ASCENT Project 59D

Multi-fidelity modeling for supersonic aircraft exhaust noise

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Cost Share Partner: TBA

Objectives:

In collaboration with ASCENT partners in Project 59, develop multi-fidelity physics-based analyses for supersonic aircraft exhaust noise.

The main goals are to develop improved jet noise prediction methods and better understand the uncertainty associated with the noise predictions for a range of engine cycle parameters and operating conditions relevant for civil supersonic aircraft.

Project Benefits:

Aircraft and engine companies, and organizations such as NASA, FAA, and DoD R&T community would also benefit from the improved methods and tools. Ultimately, supersonic jet noise tools with predictive capabilities can be used to design better noise mitigation systems and to provide estimates of noise for certification studies.

Research Approach:

- In consultation with Project 59 and other project partners in ASCENT define the plans for high-fidelity simulations and jet noise modeling
- Develop and validate high-fidelity jet noise predictions for baseline configurations
- Develop and validate RANS-based jet noise predictions for baseline configurations
- Develop and validate high-fidelity jet noise predictions for configurations with noise mitigation concepts
- Develop and validate RANS jet noise predictions for configurations with noise mitigation concepts

Major Accomplishments (to date):

- Preliminary LES of primary nozzle and primary+secondary buried nozzle (GaTech geometry)
- Development and validation of far-field noise propagation model (Adjoint-Green's function)

Future Work / Schedule:

- Noise prediction for selected cases from GaTech baseline experiments using LES (Year 2)
- Development and validation of RANS based approach
- Noise source model improvements (Year 3)
- Noise predictions for noise mitigation concepts (Year 3)

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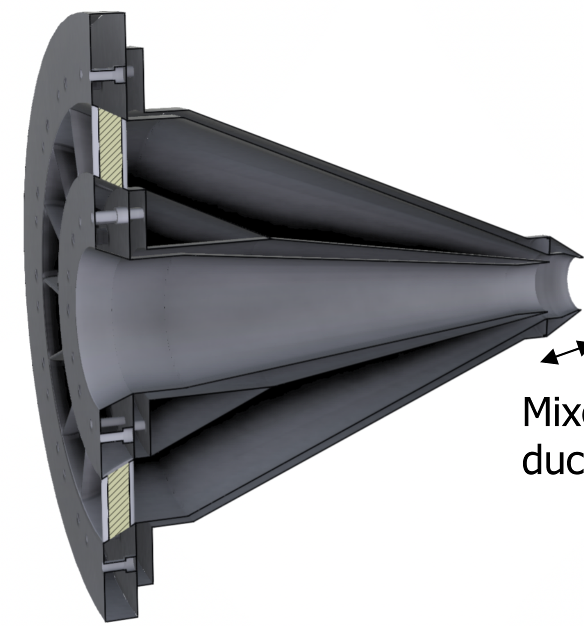
Introduction

- Objectives
  - Conduct multi-fidelity simulation data (RANS and LES) of hig speed jets from co-annular nozzle with various mixing configurations
  - Develop predictive reduced-order acoustic models using numerical datasets and experimental validation
- Nozzle Geometry
  - In alignment with Y1 experimental studies with primary & co-annular nozzle with a mixer duct of various lengths
- Computational Resources:
  - Supercomputing allocation provided by the XSEDE program unde project TG-CTS190021
  - LES are conducted using CharLES, developed by Cascade Tech
  - RANS are conducted using SU2, an open-source software tool



o: planned LES cases
x: preliminary simulations

Types of data available:
Far field acoustics
PIV mean and turbulent fields
Schlieren

