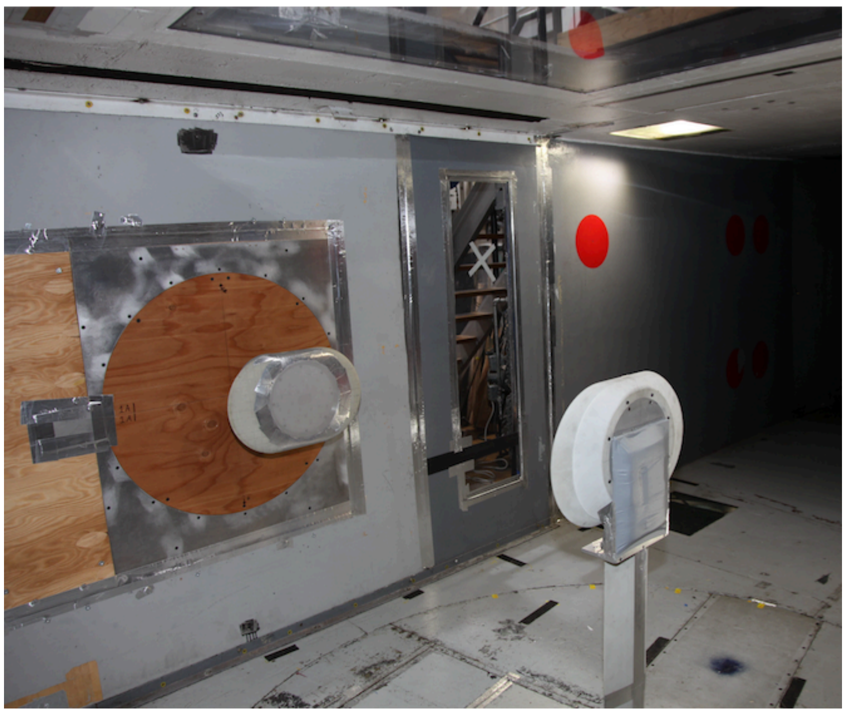
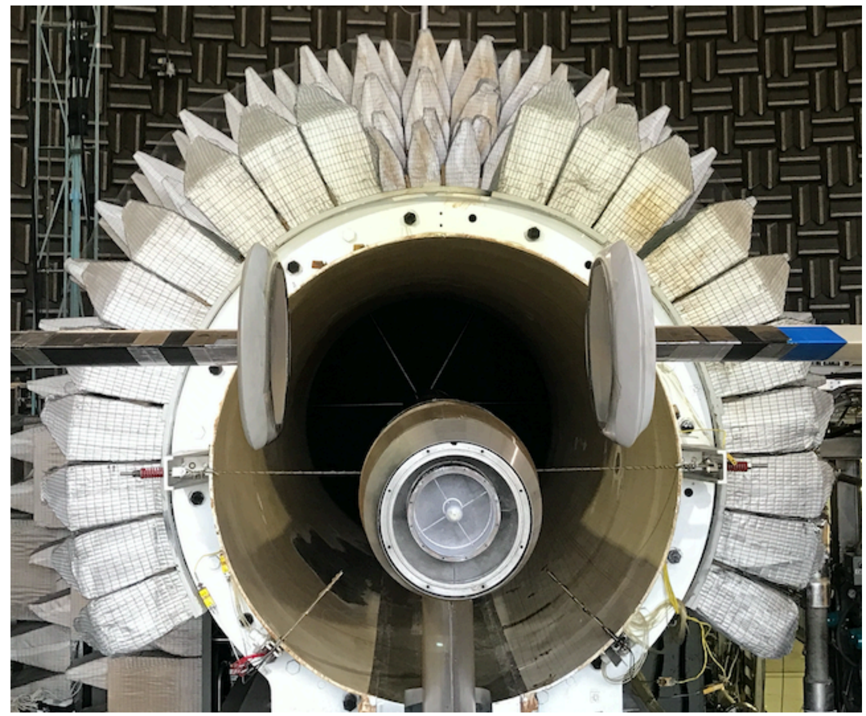
Preliminary Aeroacoustic Measurements of In-Flow Reference Arrays and Sources at ARC

Clif Horne, Nate Burnside, NASA Ames



7x10 WT test at ARC, July 2017



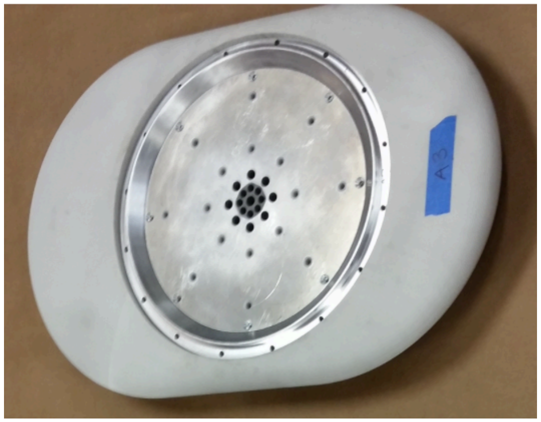
AAPL test at GRC, May 2017 (Podboy)

Fall 2017 Acoustics Technical Working Group Meeting, October 17-18, Cleveland OH

Topics

- Progress in developing and testing in-flow reference arrays and sources at ARC
- Large open-frame array for measuring forward radiated noise from settling chamber
- CAS proposal for mitigating slat noise impact on communities near airports (B. Storms, J. Ross)

Challenge: improve level-measurement accuracy and dynamic range of microphone arrays used in wind tunnel aeroacoustic research



8 in. diam. array fairing (SADA pattern, 33 mics)

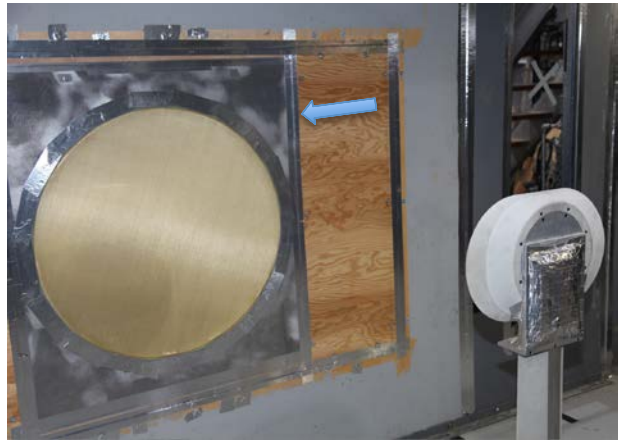
Dual tweeter source fairing

Half-airball source fairing with P and T sensors.(roam removed)

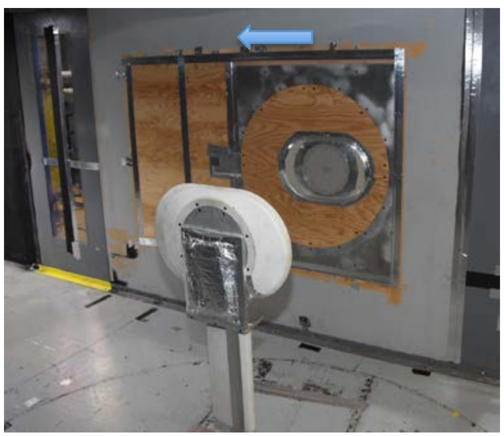
- Approach: 2O16 OGL, 2017 base goal to develop and test common in-flow arrays and sources to improve microphone array level measurement accuracy and repeatability.
- Build array and source fairings for ARC, GRC, and LaRC.
- Assess system performance with tests at ARC, GRC(Podboy, Stephens), and LaRC (Bahr, Humphreys)

