

Recent Progress on Sonic Boom Modeling Research at NASA

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NASA Dryden



Sonic Boom Modeling Overview

What are we trying to do?

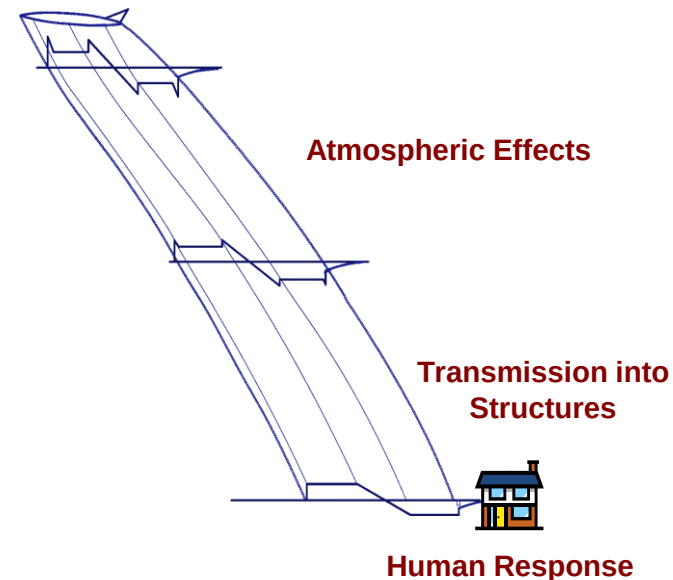
Understand the impact of sonic booms from new low-boom aircraft designs on community residents

What is our approach?

- **Atmospheric Propagation:** Develop more accurate sonic boom propagation models
- **Structural Response & Modeling:** Examine sonic boom transmission into small and large structures
- **Human Response & Modeling:** Develop psychoacoustic model of human response to low booms (both outdoors and indoors) for single and multiple events
- Work cooperatively with regulators (FAA, ICAO) and other researchers (industry, academia, JAXA, others)

What are the payoffs if we are successful?

- Replace current prohibition of civil supersonic overland flight with a noise-based standard for aircraft certification

