# Development of a Broadband Acoustic Emulator to Mature Propulsion Noise Reduction (CFANS-BB)

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# HISTORY

## Prior Work:

- From 1995 to 2001 a variety of ANC concepts were developed and evaluated primarily on the ANCF.
- NASA GRC/LaRC partnerships with several contractors:

  BBN, BYU, CSU, GE, HWAE, Pratt & Whitney, Rice Consulting, VPI, SPS
- Series of NASA NRAs, SBIRs, & in-house SRFs. (–> engine demo).
- Addressed only Tone Modes due to Rotor/Stator Interaction.
- Modes are synchronized to shaft rotation allowing for a *non-acoustic reference signal* eliminating possibility of acoustic feedback instability -- i.e., tach signal feed-forward.
- Well-defined Source Allowing for Physical Assumptions to be Incorporated into ANC System.

# STATUS

## Summary of Effort:

- Tonal ANC can ‘mostly’ eliminate fan tones composed of modes.
- Integration into passive treatment desirable & practical.
- Complexity (e.g. # of actuators/sensors) not worth benefit obtained from tone ‘elimination’.
- ‘Reduced complexity’ schemes worsened cost/benefit.

## Conclusion:

- To allow cost/benefit viability requires Broadband ANC.

## Issue:

- TRL for turbofan BB-ANC ~1.
- BB-ANC is an order of magnitude more difficult.
- Funding an order of magnitude less.
- **Control Algorithm is the key.**

# PROPOSED EFFORT

## Enabling Solution:

An Artificial Broadband Source to be used for RDT&E of:

- Broadband control algorithms (ANC).
- Broadband noise reduction concepts (non-ANC).
- Source detection/localization/measurement techniques.
- Duct/farfield propagation CAA codes.

This Artificial Broadband Source:

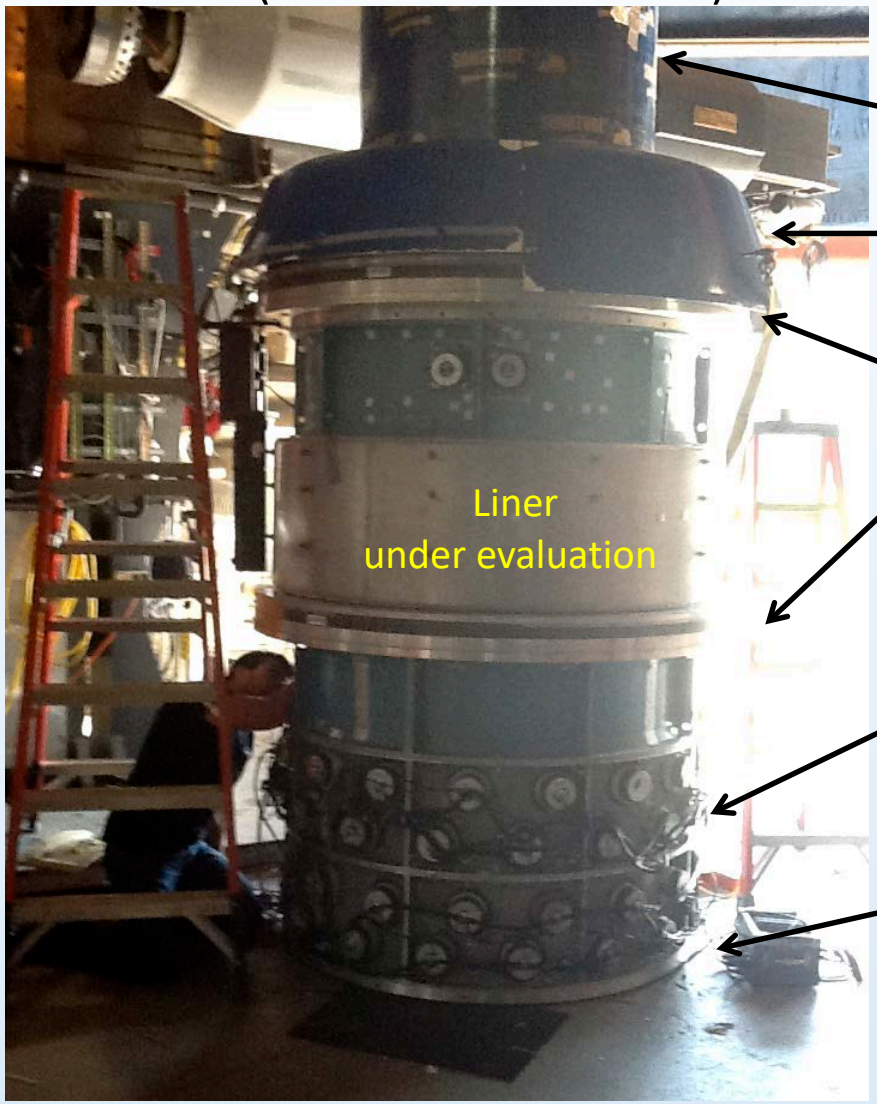
- Controllable - know what you're expected to generate.
- Modal or random sources <-> dependent on source modeling.
- 'Match' farfield 'signature' of 'relevant' engine source.

