

Source Identification and Location Techniques

Donald Weir
Honeywell

James Bridges and Femi Agboola
NASA Glenn Research Center

Robert Dougherty
Boeing

Source Identification and Location Techniques - Donald Weir, Honeywell and James Bridges, Femi Agboola, NASA Glenn Research Center and Robert Dougherty, Boeing summarized by Eugene Krejsa as summarized by Eugene Krejsa.

Mr. Weir presented source location results obtained from an engine test as part of the Engine Validation of Noise Reduction Concepts program. Two types of microphone arrays were used in this program to determine the jet noise source distribution for the exhaust from a 4.3 bypass ratio turbofan engine. One was a linear array of 16 microphones located on a 25 ft. sideline and the other was a 103 microphone 3-D “cage” array in the near field of the jet. Data were obtained from a baseline nozzle and from numerous nozzle configuration using chevrons and/or tabs to reduce the jet noise.

Mr. Weir presented data from two configurations: the baseline nozzle and a nozzle configuration with chevrons on both the core and bypass nozzles. This chevron configuration had achieved a jet noise reduction of 4 EPNdB in small scale tests conducted at the Glenn Research Center. IR imaging showed that the chevrons produced significant improvements in mixing and greatly reduced the length of the jet potential core.

Comparison of source location data from the 1-D phased array showed a shift of the noise sources towards the nozzle and clear reductions of the sources due to the noise reduction devices. Data from the 3-D array showed a single source at a frequency of 125 Hz. located several diameters downstream from the nozzle exit. At 250 and 400 Hz., multiple sources, periodically spaced, appeared to exist downstream of the nozzle. The trend of source location moving toward the nozzle exit with increasing frequency was also observed. The 3-D array data also showed a reduction in source strength with the addition of chevrons. The overall trend of source location with frequency was compared for the two arrays and with classical experience. Similar trends were observed. Although overall trends with frequency and addition of suppression devices were consistent between the data from the 1-D and the 3-D arrays, a comparison of the details of the inferred source locations did show differences. A flight test is planned to determine if the hardware tested statically will achieve similar reductions in flight.

The following conclusions were made by Mr. Weir:

- IR imaging is effective in confirming that chevrons produce increased core flow mixing.
- The improvement in core/fan mixing results in significant noise reduction.

- Both 1-D and 3-D array measurement techniques were successful in identifying noise source locations.
- Source location data from this test program confirms the classical semi-empirical location model.

In the discussion following the presentation, the observation was made that the microphones in the 3-D array are in the acoustic and geometric near fields. Thus the point source and far field assumptions used to derive the steering vectors are not appropriate for the 3-D array. The comment was made that acoustic holography does allow for the microphones to be in the near field.

**Honeywell Engines and Systems
Engine Validation of Noise Reduction Concepts**

**AeroAcoustics Research Consortium
Jet Noise Workshop**

Source Identification and Location Techniques

Donald Weir

(602) 231-1214

James Bridges and Femi Agbooli (NASA Glenn)

Robert Dougherty (Boeing)

November 8, 2000

Outline

- **Test Description**
- **Far Field Noise**
- **1-D FF Array**
- **3-D NF Array**
- **Comparisons**
- **Conclusions**



Honeywell EVNRC - Some Statistics

- Engine Starts: 187
- Engine Hours: 136
- Far Field Test Points: 374
- Test Configurations: 157
- Digital Photographs: 683
- Organizations: 7
- Test Site Visitors: 24
- Microphones: 292
- 28-Channel Tapes: 25
- Far Field Spectra: 11,968

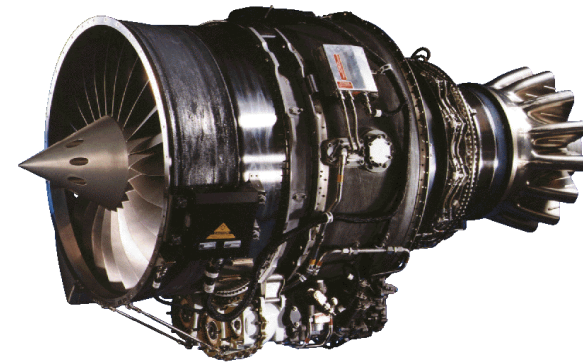


Honeywell

Engine Description

TFE731-60 Turbofan Engine

- Takeoff, Sea Level, Static Thrust = 5000 lb
- Takeoff Bypass Ratio = 4.3
- Cycle Pressure Ratio = 22
- Geared Fan Pressure Ratio = 1.70
- Fan Blades = 22
- Fan Exit Vanes = 52



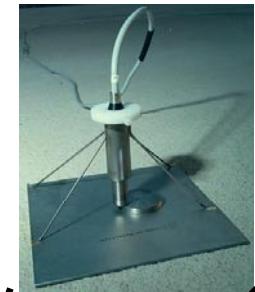
- Engine is currently certified on the Dassault Falcon 900EX
- Part of the TFE731-20/40/60 engine family that also powers
 - Learjet 45
 - IAI Astra SPX
 - Dassault Falcon 50EX
 - Hawker 450



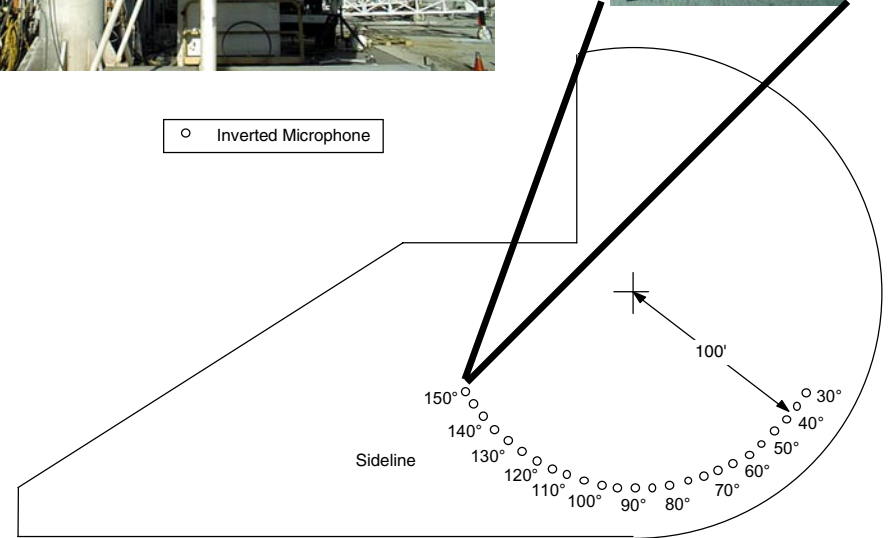
Honeywell

Honeywell Outdoor Acoustic Test Facility

- SAE ARP 1846 Standard
- FAA Approved



- Large acoustically reflecting surface
- Minimum interference test stand
- Instrumentation for weather measurements
- Engine inflow control device (ICD)
- Polar arc and sideline noise measurements
- Low ambient noise levels



