ASCENT Project 59B
A059B – Experimental Supersonic Jet Noise Reduction

(Original Title: Jet Noise Modeling and Measurements to Support Reduced LTO Noise of Supersonic Aircraft Technology Development)

Georgia Institute of Technology

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Experimental support: Aharon Karon, Robert Funk and Nate Ramsey (GTRI)

Cost Share Partner: Gulfstream (POC: Brian Cook)

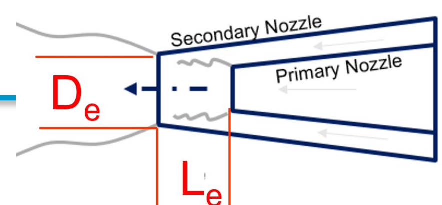
PM: Sandy Liu

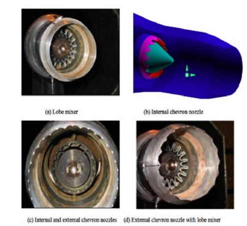
Objective:

To acquire acoustic and flow measurements to be used by Project 59 jet noise modelers for the validation of low, medium, and high-fidelity jet noise prediction methods for supersonic transport applications (SST).

Project Benefits:

The validation of these prediction codes will give confidence in the noise prediction, which will aid in the design of low noise engines for reduced landing and takeoff noise of supersonic aircraft





Research Approach:

- Design and fabricate a simple model-scale test nozzle made of a round core primary nozzle buried in a coaxial secondary flow with the mixed flow exhausting some distance downstream of the primary nozzle exit.
  - Geometry was designed as a scaled model of a paper engine design
- Acquire acoustic and related flow measurements as a function of mixing distance between the primary nozzle exit and the final exhaust nozzle exit
- Provide the measured data to modeling teams for validation of prediction codes

Major Accomplishments (to date):

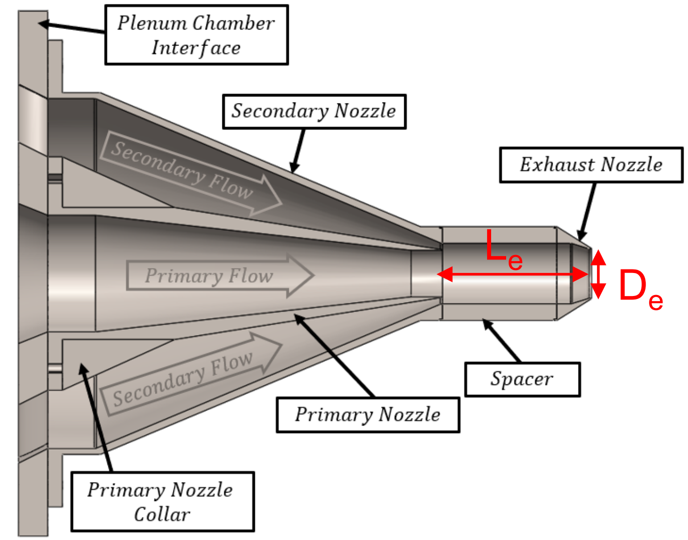
- The test nozzle designed and fabricated
- The model design shared with the modelers
- Acoustic data measured for approximately 400 out of 475 ((49+7)*2*4) setpoint-configuration pairs. Selected small extraction ratio measurements still needed

Future Work / Schedule:

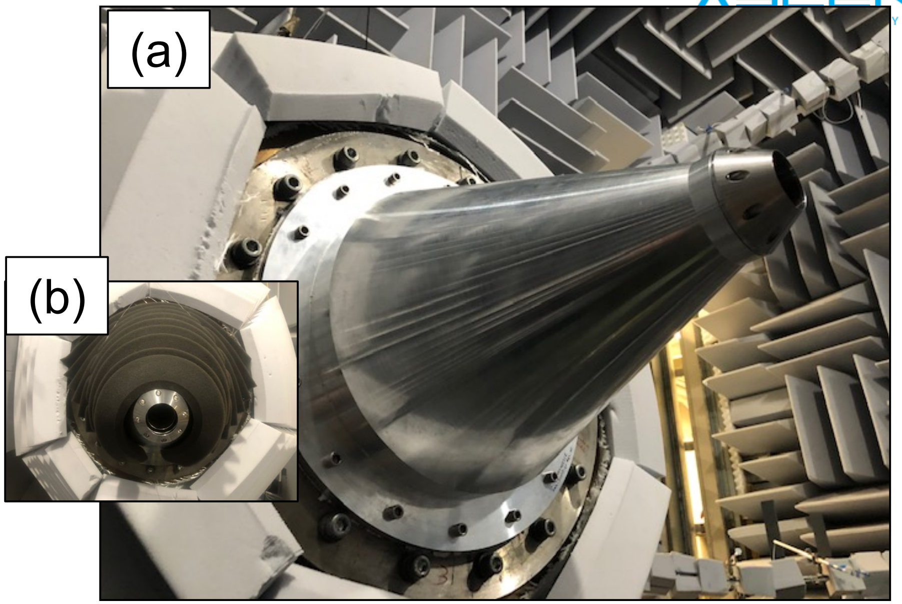
- Fix Flow facility after major structural failure
- Measure remaining acoustic and flow data
- Share all data with modelers and be available for interactions
- Select year 2 mixer design

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 59 through FAA Award Number 12972897 under the supervision Krishan Ahuja (PI), Dimitri Mavris (Co-PI), and Jimmy Tai (Co-PI). Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

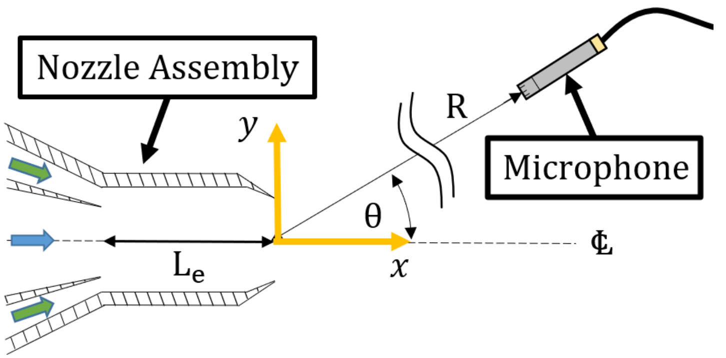
ASCENT #59B Test Hardware and Setups



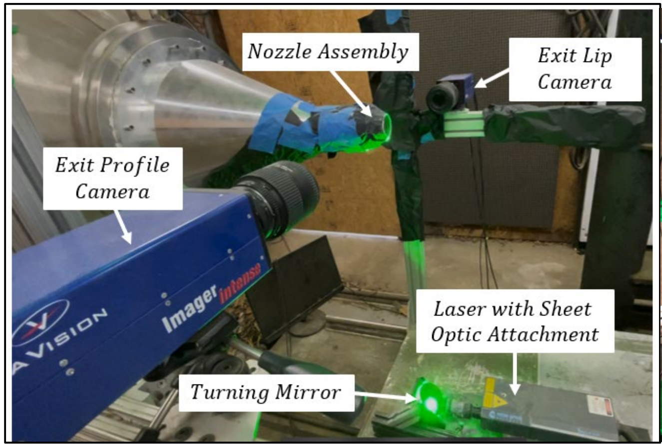
Cross-section view of nozzle assembly. Mixing length (L_e) varied using different spacers.

