

AFC Sweeping Jet Aeroacoustic Measurements and Phased Microphone Array Development

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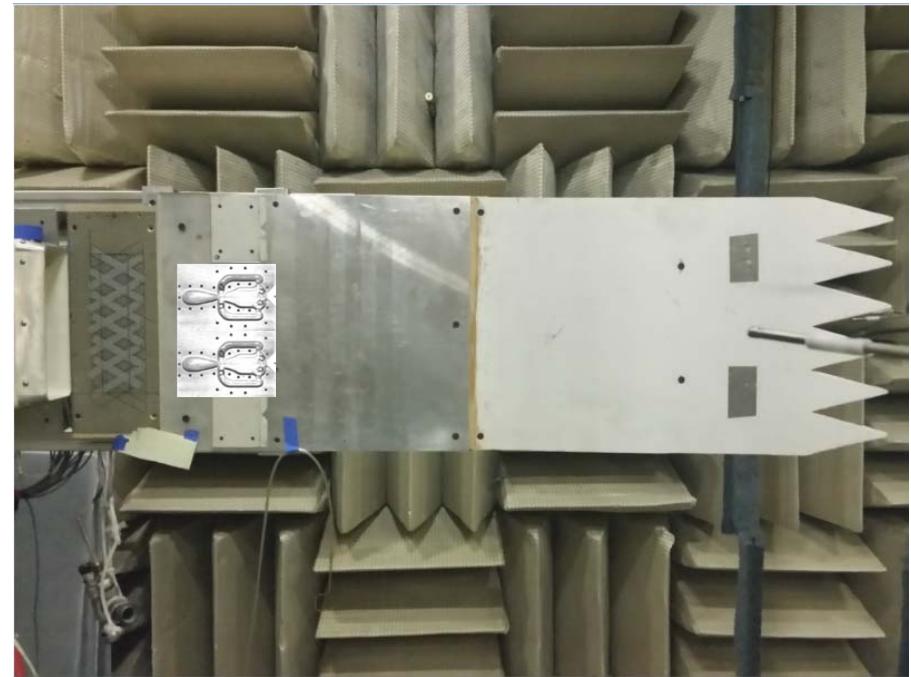
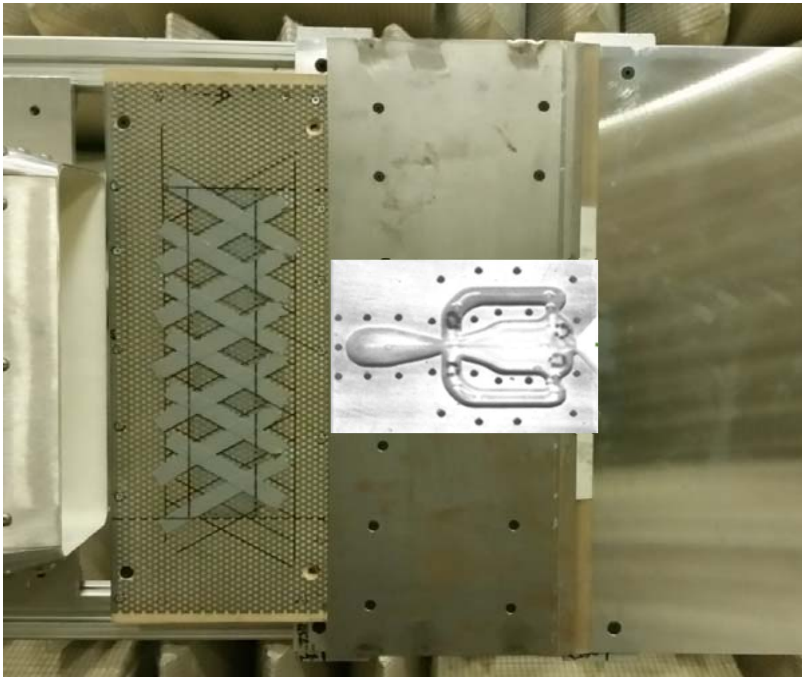
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Spring 2016 Acoustics Technical Working Group Meeting, April 19-20, Hampton, VA

Topics

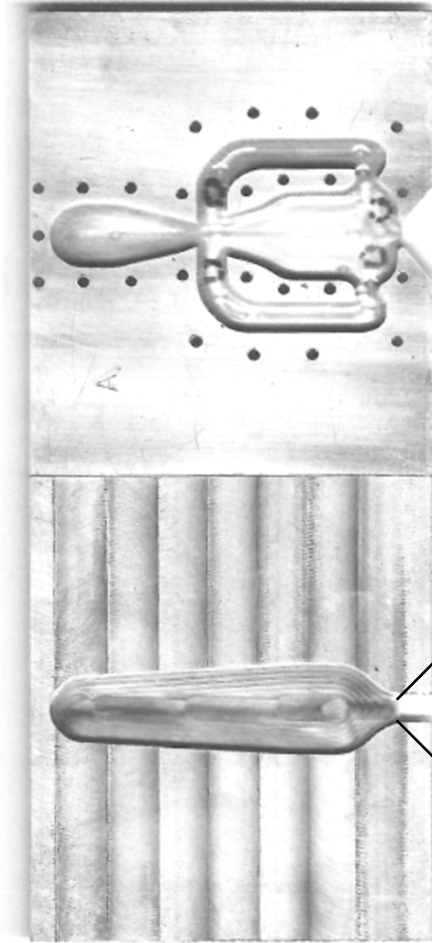
- Active Flow Control(AFC) sweeping jet acoustic and flow measurements (AATT High Aspect Ratio Wing) – paper submitted to 22nd AIAA/CEAS Aeroacoustics Conf
- Array fairing, windscreen optimization (TTT Advanced Sensors)
- ARC/GRC/LaRC common reference phased microphone array and calibration sources(AATT ANR FY16 OGL task)

