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

NASA
Aeronautics Research Mission Directorate
Fundamental Aeronautics Program
Supersonics Project

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.

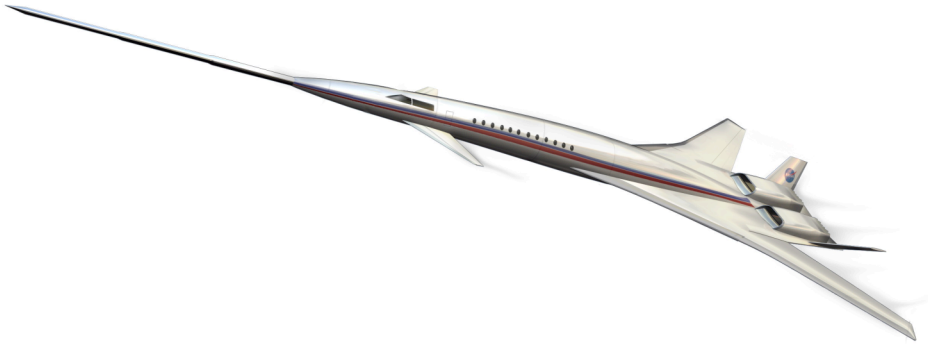
Supersonics Project
Technology Challenge Areas

Efficiency Challenges

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

Environmental Challenges

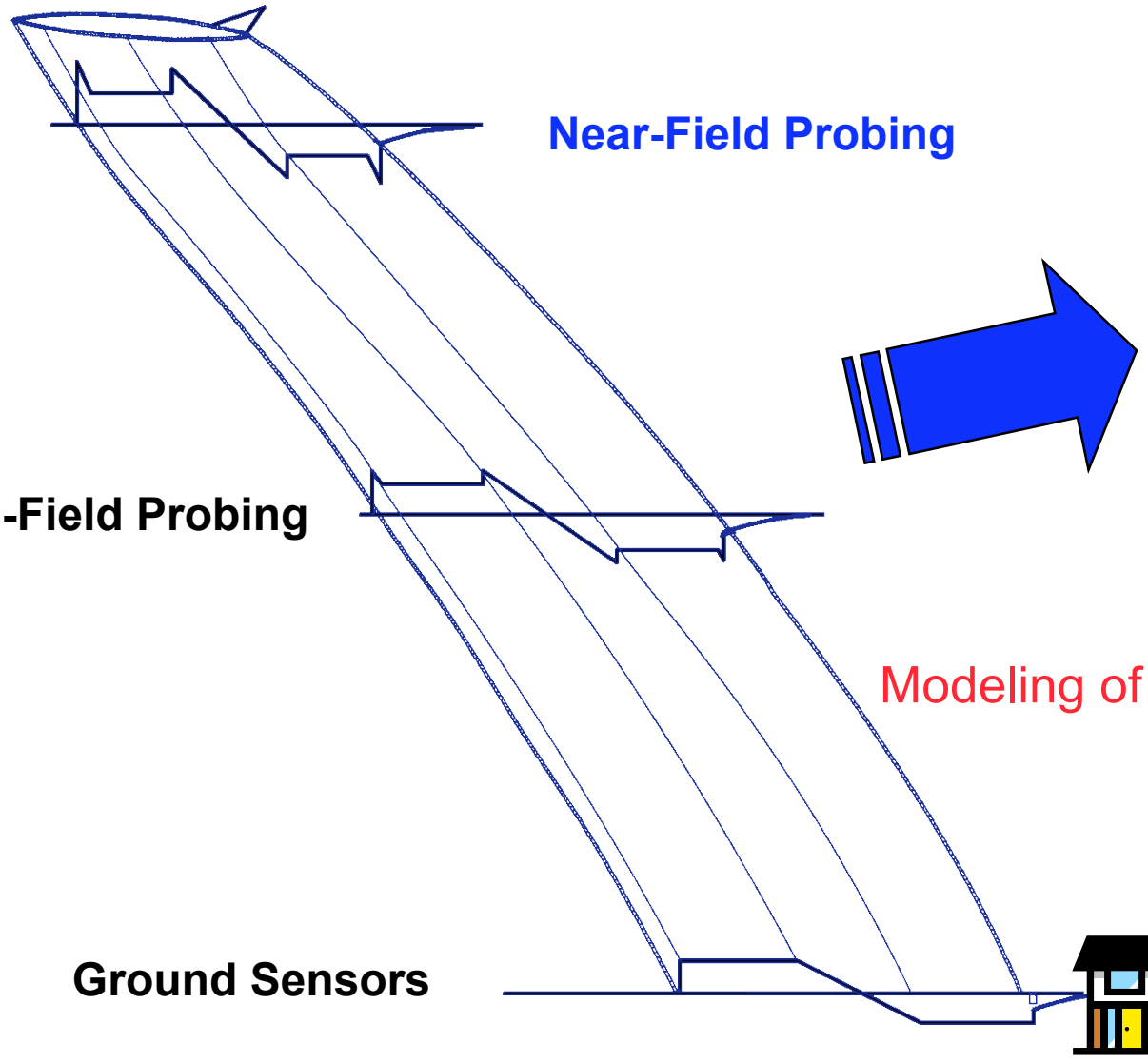
- Airport Noise
- **Sonic Boom**
- High Altitude Emissions