Array installations in Army 7x10 Wind Tunnel

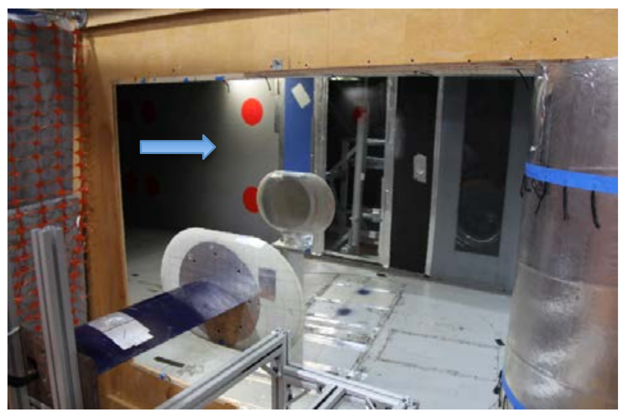
Strut mount, looking upstream



Source fairing in front of Kevlar window



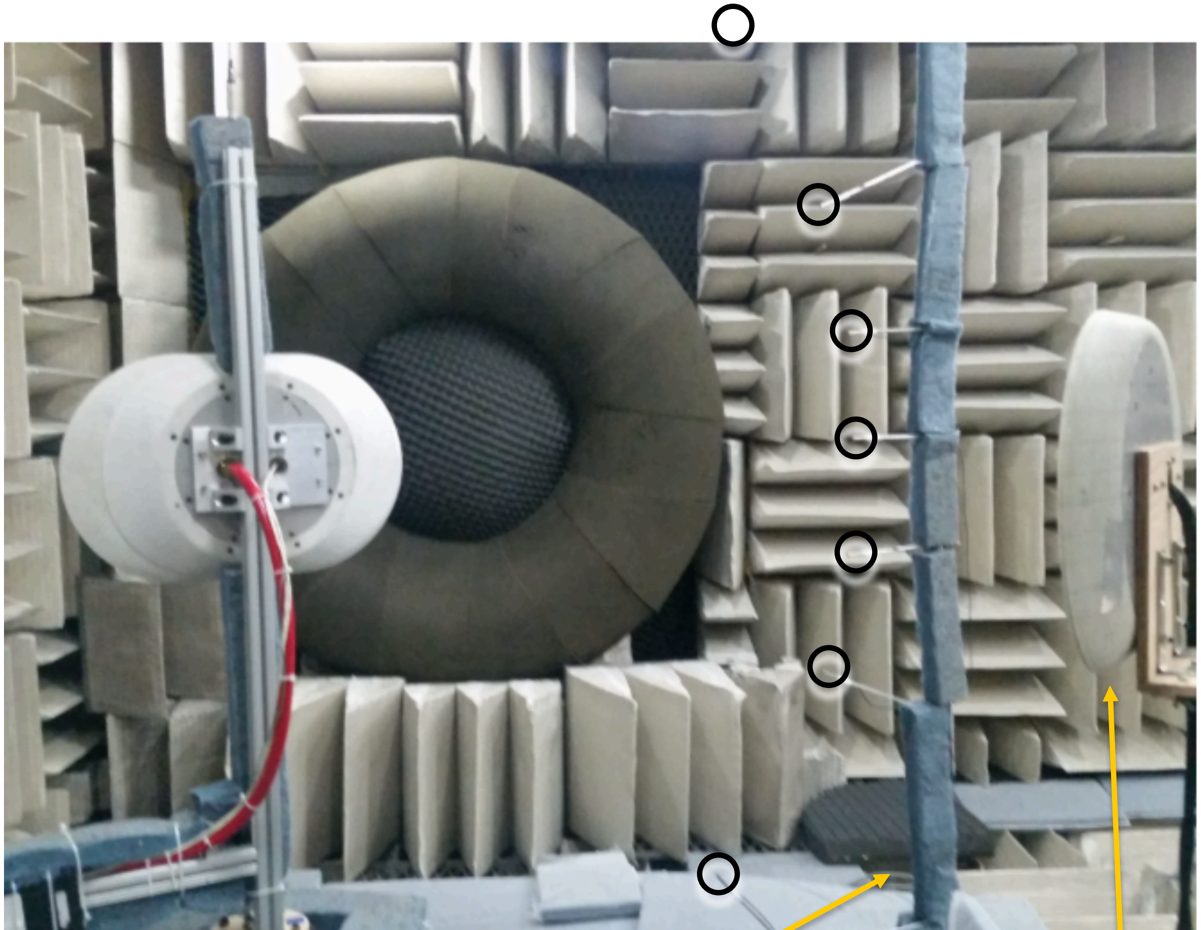
Wall mount



Free-shear-layer aperture, with downstream collector and semi-anechoic enclosure

- Modified existing laser window wall panel to accommodate array and probe traverse
- Maintained 48-inch lateral separation between source fairing and array fairing
- Array , probe traverse mounted on 80-20 frame isolated from wall

Anechoic chamber calibration (May 2017)



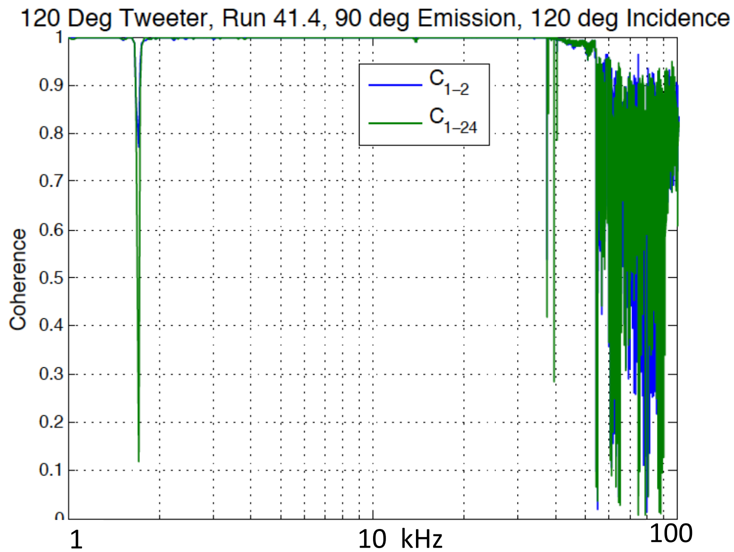
Rear of airball source fairing on turntable, emission: 0˚< θ <180˚

Fixed microphone stand, 48” radius

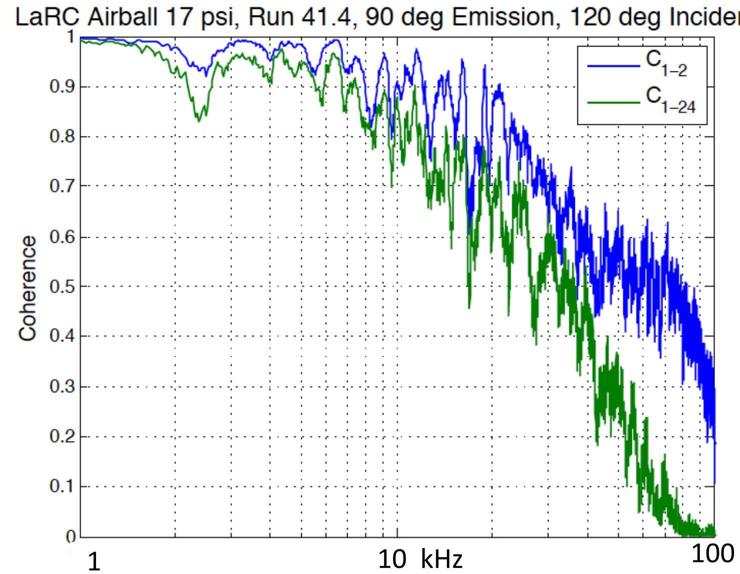
Fixed array, 48” radius

- 2017 array test pattern is 3 arm spiral, 8 microphones per arm
- Microphone azimuth angles of 0˚, +/- 11.25˚, +/- 22.5˚, +/- 45˚
- Source field measured at θ = 0˚, 5˚, 10˚,…180˚ with mic stand and array
- Array covered with foam during measurements with fixed microphone stand
- Array corrections:
  - -6 dB flat plate
  - Convert free-field microphone response to pressure type for
  - Atmospheric absorption

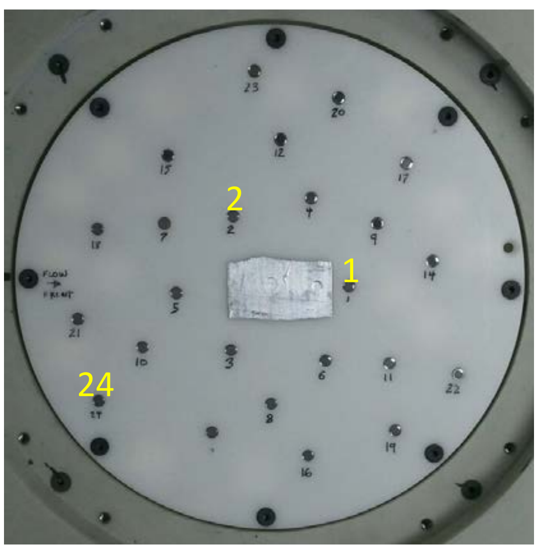
Array coherence, microphone and array corrections,



