ASCENT Project 59A

Jet Noise Modeling To Support Low Noise Supersonic Aircraft Technology Development.

Georgia Institute of Technology

PI: Jimmy Tai & Dimitri Mavris

PM: Sandy Liu

Cost Share Partner: Georgia Institute of Technology

Objective:

To develop method for identifying the LTO thrust-noise breakeven point for a given supersonic nozzle-based noise technology.

To identify off-design configurations for fixed inlets to minimize performance impacts from implementation of noise reduction technologies (shift the thrust-noise breakeven point).

Project Benefits:

The developed approach will enable airframe and engine manufacturers to analyze and explore the design space of supersonic inlets, and determine whether a selected propulsion system is feasible for use with a given nozzle-based jet noise reduction technology. If an inlet is not feasible, tool will help determine potential alternative designs.

Research Approach:

Assemble zeroth-order methods for predicting supersonic inlet performance.

Extend inlet analysis tool with accurate zeroth-order low speed aerodynamic model for supersonic inlets.

Develop and integrate method to identify thrust-noise break-even point for supersonic inlet-engine system during LTO conditions utilizing inlet code with aircraft analysis suite.

Develop tools and method to identify how modifications to supersonic inlet will affect the thrust-noise break-even point for any given nozzle technology.

Major Accomplishments (to date):

Initial zeroth-order supersonic inlet performance and structural analysis tool for 2D inlets complete; tool continues to be developed with added capabilities.

Zeroth-order performance analysis tool validated against public literature for total pressure recovery, flow station behavior, and drag predictions.

Future Work / Schedule:

Extend inlet analysis tool to include improved low speed aerodynamics predictions and alternative pressure recovery improvement methods.

Develop requisite thrust-noise breakeven study capabilities and perform study.

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 59a through FAA Award Number 13-C-AJFE-GIT–070 under the supervision of Sandy Liu. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

Year 1 Work

- Completed parametric 2D analysis tool which could predict the following:
  - Pressure recovery between freestream and engine face
  - Oblique and normal shock predictions
  - Inlet geometry schematic for verification
  - Bleed, Bypass and Spillage drags
- Tool performance was validated against several published 2D inlets
  - Good agreement with mixed compression $M_d = 5.0$ inlet provided in IPAC paper [1]
  - Good agreement with external compression $M_d = 2.3$ inlet in Fundamentals of Aircraft and Airship Design [2]
  - Currently performing analysis and validation of PIPSI "R2DSST" $M_d = 2.3$ mixed compression inlet [3]

Year 2 Work

- Many capability gaps between year 1 supersonic inlet analysis tool and needs were identified and improved:
  - Inlet-engine airflow matching → bypass mass flow determination
  - Inlet capture area sizing
  - Cowl lip suction and additive drag predictions
  - Nacelle wave drag predictions
- Improved mixed compression inlet performance prediction
  - Improved accuracy of location and strength of internal oblique shock train
  - Improved accuracy of location and strength of internal terminal normal shock
- Completed initial integration of supersonic inlet tool and supersonic engine and aircraft analysis and design tools (FASST)
- Validations completed:
  - Good agreement with mixed compression $M_d = 5.0$ inlet provided in IPAC paper [1]

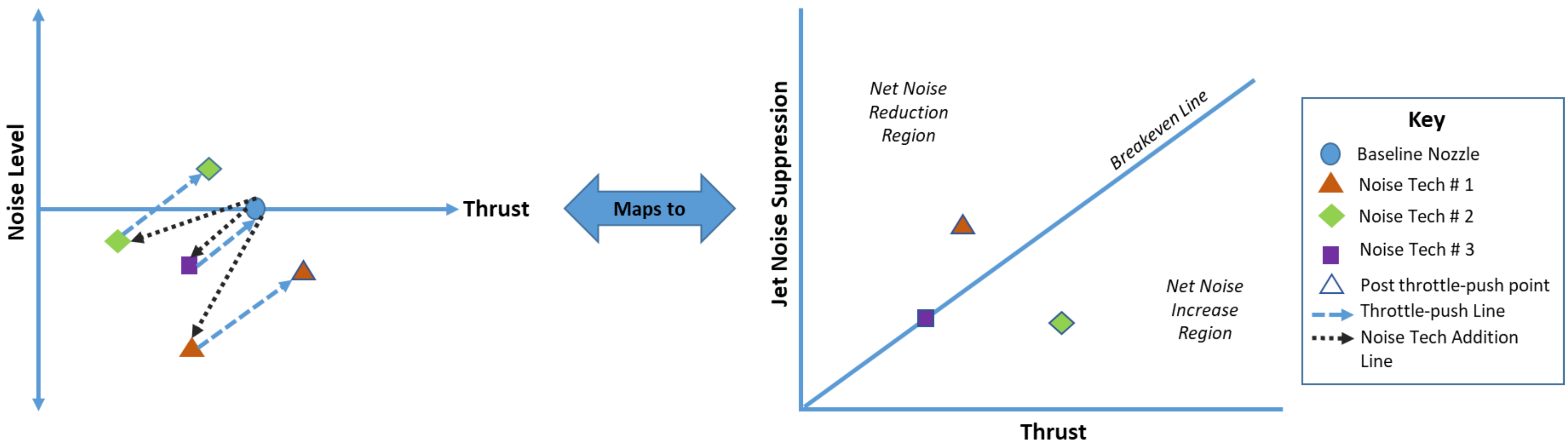
Current Year 3 Work

- Initial objective was to determine means to *design new supersonic inlets* to reduce thrust losses associated with nozzle-based jet noise reduction technologies

