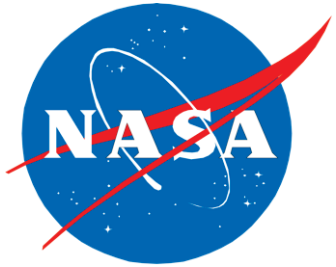
National Aeronautics and Space Administration

Sonic Boom Research at Armstrong

Supersonic Fundamental Aeronautics Project

Jim 'Clue' Less
Research Pilot
Armstrong Flight Research Center

Slides courtesy of:
Tom Jones
High Speed Deputy Project Manager for Armstrong
Larry Cliatt
Aerospace Engineer


NASA

Overview

- *Why Supersonics?*
- *Technical/Legal Challenges*
- *Sonic Boom Basics*
- *Current Research Areas*
- *Future Research*
- *Questions*

Why Supersonics?

Supersonic cruise aircraft offer faster travel choices in the future Air Transportation System

- Supersonic flight over land enables large reduction in travel time
  - Valuable to business travelers, cargo shippers, National Security and traveling public
- Opportunity for US to take the lead in new class of aircraft manufacturing
- Market potential has been validated in numerous studies
  - Business Aircraft: 350-500 units
  - Civil Airliners 500+ units
- Maintains or increases Aviation's impact on US GDP and has high value jobs
  - Aviation manufacturing contributes $75B to the US trade balance
  - Aviation is the #1 exporter of US goods, as of 2011

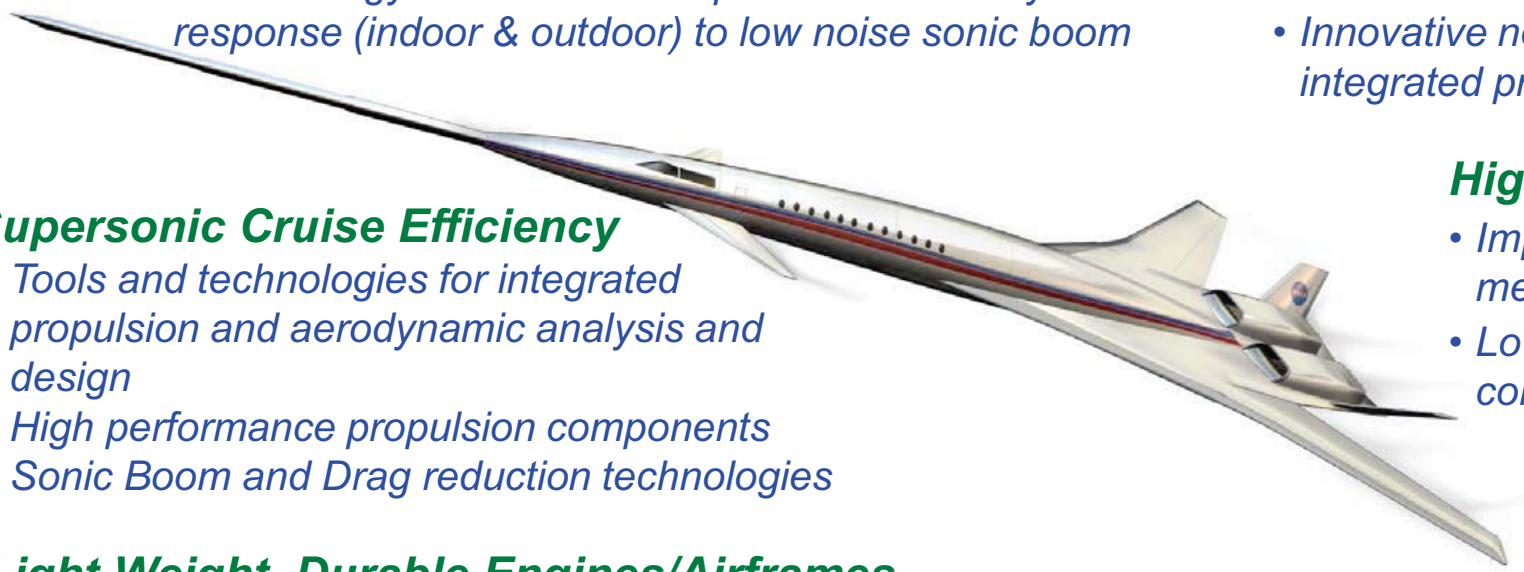
2020 **~2025** **~2030**

NASA investment in fundamental technology for supersonics enables continued US leadership in global civil aviation

SUPERSONIC PROJECT TECHNICAL CHALLENGES

Sonic Boom Community Response
- *Realistic models for propagation of low noise sonic boom*
- *Methodology to measure and predict community response (indoor & outdoor) to low noise sonic boom*

Airport Noise
- *Improved prediction techniques for supersonic propulsion noise*
- *Innovative nozzle designs for highly integrated propulsion systems*



Supersonic Cruise Efficiency
- *Tools and technologies for integrated propulsion and aerodynamic analysis and design*
- *High performance propulsion components*
- *Sonic Boom and Drag reduction technologies*

High Altitude Emissions
- *Improved analysis and measurement tools*
- *Low emissions combustor concepts*

Light Weight, Durable Engines/Airframes
- *Materials, test and analysis methods for airframe and engine efficiency, durability and damage tolerance*

Aeroservoelastic Analysis and Design
- *ASE/flight dynamic and propulsion analysis and design tool development and validation*
- *Include propulsion effects: APSE analysis and design tools*

Integrated Multi-Discipline System Design
- *Develop improved system level analysis and design capabilities, achieving low sonic boom and high performance*
- *Integrate discipline level tools into the vehicle level analysis models.*
- *Develop innovative, integrated concept designs and assess technology needs and impacts*

- ***Integration of Supersonic Aircraft in NextGen System (with Airspace Program)***
  - *Determine the characteristics for an airspace system that enables supersonic aircraft to utilize their full capabilities*