Coherence between microphones 1-2, 1-24 for tweeter source

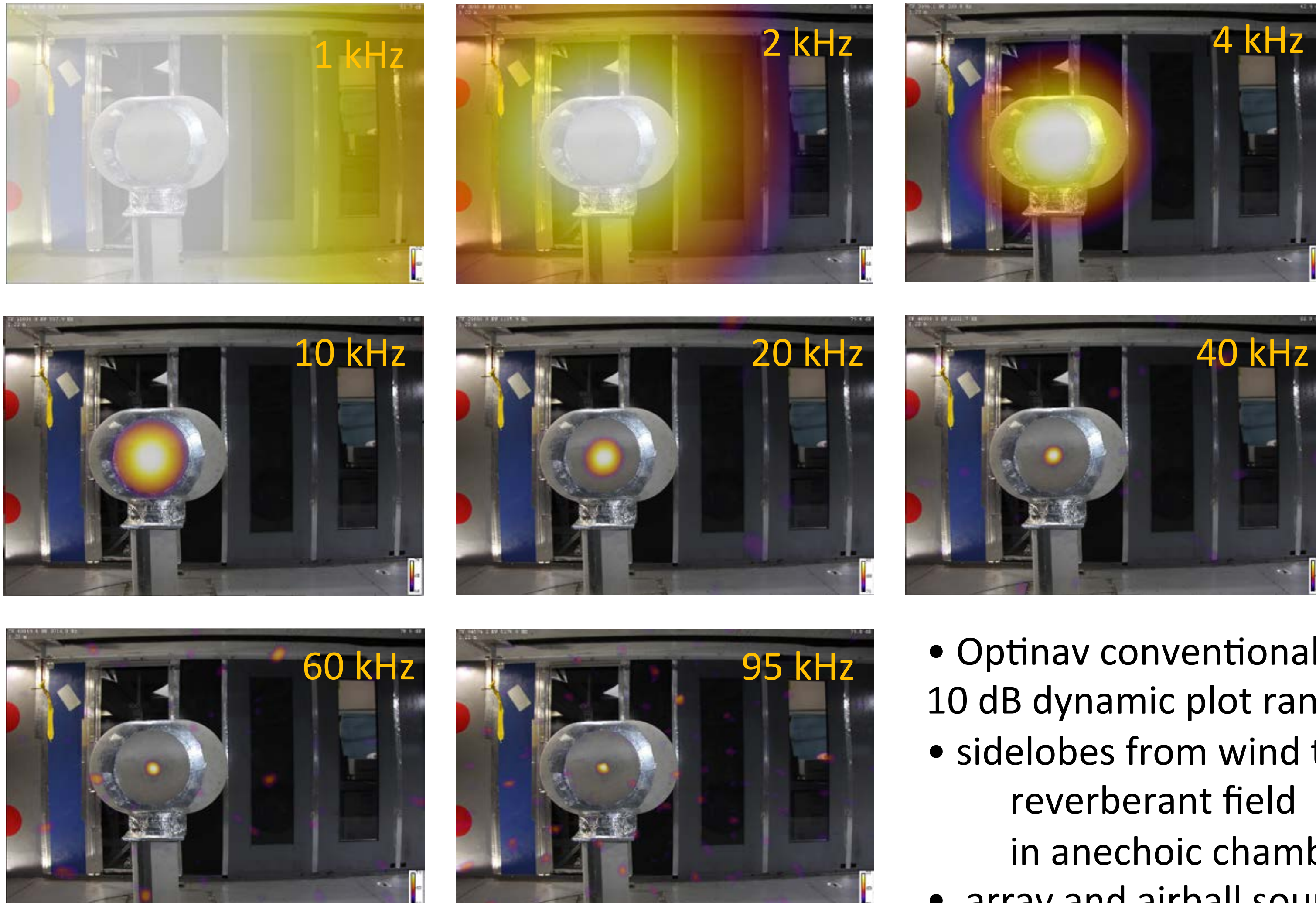


Coherence between microphones 1-2, 1-24 for airball source to be used at LaRC



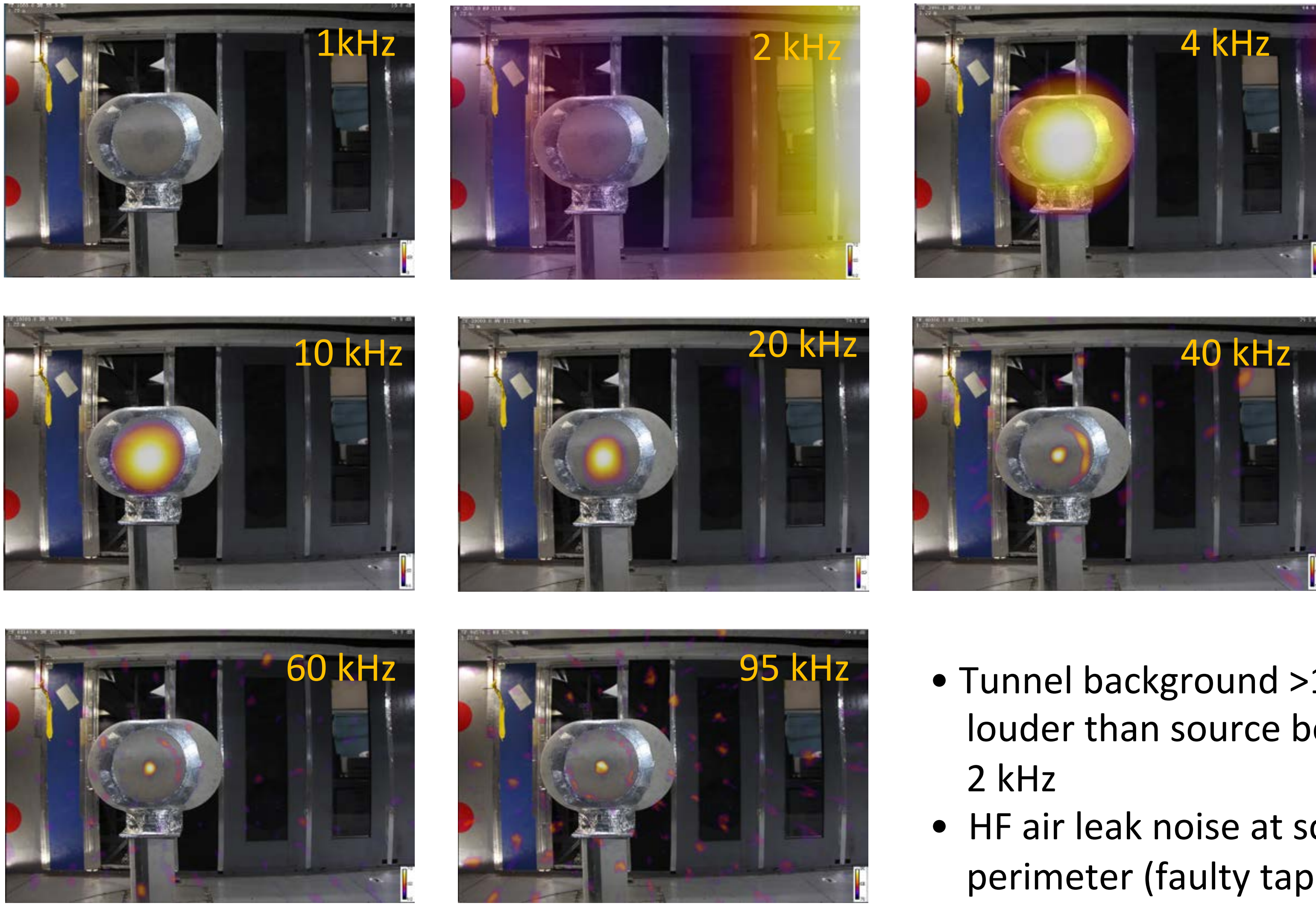
- Dual tweeter source is fully coherent across array face to 40 kHz, well defined directional response, linear output
- Airball consists of 2” sphere with 44 holes each 0.035” diameter on side facing flow, 1-17 psig
- Airball coherence falls off with mic spacing and frequency, typical of air vehicle sources (airframe, propulsive)
- Cross-spectral matrix phase accuracy most important for accurate beamforming, with coherence > 0.1 for usable result

Airball conventional beamform source location plots
M = 0, θ = 100.5˚



- Optinav conventional BF with 10 dB dynamic plot range
- sidelobes from wind tunnel reverberant field absent in anechoic chamber
- array and airball source functional for level measurement range: $2 < f < 100$ kHz

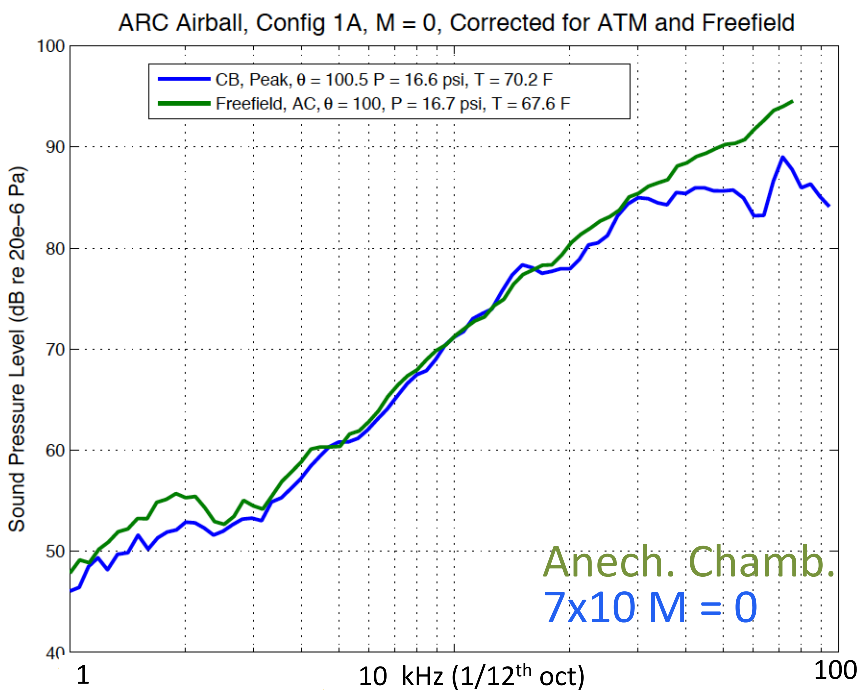
Airball conventional beamform source location plots
M = 0.15, $\theta' = 92^\circ$

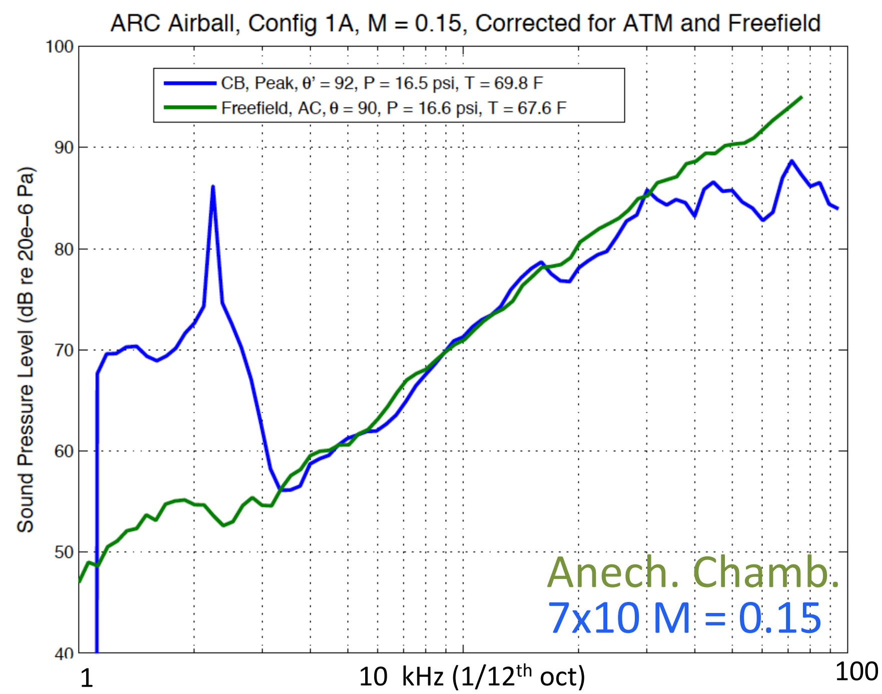


- Tunnel background >10dB louder than source below 2 kHz
- HF air leak noise at screen perimeter (faulty tape), fixed for subsequent runs