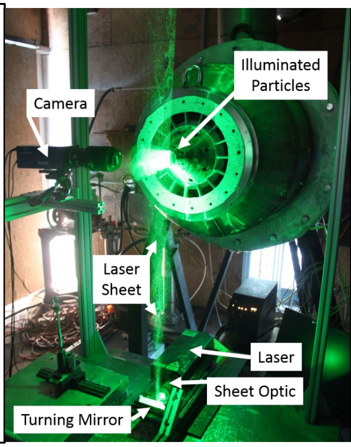


(a) Model in GTRI Anechoic Jet-Facility (L_e/D_e = 0.7) (b) with acoustic treatment



Coordinate conventions used throughout

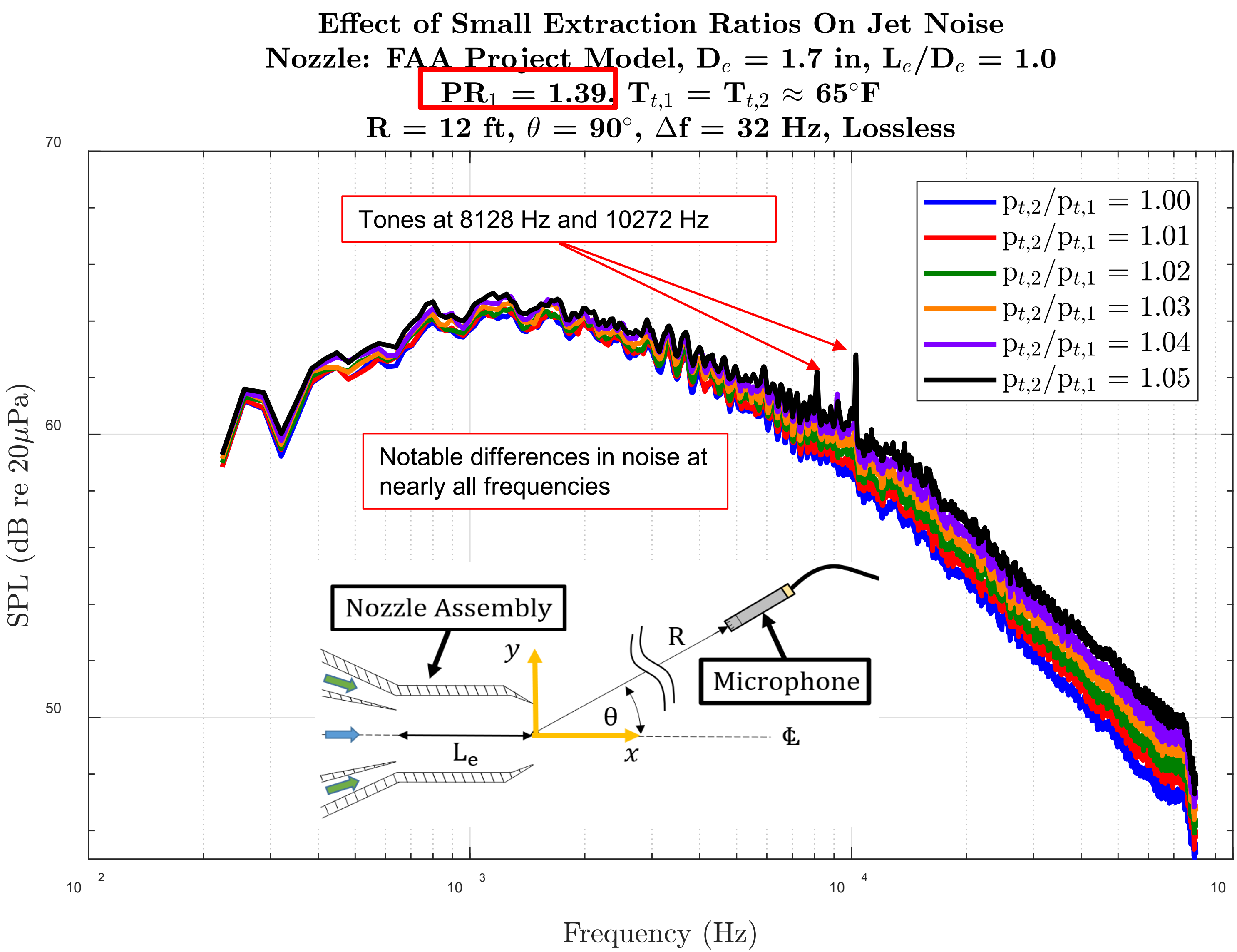




Model in GTRI Flow Diagnostic Facility Set Up for PIV (L_e/D_e = 3.0)

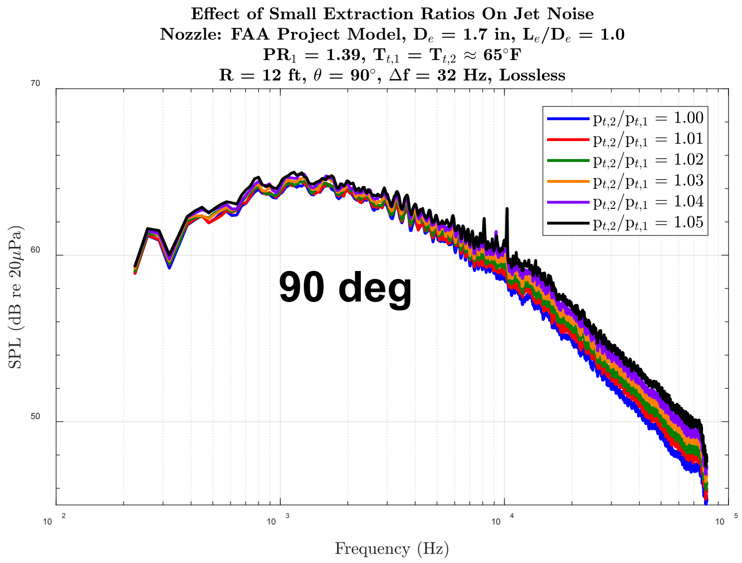
The model of a 0.045 scale of the paper engine

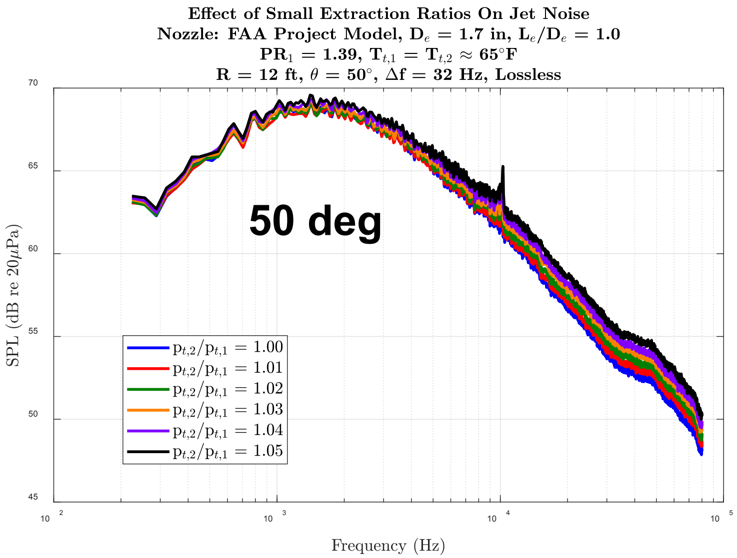
Effect of Extraction Ratio, Pr_2/Pr_1
(θ = 90° Unheated Core)

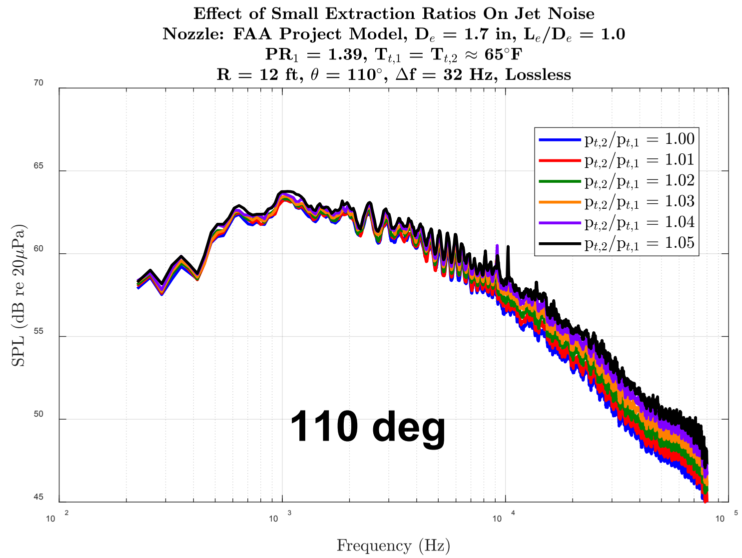


Effect of Extraction Ratios on Farfield Jet Noise Spectra at various Polar Angles

- These tones persist in the unheated case from 50 to 110 degrees.