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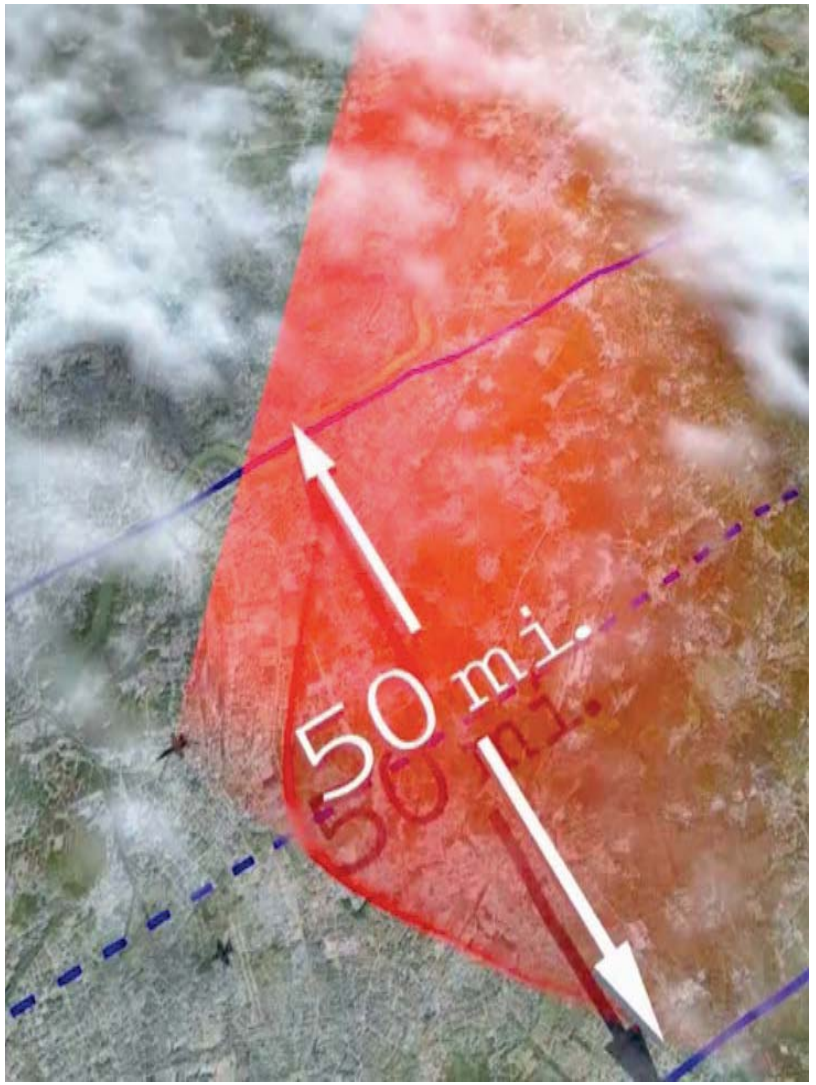
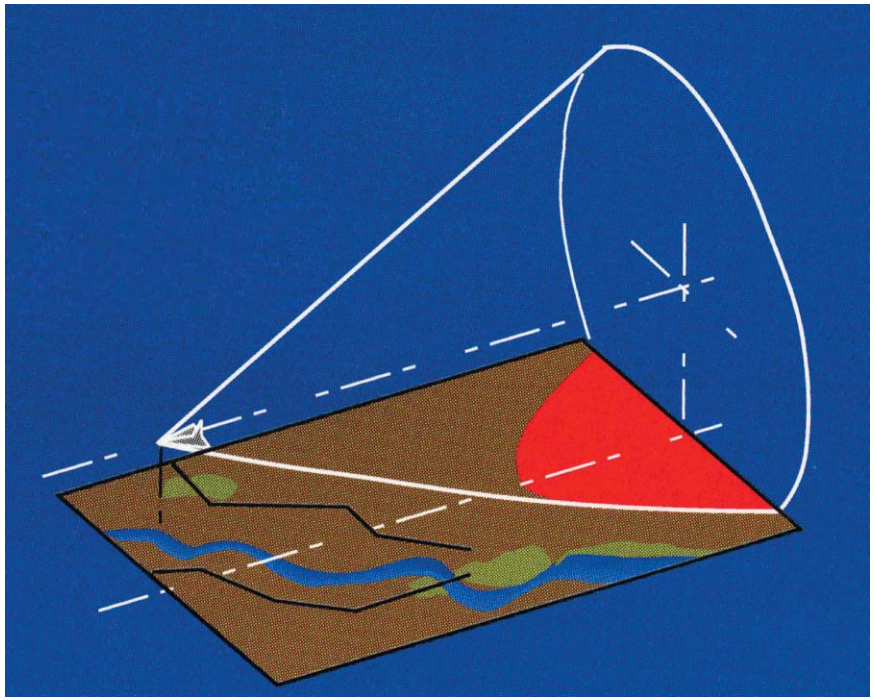
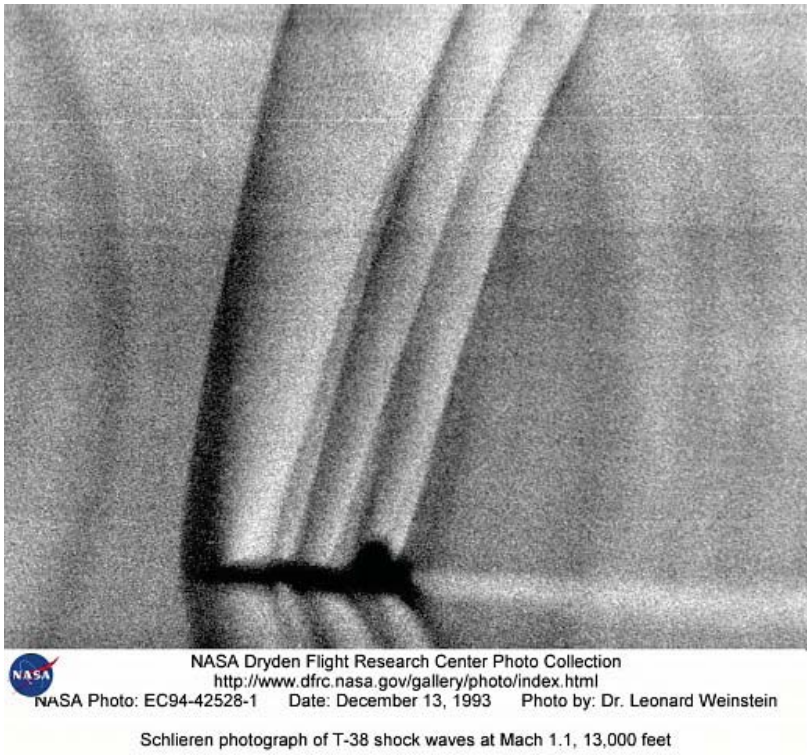
Supersonic Civil Overland Flight is Prohibited Because of Sonic Boom

- Since ~1973, U.S. (FAA) and Int'l Civil Aviation Org. regulations prohibit flight that creates sonic boom over population
  - US: No flight at Mach >1.0 (FAR 91.817)
  - ICAO: "no unacceptable situations for the public due to sonic boom"
- Overland flight is required for economically feasible supersonic operations
- An international sonic boom noise standard is required to open the supersonic civil aviation market
  - US FAA and other countries regulatory orgs align their standards to ICAO