Performance Challenges

- Aero-Propulso-Servo-Elastic Analysis & Design

Sonic Boom Research at NASA Dryden



Near-Field Probing

Mid-Field Probing

Ground Sensors

Developing & Validating Design Tools

Modeling of Atmospheric Effects

Modeling of Transmission into Structures

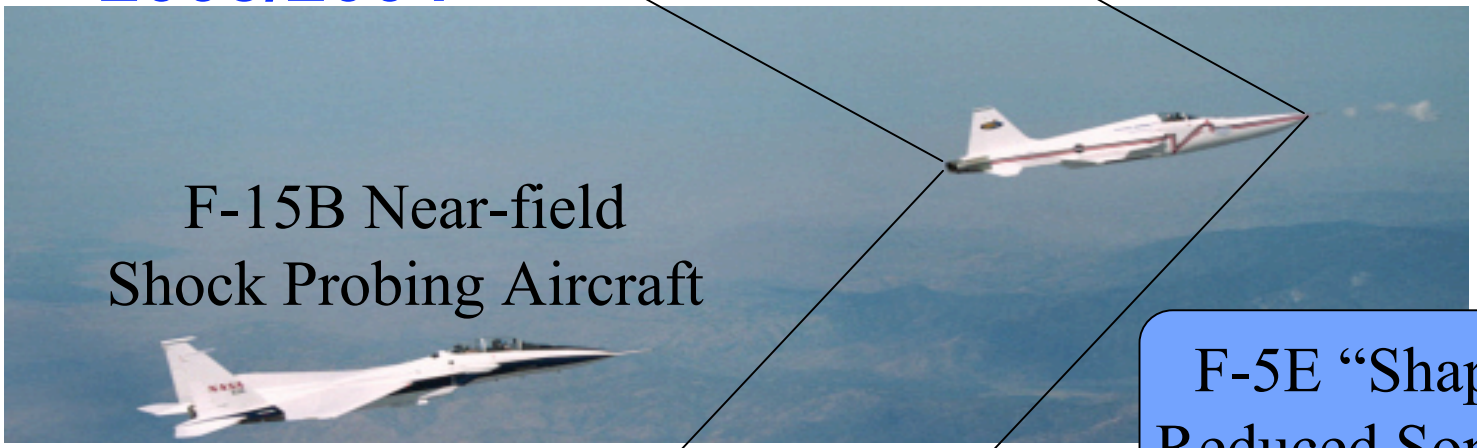
Past Probing Research

Aircraft	Researcher	Date
• F-100	Mullens	1956
• B-58, F-100, F-104	Smith	1960
• B-58 with F-100	Maglieri	1963
• F-18 with F-16XL-2	Haering	5/1993
• SR-71B with F-16XL-2	Haering	7/1993
• SR-71A with F-16XL-1	Haering	2-5/1995
• F-5E with F-15B-836	Haering	2/2002
• SSBD with F-15B-836	Haering	8/2003 & 1/2004
• F-18 with F-15-837	Haering	7/2006
• Quiet Spike with F-15B-836	Haering	12/2006

