Nearfield Unsteady Pressures at Cruise Mach Numbers for a Model Scale Counter-Rotation Open Rotor

An open rotor experiment was conducted at cruise Mach numbers and the unsteady pressure in the nearfield was measured. The system included extensive performance measurements, which can help provide insight into the noise generating mechanisms in the absence of flow measurements. A set of data acquired at a constant blade pitch angle but various rotor speeds was examined. The tone levels generated by the front and rear rotor were found to be nearly equal when the thrust was evenly balanced between rotors.

Nearfield Unsteady Pressures at Cruise Mach Numbers for a Model Scale Counter-Rotation Open Rotor

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18th AIAA/CEAS Aeroacoustics Conference (33rd AIAA Aeroacoustics Conference)

Test Campaign in Collaboration with General Electric

- Open Rotor Propulsion Rig
  - 750 SHP per rotor
  - 450 lbf thrust per rotor
  - 550 ft-lb torque per rotor
- Historical Baseline Blades
  - 12 Forward / 10 Aft
  - 28.9 / 25.4 in Diameter

NASA Project Lead: Dale Van Zante

NASA/GE 9x15 Low Speed Wind Tunnel		**NASA/GE 8x6 High Speed Wind Tunnel**	**NASA/GE/FAA (CLEEN) 8x6/9x15**
GE Gen-1 Blade Designs			GE Gen-2 Blade Designs
Takeoff and Approach Conditions	ERA Diagnostics	Cruise Conditions	TO/Approach and Cruise Conditions
•Aerodynamic performance •**Acoustics** •Hot Film flowfield measurements	•Acoustic phased array •Farfield Acoustics with Pylon •Pressure Sensitive Paint •Stereo Particle Image Velocimetry •Acoustic Shielding	•**Aerodynamic performance** •Near field unsteady pressure	• Aero and acoustic performance of optimized blade designs at low and high speed.

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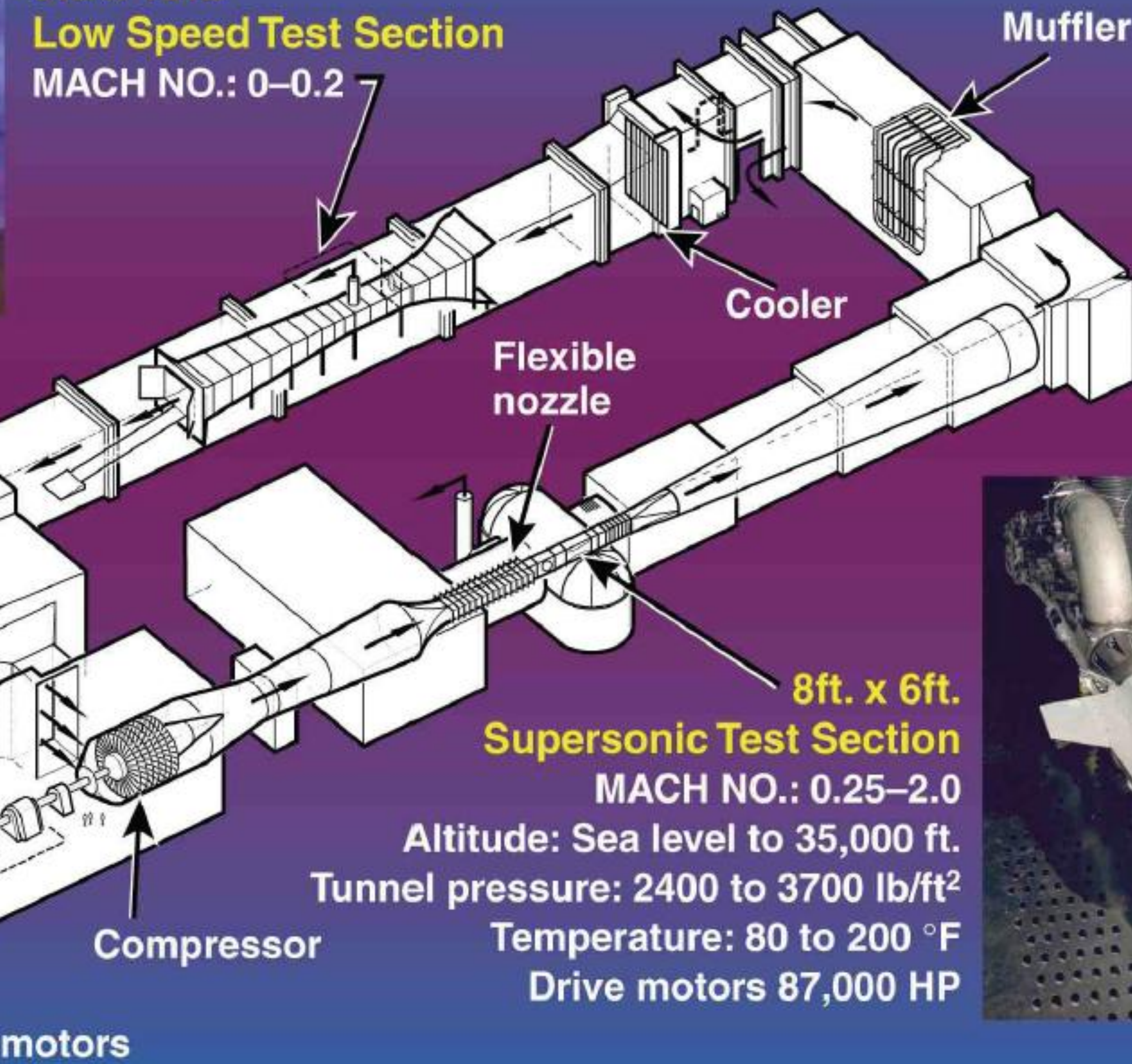
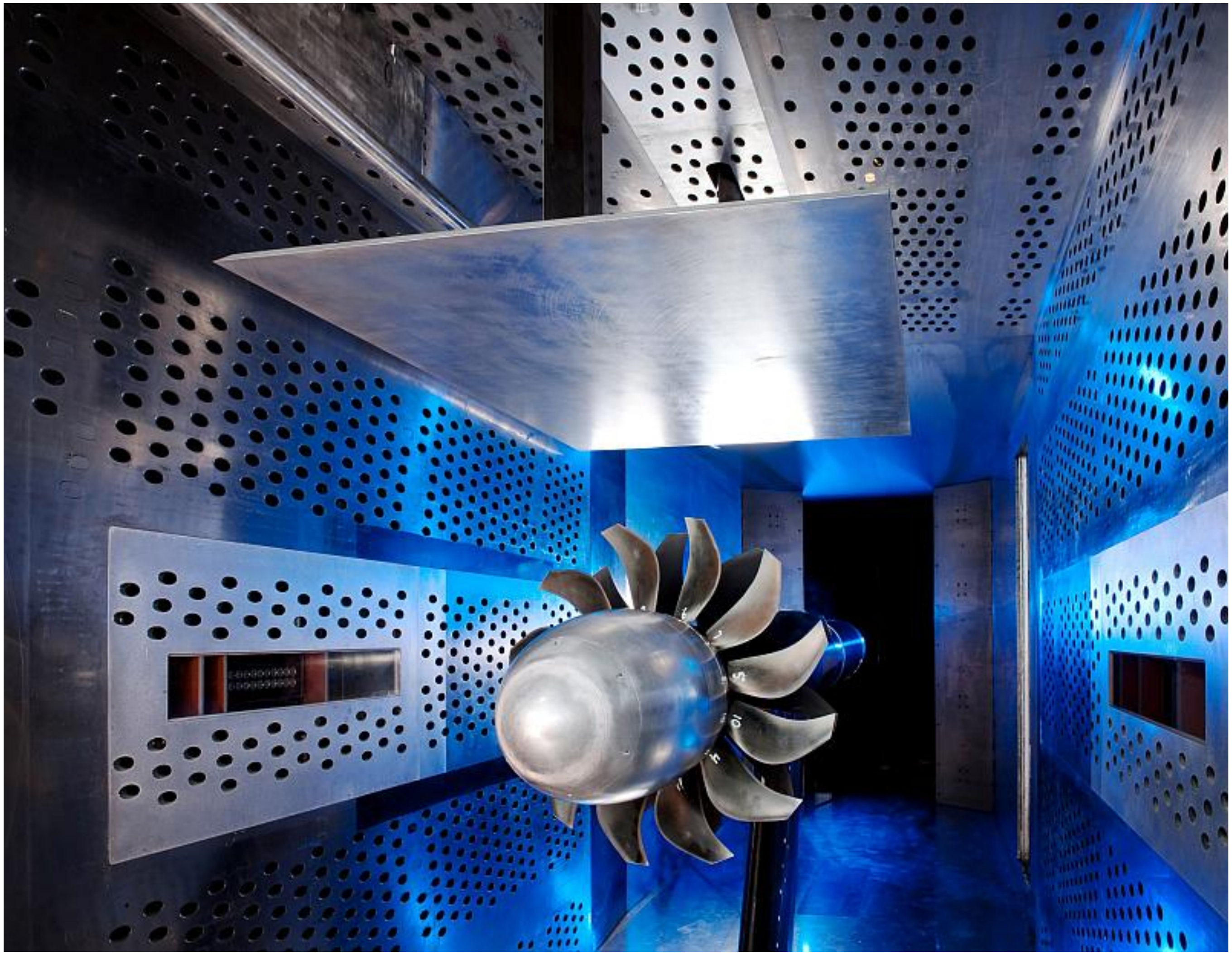
8x6 SWT/9x15 LSWT Wind Tunnel Complex



