# ASCENT Project 63

# Parametric Noise Modeling For Boundary Layer Ingesting Propulsors

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Cost Share Partner: Georgia Tech

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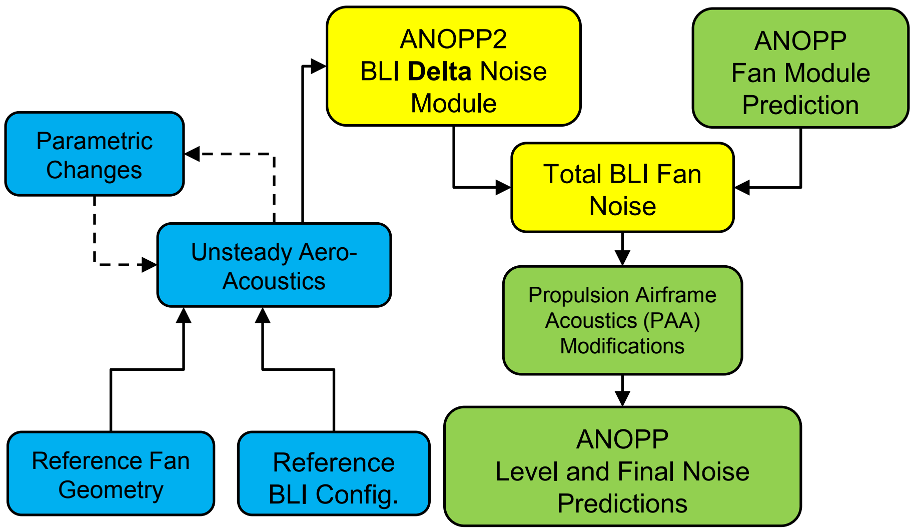
## Objective:

To identify, develop, and validate a parametric fan noise module for a generic BLI propulsor based on the specifics of a configuration and design

## Project Benefits:

- New capability for design engineers to determine the noise impact of new concepts
- Perform trades of fuel burn benefit versus noise at the conceptual level
- Reduce overall community noise by improving the accuracy of noise predictions for future advanced concepts
- Allowing vehicle designers to find the best opportunity for BLI technologies that offer fuel burn and noise benefits simultaneously

## Research Approach: Numerical Experiments




## Major Accomplishments (to date):

- Validation of fan noise module with NASA ANOPP and experimental data.
- Creation of integrated BLI geometry and designs
- Parametric sensitivities conducted to determine cases for high fidelity CAA cases
- Successful runs of SDT fan CAA in PowerFlow
- Successful runs of integrated BLI configuration

## Future Work / Schedule:

- Finish running CFD/CAA cases
- Post-process data
- Integrate into "parametric" source noise model within ANOPP2

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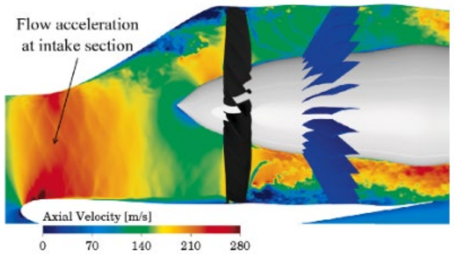
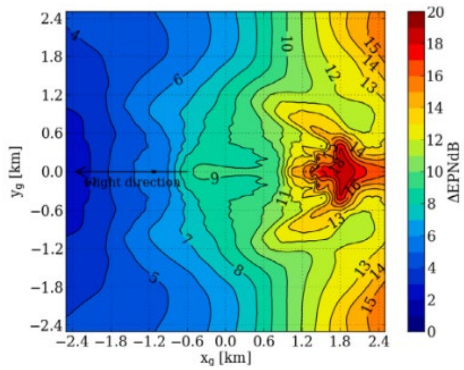
# Project Motivation and Objectives

- Boundary Layer Ingestion (BLI) Concepts to **Reduce Fuel Burn**:
  - Ingest part of the boundary layer into the propulsor to improve propulsive efficiency
  - Creates distortion at the fan face
  - Problematic for operability and performance
  - **But what about the noise impact?**


