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
University of California Davis Air Quality Research Center
Revolution in Aviation Symposium
March 1, 2009

Outline

- 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

Perspective

Concorde

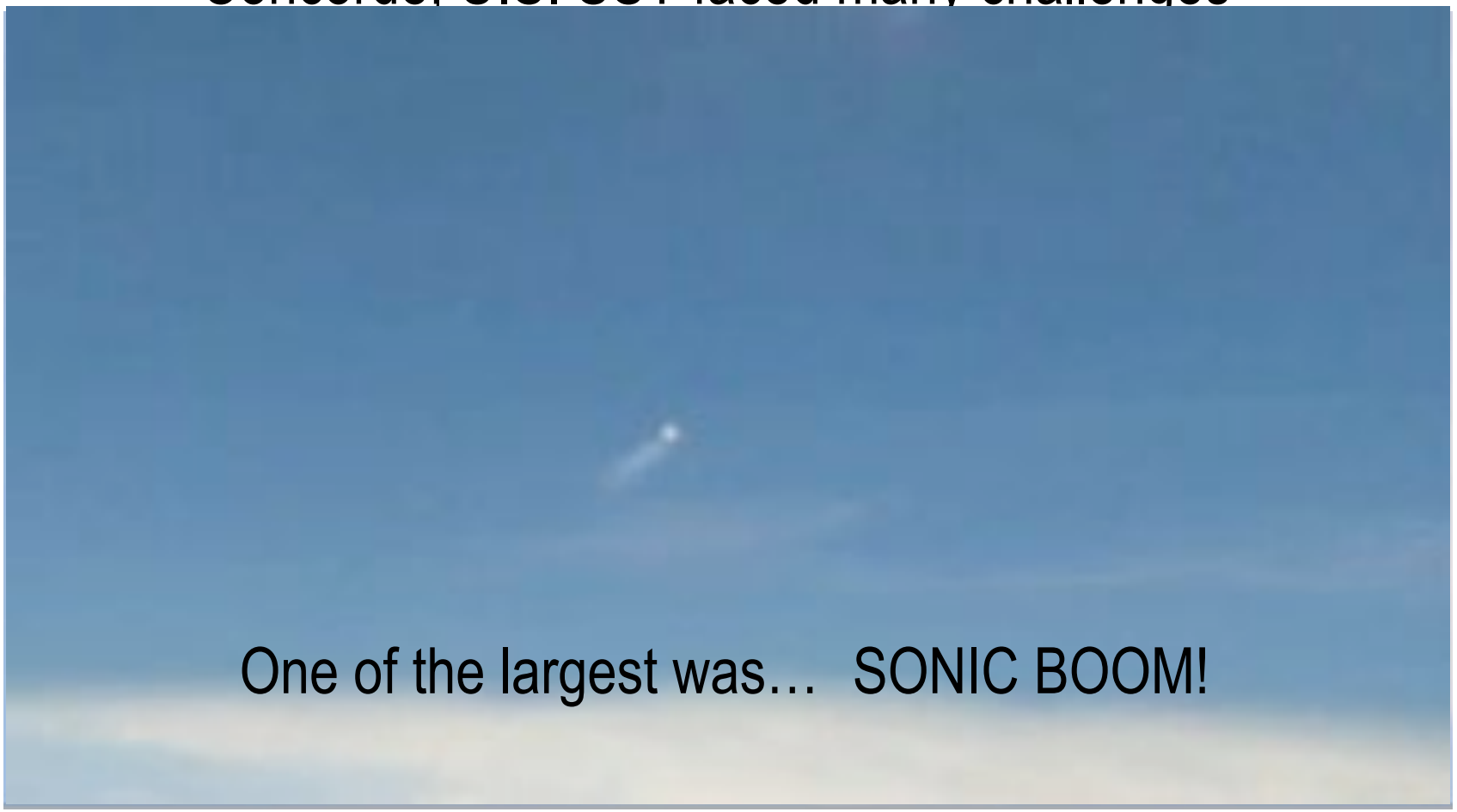
Cruise Speed	Mach 2
Takeoff Weight	400,000 lbs
Payload passengers	100
First Flight	1969
Commercial Service	1976-2004

U.S. SST

Cruise Speed	Mach 2.7
Takeoff Weight	675,000 lbs
Payload passengers	274
Program Start	1965
Program Cancelled	1971

Perspective

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

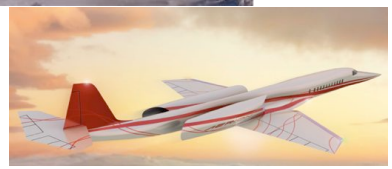
Supersonic flight over land will enable a revolution in transportation …