CD-98-77052

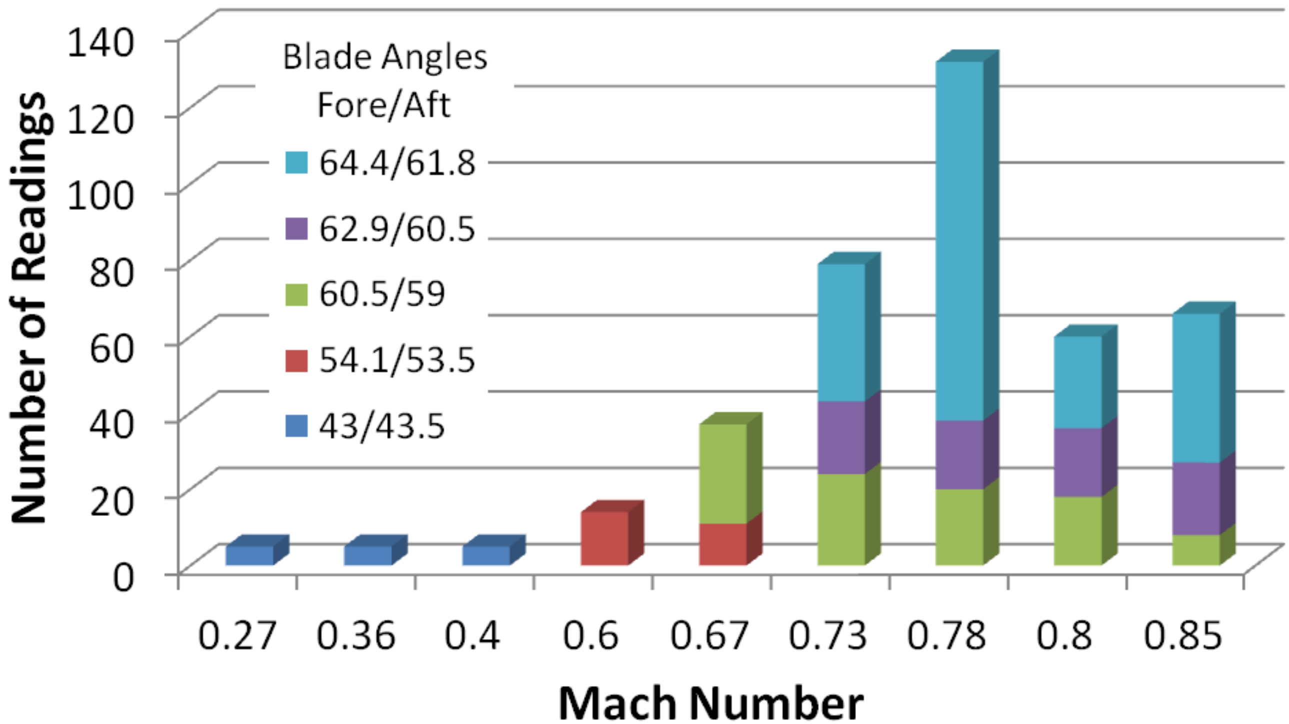
Near field Unsteady Pressure Measurements

- 17 Kulite transducers flush mounted to an aluminum plate
- Plate translates from ceiling of tunnel ($1.78D_f$) to within $0.65\ D_f$ of centerline
- Centered around aft rotor
- Non-anechoic environment
- Utility of data
  - Structural Acoustics
  - En Route Noise



Historical Baseline Database

- Parameters
  - Mach 0.27 to 0.85
  - 5 pitch angles
  - 2 rotor spacings
  - Up to 8300 RPM
  - 5 plate heights
  - 403 total readings



