NASA Jet Noise Research

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NASA

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ANOPP2: Mixed-Fidelity System Noise Capability

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Semi-empirical

ANOPP
Engine
Airframe
Shielding

ANOPP-Stone
Jet
ANOPP-PAS
Open rotor

MDOE
Jet + Chevron

Jet3D: PAA
Jet & Pylon

JENO
Jet

RISN
Jet

Semi-empirical
single and dual
stream jet
predictions

Noise reduction
predictions obtained
from experiments

* Jet-pylon interaction predictions using an acoustic analogy

*Predictions based on RANS flow-field solutions and mathematical models

* Supersonic jet predictions using an acoustic analogy

* Single and dual stream jet mixing noise predictions using an acoustic analogy

Receiver

Propagation

Source
Acoustic Analogy - RISN

Steve Miller, s.miller@nasa.gov

- Acoustic analogy for the prediction of off-design supersonic jet noise
- Mixing noise
- BBSAN
- Single/dual stream
- Three dimensional
- Uses steady RANS
- Future
  - Scattering from airframe
  - Screech tones
  - Nonlinear propagation

Example

\( \psi = 50^\circ \)

\( M_d = 1 \)

\( M_j = 1.5 \)

\( TTR = 3.2 \)
Acoustic Analogy - RISN

- Example of scattering for jet mixing noise
- Green’s function for jet noise ground effects
  - Numerical or,
  - Analytical,

\[ V = i \int \frac{H_1^{(1)}(\mu^2 + kR)}{\sqrt{\mu^2 + 2kR}} \, d\mu + i \int \frac{H_1^{(1)}(\mu^2 + kR_p)}{\sqrt{\mu^2 + 2kR_p}} \, d\mu \]

- Includes ground absorption model
Rearrangement of the Navier-Stokes equations to obtain linear propagation operator (compute via Green’s function) with nonlinear source terms (modeled).

Reduced-order models needed for Green’s function for practical prediction methods.

Example: Rectangular Jets
- Approximate mean flow in cross-flow planes by concentric ellipses.
- Conformal mapping to cylindrical elliptical coordinates.
- Resources for computation in mapped domain similar to round jets.

\[ y_2 + iy_3 = C \cosh(u + iv), \quad C \text{ is a real constant} \]
Acoustic Analogy-Based Noise Predictions for Non-Circular Jets

NPR = 1.4
Ma = 0.7

Minor axis plane
φ = 0°

Major axis plane
φ = 90°
Jet-Surface Interaction Tests

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Gary Podboy, gary.g.podboy@nasa.gov

- Jet-surface interaction noise is difficult to predict with current methods

Acquiring a new noise and flow database to:
  - Develop new and improve existing prediction methods

Jet-Surface Interaction Noise

Overexpanded Jet
Plasma Actuator for Jet Turbulence Control

Clifford Brown, clifford.a.brown@nasa.gov

- Jet Turbulence Control
  - Control jet turbulence via instabilities
  - NASA/OSU collaboration to develop high-control authority actuators for jets
  - LES simulations and adjoint optimization methods to find control strategies for minimum noise
- Experiments to show scalability of actuator system conducted
  - Noise scales **linearly** with actuator energy over 6:1 range

![Plasma Actuator Image](image.png)

- Actuator self noise
- Data scaled to 100Dj
- Baseline
- Noise scales linearly with actuator energy over 6:1 range

![Graph Image](graph.png)

- PSD (dB)
- St_Dj
- Dj=3"
- Dj=6.5"
N+2 GE IVP - Experiments

James Bridges, james.e.bridges@nasa.gov

- Full matrix + single-flow reference nozzle
- Far-field acoustics; PIV flow diagnostics; phased array source diagnostics
- Significant reduction when flow not separated

GE Three-Stream Nozzle
Inverted Velocity Profile and Fluid Shield

PIV Instantaneous Velocity Vectors

Separation

Phased Array Acoustic Source Distributions

Ideal Thrust

OAPWL (dB)

Flow separated in nozzle

CUTBACK low
REF low

5dB
• Flow separations produced tones in as-built configurations
• Flow surface modifications eliminated tones and but resulted in elevated broadband noise
• Redesign required to realize benefit of ejector
High Aspect Ratio Nozzles with Aft Deck - Acoustic Trends

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Sensitivity to Aspect Ratio (red=louder)

Sensitivity to Aft Deck Length
Three-Stream Jet Noise Studies

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![Diagram of three-stream nozzle with core, fan, and third stream highlighted.]

- mid and high frequencies
- on peak noise
- area ratio – results for other area ratios may

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**Frequency (Hz)**

**PSD (dB)**

1. Simulated 2-Stream Jet, $\text{BPR}_{\text{fan/core}} = 4.7$
2. Simulated 2-Stream Jet, $\text{BPR}_{\text{fan/core}} = 6.3$

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**Frequency (Hz)**

**PSD (dB)**

1. $1.8, 1.8, 1.0$
2. $1.8, 1.8, 1.3$
3. $1.8, 1.8, 1.5$
4. $1.8, 1.8, 1.8$
TWIN JET NOISE ACTIVITIES

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Noise from HWB deflected elevon using DAMAS phased array processing

Investigation of flexible filaments for supersonic jet noise reduction
Hybrid Wing Body Activities

Mike Doty, michael.j.doty@nasa.gov

Hybrid Wing Body (HWB) aeroacoustic test in NASA Langley’s 14-by-22-Foot Subsonic Tunnel will use two small Compact Jet Engine Simulators (CJES) mounted under inverted model.

Ultra Compact Combustor testing (valuable input from AFRL: J. Zelina)

Optimum low noise nozzles for HWB shielded configuration
Developing Technology Summary

- Acoustic analogy based prediction tools
- Jet-surface interaction studies
- Plasma actuation for noise control
- N+2 exhaust concepts
- Rectangular jet experiments
- Three-stream jet studies
- Twin-jet experiments
- Hybrid Wing Body Investigations
Abstract

The presentation highlights jet-noise research conducted in the Subsonic Fixed Wing, Supersonics, and Environmentally Responsible Aviation Projects in the Fundamental Aeronautics Program at NASA. The research efforts discussed include NASA’s updated Aircraft NOise Prediction Program (ANOPP2), acoustic-analogy-based prediction tools, jet-surface-interaction studies, plasma-actuator investigations, N+2 Supersonics Validation studies, rectangular-jet experiments, twin-jet experiments, and Hybrid Wind Body (HWB) activities.