# 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 changes in nozzle design and engine cycle

## 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 verified and validated
- V1 Input-output operator code verified
- Input-output gain sensitivities to nozzle design demonstrated

## Future Work / Schedule:

- Develop self-consistent scaling of resolvent amplitudes on RANS TKE
- Complete automated design workflow
- V2 automated resolvent operator construction

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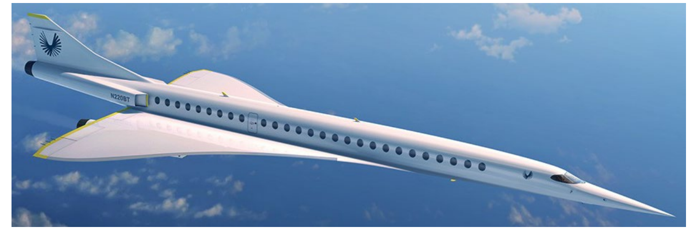
# Motivation

- 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
- 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

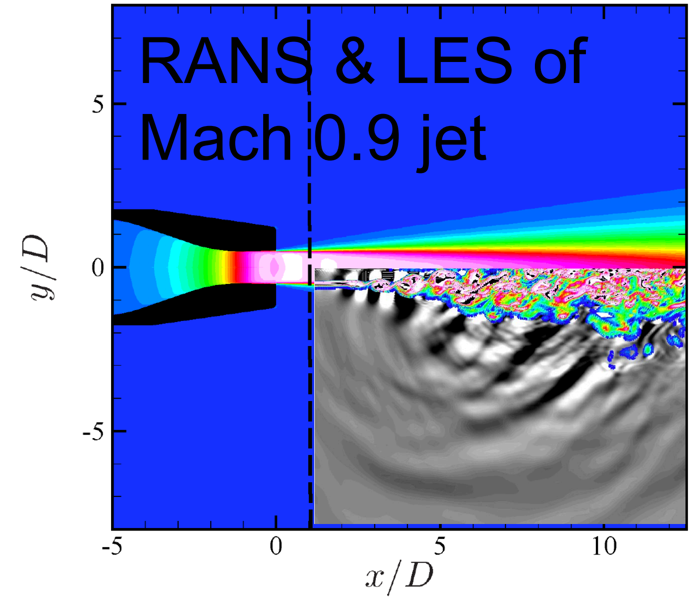


Credit: Boom


Credit: NASA

# 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:




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

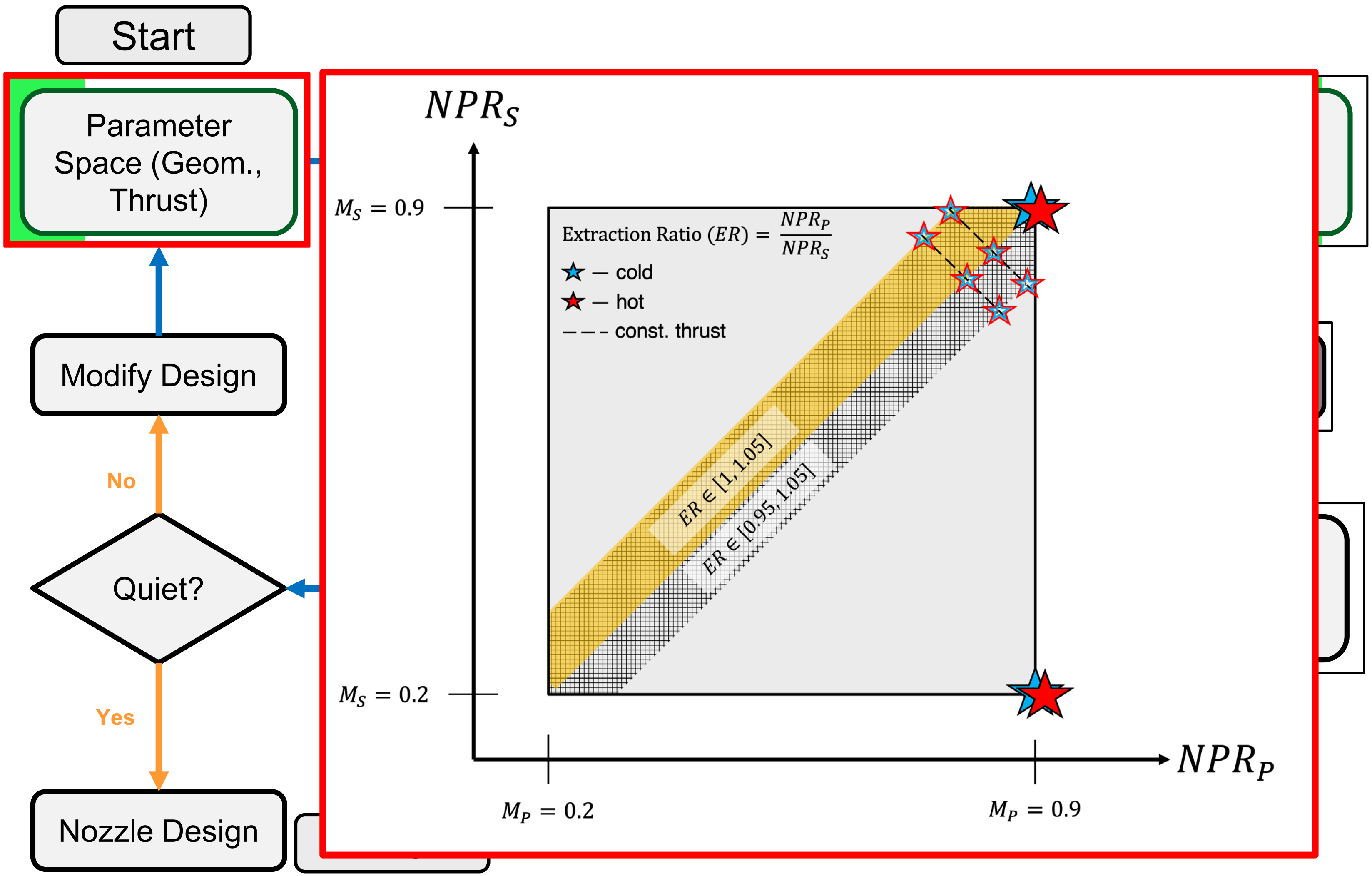
$$\boldsymbol{y} = \mathrm{C}[\boldsymbol{Q}]\boldsymbol{q}$$