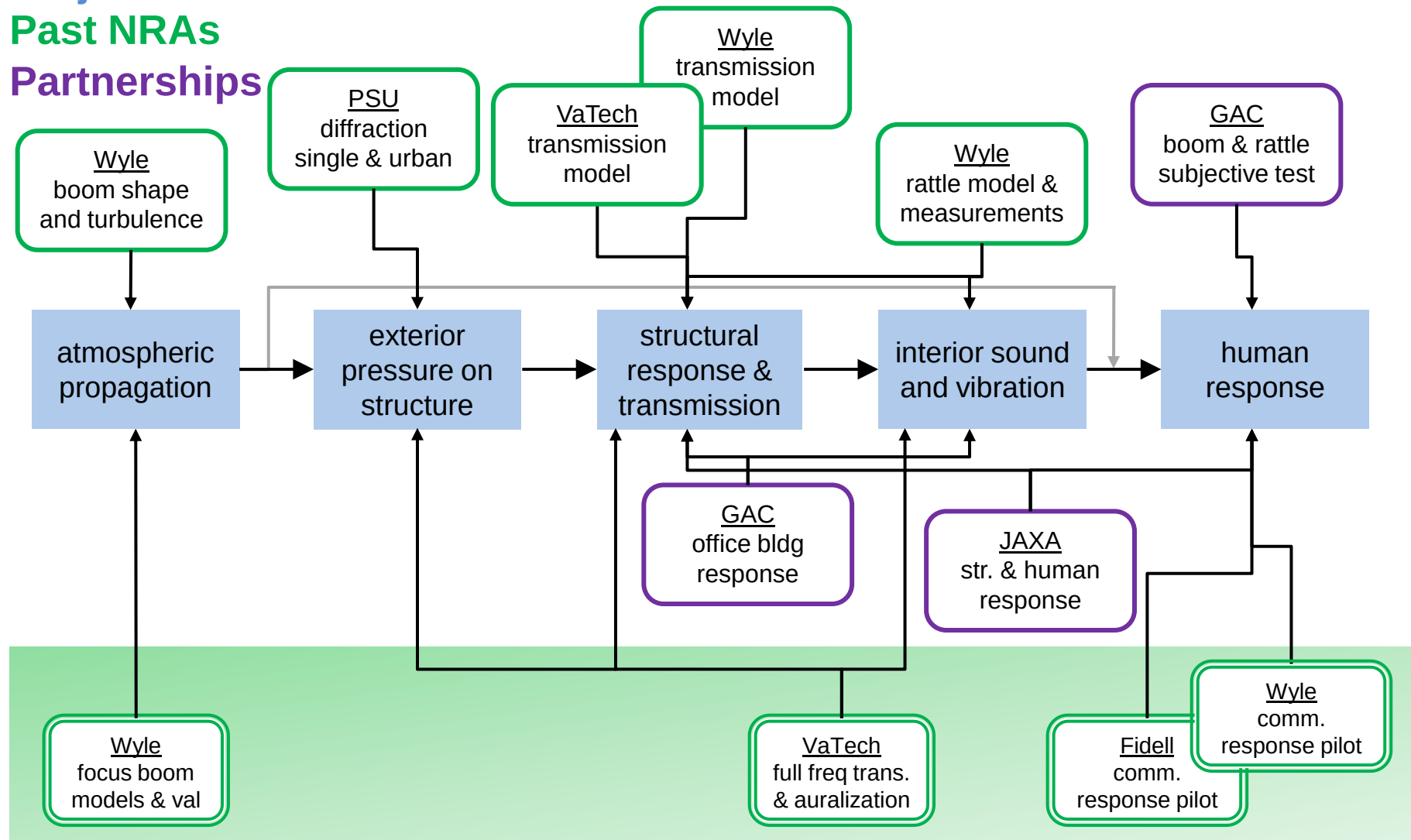


Maximizing Payoff through Partnership

Project Plan

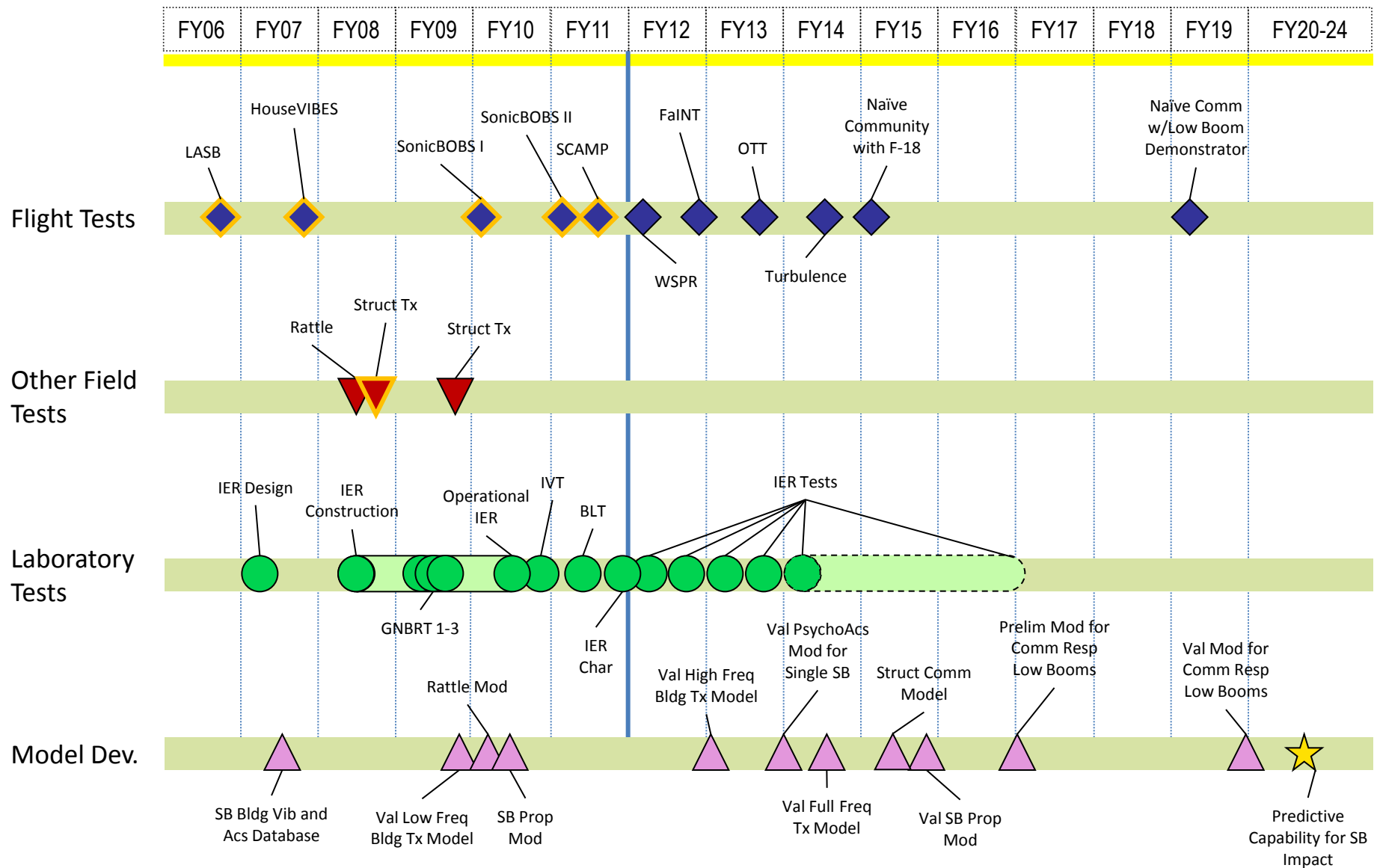
Past NRAs

Partnerships



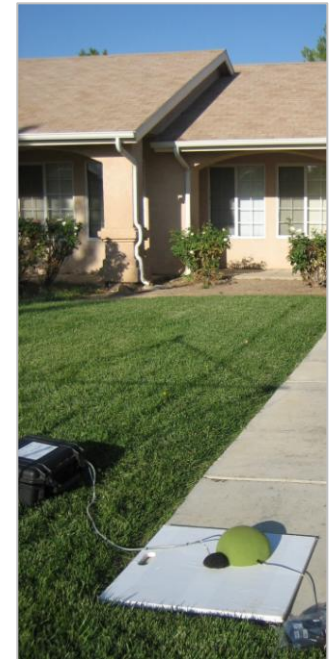
Current NRAs

Research Activities



Technical Highlights

- Focus Boom Flight Test
- Interior Effects Room (IER) Subjective Tests
- Community Response Flight Test
- Structural Response & Modeling



Focus Boom Flight Test



SCAMP Introduction

- **Superboom Caustic Analysis and Measurement Project**
