NASA Jet Noise Research

Brenda Henderson
NASA

Turbine Engine Technology Symposium 2012
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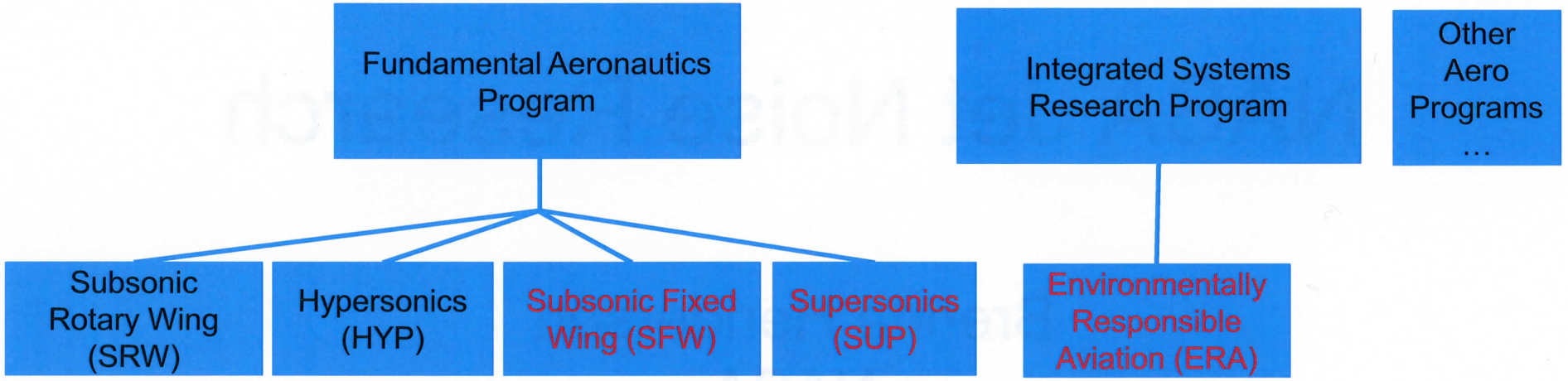
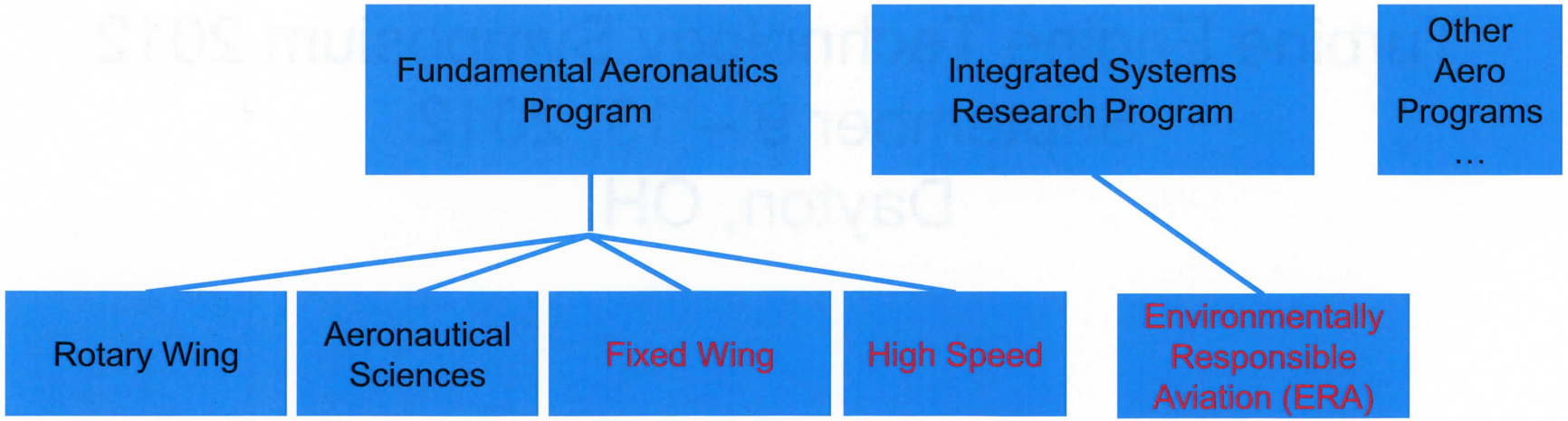
Dayton, OH

NASA Aeronautics Program

Pre FY13



FY13 +



ANOPP2: Mixed-Fidelity System Noise Capability

Casey Burley: casey.l.burley@nasa.gov

Semi-empirical ⟵ CAA

ANOPP
Engine
Airframe
Shielding

Brooks Self
Trailing edge

MIT
shielding

UCI
Jet-scattering

FSC
scattering

Brooks Self + CFD
Trailing Edge

Boeing
Slat, TE, Flap, LG

LGMAP
Landing Gear

TFAN+BFAN/CDUCT
Fan + duct propagation

ANOPP-Stone
Jet

MDOE
Jet + Chevron

Jet3D: PAA
Jet & Pylon

JENO
Jet

RISN
Jet

ANOPP-PAS
Open rotor

CRPFAN
Open rotor

Py-ASSPIN
Open rotor

(ORAS)++
Open rotor

Semi-empirical single and dual stream jet predictions

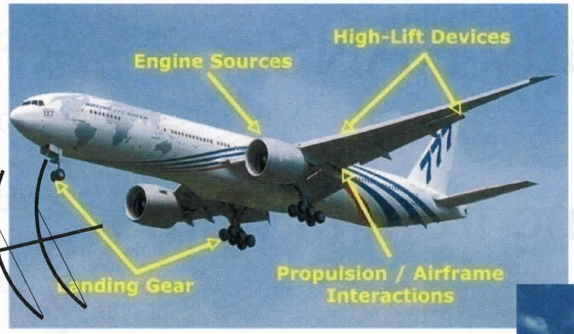
Noise reduction predictions obtained from experiments

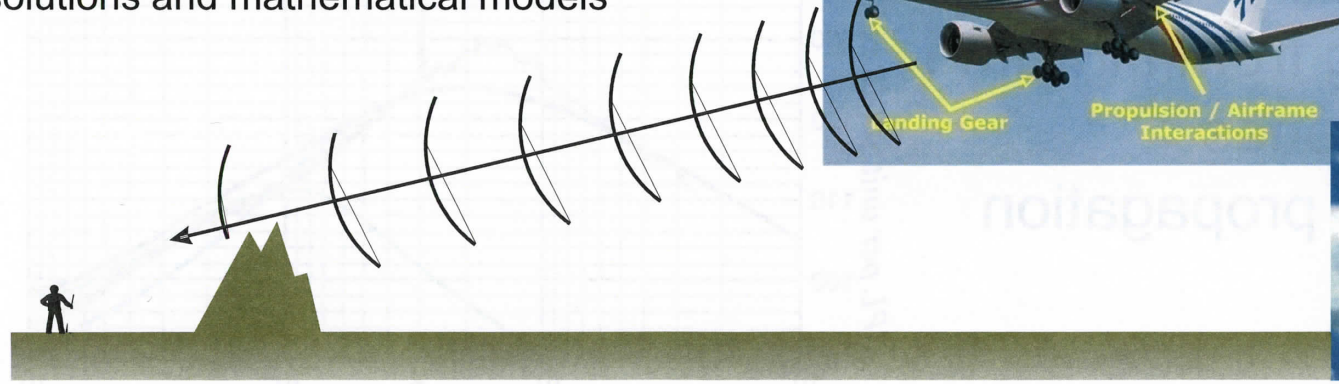
*Jet-pylon interaction predictions using an acoustic analogy