ARC airball conventional beamform peak in 7x10 wind tunnel vs free microphone in anechoic chamber

Strut mount

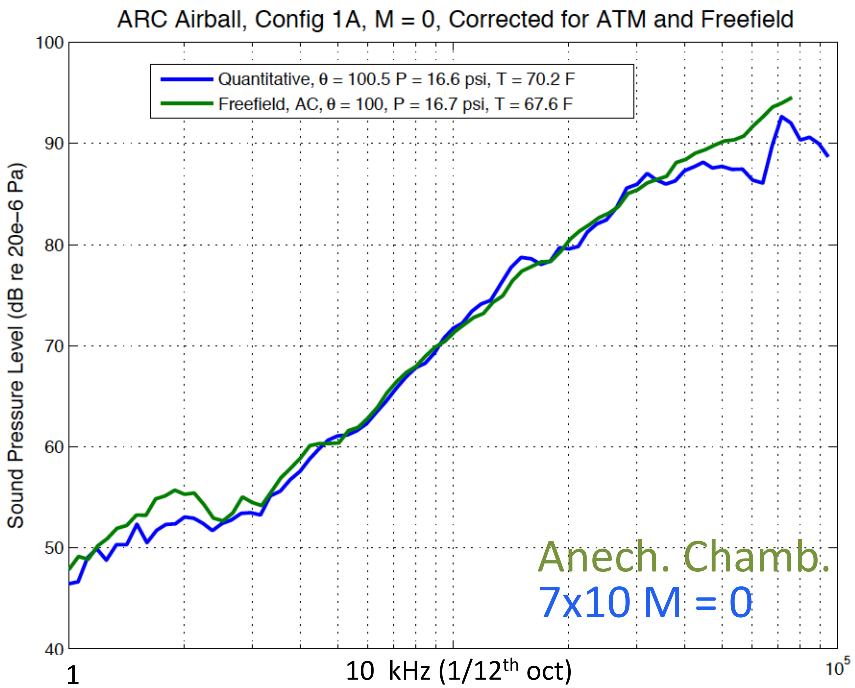


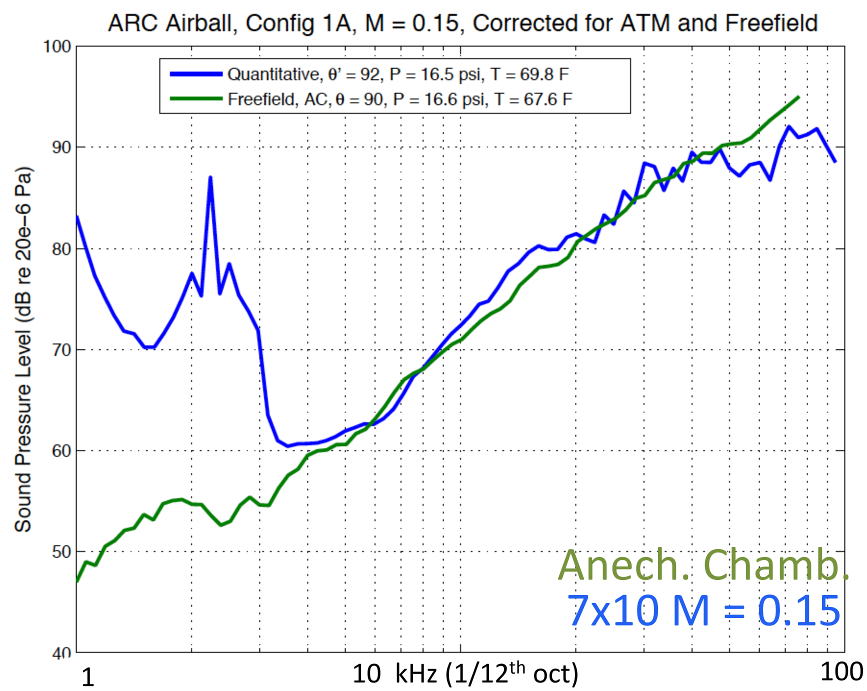


- Wind tunnel background noise dominant >15-20 dB to 3 kHz
- Wind tunnel background noise can be suppressed with CSM background subtraction
- Agreement in measured levels to 30 kHz < 3 dB, lower array levels > 40 kHz possibly due to reduced coherence across array for f > 30 kHz

ARC airball quantitative (functional) beamform integrated level in wind tunnel vs free microphone in anechoic chamber