 - Objective: Validate models for prediction of focus booms
 - NRA award to Wyle Laboratories in 2010
 - Flight test May 9-20, 2011
 - F-18 performing acceleration and dive maneuvers
 - Large ground microphone array (81 mics) in remote desert location
 - Microphones on TG-14 motorized glider and tethered blimp
 - Weather data
- Extensive collaborative work
 - 11 NASA/Industry teams on site for acoustic measurements

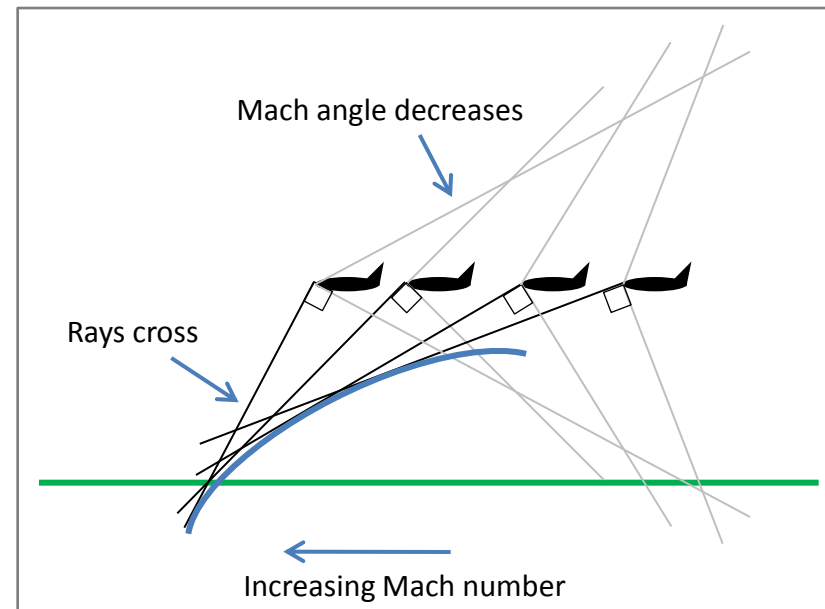
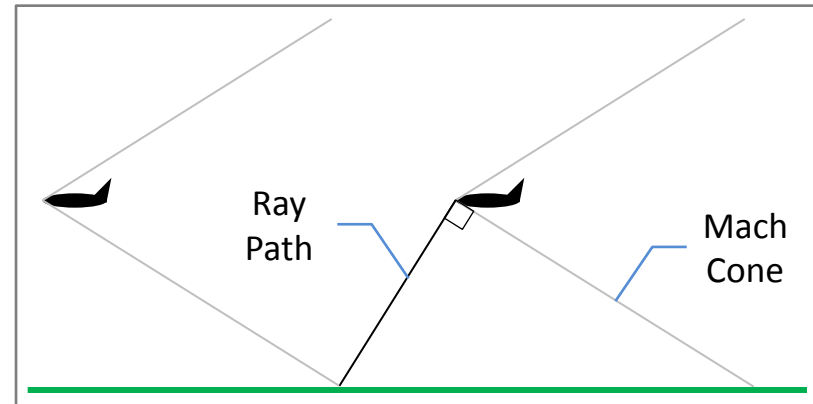