Honeywell

Various Core and Bypass Nozzle Configurations

Core Nozzles

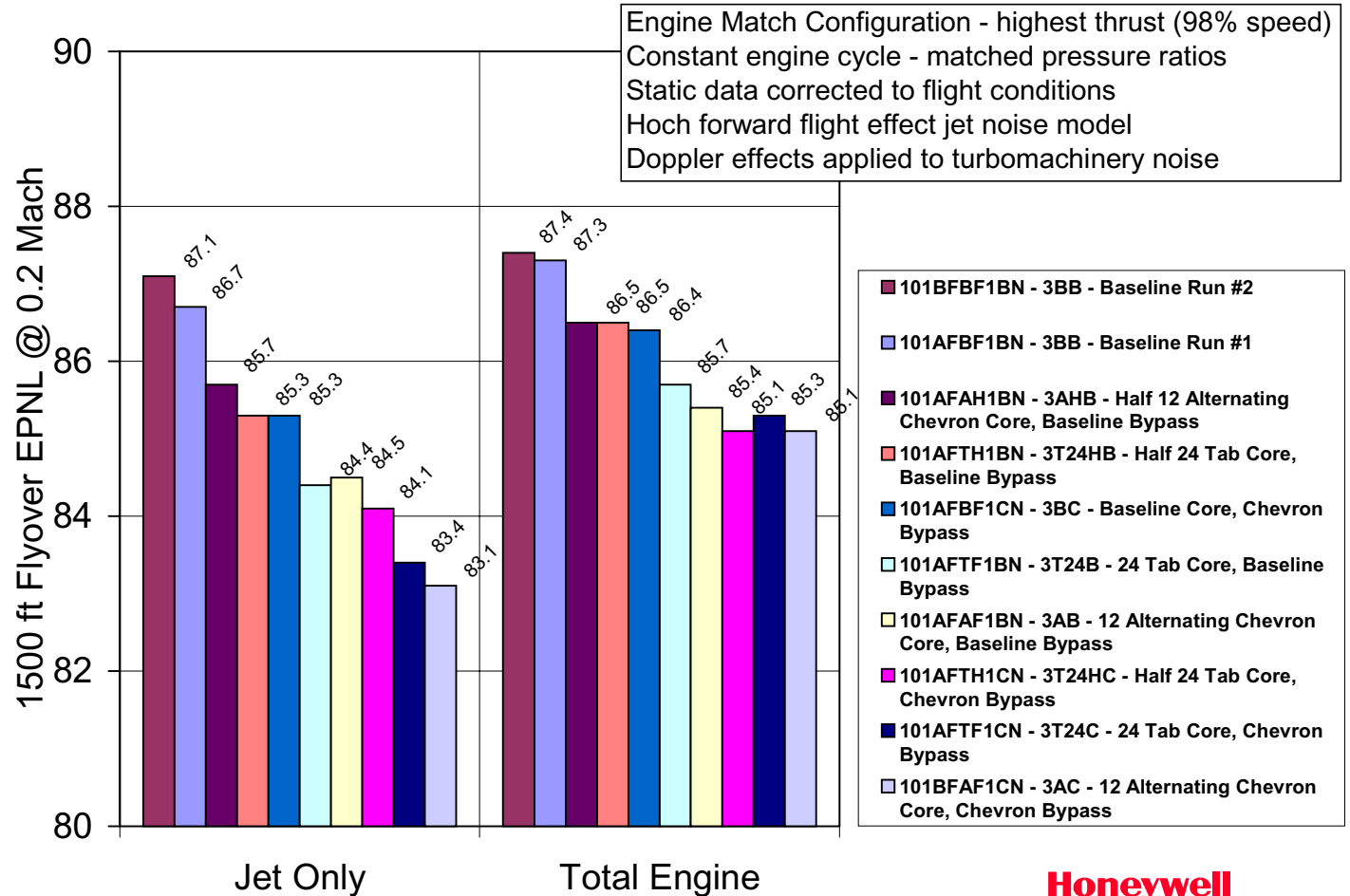


488

Bypass Nozzles



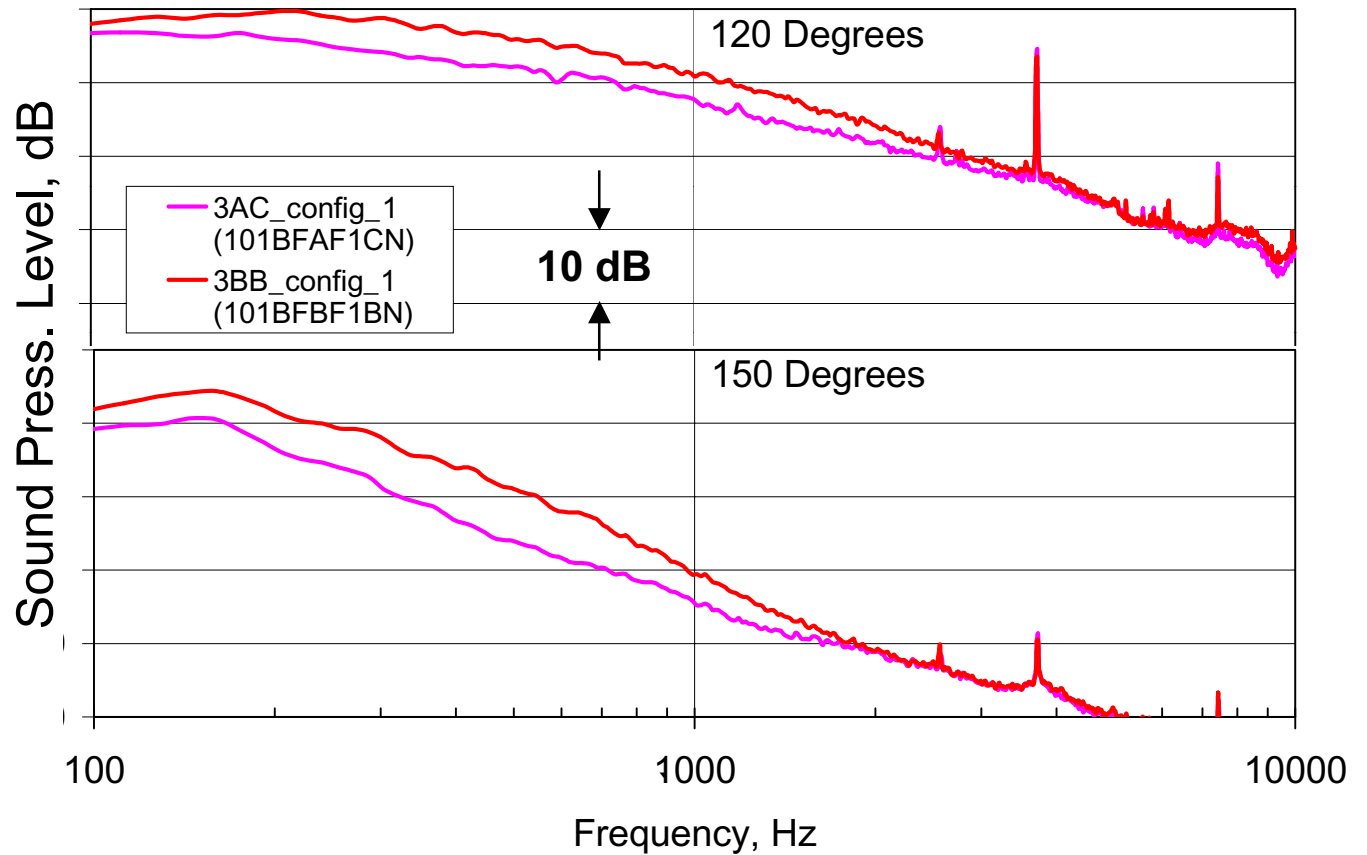
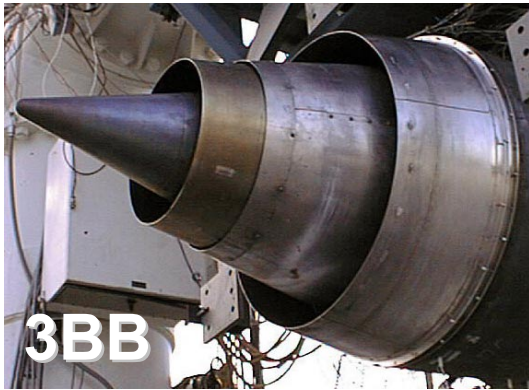
Significant EPNL benefit measured - confirmed results from NASA Glenn rig test



Honeywell

Focus on Two Nozzle Configurations...

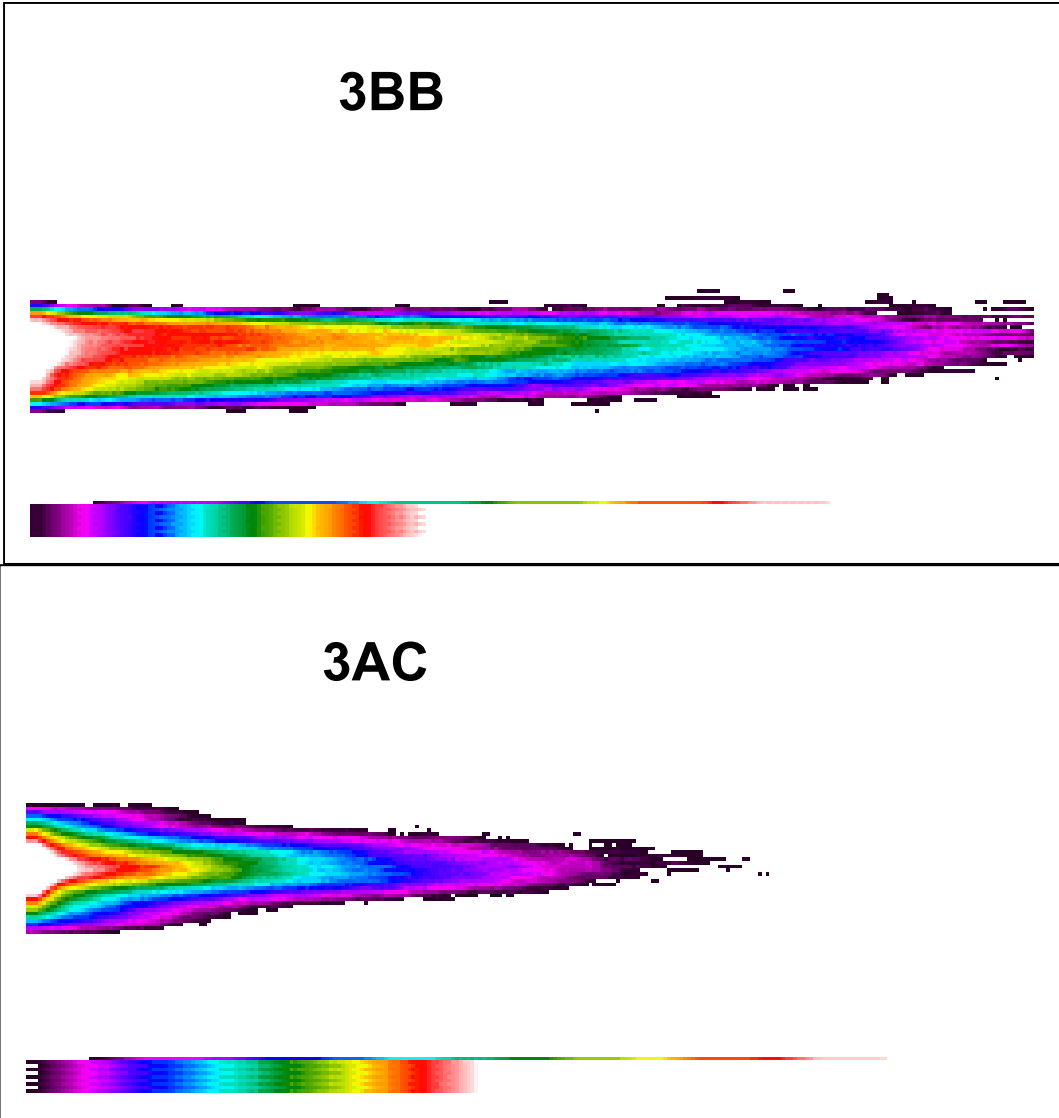
...At the highest thrust setting (1070 fps mixed jet velocity)



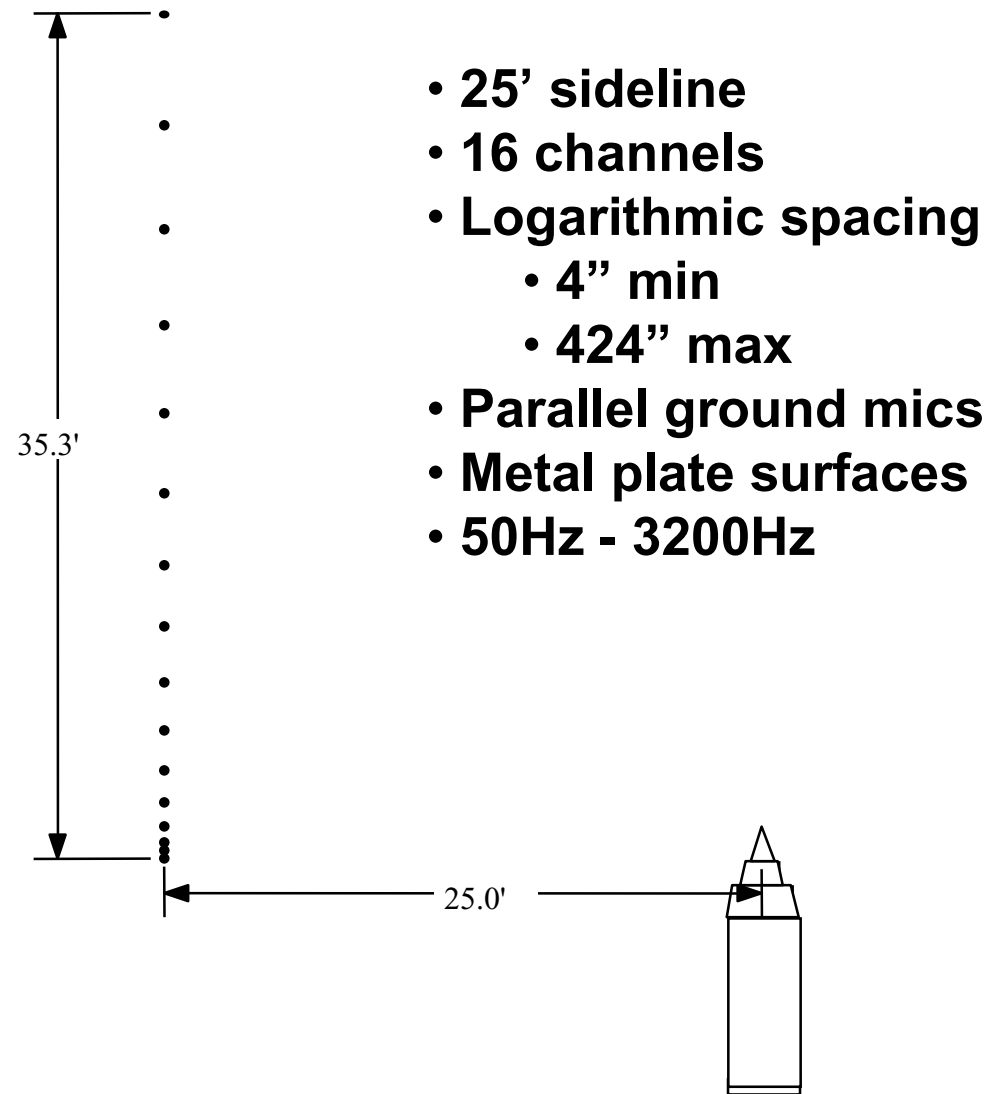
Infrared Images of Plume

- IR imaging is effective in confirming that chevrons produced radical improvements in core/fan mixing

