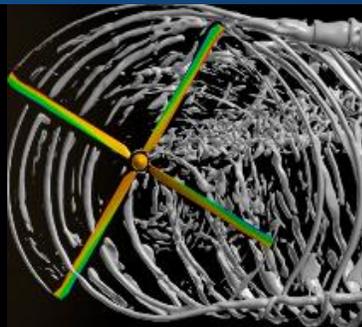# Preliminary Aeroacoustic Measurements from the AART in the NFAC 40-by 80-Foot Wind Tunnel

Natasha L. Schatzman and Benny Cheung

**Spring 2020 Acoustics Technical Working Group Virtual Meeting**

April 7-8, Hampton, VA

Aeromechanics Branch - NASA Ames Research Center

Outline

- **Introduction**
- **AART wing configurations**
- **Microphone locations**
- **Processing technique**
- **Data Quality**
  - Background noise (no wing, half wing, full wing)
  - Repeatability
    - Point-to-Point
  - Signal to Noise (Full wing and No wing)
- **Data**
  - No wing vs. Half wing vs. Full wing
- **Concluding Remarks**
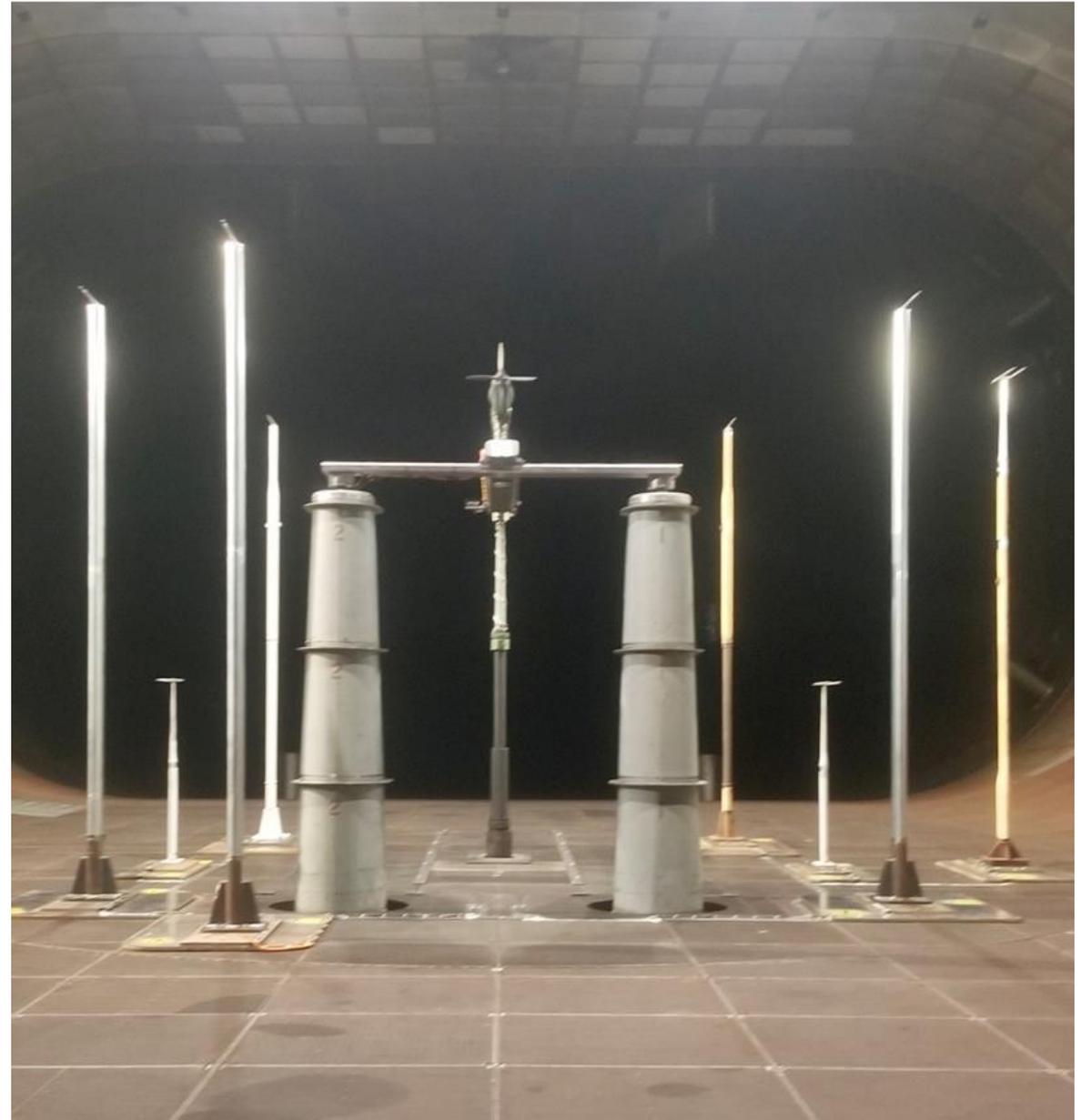
Introduction

Aerodynamic & Acoustic Rotorprop Testing (AART) Program

- The primary objective: determine the aerodynamics and acoustics related to an auxiliary propulsor mounted behind an isolated wing in the National Full Scale Aerodynamic Complex 40-by 80-Foot Wind Tunnel

- The primary data points match test conditions for in-flow stereo PIV measurements completed in the Ames 7x10 in 2018.

- The propeller consists of a Sensenich L26H commercial off the shelf blade set and hub, with a 26 inch diameter; propeller performance is measured with an internal balance integrated in the test stand

- The wing is a NACA 0015 with a 12 inch chord; 58.5 inches in height for full wing configuration; 40.5 inches in height for the half wing configuration;
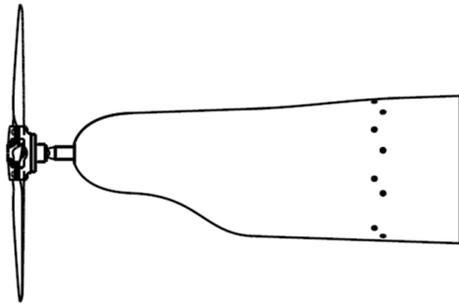

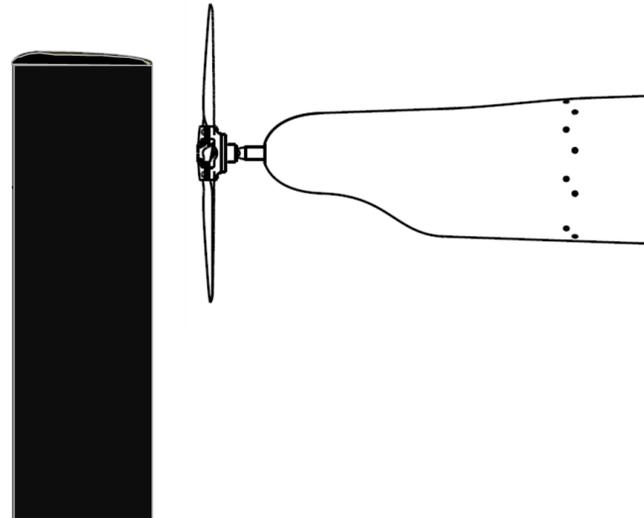Full Wing Configuration

AART Wing Configuration

- Three configuration (no wing, half wing, and full wing) for Army portion of testing, with conditions to include variation of Mtip (tip Mach number), Mtunn (tunnel Mach number), and yaw.

