Moderate Fidelity Simulations for Efficient Modeling of Supersonic Aircraft Noise (59E)

Penn State University

PI: Philip J. Morris

Co-PI: Daning Huang

GRA: Dana Mikkelsen

PM: Sandy Liu

Cost Share Partner: Penn State University (22), Gulfstream (23)

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AVIATION SUSTAINABILITY CENTER

Project 59E

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Objective:

To develop and assess computational tools to simulate the flow and noise of Civil Supersonic Aircraft engines.

Develop tools requiring moderate computational resources and computation time

Project Benefits:

The developed tools will enable airframe and engine manufacturers to assess the noise impacts of engine design changes and to determine if particular designs will meet current or anticipated noise certification requirements

Research Approach:

Perform steady and unsteady numerical simulations of the internal and external flow from dual-stream, subsonic and supersonic jet nozzles using a commercial CFD application (STARCCM+)

Predict the radiated noise using an acoustic analogy and compare with experimental measurements

Supplement numerical simulations with low-order acoustic analogy, RANS-based noise predictions

Major Accomplishments (to date):

Generated grid for RANS and LES simulations of inner nozzle geometry provided by Georgia Tech

Performed RANS simulations using STARCCM+ with boundary conditions for Georgia Tech experiments & additional validation cases

Performed LES simulations for dual-stream GT nozzle

Future Work / Schedule:

Use Ffowcs Williams & Hawkings acoustic analogy to predict radiated noise

Perform coupled RANS/LES simulations for internal mixer nozzles

Use acoustic analogy models for high frequency noise predictions

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 59E through FAA Award 13-C-AJFE-PSU-058 under the supervision of Sandy Liu. 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.

Dual-stream RANS

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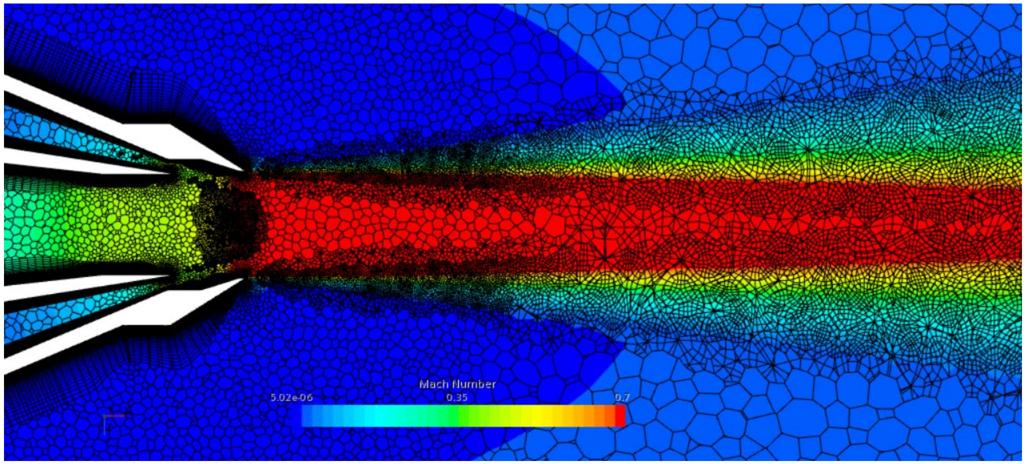
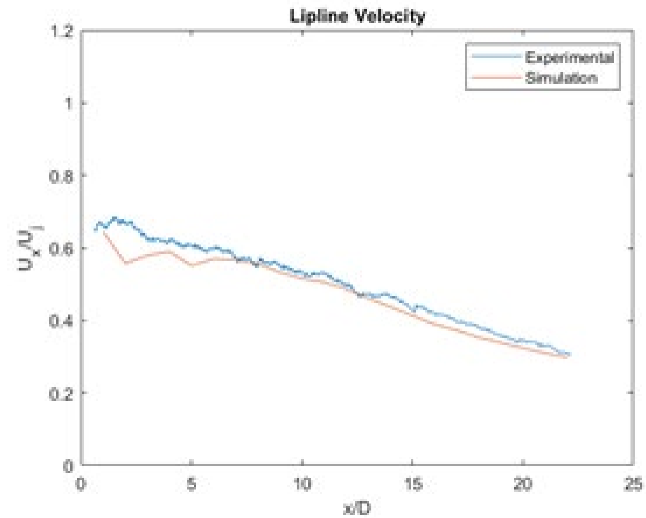
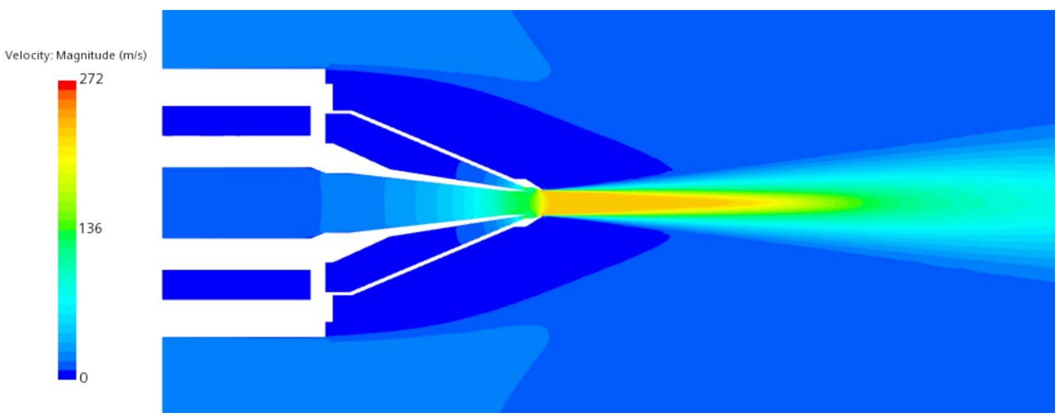
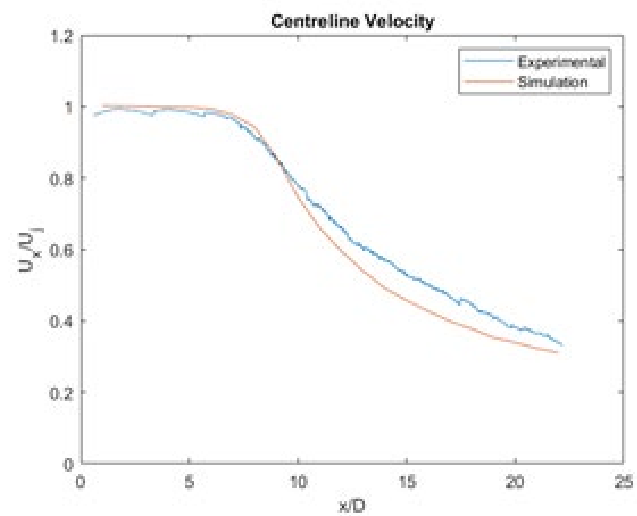
Grid for dual-stream GT nozzle