Infrared image data from Agboola and Bridges



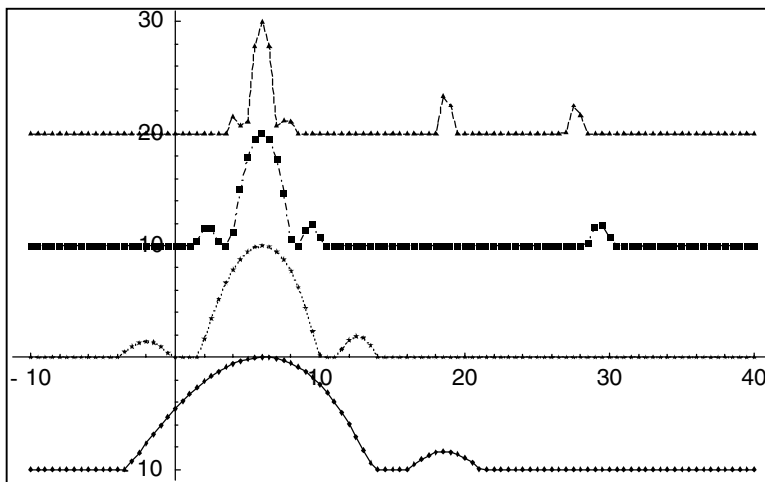
NASA Glenn 1-D Phased Array at San Tan Facility



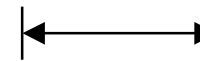
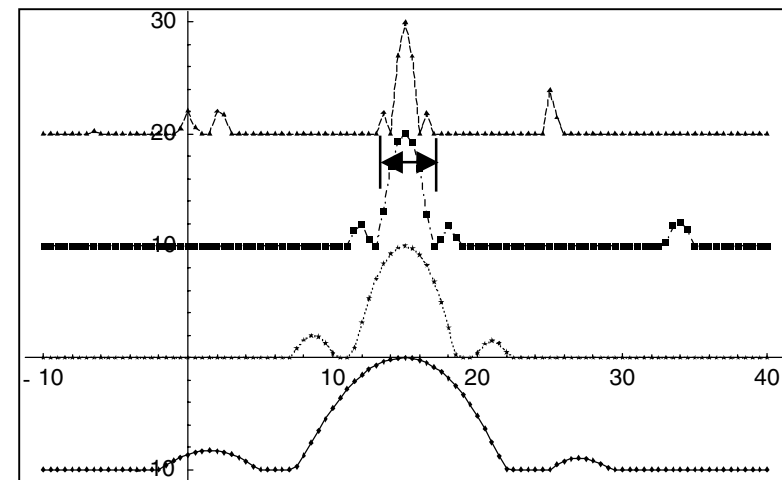
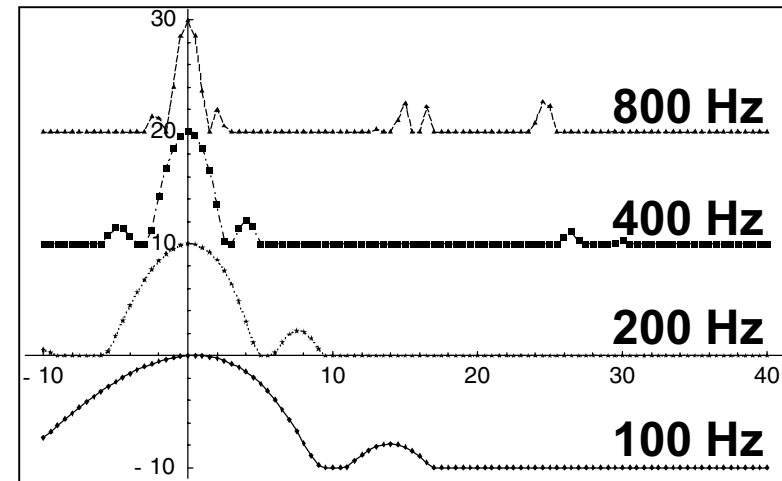
Honeywell

NASA Glenn 1-D Array Performance

- Point Spread Function obtained by synthesizing signals at array microphones for a known source location, then beamforming for all possible locations.
- Here, source is at 0, 6, and 15 feet downstream of nozzle on jet axis.
- No spurious sidebands above 6dB.

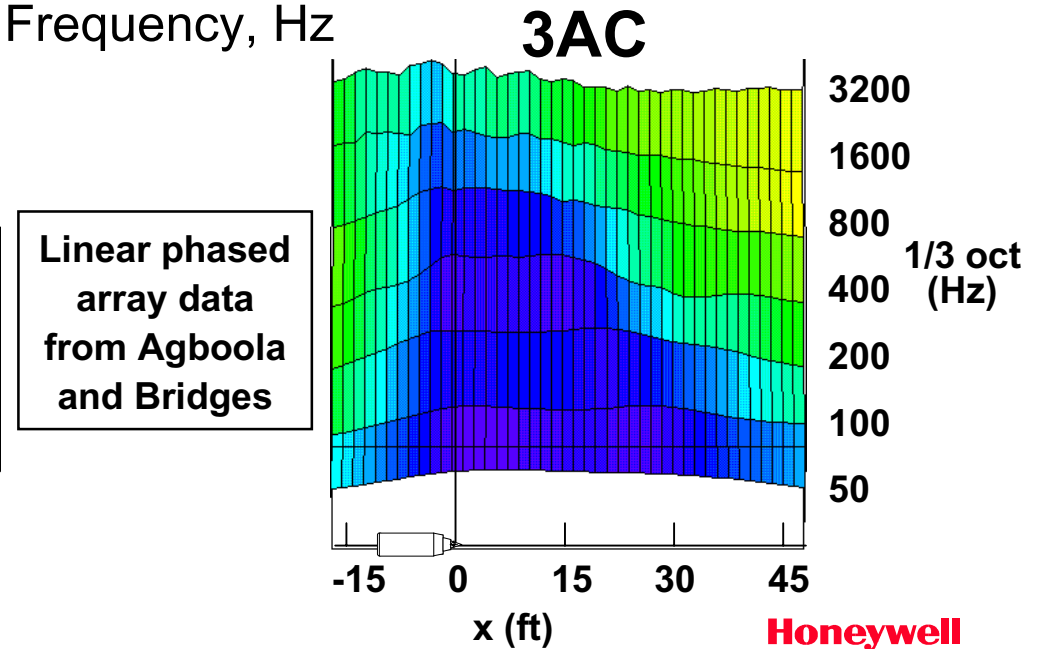
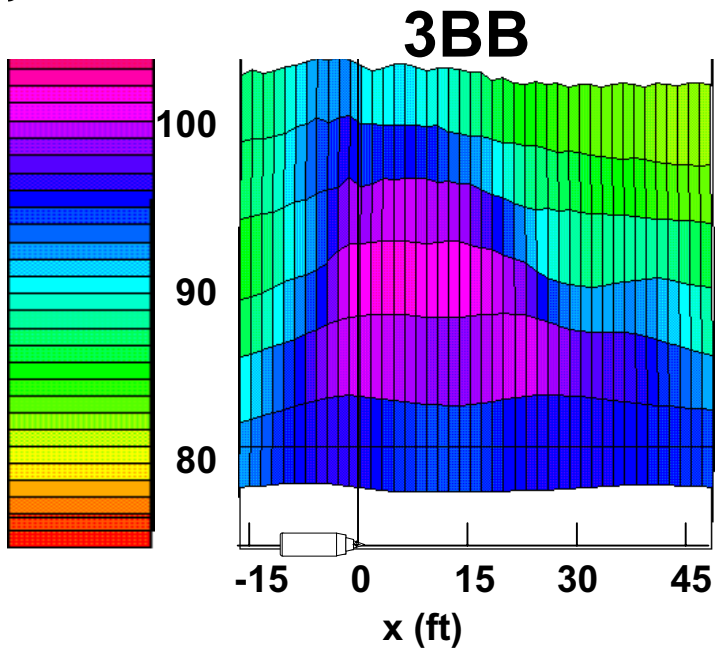
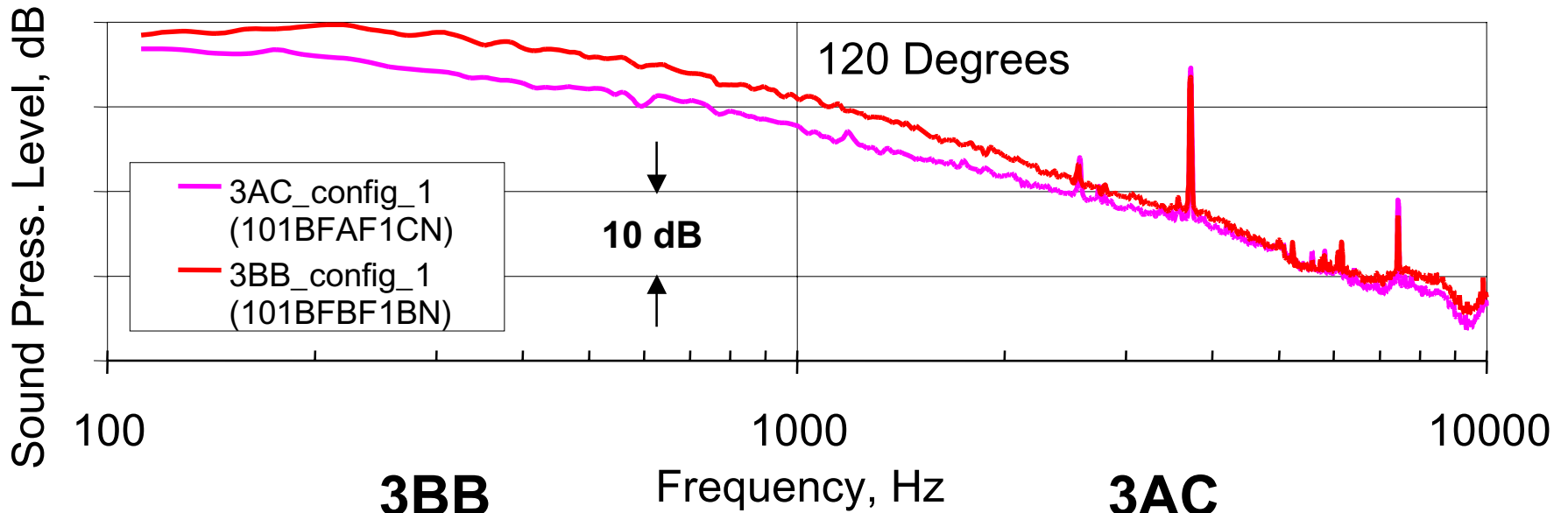