Sonic Boom Basics





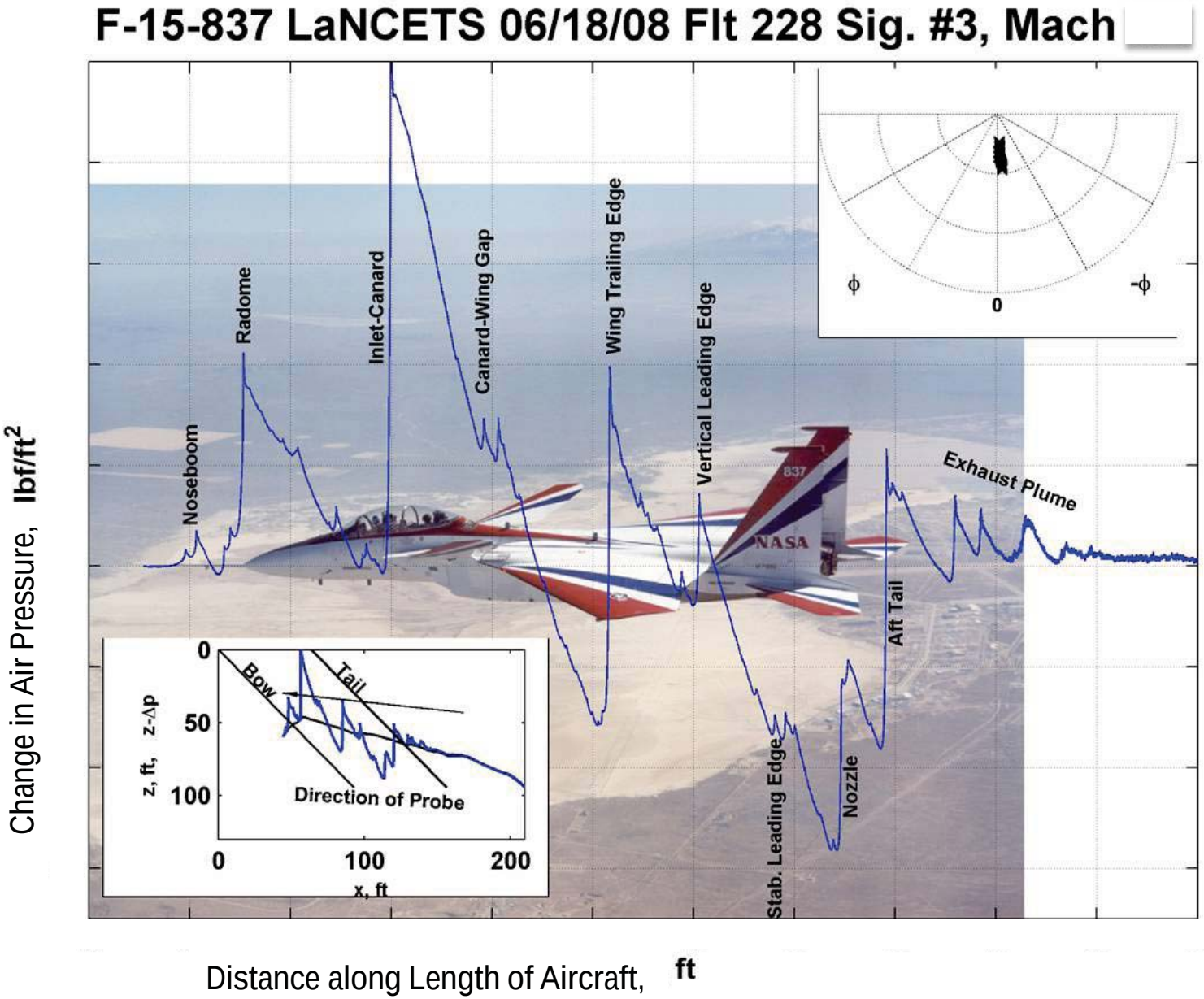
NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: EC94-42528-1 Date: December 13, 1993 Photo by: Dr. Leonard Weinstein

Schlieren photograph of T-38 shock waves at Mach 1.1, 13,000 feet

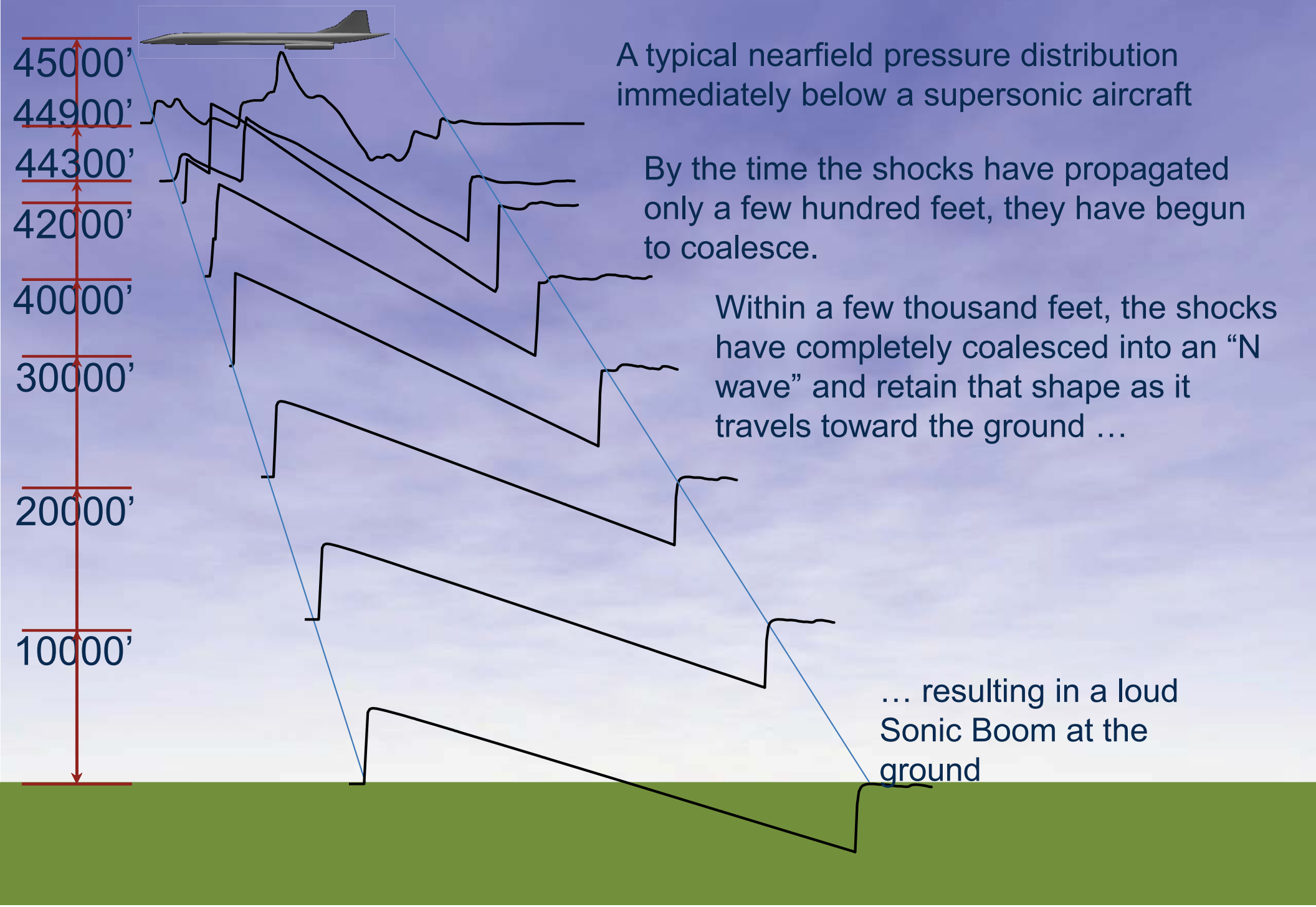
- **At supersonic speeds, pressure changes through shock waves**
- **Shock system travels in 3-Dimensions at speed of sound**
- **At the intersection with the ground, “sonic boom” is heard**
- **Boom is created over the entire length of the supersonic flight**
- **Large “Carpet” of ground is exposed as aircraft flies**
- **Noise is reduced at the edge of the carpet**