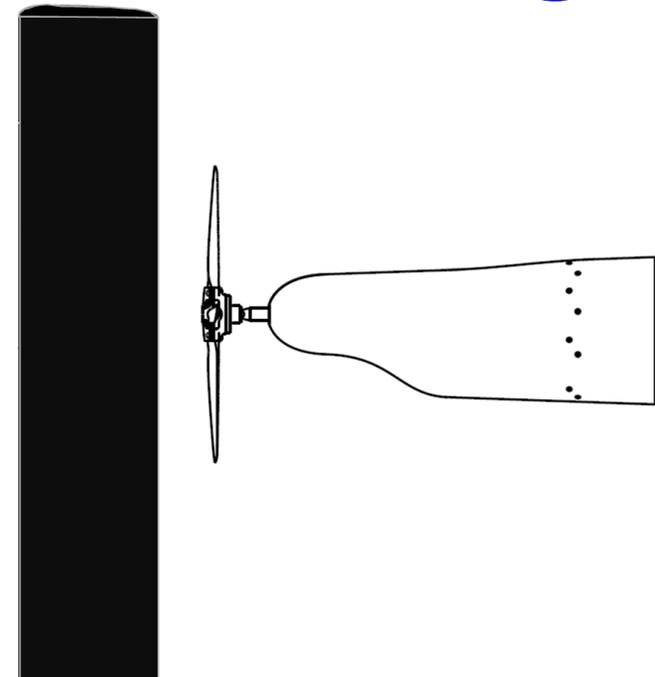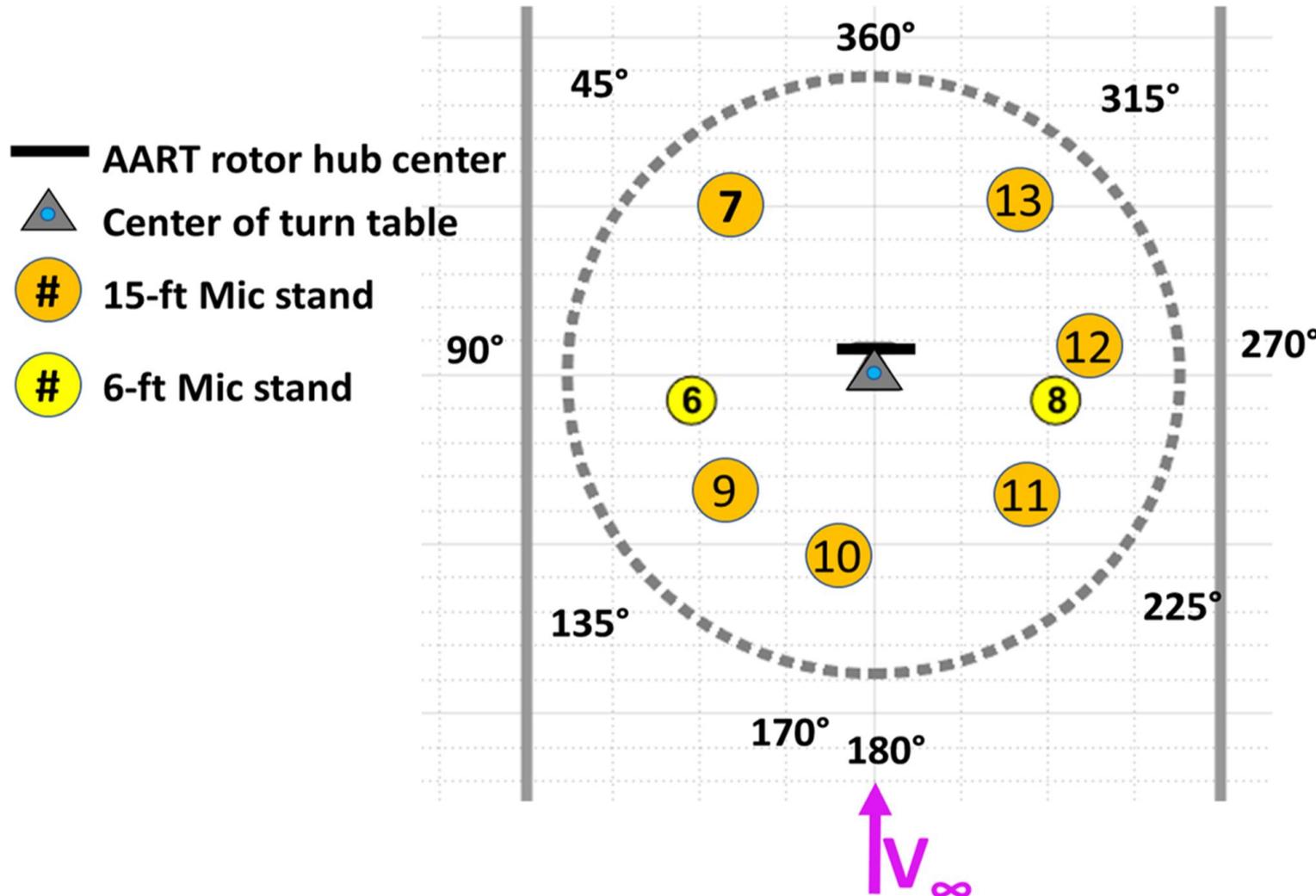**No Wing** | **Half Wing** | **Full Wing**

Microphone Locations

- **8 microphones total**
- **40AC ½" G.R.A.S free-field microphone with G.R.A.S. RA0020 nosecone**
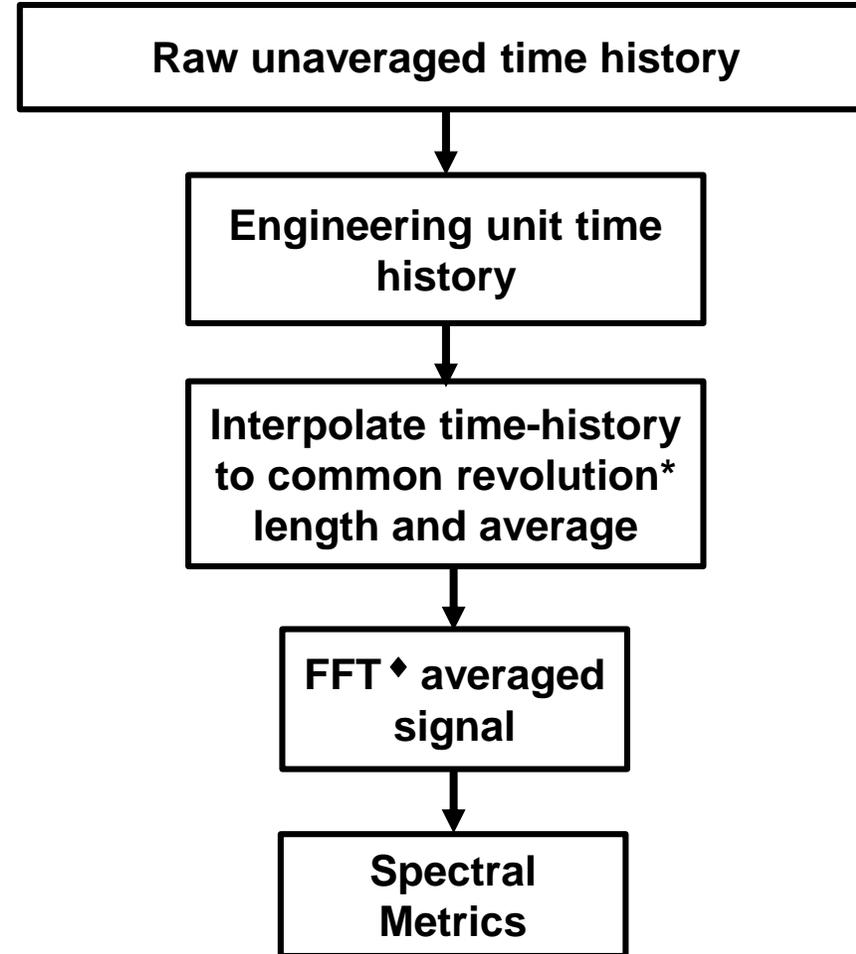

Mic #	Dimensional Distance from Rotor Center [inches]			Radial Distance From Rotor Center	
	X	Y	Z	[inches]	[feet]
Mic #6	-6.4	120.6	-110.2	163.4	13.6
Mic #7	101.8	100.4	2.0	143.0	11.9
Mic #8	-6.7	-120.1	-110.3	163.2	13.6
Mic #9	-120.4	124.4	1.4	173.1	14.4
Mic #10	-191.1	71.0	1.8	203.8	17.0
Mic #11	-119.8	-123.6	1.7	172.1	14.3
Mic #12	-4.6	-186.8	3.8	186.9	15.6
Mic #13	101.5	-100.1	1.4	142.6	11.9
NOTE: All measurements referenced to the tip of the bullet-type cap on each mic.					