Propagation of Shaped Sonic Boom

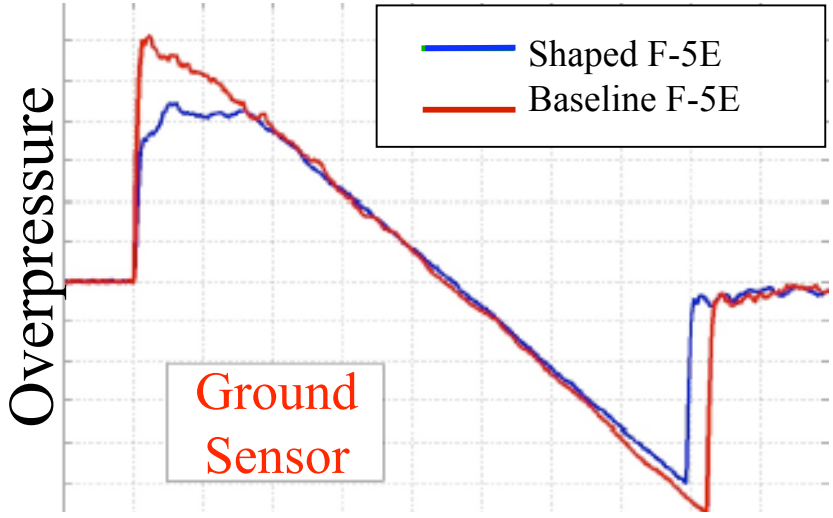
Shaped Sonic Boom Demonstrator

2003/2004



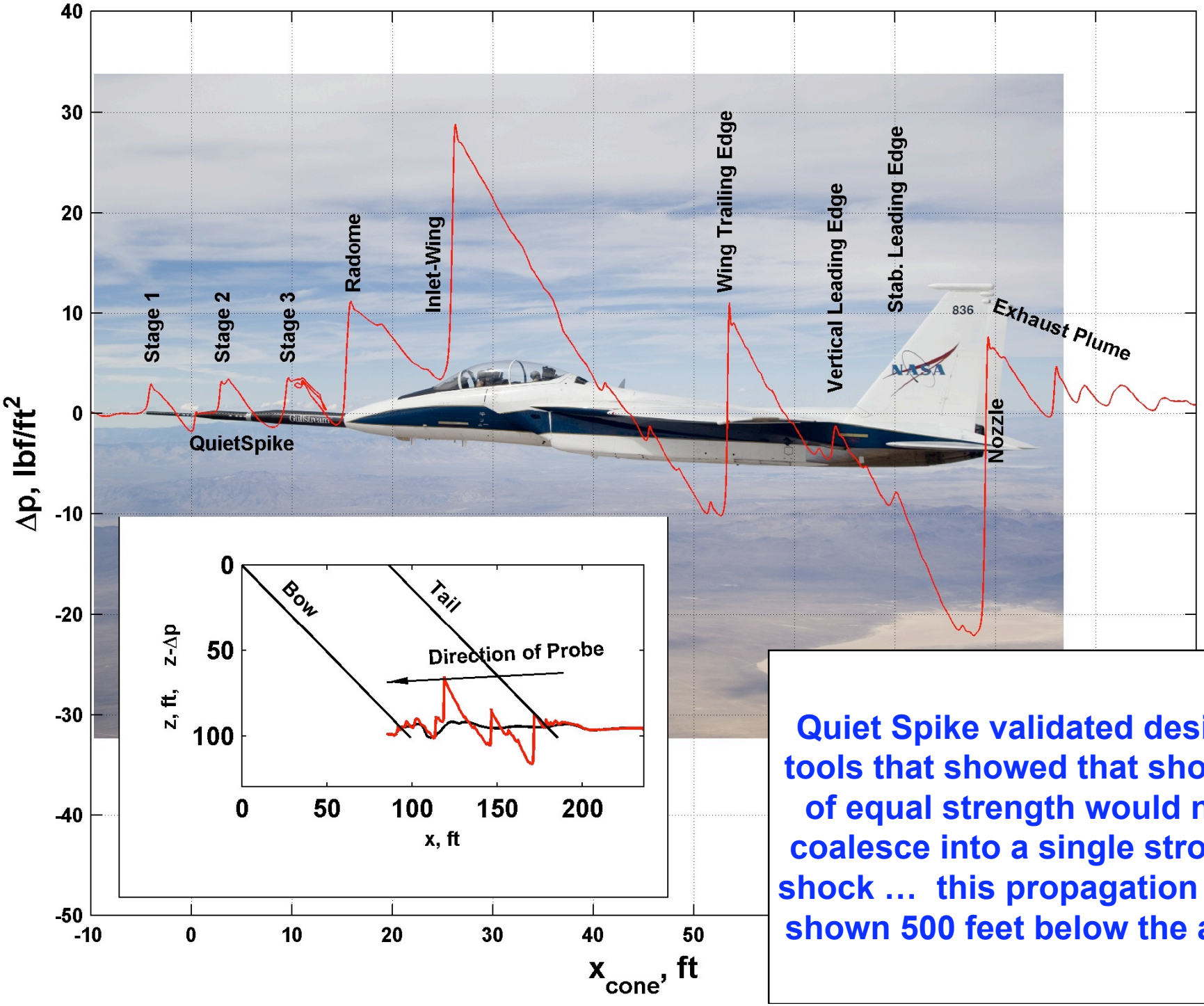
F-5E "Shaped" for Reduced Sonic Boom

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-Coalesence 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