Inputs

Far-field sound

Nozzle design → Resolvent (gain) → jet noise

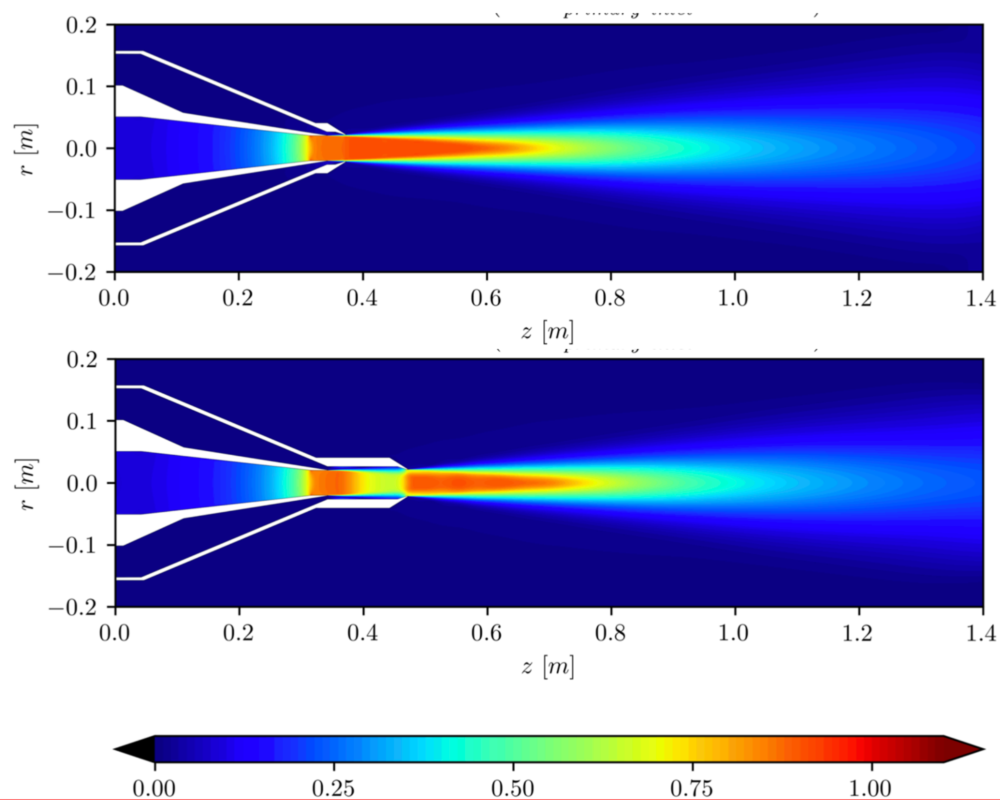
# Workflow Automation



# Workflow Automation

Start

Parameter Space (Geom., Thrust) → Computational RANS Grid → RANS Simulation




**Short nozzle**

$NPR_p = 1.7$, $NPR_s = 1.0$

$TTR_p = 1.8$, $TTR_p = 1.0$

**Long nozzle**

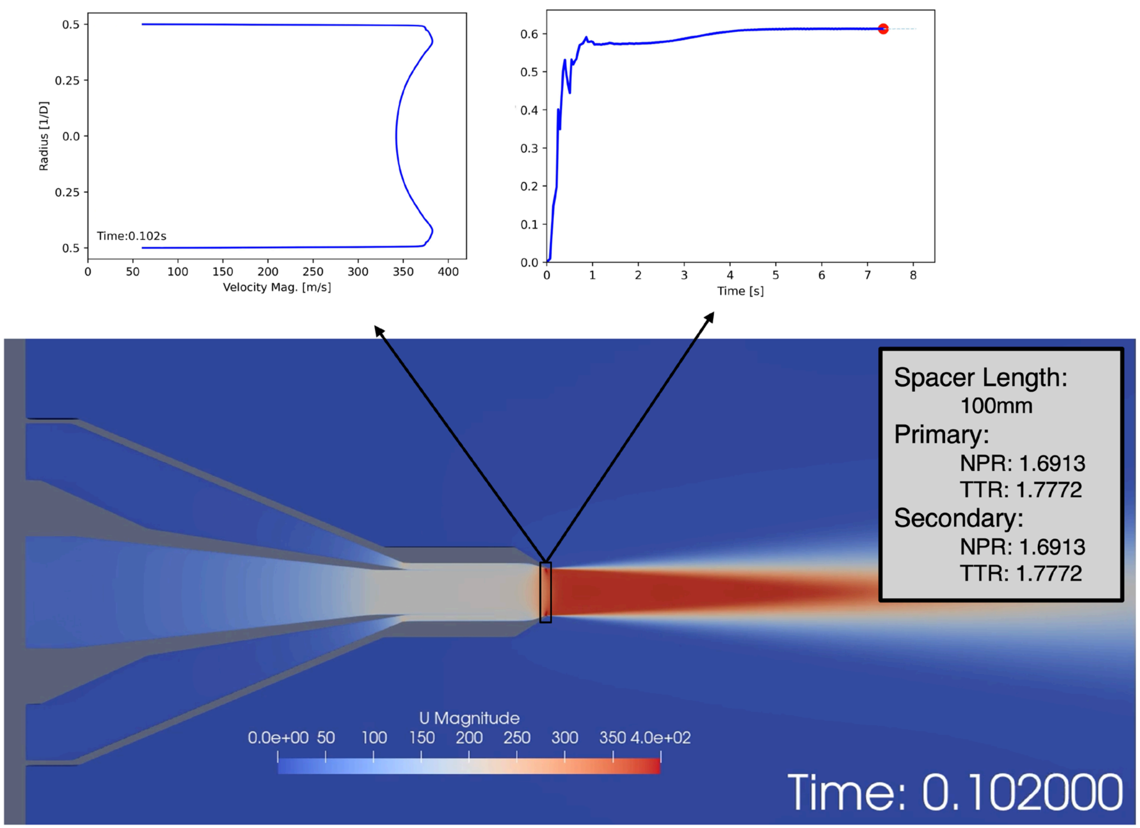
$NPR_p = 1.7$, $NPR_s = 1.0$

$TTR_p = 1.8$, $TTR_p = 1.0$

[1] Thies, A. T., Tam, C. K. (1996). Computation of turbulent axisymmetric and nonaxisymmetric jet flows using the k-e model. AIAA journal, 34(2), 309-316.