Military Aircraft, Concorde, and the predicted US SST sonic boom noise levels led to current ban on supersonic overland flight

Shockwaves Graphed Over Length or Time



Sonic Boom Basics: N Wave Sonic Boom



A typical nearfield pressure distribution immediately below a supersonic aircraft

By the time the shocks have propagated only a few hundred feet, they have begun to coalesce.

Within a few thousand feet, the shocks have completely coalesced into an “N wave” and retain that shape as it travels toward the ground …

… resulting in a loud Sonic Boom at the ground

Sonic Boom Research areas

- Understand the boom
- Quiet the boom
- Avoid the boom
  - Predict where & how strong
  - Adjust operations realtime
- Regulate the boom

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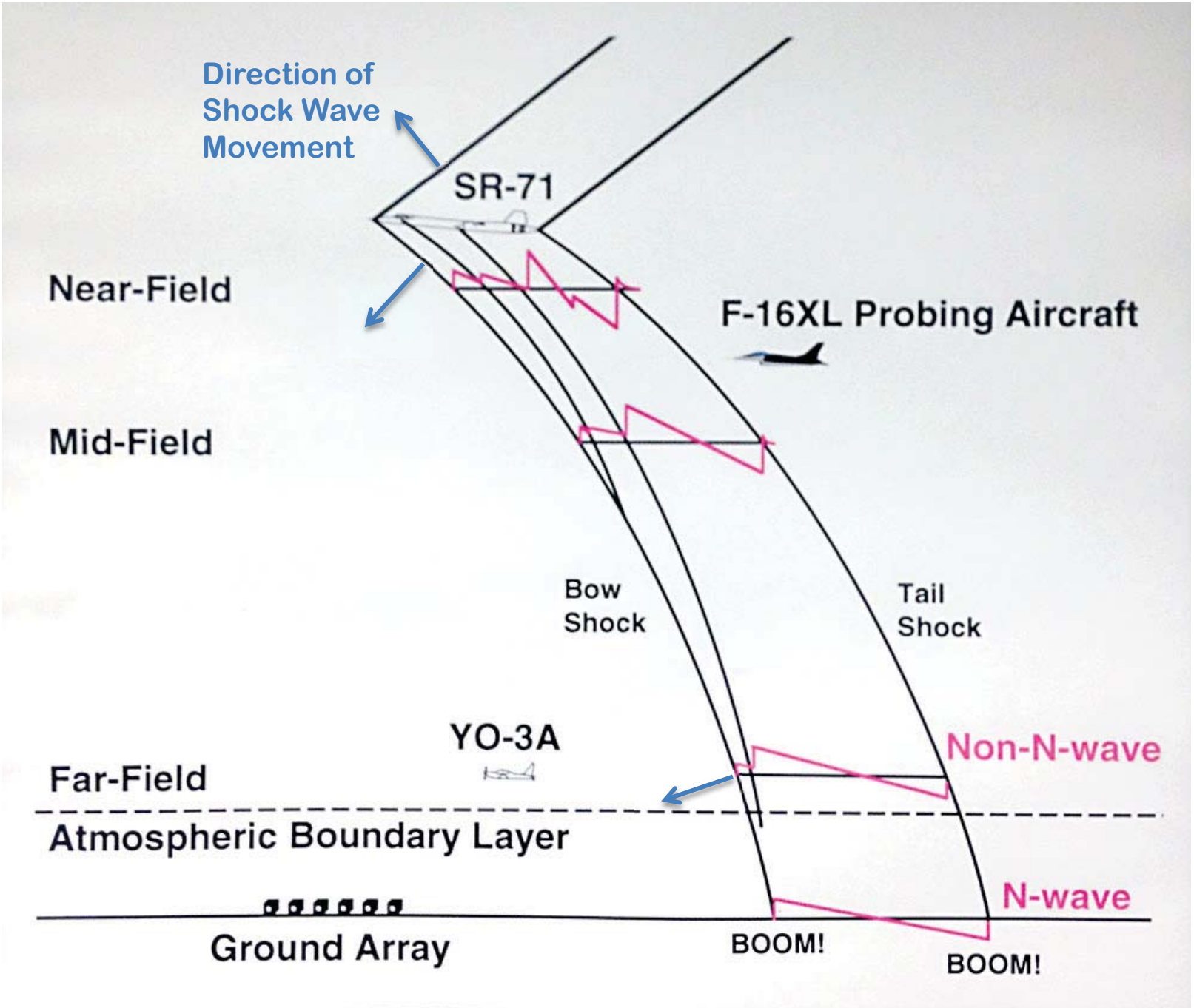
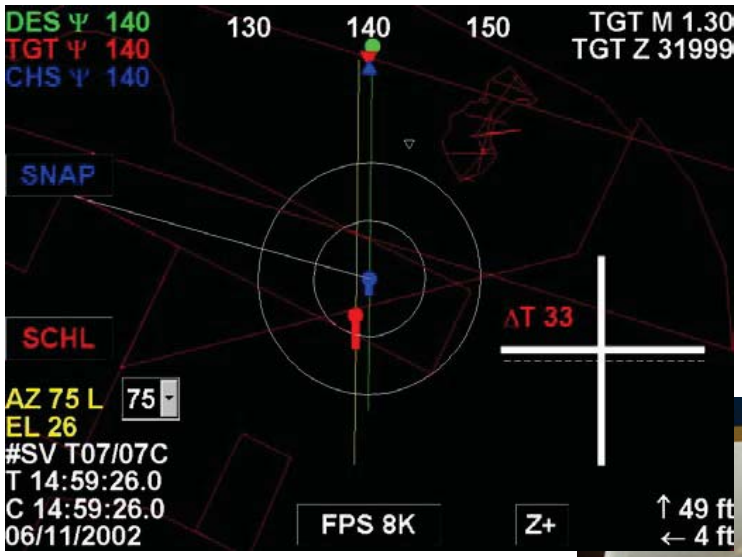
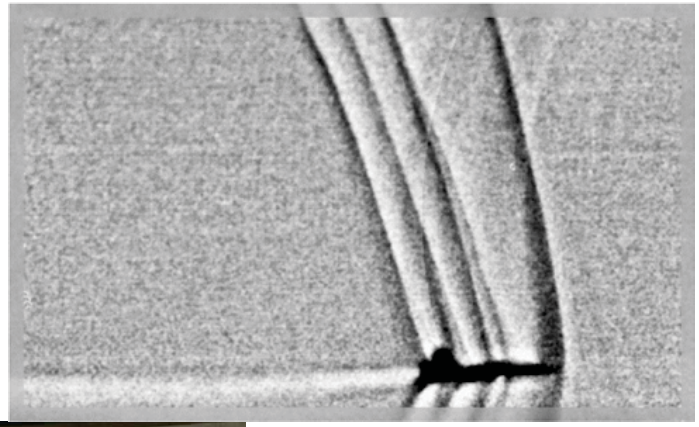
Shock Waves Coalesce as They Travel to the Ground



Air-to-Air Schlieren

- Obtain high quality Schlieren image with good spatial resolution. Will allow determination of shock location and relative strength in-flight.
- Unique capability to validate shock location and relative strength for sonic boom prediction and MDAO studies.