# PREVIOUS – TONAL BASED:

## (Ultra-Sonic) Configurable Fan Artificial Noise Source

CFANS (d=4' : 250 – 1500 Hz)

UCFANS (d=6" : 10 – 40 kHz)



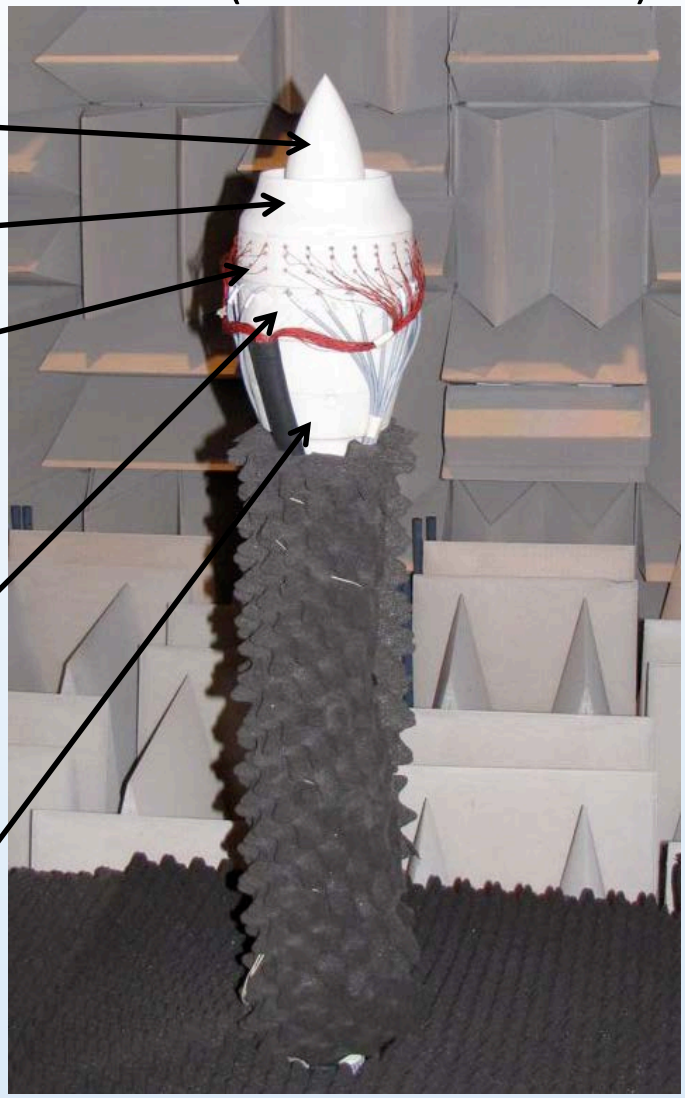

Center-body

Flow Lip

Internal Acoustic Measurement Locations

Artificial Noise Source Planes

absorptive material @ bottom



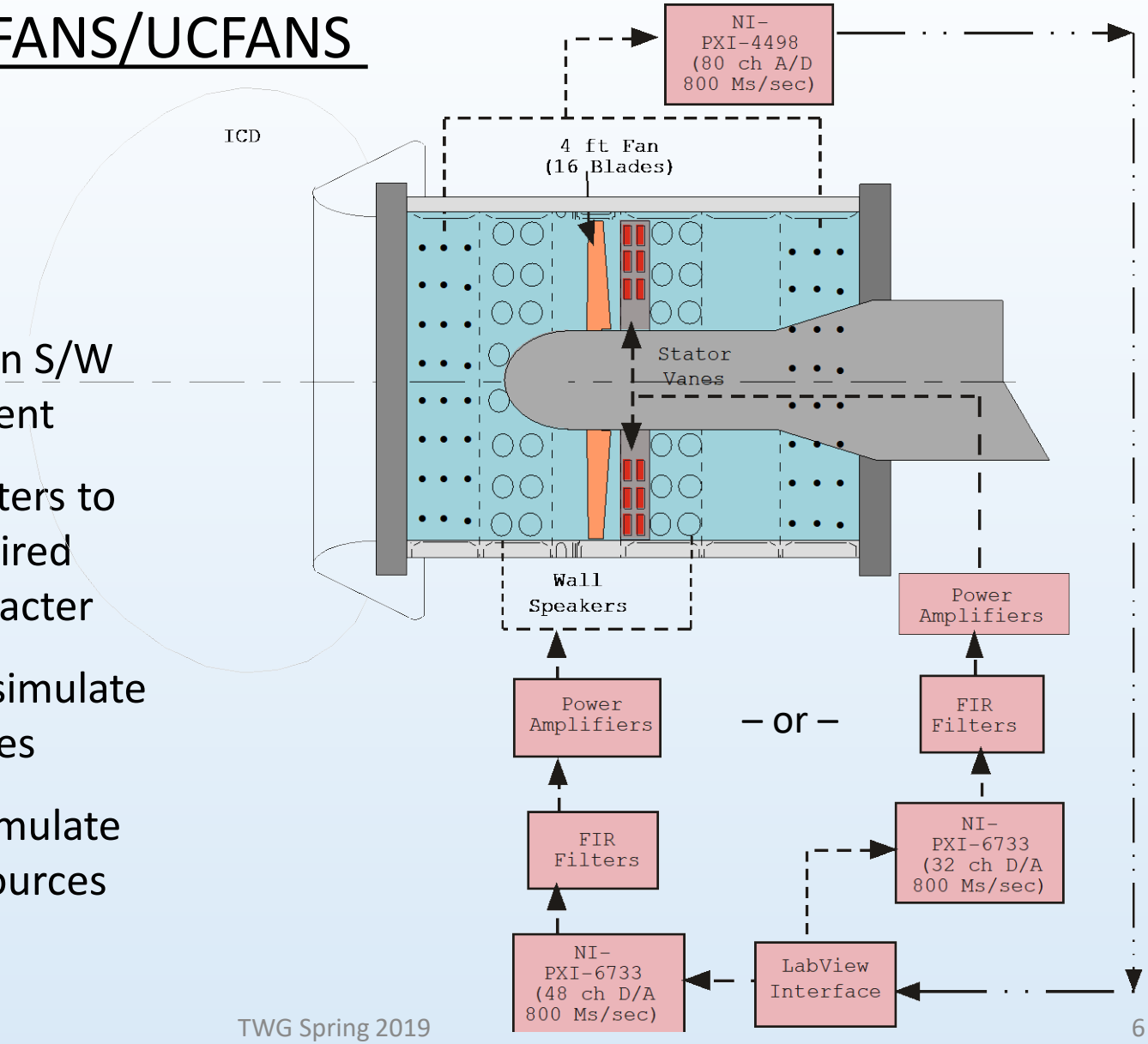
"Artificial Noise Systems for Parametric Studies of Turbo-machinery Aero-acoustics", *International Journal of Aeroacoustics*, 2016 15(1–2)
Sutliff, D. L. & Walker, B. E.