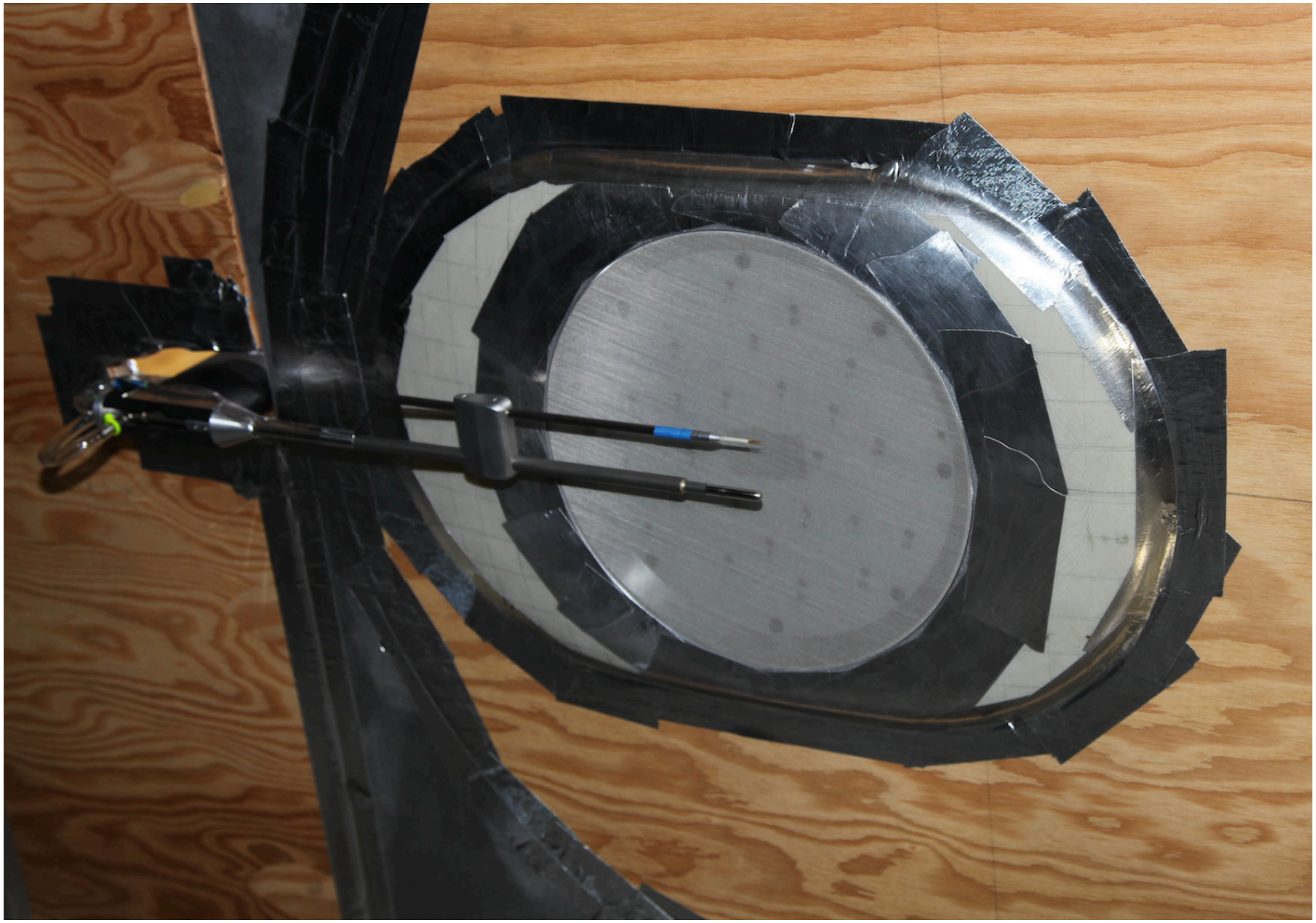
Strut mount





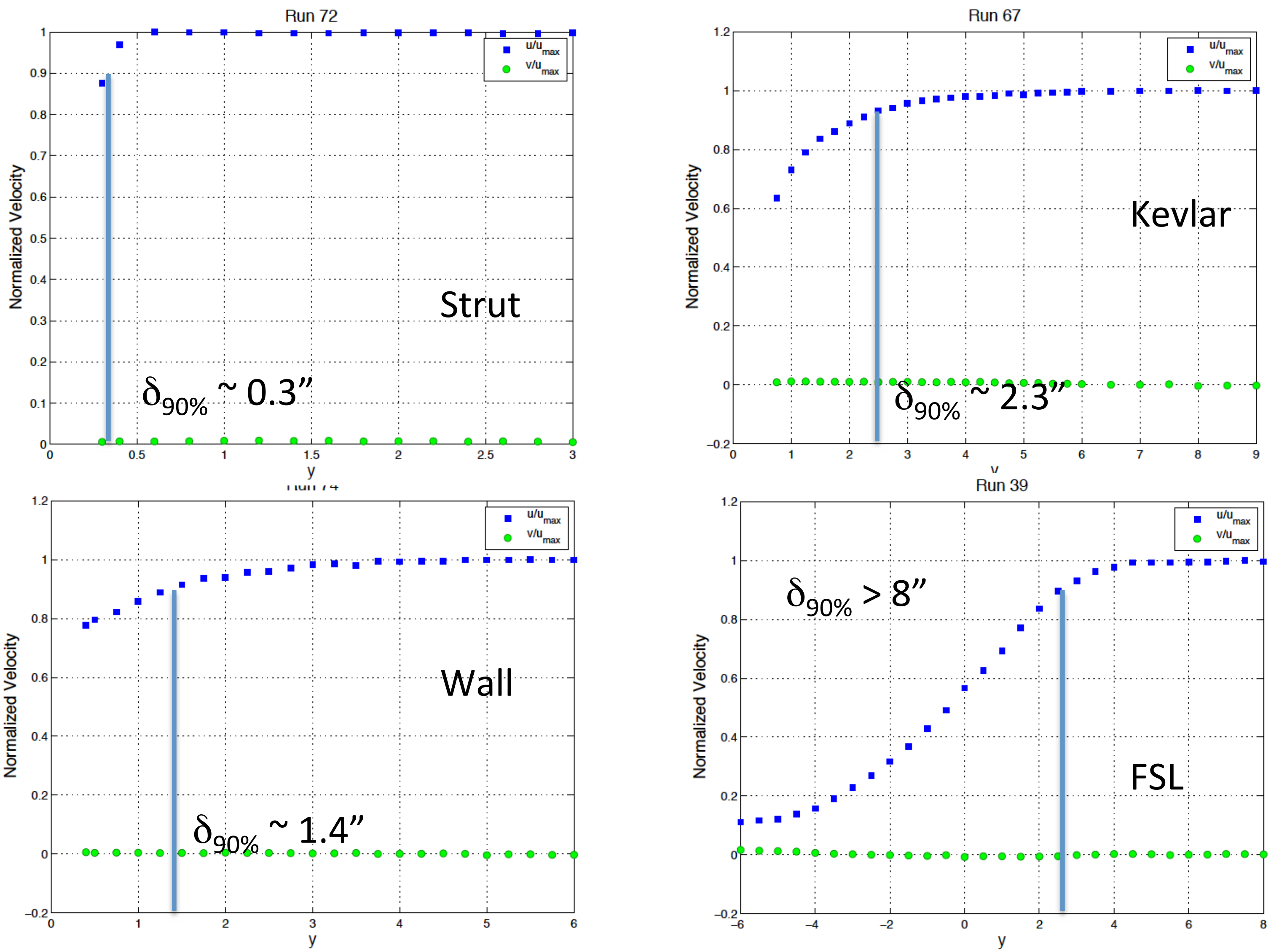
- M= 0.15; wind tunnel background noise dominant >15-20 dB to 3 kHz
- Wind tunnel background noise can be suppressed with CSM background subtraction
- Agreement in measured levels to 40 kHz < 3 dB, lower array levels > 40 kHz possibly due to reduced coherence across array for f > 40 kHz, 10 kHz higher than for conventional beamform peak level
- Further improvements may be possible with ROI integration, array shading at high frequency

Velocity probe measurements

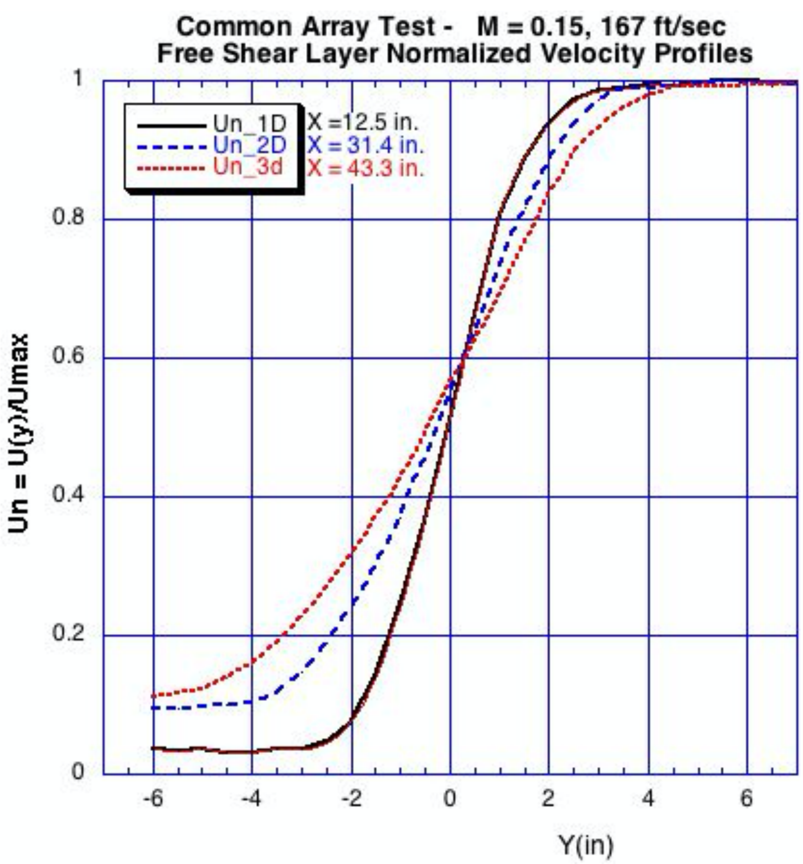


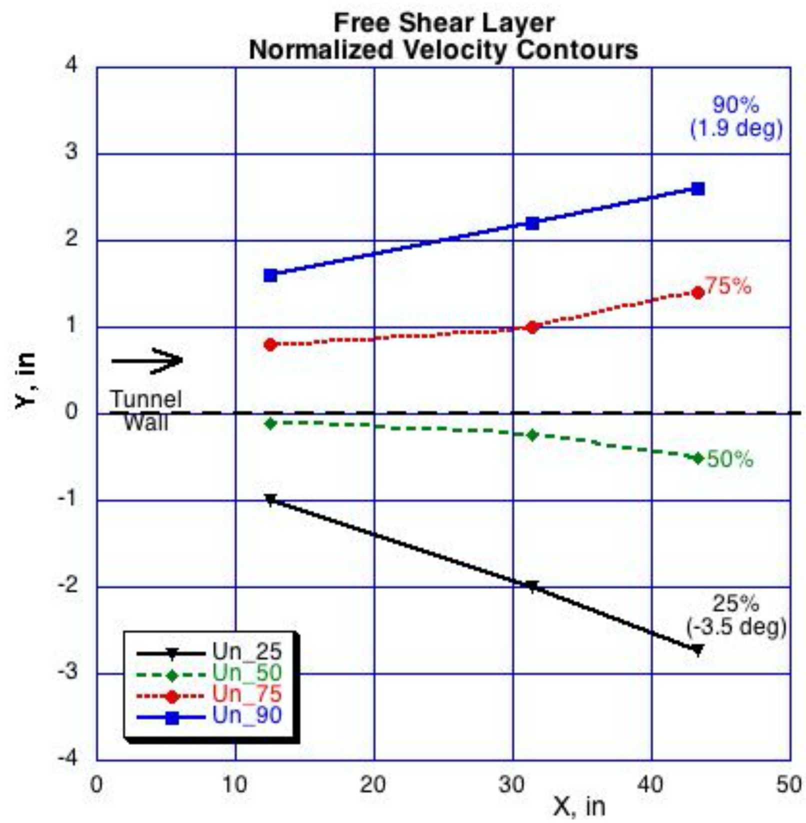
Pitot static and X-wire probe near center of wall-mounted array

X-wire mean vel. surveys, M = 0.15, 120^{o} location

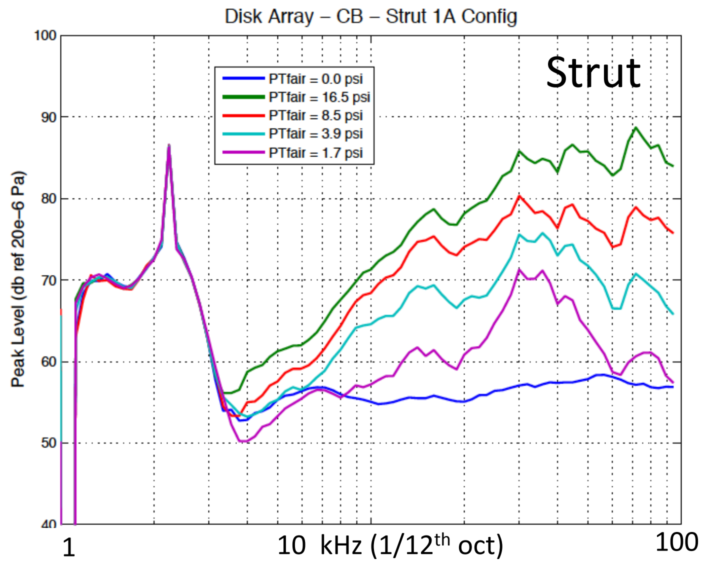


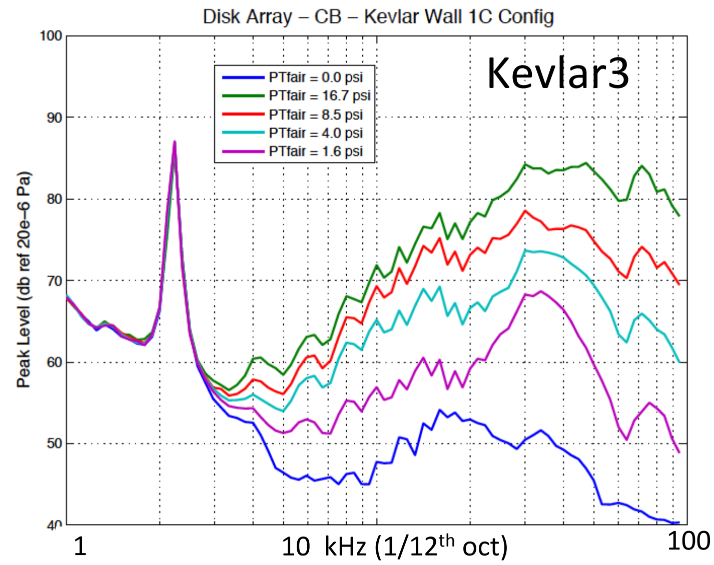
Free shear layer normalized velocity profiles and streamwise spreading