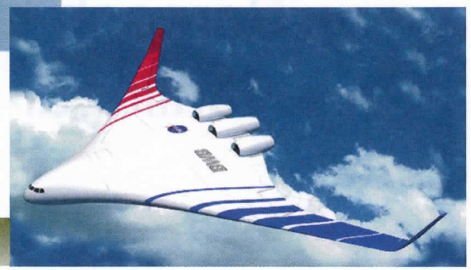
*Supersonic jet predictions using an acoustic analogy

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

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





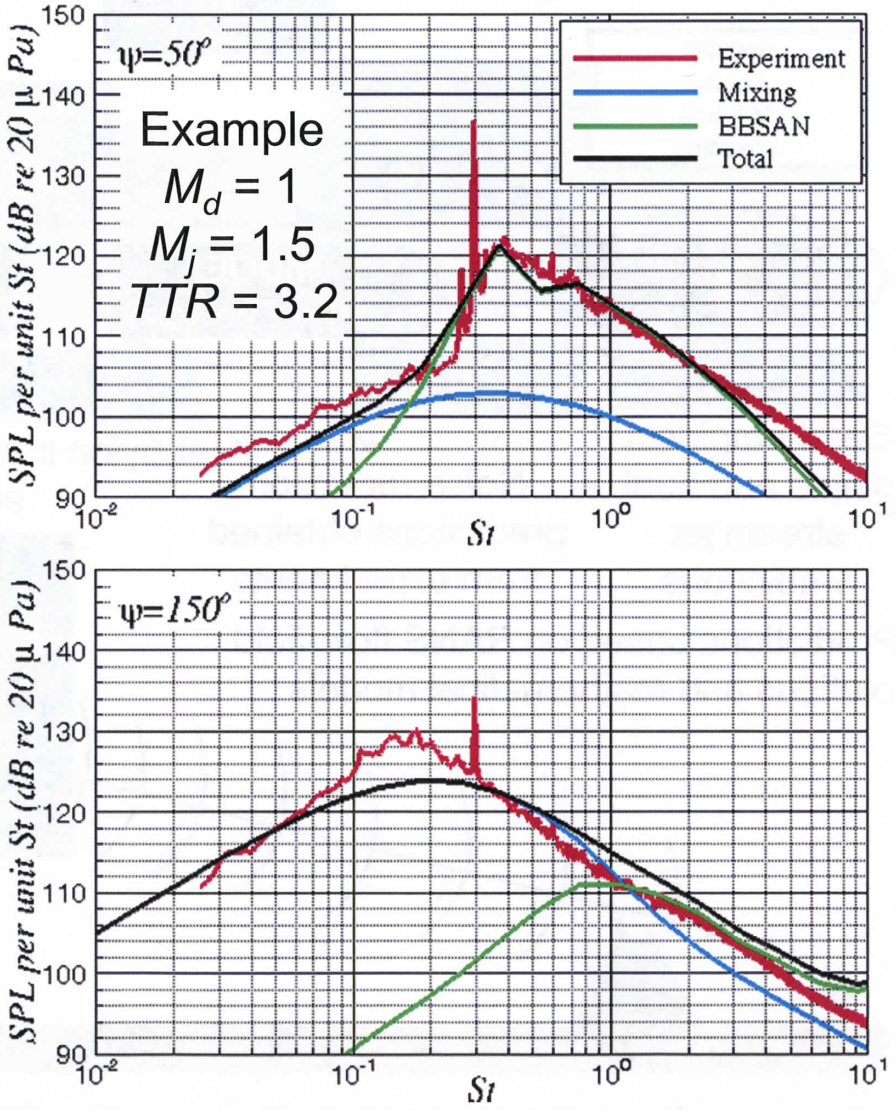


Receiver ⟵ Propagation ⟵ Source

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

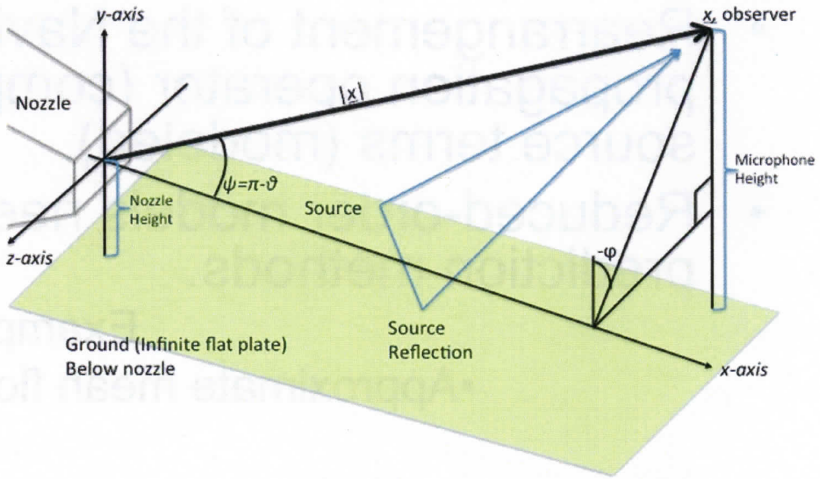


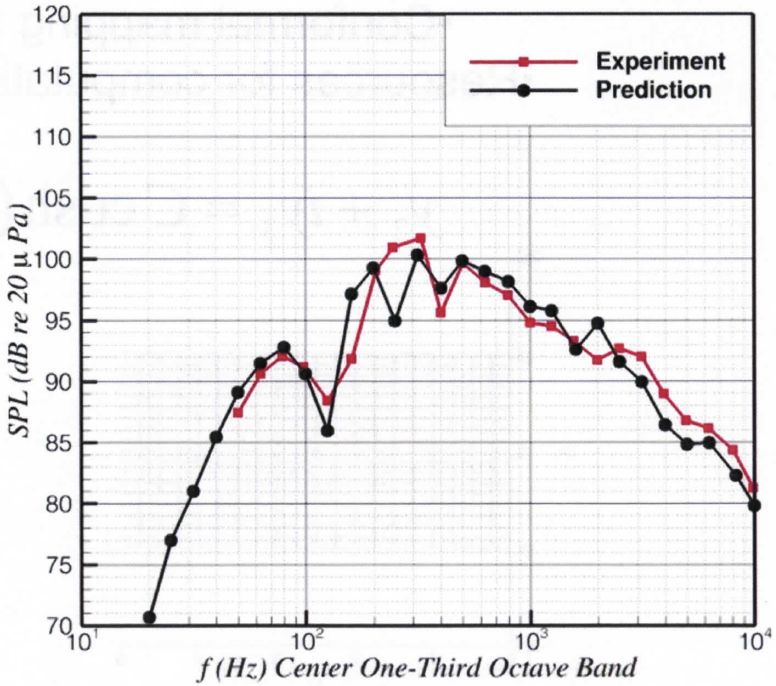
Acoustic Analogy - RISN

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

$$V = i\int_{-m}^{\infty} \frac{H_1^{(1)}\left(\mu^2 + kR\right)}{\sqrt{\mu^2 + 2kR}} d\mu + i\int_{-m_p}^{\infty} \frac{H_1^{(1)}\left(\mu^2 + kR_p\right)}{\sqrt{\mu^2 + 2kR_p}} d\mu$$

- Includes ground absorption model





Acoustic Analogy-Based Noise Predictions for Non-Circular Jets

Stewart Leib, stewart.j.leib@nasa.gov

- 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.