# SIGNAL GENERATION/CONTROL

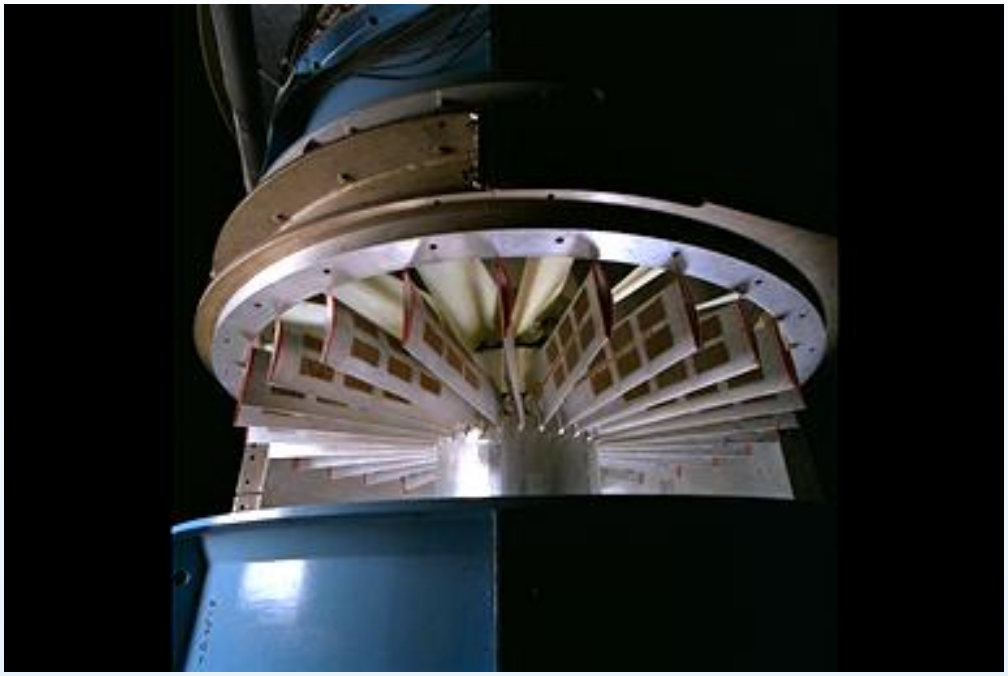
## EXTENTSION of CFANS/UCFANS

BB-CFANS:

- 16/32/64 channels
- Generate noise source in S/W Each channel independent
- S/W algorithm or FIR filters to 'shape' output with desired spectral/ temporal character
- Use of phase delays to simulate modal vs random sources
- Use of time delays to simulate rotating vs stationary sources



# VANE MOUNTED ACTUATORS



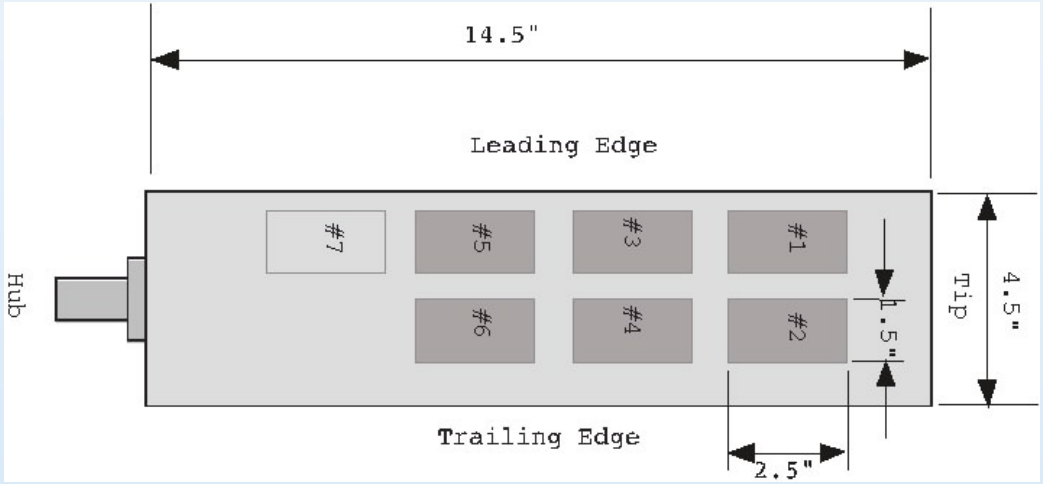
Couple very well to duct propagation & farfield radiation patterns.

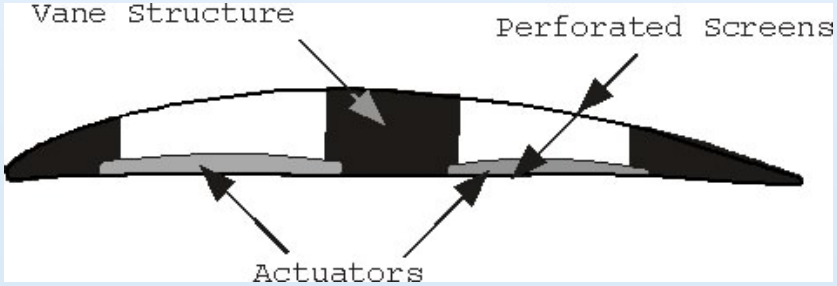
30 Vanes with 7 dipole mounted THUNDER actuators (replace or keep?).

Resonant around 1.0 to 1.2 kHz (can be compensated for).

BW ~ 1 – ~15 kHz

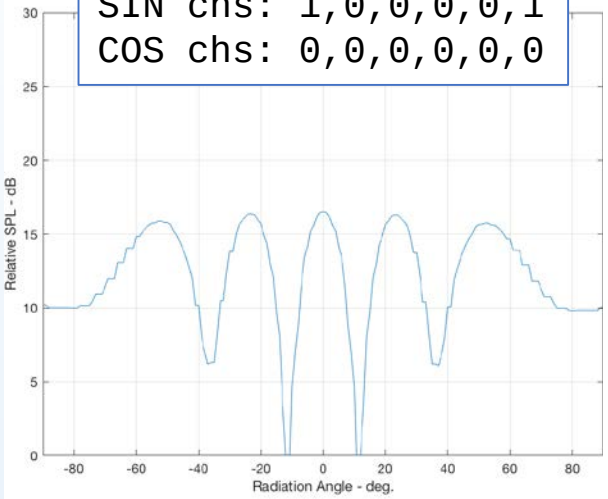
Each vane has 6 independent channels (tip/hub or LE/TE weighting/correlation).