# Workflow Automation

## Steady Flow Monitoring

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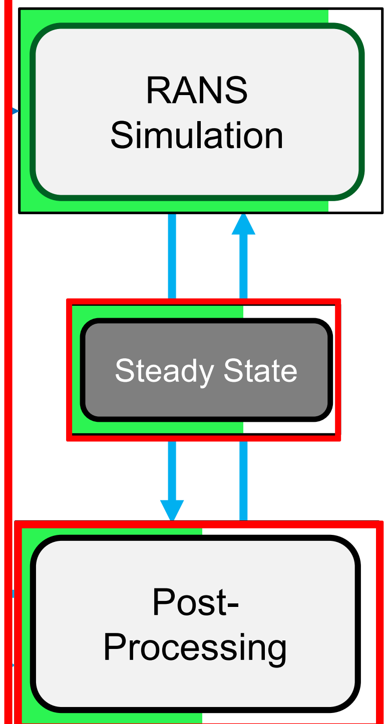
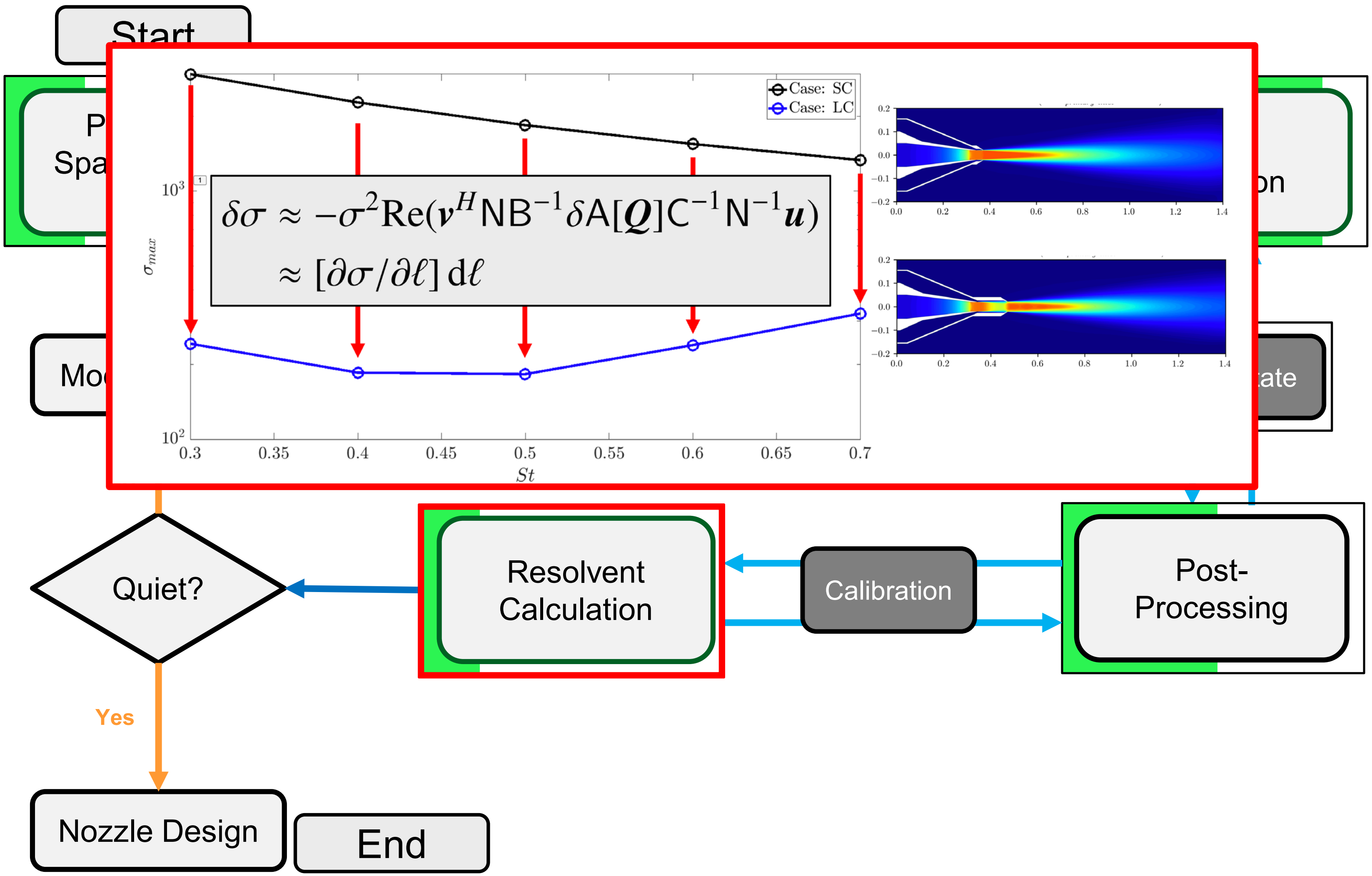