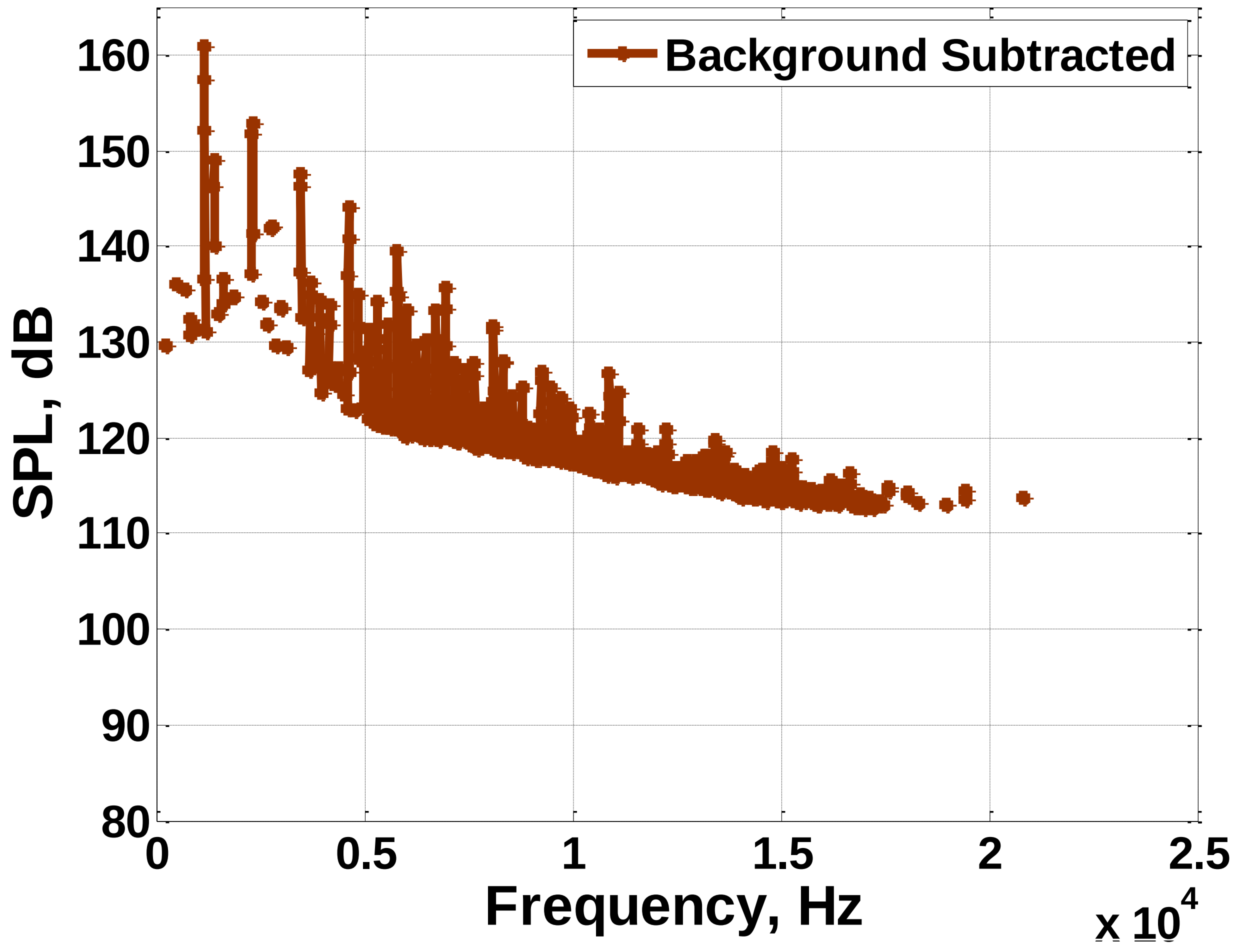
6 Readings

- Spacing: 7.84 in
- Pitch: 64.4º/61.8º
- Plate Height = 0.78 D
- Mach = 0.78
- Vary RPM

RDG	RPM	T_f+T_a	T_f/T_a	Q_f/Q_a	J	η
2938	5713	93	8.14	2.85	1.38	0.600
2943	6093	291	1.23	1.35	1.29	0.803
2948	6337	434	0.96	1.11	1.25	0.828
2953	6474	523	0.89	1.04	1.22	0.830
2958	6664	642	0.83	0.98	1.18	0.826
2966	6943	800	0.8	0.95	1.14	0.812

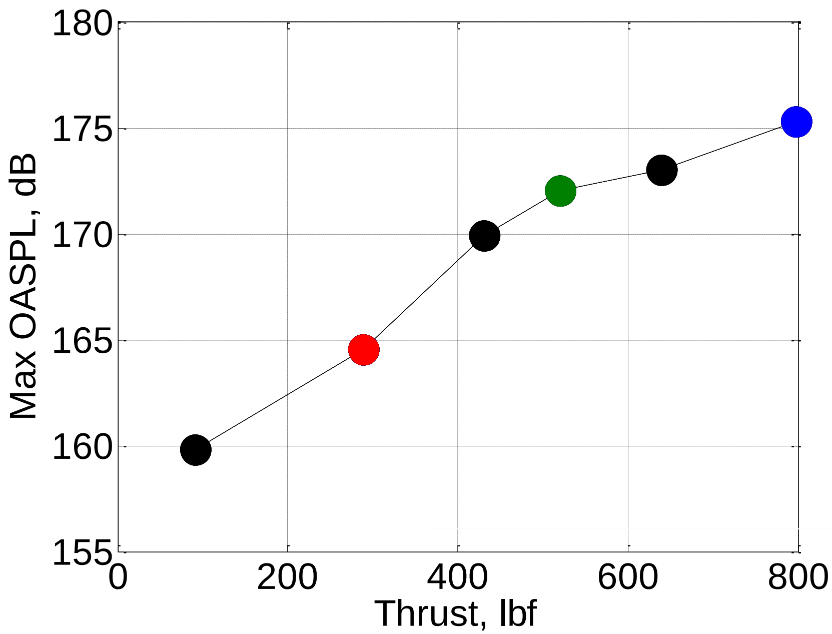
Narrowband Pressure Spectra

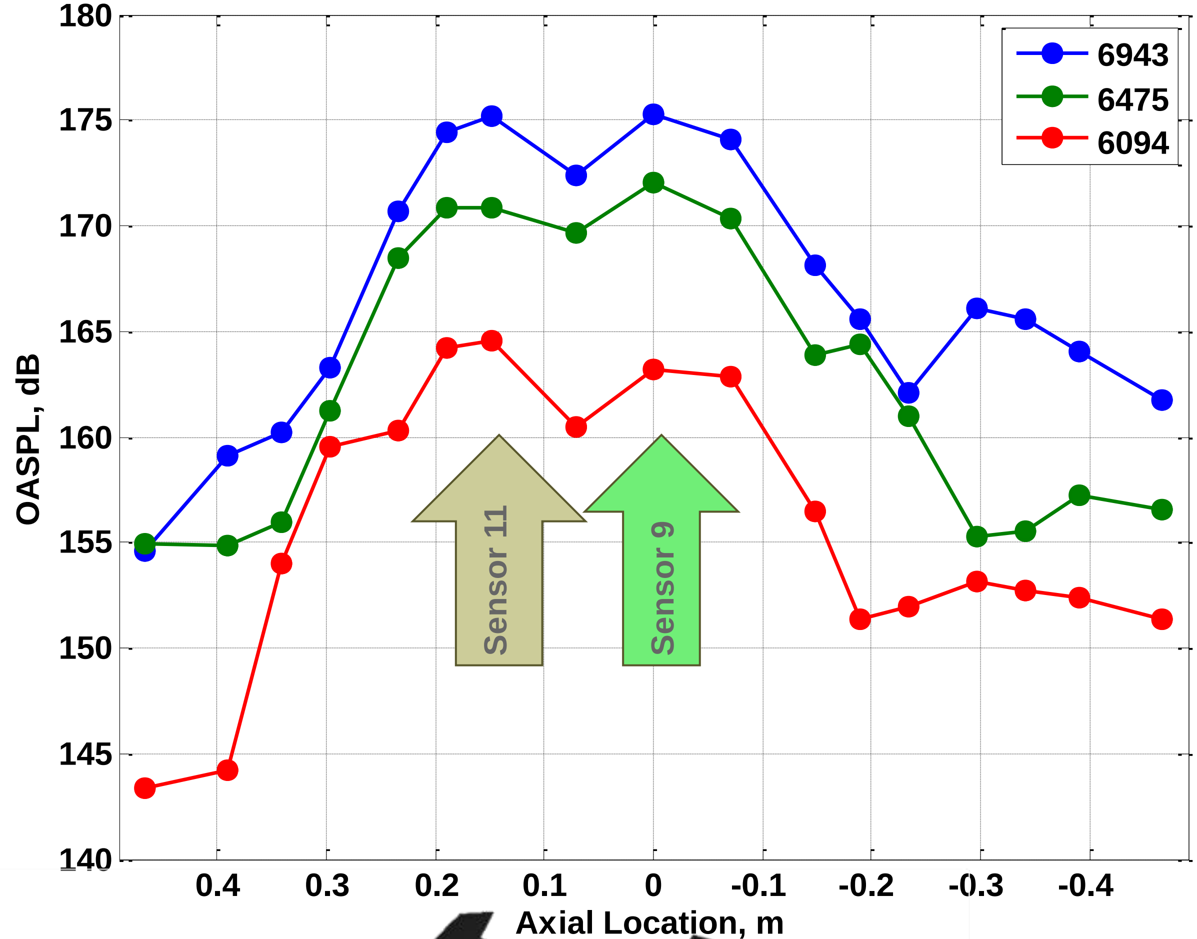
- Tare runs: Blades removed
  - Vary tunnel Mach, plate height
- Data Processing
  - SPL, ref 20µPa
  - 12.2 Hz bin width
- Background level subtraction
  - 6 dB threshold
- Pressure signal tone dominated
- Integrate to get OASPL