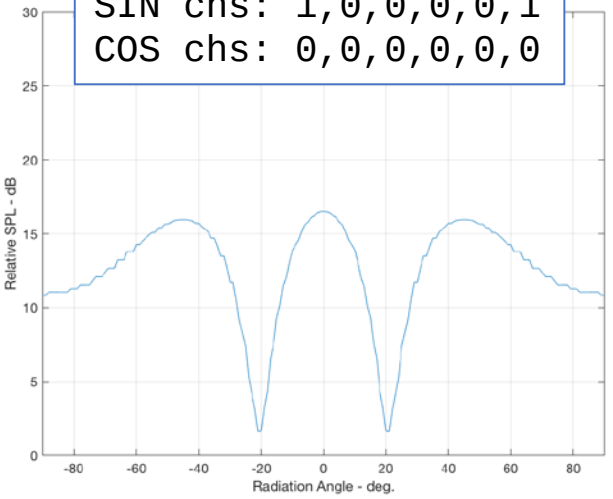



# SIX-ACTUATOR CONTROLLABILITY
## (prelim – analytical simulation)

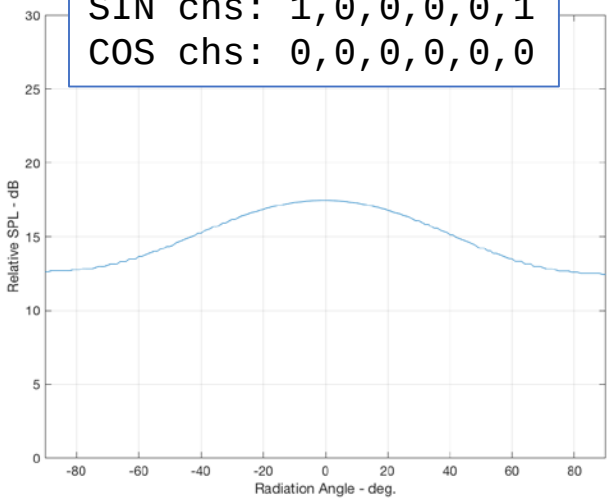
2000-2500 Hz
SIN chs: 1,0,0,0,0,1
COS chs: 0,0,0,0,0,0