… up to 50% reduction in cross country travel time

… improving personal productivity and well-being

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

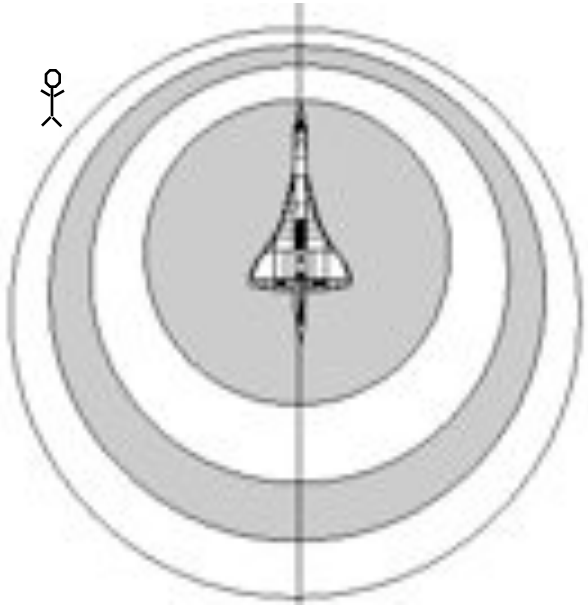
… enhancing homeland security through rapid transportation of critical responder teams



2010 **2020** **2030**

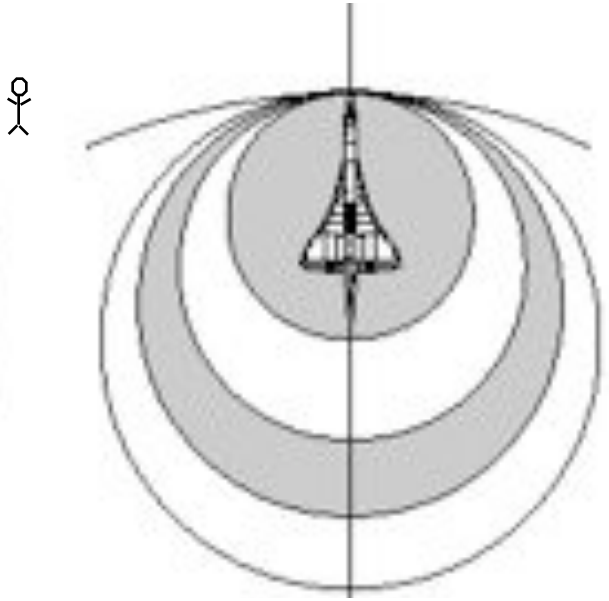
Supersonic Civil Aircraft with increasing capability will be enabled if technology and environmental barriers can be overcome

Sonic Boom Basics



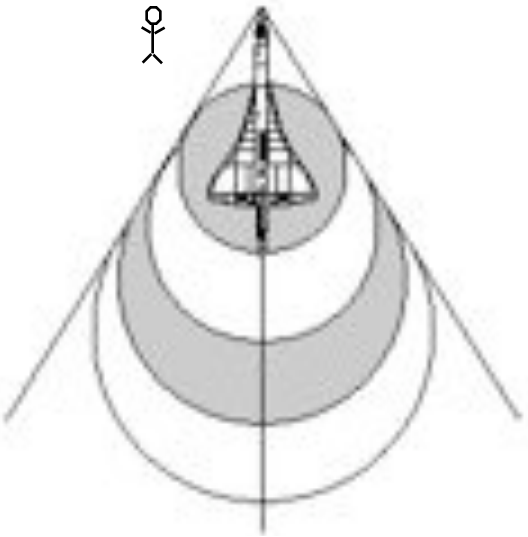
Speed < Speed of Sound (< Mach 1)

Pressure Disturbance (sound) precedes aircraft



Speed = Speed of Sound (Mach 1)

Aircraft Speed = Speed of Pressure Disturbance



Speed > Speed of Sound (> Mach 1)

