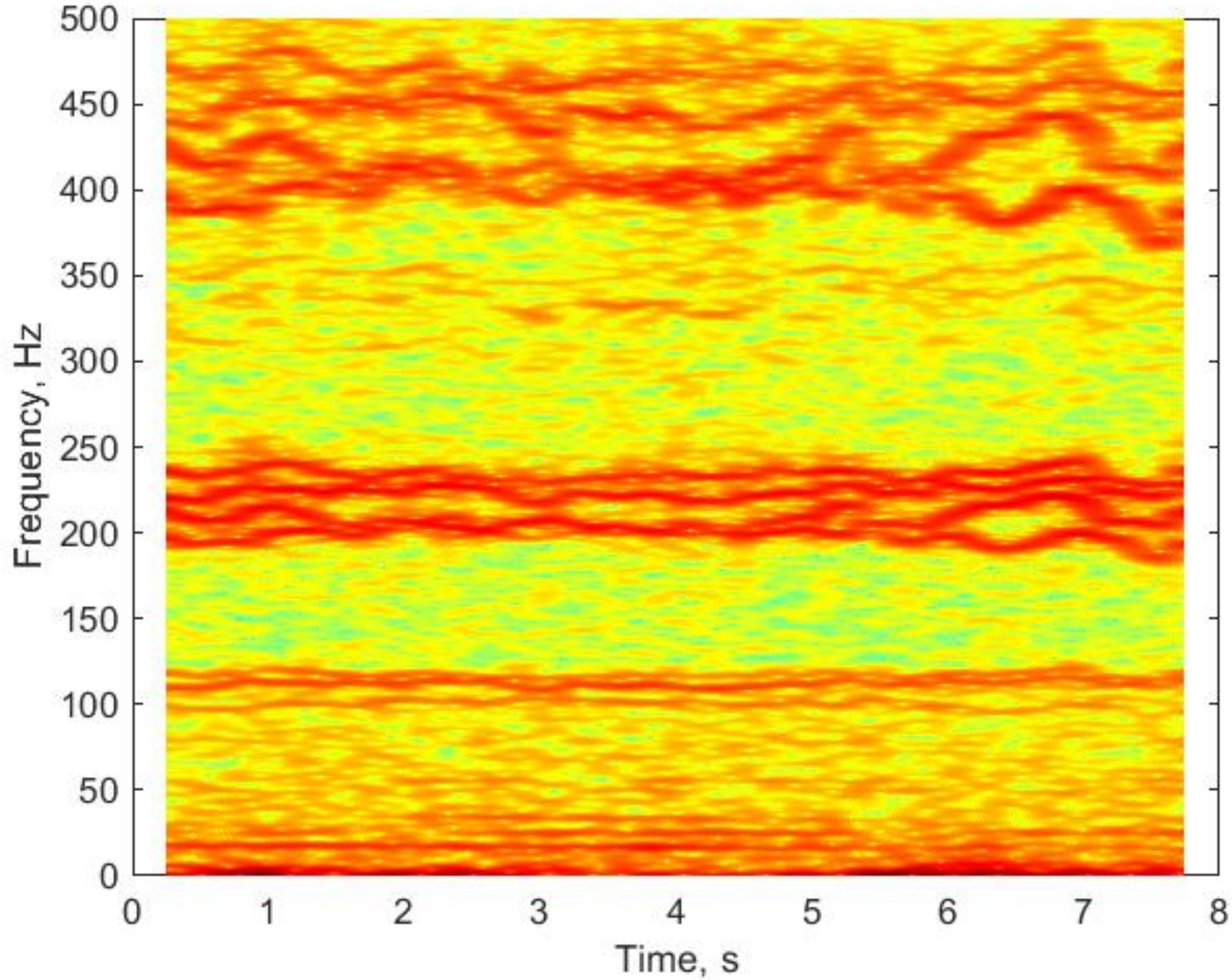
Spectrogram



Pitch Time History



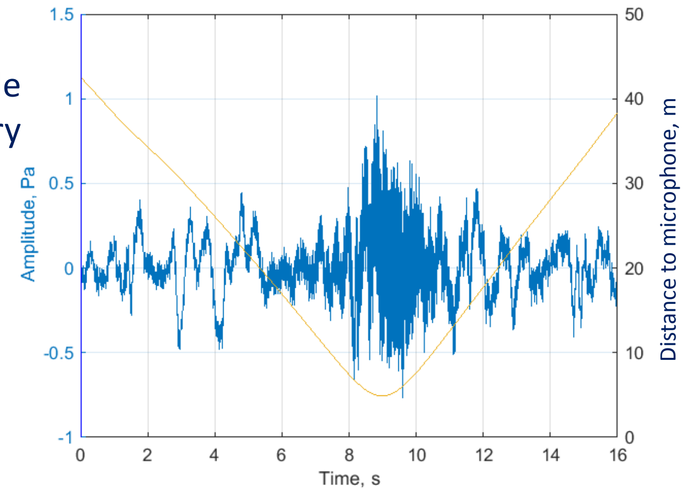
Phantom 2 – Hover over Microphone



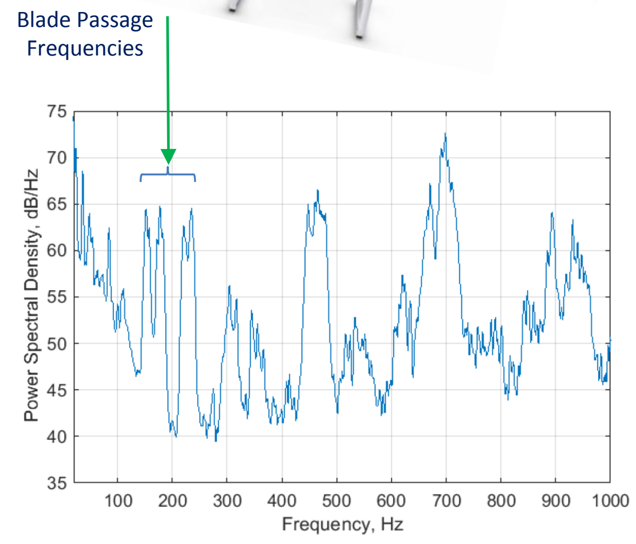
Wind fluctuations and associated pitch changes yield variations in blade passage frequencies