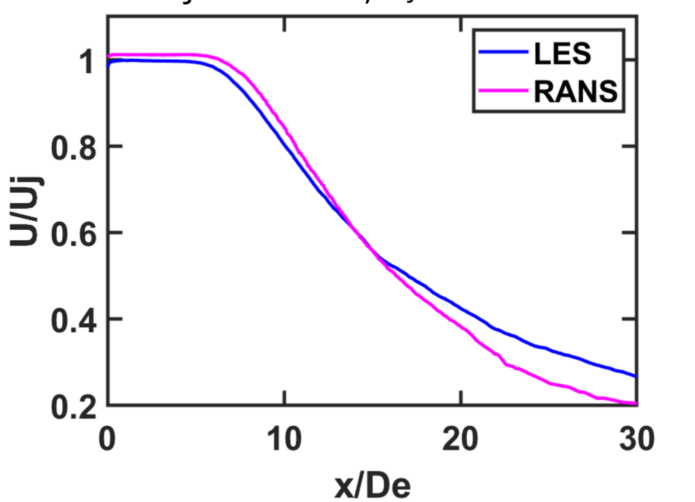
Georgia Tech Experimental Test matrix (partial)		Primary Pressure Ratio NPR1 (Mj1)						
		1.12 (0.4)	1.19 (0.5)	1.27 (0.6)	1.38 (0.7)	1.53 (0.8)	1.69 (0.9)	1.89 (1.0)
Secondary Pressure Ratio NPR2 (Mj2)	1.12 (0.4)							
	1.19 (0.5)							
	1.27 (0.6)							
	1.38 (0.7)				o			
	1.53 (0.8)					x		
	1.69 (0.9)						o	
	1.89 (1.0)							o

LES Cases

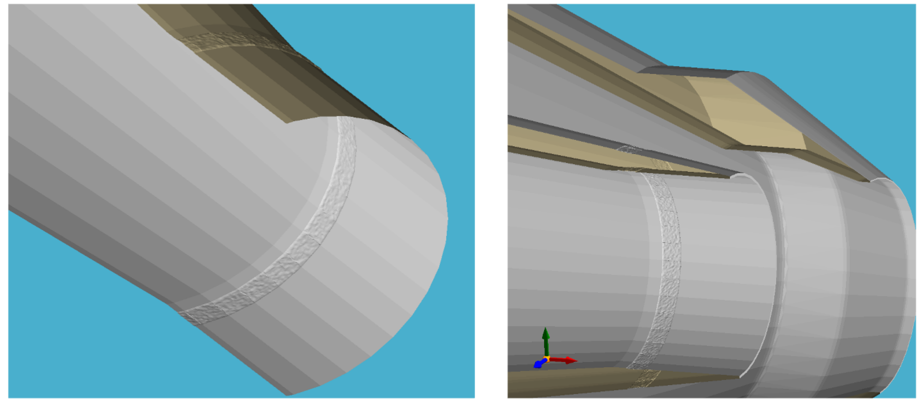
Geometry	M_{j1}	M_{j2}
Primary	**0.5**	**N/A**
Primary	**0.9**	**N/A**
Coannular + Mixer Duct (L/De = 0.7)	**0.8**	**0.8**
Coannular + Mixer Duct (L/De = 0.7)	0.7	0.7
Coannular + Mixer Duct (L/De = 0.7)	0.9	0.9
Coannular + Mixer Duct (L/De = 3.0)	0.9	0.9

Cases marked in bold have been simulated.

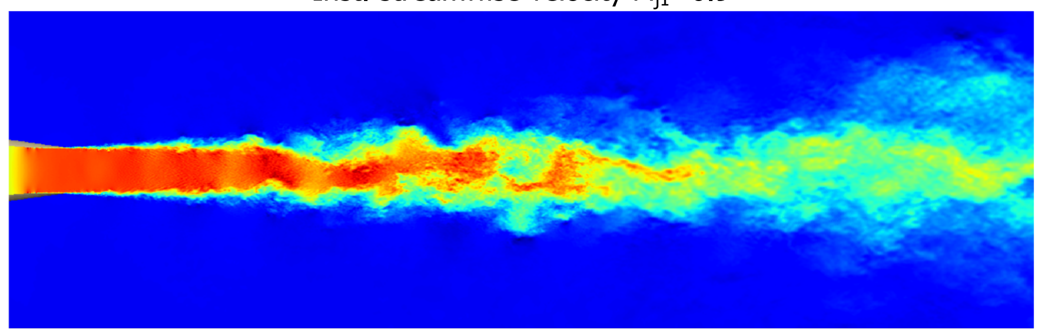
Mean velocity along the jet centerline, M_{j1} = 0.9