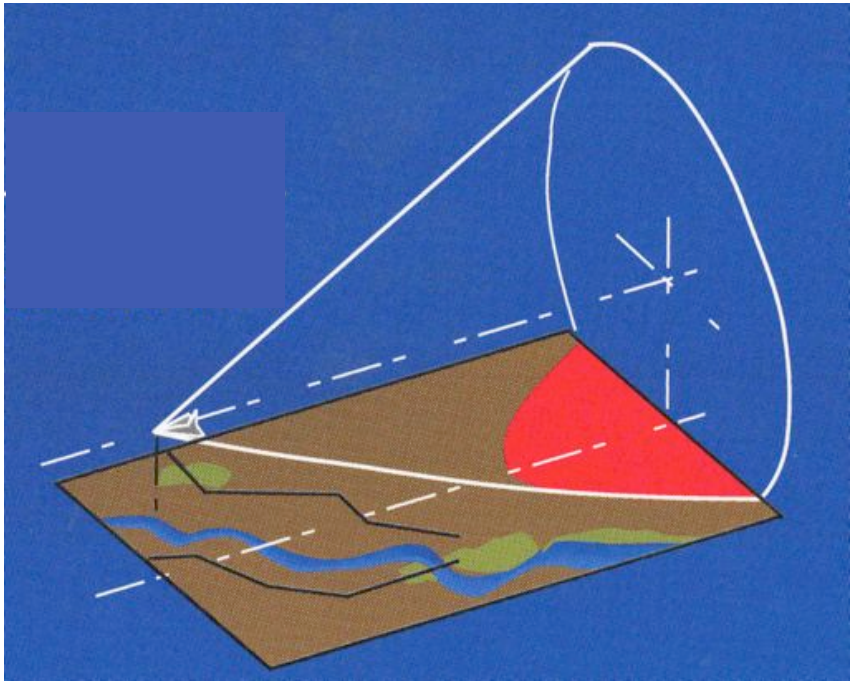
Aircraft precedes pressure disturbance,

All disturbance reaches an observer instantaneously

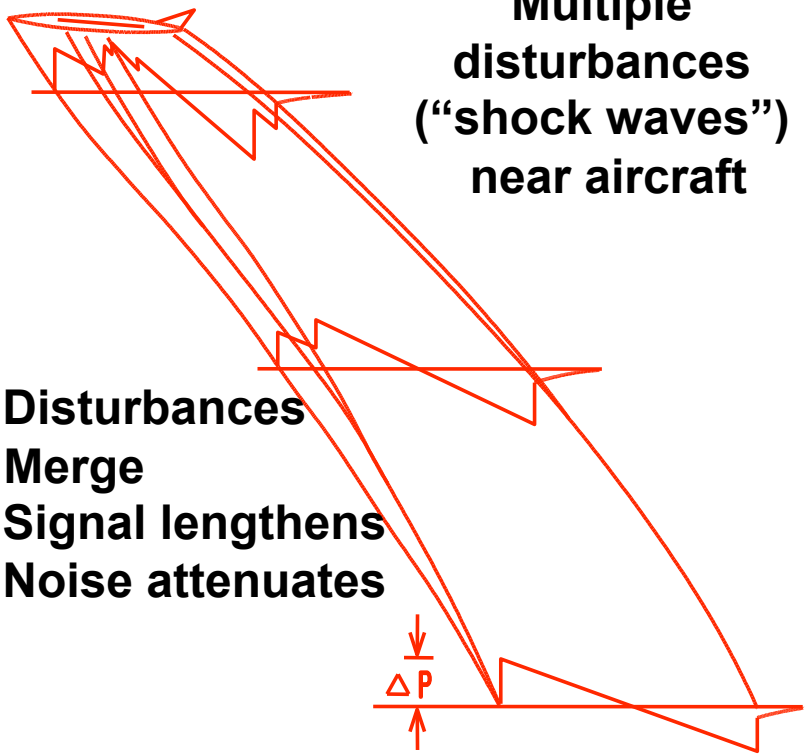
Sonic Boom is NOT the sound of an aircraft "breaking the sound barrier"

Sonic Boom is created as long as the aircraft is flying faster than Mach 1.0

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

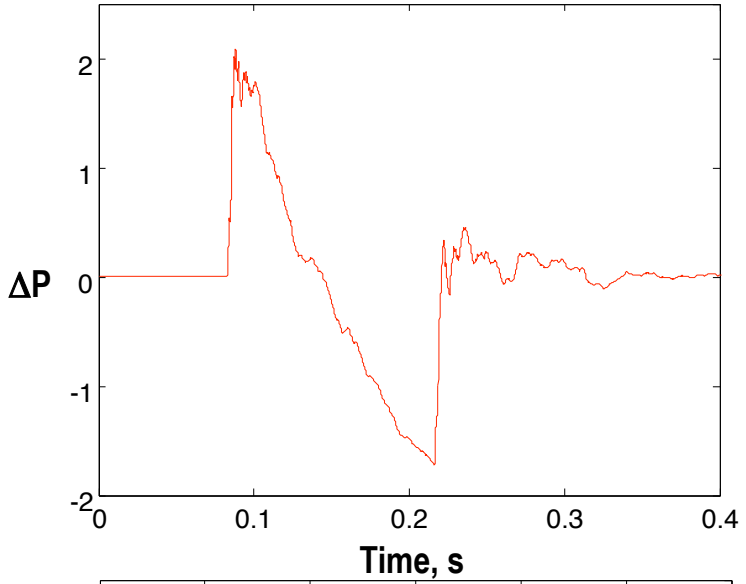


- Disturbances Merge
- Signal lengthens
- Noise attenuates

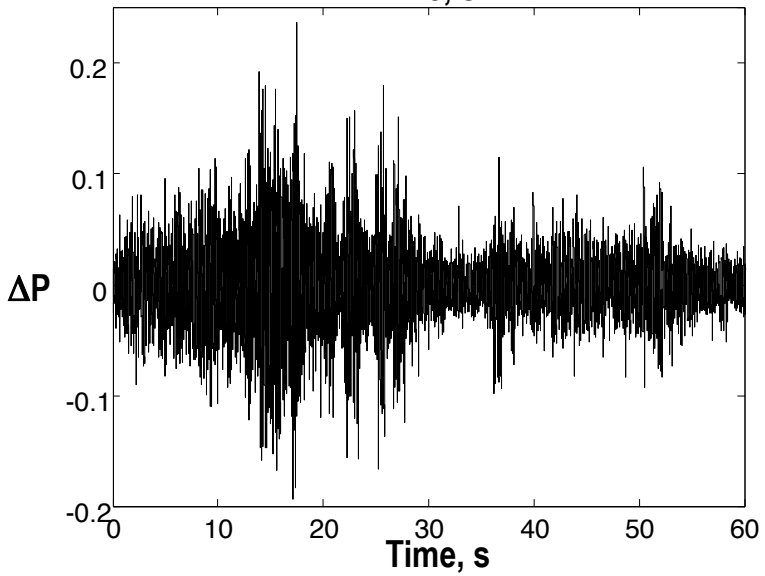
- Two disturbances remain
- Signal has a characteristic “N” shape
- Called an “N wave” boom “signature”