AFC Sweeping Jet Acoustic Study in ARC anechoic chamber

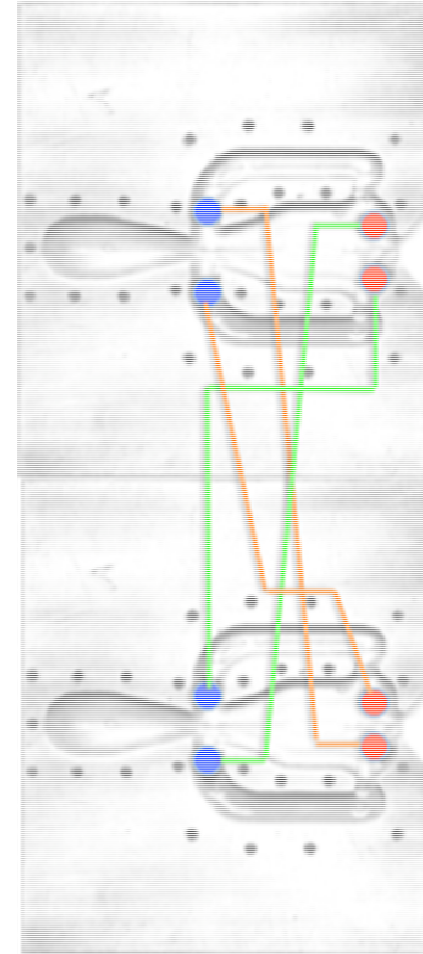


- Single full- and dual half-scale actuators relative to 2013 757 rudder test with 37 actuators
- Actuators on wall plate, exits $\sim 13''$ downstream of $4'' \times 10''$ nozzle
- $0 < M_{\text{NOZZLE}} < 0.19$, $5 < P_{\text{IN}} < 33$ psig, $\Rightarrow 24 < W < 88$ scfm(FS)

Half-scale actuator configurations

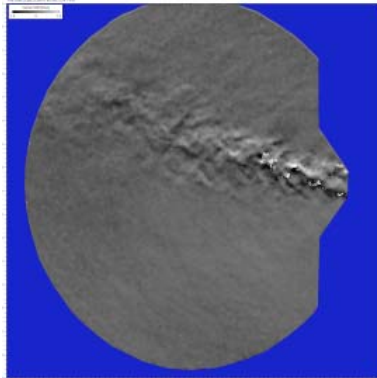


Single sweeping, steady jets
measured independently

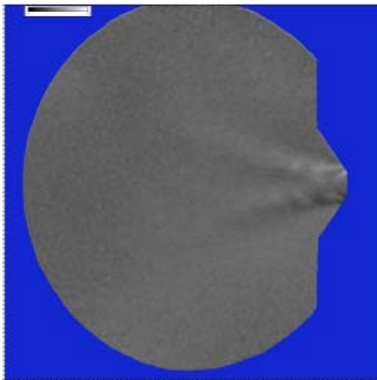


Dual sweeping jets, independent
and synchronized in- , out-of-phase
(shown)

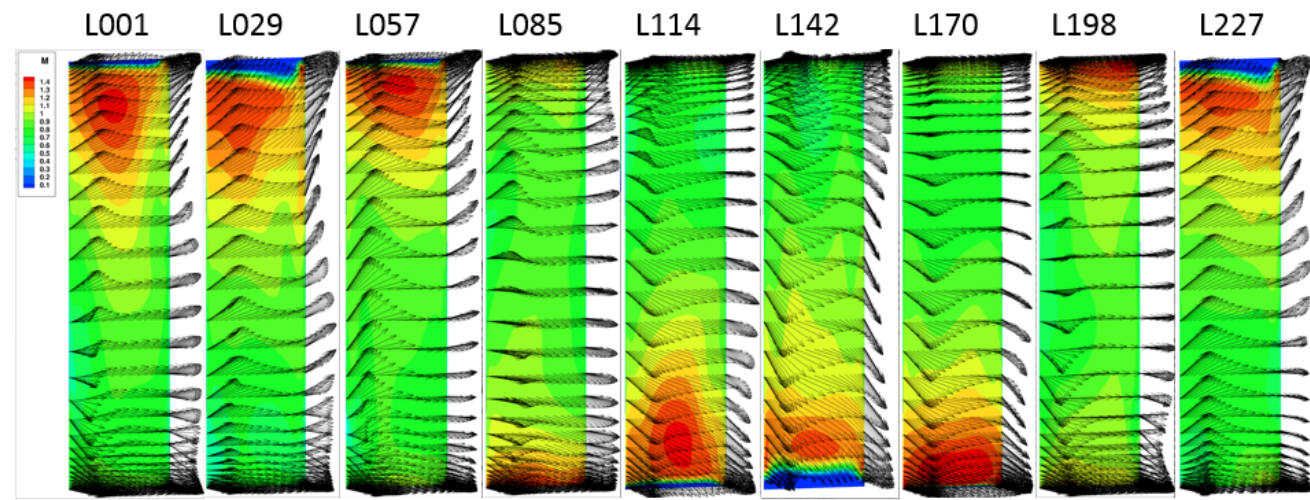
Sweeping jet visualization, computation



Instantaneous Schlieren
image of sweeping jet
actuator



Time-avg. Schlieren
image of sweeping jet
actuator

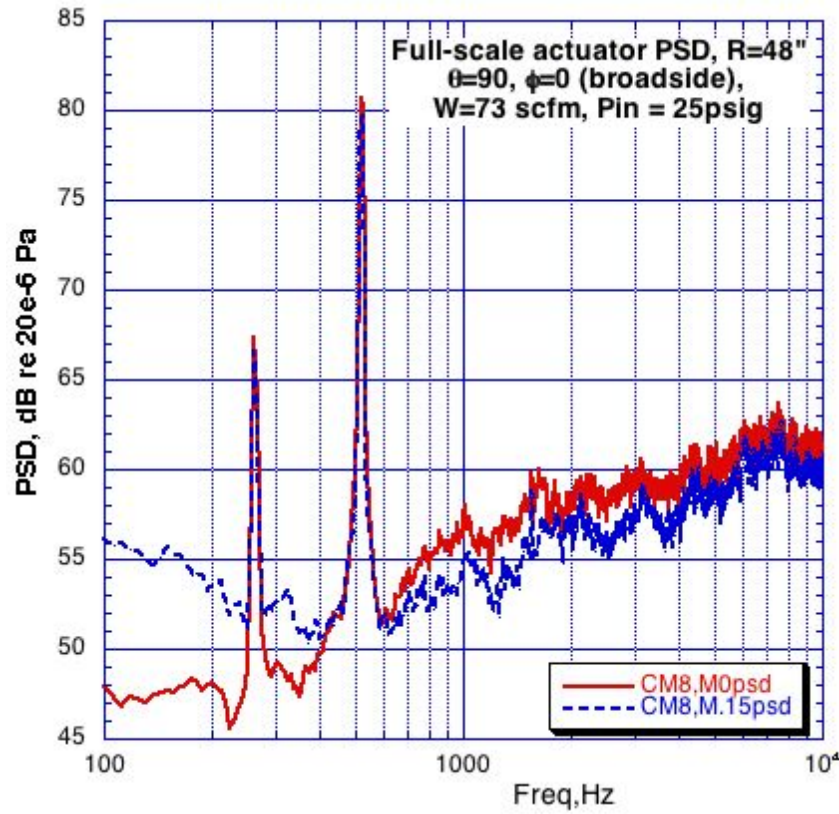


Mach No. profiles on sweeping jet nozzle exit plane at 8 intervals within one oscillation cycle. Overflow computation (Childs)