- Distortion has an impact on noise:
  - Experiments have shown impact of inlet turbulence ingestion and aerodynamic distortion on noise
  - Broadband and tonal impact
  - Variability in directivity




- Some BLI noise modeling attempts have been made:
  - NASA Study Based on **Analogous Empirical Data**:
    - Clark, I. A., et al, “Aircraft System Noise Assessment of the NASA D8 Subsonic Transport Concept”
    - Found **16 dB impact** for ND8 configuration
  - TU Delft study looked at the NOVA BLI Configuration using high fidelity CAA
    - Qingqing Ye, Francesco Avallone, Daniele Ragni, Damiano Casalino, “Numerical analysis of fan noise for the NOVA boundary-layer ingestion configuration”
    - +10 EPNdB impact of BLI

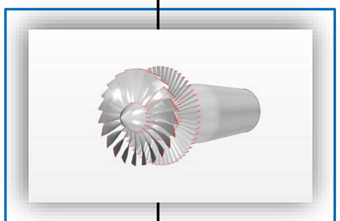



**<u>Project Purpose:</u>** To identify, develop, and validate a parametric fan noise module for a generic BLI propulsor based on the specifics of a configuration and design

# Project Technical Approach

SDT Fan Inputs → NPSS Performance Model → ANOPP Inputs → ANOPP Noise Model Calibration

Geometry Preparation in SolidWorks → SDT Mesh → PowerFlow CFD/CAA → Noise Prediction → CAA and ANOPP Calibration



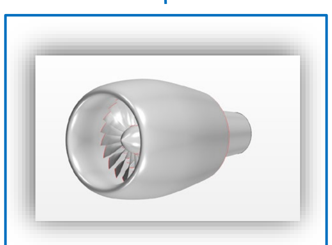
**Reference configuration:**

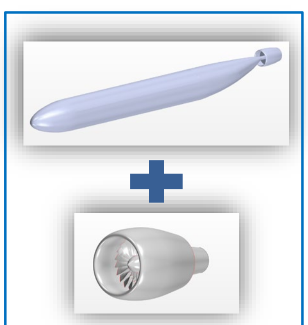
- STARC-ABL aircraft
- SDT Fan Geometry (Similar to TUD study)

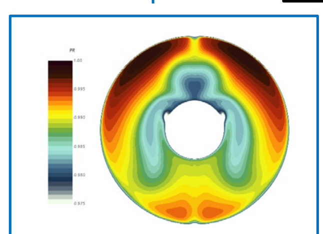
**Project has two key paths:**

- SDT Fan Noise Performance Modeling and Calibration (top)
- BLI Design and Parametric Noise Impact Generation (bottom)

Scale SDT-A to Clean Fan → Integration STARC-ABL & SDT-A → Design Changes and RANS studies → Baseline BLI Geometry → CFD/CAA