BOS

Background-Oriented Schlieren

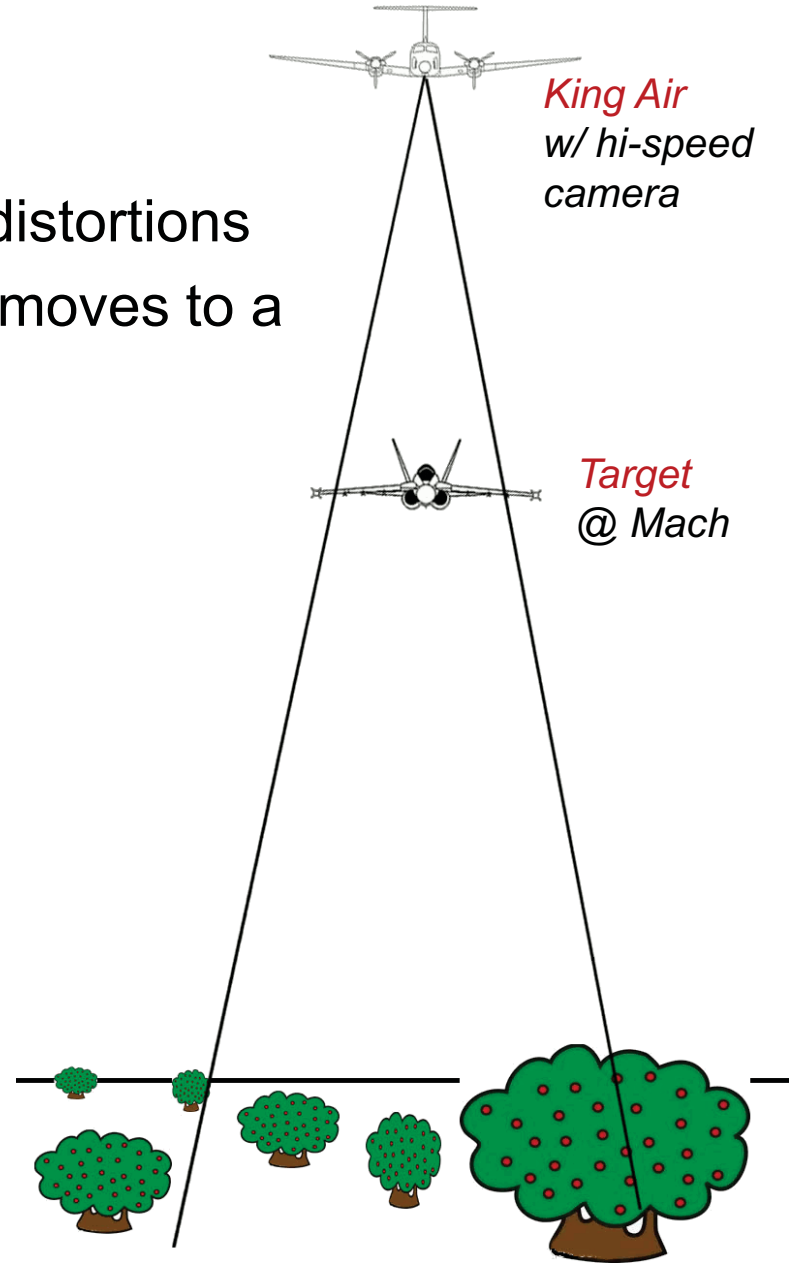
- A “synthetic schlieren” method
- Post-process images with computer
- Extract Schlieren from background distortions
- **Advantage:** Technique complexity moves to a ground computer

Project Objective:

- *Demonstrate feasibility of using BOS in flight.*

Phase 1 Specifics:

- *Desert Terrain w/ Brush (Black Mountain Corridor)*



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Sonic Boom Basics: Shaped Sonic Boom

45000’
44900’
40000’
30000’
20000’
10000’