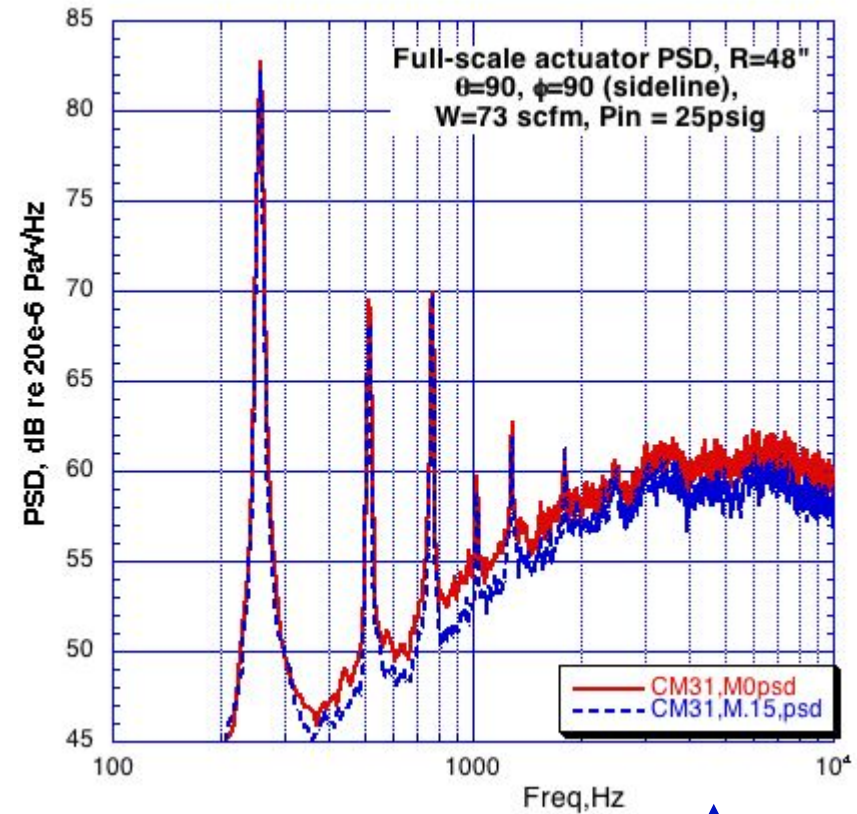
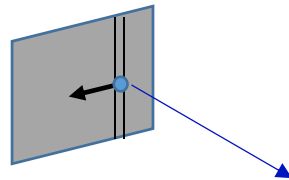
“Visualization of a Sweeping Jet by Laser Speckle Retro-reflective Background Oriented Schlieren”, Kushner, L.K., Heineck, J.T., Storms, B.L., and Childs, R.E, AIAA_2015-1697, AIAA SciTech, 53rd AIAA Aerospace Sciences Meeting, Jan 2015, Kissimmee, FL

Sweeping Jet Sound Power Spectral Density

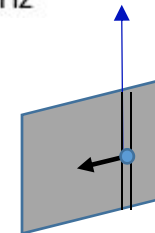
Red: $M=0$, Blue: $M=0.15$



Broadside to wall
 Emission angle $\theta = 90^\circ$
 Azimuth angle $\phi = 0^\circ$



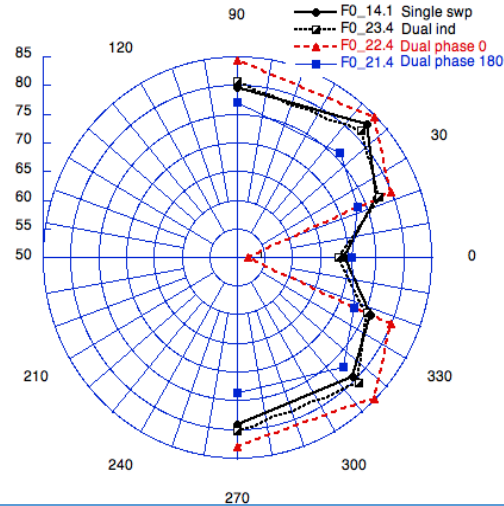
Sideline to wall
 Emission angle $\theta = 90^\circ$
 Azimuth angle $\phi = 90^\circ$



Half-scale single, dual actuator tone directivities

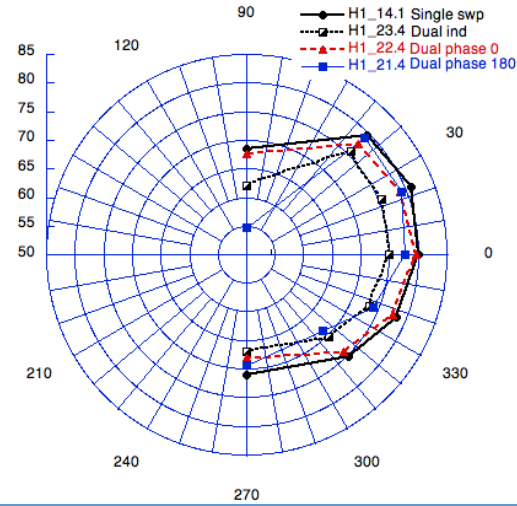
Fundamental $F_0 = 420$ Hz

Half 12th oct., $M=0$, 10 scfm, ϕ at $\theta = 90^\circ$, $F_0 = 420$ Hz

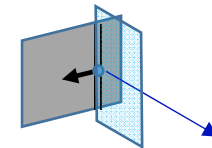


1st harmonic $F_1 = 840$ Hz

Half 12th oct., $M=0$, 10 scfm, ϕ at $\theta = 90^\circ$, $H_1 = 841$ Hz

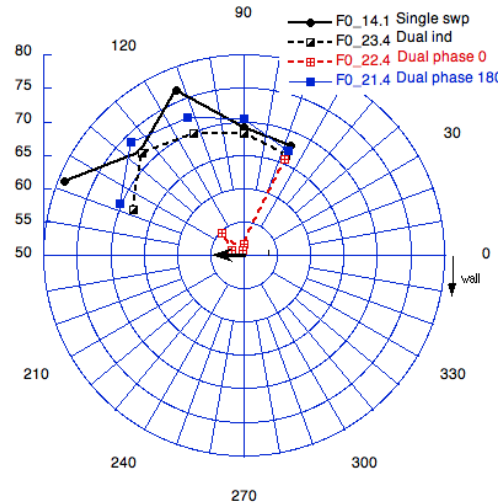


$\theta = 90^\circ$ (cross-flow plane)