Processing techniques

2048/Rev

Raw unaveraged time history

↓

Engineering unit time history

↓

Interpolate time-history to common revolution* length and average

↓

FFT ◆ averaged signal

↓

Spectral Metrics
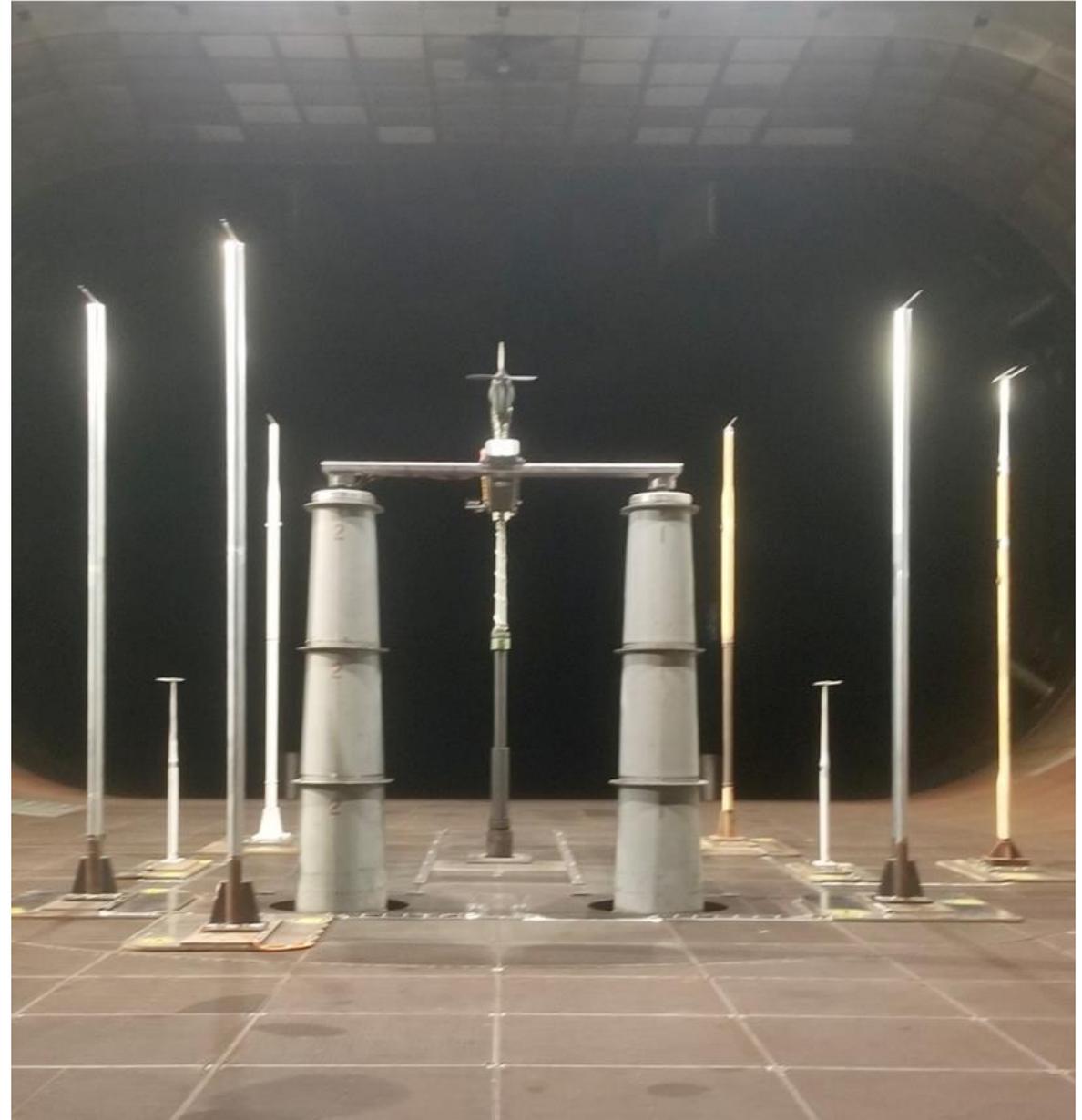
*1250 revolutions of data

◆Frequency range: 0 – 106,680 Hz (△~100 Hz), for 6,250 RPM

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- **Concluding Remarks**

Background Noise: $M_{TUN} = 0.204$ (Spectrum)

Aerotares

$M_{TUN} = 0.204$

$M_{TIP} = 0.636$

$C_T = 0.0$

Yaw = 0°

Pitch = 0°

R21 P19 (No wing)
R19 P27 (Half wing)
R20 P19 (Full wing)

Mic#7: 72.9 / 75.1 / 73.4 dB

Mic#13: 74.1 / 77.3 / 77.8 dB

Mic#12: 74.3 / 74 / 72.3 dB

Mic#6: 79.7 / 81.4 / 82.7 dB

Mic#8: 75.1 / 77.6 / 80.4 dB

Mic#9: 75.7 / 76.7 / 76.9 dB

Mic#10: 74.2 / 76.5 / 76 dB

Mic#11: 75.7 / 74.3 / 76.7 dB

V_∞
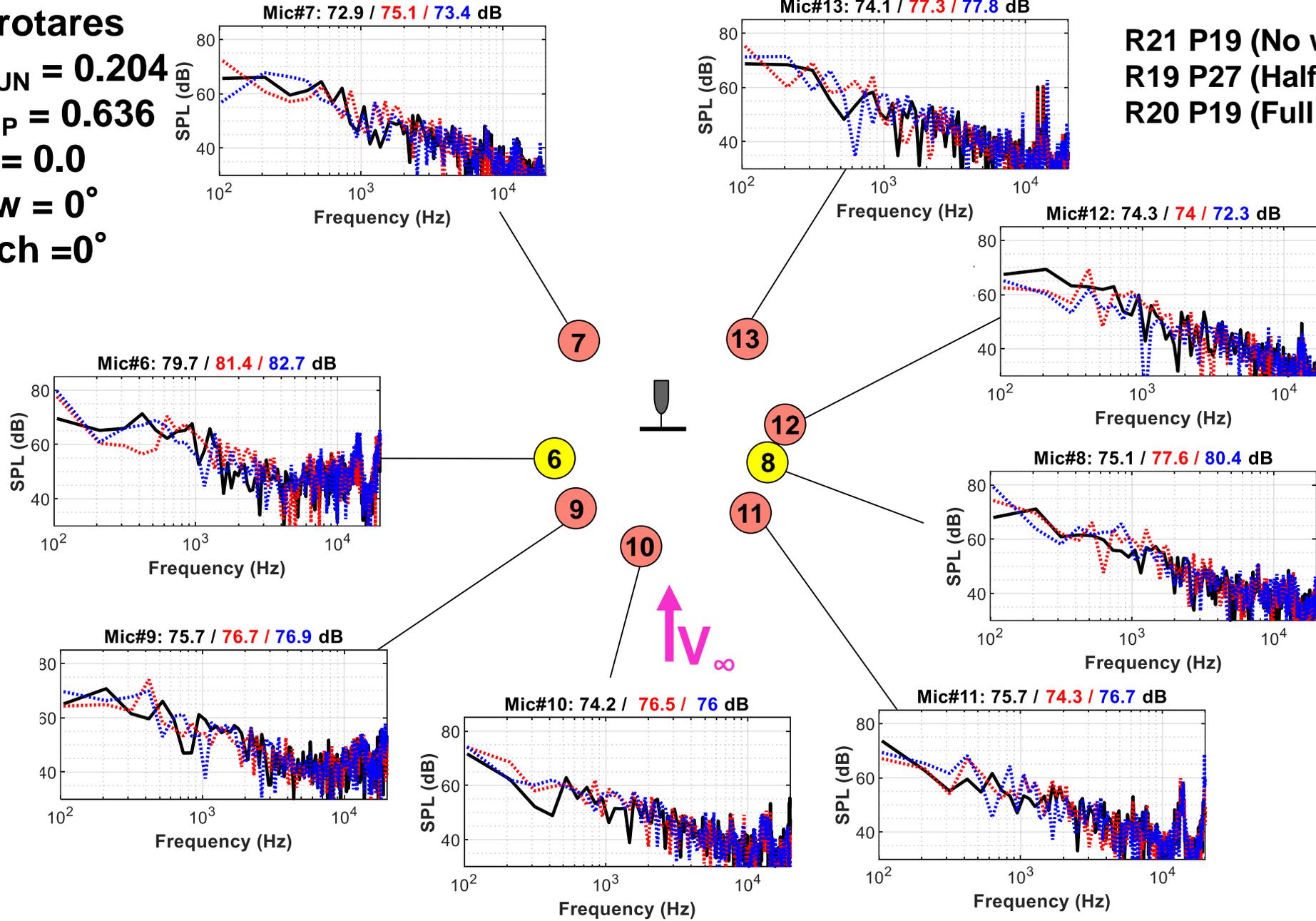
Minimal differences between each configuration are shown for background noise

Background Noise: M_{TUN} = 0.204 (Spectrum)