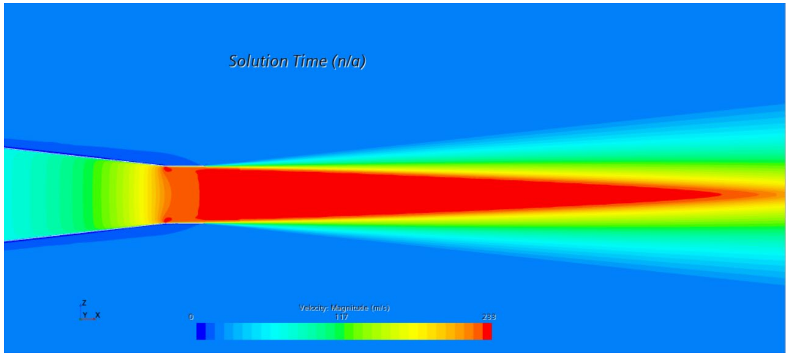
Velocity magnitude contours



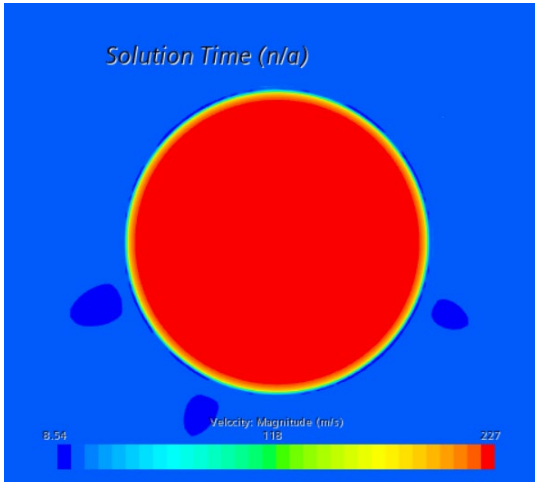


RANS exit contours

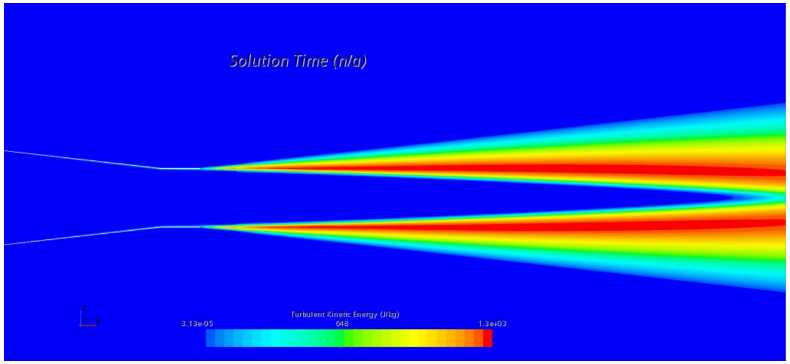
Velocity magnitude



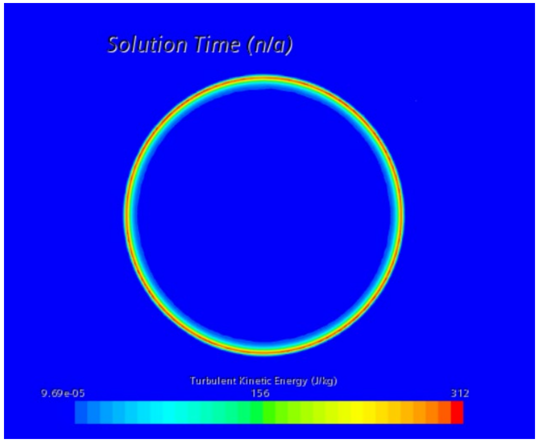
Velocity magnitude



Turbulent kinetic energy



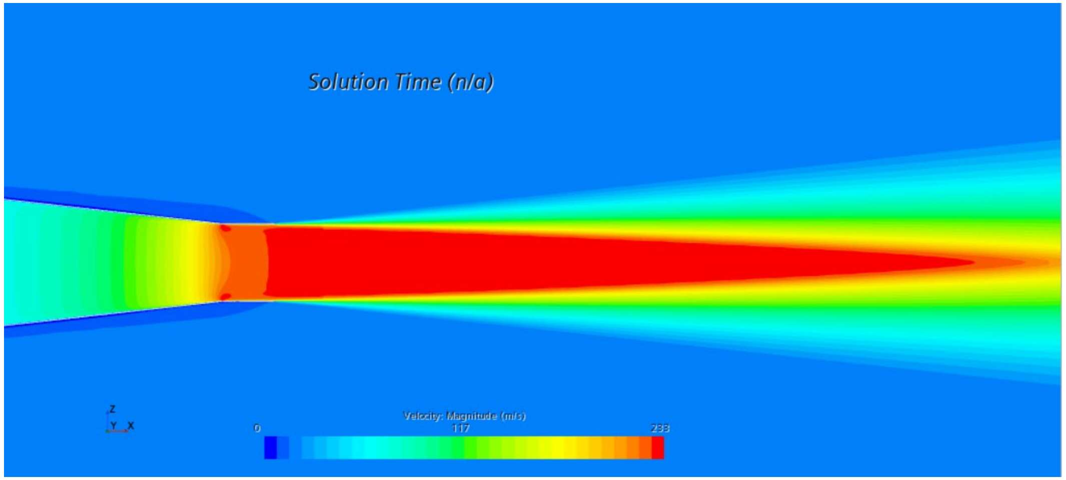