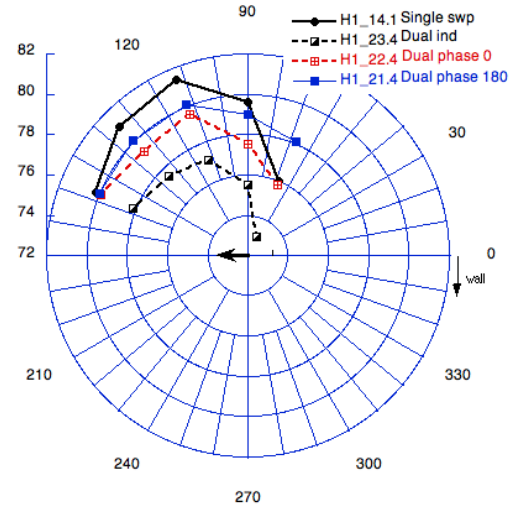
Fundamental $F_0 = 420$ Hz

Half 12th oct., $M=0$, 10 scfm, $\phi=0$, θ , $F_0 = 420$ Hz

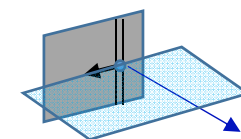


1st harmonic $F_1 = 840$ Hz

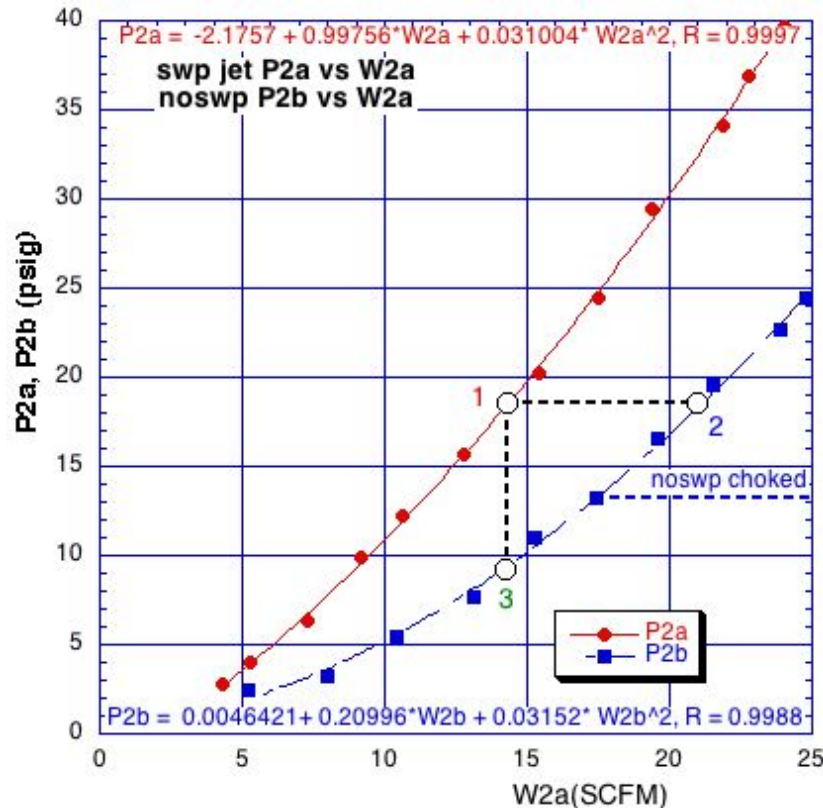
Half 12th oct., $M=0$, 10 scfm, $\phi=45$, θ , $H_1=840$ Hz



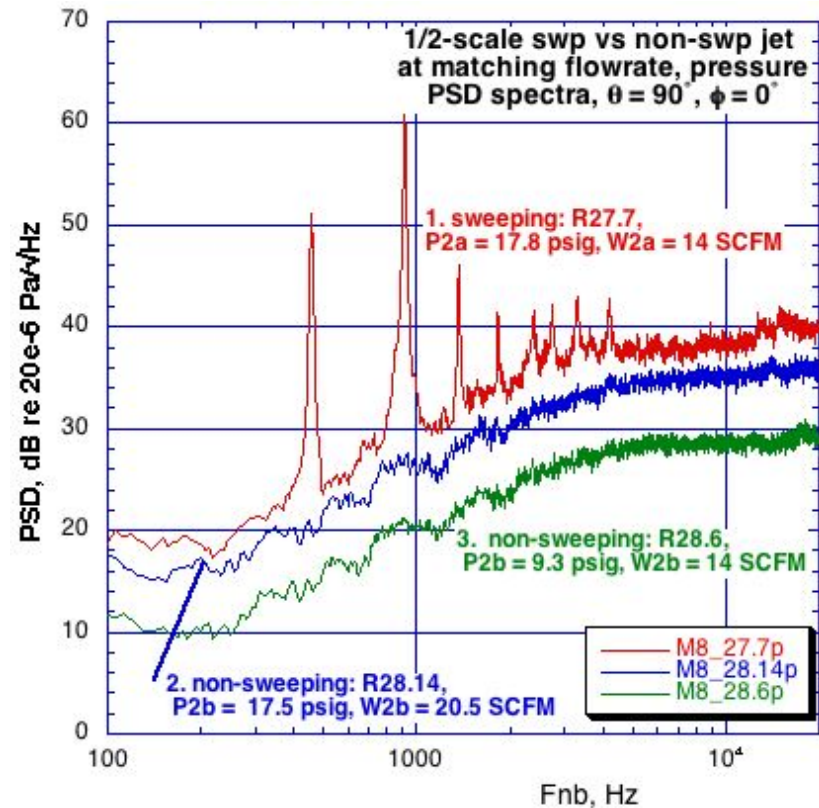
$\phi = 0^\circ$ (symmetry plane)