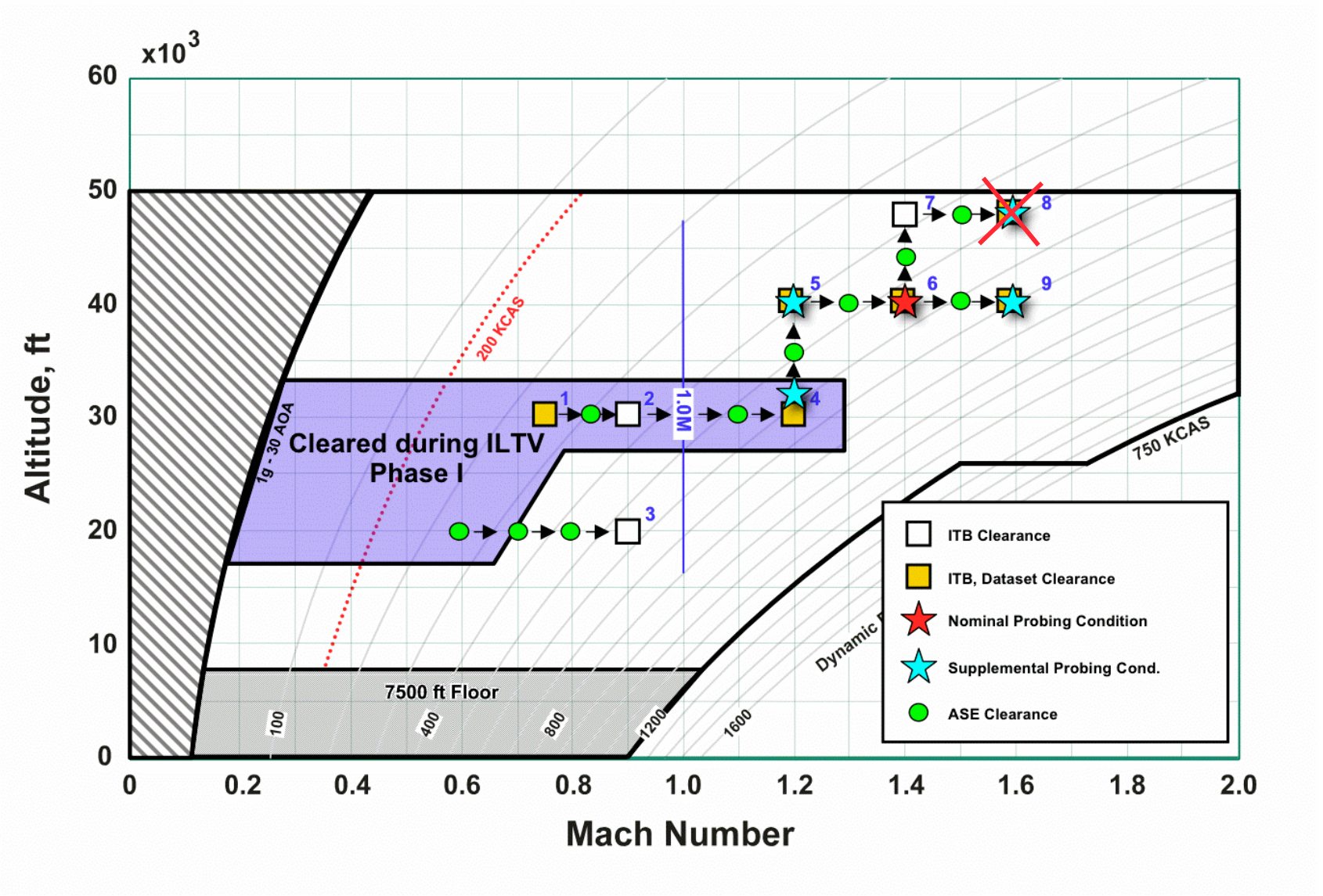
NF-15B

TN/837

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

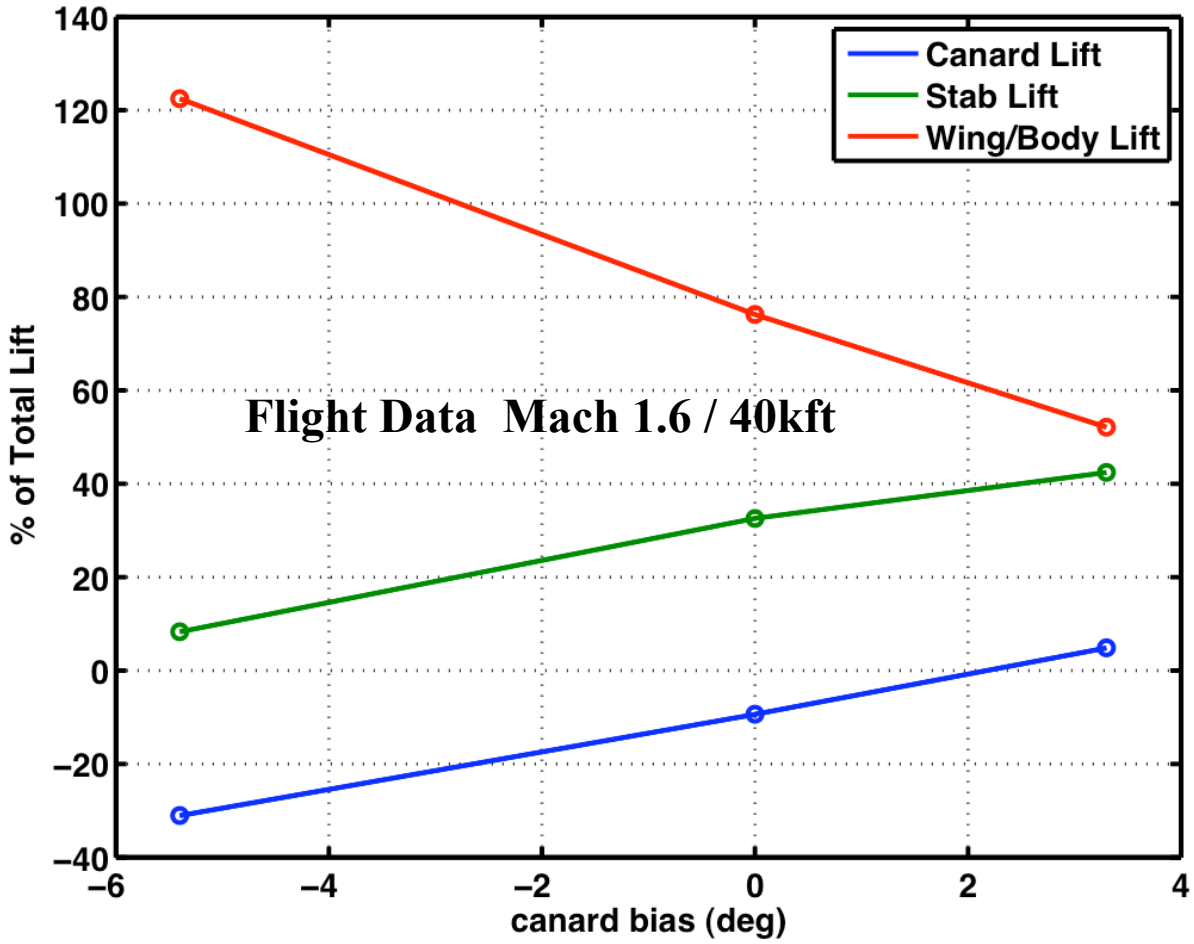
LaNCETS Flight Envelope



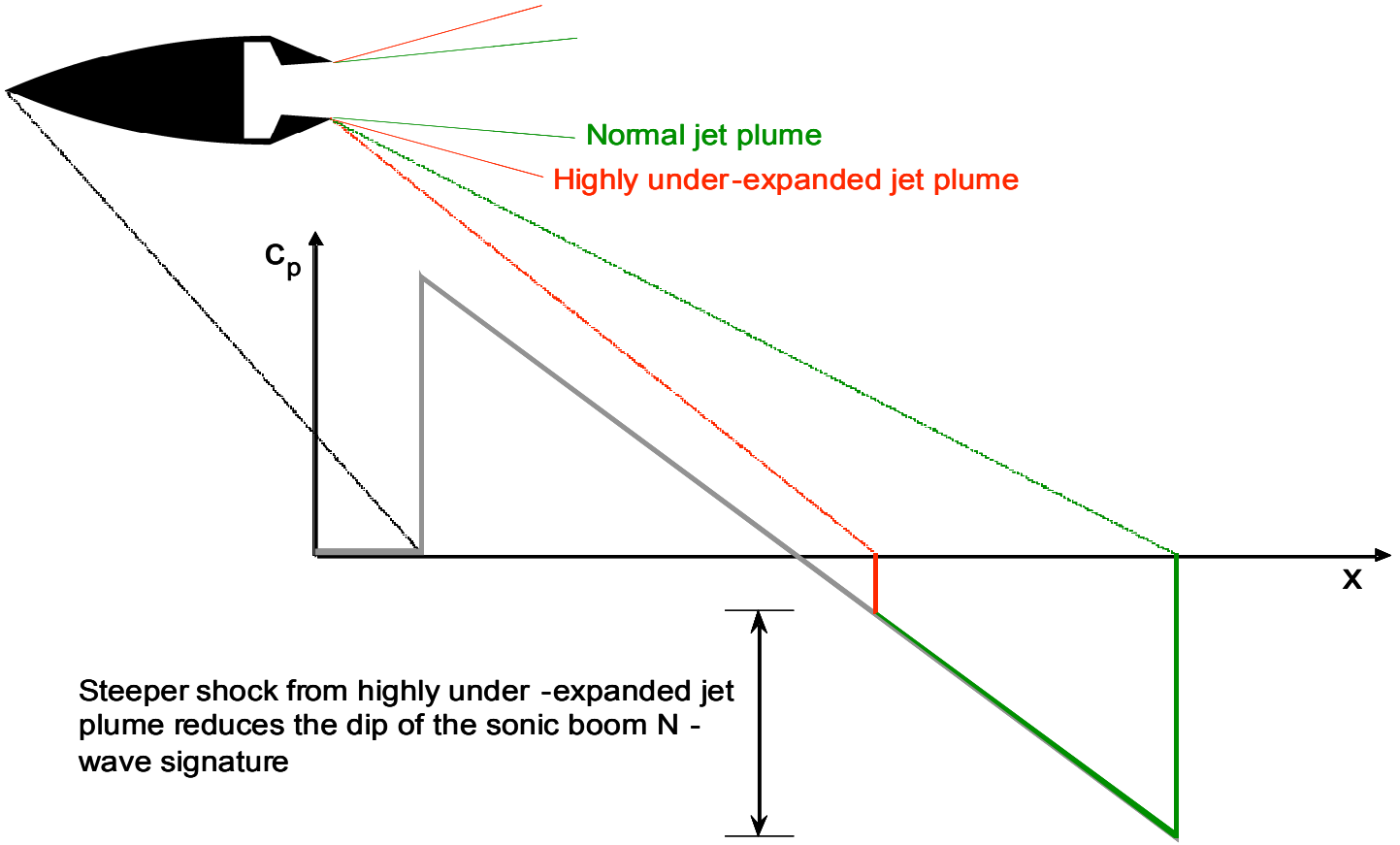
