Sonic Boom Technologies and Challenges

FAA Civil Supersonic Aircraft Workshop

Lockheed Martin Aeronautics Company
Advanced Development Programs

November 13, 2003
Key Steps to Supersonic Flight Overland
Sonic Boom Reduction Techniques

The diagram illustrates the reduction in sonic boom levels by size alone, with Concorde and HSCT represented as larger aircraft. SBJ shows additional reduction due to tailoring. The x-axis represents MTOGW (Maximum Take-Off Gross Weight) in lbs, and the y-axis represents ground shock strength in psf (pounds per square foot). The graph compares the ground shock strength for different lengths: 326 ft, 202 ft, and 130 ft.
Human perception of loudness is due to pressure change of leading & trailing shocks.
New Low Boom Technologies

- Design Requirements
  - Speed, Range, Payload
  - Low Sonic Boom
  - Takeoff/Landing from Business Airports
  - Safety

- Low Boom Distributed Lift
- Innovative Structural Bracing
- Low Emissions
- Stage IV Noise Compliant Simple Inlet and Turbofan Engines
- SS-NLF Integration
- Shock Cancellation Technology
- Low-Cost Conventional Construction
- Integrated Design Optimization
- Low Drag Nose

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Low Sonic Boom Validation

- Wind tunnel tests of lift/area minimized designs
- Sonic boom less than 0.5 psf predicted from tunnel measurements
- Refined low drag / low boom nose
- CFD prediction & NASA Ames ballistic range measurements
- Schlieren photo and measurement confirms low boom

- DARPA QSP modified F-5 for shaped sonic boom
- First flight test validation of non-“N wave” sonic boom
- LM Sonic Boom Simulator improves low boom shaping
- Supersonic natural laminar flow for low drag
- NASA Dryden flight test demonstrates full chord SS-NLF

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Sonic Boom Analysis Methodology Validation

Track Signatures at ~8 Fuselage Lengths off the SR-71

- CFD matches flight test measurements of near field pressure data

M_\infty = 1.25  
AOA = 3.16 deg.  
C_L = 0.085  
CFL3D (Euler)

From AIAA 556-2003; Peter Hartwich, et. Al.
Sonic Boom Analysis Methodology Validation

- CFD analysis matches wind tunnel measurements
- Wind tunnel & CFD data propagated to ground demonstrates acceptably low boom levels

CFD Analysis
Wind Tunnel Measurement

Prediction at the Ground

17.4 DNL(A) for 1 event/day
From CFD Analysis

16.8 DNL(A) for 1 event/day
From Wind Tunnel Measurement
Flight Test Validation of Predicted Sonic Boom

- DARPA QSP tested modified F-5 aircraft with tailored fuselage fairing to demonstrate front shock boom reduction.
- Results confirm that Lift/Area Tailoring can produce shaped sonic boom on the ground.

![Graph showing flight test validation of predicted sonic boom](image)

- Unmodified F-5E
- Predicted Improvement
- Flight Test Validation

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SSBD Flight 9
August 27, 2003
06:46:32.7602 PDT
NASA Dryden
BADS West
Sonic Boom Measurement Metrics

- **Peak Overpressure**: Not a good metric of sonic boom loudness.
- **Commonly used for impulsive sounds but not intended for quieter low level sonic booms**.

- **A-Weighted SEL (dB)**: Provides the best correlation.

- Commonly used for impulsive sounds but not intended for quieter low level sonic booms.
Sonic Boom Acceptability Metrics

Region of Acceptability

Current SBJ Design Status
(One Flight / Day)

(Ten Flights / Day)

NASA In-Home Study

FAA Guideline

Percent Highly Annoyed

DNL (A)

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Recommendations

• Establish rulemaking project to amend FAR 91 to replace current prohibition on overland sonic boom with objective criteria for supersonic flight
  – *If necessary, Conduct further low boom human reaction studies using simulators*

• Alternatively,

• Amend FAR 91 Appendix B to broaden conditions for approval of Authorizations to Exceed Mach 1
  – *Incremental approach with evolution based on experience*

• Lead efforts to establish international criteria through ICAO Committee on Aviation Environmental Protection (CAEP)