Sonic Boom Basics: The N-Wave

Measured Sonic Boom

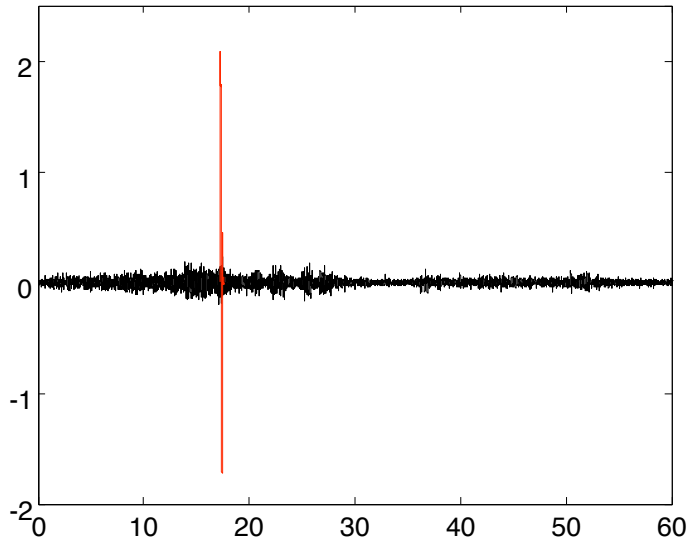


Measured Subsonic Takeoff Flyover



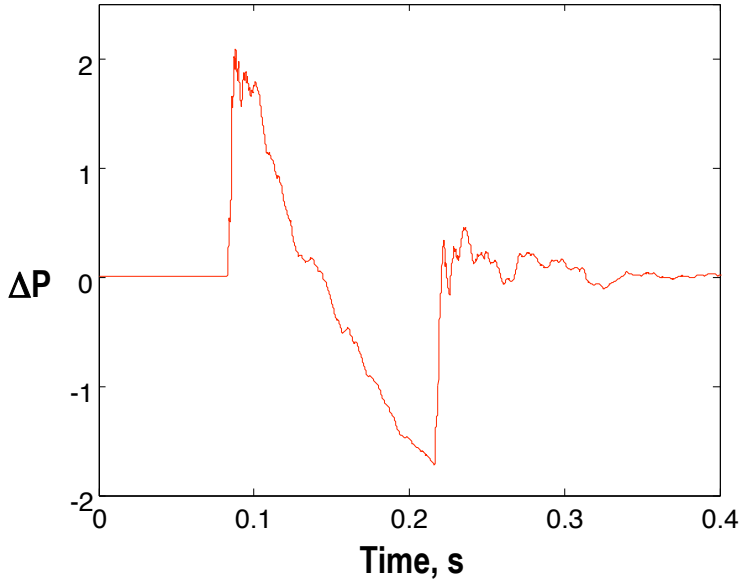
Sonic Boom Basics: The N-Wave

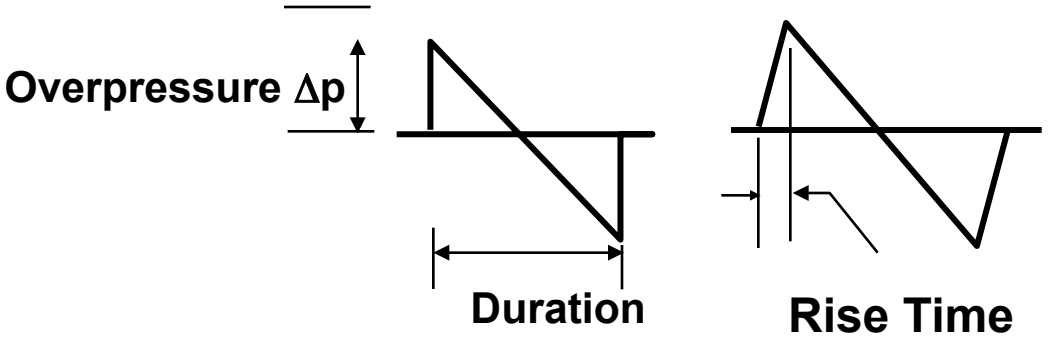
.. To the same scale