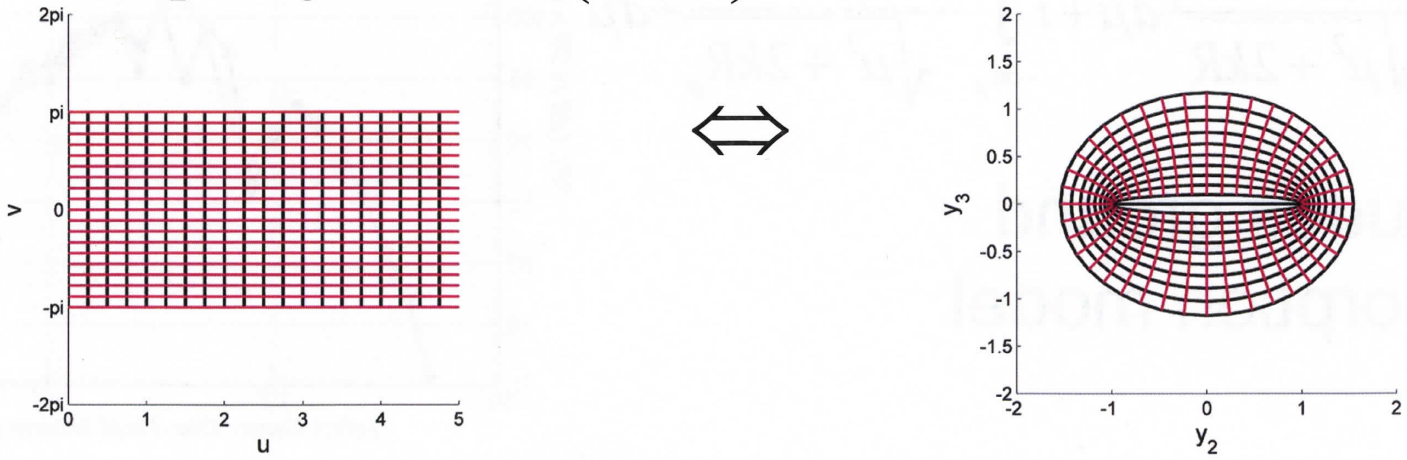
Example: Rectangular Jets

•Approximate mean flow in cross-flow planes by concentric ellipses.

•Conformal mapping to cylindrical elliptical coordinates.

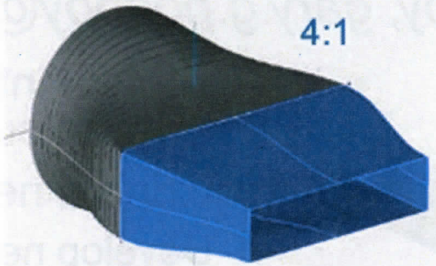
•Resources for computation in mapped domain similar to round jets.

$$y_2 + iy_3 = C\cosh(u + iv), \quad C \text{ is a real constant}$$



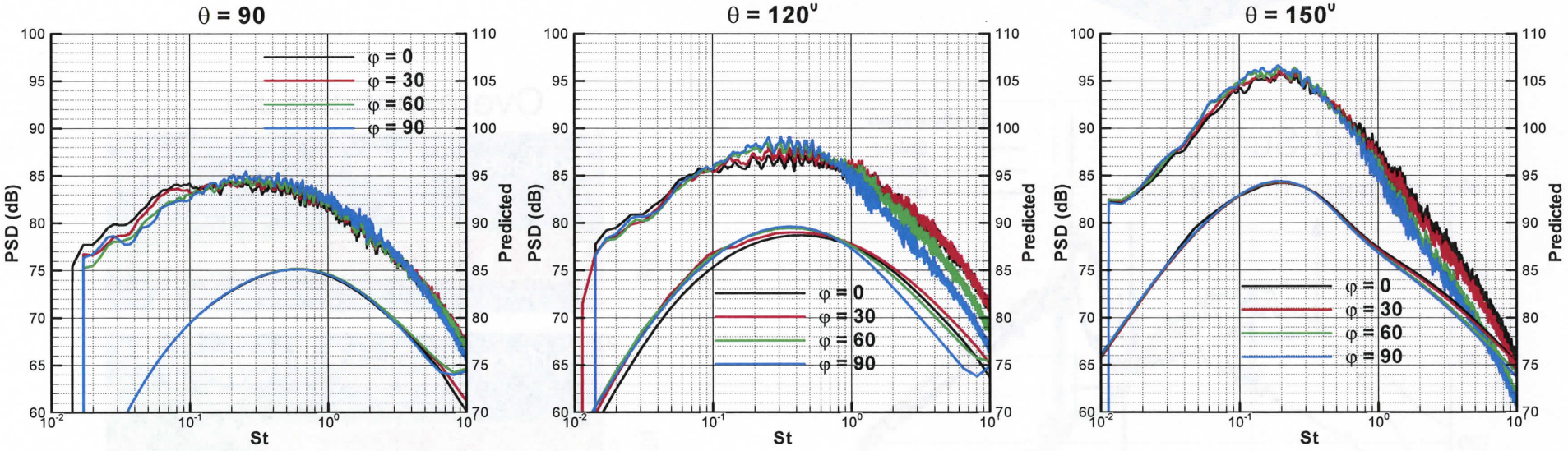
Acoustic Analogy-Based Noise Predictions for Non-Circular Jets