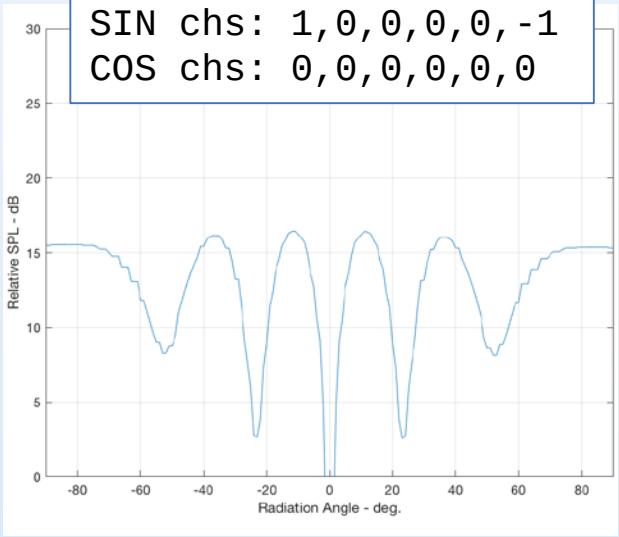

1000-1500 Hz
SIN chs: 1,0,0,0,0,1
COS chs: 0,0,0,0,0,0



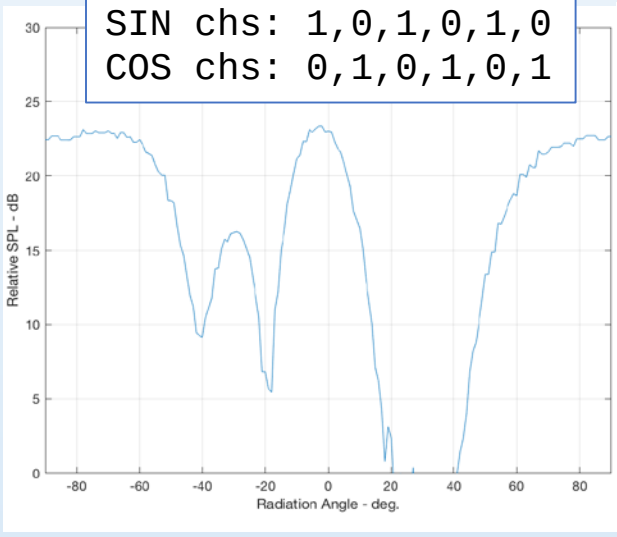

100-500 Hz
SIN chs: 1,0,0,0,0,1
COS chs: 0,0,0,0,0,0



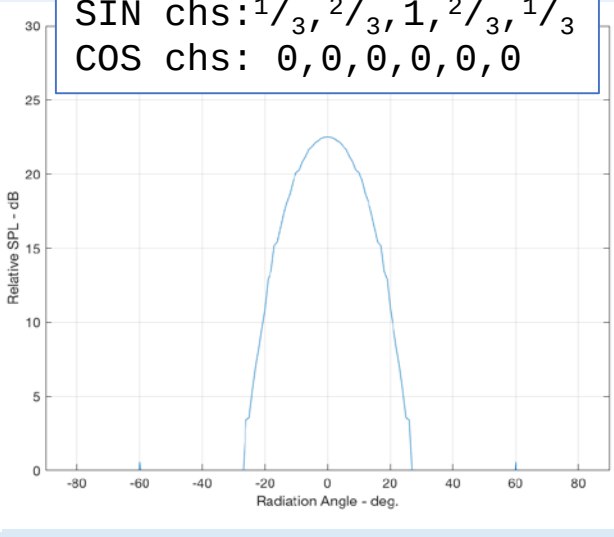

2000-2500 Hz
SIN chs: 1,0,0,0,0,-1
COS chs: 0,0,0,0,0,0




2000-2500 Hz
SIN chs: 1,0,1,0,1,0
COS chs: 0,1,0,1,0,1




2000-2500 Hz
SIN chs: $^{1}/_{3}, ^{2}/_{3}, 1, ^{2}/_{3}, ^{1}/_{3}$
COS chs: 0,0,0,0,0,0