Phantom 2 – Microphone Flyover

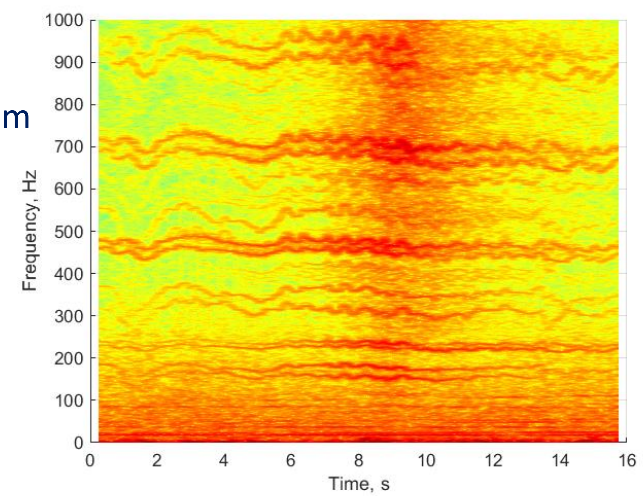
Amplitude Time History



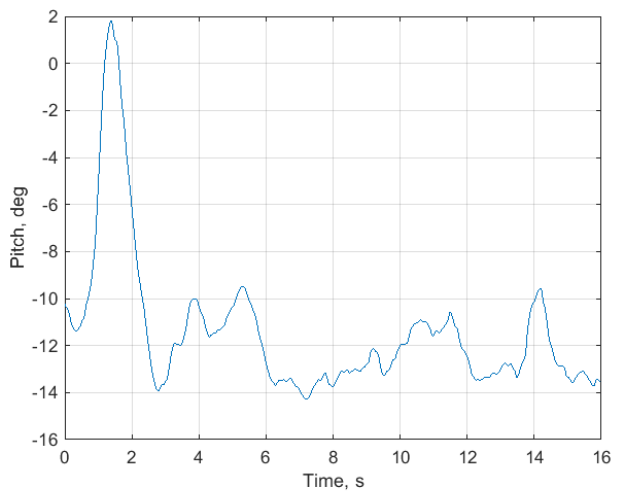
Power Spectral Density



Spectrogram

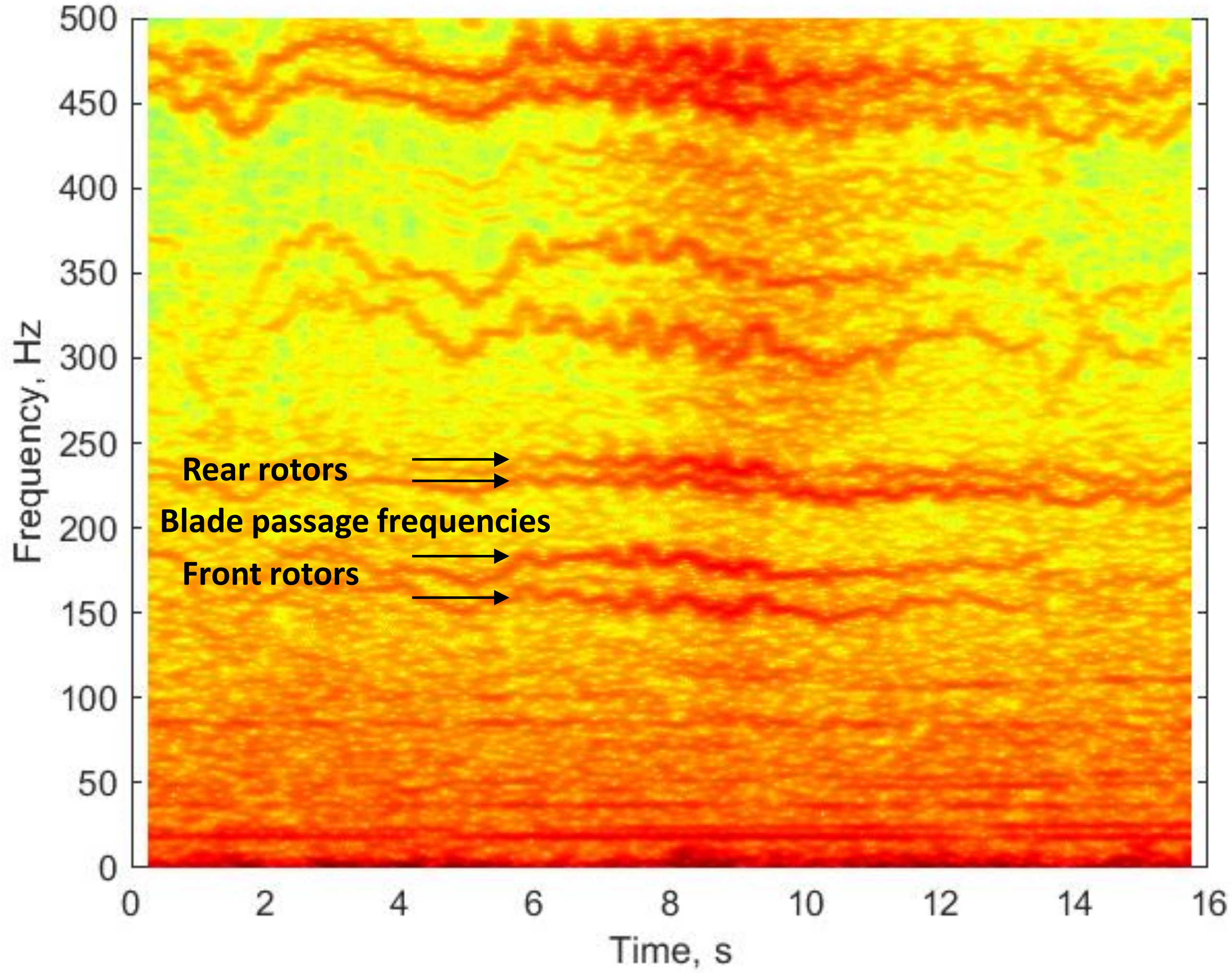


Pitch Time History



Y6

Phantom 2 – Microphone Flyover