What is a focus boom?

- Focusing of sound rays
- Due to accelerations or other maneuvers

Why do we care?

- Boom amplitude much higher than from cruise
- Unavoidable during accel to supersonic speed
- Need to evaluate focus boom from future low-boom aircraft
- Acceptability of overland supersonic flight

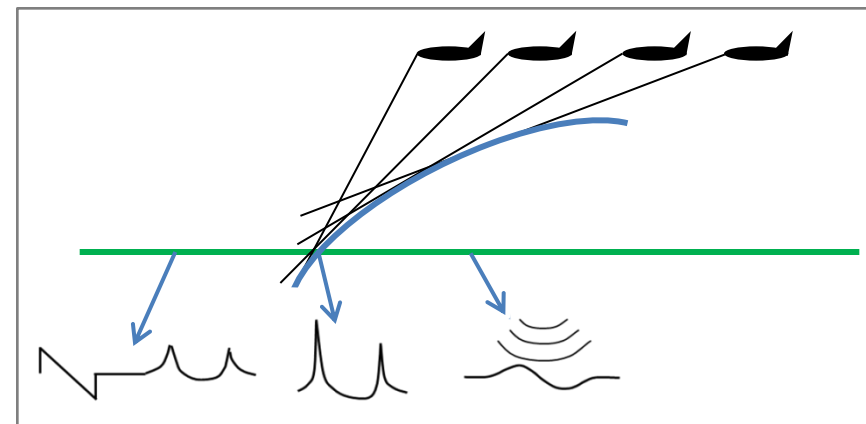
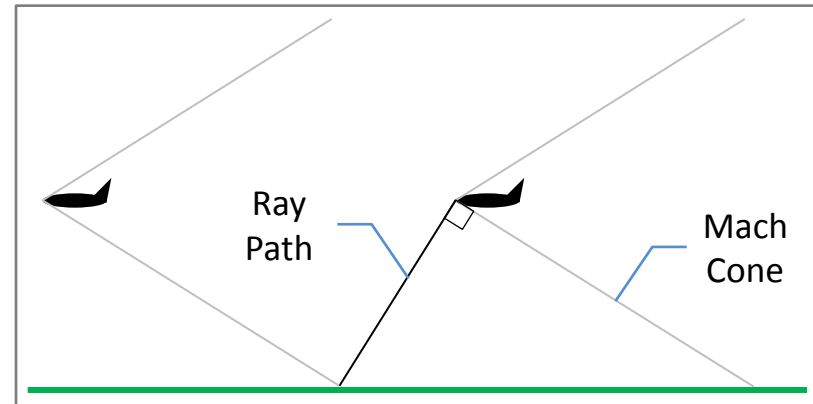


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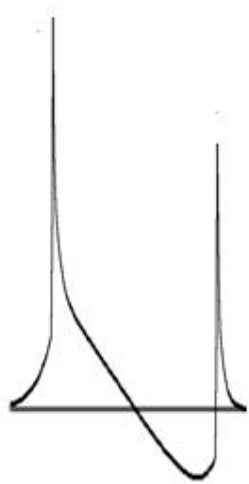
Test Results

- 2 weeks of testing
- 13 Flights, 70 array passes
- 37 focus booms recorded
- $P_{\max} = 7-8 \text{ psf}$ ($\sim 4 * P_{\max}$ cruise boom)

