ASCENT Project 59C

Modeling Supersonic Jet Noise Reduction with Global Resolvent Modes

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Cost Share Partner: Boom (in negotiation)

Objective:

Develop a rapid prediction capability to estimate changes in jet take-off noise due to design changes

Project Benefits:

Reduce sound environmental impact due to anticipated return of supersonic civilian transport aircraft

Research Approach:

Utilize input-output (resolvent) descriptions of the jet aeroacoustics to link nozzle design choices to their impact on the radiated noise.

Envisioned usage:

1. Compute RANS of baseline nozzle with identified design parameters
2. Compute input-output operator and its derivatives wrt design parameters
3. Select new design parameters that reduce far-field noise
4. Return to 1.) with new nozzle and repeat

Major Accomplishments (to date):

- Python-based nozzle CAD → RANS grid ready
- RANS solver modified for hot jet flows and verified
- Input-output operator code developed and verified
- Evaluation of input-output gain sensitivities to nozzle design demonstrated

Future Work / Schedule:

- Develop self-consistent scaling of resolvent amplitudes on RANS TKE
- Develop automated design workflow

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 59c through FAA Award Number 13-C-AJFE-UI (Amendment 31) under the supervision of Dr. 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.

Motivation

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- Return of civil supersonic transport aircraft highly anticipated
- Likely jet engine parameters are different from subsonic transport:
  - Bypass ratio ~ 2 turbofans
  - Mixed fan and core streams
  - Jet exit Mach number ~ 0.9

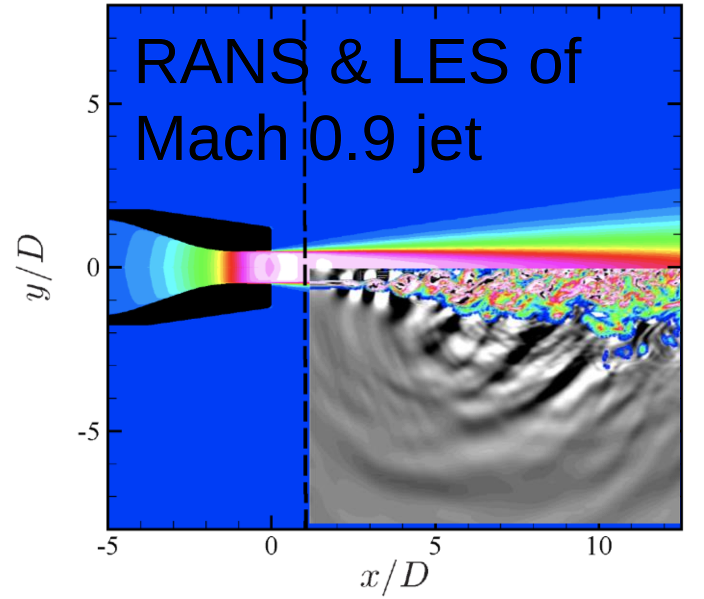
Credit: Boom

Credit: NASA

- Jet take-off noise key environmental barrier to community acceptance
- Need means to quickly and reliably assess engine design choices on radiated take-off noise

Resolvent-based Jet Noise Prediction

- RANS calculations are inexpensive, lack acoustic field
- Large-eddy simulations (LES) are expensive, include acoustic field
- Idea: approximate noise field as output of resolvent operator from RANS mean-flow:



$$\boldsymbol{R}_{\mathrm{RANS}}(\boldsymbol{Q}) = 0 \longrightarrow \frac{\partial \boldsymbol{q}}{\partial t} = \mathrm{A}[\boldsymbol{Q}]\boldsymbol{q} + \mathrm{B}[\boldsymbol{Q}]\boldsymbol{f}$$