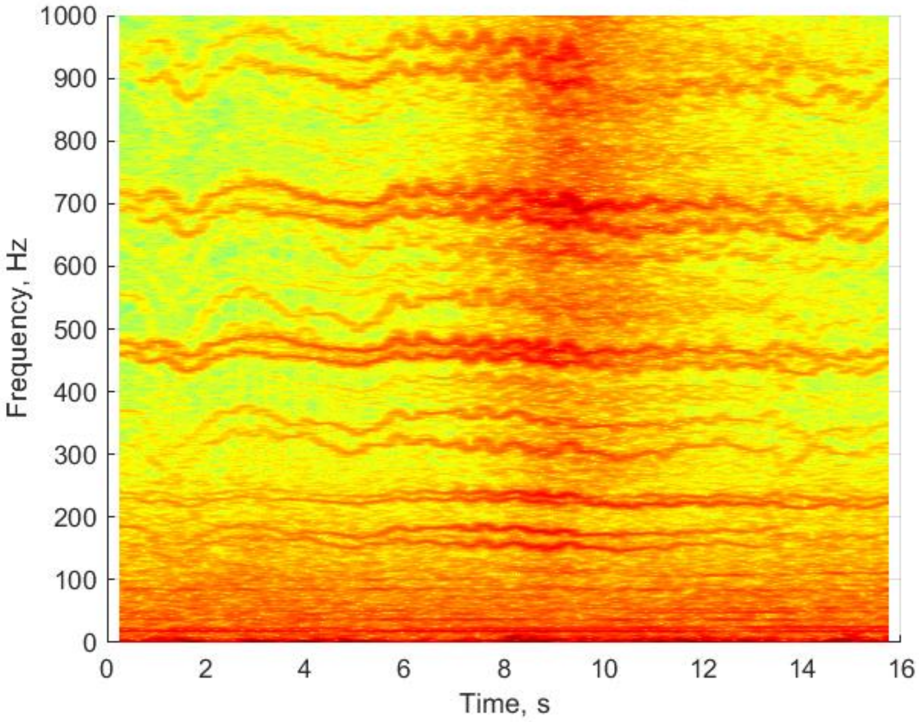


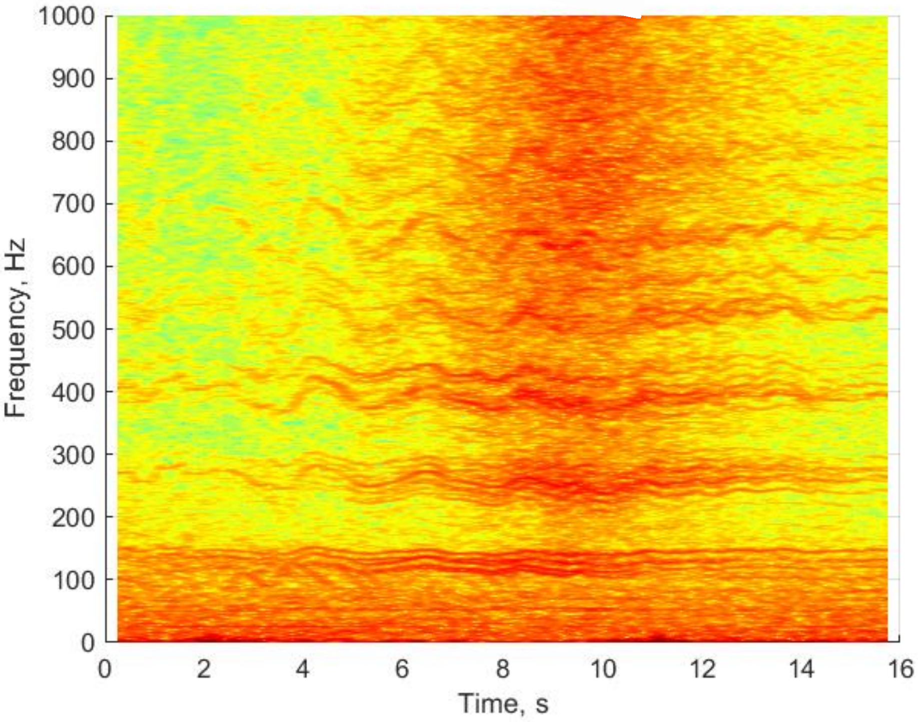
When aerodynamic center and center of gravity are not collocated, maintaining forward speed and associated vehicle pitch produces significant changes in the rotor blade passage frequencies