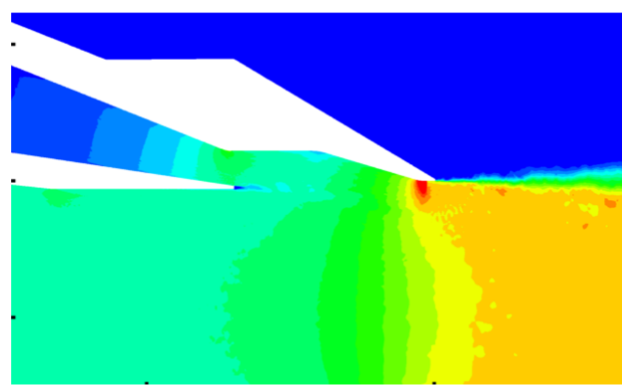
Geometric roughening for boundary layer tripping



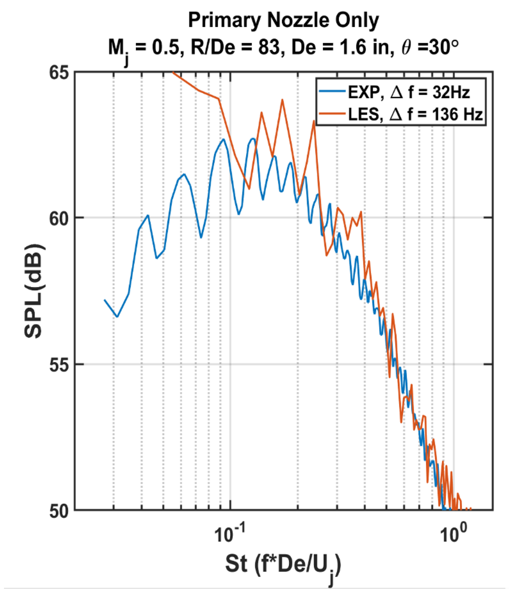
Inst. streamwise velocity M_{j1}=0.9

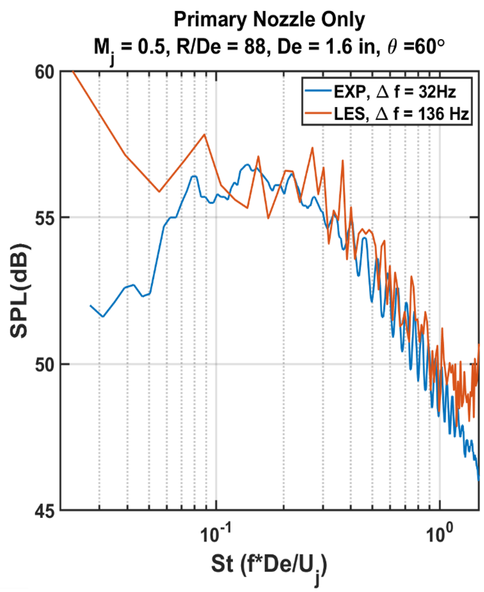


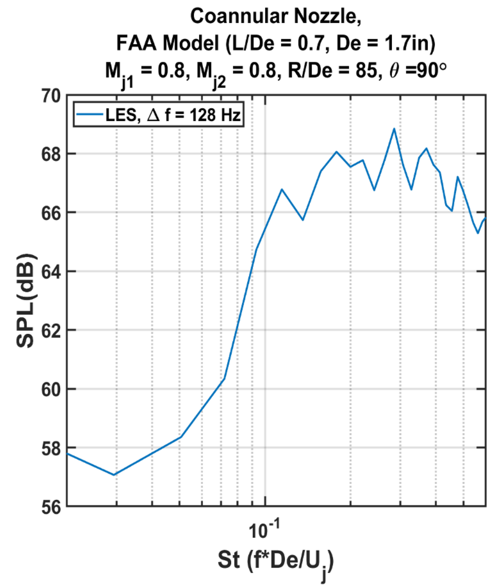
Coannular + Mixer Duct at M_{j1}=M_{j2}=0.8
Inst. Mach number near nozzle exit