Aerotares

M_{TUN} = 0.204

M_{TIP} = 0.636

C_T = 0.0

Yaw = 0°

Pitch = 0°
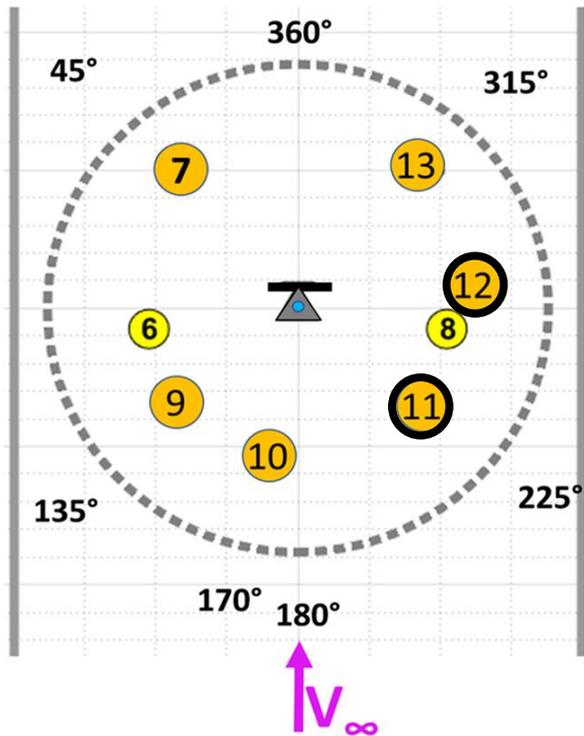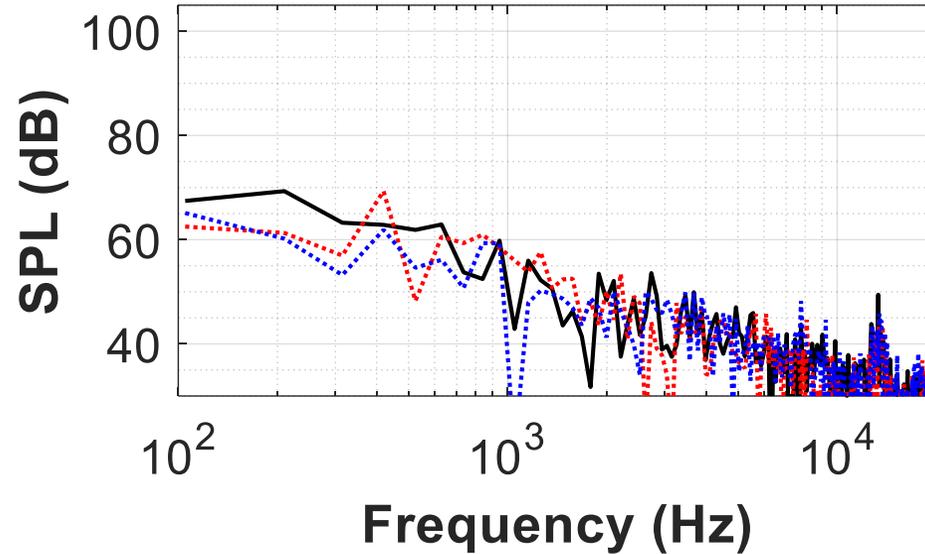
Mic#12: 74.3 / 74 / 72.3 dB
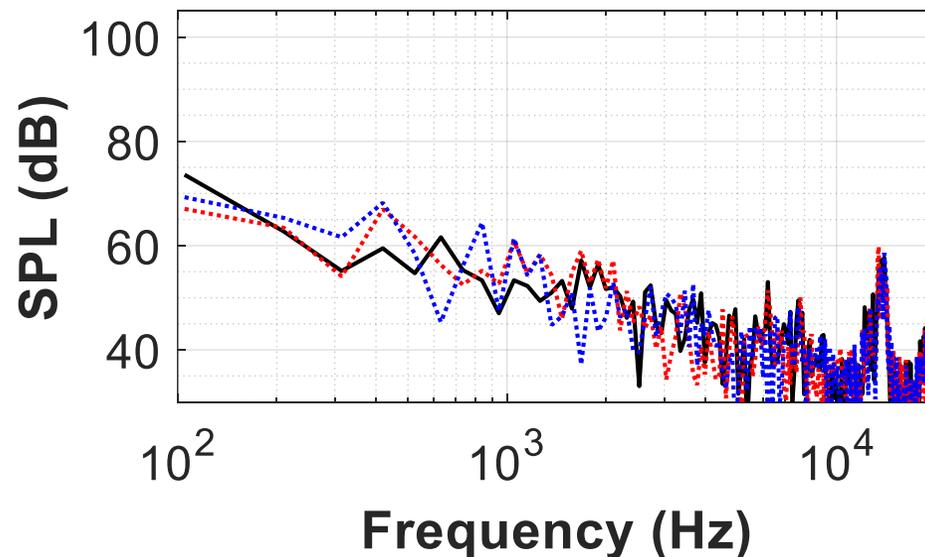
R21 P19 (No wing) ⎯⎯

R19 P27 (Half wing) - - - -

R20 P19 (Full wing) - - - -

Minimal differences between each configuration are shown for background noise

Mic#11: 75.7 / 74.3 / 76.7 dB

For this presentation, only Mics 11 (out-of-plane) and 12 (in-plane) will be shown from this point on

Blades on

No Wing

$M_{TUN} = 0.204$

$M_{TIP} = 0.636$

$C_T = 0.05$

Yaw = 0°

Pitch = 0°
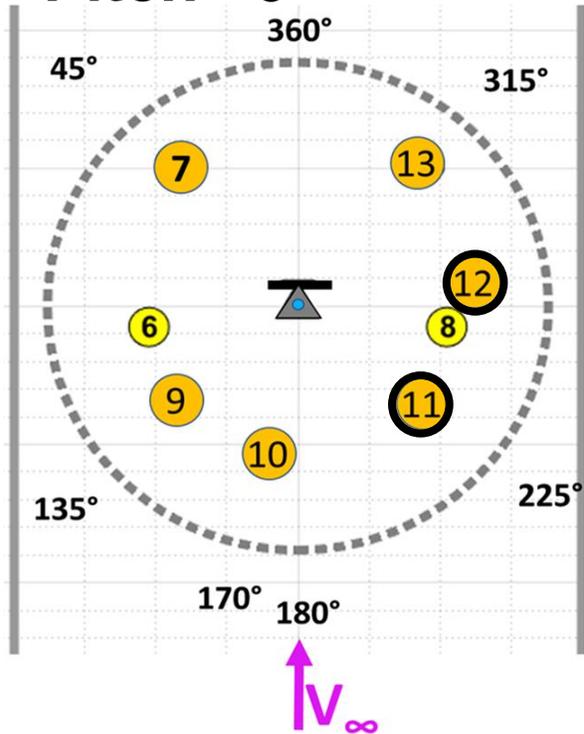
Mic#12: 94.2 / 94.3 / 94.1 / 94.2 dB