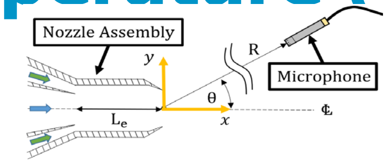


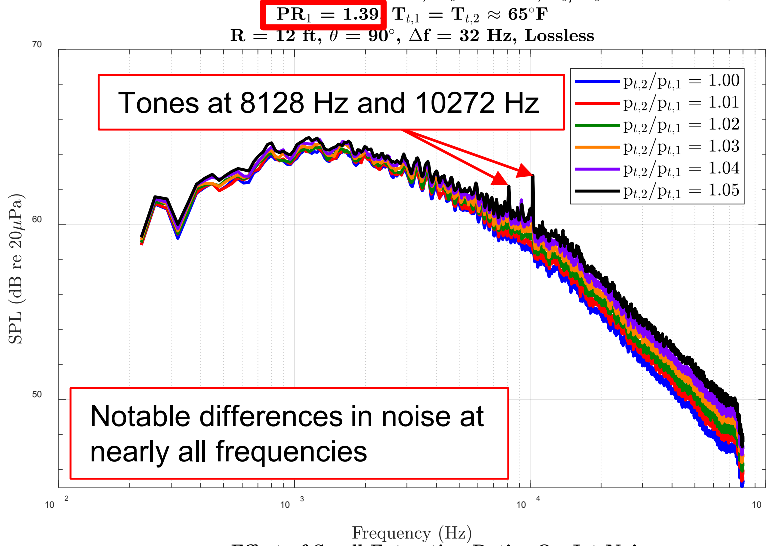


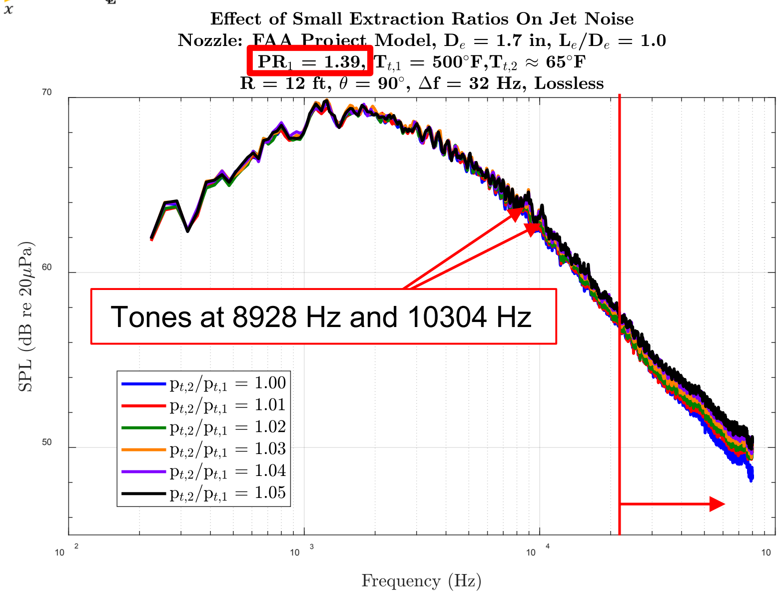
Effect of Extraction Ratio and Core flow Temperature (θ = 90°)