A nearfield pressure distribution of a low boom shaped supersonic aircraft

Very little coalescing after a few thousand feet

Signature retains it shape all the way to the ground …

… resulting in a significantly quieter Sonic Boom at the ground

Sonic Boom Research areas

- Understand the boom
- Quiet the boom
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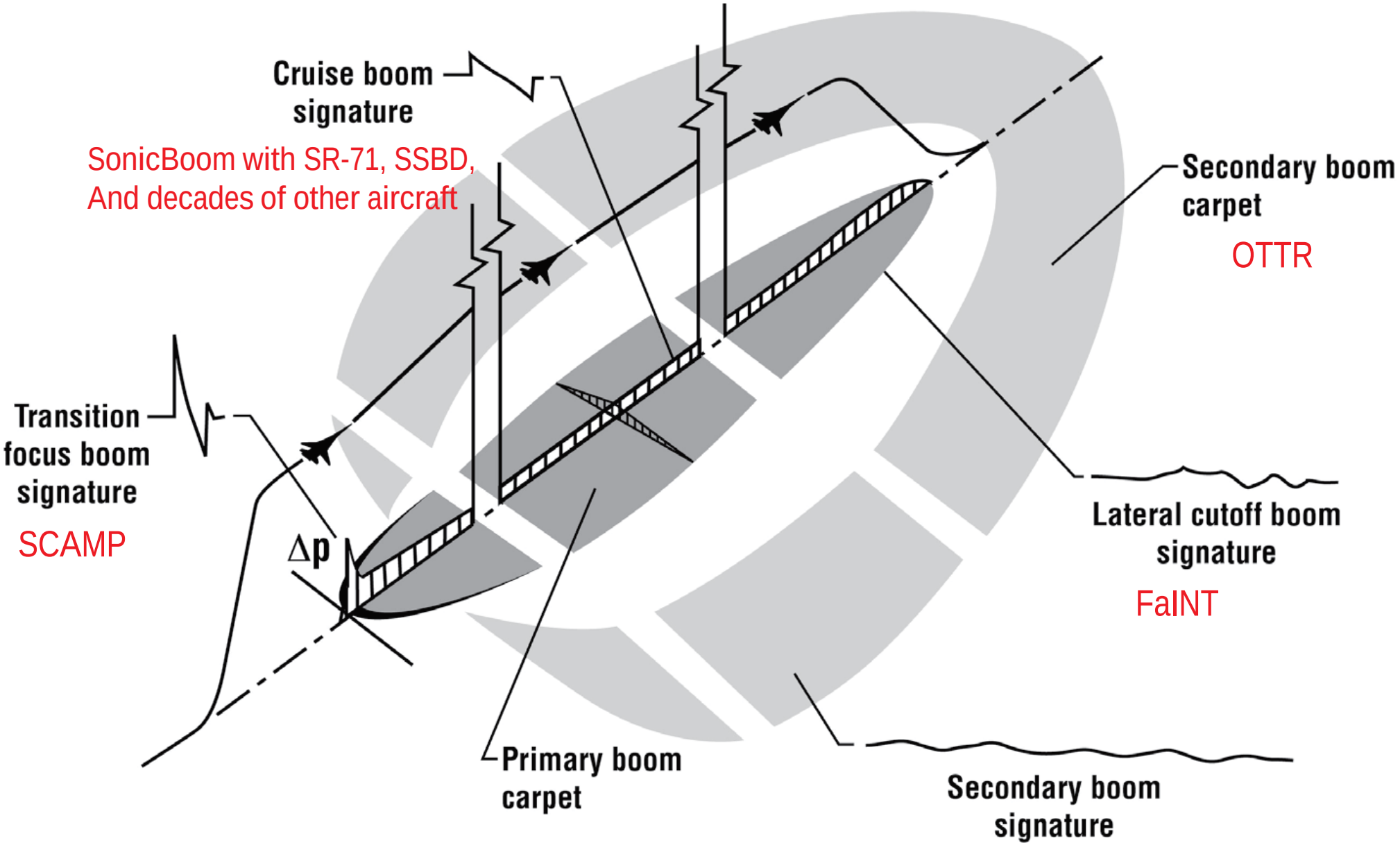
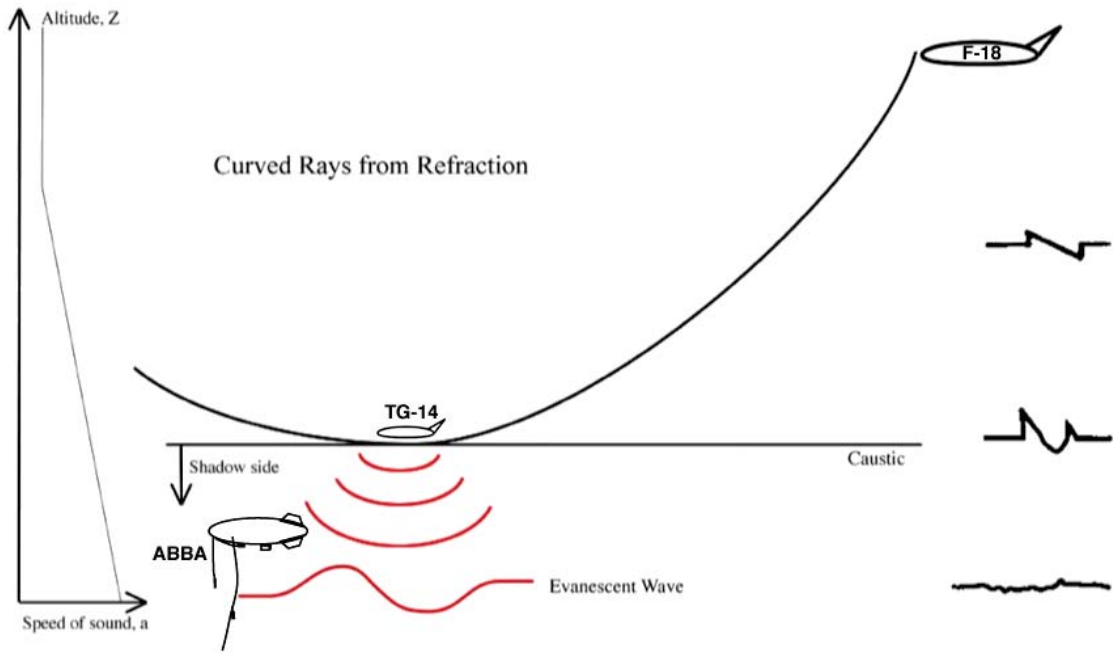
Armstrong Efforts to Study Boom Propagation

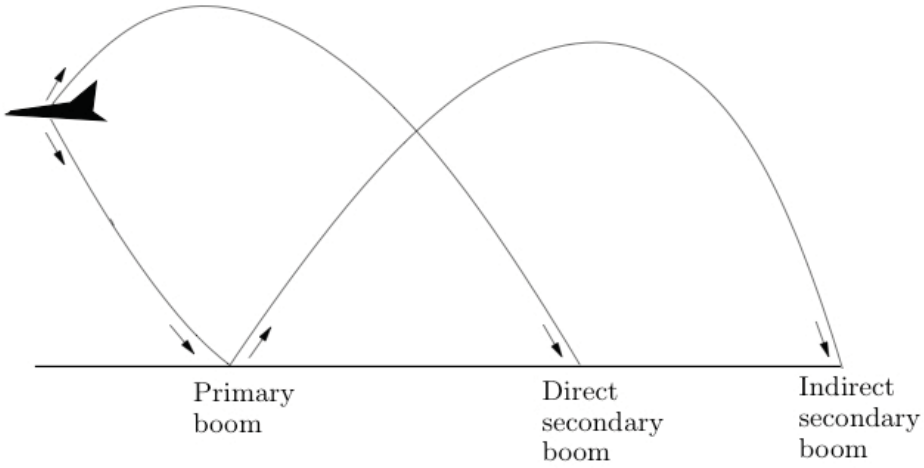


Sonic Boom Propagation Research

Farfield Investigation of No-boom Thresholds (FaINT)



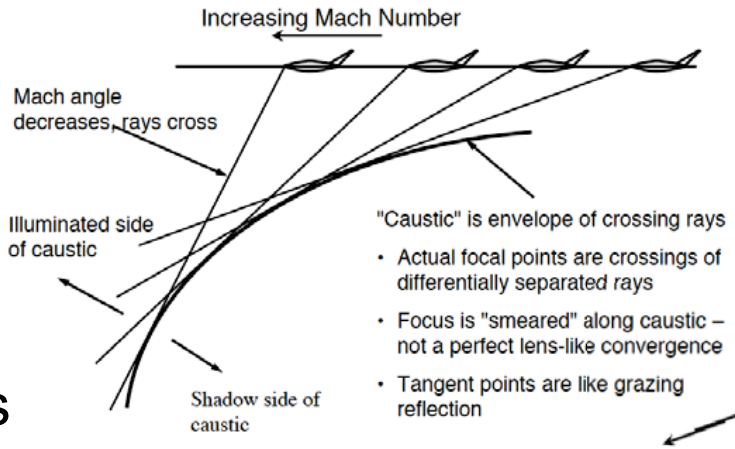
Over-The-Top Research (OTTR)