Lift Distribution Changes

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



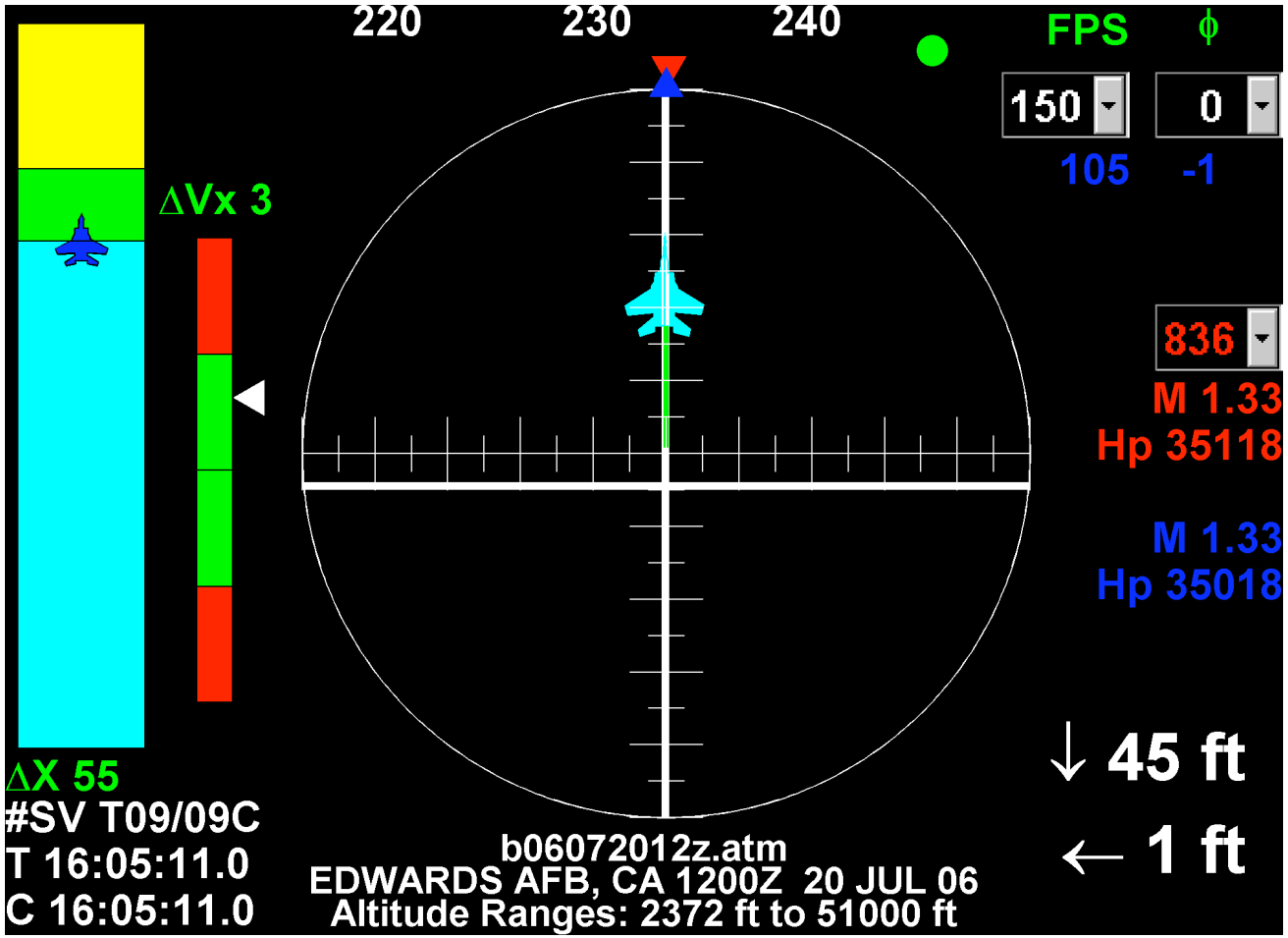
"Simplified" Nozzle Plume or Thrust Vectoring Effect on Shock Structure