Turbulent kinetic energy



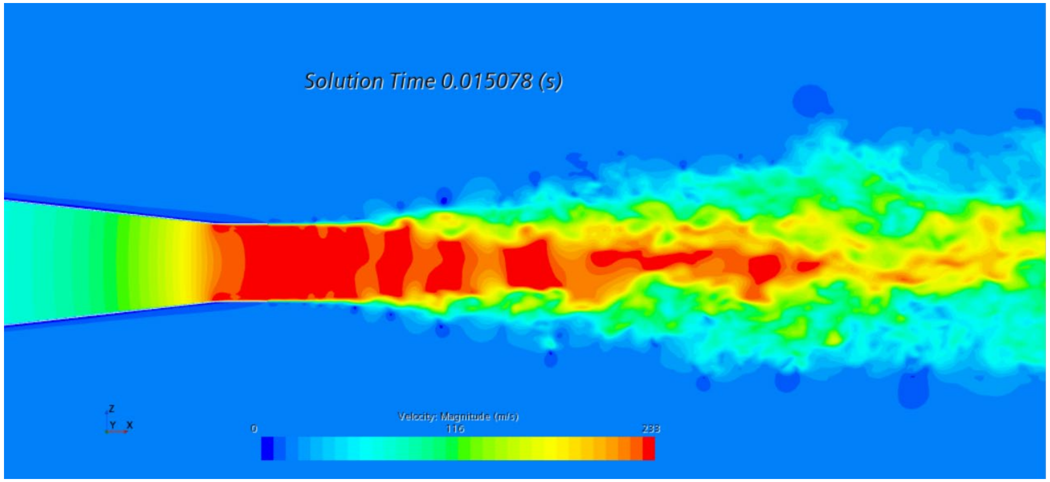
RANS/LES comparison

Velocity magnitude

RANS



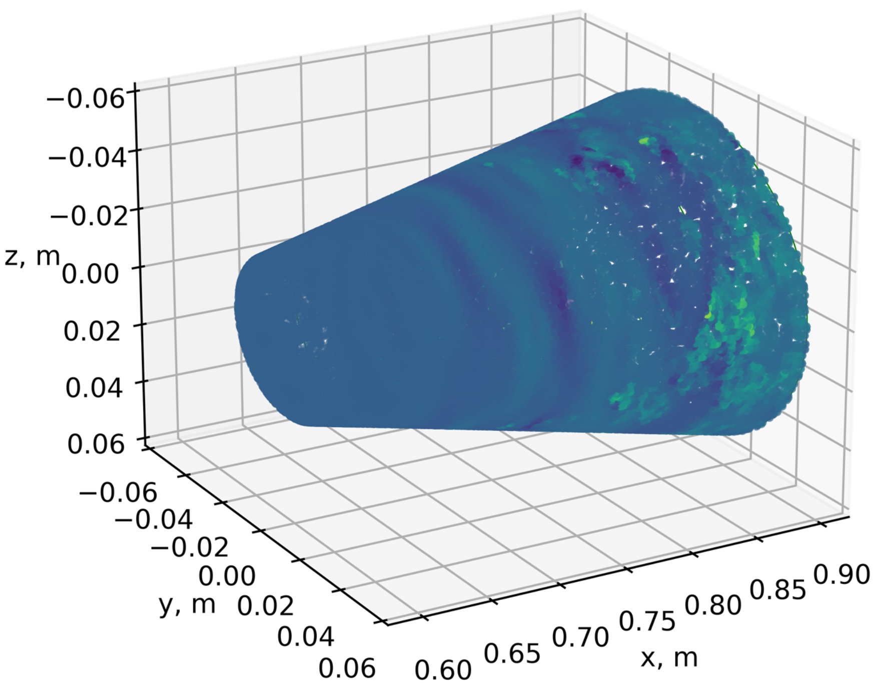
LES



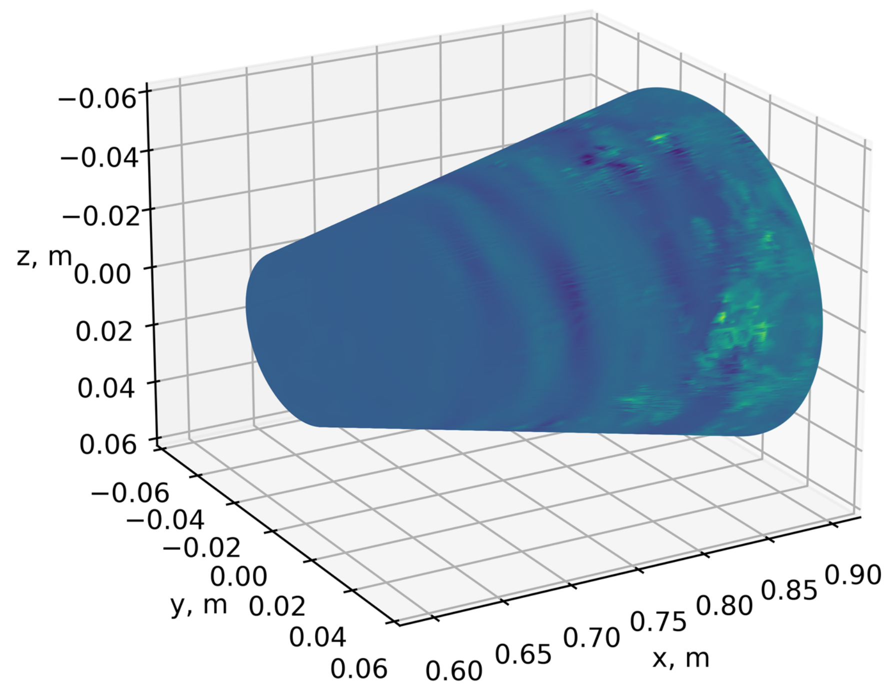
Extracted data

- Data extracted from STARCCM+
- Interpolation to FWH surface

Raw scattered data (from StarCCM+)