Linear phased array data
from Agboola and Bridges



Honeywell

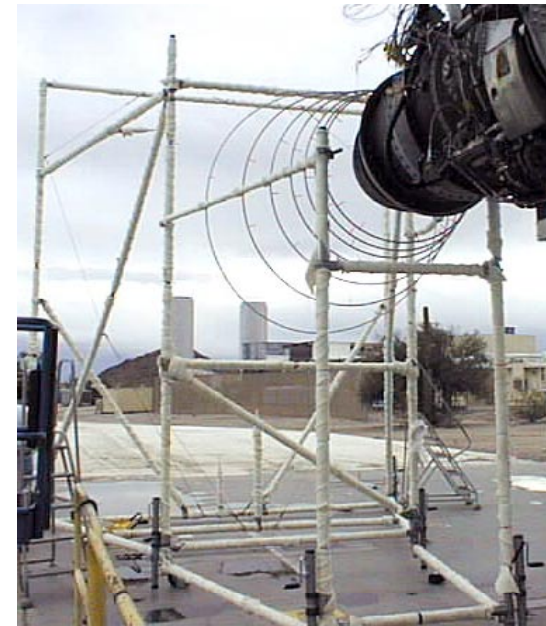
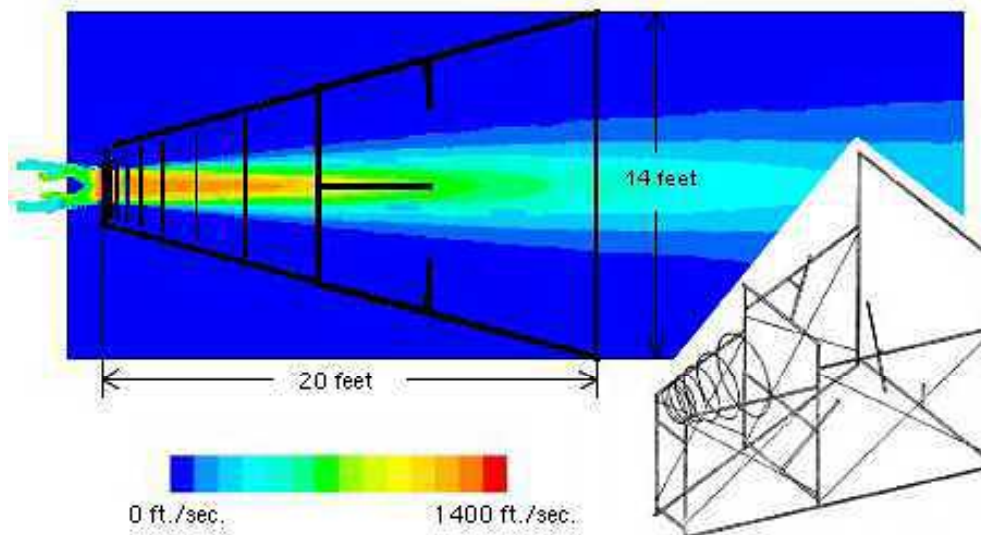
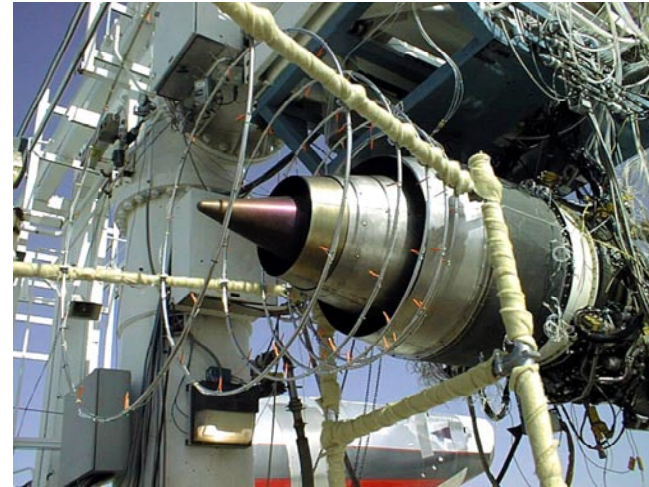
NASA Glenn 1-D Array Location Results



Honeywell

Boeing Near Field 3-D “Cage” Array

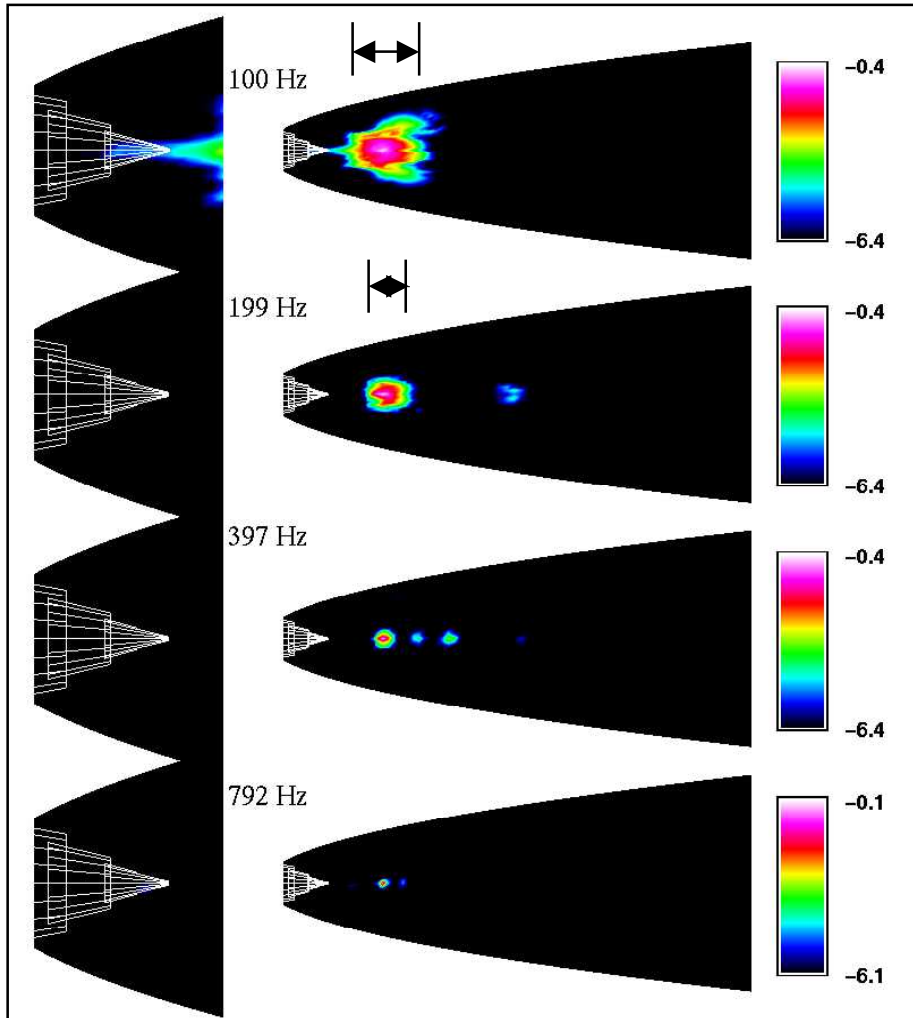
- 103 Kulite microphones in a sparse, logarithmic array
- Speakers used for calibrations
- Photogrammetry used for positions
- Coaxial shear layers modeled for ray tracing analysis