Compare sweeping vs steady jet at similar pressure, flow rate

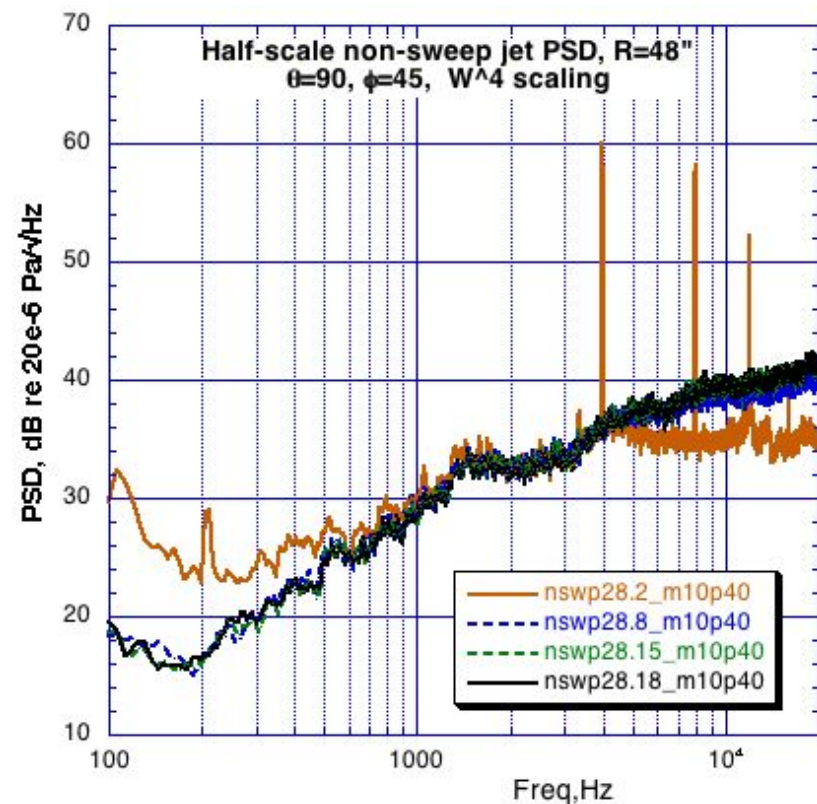
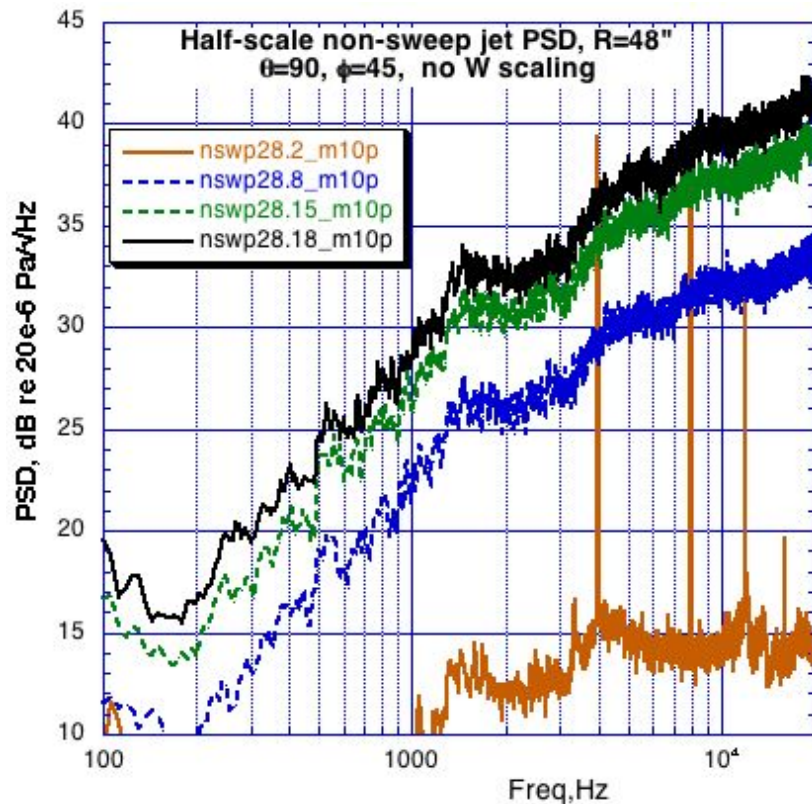


Pressure vs flow rate characteristics for sweeping jet (red) vs steady jet (blue)