Interpolated structured data (for FWH prediction)

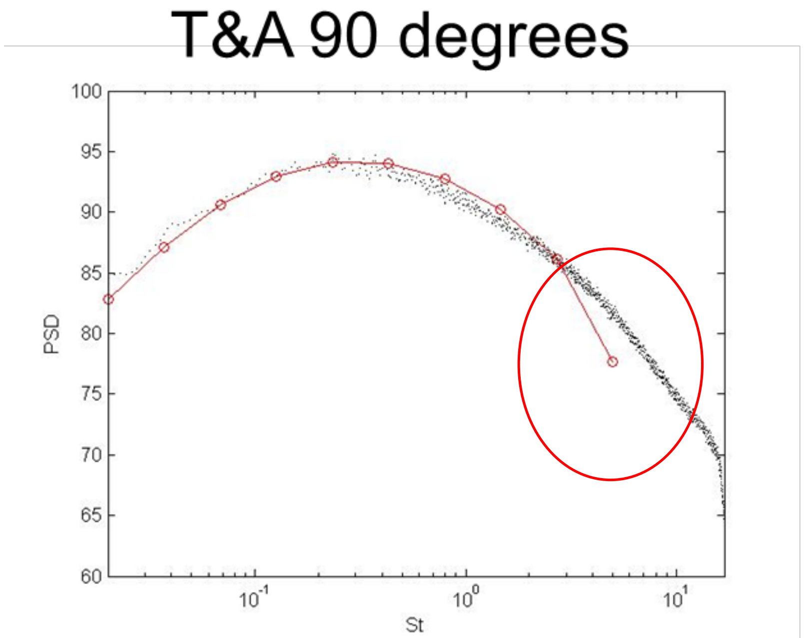


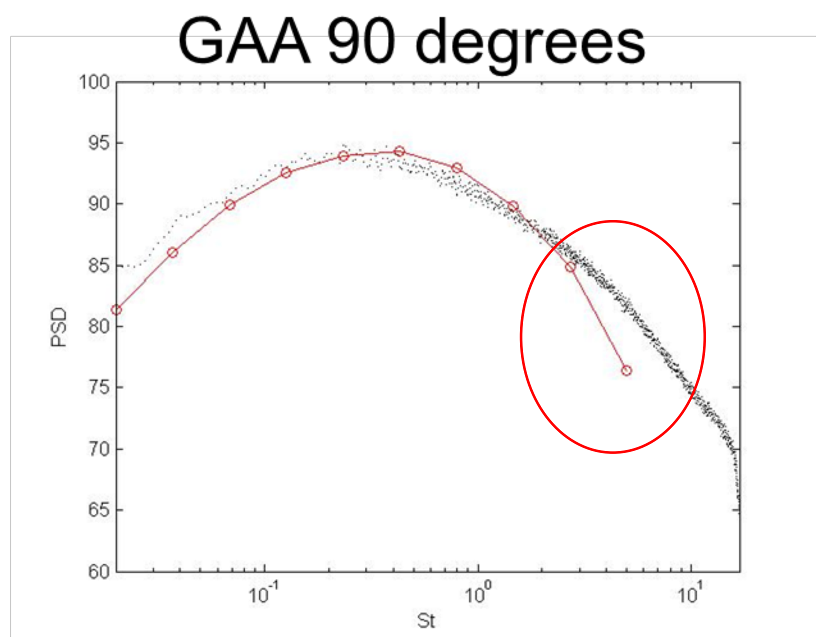
Low Order Acoustic Analogy Models

- High frequency predictions using LES require significant computational resources
- High frequencies are important for perceived noise calculations
- Supplement moderate fidelity LES predictions with RANS-based acoustic analogies
- General approach
  - Perform RANS simulation
  - Calculate Green's function for sound propagation
  - Use RANS data to inform noise source model
- Several acoustic analogy noise models are available as a starting point

Example Calculations

Tanna, SP7: unheated, M_a=0.9





T&A: Tam & Auriault, *AIAA Journal,* **37**(2) 1999
GAA: Goldstein, *JFM*, **488** 2003
Gryazev & Karabasov, AIAA Paper 2018-2828

Ongoing Work and Future Plans

- Noise predictions for single and dual-stream GT nozzles
- Coupled RANS/LES flow simulations and noise predictions
- Flow simulations for internal mixer nozzles
- Extend acoustic analogies with focus on high frequency spectral content