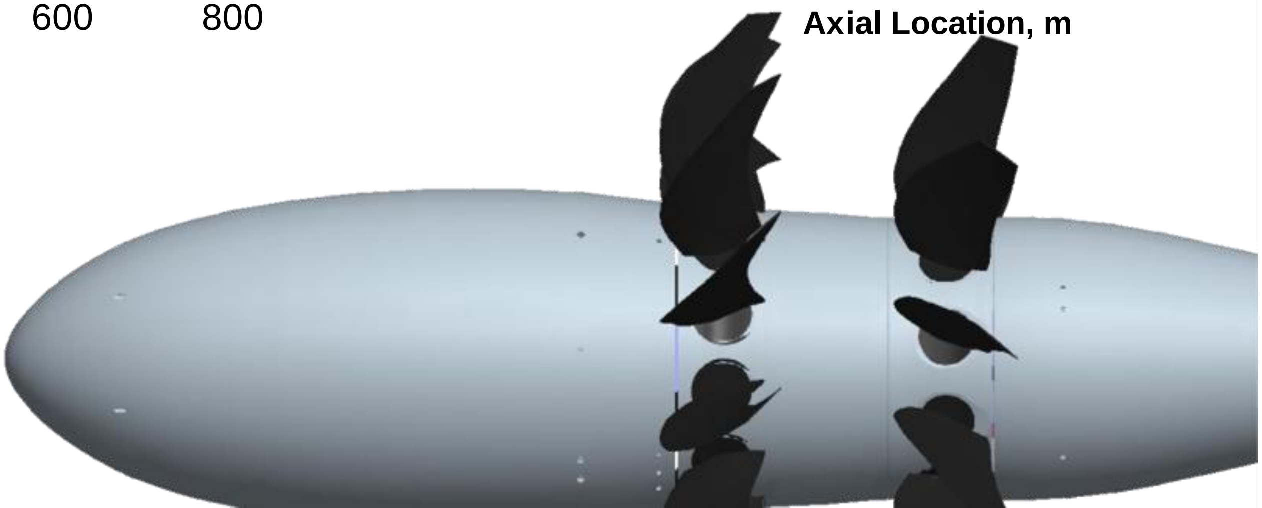


Sideline OASPL Levels

- Plate Height = 0.78Df
- Two local maxima correspond to rotor locations

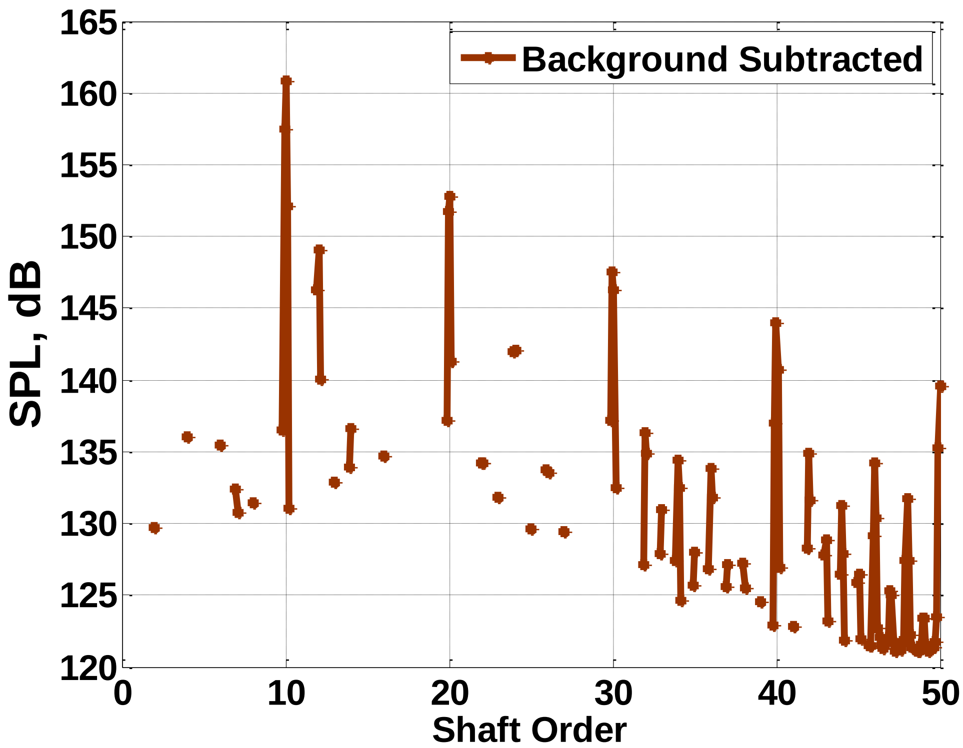


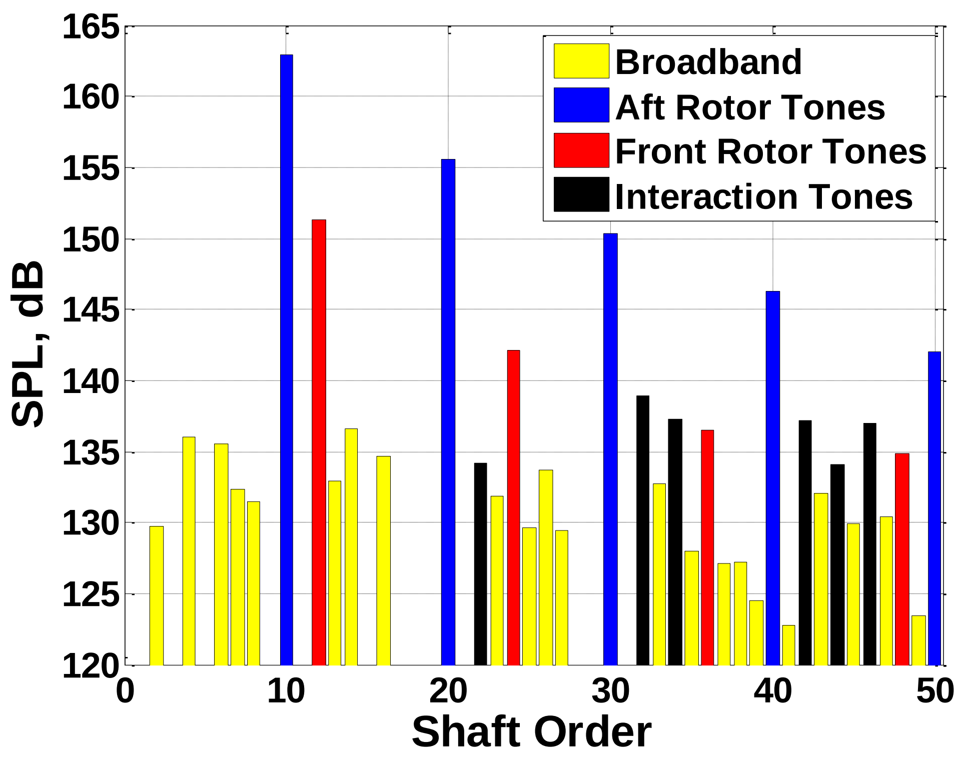




Tone and Broadband Levels

- Integrate tones, average broadband level

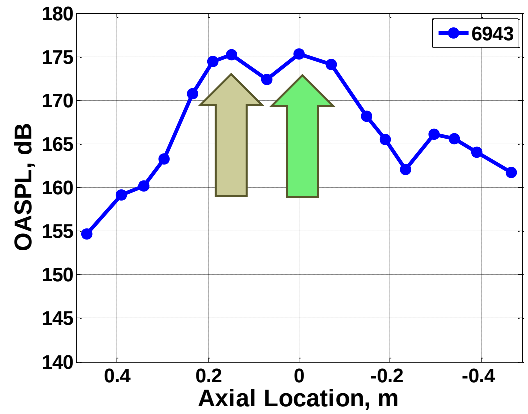