Sonic Boom Basics: The N-Wave

Measured Sonic Boom

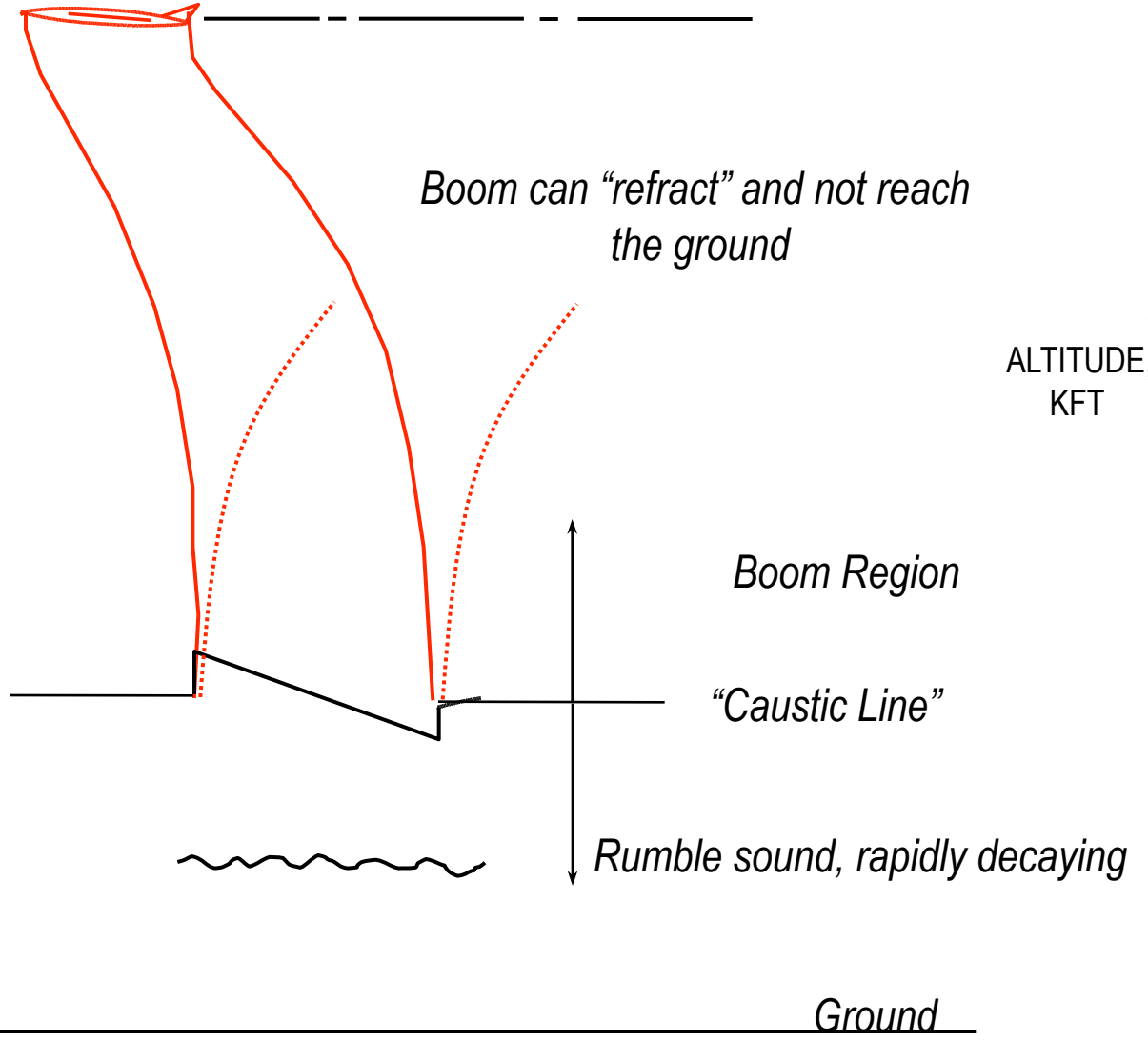


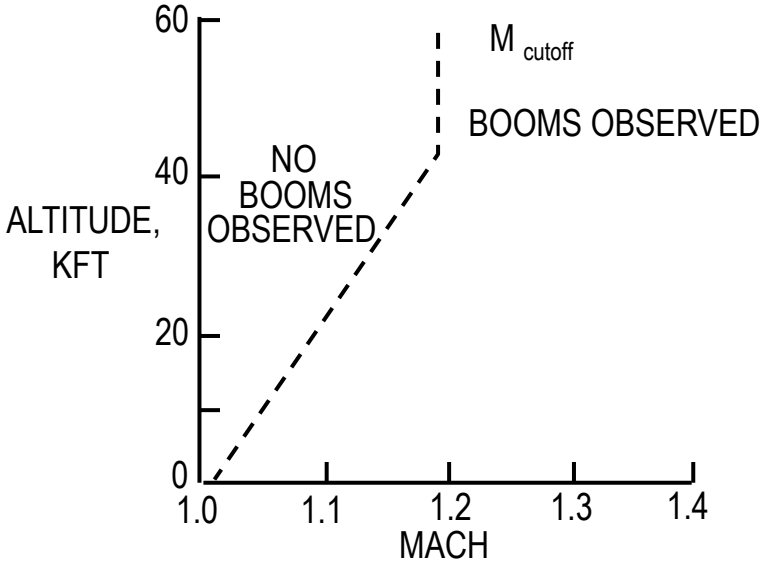


Factors in N wave annoyance

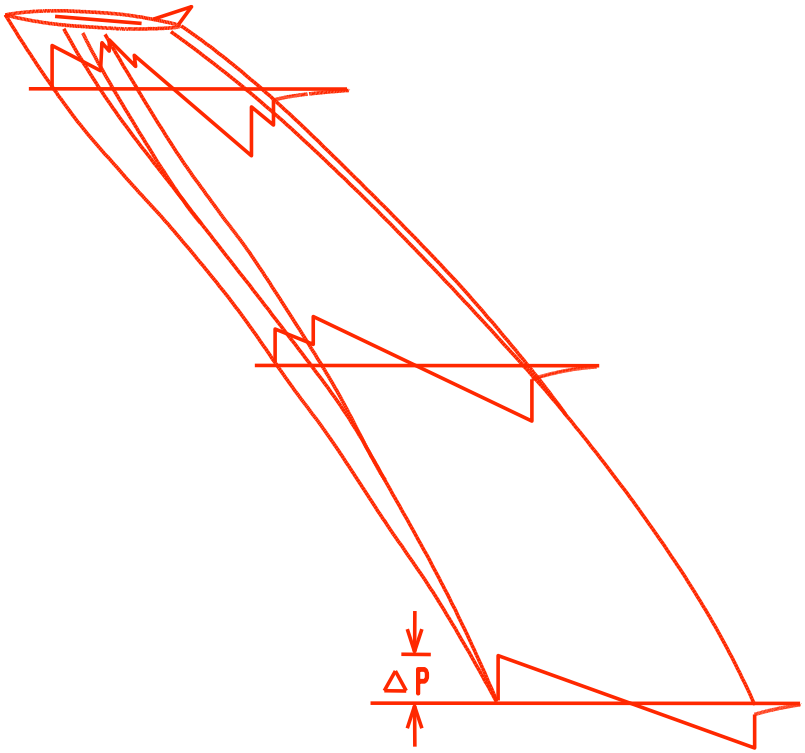
Practical Approaches to Sonic Boom Reduction