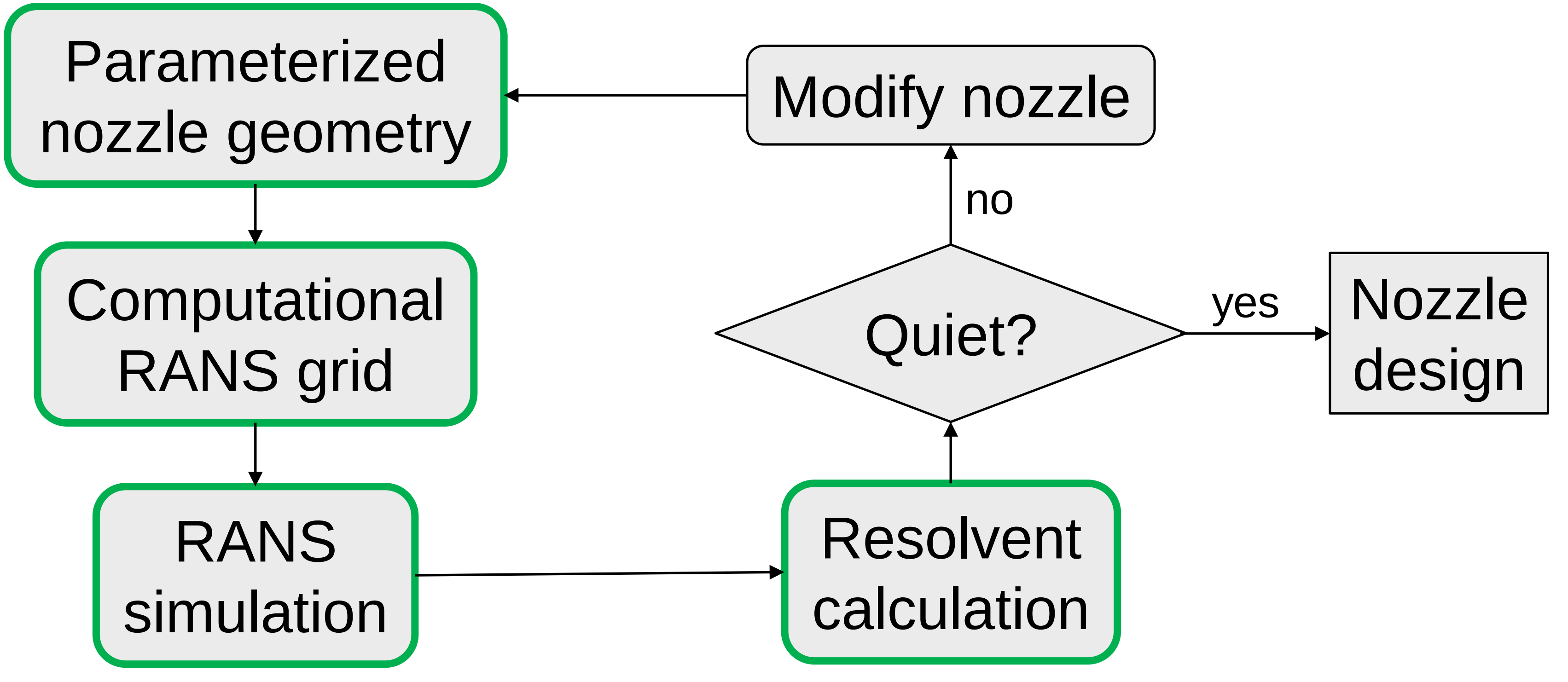
$$\boldsymbol{y} = \mathrm{C}[\boldsymbol{Q}]\boldsymbol{q}$$

Inputs: $\boldsymbol{f}$

Far-field sound: $\boldsymbol{y}$

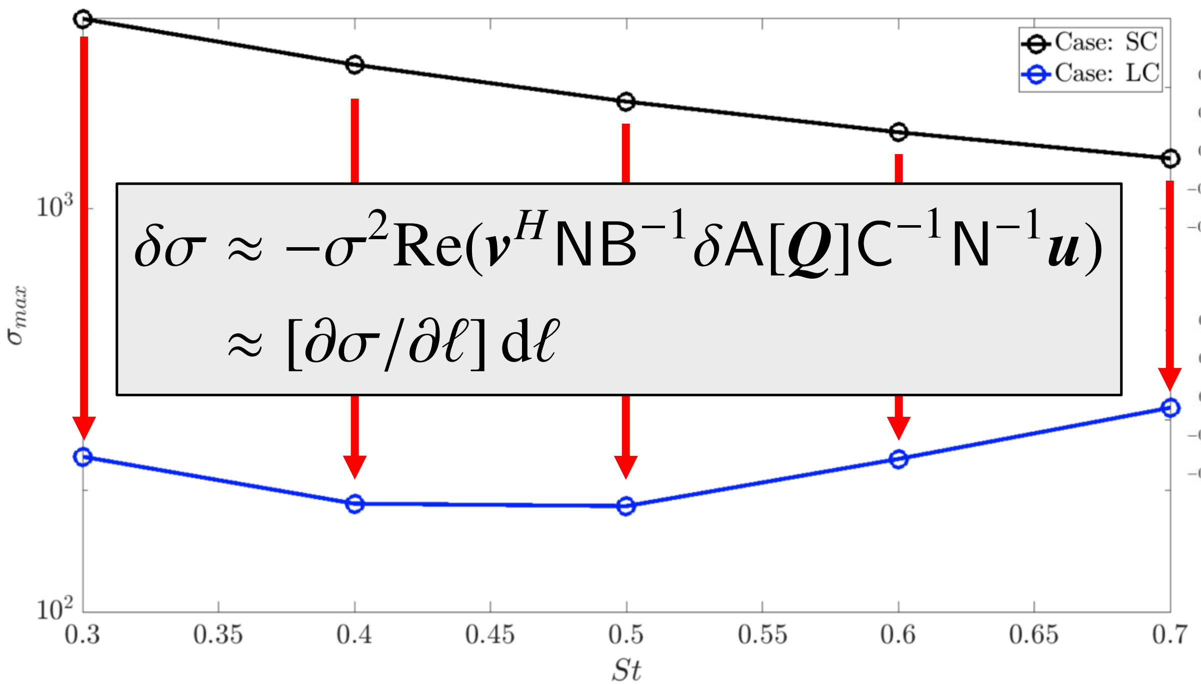
Research Plan

- Find the best mean flow $\boldsymbol{Q}$ that minimizes the sound $\boldsymbol{q}$ using the input-operator gains as a "guide"
- Developing workflow to:



Input-Output Predictions

- Measurable difference in gains between two hot jet nozzle lengths, ℓ
- Observe measurable gain differences across larger parameter space



$$\delta\sigma \approx -\sigma^2 \mathrm{Re}(\boldsymbol{v}^H \mathsf{N}\mathsf{B}^{-1}\delta\mathsf{A}[\boldsymbol{Q}]\mathsf{C}^{-1}\mathsf{N}^{-1}\boldsymbol{u})$$
$$\approx [\partial\sigma/\partial\ell]\,\mathrm{d}\ell$$