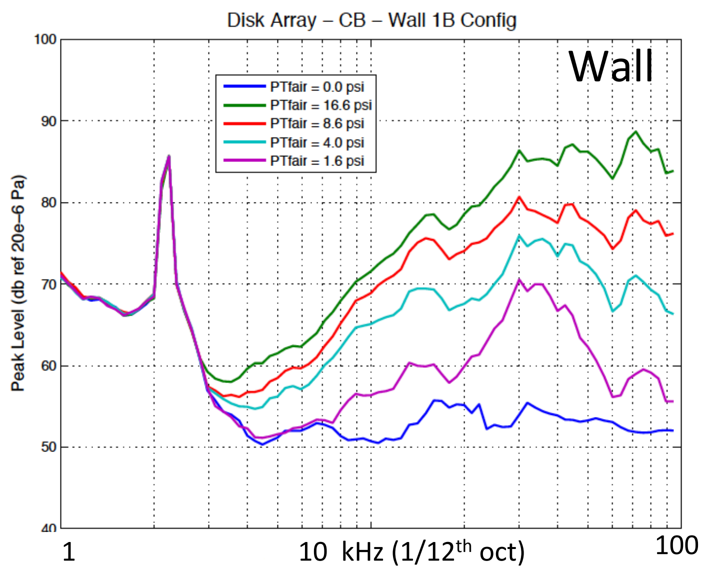


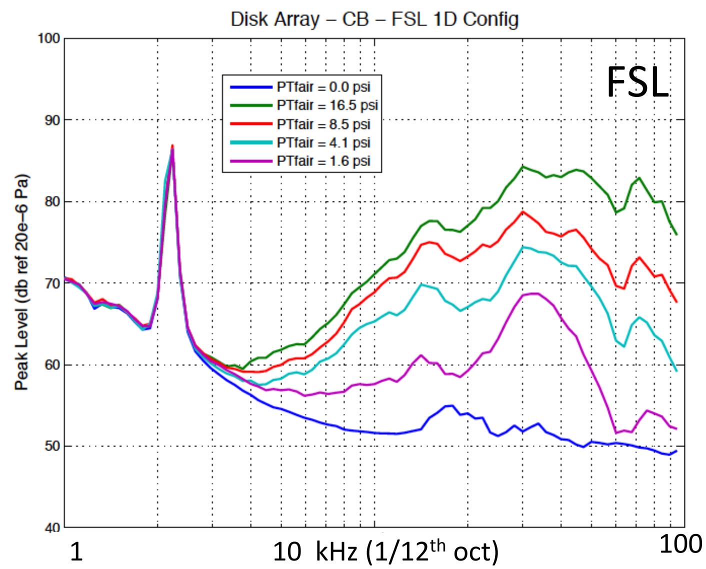


Airball levels, M = 0.15, θ’ = 92°, Y = 48”

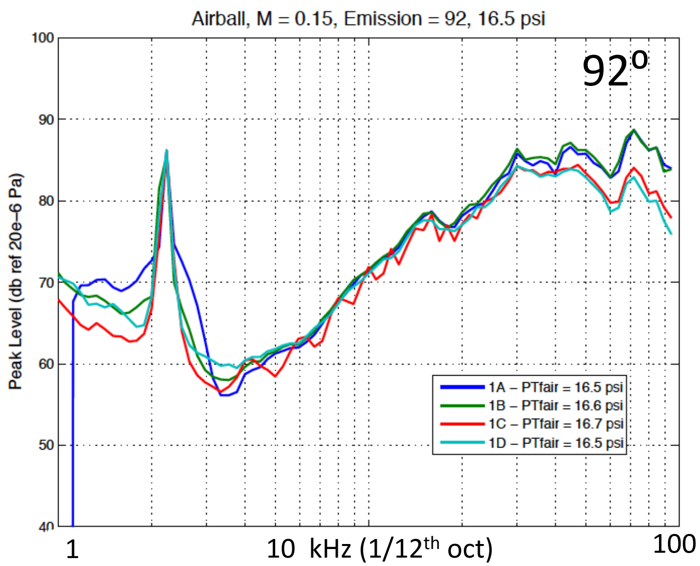


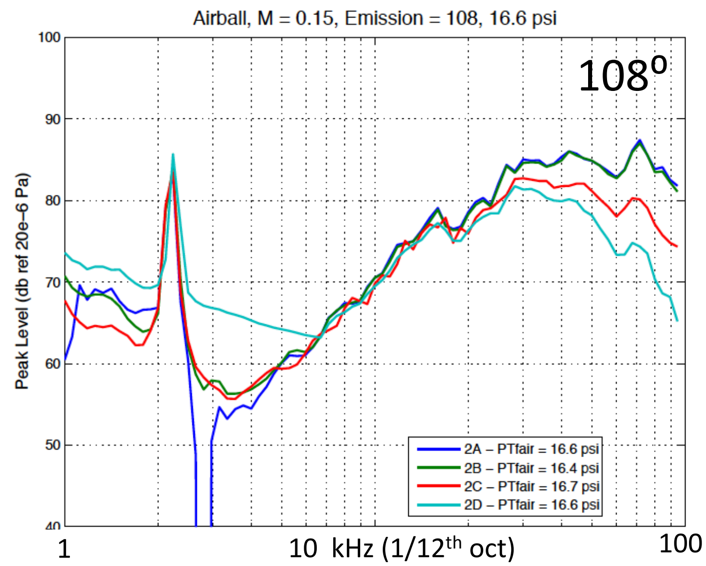


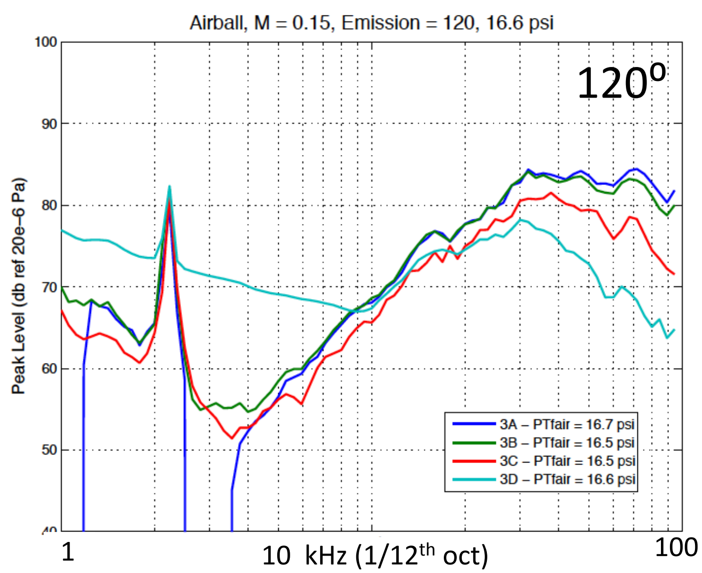




Compare airball levels for 4 installations, M = 0.15, Y = 48”, P ~ 17 psig





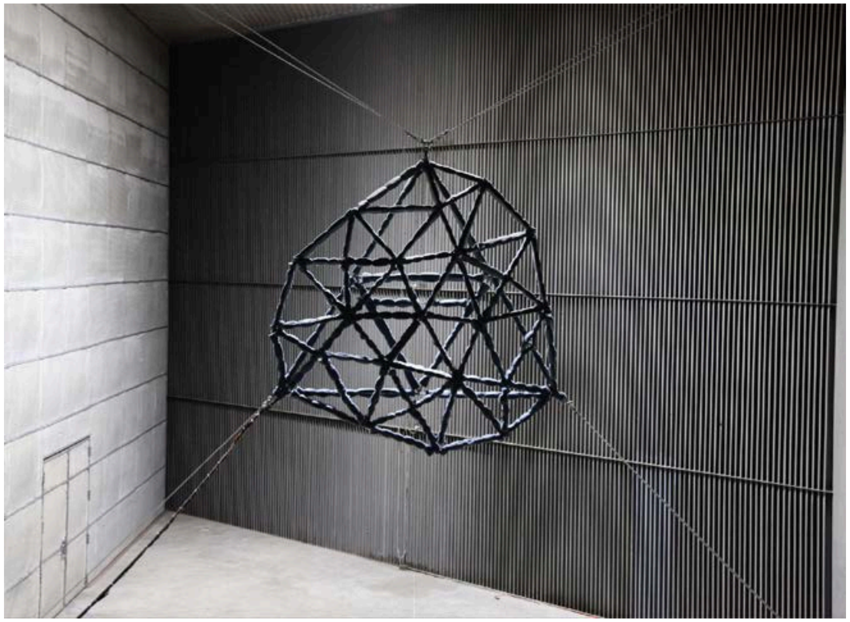


- Strut mount- dark blue
- Wall mount – green
- Kevlar –red
- FSL – light blue

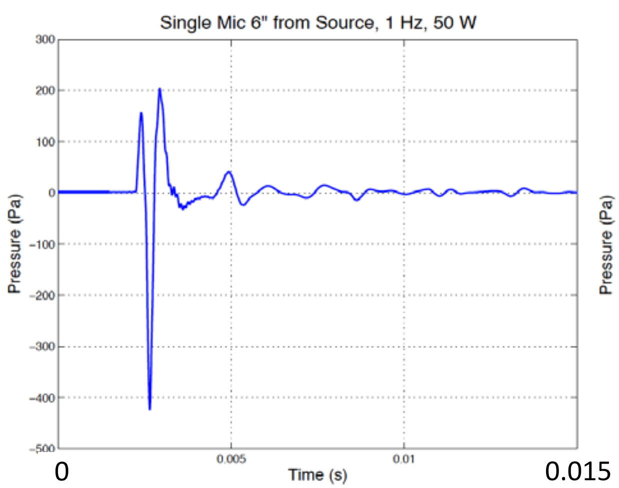
FY18 ARC Plans for in-flow reference array/sources

- Support GRC and LaRC testing plans: (9x15 mod, CRM hard-wall acoustics, CRM AFC)
- Complete anechoic chamber calibrations including airball source temperature effects (expect airball level to vary as 4th power of density)
- Report results from 2017 test
- Build 34"D stainless steel screen porous window
- Build new larger nested array, wider bandwidth
- Build new wideband source – 32-32000 Hz speaker
- 2nd 7x10 entry with wider emission angle range (45˚–135˚), focus on strut, wall mount, and porous window.