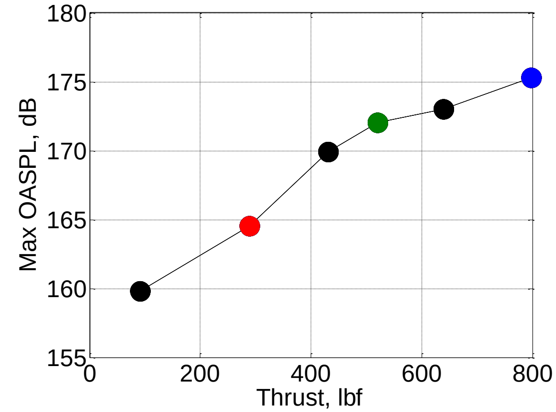


$$\text{Shaft Order Interaction Tones} = \frac{mB_f N_f + nB_a N_a}{.5\,(N_f + N_a)}$$

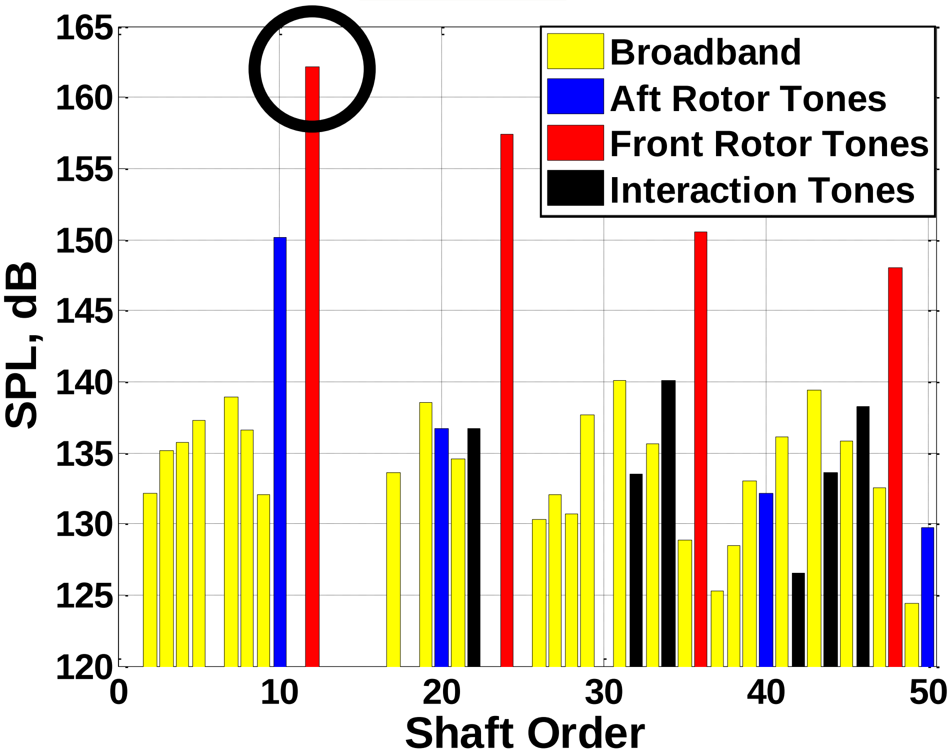
Spectral Content

- Sensors nearest forward and aft rotors
- Mach = 0.78, Plate Height = 0.78 D
- 800 lb Thrust
- Tone levels show considerable symmetry