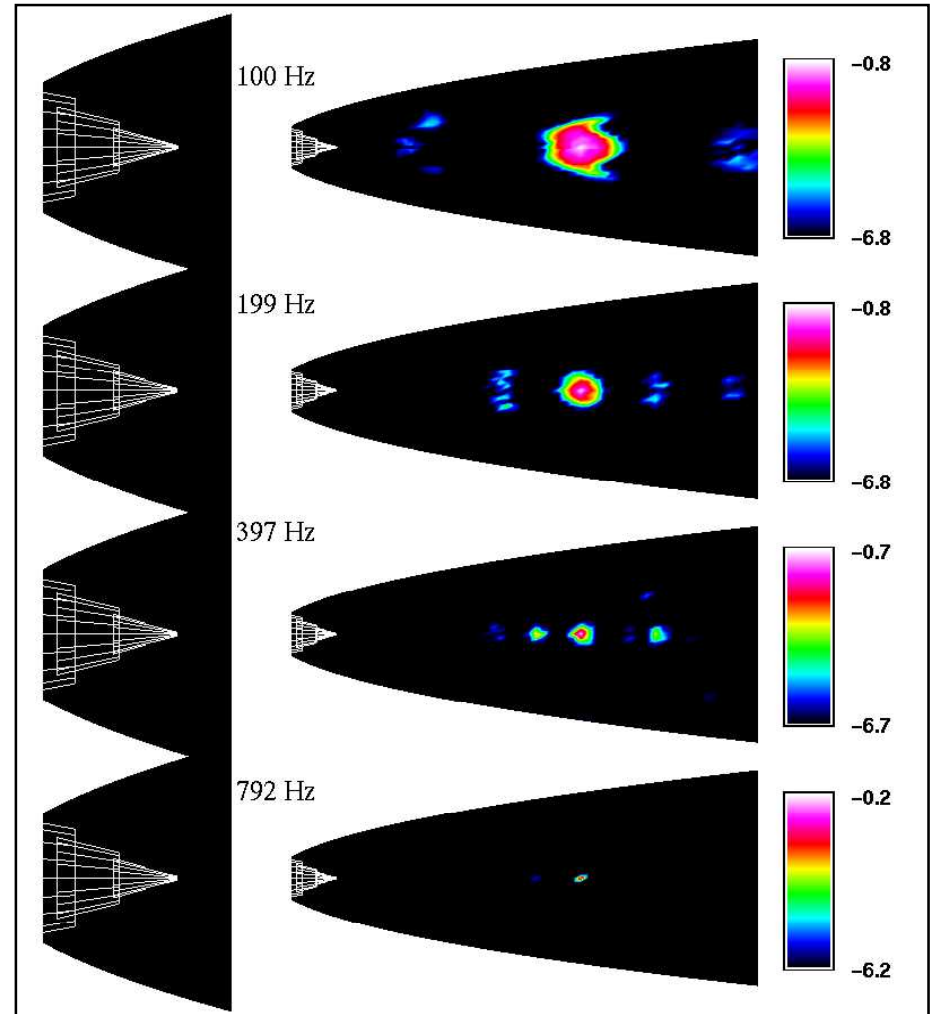
Honeywell

Cage Array Point Spread Functions

2.5 Fan nozzle dia. downstream



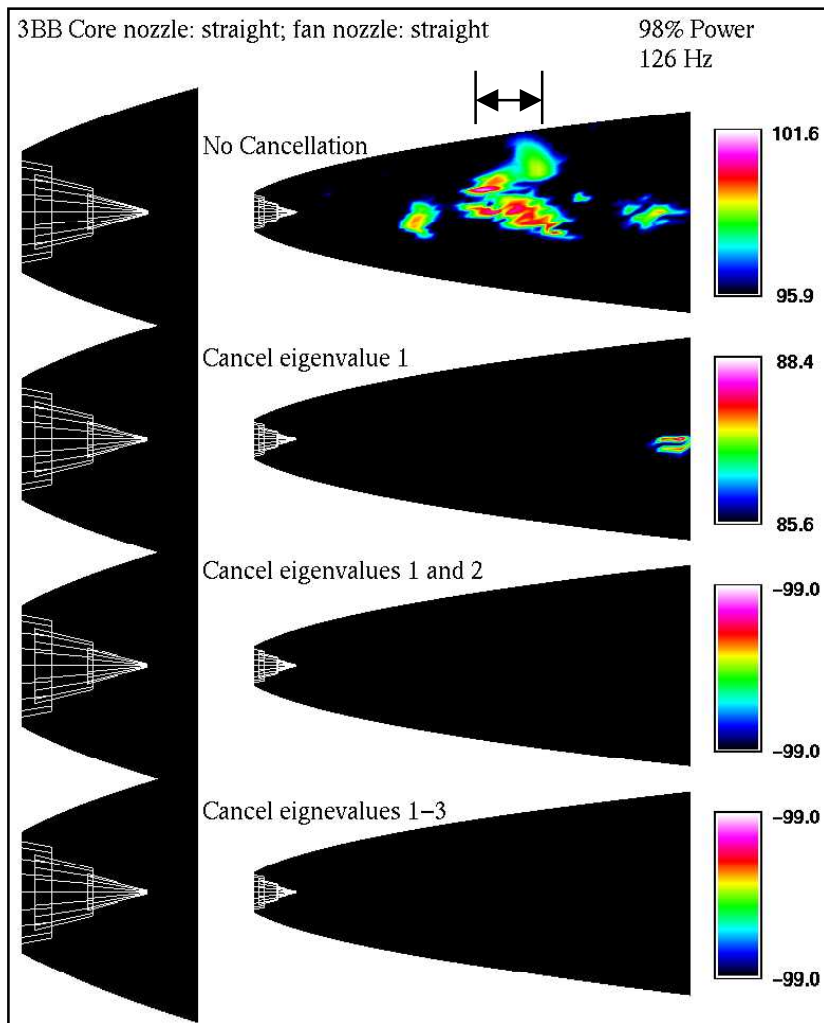
8.25 fan nozzle dia. downstream



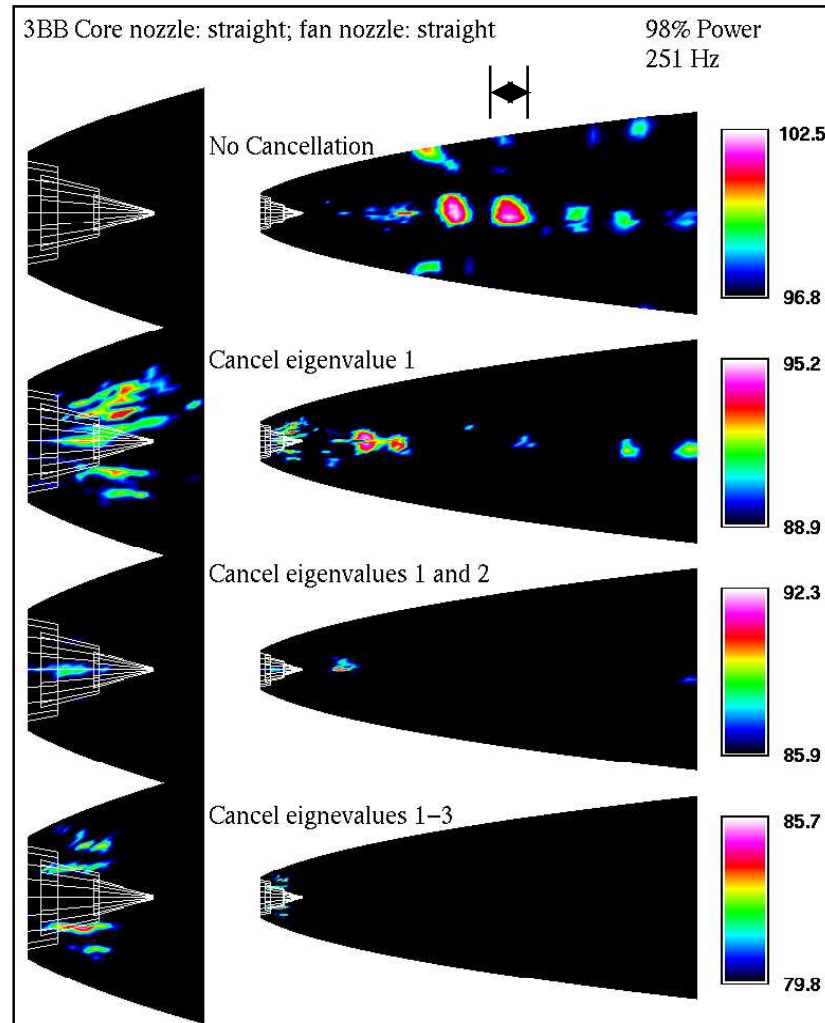
Cage array data from Dougherty

Cage Array Results - Baseline Nozzle (3BB)

125 Hz



250 Hz

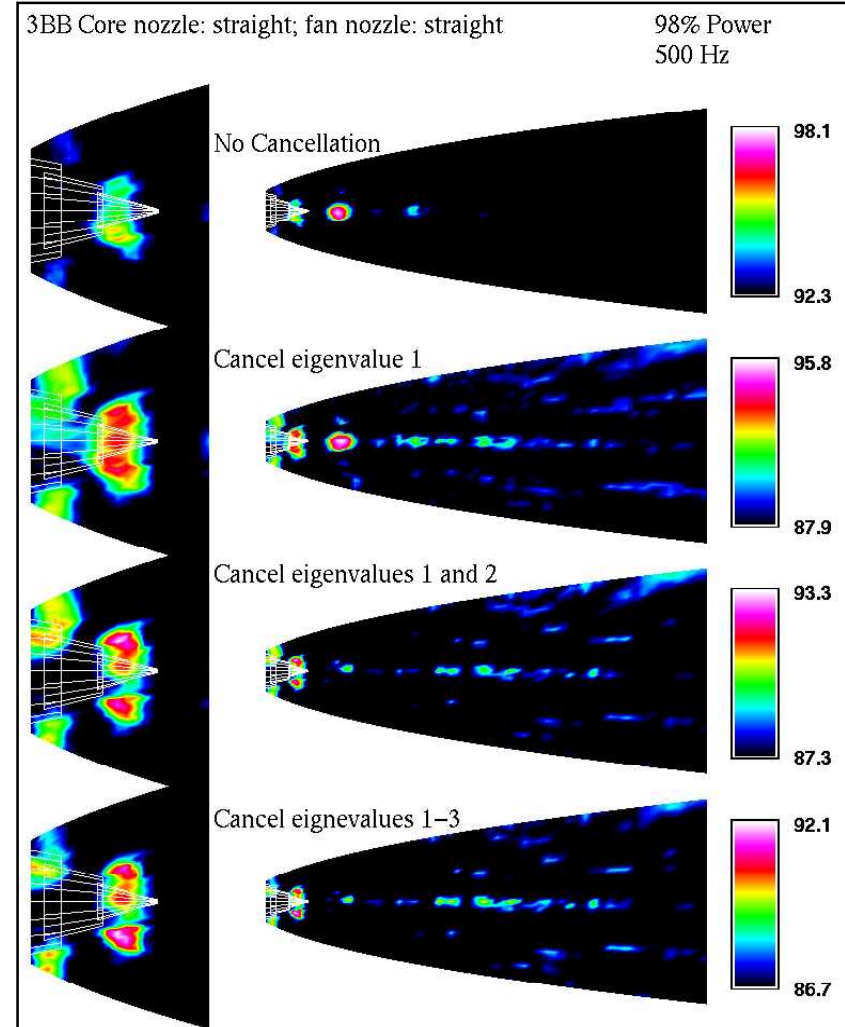
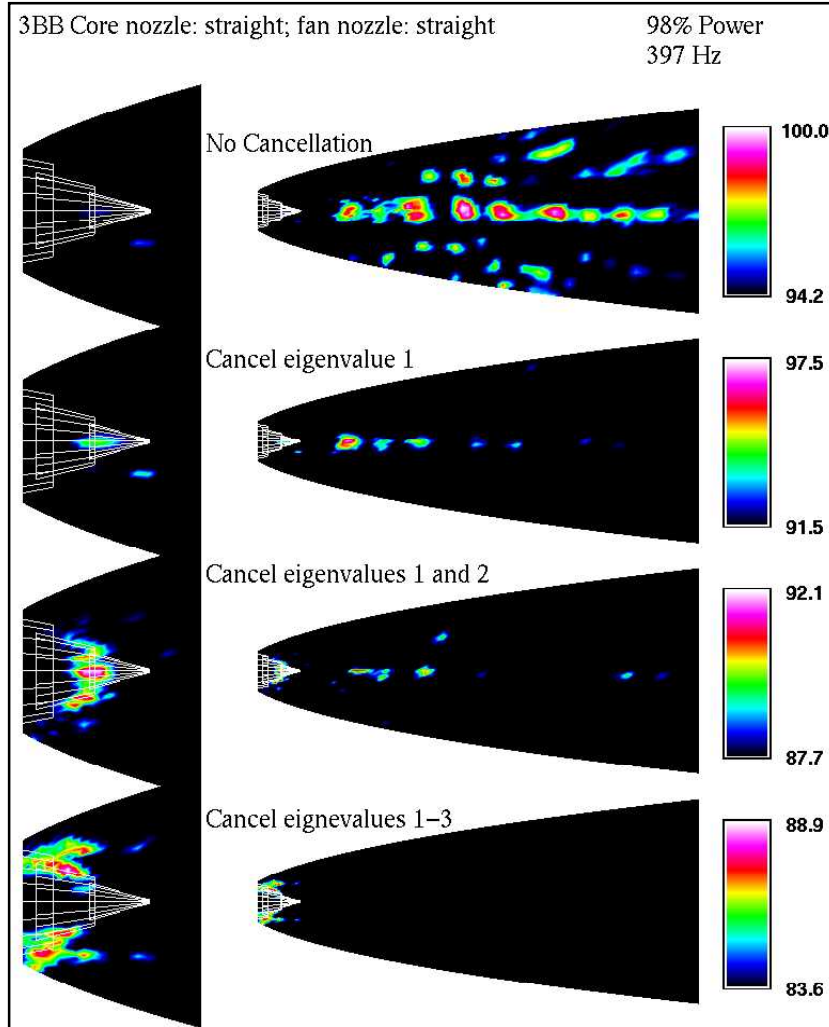