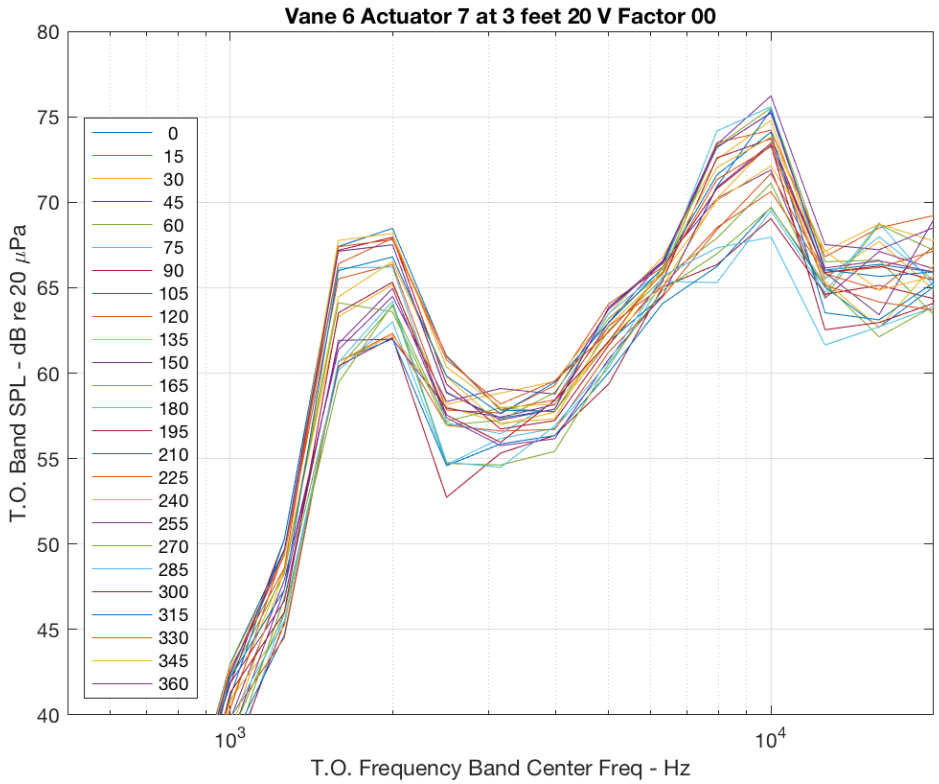


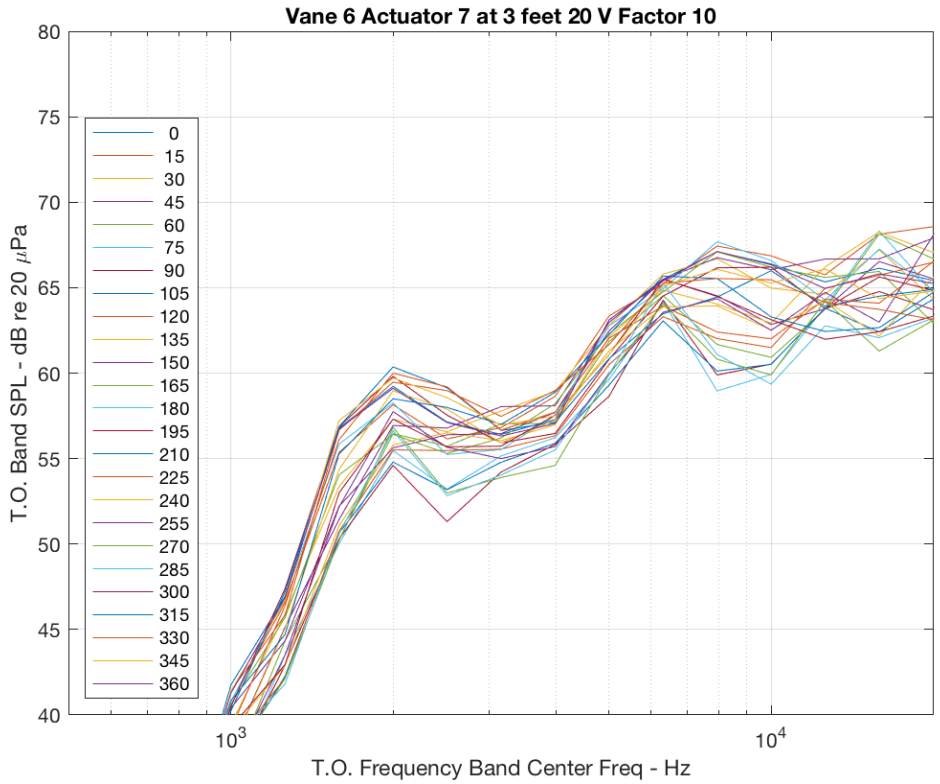



Courtesy: Dr. Bruce Walker / ChIA