- Upon further examination in the second year of work, the overall objective was modified
  - Nozzle-based noise technologies will have adverse affect on thrust while mitigating noise
  - However, supersonic engines are likely *throttled-back* at LTO takeoff conditions
  - Each nozzle technology has unique thrust loss and noise reduction characteristics—want to ***determine thrust-noise breakeven line*** for given engine and arbitrary noise reduction technology
  - Determine whether variable geometry inlet models can affect this relationship at LTO conditions

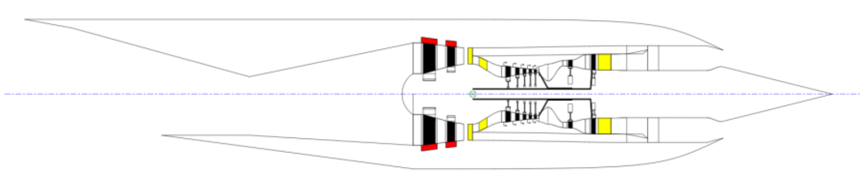
- Accomplishing this requires various other preliminary tasks
  - ❑ Add low-speed viscous effects to model
  - ❑ Develop variable geometry inlet modeling to explore thrust recovery at LTO
  - ❑ Perform break-even studies
  - ❑ Lastly: see if variable geometry configurations can recover thrust at LTO

Thrust-Noise Break-even Study



- Supersonic engines are likely to be throttled back at takeoff
  - Thus, any loss of thrust due to noise technology addition could be offset by pushing throttle forward (not a performance-limiting factor)
  - Pushing forward throttle forward will *likely* reduce or offset noise benefits provided by tech
  - If this is the case—will need alternative way to recover thrust during LTO (variable geometry)
- Proposed idea: For any given engine assembly (engine, inlet, nozzle), a break-even line exists where the **thrust impact cost outweighs the noise reduction benefit**
- Objectives: Perform this study on various nozzle technology models (collaboration point), and determine if off-design inlet configurations can overcome this thrust loss

Thrust-Noise Break-even Study (contd.)

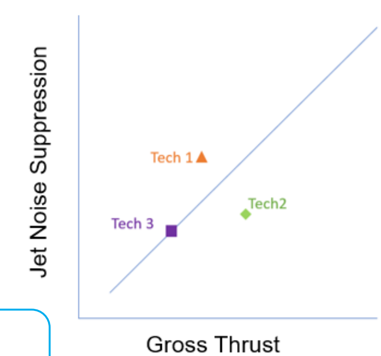


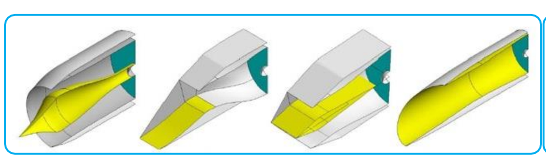
Establish Baseline
Determine noise and thrust levels with baseline engine system (inlet-engine-nozzle)

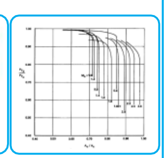
Model Nozzle Impacts at LTO
Model nozzle technology impact: jet suppression factor in *ANOPP*, nozzle C_{fg} reduction in *NPSS* engine model and additional weight in *WATE++* → ***run full engine model in EDS, determine overall thrust loss and noise benefit***

Model Nozzle Impacts at LTO with Throttle Push
Increase throttle setting required for takeoff and conduct study again

Establish Breakeven Line
Determine breakeven line for variety of nozzle technologies







Determine Off-Design Inlet Effects
Change variable geometry cowl lip (VGCL) and external ramps to determine if thrust can be recovered (line shift)

References

[1] Barnhart, P., "IPAC - Inlet Performance Analysis Code," *NASA Technical Reports Server (NTRS)* Available: https://ntrs.nasa.gov/search.jsp?R=20050177169.

[2] Nicolai, L. M., and Carichner, G. E., "Chapter 15, Section 7," *Fundamentals of Aircraft and Airship Design*, Reston (Va.): American Institute of Aeronautics and Astronautics, 2013, pp. 402–412.

[3] E.J Kowalski, R.A. Atkins Jr, "A Computer Code for Estimating Installed Performance of Aircraft Gas Turbine Engines". *Library of Inlet/Nozzle Configurations and Performance Maps.* Vol III. Dec. 1979.