Fundamental Aeronautics Program

Supersonics Project

Airport Noise Overview
James Bridges, Technical Lead

2012 Acoustic Technical Working Group
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Cleveland, Ohio

www.nasa.gov
Technical Challenge: Airport Noise

• What are we trying to do?
  – Allow supersonic aircraft to be acoustically acceptable around airports.
  – Develop low noise concepts and the ability to engineer them on low-boom supersonic aircraft.

• What is our approach?
  – Develop and use physics-based codes more and experiments less.
  – Couple both code and concept development to delivery of system-level noise prediction modules

• What are the payoffs if successful?
  – Documented noise reduction technologies with ability to trade design parameters against other design goals.
  – Detailed, physics-based jet noise prediction tools applicable to all stages of aircraft design.
Measuring Progress:
Airport Noise Technical Challenge Milestones

What are the intermediate and final exams to check for success?

- Suite of noise prediction codes at multiple fidelities, validated in component tests.
- Refinement of key low-noise concepts, captured in system-level prediction tools.
- Suite of tools used in multi-objective optimization exercise.

Recent Progress Toward Meeting Technical Challenge

- Tool Development
  - Completed Greens function code for HARN jets.
  - Validated unstructured CFD (RANS & LES) for prediction of nozzle plumes.
- Concept Development
  - Assessed three-stream mixer-ejector variable cycle nozzle concept
  - Assessed inverted velocity profile and fluid shield concept
  - Assessed scalability of plasma actuation for jet turbulence control.
  - Designed low-noise high-aspect ratio nozzles.
NASA External Collaborations

Recently Completed NRA


Ongoing

- **NRA: N+2 System Validation**, Lockheed-Martin, Rolls-Royce LibertyWorks, GE Global Research, John Morgenstern, PI
- **SBIR Phase II: LES of Rectangular Nozzles**, CRAFT Tech, Neeraj Sinha, PI.

Other Government Agencies

- **Air Force/Navy/NASA Cooperation on SBIR/STTR** for Jet Noise Research topics
- **Navy/NASA Research Opportunity**: joint funding of 8 awards in jet noise experiments, LES development, and noise reduction

14:20 Thursday—Brenda Henderson
### Airport Noise Tech Challenge at a Glance

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**Tool Development Scale**

- Needs Development
- Ready
N+2 System Validation Nozzle Test—NASA

- N+2 Low Noise Nozzle concepts use three-stream engine architecture to achieve highly variable cycles.
- Test rig required second fan stream to test concepts for noise.
- NASA GRC High Flow Jet Exit Rig modified to provide *quiet* third stream coannular to existing Rig in same outer envelope.
N+2 System Validation Nozzle Test—LM/RRLW

- Three-Stream Mixer-Ejector
  - Lockheed Martin/RR-LibertyWorks contract
  - Model hardware designed and built by RR-LW
  - Three-stream engine test rig provided by NASA
  - Acoustic and flow diagnostic testing performed at NASA
  - Nozzle tested in complicated subsonic ejector mode

- Objective
  - Validate low-noise operation of highly variable nozzle
  - Validate acoustic design tools

- Outcome
  - External jet noise satisfy noise requirements
  - Internal resonances spoil total success
  - Steady RANS CFD did not foreshadow resonances
  - Shows importance of unsteady flow design tools, unstructured grid methods
N+2 System Validation Nozzle Test—LM/GE

- Inverted Velocity Profile w/Fluid Shield
  - Lockheed/GE Global Research contract
  - Model hardware designed and built by GE GR
  - Acoustic and flow diagnostic testing performed at NASA
  - Hot stream inversion in GE model hardware.

- Objective
  - Validate low-noise operation of nozzle with variable cycle conditions, shield orientations
  - Validate acoustic design tools

- Outcome
  - IVP and fluid shield benefit demonstrated when nozzle operating properly expanded.
  - Over-aggressive divergence removed benefit at low-speeds.
  - Steady RANS CFD did not predict divergence issue.
  - Shows need for prediction of noise from separations.
Plasma Actuator for Jet Turbulence Control

- Jet Turbulence Control
  - Control jet turbulence via instabilities
  - NASA/OSU collaboration to develop high-authority actuators for jets
  - LES simulations and adjoint optimization methods to find control strategies for minimum noise

- Objective
  - Replicate jet control in university lab
  - Demonstrate scaling of actuator authority with nozzle size

- Outcome
  - Small-scale results replicated
  - Jet response scales \textit{linearly} with actuator energy over 6:1 range
  - Require more work on optimization strategies for reduction

16:10 Thursday—Cliff Brown
Validation of Unstructured CFD—RANS & LES

- CFD critical to design of realistic exhaust systems
  - Accurate TKE in plume for noise
  - Accurate separation prediction
  - Non-dissipative LES schemes
- Objective
  - Validate total CFD approach—grid, solver, turbulence models—for several codes
  - Adopt best practices to obtain “good enough” solutions
- Outcome
  - New Wind-US unstructured code validated and documented
  - Low-order LES demonstrated and limitations explored

Grid:
- 11M
- 293M

Data
- Rectangular jet
- Isotemperature
- (CharLES code)

Far-field sound spectra

Jet centerline
Nonaxisymmetric Greens Functions

- CFD-based noise prediction
  - Requires Greens function to couple turbulent source to far-field observer
  - Important to capture beneficial noise refraction

- Objective
  - Create and validate analytic approximations for twin jets, fluid shield, etc.

- Outcome
  - Initial results encouraging, illustrative
  - Validation in process

![Twin Jet Test Rig, AAPL](image)

15:40 Thursday—Stew Leib
Including Surfaces in Propulsion Noise

- Airframe critical in prediction of source and propagation of propulsion noise
- Green's functions for RANS-based prediction tools must include surfaces
- Adjoint methods make computation feasible
- Requires stretch in far-field approximation
- Pushing acoustic analogy where it hasn't gone before, starting with ground effects.

Minimum Propulsion-Airframe Interaction...
Recent Publications