Cage array data from Dougherty

Cage Array Results - Baseline Nozzle (3BB)

400 Hz

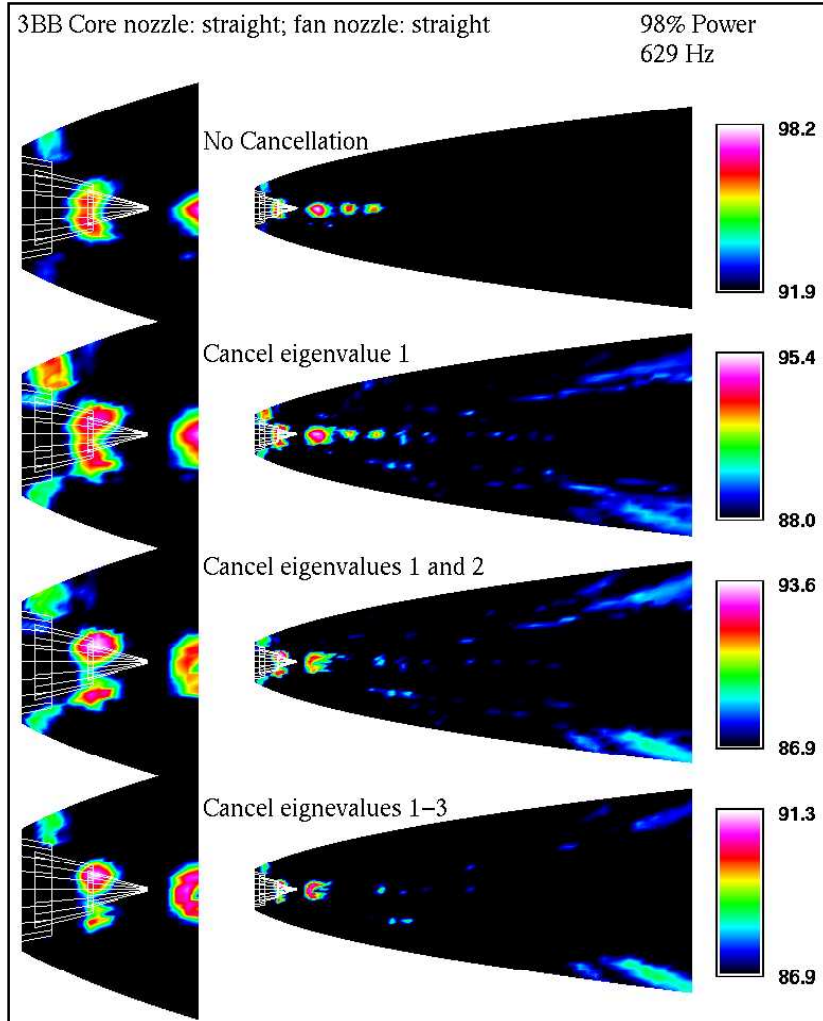
500 Hz



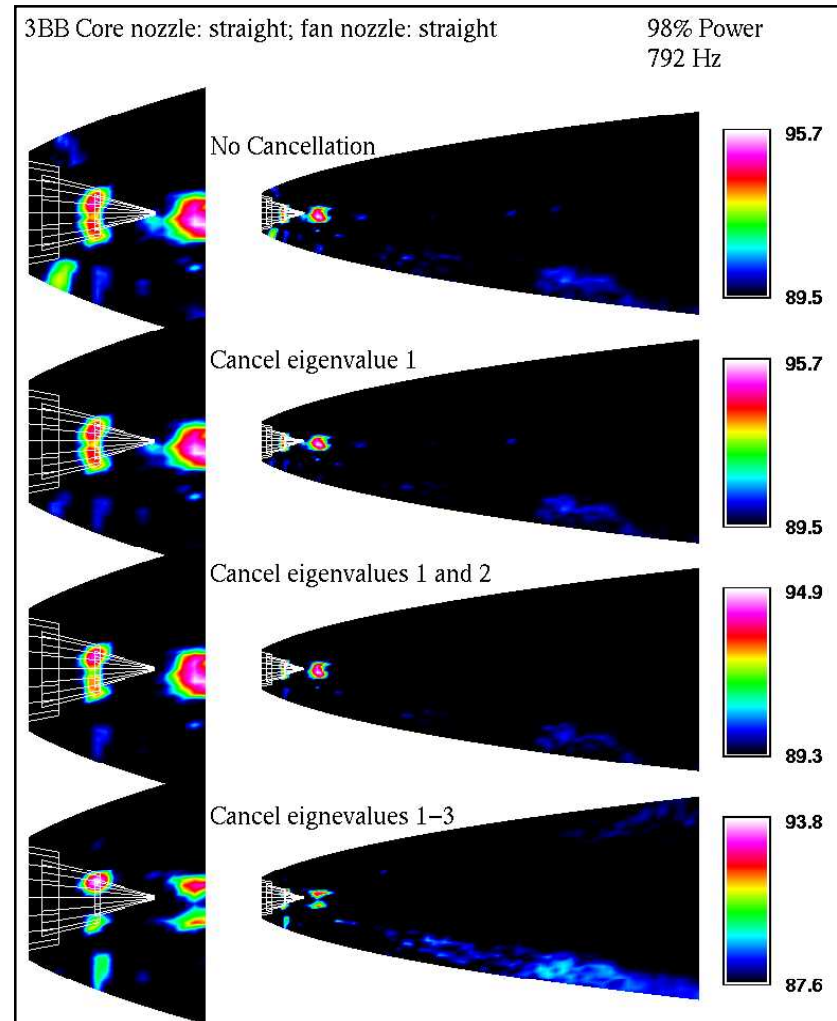
Cage array data from Dougherty

Cage Array Results - Baseline Nozzle (3BB)