If Aircraft ground speed < Speed of Sound at the ground (~660 kts)…





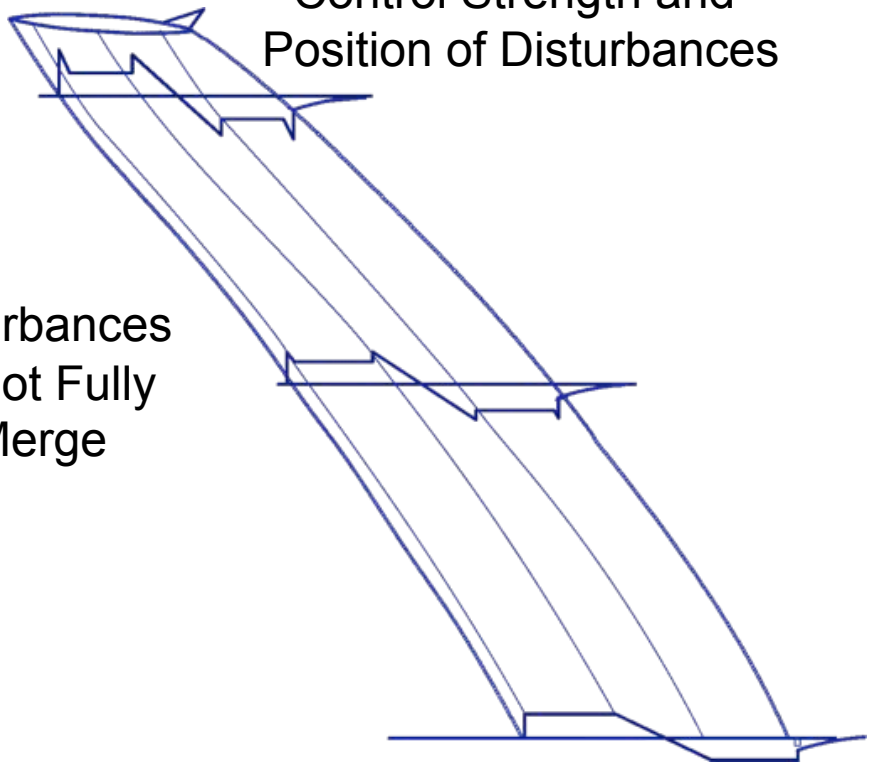
Sonic Boom Minimization Through Aircraft Shaping



Shocks Coalesce into “N-wave”

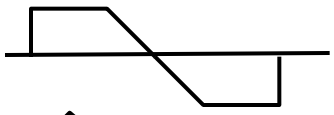
Control Strength and
Position of Disturbances