Mic#11: 93.7 / 93.8 / 94.1 / 94 dB
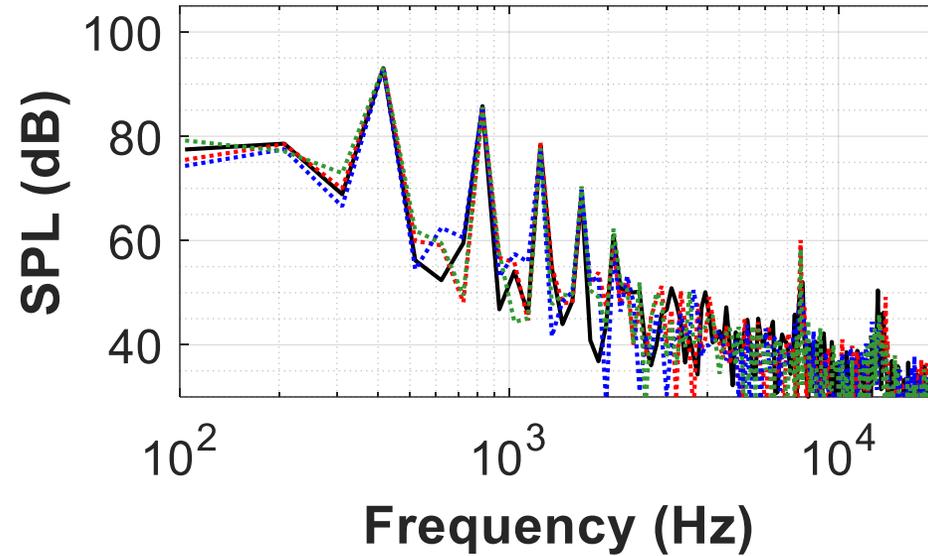
Run 23 Point 21 ----
Run 23 Point 26 ----
Run 23 Point 31 ----
Run 25 Point 15 ----
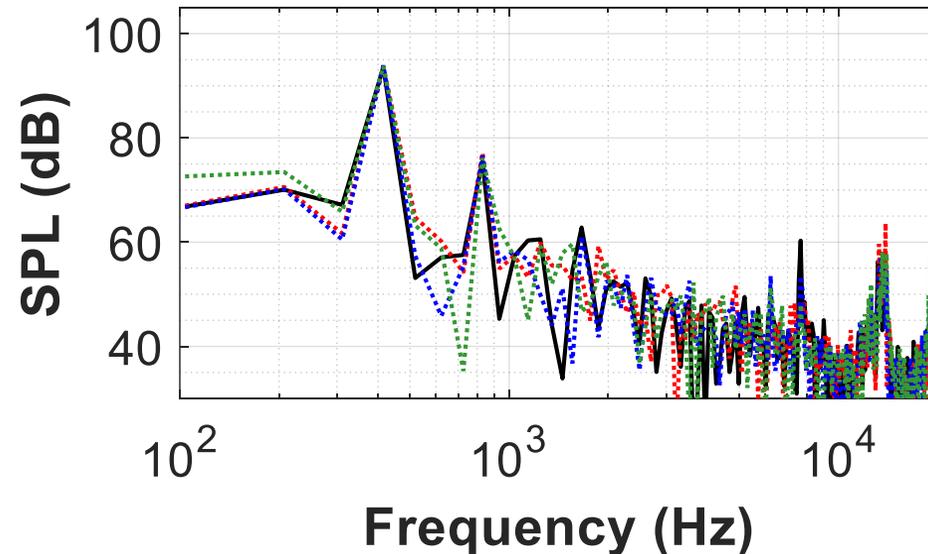
OASPL less than 2 dB variation <u>for this conditions</u>
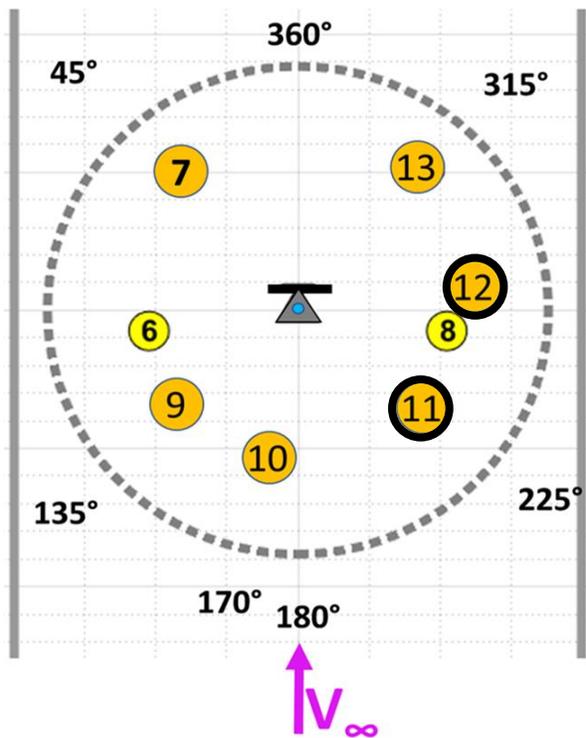
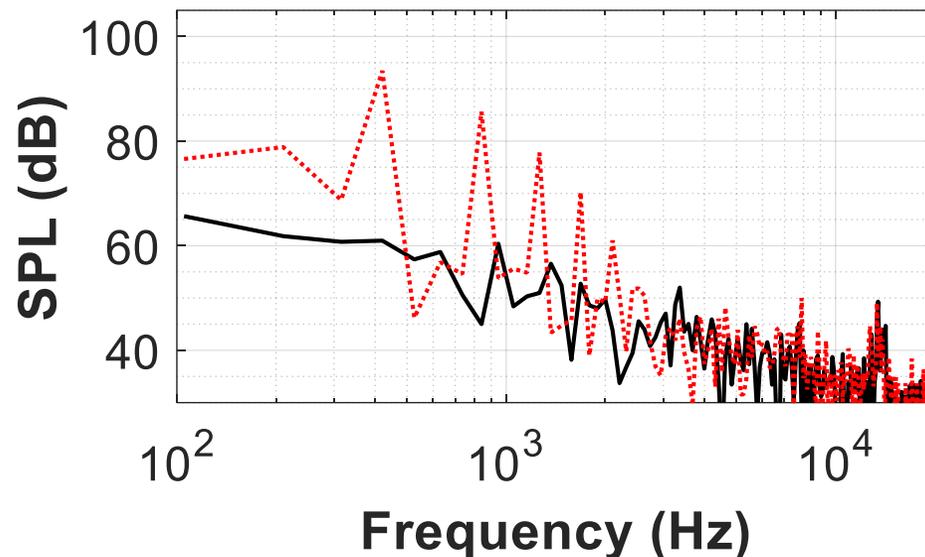# Signal-to-Noise: No wing (Spectrum)

No Wing
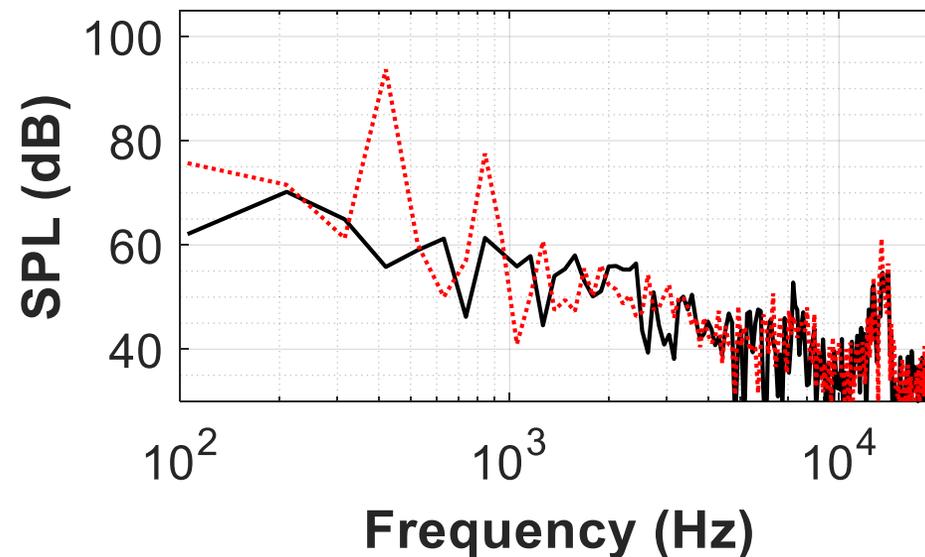
M_{TUN} = 0.204

M_{TIP} = 0.636

Yaw = 0°

Pitch = 0°

Mic#12: 72.4 / 94.4 dB

Run 21 Point 24 (Aerotare) ——
Run 37 Point 29 (Blades on) ·········

Mic#11: 74.8 / 93.9 dB

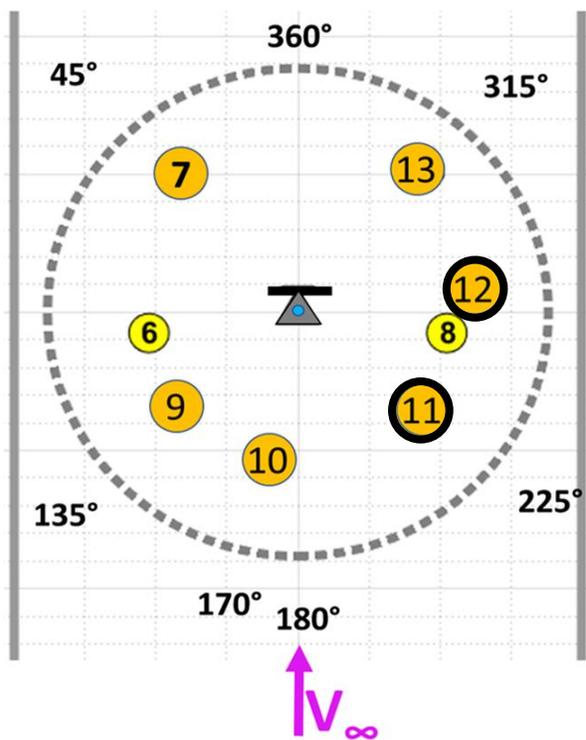|	1st BPF (ΔdB)	2nd BPF (ΔdB)	3rd BPF (ΔdB)
Mic #6	32.4	24.4	22.9
Mic #7	28.4	28.0	2.9
Mic #8	55.4	24.0	25.9
Mic #9	28.9	17.9	13.6
Mic #10	33.3	9.9	11.7
Mic #11	37.9	16.2	16.1
Mic #12	32.5	40.6	26.8
Mic #13	27.4	19.7	16.3