# SINGLE ACTUATOR RESPONSE
## (prelim - experimental)

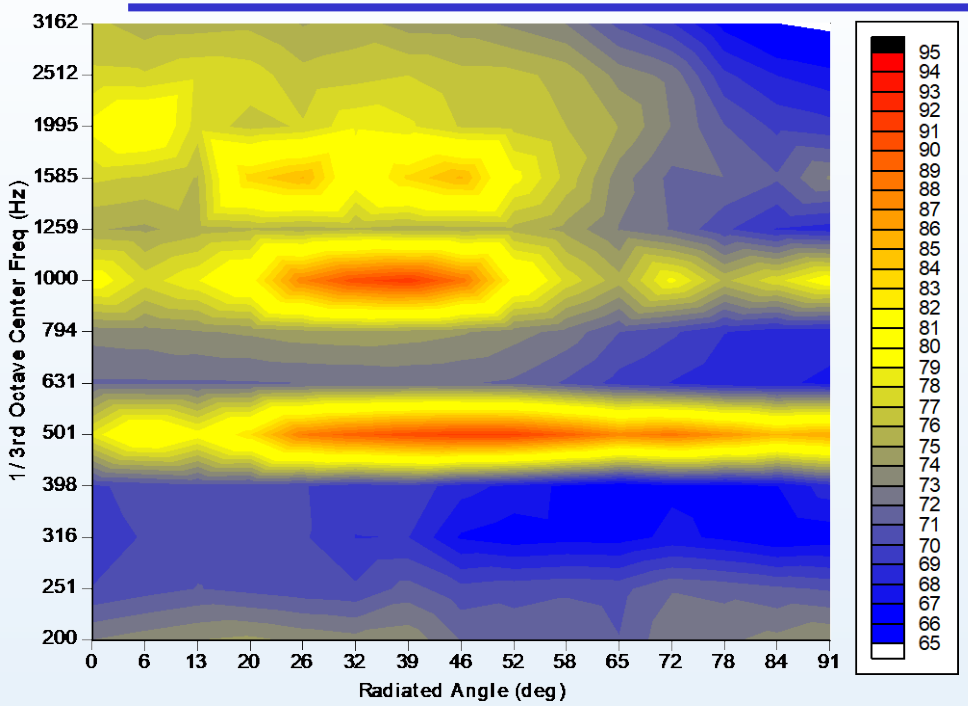
Unfiltered From MLS (White Noise) Filtered (2 BS)