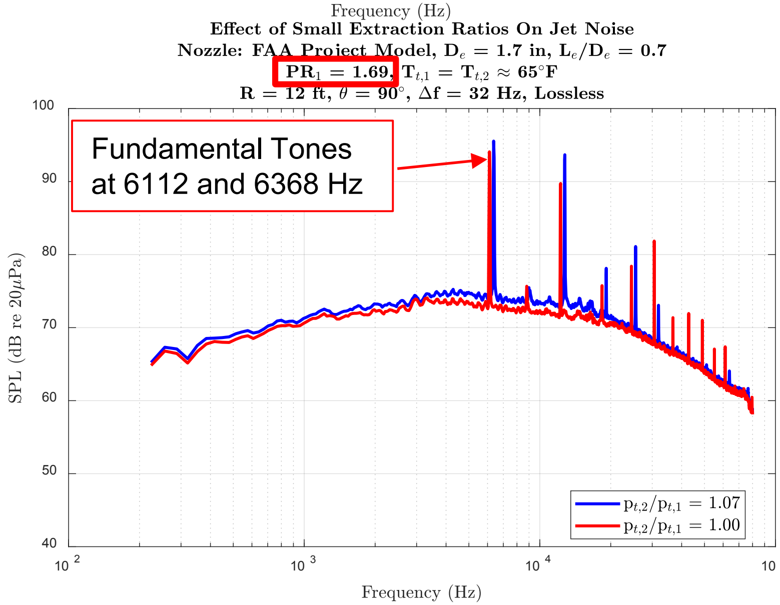
Unheated Core

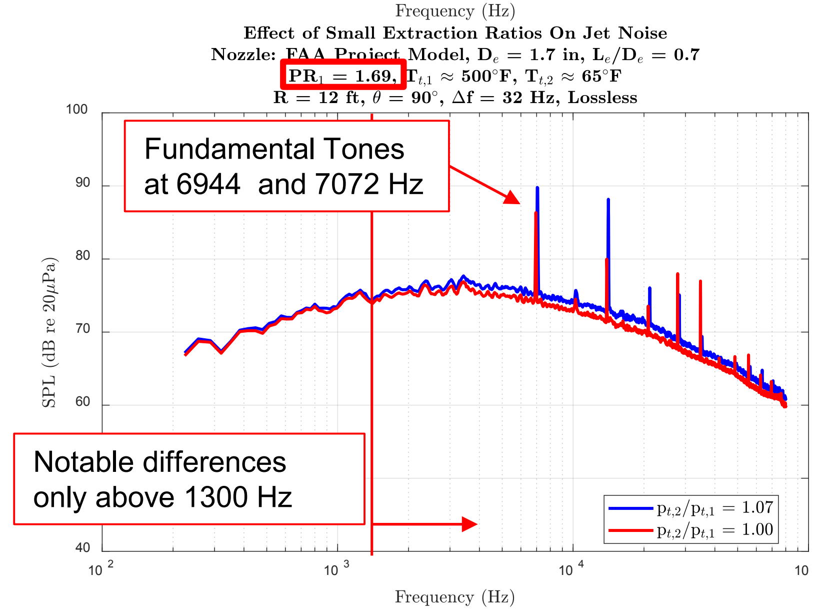
Heated Core





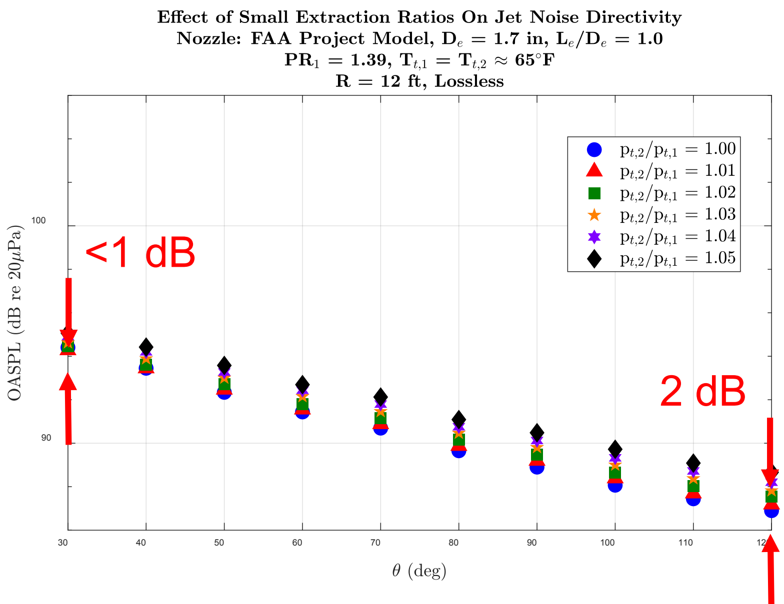




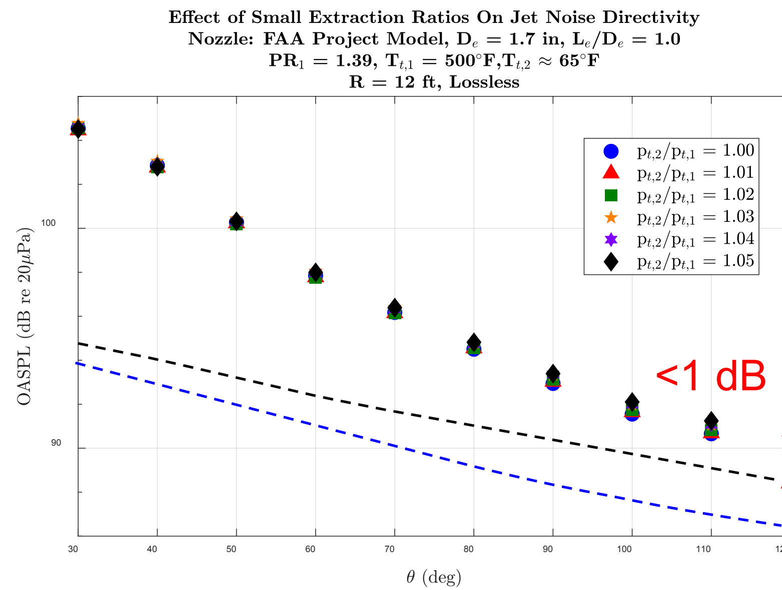


Farfield Directivity as a Function of Extraction Ratio

Unheated Core



Heated Core

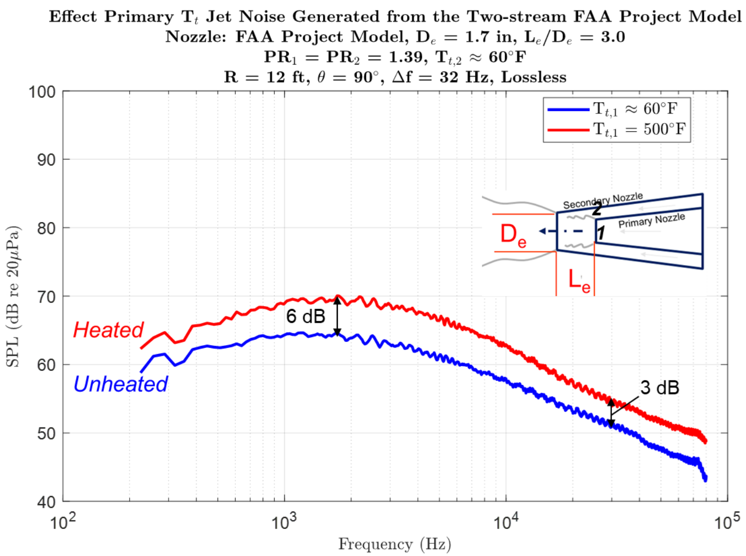


- Unheated Core:
  - OASPL increases at all angles: less than 1 dB difference in the rear arc and up to 2 dB increase in forward arc (from ER = 1 to 1.05)
- Heated Core:
  - Below θ = 70°, the OASPL is identical for all ER, above the OASPL differences are less than 1 dB

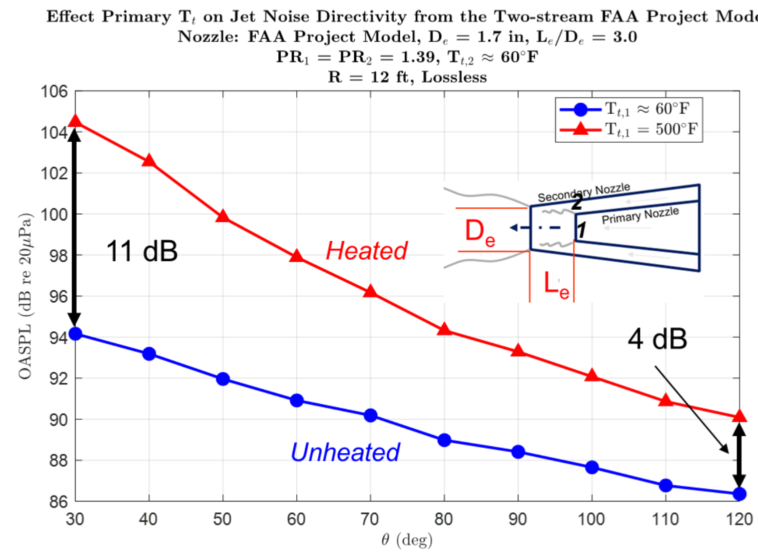
Directivities for 10 out of over 400 measured setpoints

Effect of Core Flow Temperature

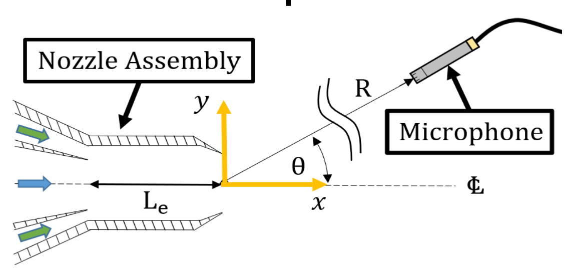
Spectral Comparison @ θ = 90°



Directivity

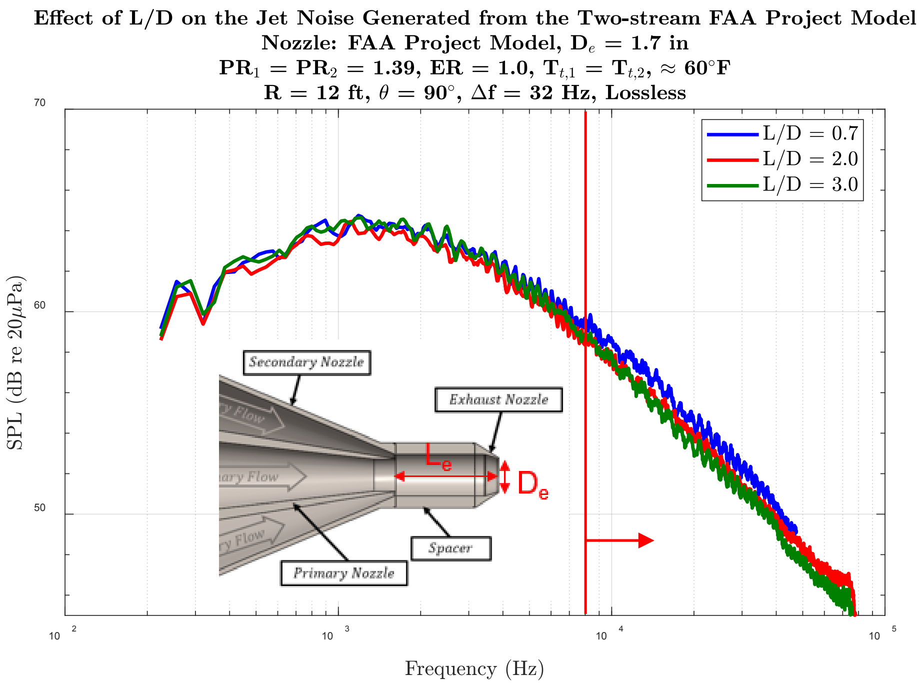


- Rear angles show much larger increases than forward angles
- Results in steeper directivity