Graphic from Trong Bui's AIAA paper presented at ASM in January 2009

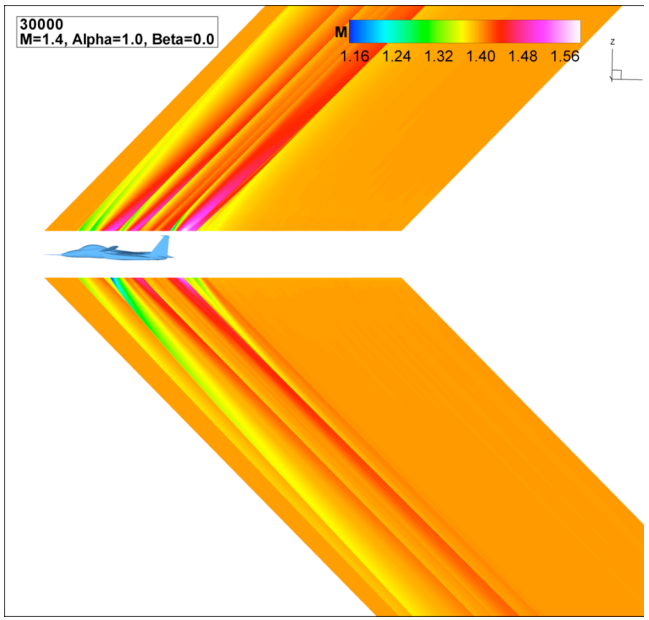
Cockpit Aircraft Position Display

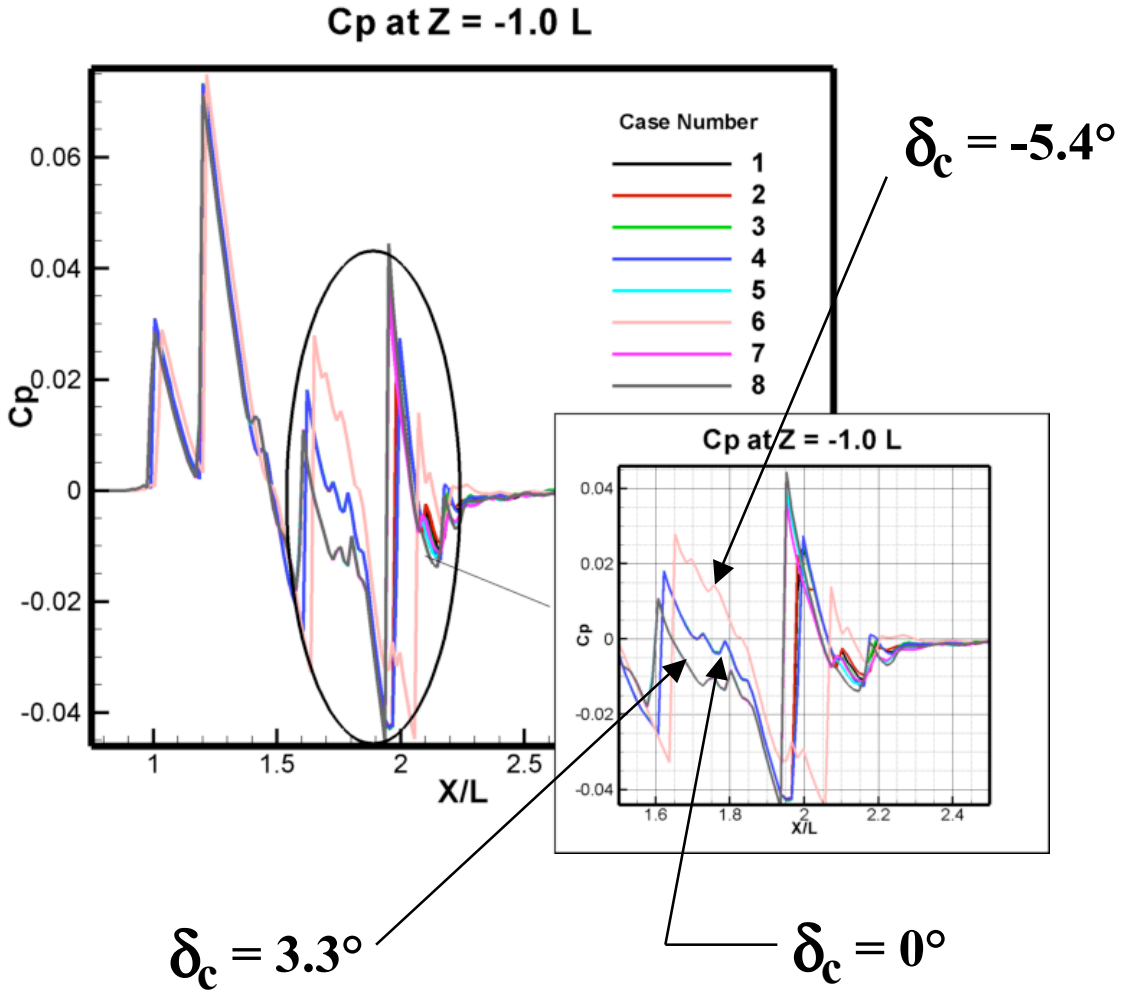
- Computer & display mounted in rear cockpit of the probing aircraft
- Rear seater can suggest fine position and rate adjustments to the pilot
- Enhances test point efficiency and quality



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.





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

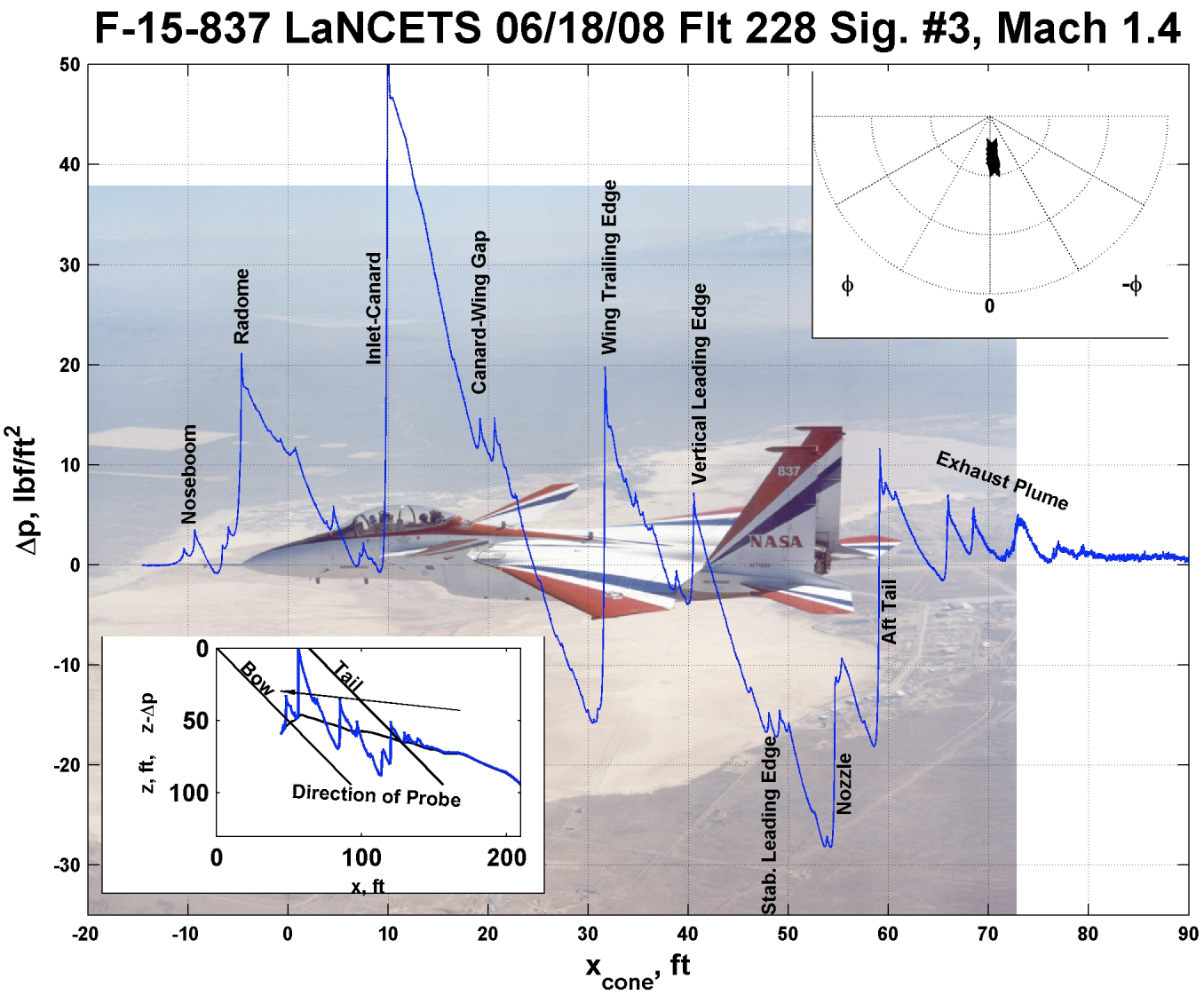
  Conventional Mode Area Ratio = 1.3
- **Thrust vectoring probing**