Disturbances
do not Fully
Merge

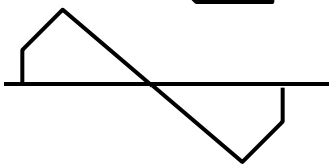


Shaped Boom at the Ground

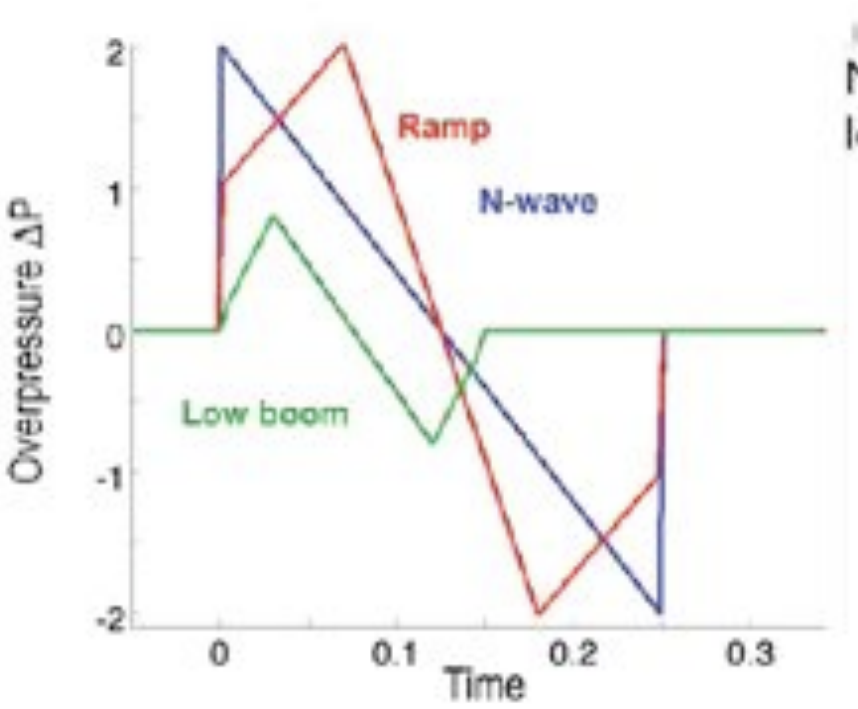
Minimum Overpressure



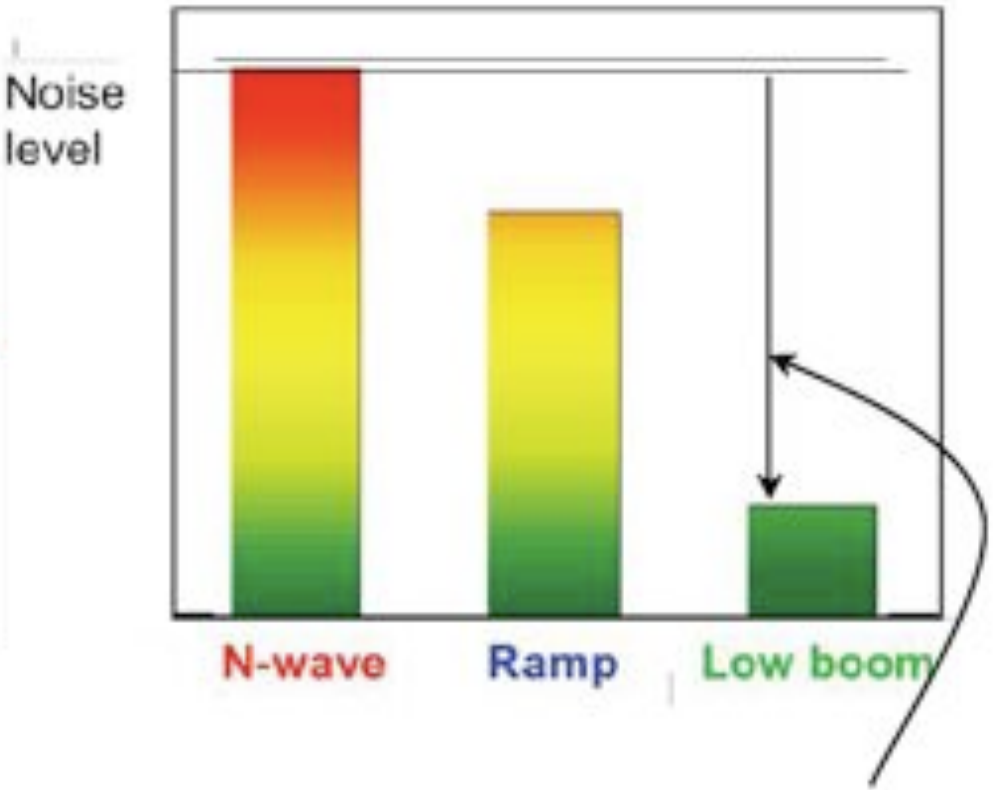
Minimum Initial Shock



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

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!