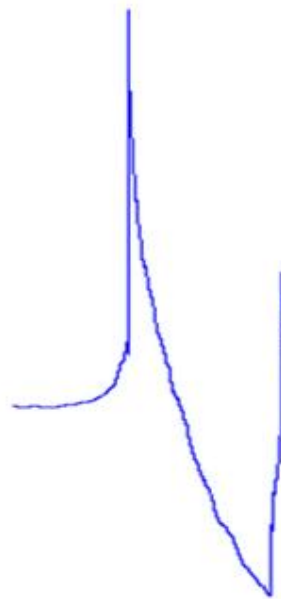
Example Data



Preliminary Predictions



PCBoom Prediction



Measurement



Pseudospectral
Tricomi Prediction
(approx. scale)

- Comparisons of flight data to 1st generation predictions from 4 codes this week
- Final versions of codes in Summer 2012
- Predictions of focus booms from low-boom vehicle designs

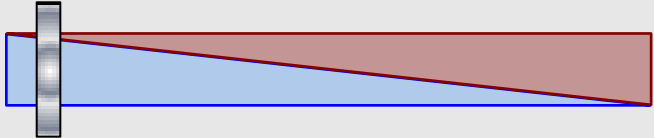
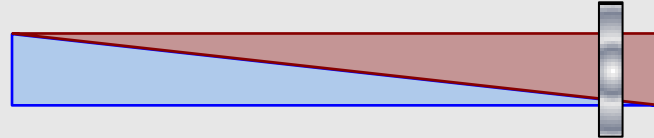


Interior Effects Room (IER) Subjective Tests



Psychoacoustic Testing

Develop psychoacoustic model of human response to low booms
(both outdoors and indoors) for single and multiple events

Field Test	Laboratory Test
Realism Control 	Realism Control 
• Realistic boom exposure – Levels – Time period • People in real communities • Absolute annoyance	• Isolate effects of – loudness – rattle – vibration – room acoustics – visual cues – ambient noise • Relative rather than absolute annoyance

Interior Effects Room (IER) Overview

Objective

- Assess human response to sonic booms experienced indoors
- Investigate response to simulated booms from new low-boom aircraft designs

Approach

- Controlled and repeatable tests
- Realistic living room environment
- Realistic low-frequency reproduction and transmission of sonic booms

Significance

- Will ultimately lead to a psychoacoustic model of human response to single sonic booms indoors
- Complement community studies and previous lab tests



Two IER Subjective Tests

Objectives

- 1) Systematically vary spectral content of sonic boom test sounds
- 2) Does indoor annoyance increase with loudness?
- 3) Is rise time inversely related to annoyance indoors?
- 4) What is acoustical variation across listener locations?
- 5) Evaluate performance of loudness/sound quality metrics to predict indoor annoyance to sonic booms



Test Method

- 30 subjects for each test
 - 3 subjects tested at a time
 - All subjects repeated test at all 3 locations in Test 1
- Test signals
 - Synthesized waveforms
 - Field measurements
- Paired comparison to a reference
 - Each pair presented in two orders A-B and B-A
 - Signal levels varied
 - Level of each signal equally annoying as reference



First

~~Second~~

If the first sound is more annoying depress the button labeled 'First'.
If the second sound is more annoying depress the button labeled 'Second'.

IER Test Summary

New facility validated as a laboratory research tool for studying indoor human response to sonic booms

- 1) New method devised to design boom-like sounds with varied spectral content
- 2) Does indoor annoyance increase with loudness? Yes
- 3) Is rise time inversely related to annoyance indoors? Yes
- 4) What is variation in loudness across listener locations? ≤ 7 dB
 - Test method must account for variation **or** locations must be changed to decrease variation
 - Listener locations 1-4-5 give more uniform exposure than 1-2-3
- 5) Evaluate performance of loudness/sound quality metrics: best metrics identified
 - No loudness metric predicts annoyance to indoor signals better than PL
- 6) Vibration contributes to annoyance

Community Response Flight Test



WSPR Introduction

Pilot test of community response to multiple low-boom events using F-18 dive maneuver and residents accustomed to booms

- **Waveforms and Sonic boom Perception and Response**
 - 2 NRA Contract awards: Wyle Laboratories and Fidell
 - Design and execute an experiment at EAFB to gather data relating the impact of sonic boom exposure to EAFB community residents
- Develop experimental methodologies
 - Annoyance survey methods
 - Acoustic data acquisition
 - Analysis methods
- Prepare for future community studies