  M1.2/40kft --> +6° pitch, -6° pitch, and ±3° yaw splay

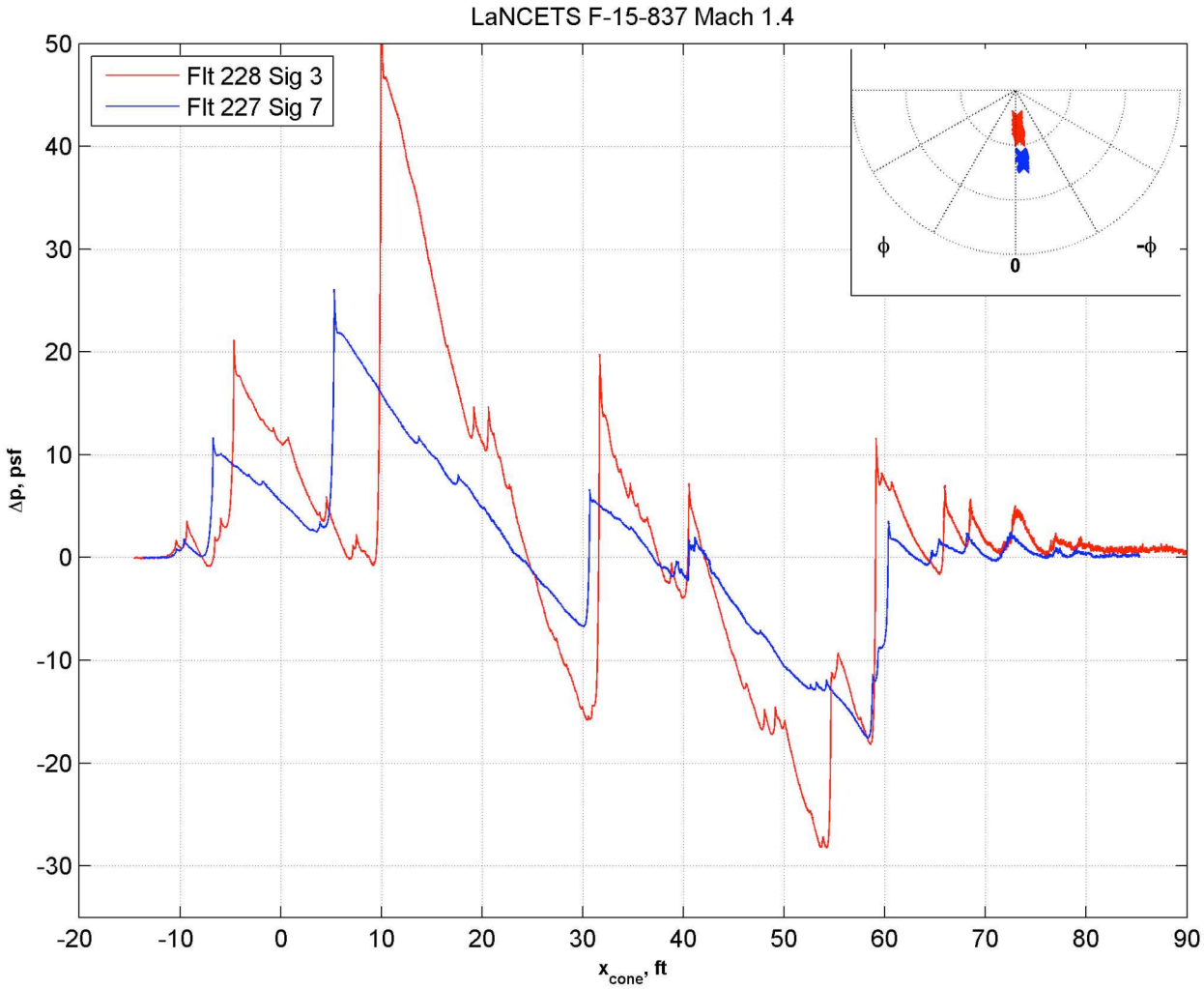
  M1.4/40kft --> +8° pitch and -8° pitch

  (note: positive pitch vectoring causes nose down pitching moment)