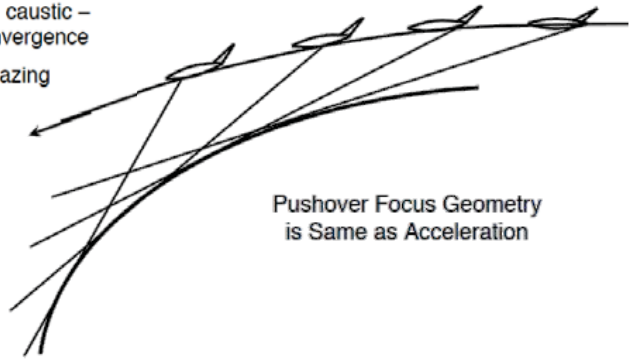


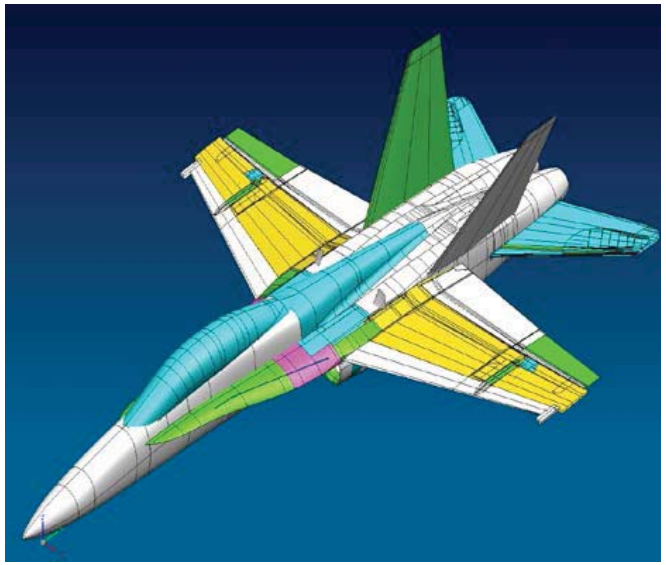
SCAMP

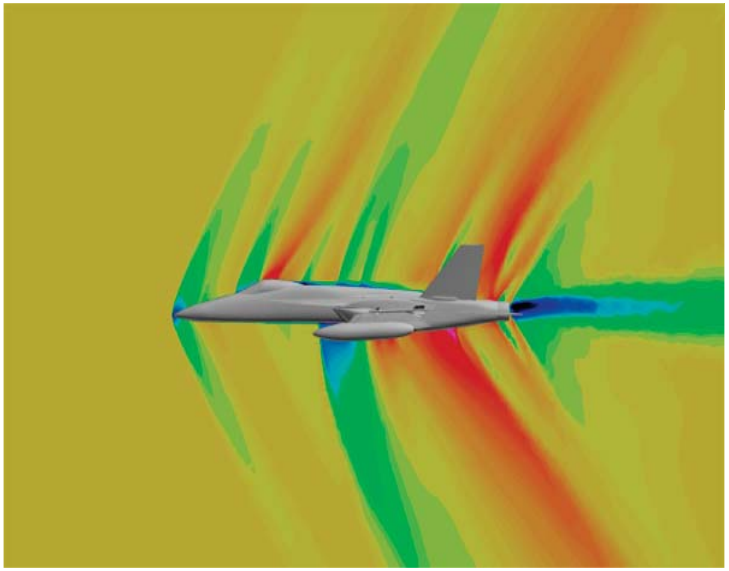
Superboom Caustic Analysis and Measurement Program

The objectives are to validate, via flight test measurements, models for sonic boom signatures in and around focal zones, and to apply these models to predict focus booms for low-boom aircraft designs.







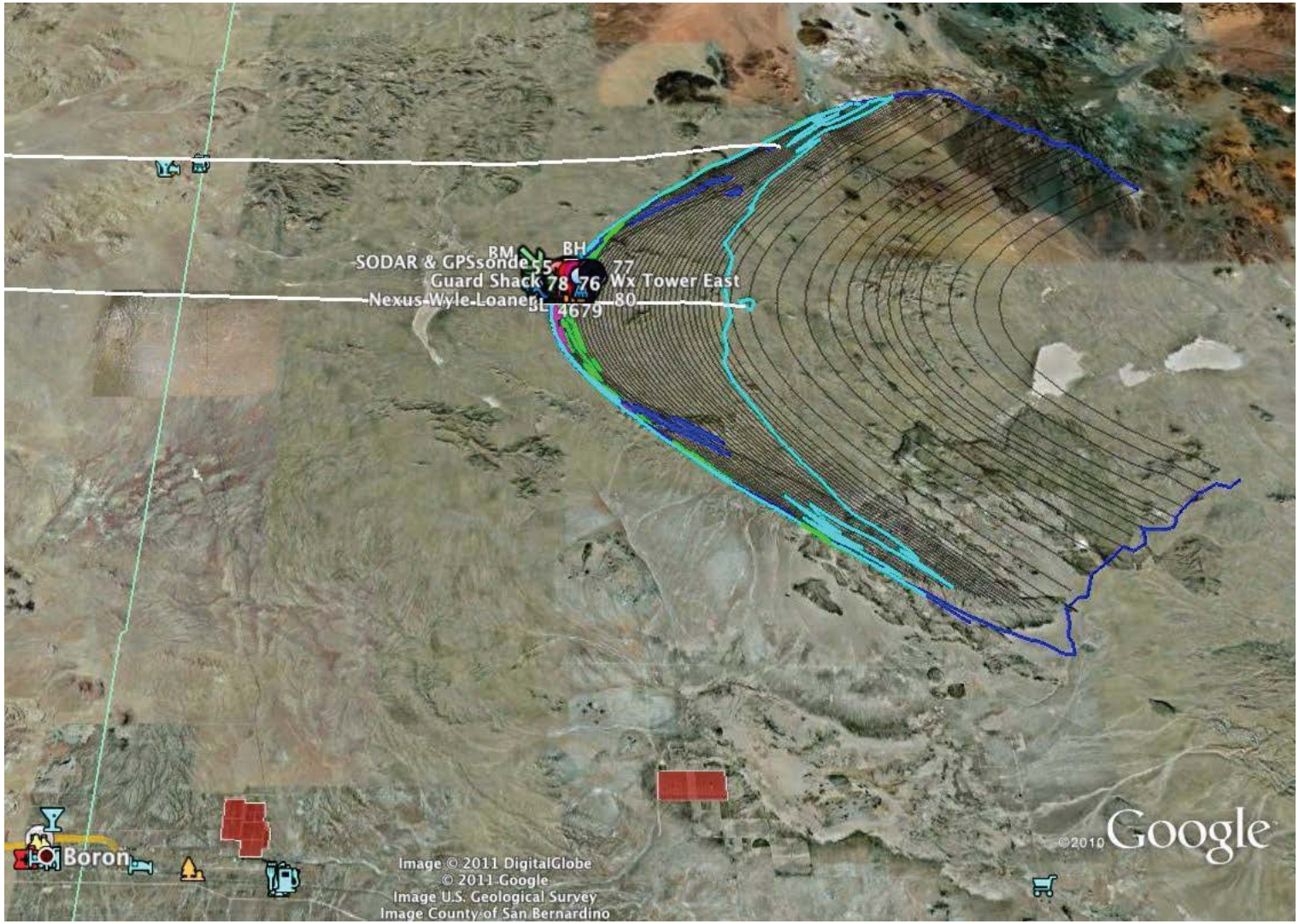


Validation of Focused Boom Models will utilize high fidelity aircraft maneuvering source inputs based on CFD at as-flown conditions.