Test Design

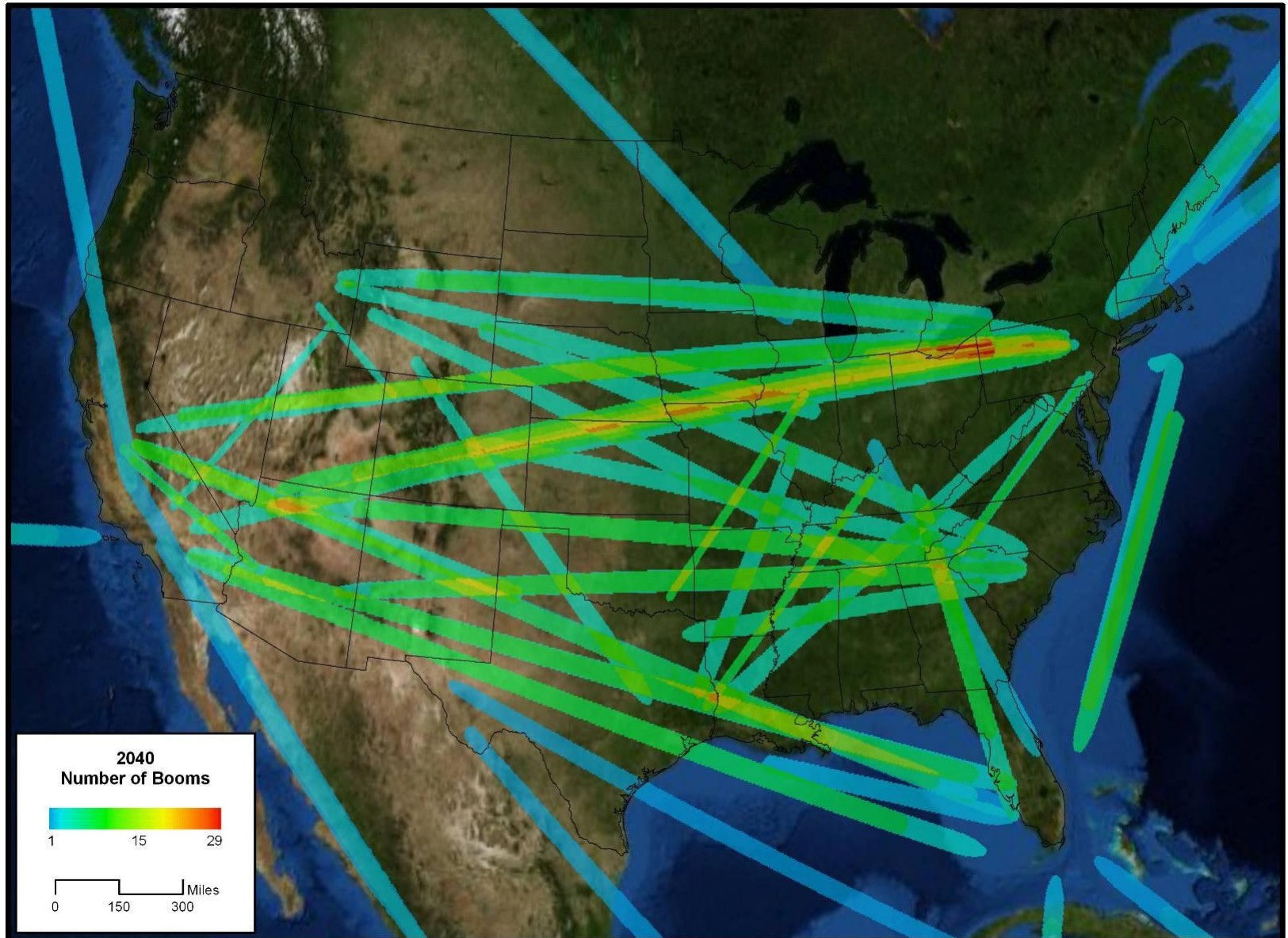
- Experimental design
 - Noise exposure
 - 100+ residents at EAFB
 - Subjective survey methods
 - Paper/pencil
 - Website
 - Smartphone
- Data collection
 - Sonic boom measurements throughout community
 - Residents fill out a survey each time they hear a boom
 - Residents fill out a daily survey
- Two weeks in Nov. 2011
- 3 low-boom target levels: 0.1, 0.3, 0.5 psf
- 3-10 booms/day
 - Morning and afternoon