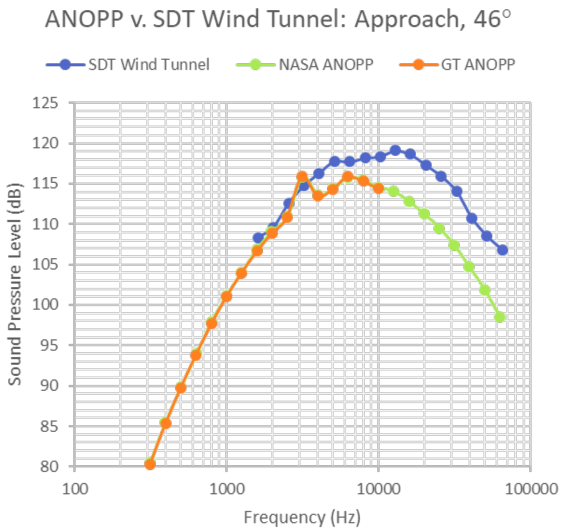


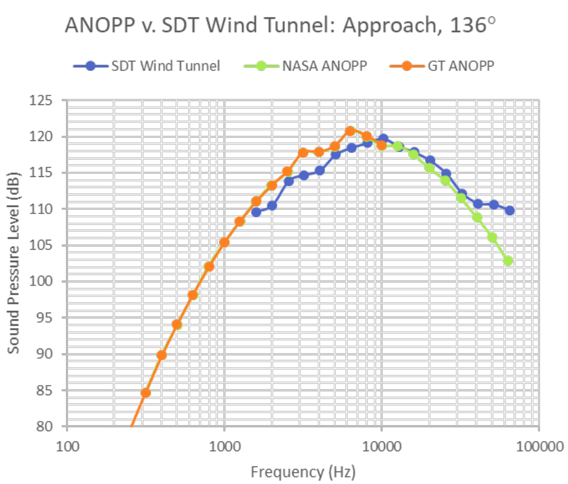
Parametric Changes

ANOPP2 BLI **Delta** Noise Module

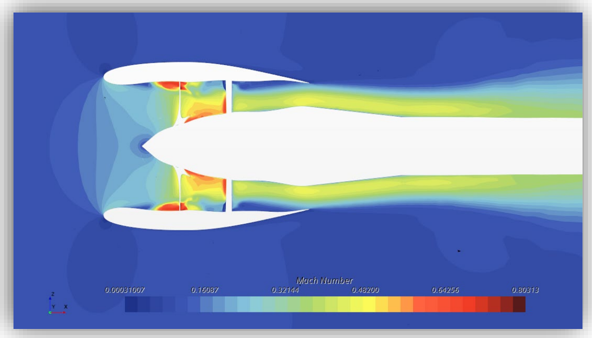
# Previous Work Shown Last Spring

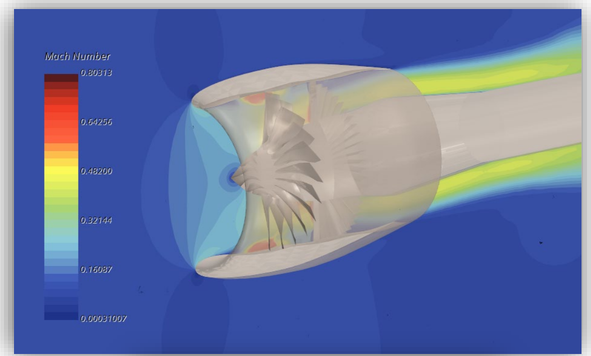
**Accomplishment #1:**
Validation of fan noise module with NASA ANOPP and experimental data.