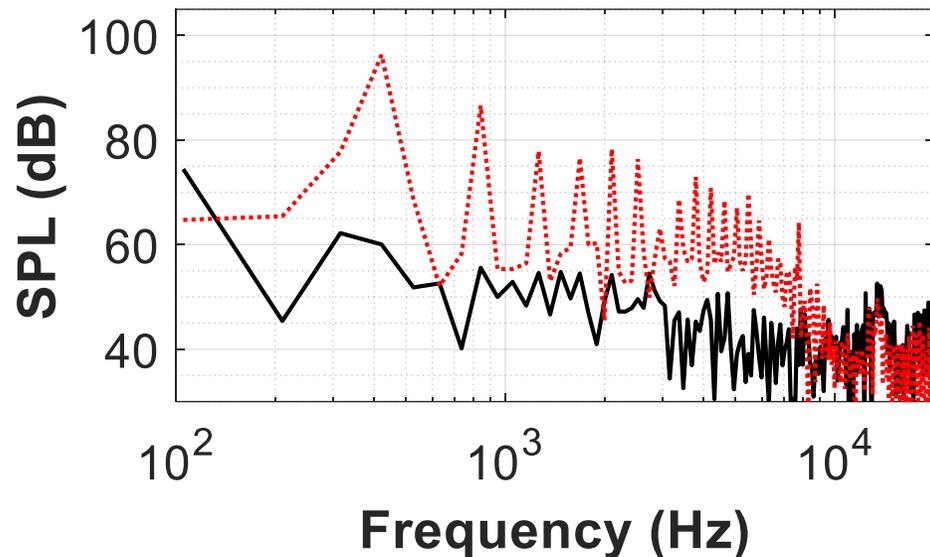# Signal-to-Noise: Full wing (Spectrum)

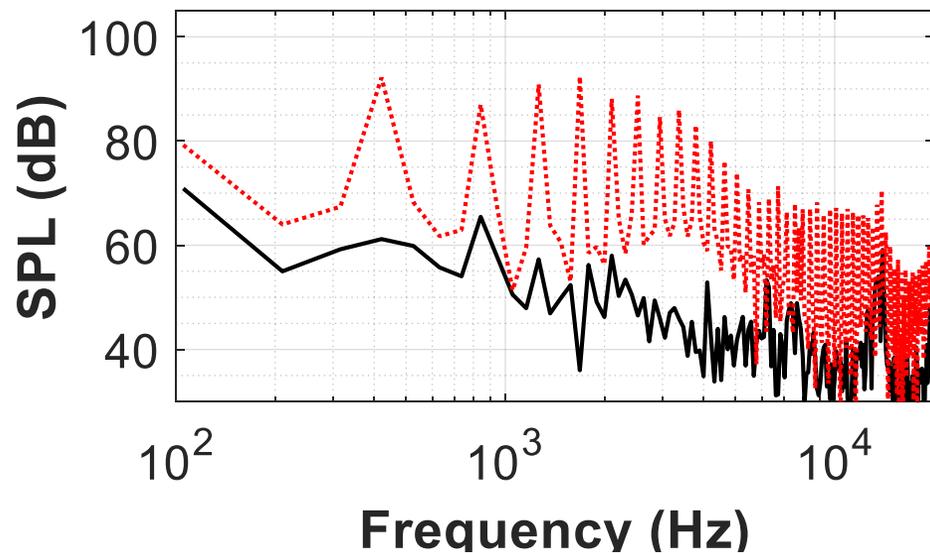**Full Wing**

M_{TUN} = 0.204

M_{TIP} = 0.636

Yaw = 5°

Pitch = 0°

Mic#12: 75.9 / 97.1 dB

Run 16 Point 19 (Aerotare) ——
Run 34 Point 24 (Blades on) ·········

Mic#11: 74.6 / 98.9 dB

	1st BPF (ΔdB)	2nd BPF (ΔdB)	3rd BPF (ΔdB)
Mic #6	32.4	24.4	22.9
Mic #7	28.4	28.0	2.9
Mic #8	55.4	24.0	25.9
Mic #9	28.9	17.9	13.6
Mic #10	33.3	9.9	11.7
Mic #11	37.9	16.2	16.1
Mic #12	32.5	40.6	26.8
Mic #13	27.4	19.7	16.3

Adequate S/N for all mics and first three BPF <u>for this condition</u>

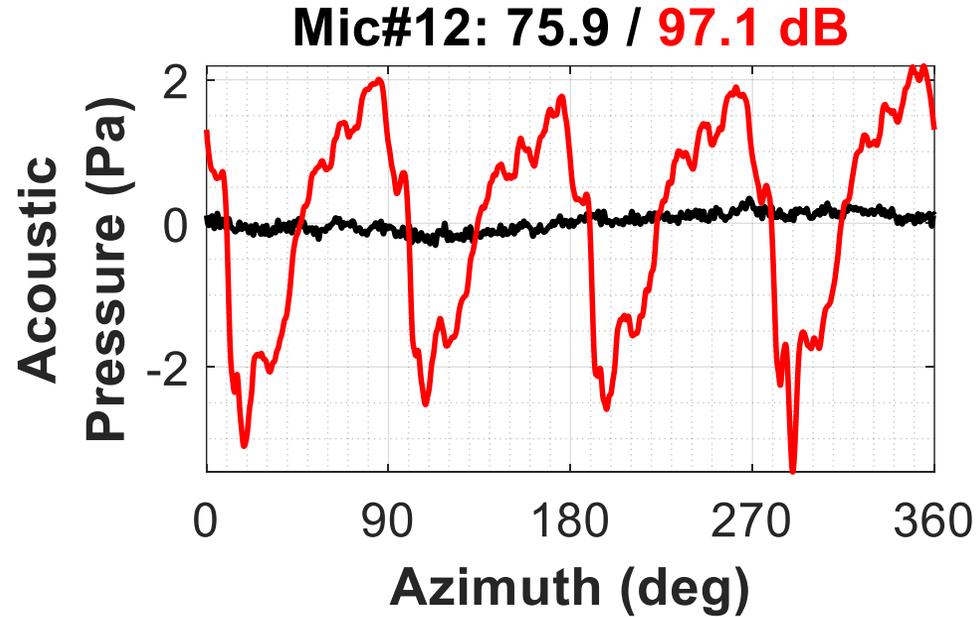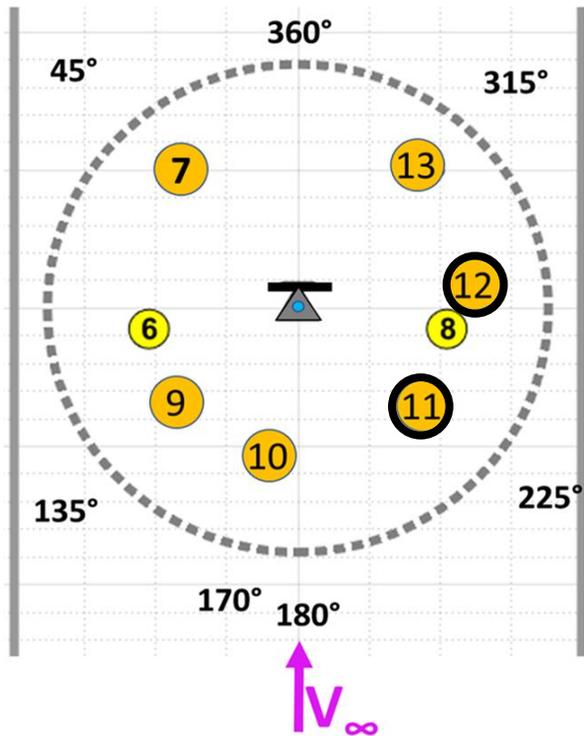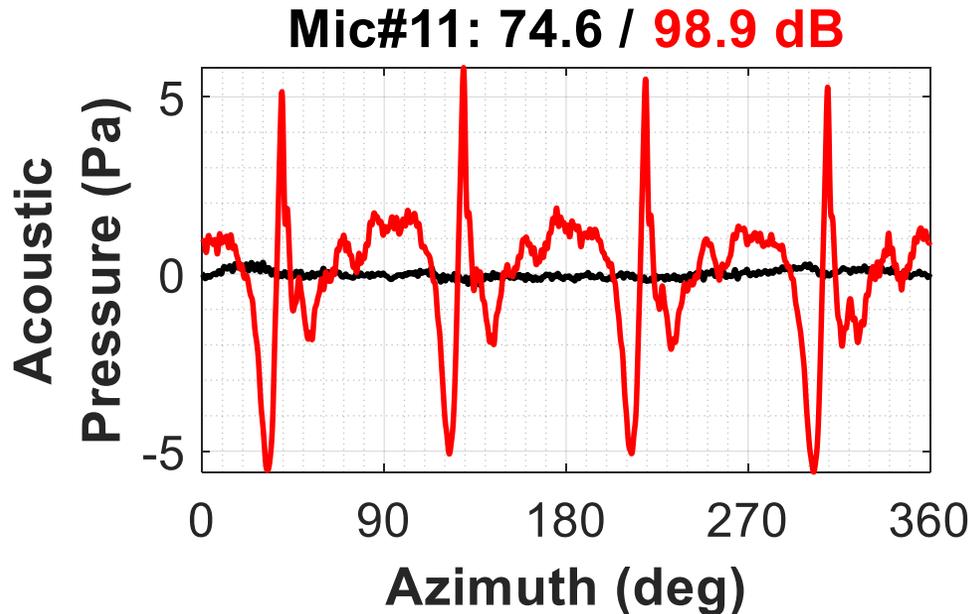# Signal-to-Noise: Full wing (Time History)