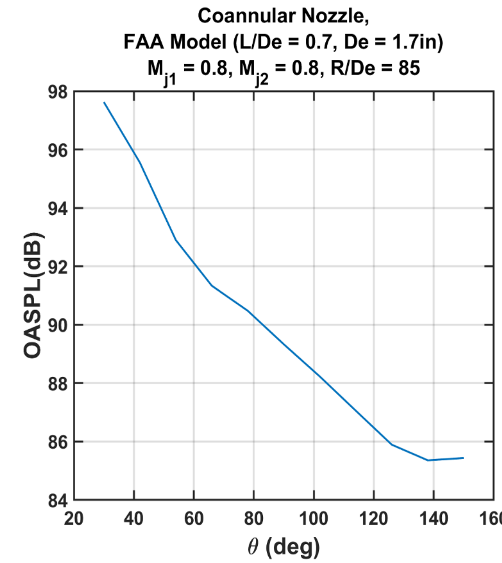


LES





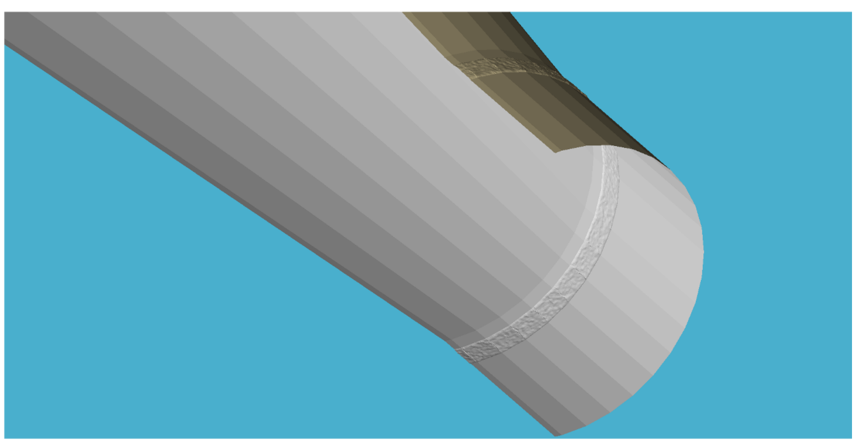


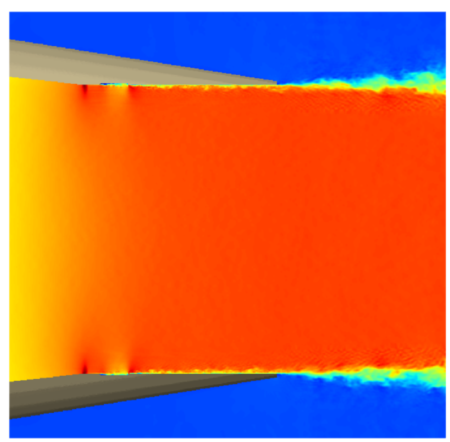


LES results are calculated using a record of T=0.090s
EXP data are from Dr. Aharon Zamir Karon's PhD thesis

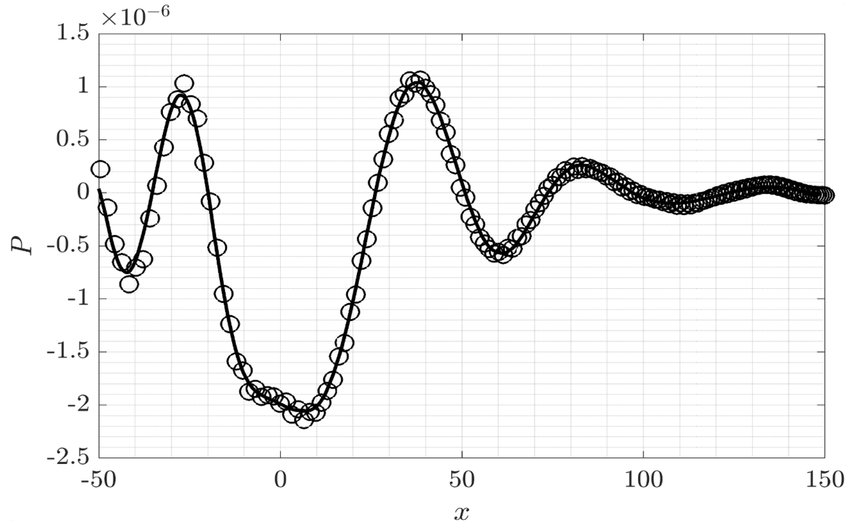
LES are calculated using a record of T = 0.085s