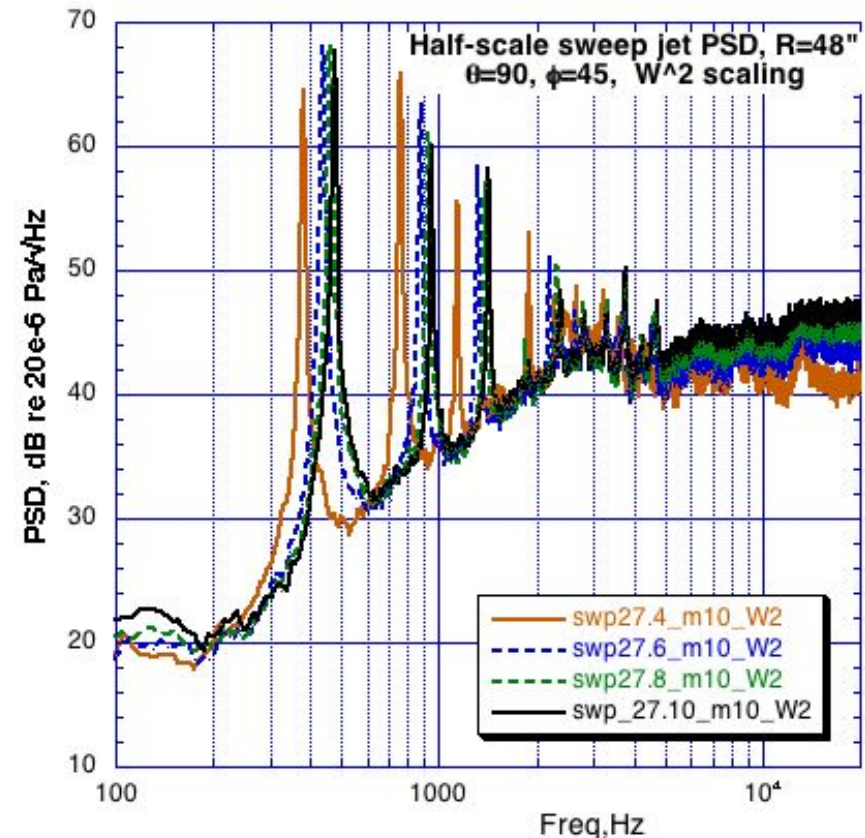
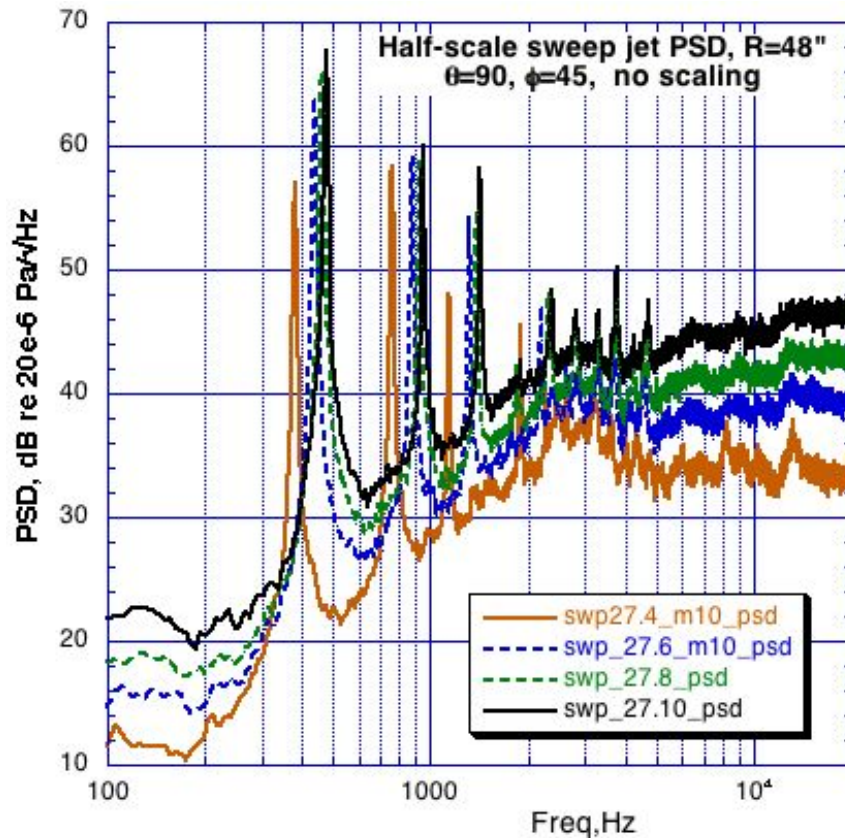
At same supply pressure, sweeping jet broadband level ~3 dB higher than steady jet. At same flow rate, sweeping jet bb. Level is ~10 dB higher

Steady Jet: Flow Rate Scaling (low freq)



Half-scale non sweeping jet PSD's, R = 48", $\theta = 90^\circ$, $\phi = 45^\circ$, M = 0, unscaled (left) and scaled with 4th power of flow rate, $7.1 < W < 23.4$ SCFM. ($+40 \log(W/W_{\text{REF}})$)

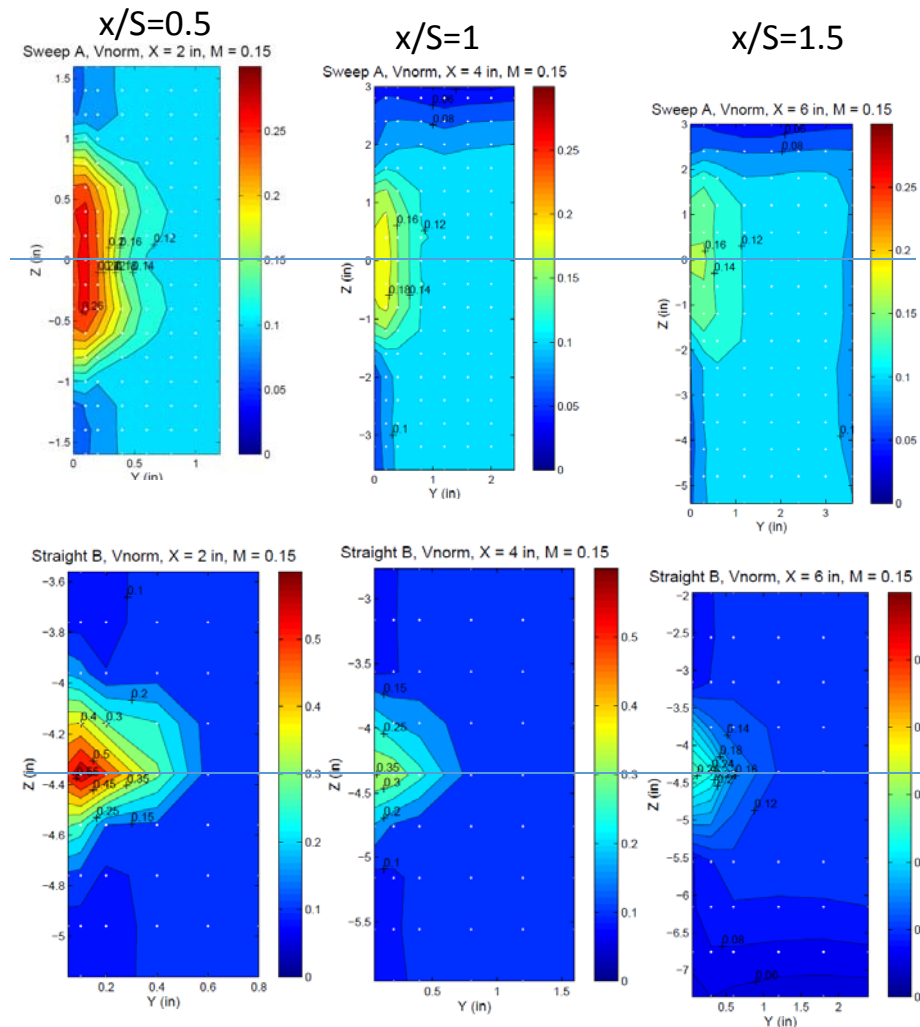
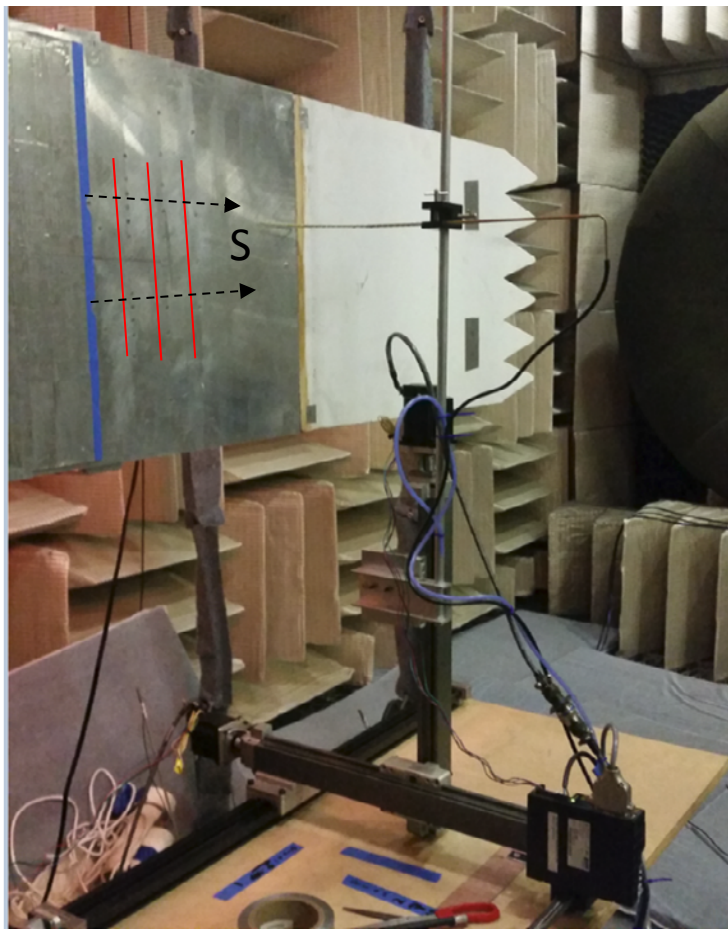
Sweeping Jet: Flow rate scaling (low freq)