Courtesy: Dr. Bruce Walker / ChIA

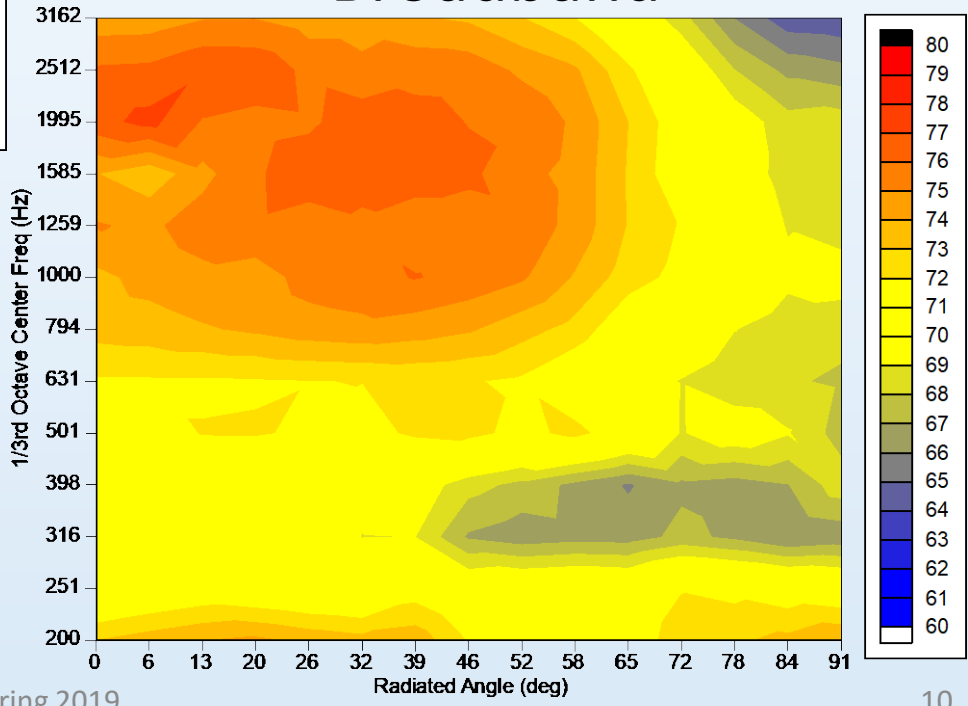
# 1/3rd OCTAVE SPECTRA




Full

INITIAL TARGET
ANCF @ 1800 RPM-c

Broadband



# DEVELOPMENT PROCESS

Source Generation Technique Proposed and Verified in Simulation.
Practical Microphone Arrangement Defined in Farfield.

Generate Artificial Sources in No-Flow Condition to Checkout.
Modify & Validate Technique.

Generate Artificial Sources with Fan Running to Provide Flow & other Signal-to-Noise Ratio “Challenges”

Sensitivity/error analysis & flow noise insensitivity techniques.

Farfield signature matching (e.g. ANCF,ADP,SDT,LPRF,DART).
Determine resolution, BW, scaling (2-3?), etc.

Finally, Use Technique in Practical Problem.

# Propulsion mid-TRL Noise Characterization and Reduction Tech Development

## Milestones

L1
L2
L3

GE/CLEEN 9x15 entry
Rotor source noise reduction

DART SDT Entry
Core noise + flowfield measurements

ADP Commissioning Test 9x15

Variable Pitch Fans 9x15 Baseline

PAI Test 14x22
LPR Fan + semi-span

DART Noise Tech
Soft Vanes

| FY18 | FY19 | FY20 | FY21 | FY22 | FY23 | FY24 |
|---|---|---|---|---|---|---|

Broadband noise simulator

LPR Fan 9x15 Test Complete
Baseline + X-Wind

DART SDT Entry 2
Mode measurements

ADP Research Entry
OGV-Rotor spacing
+ distortion noise

LPR Fan 9x15 Tech
3D Acoustic effects/modes

Broadband Noise control Pathfinder test



Courtesy: Dale VanZante / GRC

# SUMMARY

**END RESULT:** A Broadband Synthesizer that generates a desired farfield acoustic signature – will be used to quickly & efficiently evaluate & ***improve*** proposed broadband noise reduction concepts (especially high risk/payoff).

National Aeronautics and Space Administration
Aeronautics Research Mission Directorate
Advanced Air Vehicles Program
Advanced Air Transportation Technology Project
Aircraft Noise Reduction Technical Challenge

Great Lakes Sound Vibration, Inc
University of Notre Dame/Turbomachinery Lab
Channel Islands Acoustics