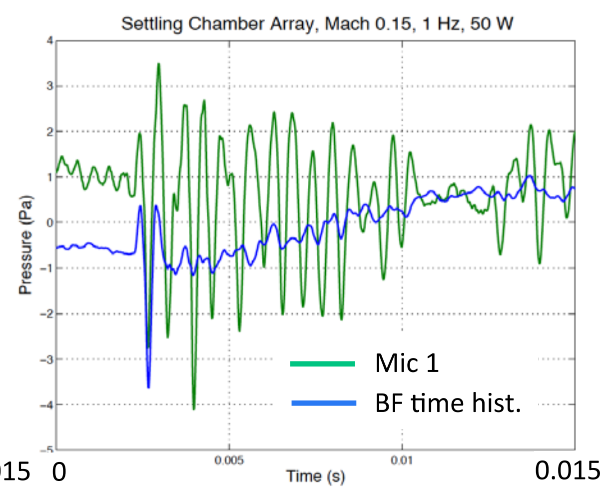
Large Open Frame Dome Array Development; Collaboration with Dr. Ben Sim (Army helictopter acoustics)



- 120”diam., 24 microphone dome array in settling chamber to measure forward radiated noise in untreated wind tunnel
- Spherical cap shape increased array frame stiffness, stability (drogue chute), front/back directional response
- Test section turbulence increased to ~ 1.2% at M = 0.25 for which settling chamber speed was 11 kts
- 7x10 test planned for Jan. ‘18 with improved array (85 mics), side array, speaker and wake-cutting rotor sources
- Can use dome array outside for UAS/UAM flight/ground testing

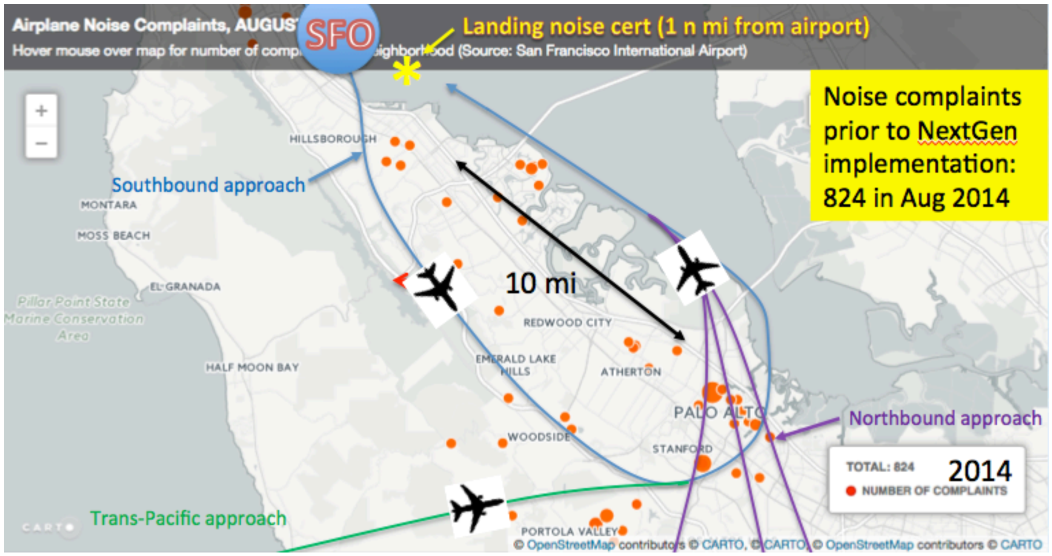


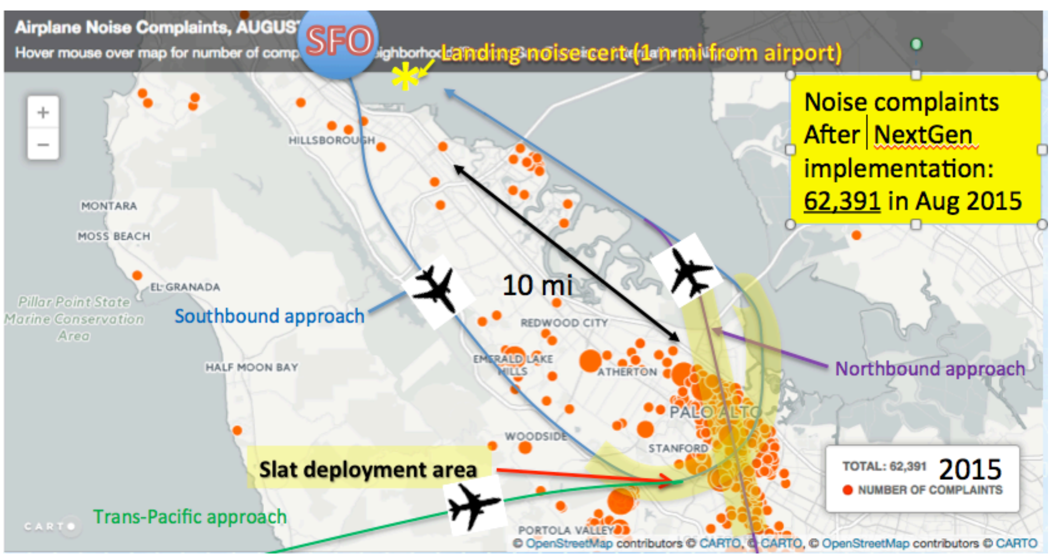
Test section speaker source output



Single mic and dome array response

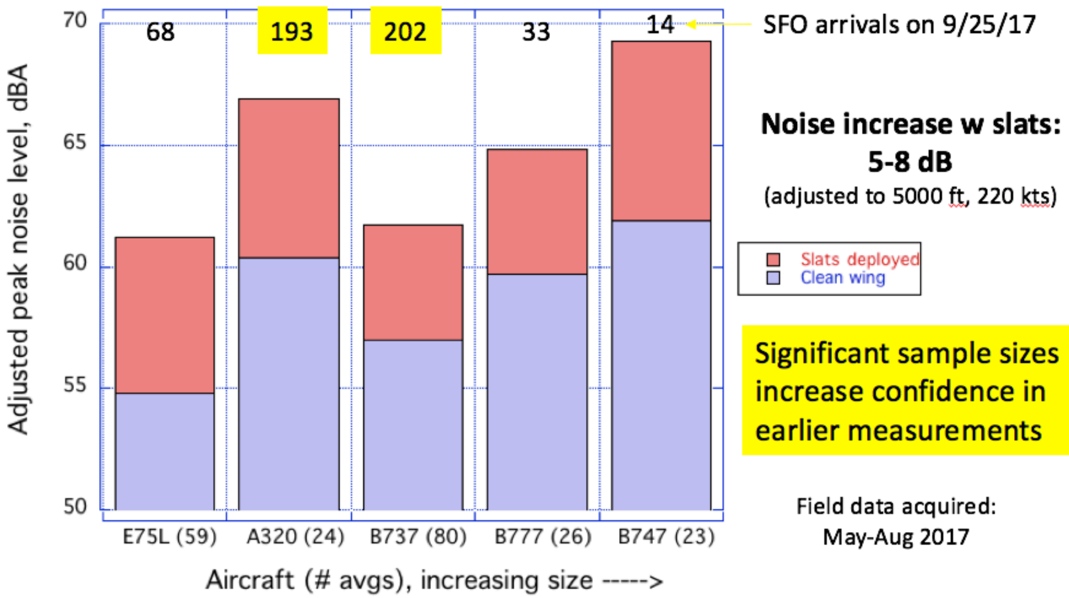
Impact of Approach Flight Operations on Communities
Bruce Storms, James Ross – 2017 CAS Proposal

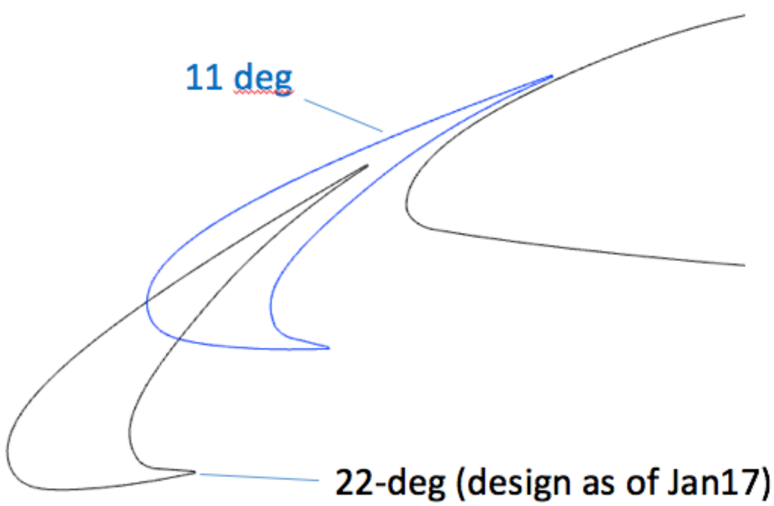




- Community noise impact, complaints exacerbated by flight path changes (RNAV) and early slat deployment on approach
- ARC proposed CAS project to assess safe high lift configuration changes that mitigate community noise
- Communities (Phoenix) challenging flight path changes in court
  "Appeals Court nixes FAA flight-path changes in early court test"- Palo Alto Online 8/30/17