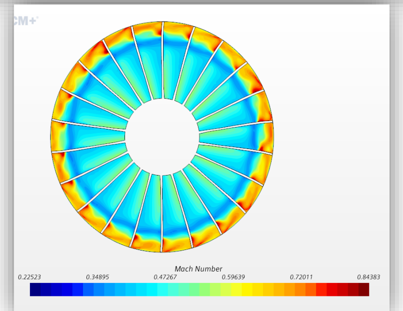


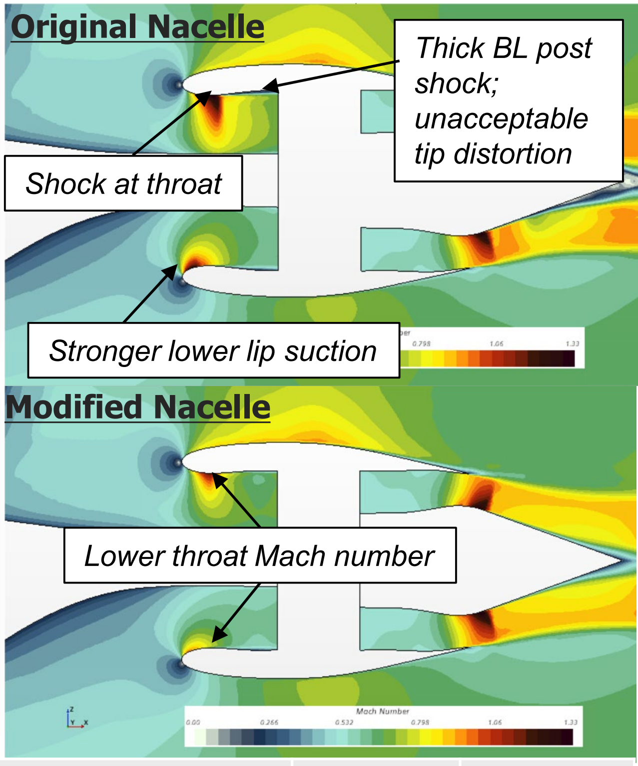

**Accomplishment #2:**
Successful Creation of CFD meshes for Unsteady CAA with baseline SDT geometry




**Accomplishment #3:**
Integrated Geometry Design and Testing in STAR-CCM steady RANS for Tail Cone Thruster

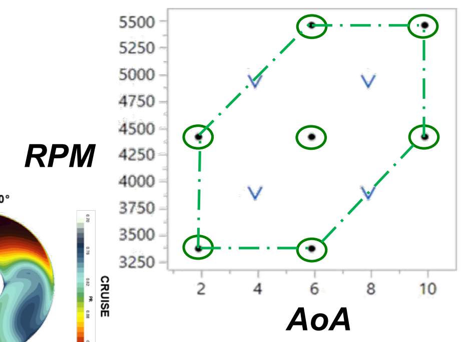


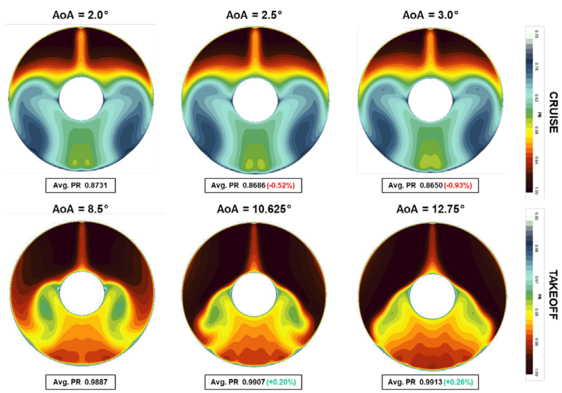

| *Approximate Values* | Original Nacelle | Modified Nacelle |
|---|---|---|
| **Peak** upper throat Mach number | 1.27 | 1.14 |
| **Peak** lower throat Mach number | 1.18 | 0.90 |

# High Fidelity Simulation Progress

## Design Space Analysis

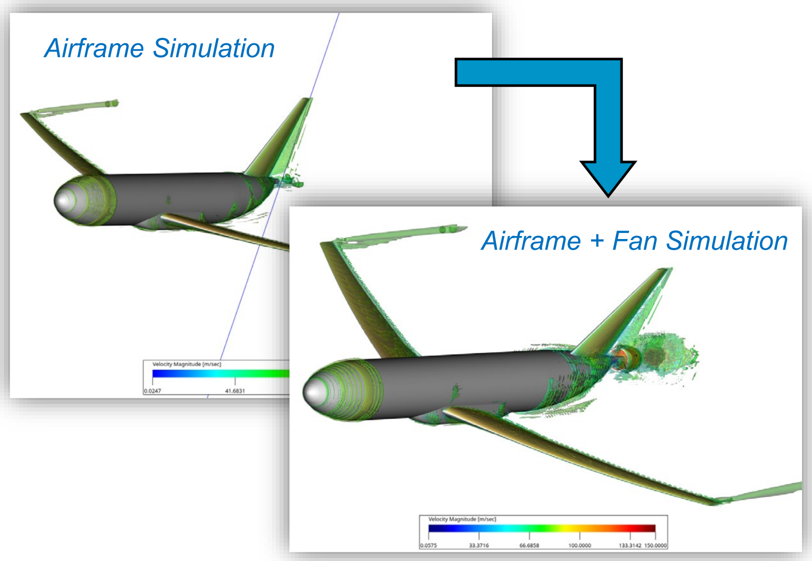
- Mach number & altitude are negligibly different for certification noise points
- Geometry perturbations explored, and no clear winner emerged
- Fan RPM and angle of attack (AoA) had largest influence
- Sampling plan (green symbols) focus on feasible operational space of fan
- Variables and ranges reflect real world operational envelope for noise certification points