Phantom 2 & Y6 – Microphone Flyover

Phantom 2

Y6

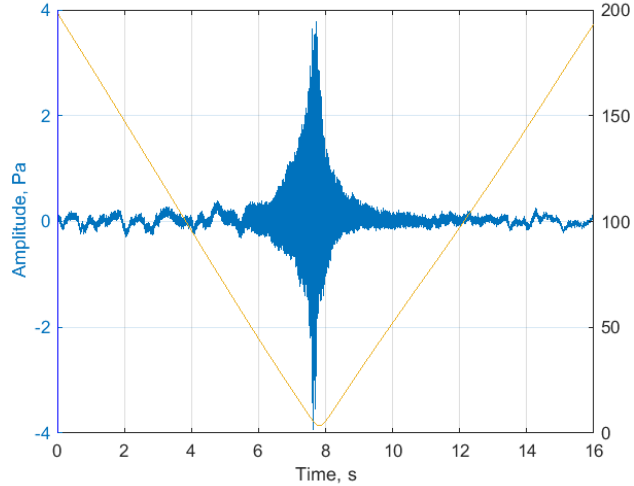




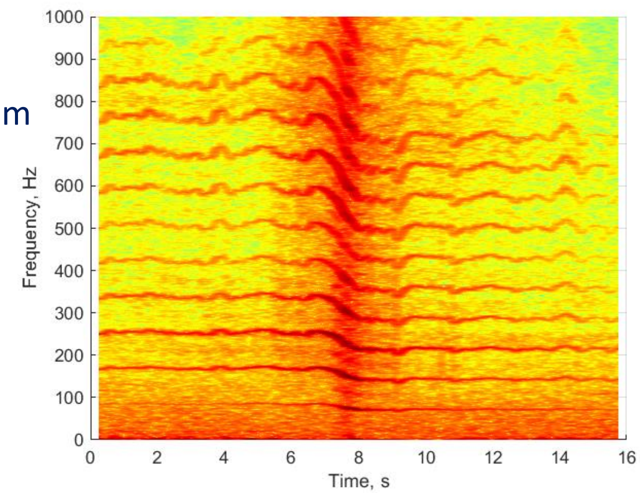
Microphone Flyovers

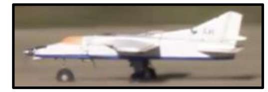
Edge 540  piston

Amplitude Time History

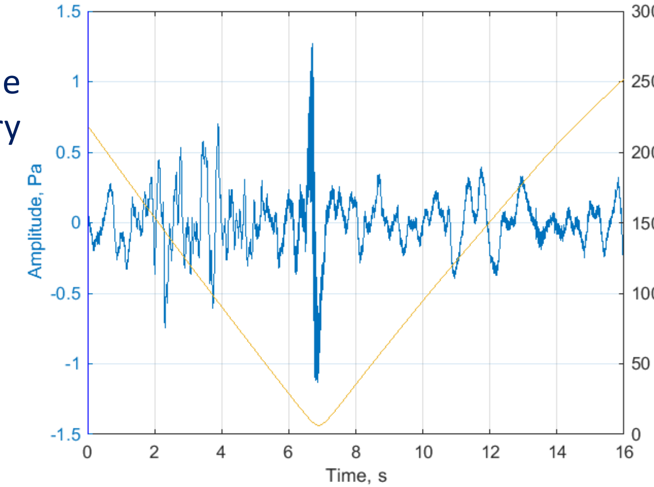


Spectrogram

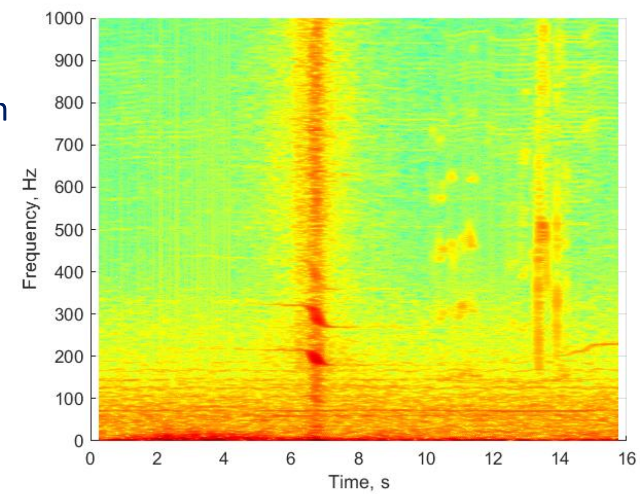


MigLH  electric

Amplitude Time History



Spectrogram



Conclusions

- Test stand isolated rotor => flight test anechoic chamber => field acoustic flight test approach is useful to separate and investigate relevant acoustic, flight and environmental parameters
- RTK GPS system has proven centimeter accuracy to determine the distance between the base and rover receivers (microphone and noise source), but has still reliability issues that are being investigated
- When attaching a payload to a multicopter (like the FDAS), the center of gravity moves away from the aerodynamic center. When the vehicle travels, the dissimilar speeds of the rear and front rotors (to maintain the pitch angle) yield different rotor blade passage frequencies
- sUAS vehicles require frequent adjustments in rotor rpm with associated changes in the noise signature
- Doppler effect becomes a factor at higher speeds and closer range

Acknowledgments