Fixing the Sound Barrier

Three Generations of U.S. Research into Sonic Boom Reduction

... and what it means to the future

Presented in Conjunction with the 159th Meeting of the Acoustical Society of America
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• Perspective
  – Concorde & The U.S. SST
  – Recent interest in supersonic civil aircraft
• Sonic Boom Basics
• Progress in Sonic Boom Minimization
• What’s happening now
• Looking forward
Cruise Speed: Mach 2
Takeoff Weight: 400,000 lbs
Payload: 100 passengers
First Flight: 1969
Commercial Service: 1976-2004

Cruise Speed: Mach 2.7
Takeoff Weight: 675,000 lbs
Payload: 274 passengers
Program Start: 1965
Program Cancelled: 1971
Concorde, U.S. SST faced many challenges

One of the largest was… SONIC BOOM!
Concorde, U.S. SST faced many challenges

...Leading to the FAR prohibiting supersonic commercial flight over U.S.
Interest in Supersonic Flight has not Diminished

Supersonic cruise aircraft offer significant mobility improvements in the NextGen System

Supersonic flight over land will enable a revolution in transportation …

… up to 50% reduction in cross country travel time

… improving personal productivity and well-being

… moving time-critical cargo, including life-saving medical supplies

… enhancing homeland security through rapid transportation of critical responder teams

Supersonic Civil Aircraft with increasing capability will be enabled if technology and environmental barriers can be overcome
Sonic Boom Basics

Sonic Boom is NOT the sound of an aircraft “breaking the sound barrier”
Sonic Boom is created as long as the aircraft is flying faster than Mach 1.0

Speed < Speed of Sound (< Mach 1)
Pressure Disturbance (sound) precedes aircraft

Speed = Speed of Sound (Mach 1)
Aircraft Speed = Speed of Pressure Disturbance

Speed > Speed of Sound (> Mach 1)
Aircraft precedes pressure disturbance,
All disturbance reaches an observer instantaneously
Sonic Boom Basics

- Sonic Boom is 3-Dimensional
- Large “Carpet” of Ground is exposed as aircraft flies
- Noise is reduced at the edge of the carpet

Multiple disturbances (“shock waves”) near aircraft

- Disturbances Merge
- Signal lengthens
- Noise attenuates

- Two disturbances remain
- Signal has a characteristic “N” shape
- Called an “N wave” boom “signature”
Sonic Boom Basics: The N-Wave

Measured Sonic Boom

Measured Subsonic Takeoff Flyover
.. To the same scale
Sonic Boom Basics: The N-Wave

Measured Sonic Boom

Overpressure $\Delta p$

Duration

Rise Time

Factors in N wave annoyance
If Aircraft ground speed < Speed of Sound at the ground (~660 kts)…

Boom can “refract” and not reach the ground

"Caustic Line"

Rumble sound, rapidly decaying

Ground
Sonic Boom Minimization Through Aircraft Shaping

Shocks Coalesce into “N-wave”

Control Strength and Position of Disturbances

Disturbances do not Fully Merge

Shaped Boom at the Ground

Minimum Overpressure

Minimum Initial Shock
Impact of Boom Shaping

Low Boom signatures are achieved by applying shaping to smaller aircraft.

Potentially more than 35 dB(a) of Reduction!
Sonic Boom Research in Supersonic R&D Programs

3rd Generation

1st Generation

60’s-70’s Concorde U.S. SST
Mach: 2.0 -2.7
TOGW 400,000 - 675,000 lbs
Payload: 100 -234 Passengers
Sonic Boom Basics
Community Impact
Shaping Concepts

2nd Generation

80-90’s High-Speed Research
Mach: 2.4
TOGW 750,000 lbs
Payload: 300 Passengers
Shaping Benefit
Low Boom Design
Community & Wildlife Impact

Current Efforts
NASA, FAA & Industry
Mach: 1.2-2.0
TOGW 100,000- 300,000 lbs
Payload: 8-100 Passengers
Integration of Low Boom Design
Indoor Noise Impact
Atmosphere Effects

DARPA Quiet Supersonic Platform
Mach: 2.4
TOGW 100,000 lbs
Payload: 20,000 lbs
Benefit of Small Size
Low Boom Design
Flight Validation of Boom Shaping

We are doing something!
Can we do something?
Can we live with it?
Research on Low Boom Design
Research on Boom Acceptability
Summary of Sonic Boom Research

• Basics of Sonic Boom creation, propagation and impact are well understood
  – Includes structural damage, avalanches, animal life
• Several practical reduction approaches have been identified
  – Flight below the cutoff Mach number
  – Shaped booms
• Theory, design approaches and benefits have been validated
  – Analysis, ground experiments, simulation, flight tests
Current Research Focus

• Understanding impact of booms heard by people indoors
  – Transmission of the boom sound into a house/building
  – Effects of rattle and startle

• Understanding effect of atmospheric turbulence

• Full integration of boom reduction into aircraft design
  – Shaping the aft portion of the signature
  – Engine exhaust jet effects
  – Simultaneous design for low boom, high efficiency, light weight, etc.
Future Vision

Efficient, Affordable Supersonic Flight…..

Thank you for your attention!

… with little or no sonic boom noise