Half-scale sweeping jet PSD's, R = 48", $\theta = 90^\circ$, $\phi = 45^\circ$, M = 0, unscaled (left) and scaled with 2nd power of flow rate, $8.2 < W < 19.4$ SCFM ($+20 \log (W/W_{REF})$)

Velocity Profiles from Total Pressure Surveys

Velocity scaled by avg exit value for the configuration, max at $x/W_j = 2$
 Spatial scale increases linearly with downstream distance
 Dual actuator profiles in progress: indep, in-/out-of-phase



(Plot size scale grows with downstream distance)

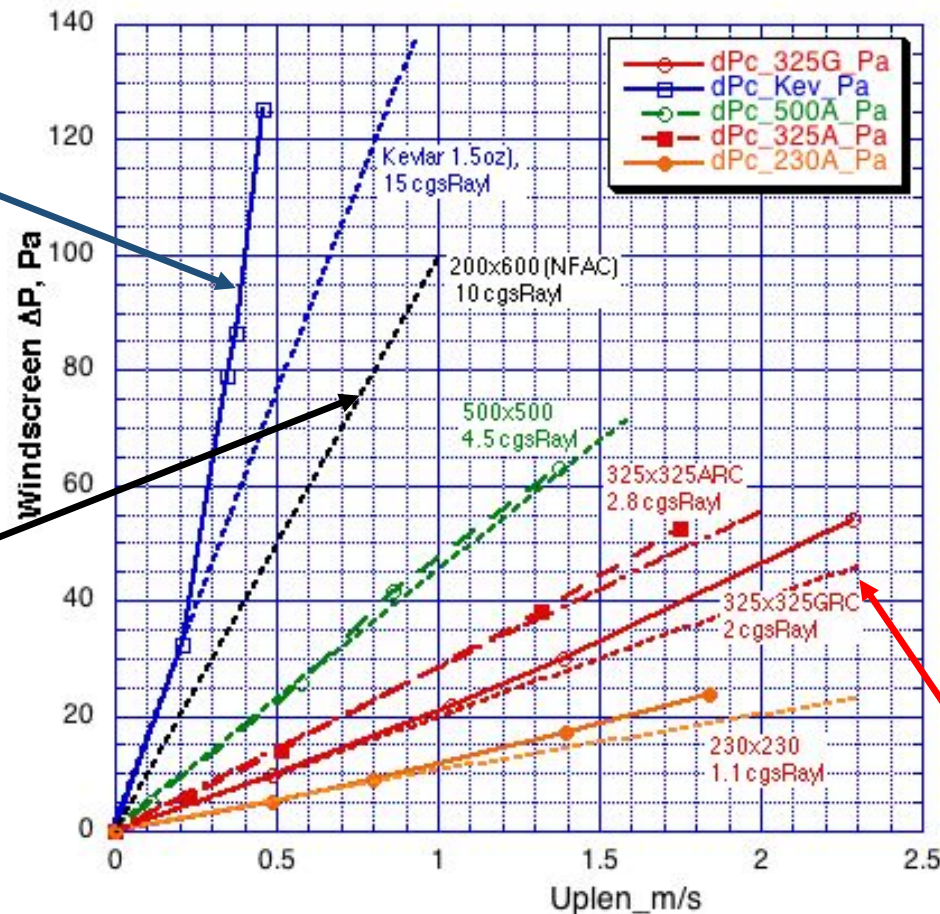
TTT: Assess New Windscreen Design, Microphone Mounting on Array Background Noise/Response

ARC 1.5 oz Kevlar
screen, 15 cgs Rayl,
2-6 dB reverb +
20kHz noise

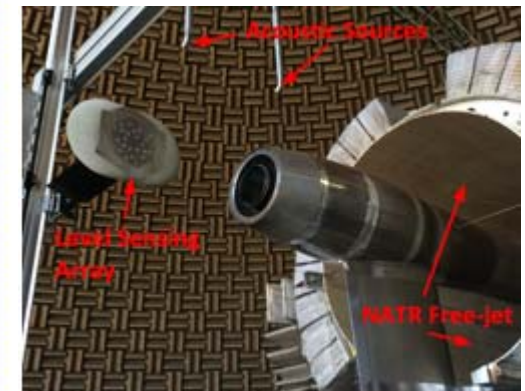


ARC 200x600 s.st.
windscreen,
15 cgs Rayl, 2-6
dB reverb, no HF
noise

Windscreen material pressure loss, low speed normal flow
CH, NB ARC Acoustic Lab 2/17/2016