Effects of high-lift configuration on slat noise

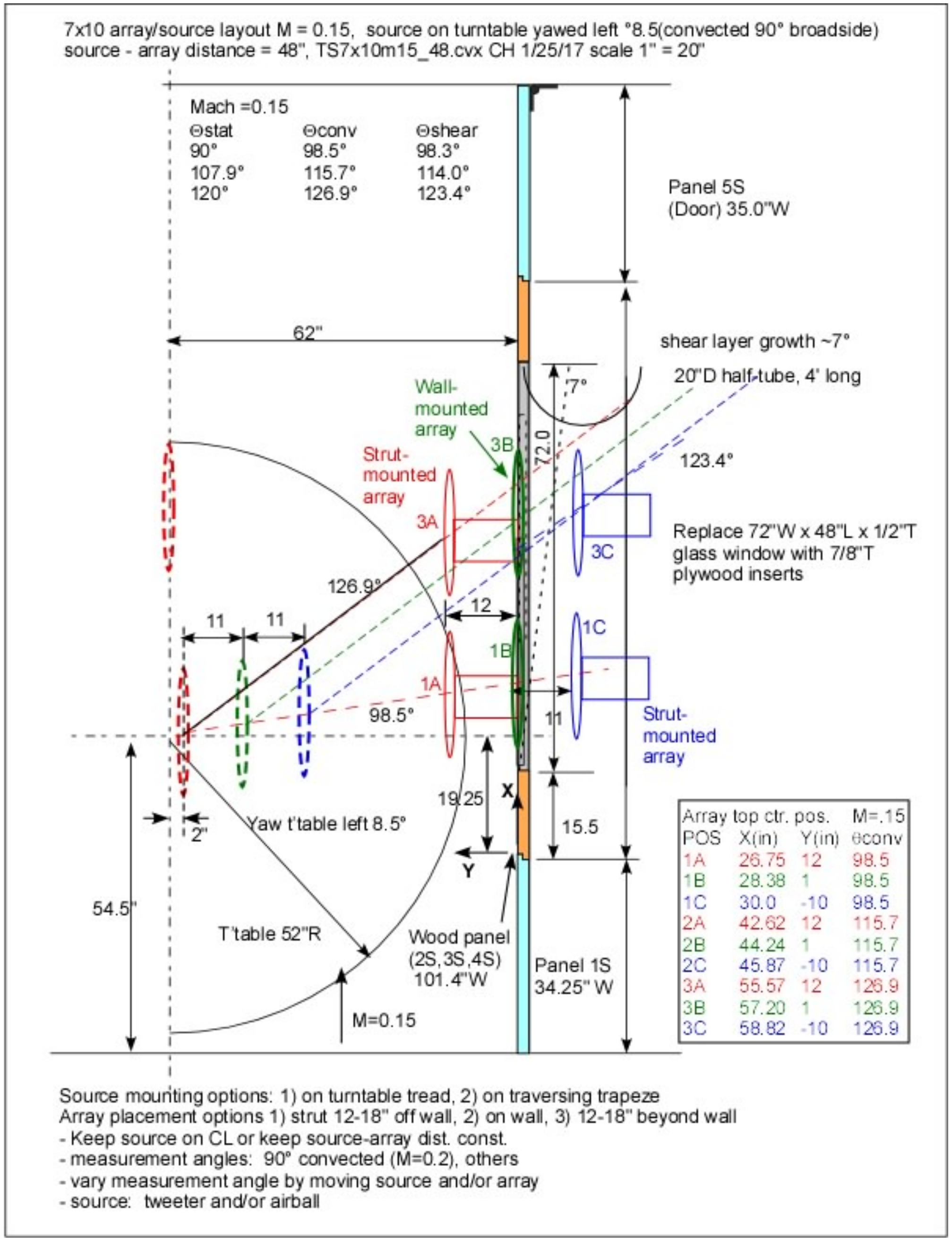




- Currently, slat is deployed to landing configuration (22˚) below 10 kft for max lift margin during approach
- Initial slat deployment early creates noticeable noise event
- Assess intermediate slat deployment (11˚) that should preserve lift margin but reduce noise
- Proposed CAS study (not selected) of CFD aero and wind tunnel aeroacoustics during hard-wall CRM 14x22 test

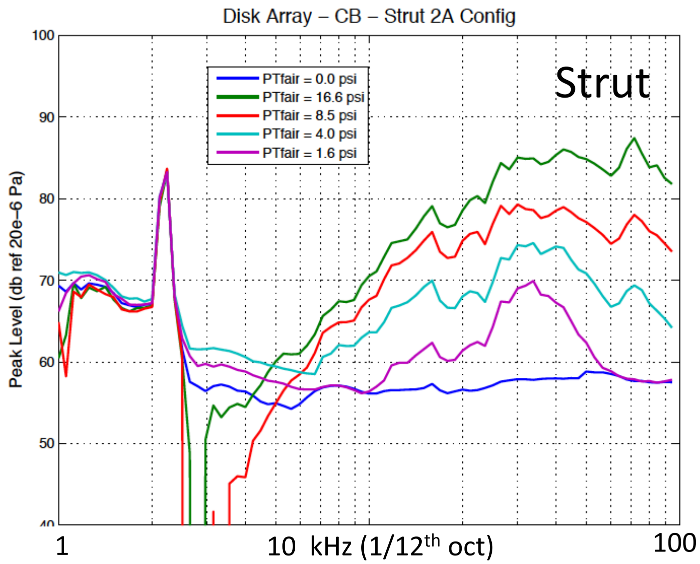
Backup Slides

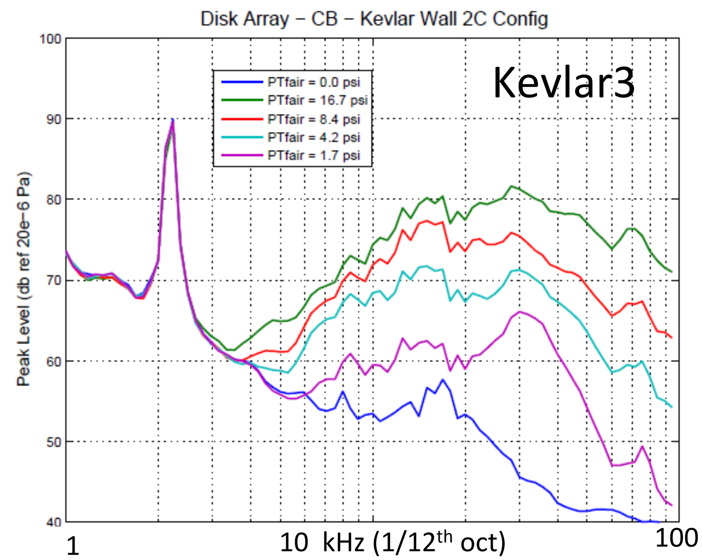
Array test set-up in Army 7x10

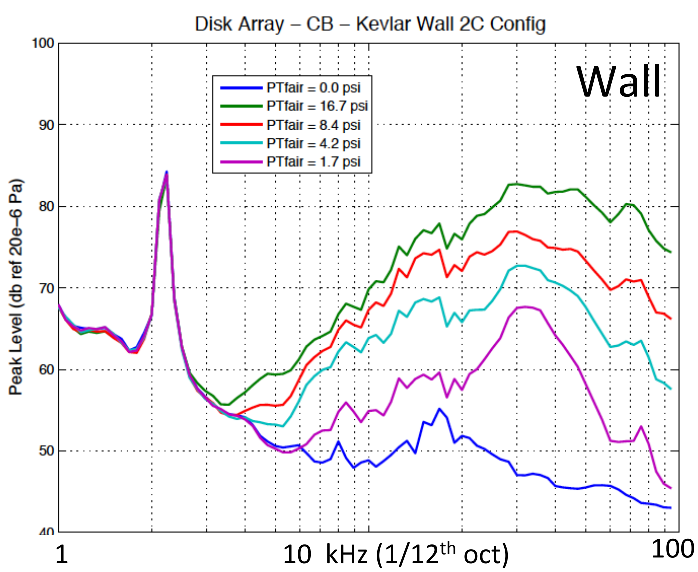


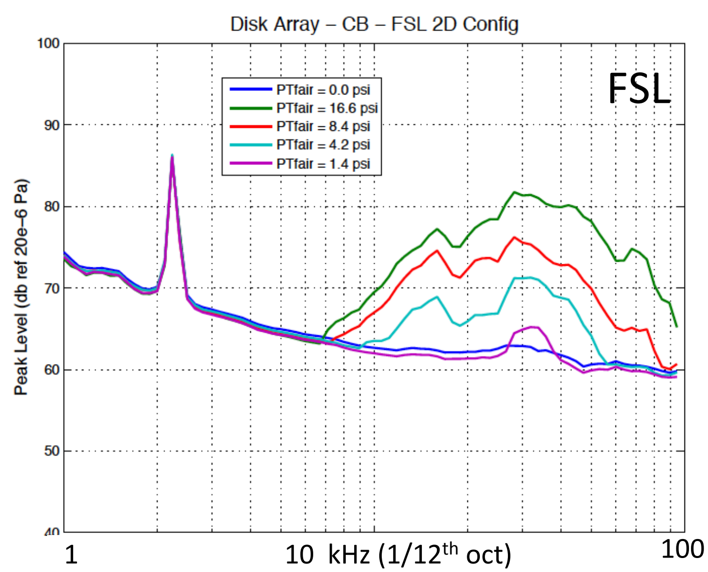
Note: The upstream array position was tested at 92˚ rather than 90˚ as shown. The source was translated along a 98.5˚ line as shown, emission angle for M = 0.15

Airball levels, M = 0.15, $\theta = 108^o$, r = 48”









Airball levels, M = 0.15, θ = 120°, r = 48”