NPR=1.4
Ma = 0.7



Minor axis plane
$\varphi = 0^{o}$

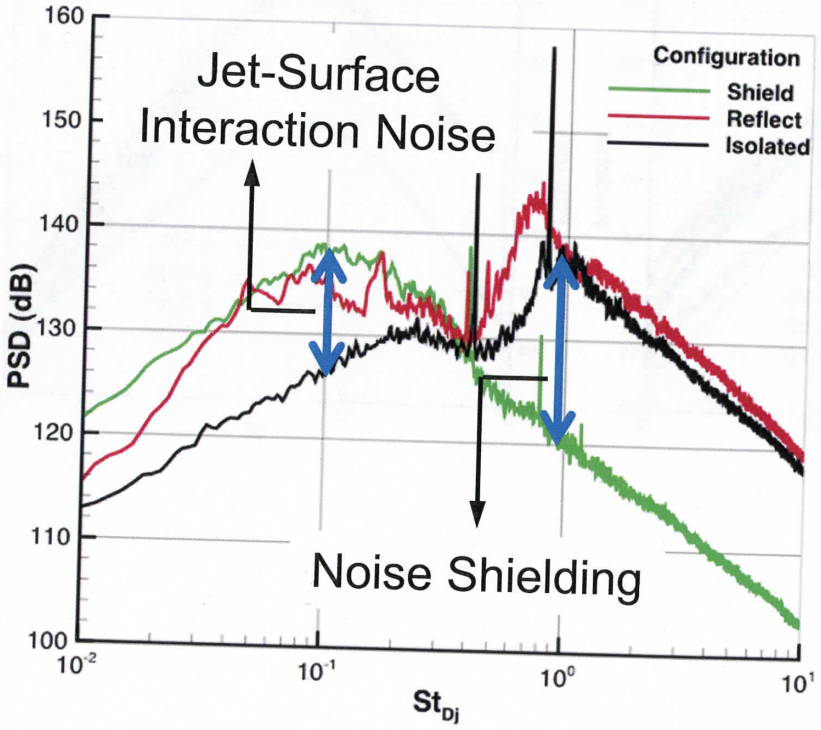
Major axis plane
$\varphi = 90^{o}$

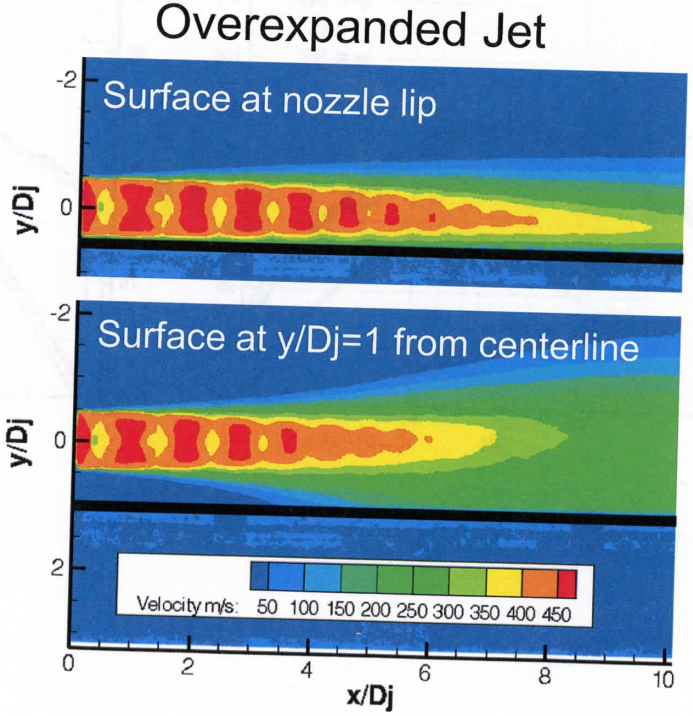


Jet-Surface Interaction Tests

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

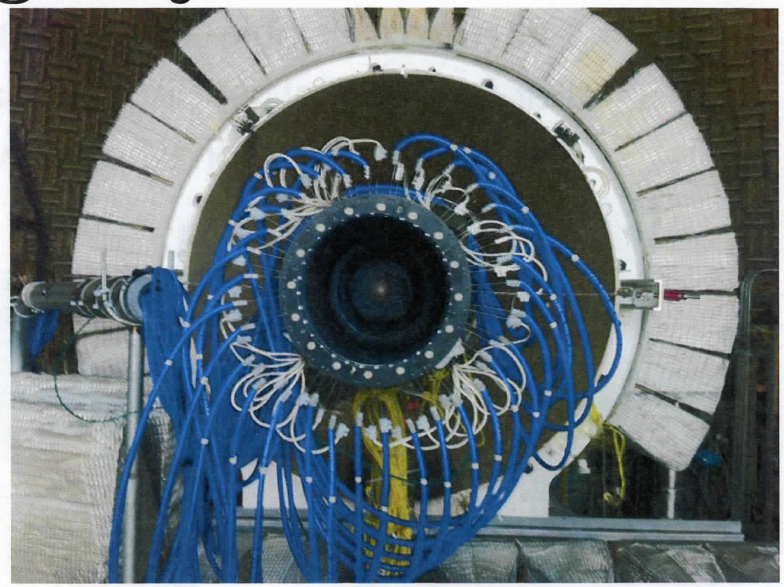


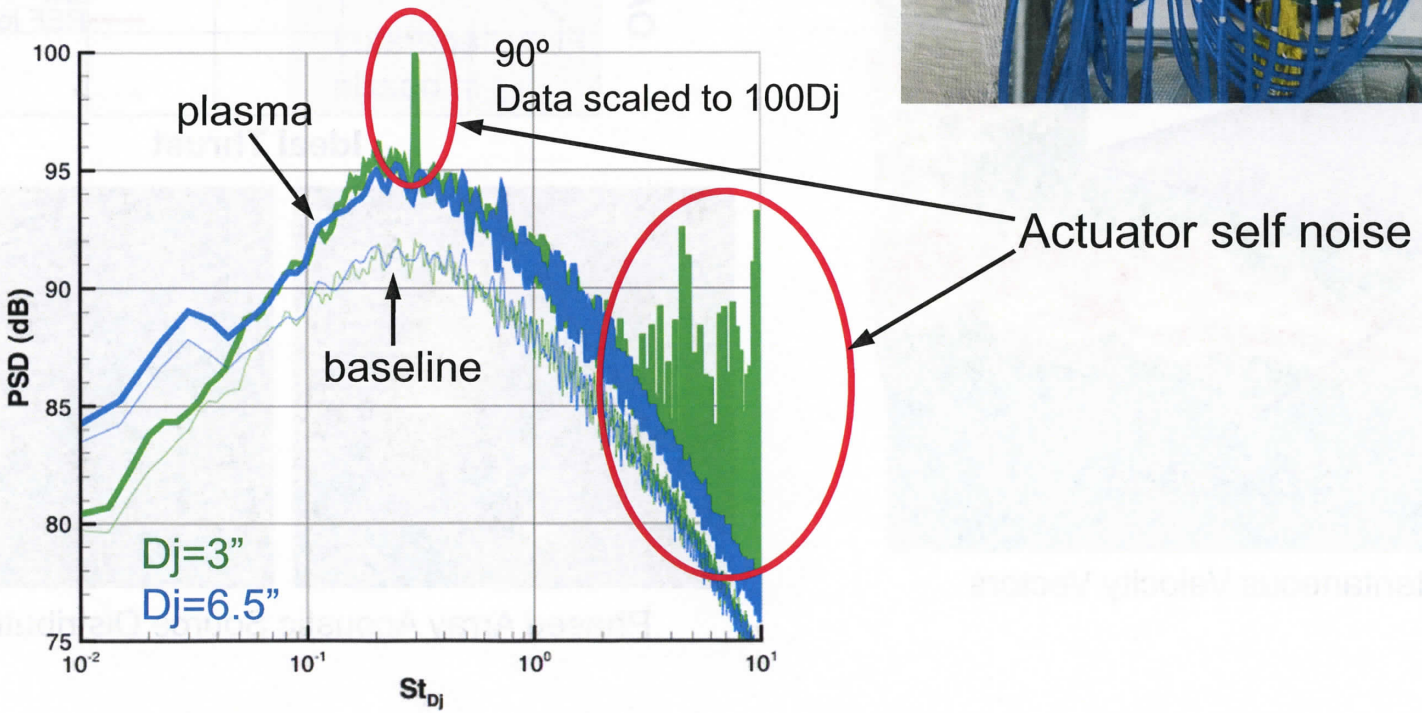


Plasma Actuator for Jet Turbulence Control

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

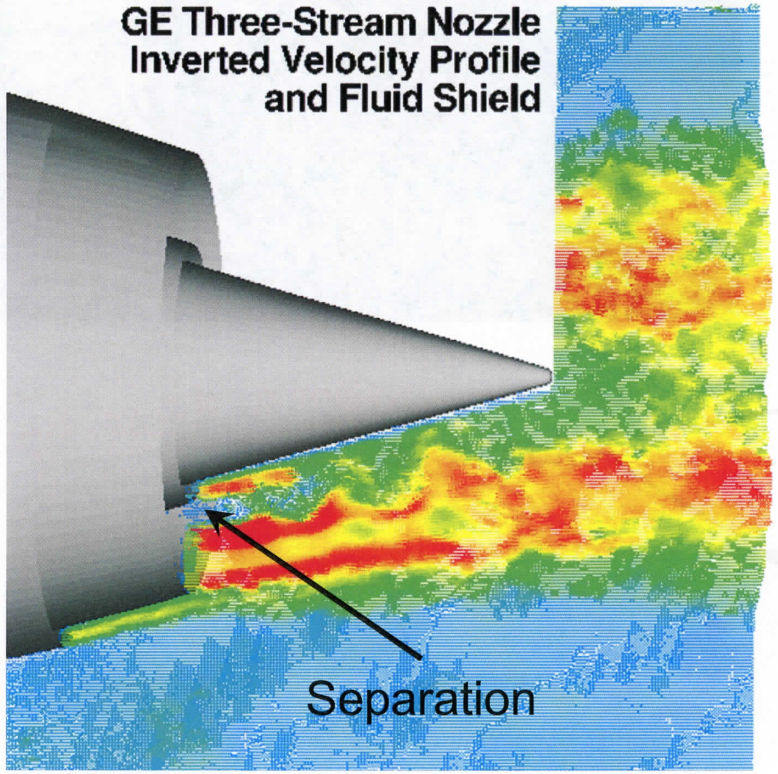