630 Hz

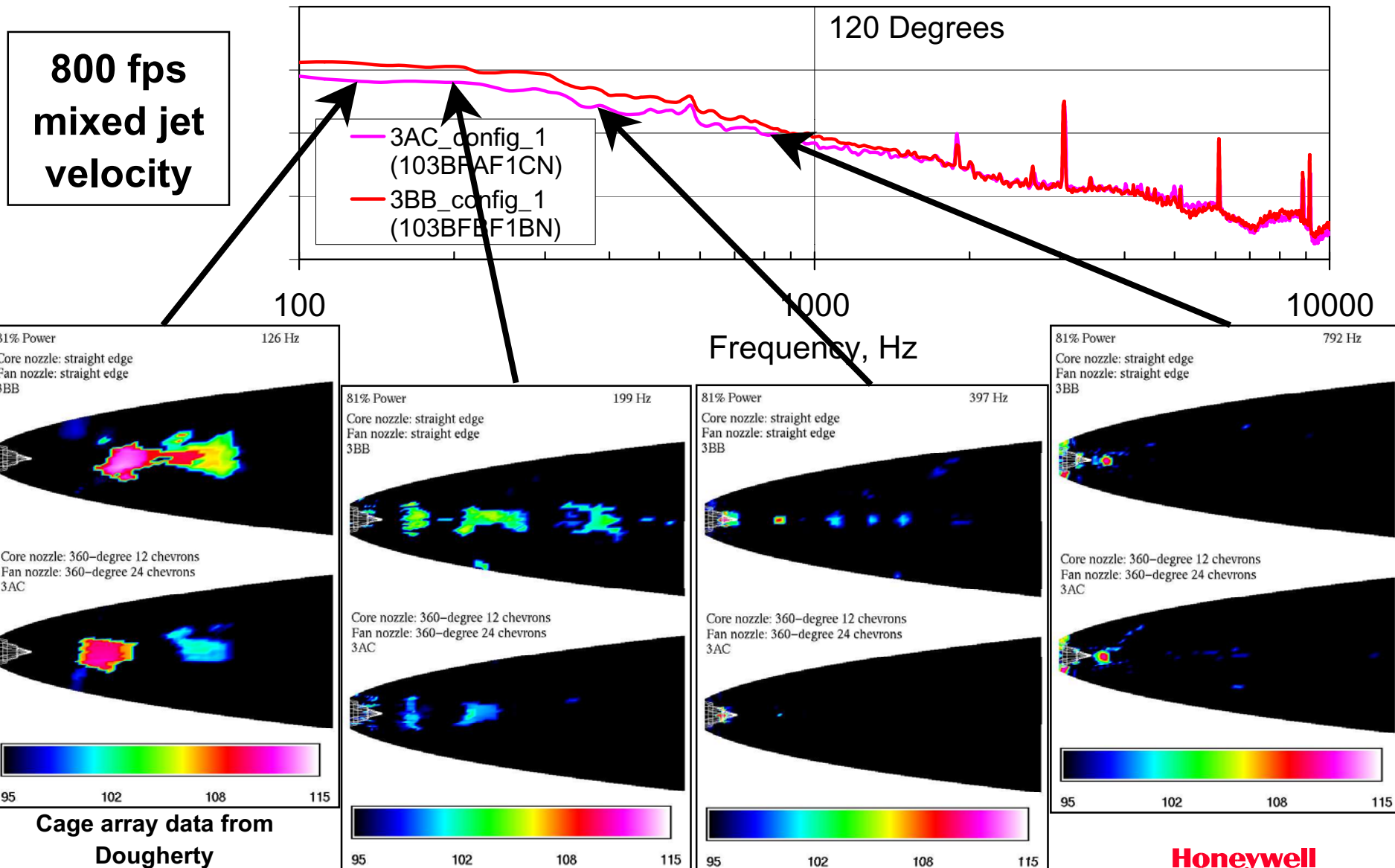


800 Hz



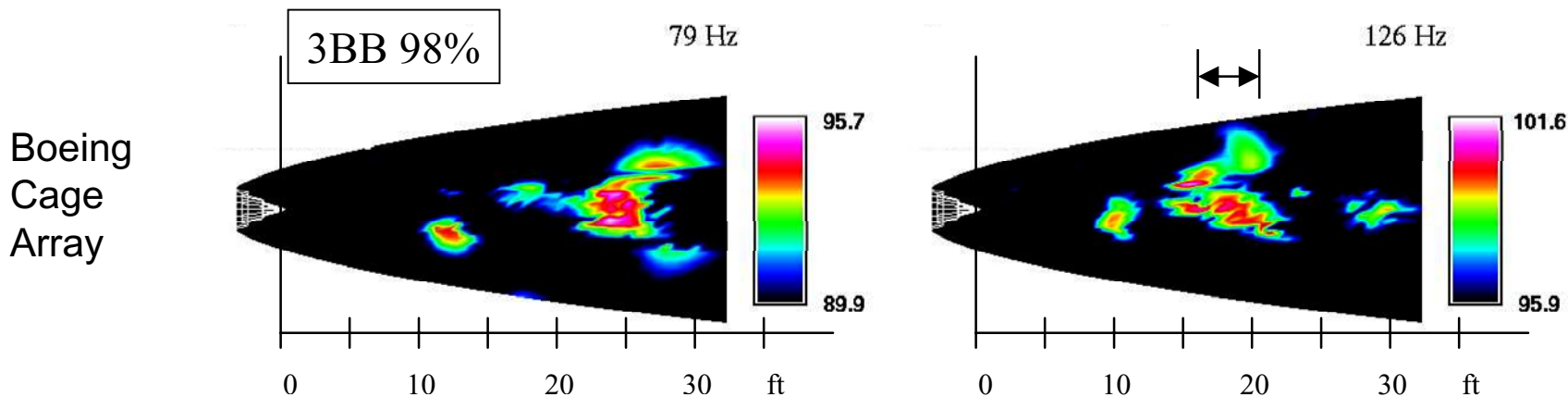
Cage array data from Dougherty

Cage Array Estimate of Noise Benefit of 3AC Nozzle

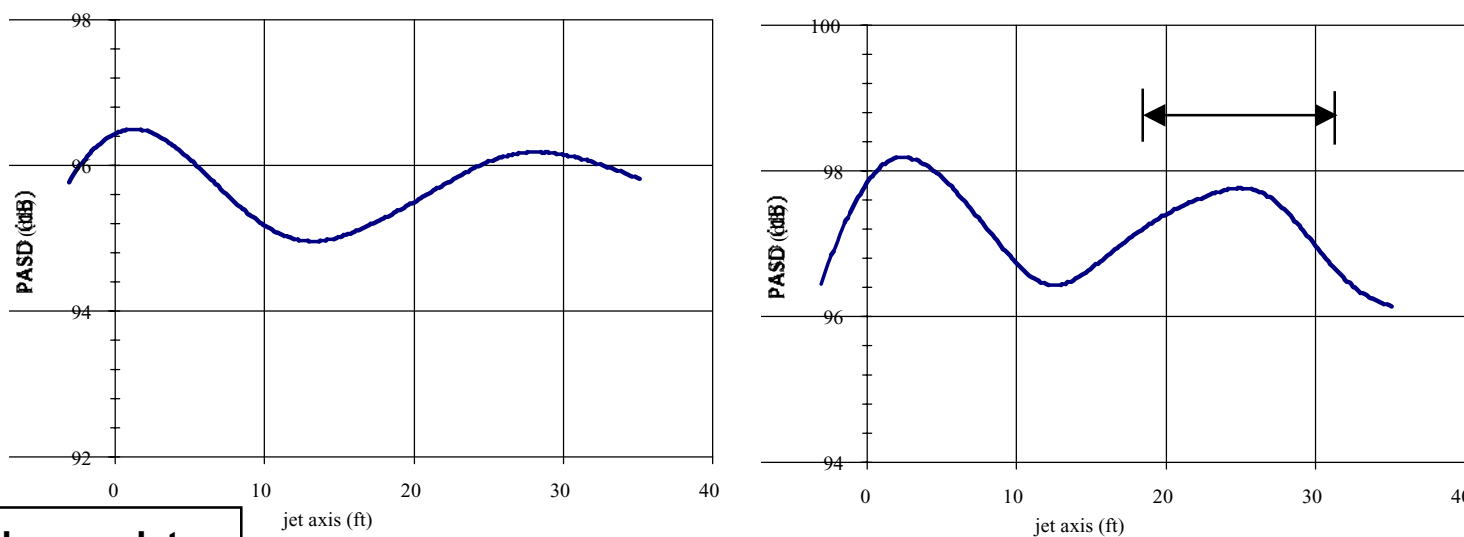


Comparison of Far Field 1-D & Near Field 3D Arrays

Cage array data from Dougherty



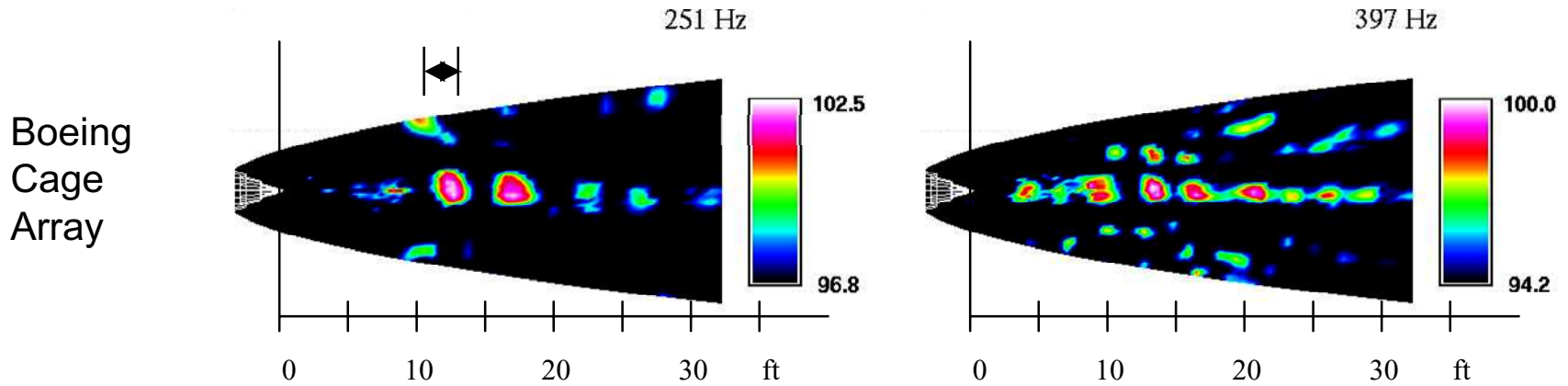
GRC Linear Array



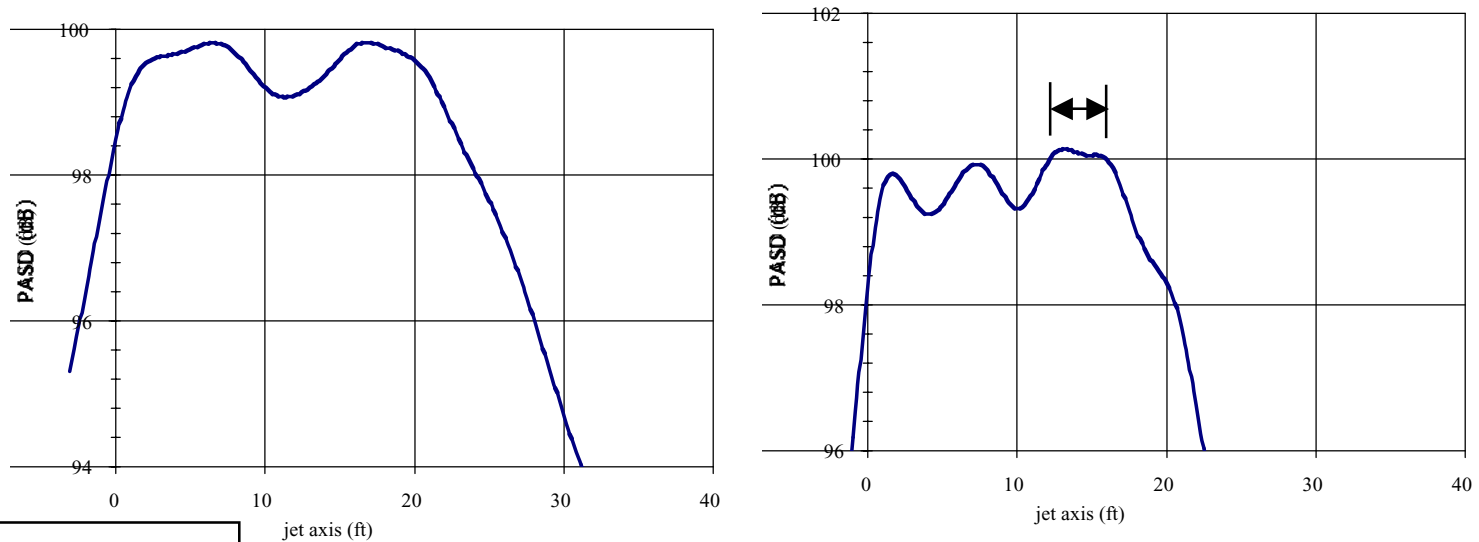
Linear phased array data from Agboola and Bridges

Comparison of Far Field 1-D & Near Field 3D Arrays

Cage array data from Dougherty



GRC Linear Array

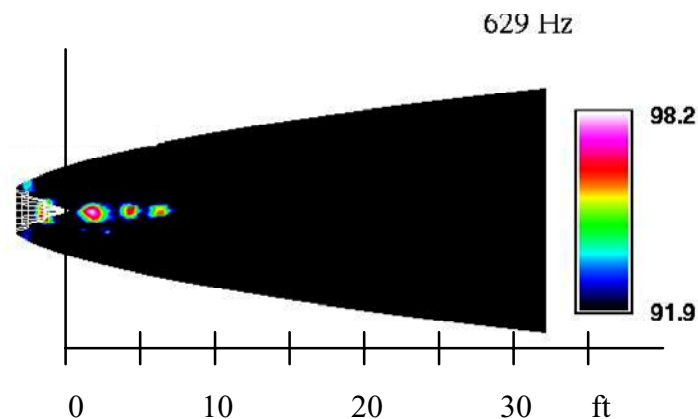
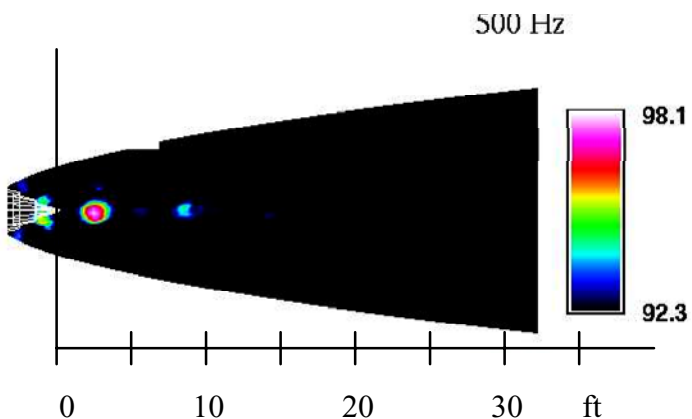