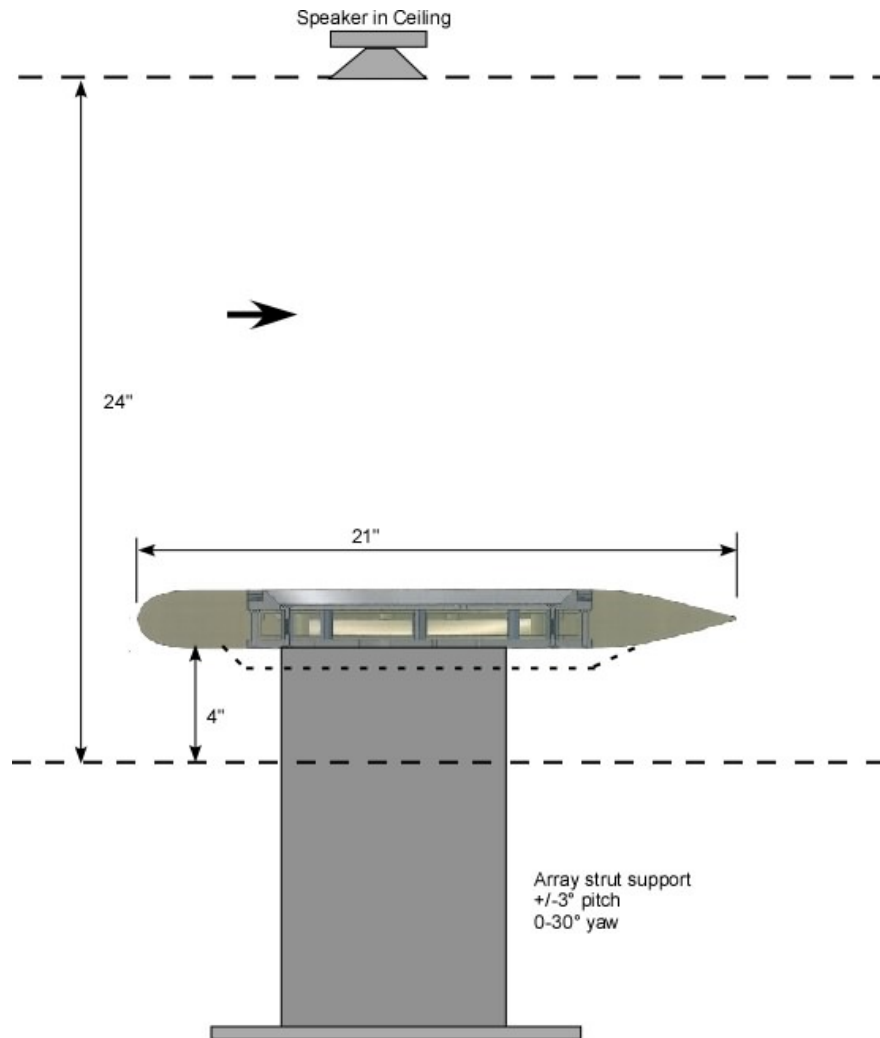


Windscreen DP vs normal flow vel
Slope is $d\Delta P(\text{Pa})/dV_n(\text{m/s})$ or MKS Rayls



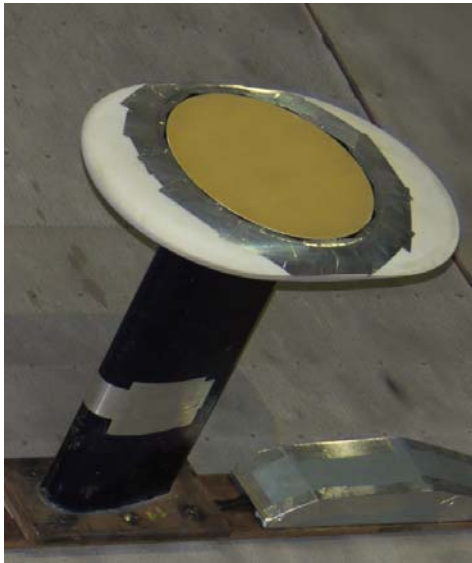
2nd Small array at
GRC(Podboy) with 2
cgs Rayl s.st.
windscreen. No HF
noise, reverberation
seen

TTT: Assess small array fairing flow quality, deeper recess mods

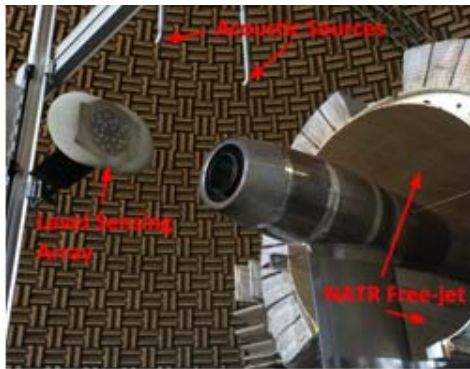


- Mount existing array in floor of FML LSWT , speaker in ceiling
- +/- 3° pitch, 0-30° yaw
- Look for separation (tufts) variation in background noise
- Add lower dummy fairing and assess flow quality (tufts), noise, try different windscreens, fairing mods

AATT ANR FY16 OGL: “Supermic” – develop common in-flow reference array and calibration sources



ARC 8" D, 24 element array,
21"L x 14"W fairing, M = 0.3
(200 kts)



GRC 2nd array tested in NATR, 9x15

- Proposal from Microphone Array Experimental Methods Team
 - (ARC: Horne, Burnside, GRC: Podboy, Stephens, LaRC: Bahr, Humphreys)
- Build on success with TTT small in-flow fairing array,
 - 10-20 dB background noise suppression relative to single microphone, $2 < f < 50$ kHz for in-flow acoustic measurement.
 - inherent level accuracy with small measurement capture angle, similar to LaRC SADA in QFF
 - Size is compatible with small (QFF) → large (14x22, 9x15, 40x80) acoustic test facilities
 - Test bed for assessing new sensors, processing algorithms, etc, Open design for govt, industry, university aeroacoustic facilities.
- FY16 tasks
 - ARC: build 3rd array for LaRC
 - GRC: continue development and calibration methods, goal +/- 0.5 dB level accuracy with 10-20 dB background suppression
- FY17 proposed tasks
 - assess in-flow array performance re SADA out-of-flow in QFF
 - Quantify characteristics of 4 array installations: 1) in-flow, strut mounted, 2) in-flow, wall mounted, 3) out-of-flow looking through shear layer, 4) out-of flow, looking through porous screen (Kevlar, s. steel)

Concluding Remarks

- Acoustic measurements of full, half-scale single and dual actuators at $M = 0, 0.15$ complete at ARC. Planning acoustic test tasks supporting FY17 AFC high-lift experiment
- Velocity profiles from total pressure probe surveys in progress in ARC anechoic chamber
- Small reference array optimization (windscreens, fairing aero) in progress at ARC, GRC
- AATT ANR FY16 OGL task to further develop small in-flow array as a common research and reference array in progress