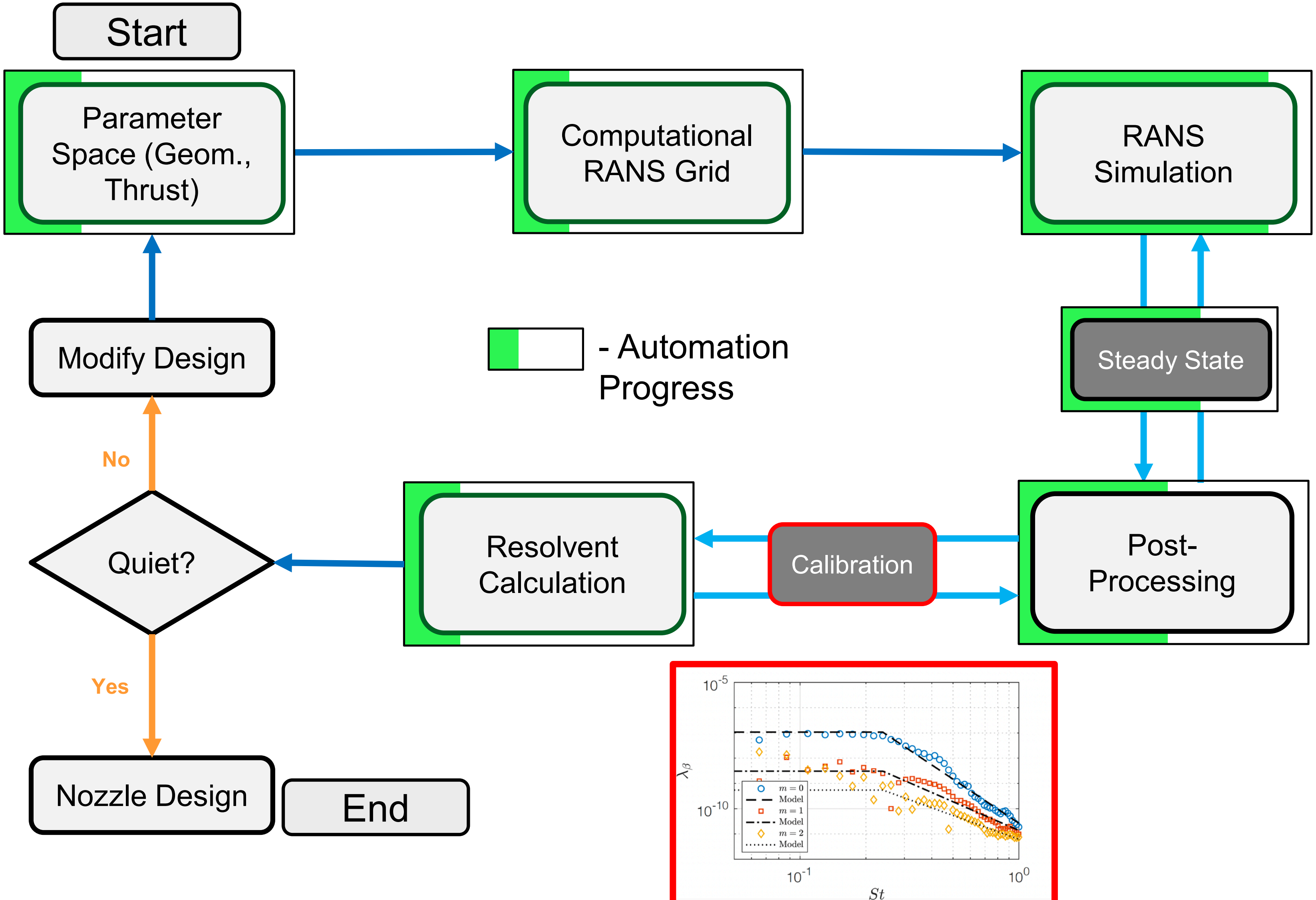

Nozzle Design

End

# Workflow Automation



# Next Steps


Start
Parameter Space (Geom., Thrust)
Computational RANS Grid
RANS Simulation
Steady State
Post-Processing
Calibration
Resolvent Calculation
Quiet?
No
Yes
Modify Design
Nozzle Design
End
- Automation Progress
10^-5
10^-10
10^-1
10^0
St
m = 0
Model
m = 1
Model
m = 2
Model