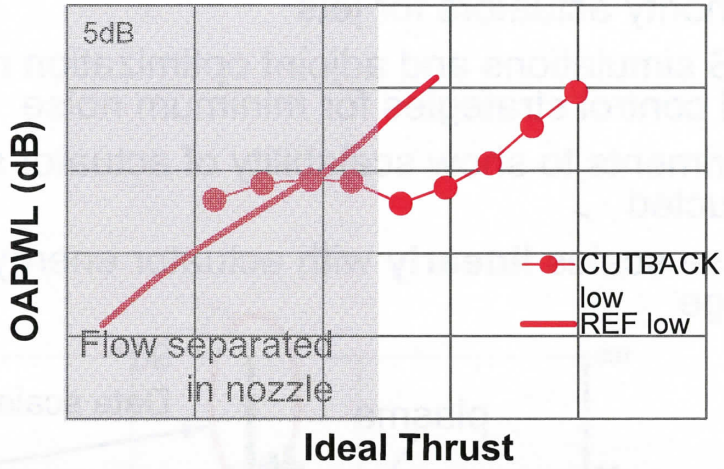
N+2 GE IVP - Experiments

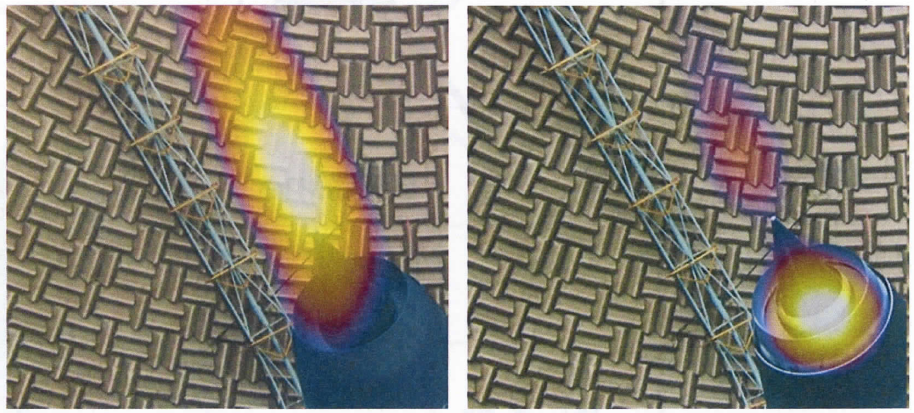
James Bridges, james.e.bridges@nasa.gov

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



PIV Instantaneous Velocity Vectors

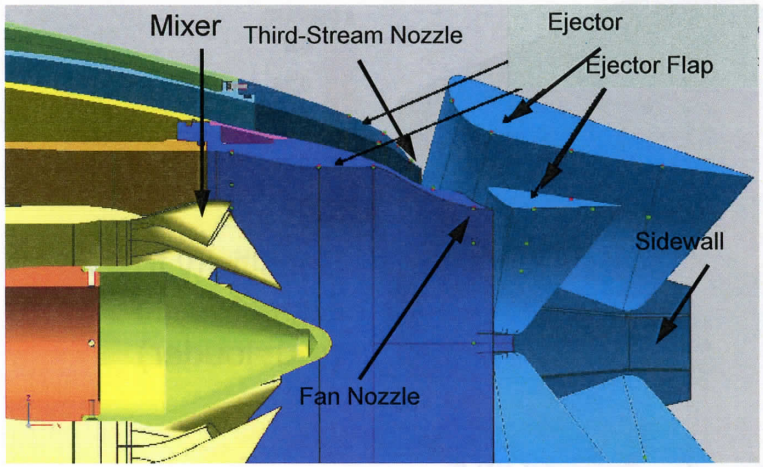




Phased Array Acoustic Source Distributions

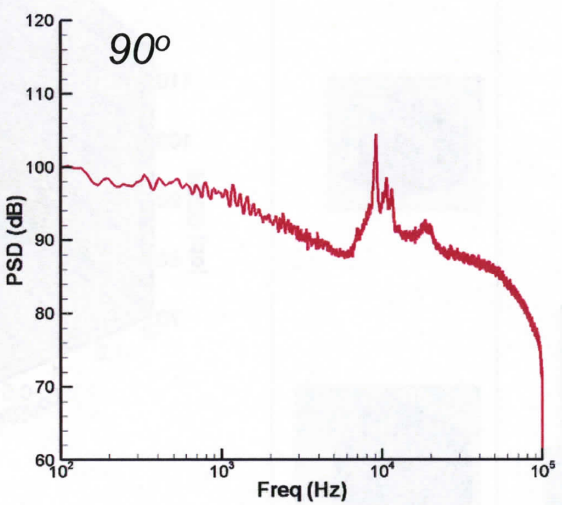
N+2 Rolls-Royce Ejector

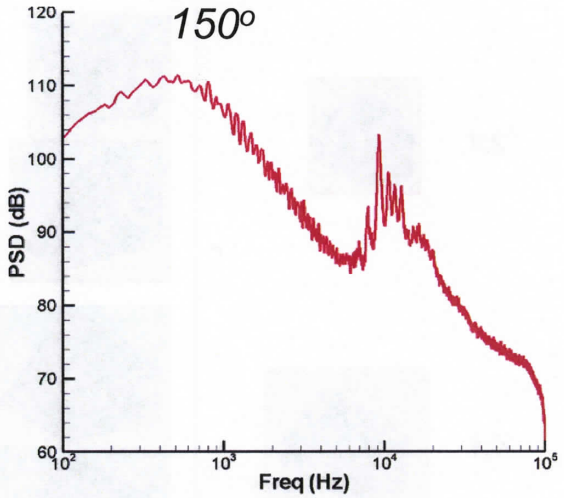
Brenda Henderson, brenda.s.henderson@nasa.gov