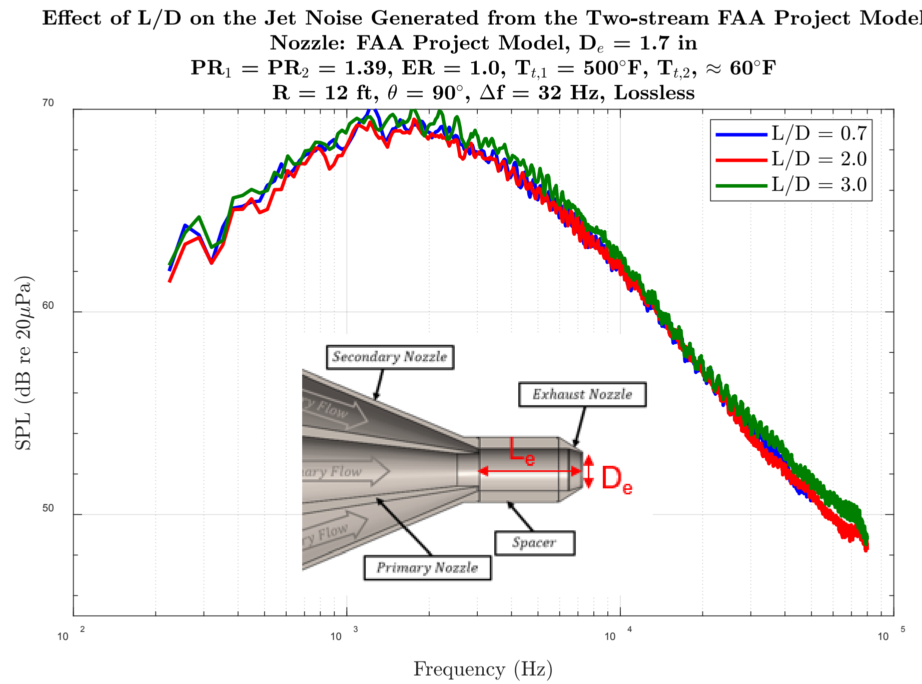


Effect of Mixing Length L_e/D_e on Farfield Jet Noise Spectra at $\theta = 90^o$

Unheated Core

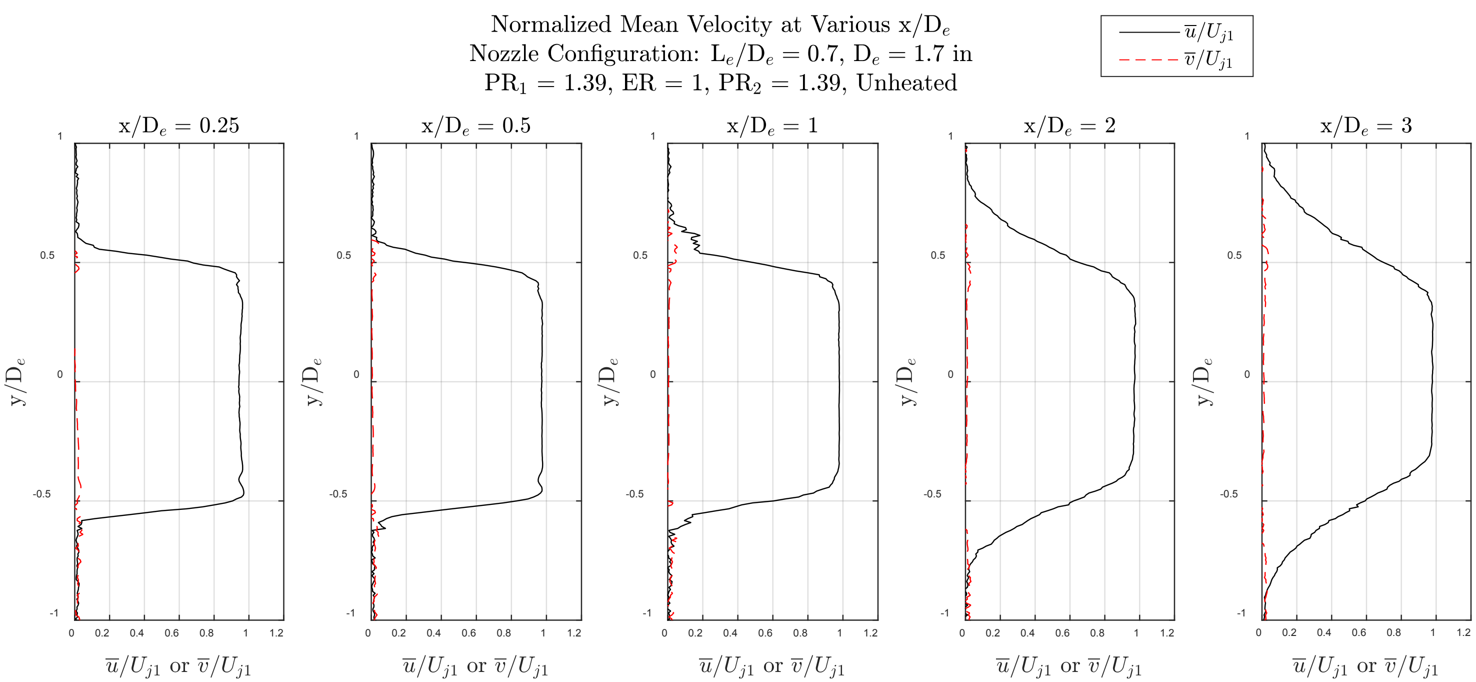


Heated Core



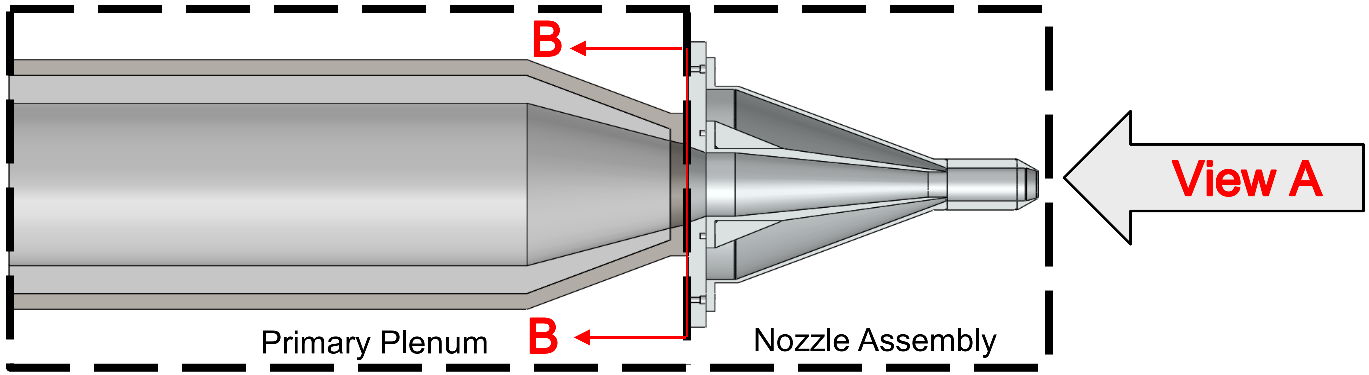
- Unheated Case: Above 8 kHz (vertical red line), there is 1-2 dB reduction when the L_e/D_e is increased from 0.7 and 2.0
- Heated Case: No appreciable high-frequency difference between all L_e/D_e