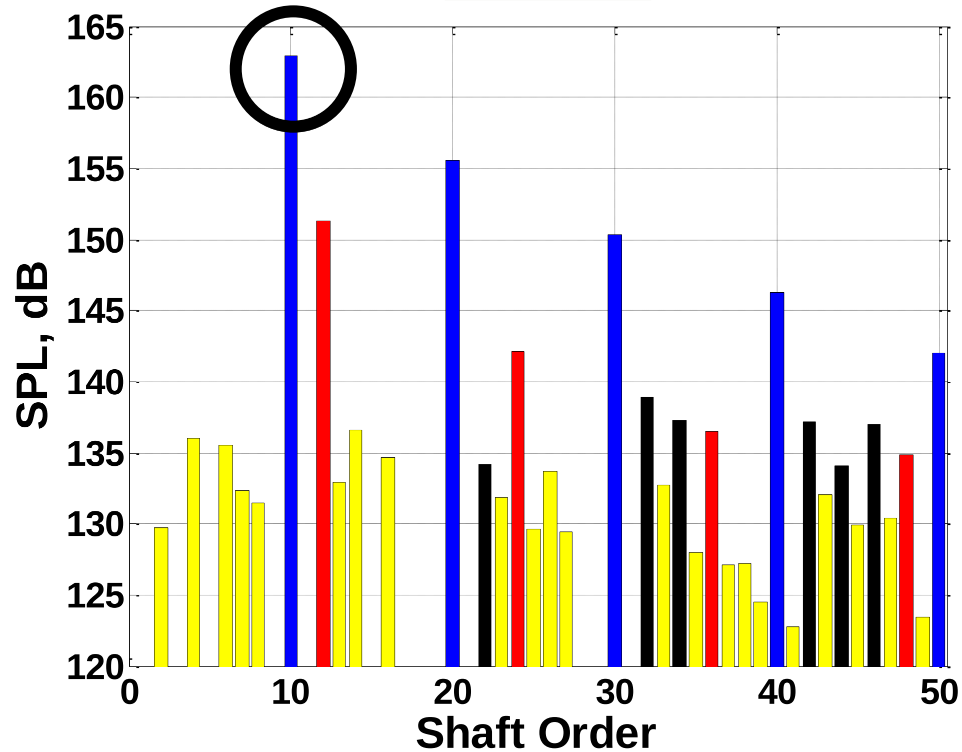




Sensor 11

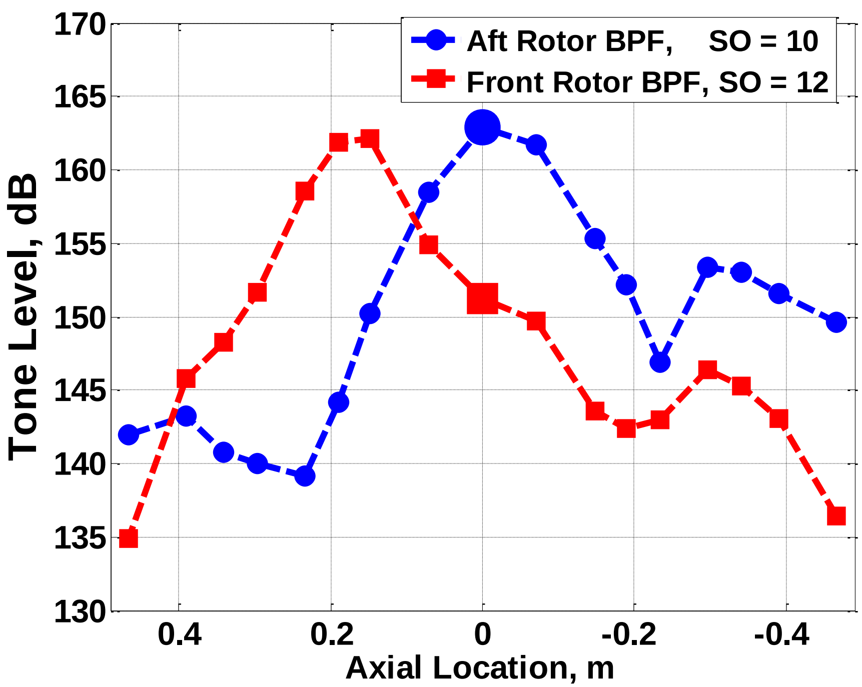


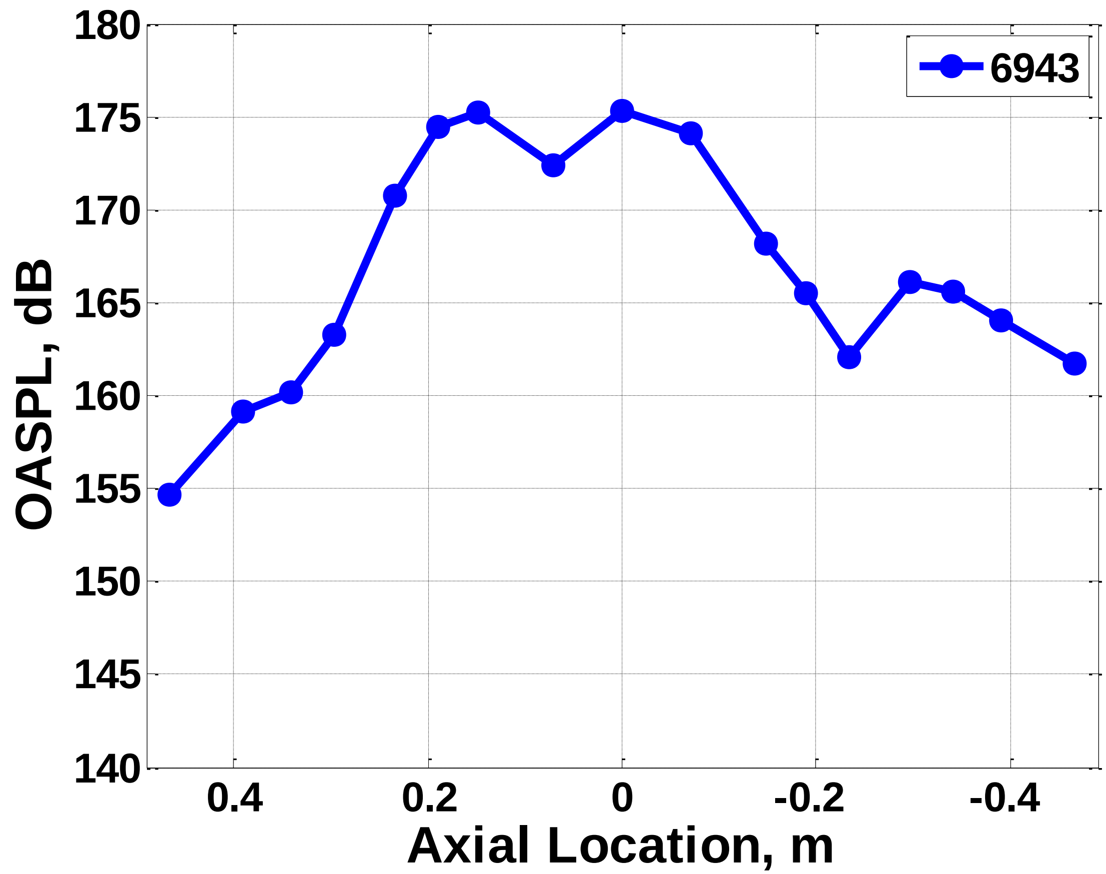
Sensor 9



Blade Passing Frequency Tones

- Sideline OASPL shows two peaks due to very close measurement
- Frequency content of signals assigns responsibility to each rotor