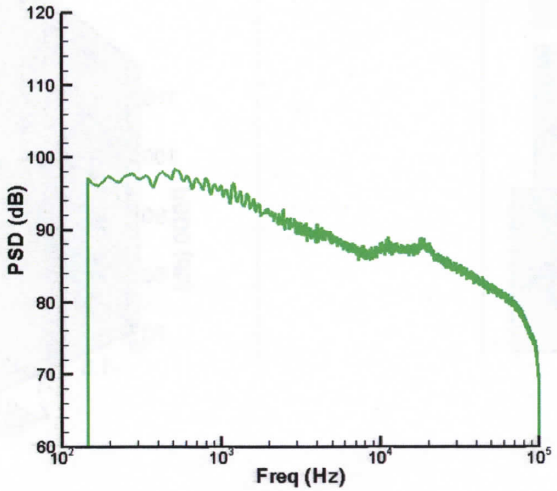
- Flow separations produced tones in as-built configurations
- Flow surface modifications eliminated tones and but resulted in elevated broadband noise
- Redesign required to realize benefit of ejector

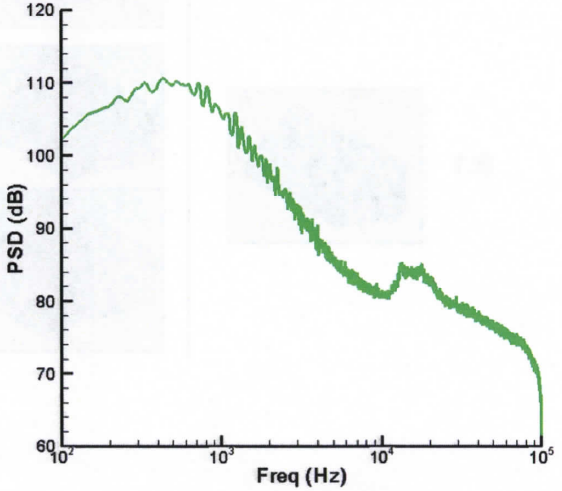
As-Built Configurations





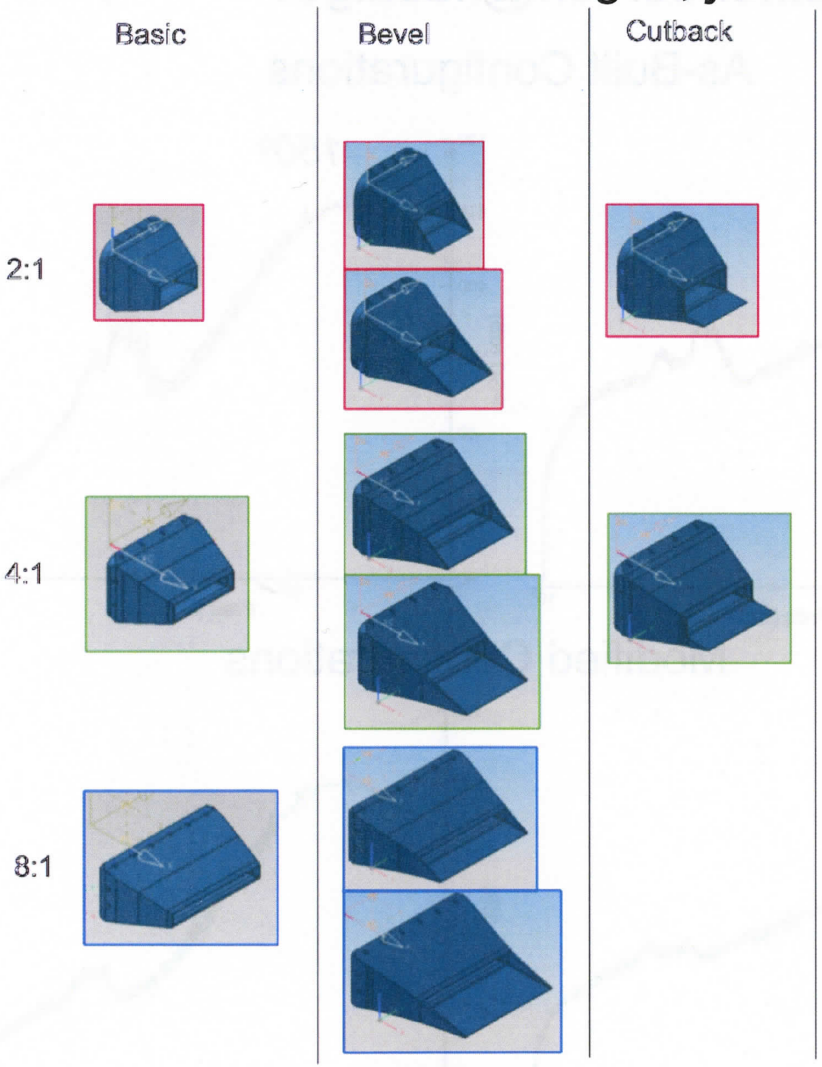
Modified Configurations

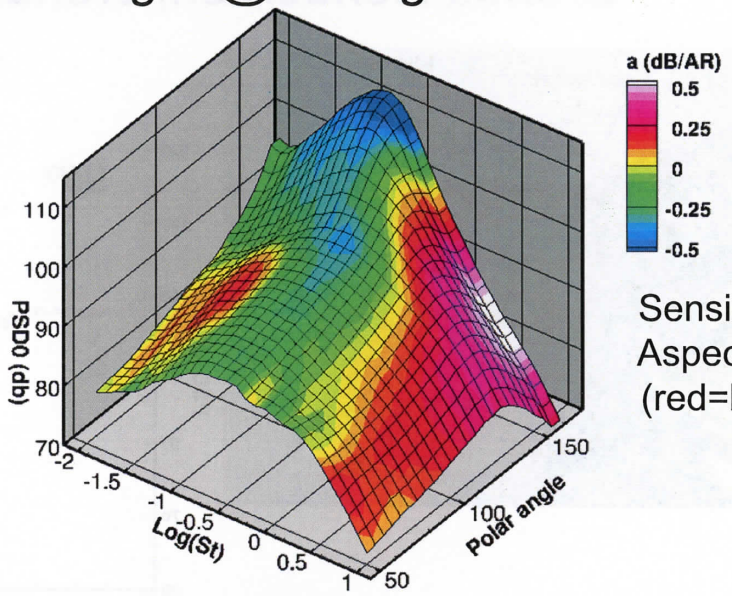




