Sonic Boom Research at NASA Dryden: Objectives and Flight Results from the Lift and Nozzle Change Effects on Tail Shock (LaNCETS) Project

Presentation to the
International Test & Evaluation Association

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Outline

Big Picture – Sonic Boom Research
Previous Flight Projects
LaNCETS Objectives
Flight Research Approach
Results
Questions
The principal objective of the Supersonics Project is to develop and validate multidisciplinary physics-based predictive design, analysis and optimization capabilities for supersonic vehicles. For aircraft, the focus will be on eliminating the efficiency, environmental and performance barriers to practical supersonic cruise.
Supersonics Project
Technology Challenge Areas

Efficiency Challenges
Supersonic Cruise Efficiency - Airframe & Propulsion
Lightweight & Durable Materials at High Temperatures

Environmental Challenges
Airport Noise
Sonic Boom
High Altitude Emissions

Performance Challenges
Aero-Propulso-Servo-Elastic Analysis & Design
Sonic Boom Research at NASA Dryden

Modeling of Atmospheric Effects

Near-Field Probing

Mid-Field Probing

Developing & Validating Design Tools

Modeling of Transmission into Structures

Ground Sensors
### Past Probing Research

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Researcher</th>
<th>Date</th>
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<tbody>
<tr>
<td>F-100</td>
<td>Mullens</td>
<td>1956</td>
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<tr>
<td>B-58, F-100, F-104</td>
<td>Smith</td>
<td>1960</td>
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<tr>
<td>B-58 with F-100</td>
<td>Maglieri</td>
<td>1963</td>
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<tr>
<td>F-18 with F-16XL-2</td>
<td>Haering</td>
<td>5/1993</td>
</tr>
<tr>
<td>SR-71B with F-16XL-2</td>
<td>Haering</td>
<td>7/1993</td>
</tr>
<tr>
<td>SR-71A with F-16XL-1</td>
<td>Haering</td>
<td>2-5/1995</td>
</tr>
<tr>
<td>F-5E with F-15B-836</td>
<td>Haering</td>
<td>2/2002</td>
</tr>
<tr>
<td>Quiet Spike with F-15B-836</td>
<td>Haering</td>
<td>12/2006</td>
</tr>
</tbody>
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Propagation of Shaped Sonic Boom
Shaped Sonic Boom Demonstrator

2003/2004

F-15B Near-field Shock Probing Aircraft

F-5E “Shaped” for Reduced Sonic Boom

Blanik L-23 Mid-field measurements

Proved that a Shaped Sonic Boom could propagate all the way to the ground

Aug 27, 2003 1st ever recorded shaped boom propagated to the ground
Non-Coalescence of forebody shocks
Quiet Spike validated design tools that showed that shocks of equal strength would not coalesce into a single strong shock ... this propagation was shown 500 feet below the a/c.
Propagation of Shaped Sonic Boom through the atmosphere to the ground (F-5 SSBD experiment)

Validation of Design Tools for Forebody Shape Modifications (F-5 SSBD & Quiet Spike experiments)

What’s Next?

Need to validate design tools for Tail Shock modification

Aft region shocks difficult to predict / design

→ Tail surfaces
→ Propulsion system
Supersonics Project
FY08 Congressional Milestone
8AT12

Demonstrate a high fidelity analysis
technique for assessing the impact of nozzle
plume effects on the off body flow field of a
supersonic aircraft and validate predicted
results within 5% of flight data.

NASA Langley, Ames, & Dryden -
Analysis techniques (i.e. CFD prediction tools)

NASA Dryden - Flight Research
Lift and Nozzle Change Effects on the Tail Shock (LaNCETS)

Research Objective

Obtain Flight Data to Develop and Validate design tools for low-boom Tail Shock modifications

Research Approach

Alter the shock structure of NASA’s unique NF-15B TN/837 by:
- changing the lift distribution by biasing the canard positions
- changing the plume shape by under- and over-expanding the nozzles
- changing the plume shape using thrust vectoring

Measure resulting shocks with a probing aircraft (F-15B TN/836)