Turbulence tripping with geometric roughening

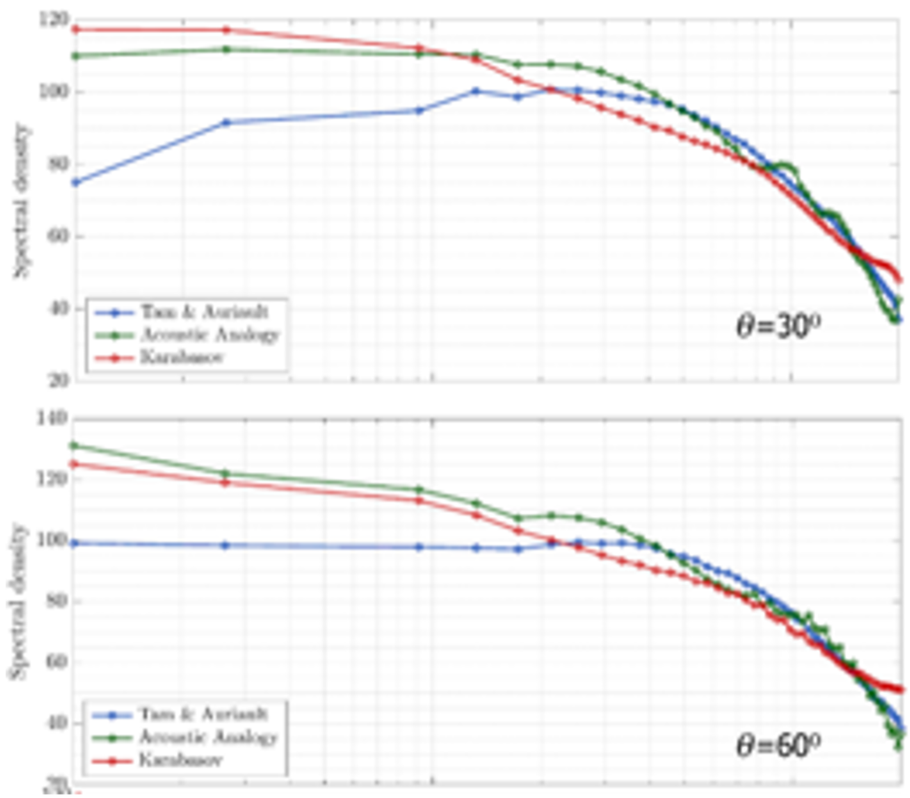


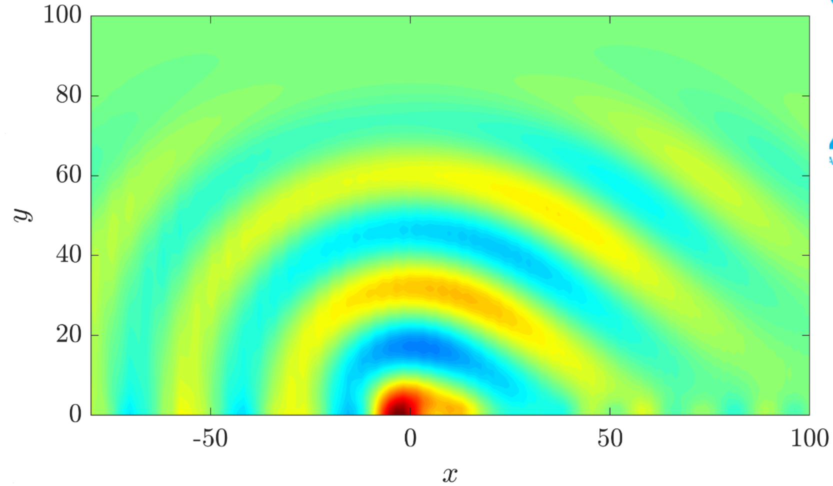


Jet noise analysis



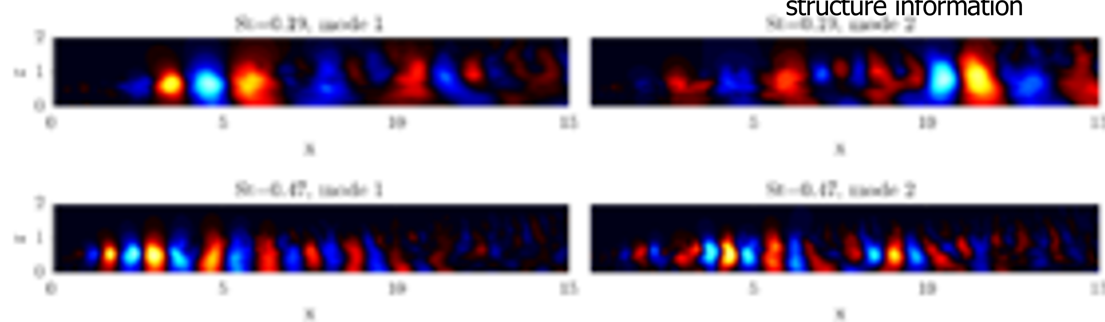
Adjoint Green's function solver - 3 source term models tested

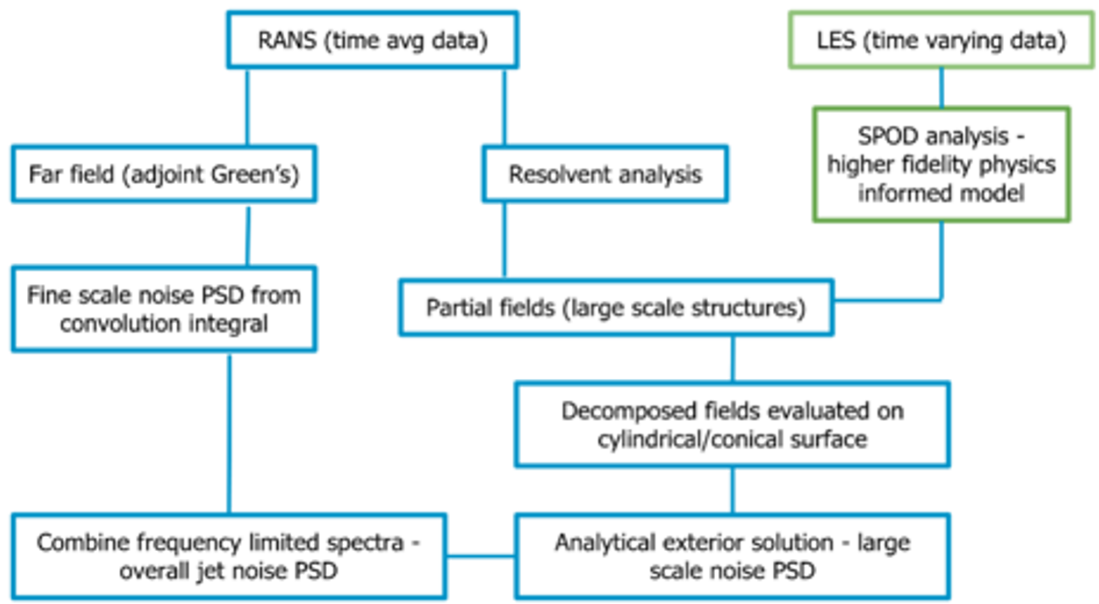




Solver validation - Agarwal & Morris KH benchmark

Spectral Proper Orthogonal Decomposition (SPOD) analysis - large scale structure information





Conclusions and Future Work

- RANS and LES simulations of jets with primary & co-annular nozzle geometry for jet noise predictions including noise mitigation concepts (buried nozzle with mixer)
  - Validation of LES with experiments (low and high Mj, heating, co-annular)
  - RANS acoustic source model improvements
  - Parametric exploration of design space
- Further improvements in LES (turbulence tripping, nozzles with mixer)
  - far-field noise and thrust prediction
- Further development of low-fidelity models:
  - Augment resolvent analysis with SPOD information to construct partial fields
  - Obtain far field PSD for low frequencies via Kirchoff BVP or alternative methods
- Evaluation of jet noise mitigation concepts for supersonic civilian aircraft
- Results will be presented in AIAA SciTech 2022 conference