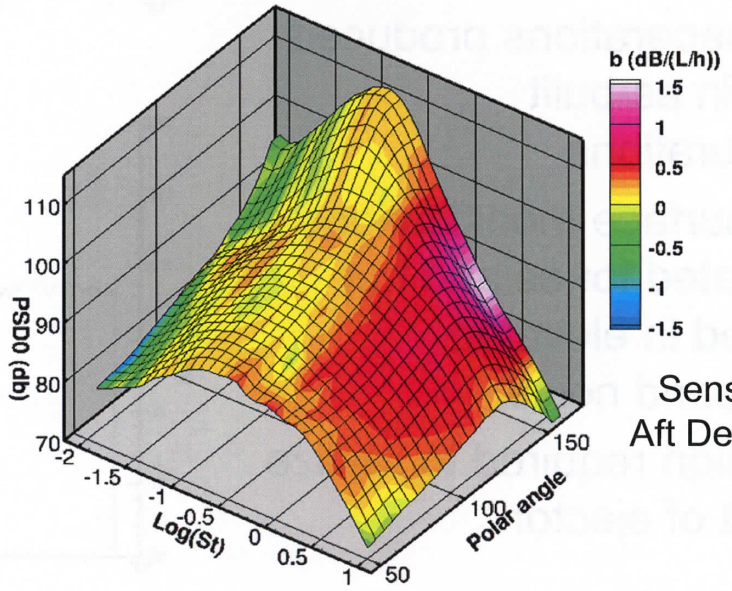
High Aspect Ratio Nozzles with Aft Deck - Acoustic Trends

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





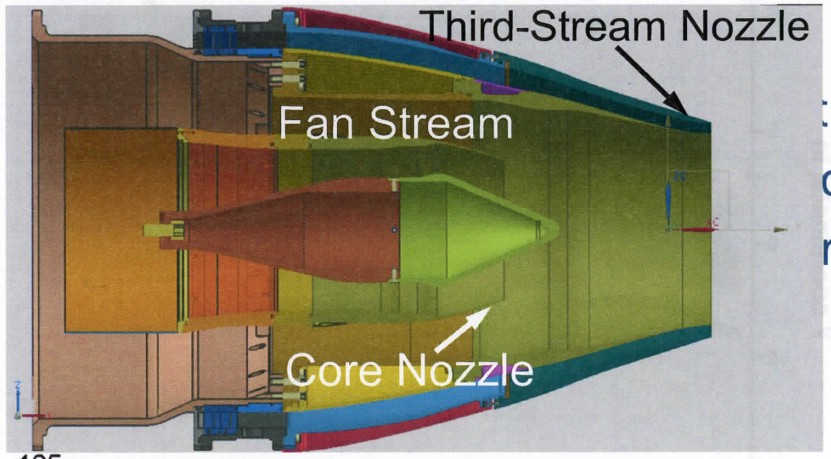
Sensitivity to Aspect Ratio (red=louder)



Sensitivity to Aft Deck Length

Three-Stream Jet Noise Studies

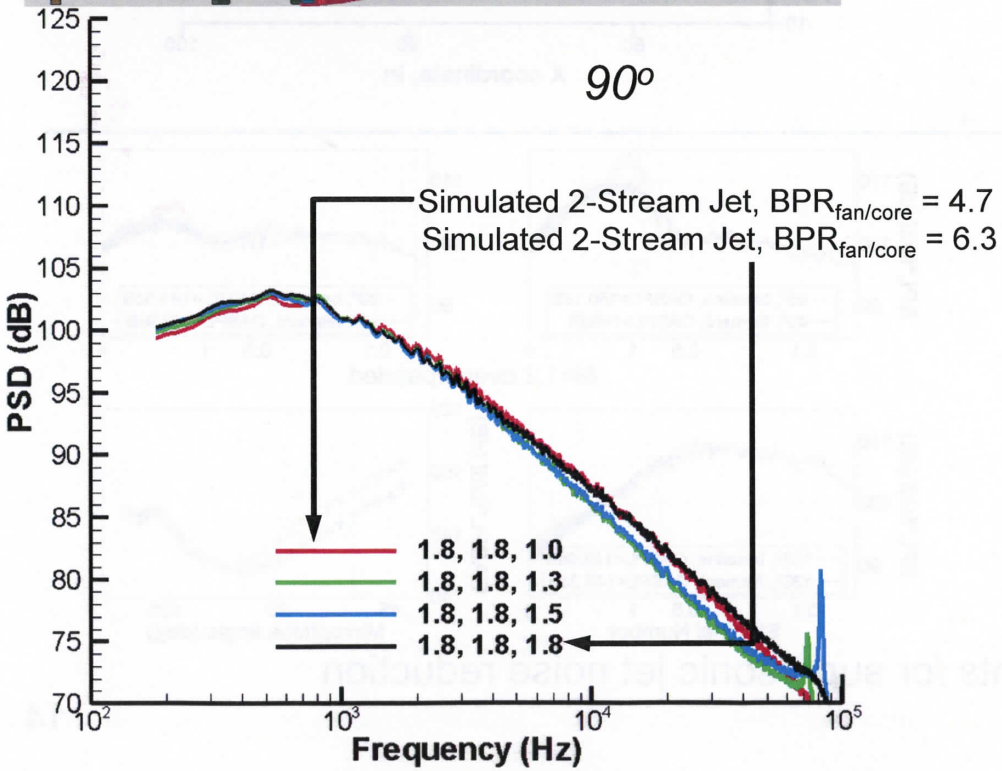
Brenda Henderson, brenda.s.henderson@nasa.gov