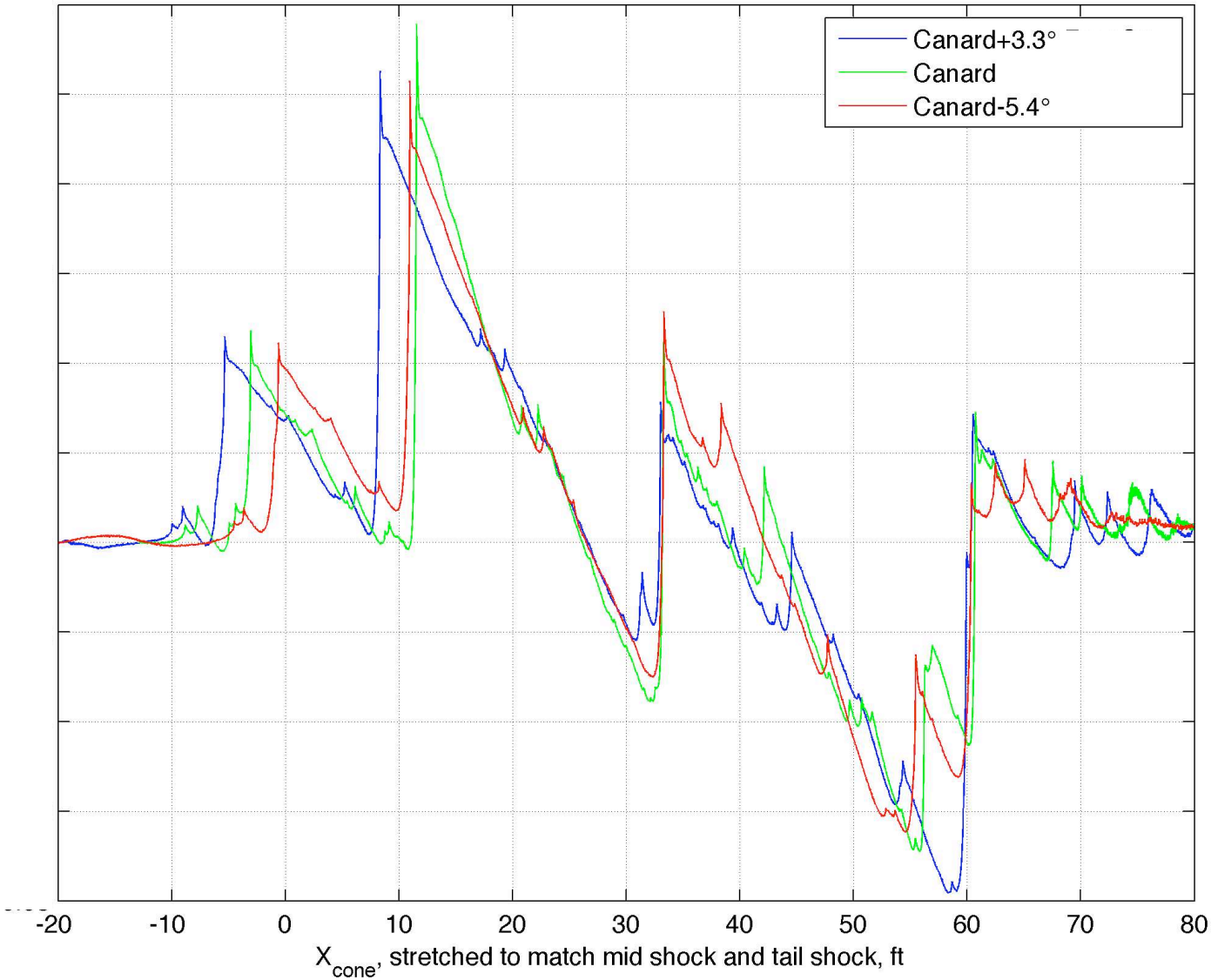
Phase 1 Baseline Aircraft Nearfield Probing Data



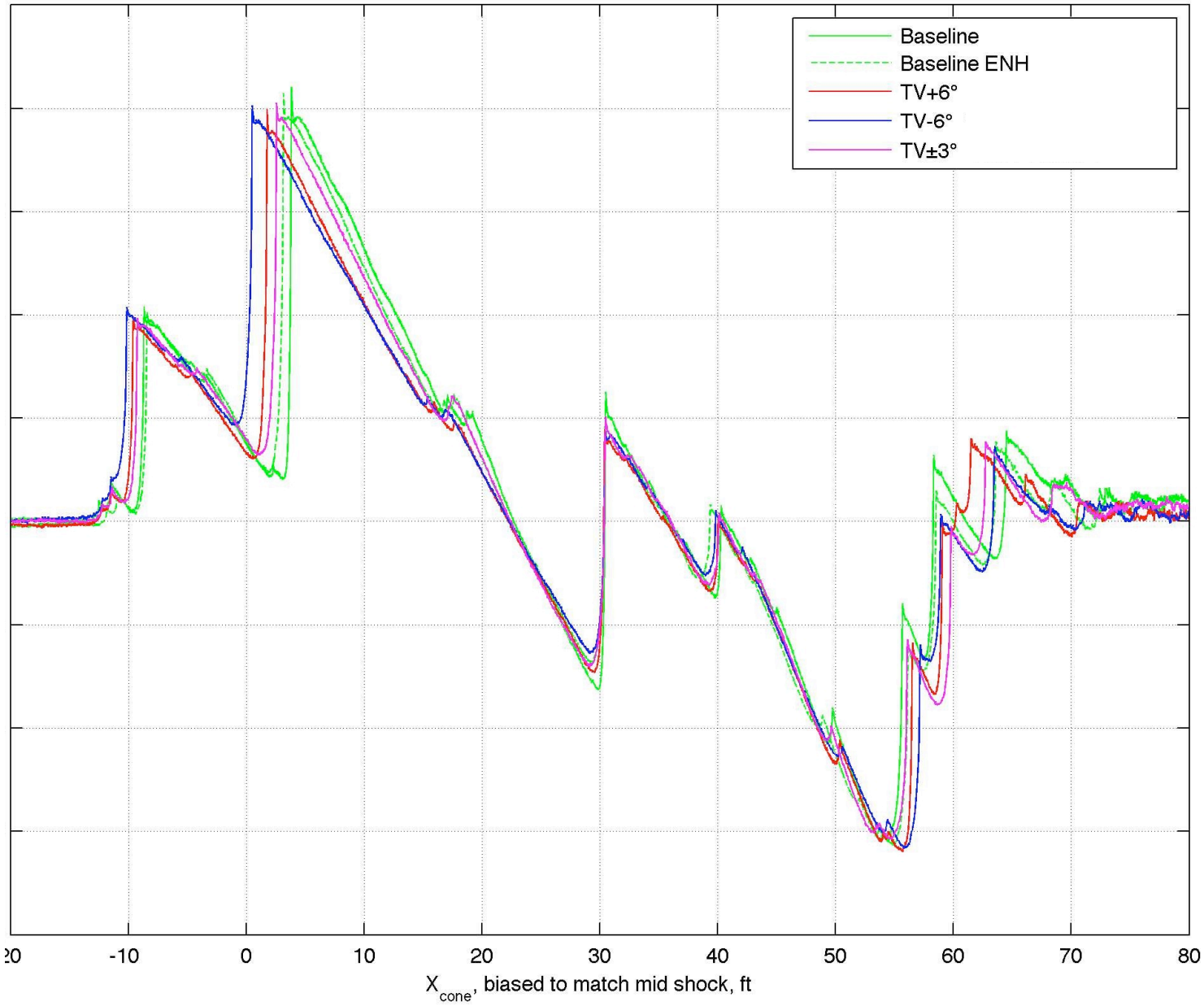
Mach 1.4 - Shock propagation results



Canard deltas - probing comparisons



Thrust Vectoring deltas - probing comparisons



Concluding Remarks

- 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