SCAMP *CONT.*

Flight Research Overview

- *May 2011 flights*
- *10,000-foot ground microphone array*
- *3,500-foot vertical microphone array*
- *Airborne acoustic measurement platform (up to 12,000 ft. MSL)*



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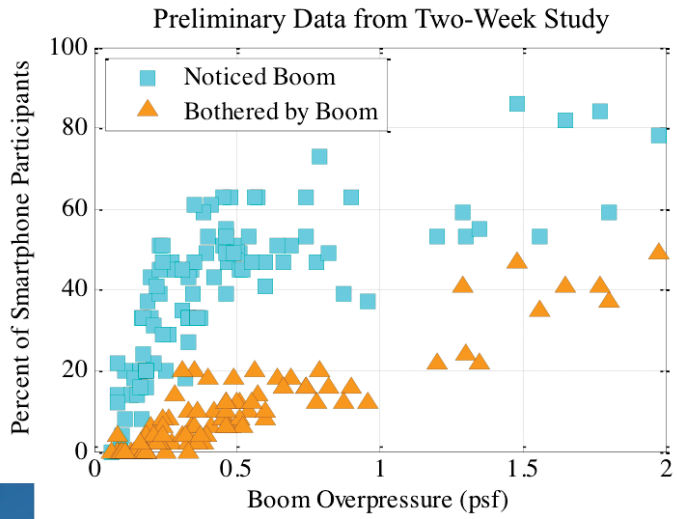
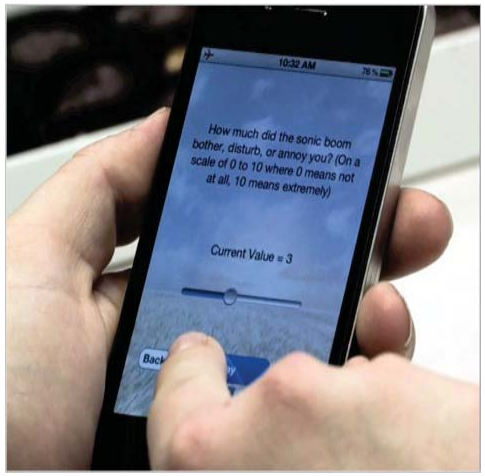
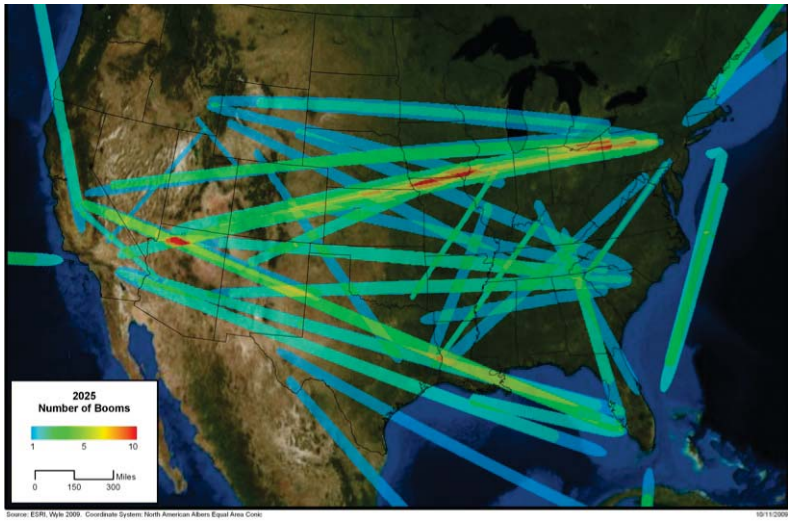
WSPR – Waveforms and Sonic boom Perception & Response

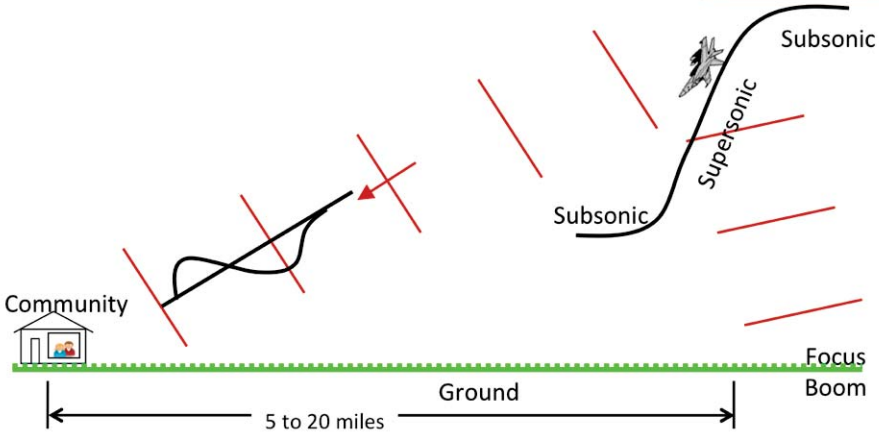
- **Objective**: Pilot program for future, widespread sonic boom community response program
- **Need**: Method to gather data relating the impact of sonic boom exposure to communities, for FAA and ICAO rule change allowing quiet supersonic flight over-land
- **Design**: Unique Low Boom Dive maneuvers used to simulate *NextGen civil supersonic aircraft design*, (0.1 – 0.6 psf). Paper/pencil, web-based, smart phone surveys

Wireless ground microphone array









Supersonic Low-Boom Flight Demonstration (LBFD)

Research & leadership to overcome the sonic boom barrier and open the door for development of a new generation of supersonic civil transport aircraft

Supersonic civil aircraft have great potential to positively impact future US leadership in global air transportation

- *Quiet overland flight is the key barrier to be overcome*
- *Creates an environment for private investment in a new market*

Requirement:

- *Demonstrate that noise from sonic booms can be reduced to a level acceptable to the population residing under future supersonic flight paths.*

Approach:

- *Revitalize the excitement of manned X-Planes using a focused and cost-effective approach to design a low boom research aircraft for validation and community overflight*
- *Partner with regulatory agencies and communities to create a database of acceptance that will lift the current prohibition on overland supersonic flight.*

Questions???