Typical PIV Data:
Mean velocity distribution

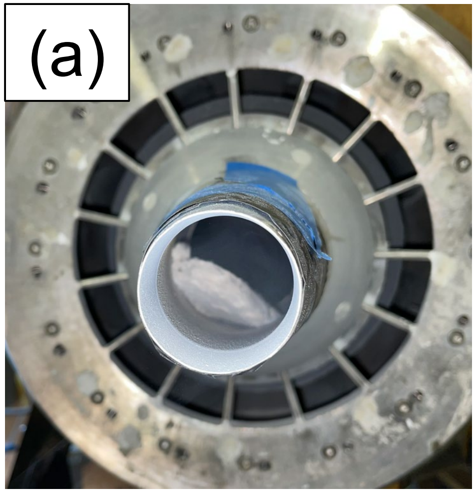


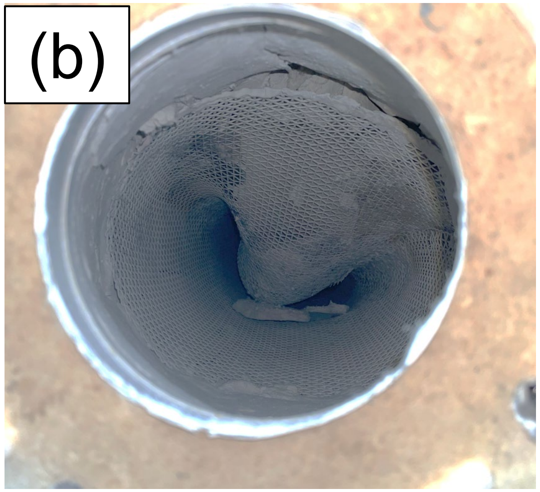
Mean velocity profiles acquired at GTRI using PIV

Major Structural Failure of the Flow Facility



Cross-section of primary plenum and nozzle assembly in Flow Diagnostic Facility (secondary plenum not shown)





(a) View A. Liberated chunk of insulation in primary nozzle (outer nozzle removed) (b) view at Section B-B. Insulation collapse inside plenum viewed downstream (nozzle assembly removed)

Concluding Comments

Major Accomplishments (to date):

- The test nozzle designed and fabricated
- The model design shared with the modelers
- Acoustic data measured for approximately 400 out of 475 ((49+7)*2*4) set point-configuration pairs. Selected **small** extraction-ratio measurements still needed
- PIV methodology has been thoroughly investigated and will require long duration measurements to get smooth curves.

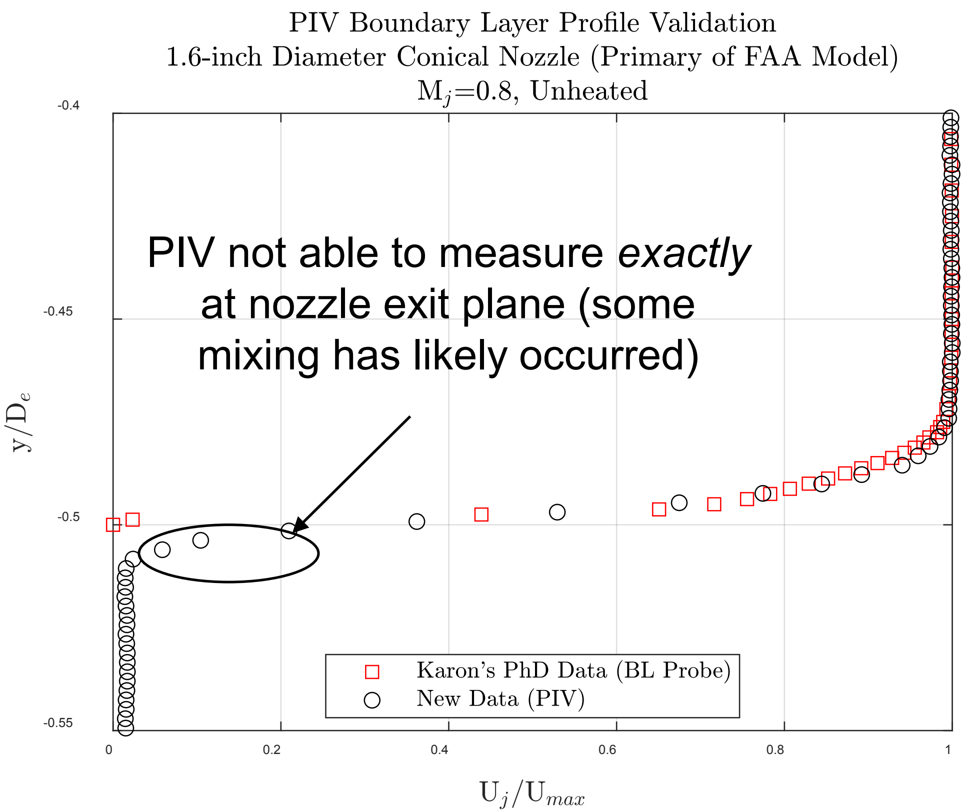
Planned Work

- Repair Flow facility
- Maintain unheated capability in the interim
- Acquire remaining acoustic and flow data
- Share all data with modelers and be available for interactions
- Select year-2 mixer design

BACK UP SLIDES

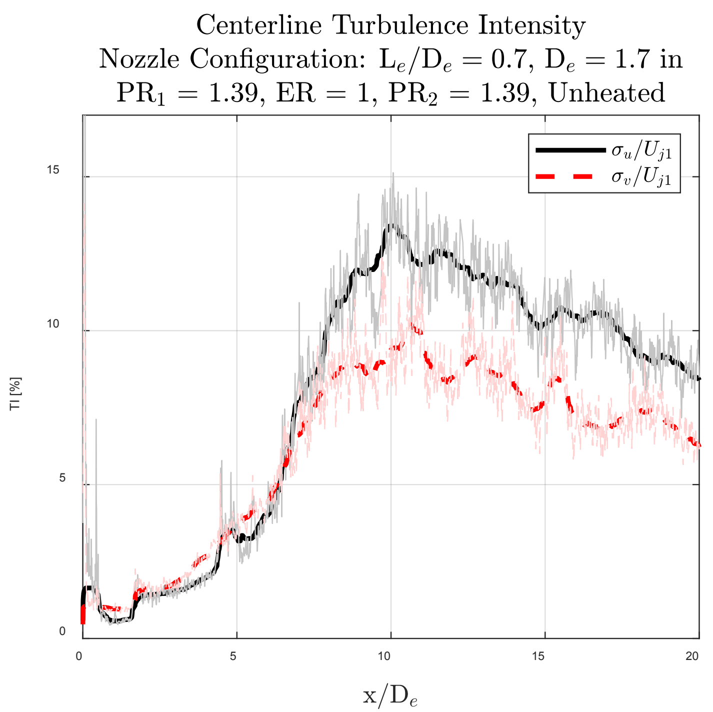
Typical PIV Data:
Boundary Layer Profile Validation

- Primary flow only (no mixing duct or exhaust nozzle)
- PIV profile taken slightly downstream of nozzle exit plane

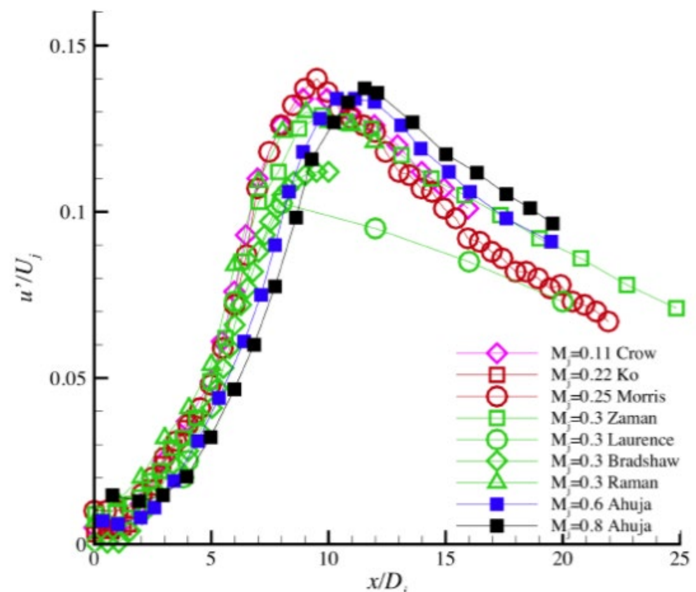


Typical PIV Data:
Centerline turbulence

- Turbulence statistics follow trend observed in literature in this case; in shear layer, measured turbulence is too high.
- Possible issues (laser head misalignment and too small of a sample size) will be addressed