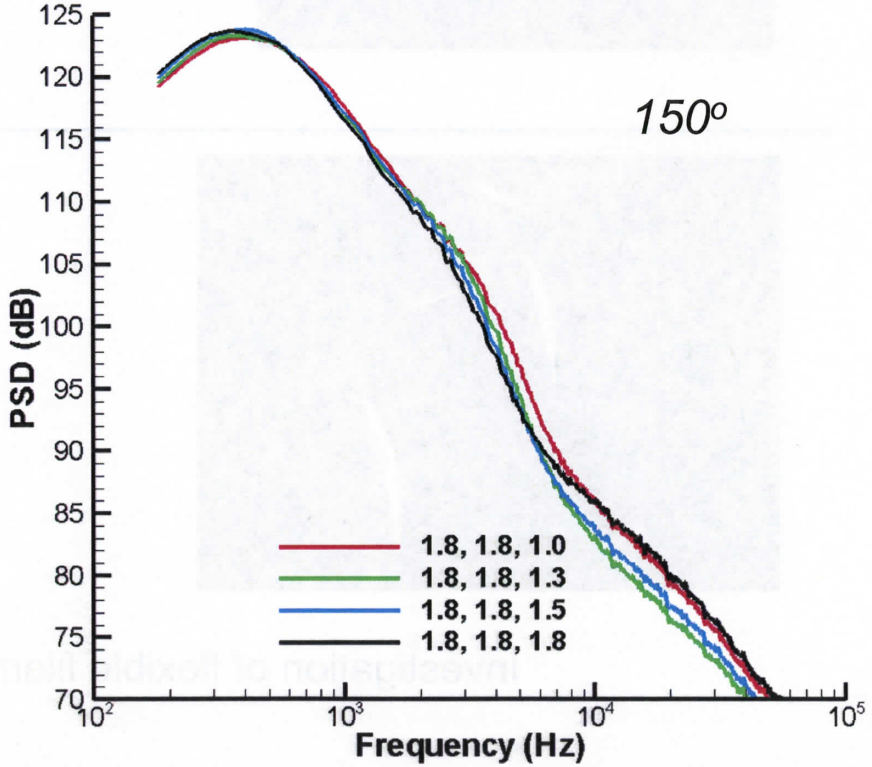


: mid and high frequencies

on peak noise

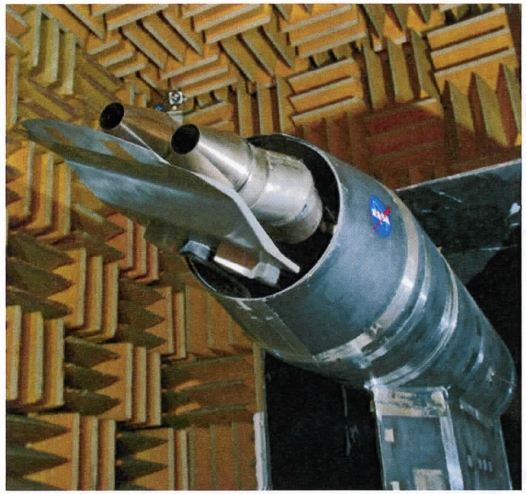
rea ratio – results for other area ratios may



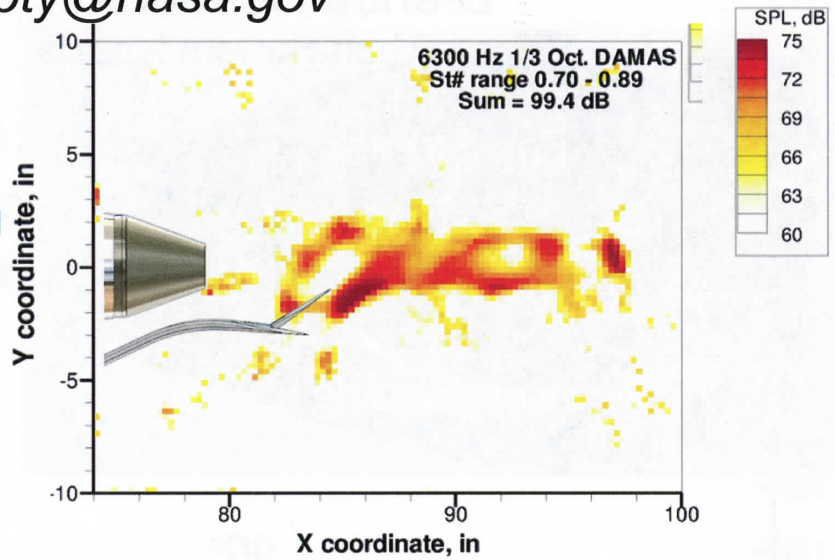


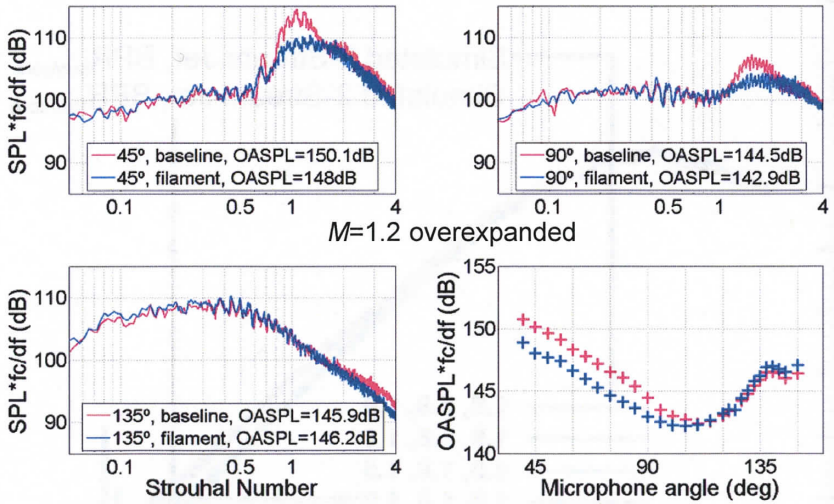
TWIN JET NOISE ACTIVITIES

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



Noise from HWB deflected elevon using DAMAS phased array processing



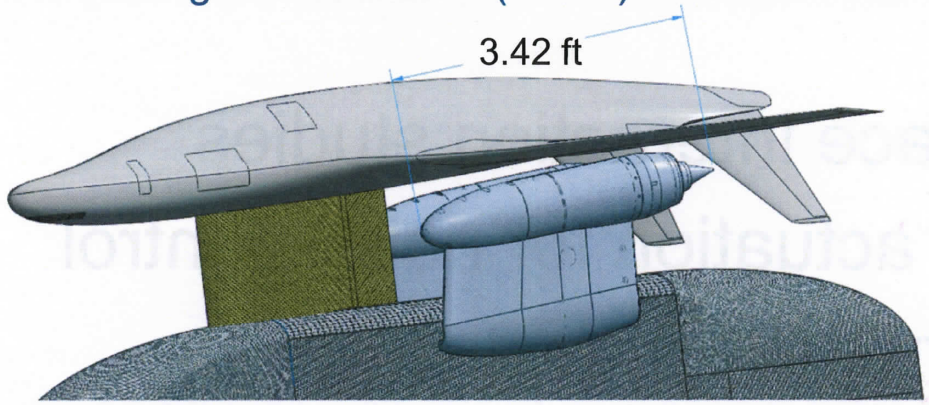


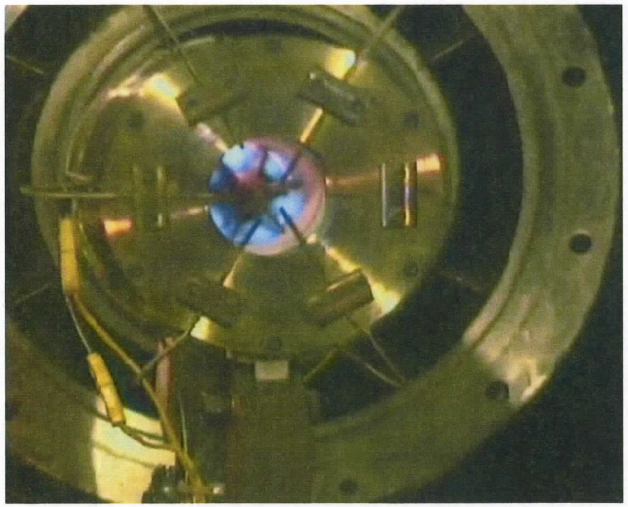
Investigation of flexible filaments for supersonic jet noise reduction

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.