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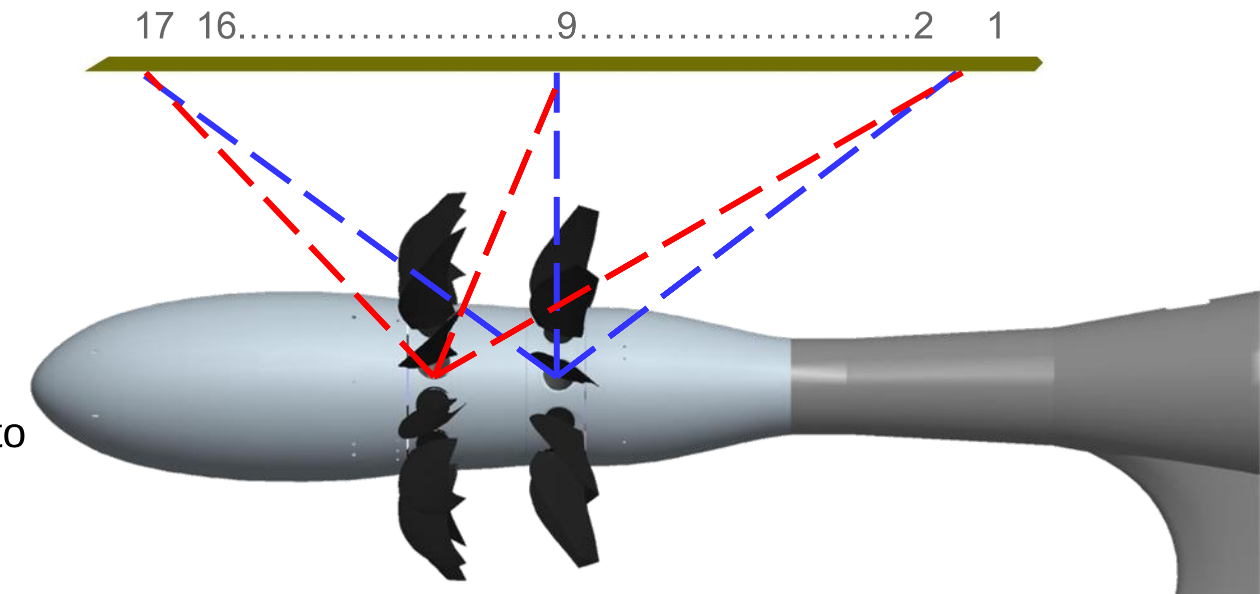
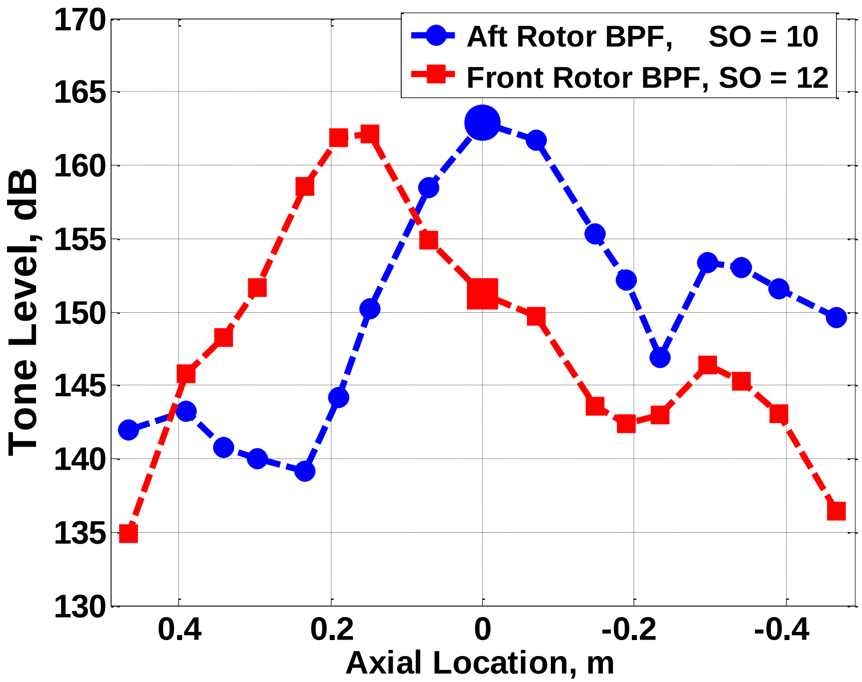
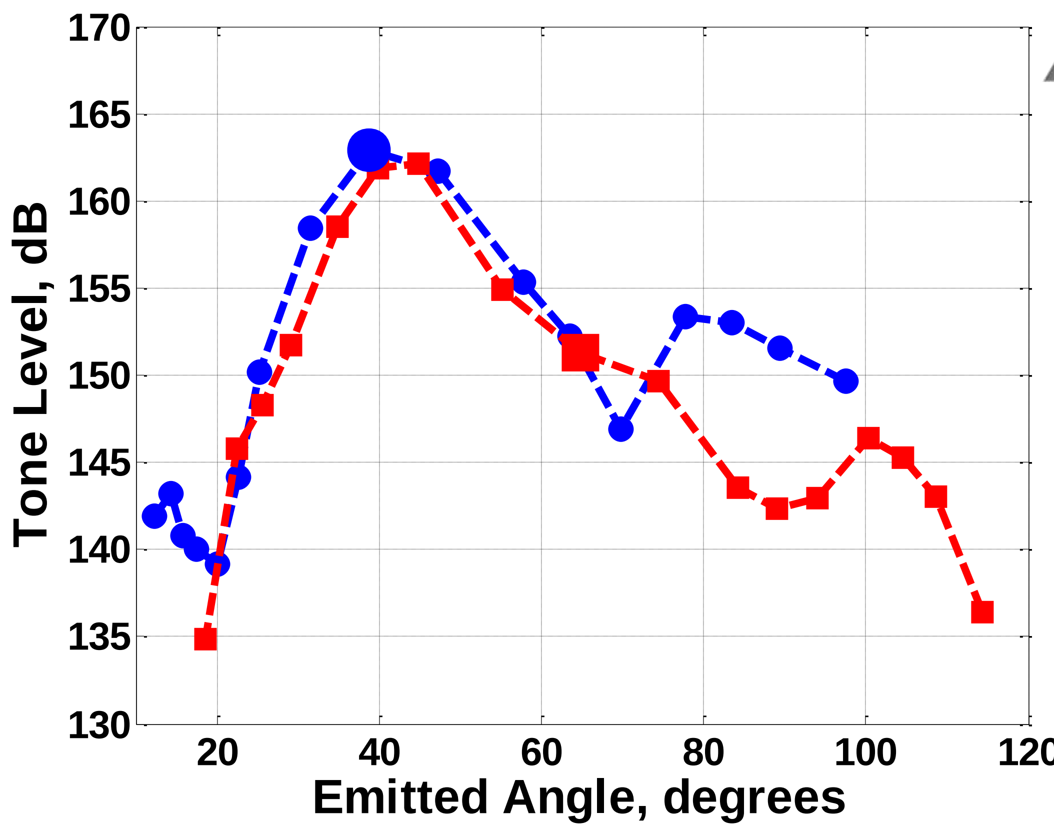


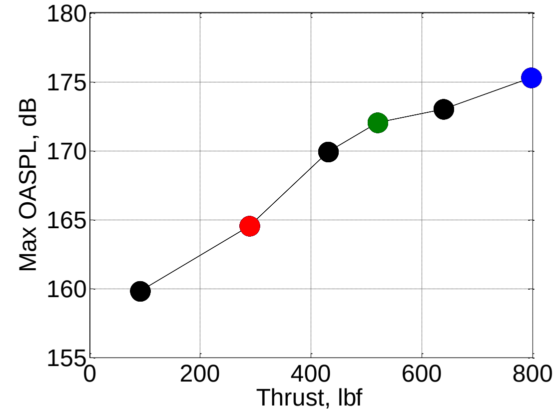
$$\theta_e = \theta_g - \arcsin\left(M_0 \sin\left(\theta_g\right)\right)$$