Turbulence intensity acquired at GTRI

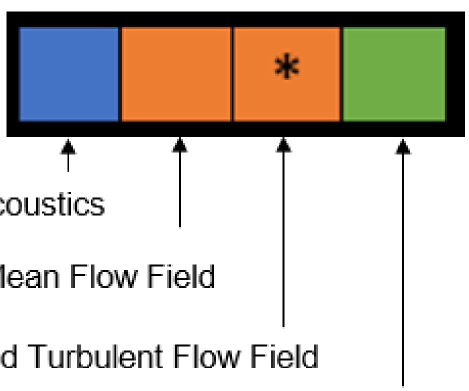


Summary of reference turbulence intensity data compiled by Bridges and Wernet*

*James Bridges and Mark P. Wernet, The NASA Subsonic Jet Particle Image Velocimetry (PIV) Dataset (2011)

Test Matrix

- Farfield acoustics are measured for heated and unheated setpoints
- PIV and Source Localization/Schlieren will be restricted to unheated setpoints
- Four internal mixing lengths (L_e/D_e = 0.7, 1.0, 2.0, 3.0)



Farfield acoustics

PIV Mean Flow Field

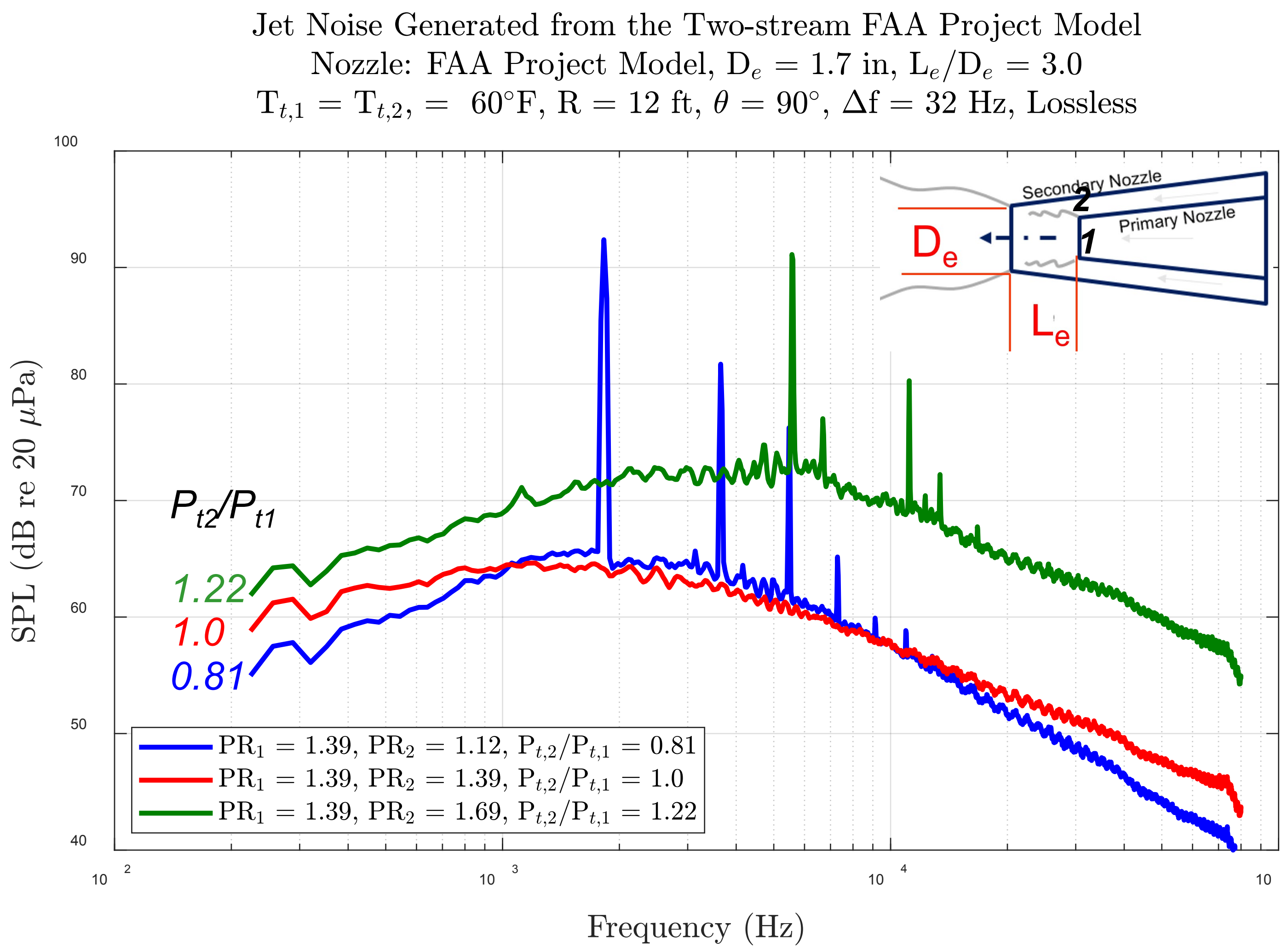
PIV Mean and Turbulent Flow Field

Source Localization/Schlieren

		Primary Pressure Ratio, PR1						
		1.12 (M_{j1}=0.4)	1.19 (M_{j1}=0.5)	1.28 (M_{j1}=0.6)	1.39 (M_{j1}=0.7)	1.52 (M_{j1}=0.8)	1.69 (M_{j1}=0.9)	1.89 (M_{j1}=1.0)
Secondary Pressure Ratio, PR2	1.12 (Mj2=0.4)	✓ ER = 1.00	✓ ER = 0.94	✓ ER = 0.88	✓ ER = 0.80	✓ ER = 0.73	✓ ER = 0.66	✓ ER = 0.59
	1.19 (M_{j2}=0.5)	✓ ER = 1.06	✓ ER = 1.00	✓ ER = 0.93	✓ ER = 0.86	✓ ER = 0.78	✓ ER = 0.70	✓ ER = 0.63
	1.28 (M_{j2}=0.6)	✓ ER = 1.14	✓ ER = 1.08	✓ ER = 1.00	✓ ER = 0.92	✓ ER = 0.84	✓ ER = 0.75	✓ ER = 0.67
	1.39 (M_{j2}=0.7)	✓ ER = 1.24	✓ ER = 1.17	✓ ER = 1.09	✓ * ER = 1.00	✓ ER = 0.91	✓ ER = 0.82	✓ ER = 0.73
	1.52 (M_{j2}=0.8)	✓ ER = 1.37	✓ ER = 1.29	✓ ER = 1.20	✓ ER = 1.10	✓ ER = 1.00	✓ ER = 0.90	✓ ER = 0.81
	1.69 (M_{j2}=0.9)	✓ ER = 1.51	✓ ER = 1.43	✓ ER = 1.33	✓ ER = 1.22	✓ ER = 1.11	✓ ER = 1.00	✓ ER = 0.89
	1.89 (M_{j2}=1.0)	✓ ER = 1.70	✓ ER = 1.60	✓ ER = 1.48	✓ ER = 1.36	✓ ER = 1.24	✓ ER = 1.12	✓ * ER = 1.00
Extraction Ratio, ER	1.01				✓ PR2 = 1.40			
	1.02				✓ PR2 = 1.41			
	1.03				✓ PR2 = 1.43			
	1.04				✓ PR2 = 1.44			
	1.05				✓ PR2 = 1.46			
	1.06				✓ PR2 = 1.47			
	1.07				✓ * PR2 = 1.48			

White checks: Measurement complete. For small ER (bottom half of chart), acoustics measured only for L/D = 1.0 configuration, other mixing lengths remain to be done. Repeats being conducted for L/D = 0.7 due to unusual microphone response.