Full Wing

$M_{TUN} = 0.204$

$M_{TIP} = 0.636$

Yaw = 5°

Pitch = 0°

Mic#12: 75.9 / 97.1 dB

Run 16 Point 19 (Aerotare)
Run 34 Point 24 (Blades on)

Mic #11 (out-of-plane) reveals wing wake interaction (impulsive)

Mic#11: 74.6 / 98.9 dB

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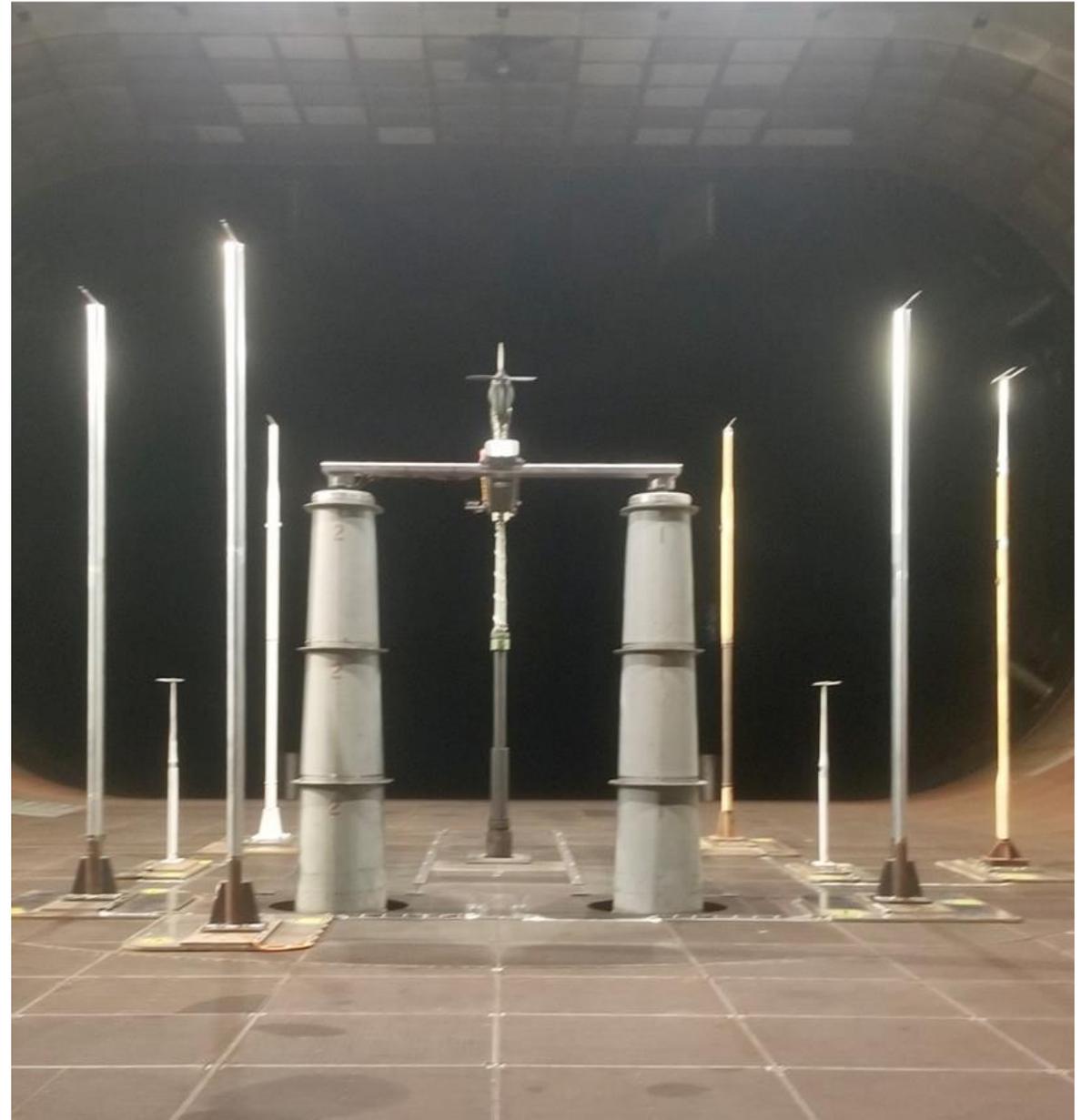
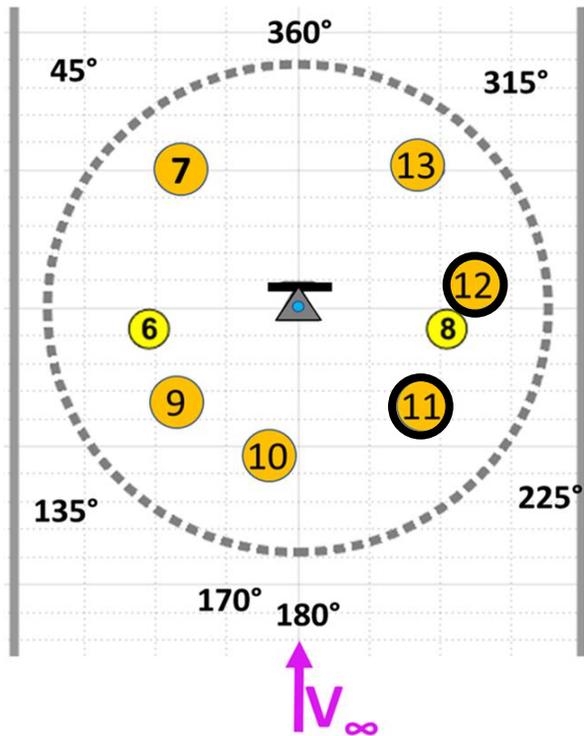# No wing vs. Half wing vs. Full Wing (Spectrum)