## Simulation Effort: Unsteady Aerodynamics

- Unsteady aerodynamics simulation by a lattice Boltzmann commercial solver (PowerFlow)
- Flowfield is first obtained on an airframe only simulation
- Run for several flow-through times with a coarse discretization (30 millions voxels)
- Then used for initiating actual configuration (airframe & fan) on a coarse discretization (140 millions voxels)



# Integrated Simulation Progress

## Simulation Effort: Unsteady Aerodynamics (cont.)

- Final simulation:
  - Discretization size = 807 Million voxels
  - Smallest resolution = 0.375 mm
    => (at blade tip –nacelle gap, and blade LE & TE)
  - Time step : $0.28 \times 10^{-6}\ secs$
  - Computational cost : ~10,000 core-hours / revolution

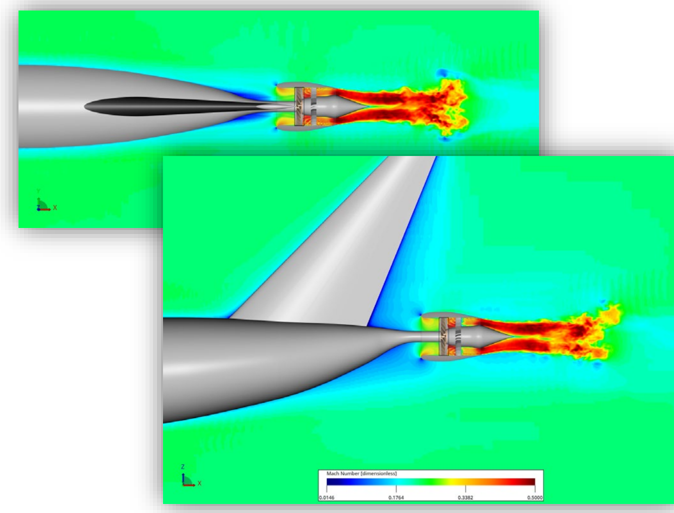
- Simulation expected to run for 10 fan revolutions in order to collect flow data for aeroacoustics analysis

## Simulation Effort: Far-Field Aeroacoustics

- Far-field aeroacoustics by Ffowcs Williams and Hawkings (FW-H) method
- Noise sources from turbo-fan are captured by a permeable FW-H surface surrounding the engine
- Resolution allows solving for frequencies up to 4.7 kHZ
- Sample rate 74.4 kHz
- Flow data collected at FW-H permeable surface to be use for far-field aeroacoustics (after simulation completion)

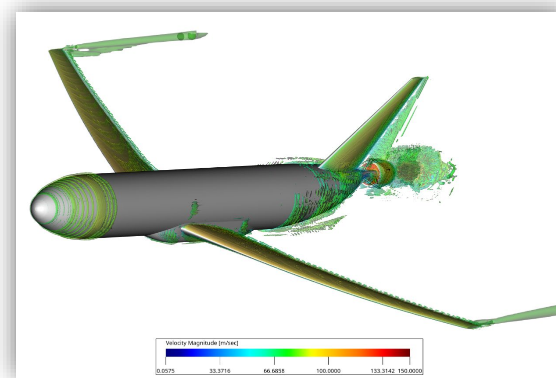
***Mach Flowfield***

*(AoA=2º, RPM = 3371)*



***Vortical Structures***

*(AoA=2º, RPM = 3371)*



# Next Steps and Expected Project Outcomes

- High fidelity simulations are in the queue for each case in the operational space
- Expected to finish simulations by December
- On-going ANOPP work to create "parametric" noise module
  - High fidelity CAA results will be integrated into the source noise module
- Project ends Feb. 6th 2022 and is on-target to finish deliverables