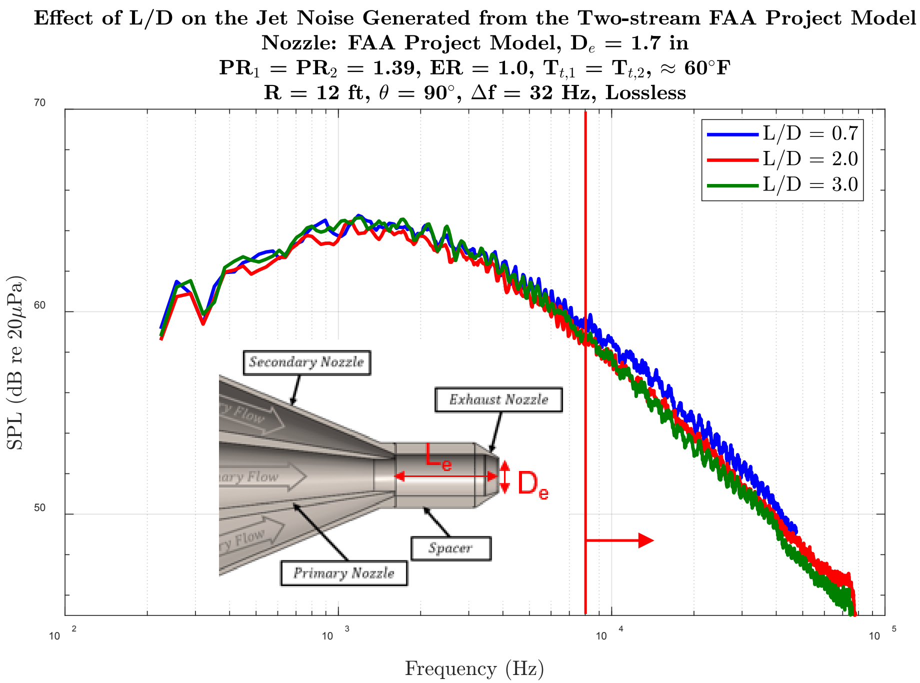
Examples of Unexpected Tones at Non-unity Extraction Ratios



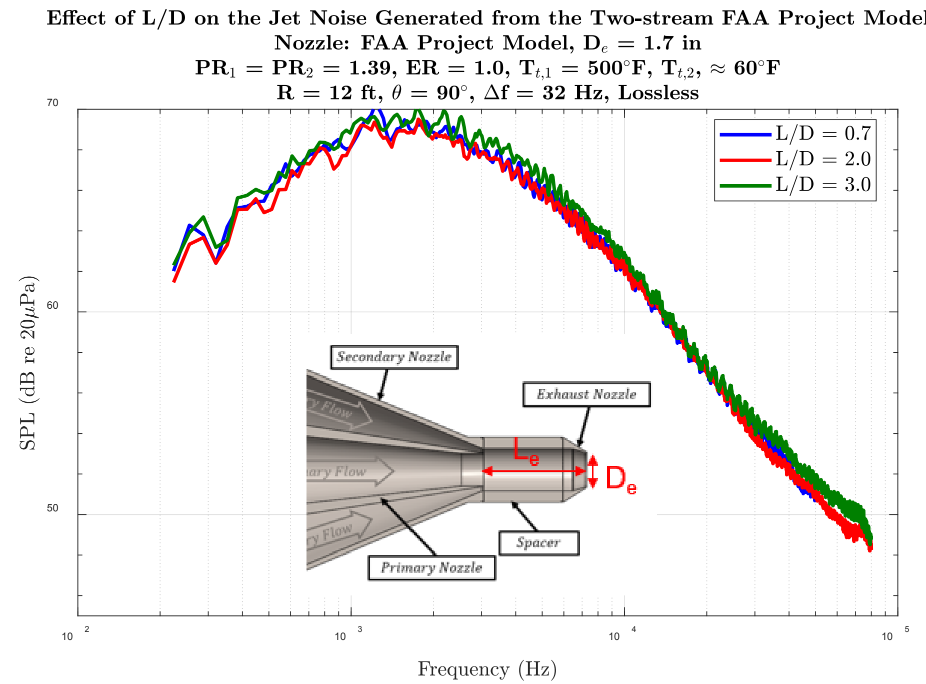
Spectra for 3 out of over 400 measured setpoints

Effect of Mixing Length L_e/D_e on Farfield Jet Noise Spectra at $\theta = 90^{\circ}$

Unheated Core



Heated Core

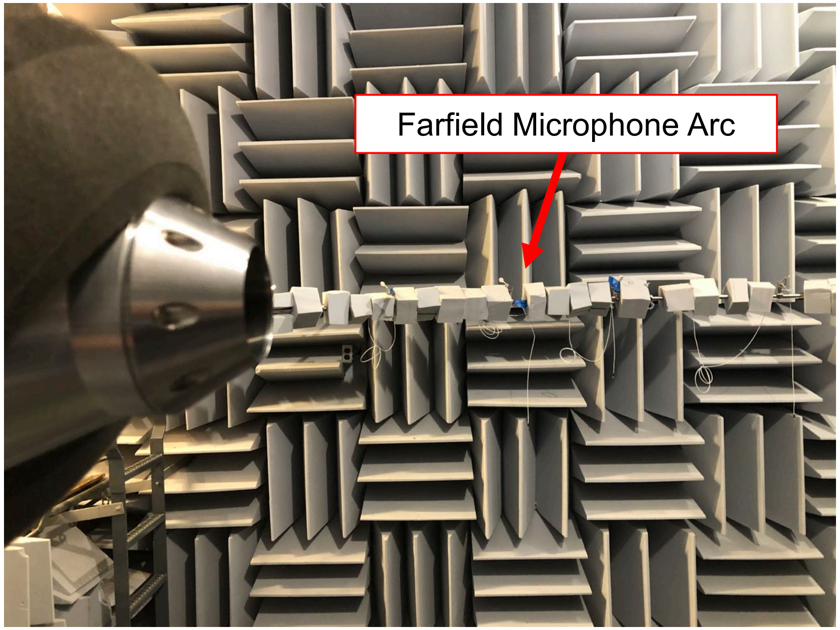


- Unheated Case: Above 8 kHz (vertical red line), there is 1-2 dB reduction when the L_e/D_e is increased from 0.7 and 2.0
- Heated Case: No appreciable high-frequency difference between all L_e/D_e

Spectra for 6 out of over 400 measured setpoints

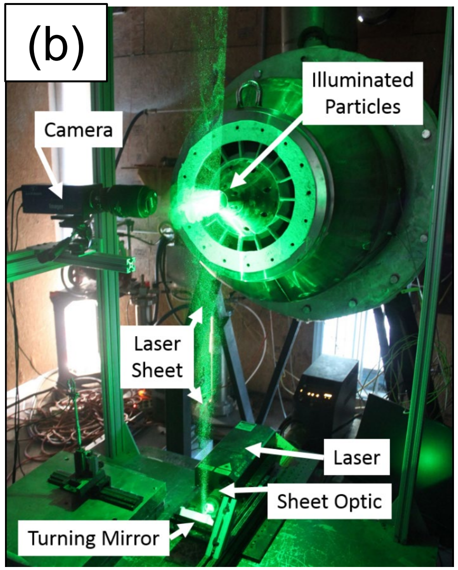
GTRI Anechoic Chamber and the Flow Diagnostic Facility

Anechoic Jet Facility



- Farfield acoustic spectra at 10-degree increments (30 degrees through 120 degrees)

Flow Diagnostic Facility



- Flow field characterization using PIV
- Jet source localization
- High-speed Schlieren photography

GTRI's dual-stream jet facilities used for ASCENT #59B with relevant capabilities listed