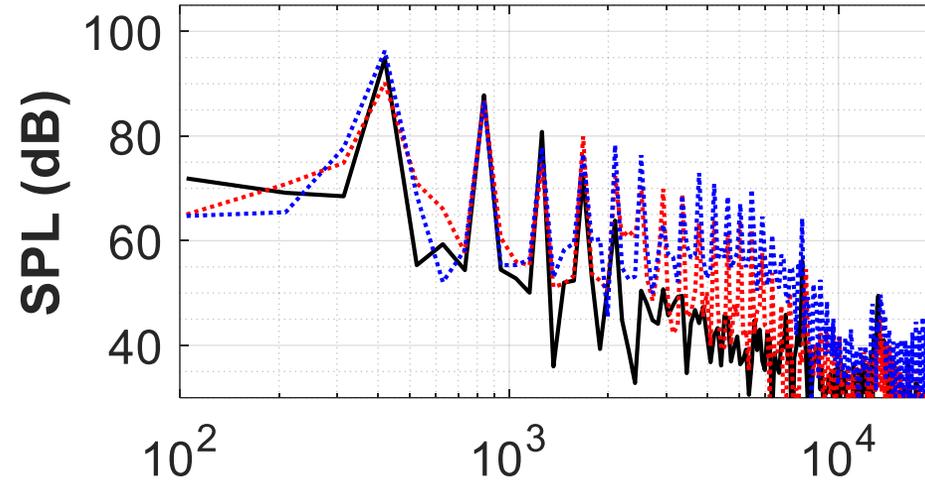**Blades on**

$M_{TUN} = 0.204$

$M_{TIP} = 0.636$

$C_T = 0.06$

Yaw = 5°

Pitch = 0°

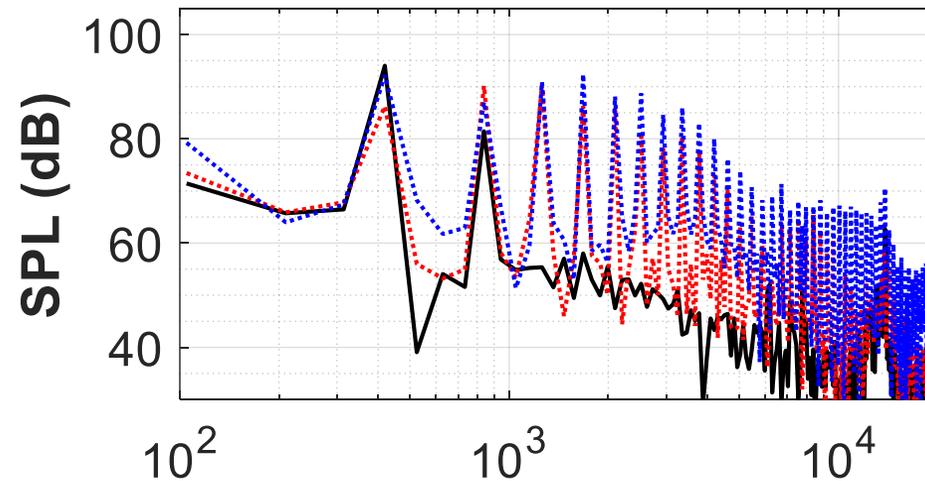**Mic#12: 95.8 / 92.5 / 97.1 dB**

Run 36 Point 23 (No Wing) ——
Run 31 Point 25 (Half Wing) ·······
Run 34 Point 24 (Full wing) ·······

Mic#11: 94.3 / 95.8 / 98.9 dB

Addition of the wing compared to no wing resulted in increase in OASPL
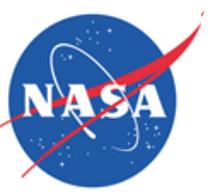
Blades on

$M_{TUN} = 0.204$

$M_{TIP} = 0.636$

$C_T = 0.06$

Yaw = 5°

Pitch = 0°
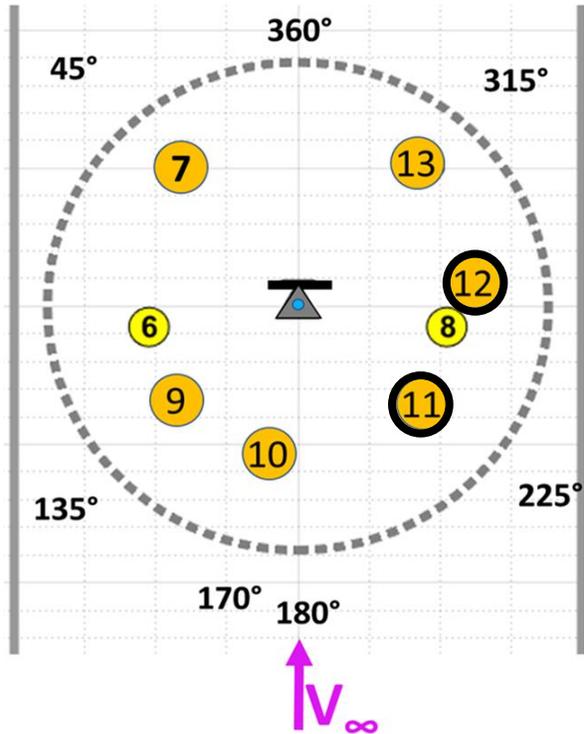
Mic#12: 95.8 / 92.5 / 97.1 dB

Run 36 Point 23 (No Wing) ──────
Run 31 Point 25 (Half Wing) ·········
Run 34 Point 24 (Full wing) ·········
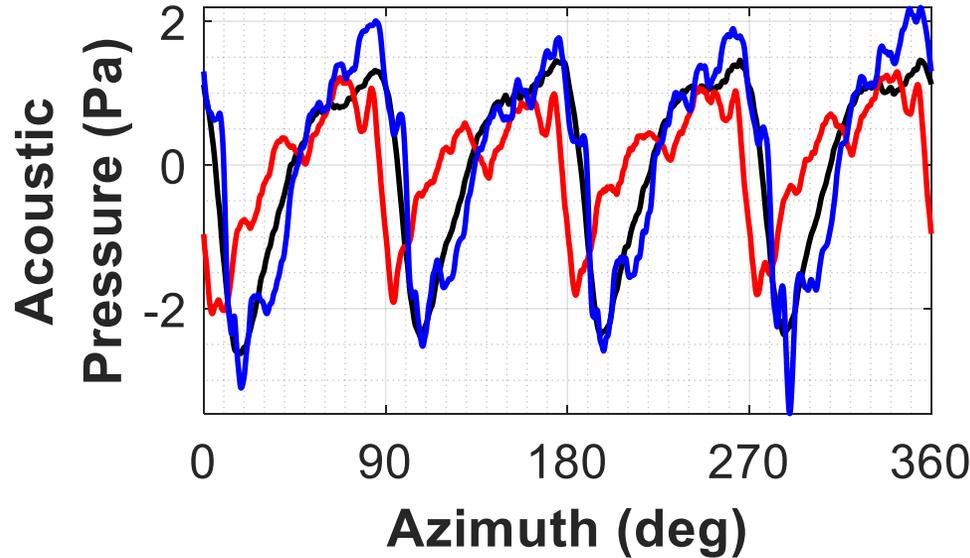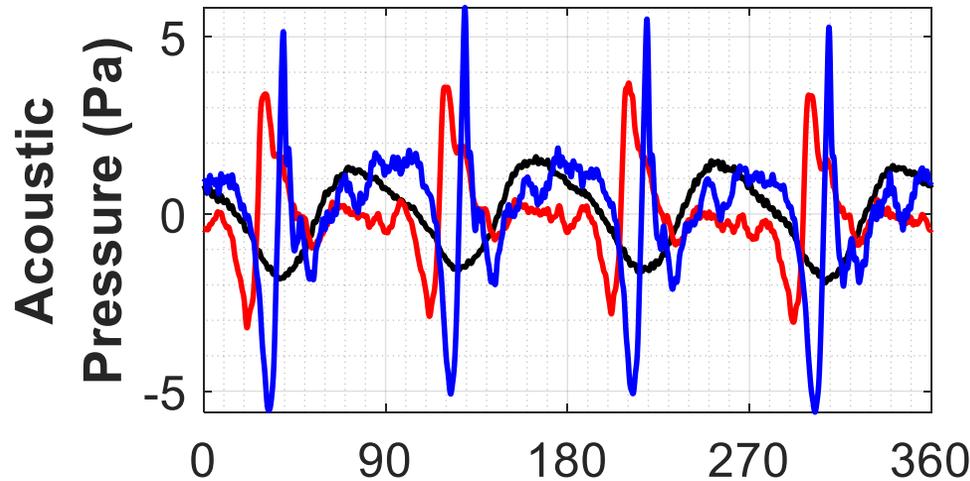
Mic#11: 94.3 / 95.8 / 98.9 dB

Time history reveals significance peak-to-peak difference of no wing compared to half and full wing

Concluding Remarks

- Background noise for wing configurations are consistent and minimal.

- Data is repeatable for the 4 selected points

- S/N adequate for further analysis, especially for wing/prop configurations

- Addition of wing and half-wing produced anticipated changes in the unsteady loading noise of the propeller

Further analysis to be completed