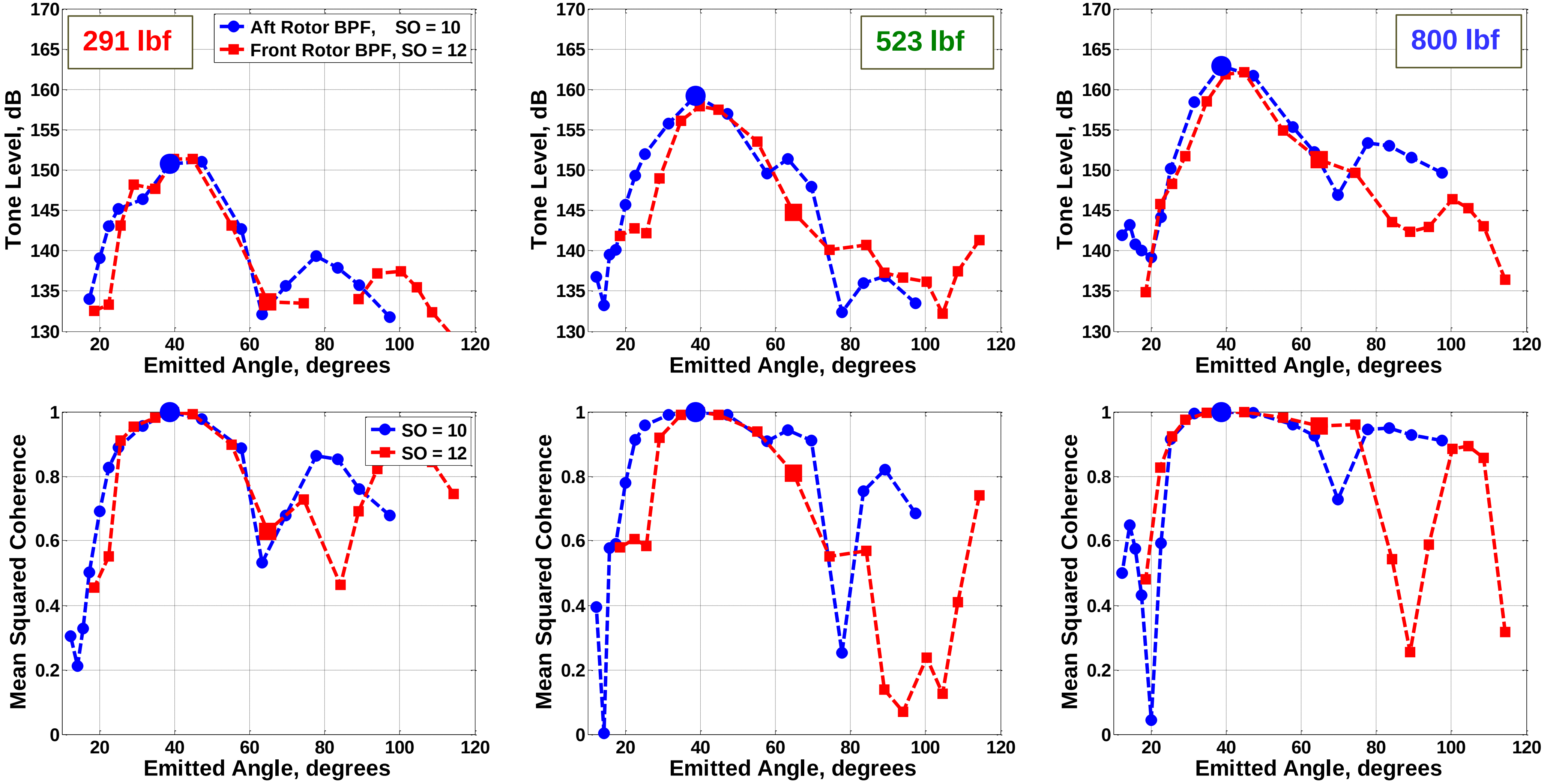




Tone Directivity and Coherence

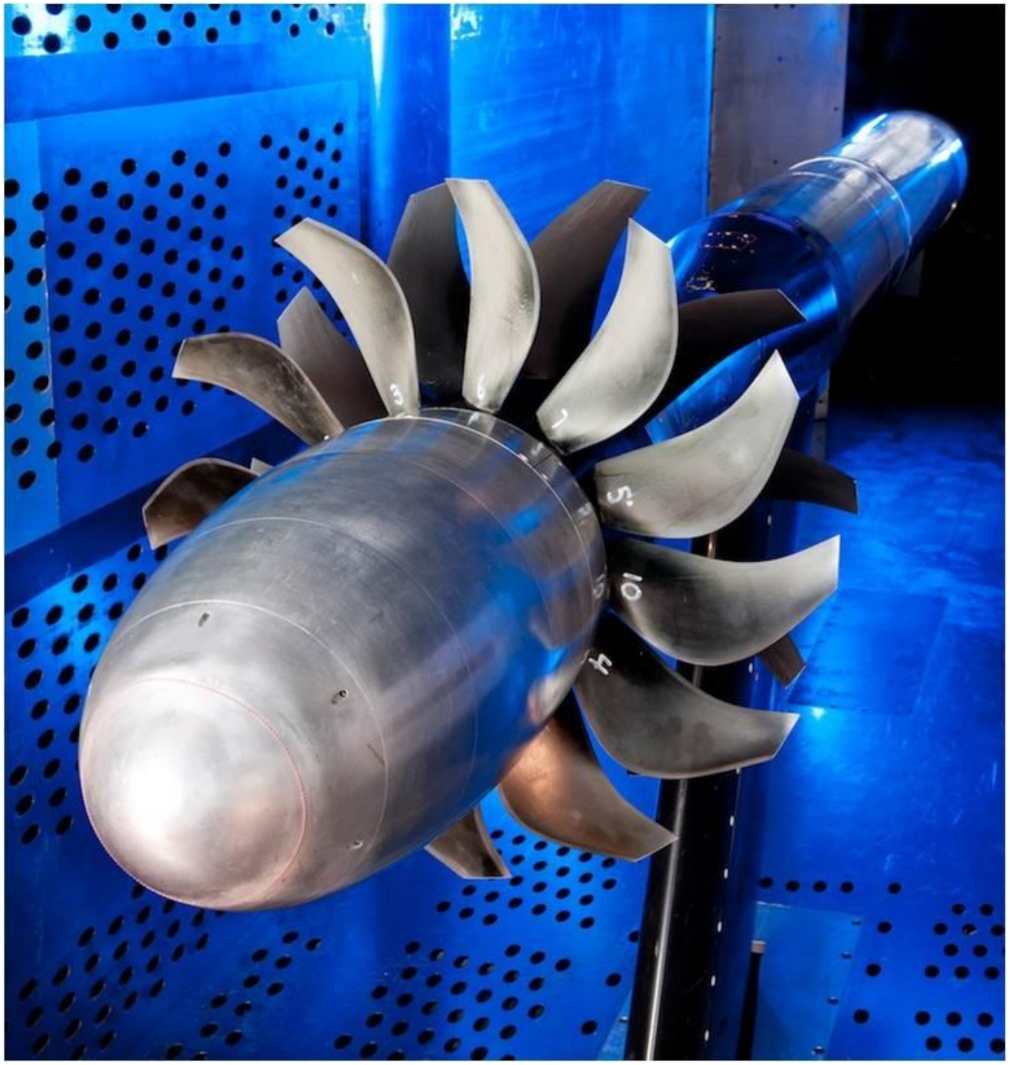
- Tone levels for each rotor very similar, despite blade count and diameter differences
- Coherence suggests reflections





Conclusions

- Extensive test campaign and considerable database exists
- OASPL on a 0.78Df sideline exceeds 175 dB
- Blade rate tones and harmonics largest contributor
- Front and rear rotor BPF tones nearly equal
  - Equal RPM
  - Near equal thrust and torque
- Pressure spectra have high coherence over emitted angles between 25 and 75 degrees



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