Structural Response & Modeling



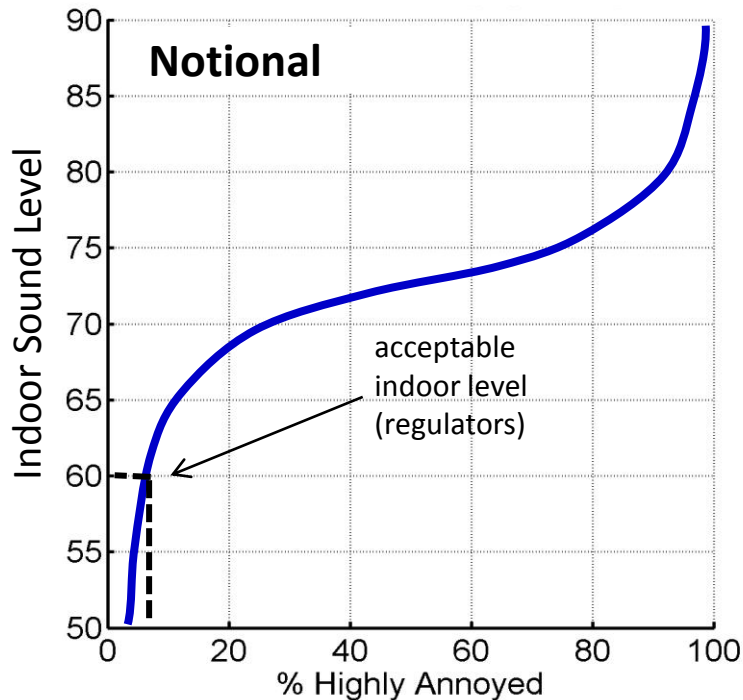
Daily Sonic Boom Exposure in 2040 (Wyle)



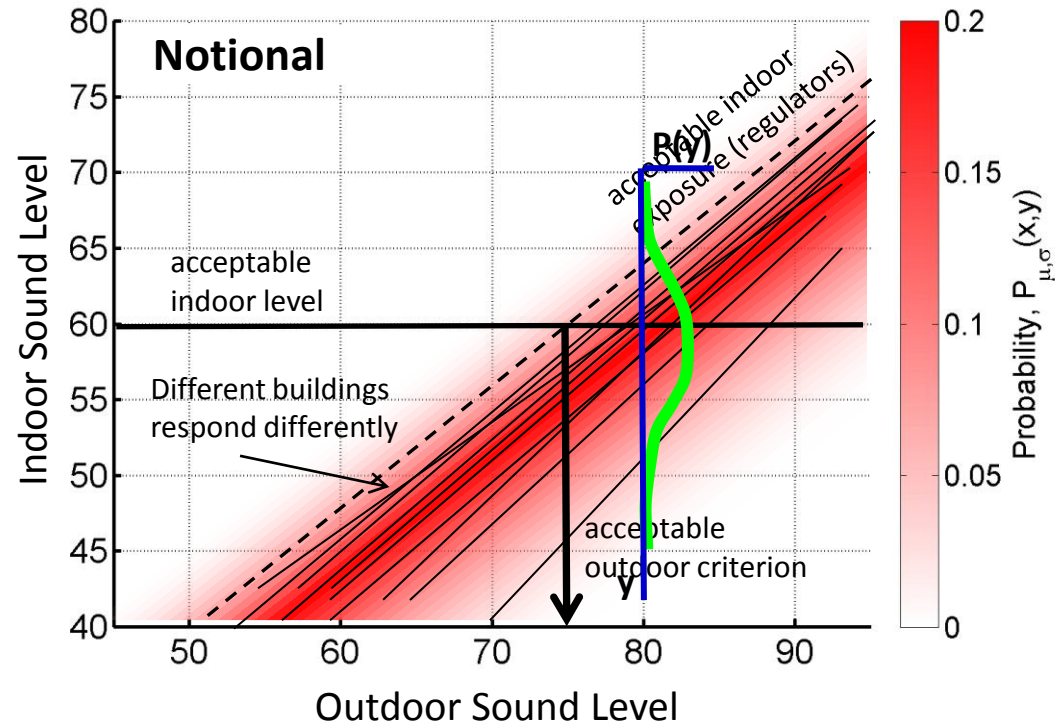
Path Towards Regulation Change

Relating indoors to outdoors:

Indoor Annoyance Model



Indoor Exposure



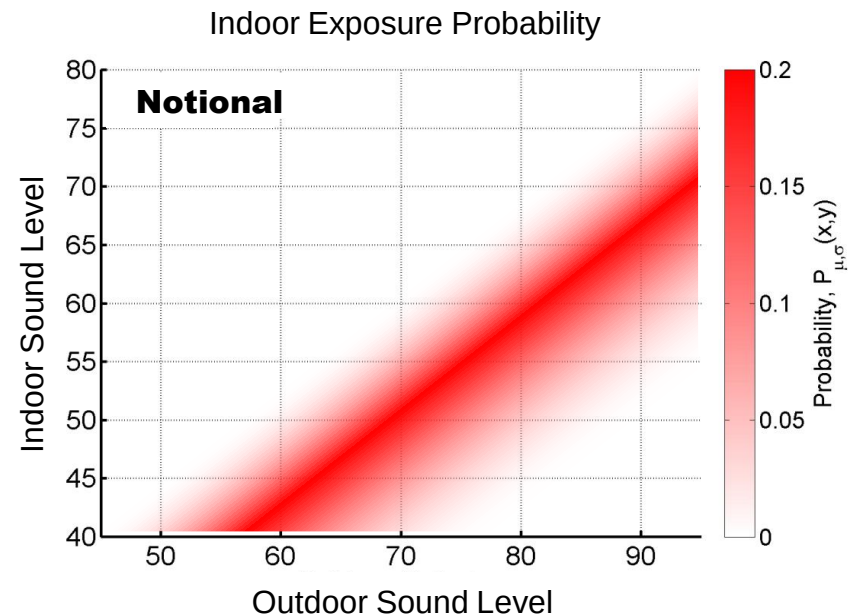
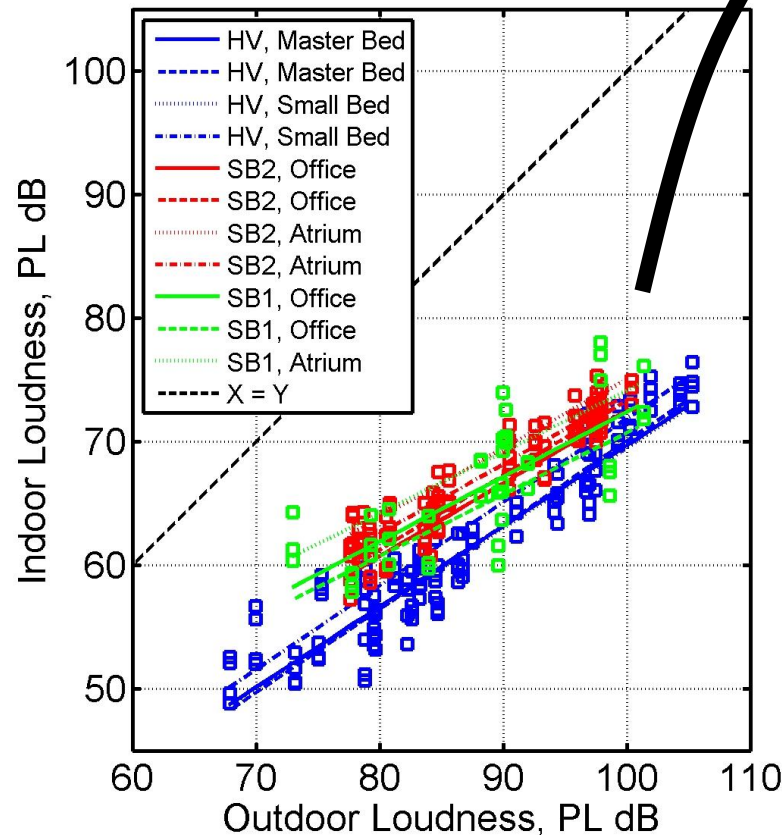
Going from indoors to outdoors:

- NASA**
 - Defining exposure probability density function (structural acoustic problem)
 - Defining indoor (and outdoor) metrics (psychoacoustic problem)
- Regulators**
 - Defining an acceptable indoor level
 - Defining an acceptable indoor exposure probability

Structural Response Research Goal



Validate and use prediction tools to create a probability density function representing indoor community exposure



Key FY12 Activities

- Atmospheric Propagation
 - Analysis of focus boom flight test and model development (SCAMP)
- Structural Response & Modeling
 - Apply structural models to IER
- Human Response & Modeling
 - Low boom community response test (WSPR), Nov 2011
 - Additional subjective tests in Interior Effects Room



Backup Slides

Low-Boom Dive Maneuver

- Sonic boom is generated during supersonic dive of an F/A 18 aircraft (Dryden operated)
- Boom propagates very far, attenuating before reaching the building
- Boom amplitude is adjusted by moving dive location relative to the building

NASA Dryden low boom maneuver