Linear phased array data from Agboola and Bridges

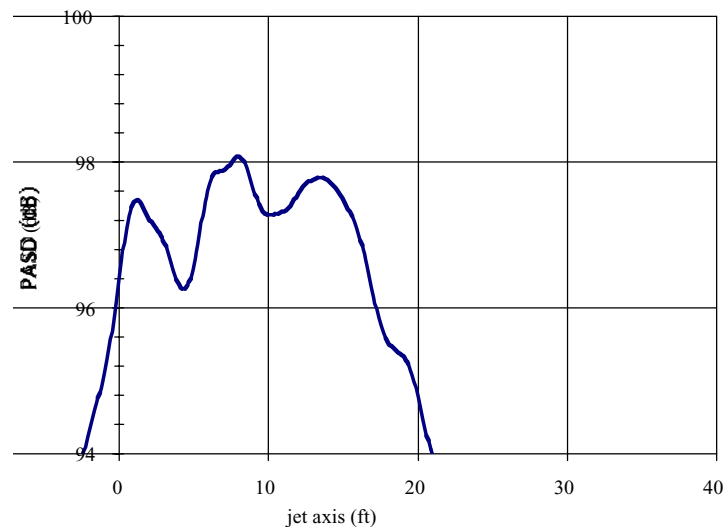
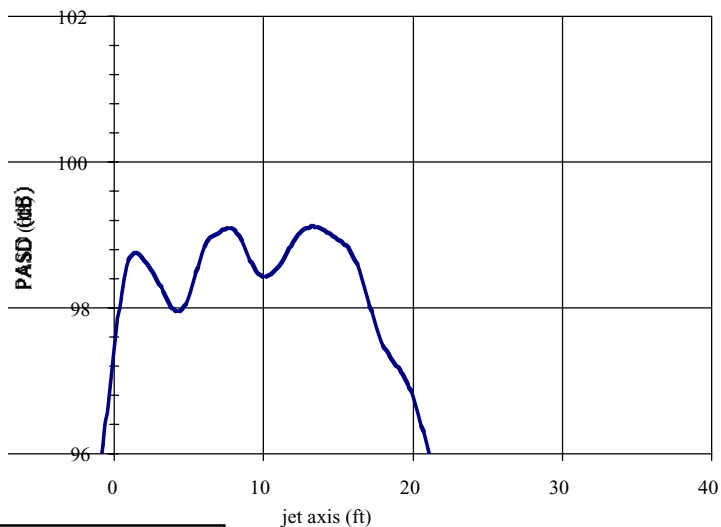
Comparison of Far Field 1-D & Near Field 3D Arrays

Cage array data from Dougherty

Boeing
Cage
Array



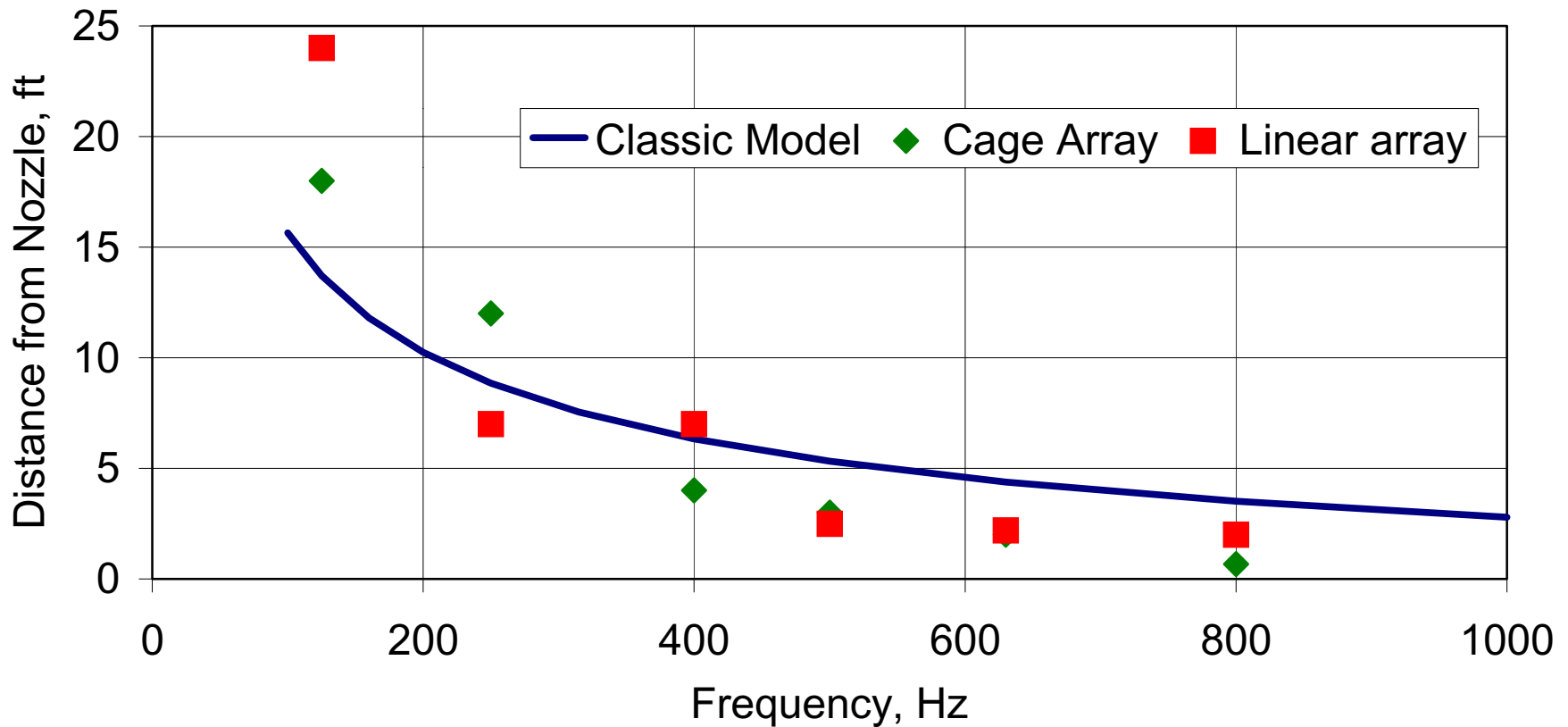
GRC
Linear
Array



Linear phased array data from Agboola and Bridges

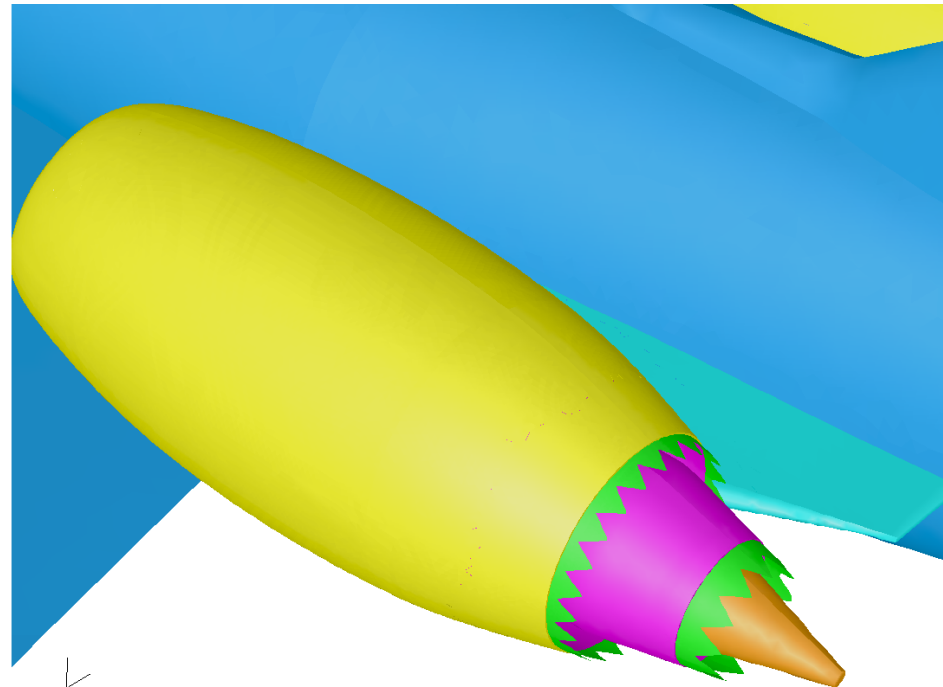
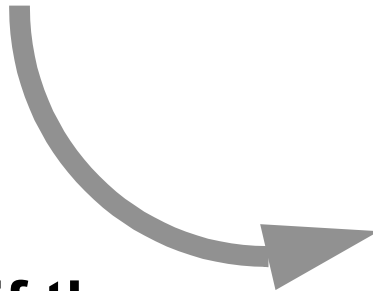
Source Location Comparison

- **Maximum SPL estimated from classical beam-forming**
- **Comparison made with “classic” source location empirical model, $x/D = (0.057 \cdot S + 0.021 \cdot S^2)^{-1/2}$**



Honeywell

Next Step - EVNRC Flight Test



- **Determine if the hardware tested statically will achieve similar noise reductions in flight**

Conclusions

- **IR imaging is effective in confirming that chevrons produce increased core flow mixing**
- **The improvement in core/fan mixing results in significant noise reduction**
- **Both 1-D and 3-D array measurement techniques were successful in identifying noise source locations**
- **Source location data from this test program confirms the classical semi-empirical location model**

D. Weir References

1. Dougherty, R.P., and R.W. Stoker, "Sidelobe suppression for phased array aeroacoustic measurements", AIAA/CEAS 98-2242.
2. Dougherty, R.P., "Source location with sparse acoustic arrays; interference cancellation" CEAS-ASC Workshop, "Wind Tunnel Testing in Aeroacoustics", DNW, Noordoostpolder, the Netherlands, November 5-6, 1997.