Use results to validate / update predictive tools
1st pre-production F-15B
Modified ~ mid-80’s for Air Force STOL/MTD
   - Digital Fly-by-wire Flight Control System
   - Canards
   - 2-DThrust vectoring capability
NASA obtained the aircraft in the early 90’s
   - Multi-axis thrust vectoring (up to 20°)
   - F100-PW-229 engines
   - Research Flight Control System
      - Inner-Loop Thrust Vectoring Control Laws
      - Dataset for Programmed Test Inputs
LaNCETS Flight Envelope

The diagram shows a flight envelope with axes for Mach number and altitude. The envelope includes various symbols and annotations:

- ITB Clearance
- ITB, Dataset Clearance
- Nominal Probing Condition
- Supplemental Probing Condition
- ASE Clearance

The envelope is marked with cleared areas during ILTV Phase I and includes annotations for different operational phases and conditions.
Lift Distribution Changes

Canard position used to alter the lift distribution longitudinally over the aircraft

- trailing edge down offloads wing / increases lift on stabs
- trailing edge up increases wing loading / offloads stabs

Flight Data Mach 1.6 / 40kft
“Simplified” Nozzle Plume or Thrust Vectoring Effect on Shock Structure

Graphic from Trong Bui’s AIAA paper presented at ASM in January 2009
Cockpit Aircraft Position Display

- Computer & display mounted in rear cockpit of the probing aircraft
- Rear seater can suggest fine position and rate adjustments to the pilot
- Enhances test point efficiency and quality
Preflight Prediction - LaRC CFD

Computation Tools are being developed at LaRC, ARC, & DFRC for predicting tail wake / shock / plume interactions. CFD predicted significant changes due to canard trims at M1.4 / 40kft.

\[ \delta_c = -5.4^\circ \]

\[ \delta_c = 3.3^\circ \]

\[ \delta_c = 0^\circ \]
Flight Results

Preliminary … Still a work in progress
Probing Data Set

Phase 1 - baseline F-15 probing (Completed June 19, 2008 - Mach 1.2, 1.4, & 1.6 at 40kft)

Phase 2 - probing with canard and nozzle area ratio changes and thrust vectoring (Completed Jan 30, 2009)

- 13 Flights (11 with F-15 836 probing aircraft)
- Completed shock wave probing of canard trims at
  - M1.2 / 40kft (positive & negative canard trim)
  - M1.4 / 40kft (positive & negative canard trim)
  - M1.6 / 40kft (positive & negative canard trim)
- Unable to effect nozzle area ratio change with datasets supersonically (successfully demonstrated subsonic nozzle AR trim change)
- Investigated plume effects without nozzle area ratio trim at 40kft (M1.2 & M1.4) and at 48kft (M1.4) in conventional mode
  - Enhanced Mode Area Ratio = 1.5
  - Conventional Mode Area Ratio = 1.3
- Thrust vectoring probing
  - M1.2/40kft --> +6° pitch, -6° pitch, and ±3° yaw splay
  - M1.4/40kft --> +8° pitch and -8° pitch
    (note: positive pitch vectoring causes nose down pitching moment)
Phase 1 Baseline Aircraft Nearfield Probing Data

F-15-837 LaNCETS 06/18/08 Flt 228 Sig. #3, Mach 1.4

Diagram showing pressure distribution and locations such as noseboom, radome, inlet-canard, canard-wing gap, wing trailing edge, vertical leading edge, exhaust plume, bow, and tail. The diagram includes axes for x, ft, and z, ft, with a scale for direction of probe.
Mach 1.4 - Shock propagation results
Canard deltas – probing comparisons
Thrust Vectoring deltas - probing comparisons
• NASA NF-15B #837 last flight flown on Jan 30, 2009
• Last flight phase supported ARMD Supersonics Project
  LANCETS – Lift And Nozzle Change Effects on Tail Shock
  Changed lift with canard command bias
  Vectored nozzles – up, down, split
• Flight results are now available to provide truth data for developing and validating the CFD tools required to design low-boom supersonic aircraft
Questions?

The LaNCETS Team ... Final Flight Jan 30, 2009