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*

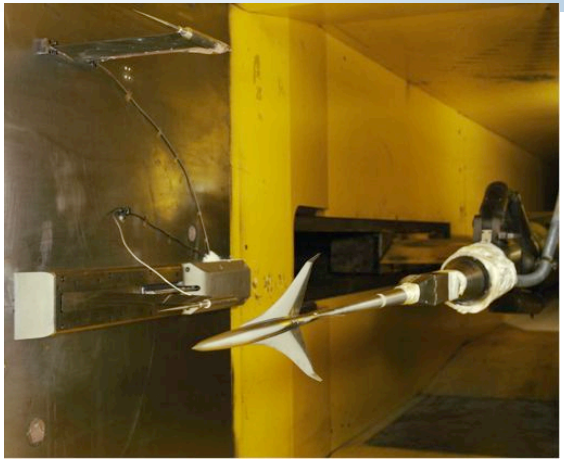
Can we do something?

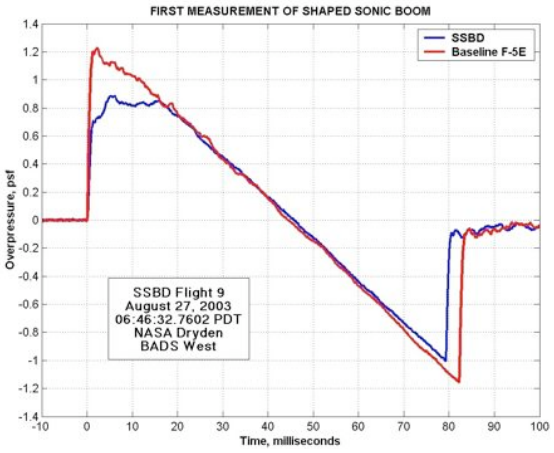
1st Generation

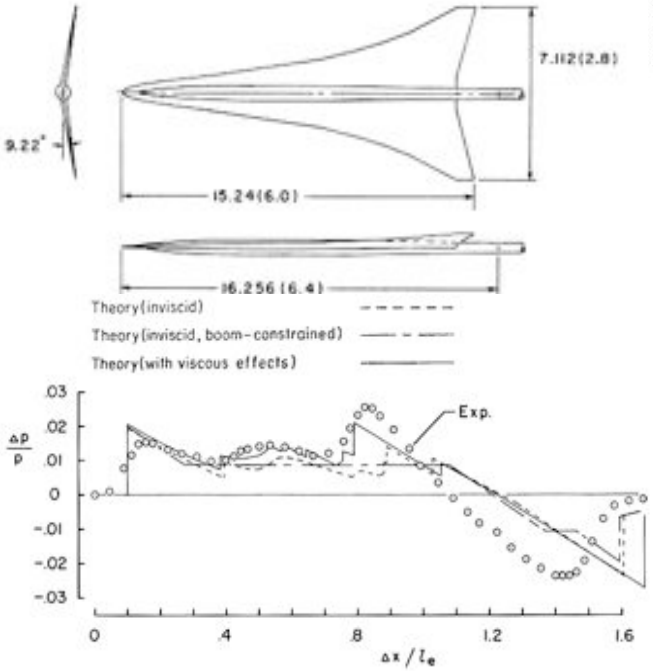
60's-70's Concorde U.S. SST	*Mach: 2.0 -2.7* *TOGW 400,000 - 675,000 lbs* *Payload: 100 -234 Passengers*	*Sonic Boom Basics* *Community Impact* *Shaping Concepts*

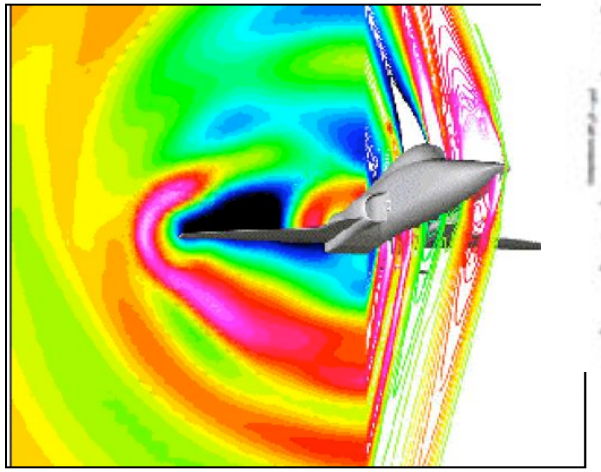
Can we live with it?

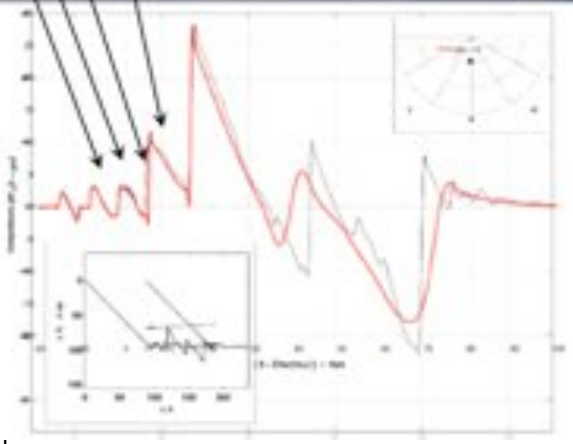
Research on Low Boom Design



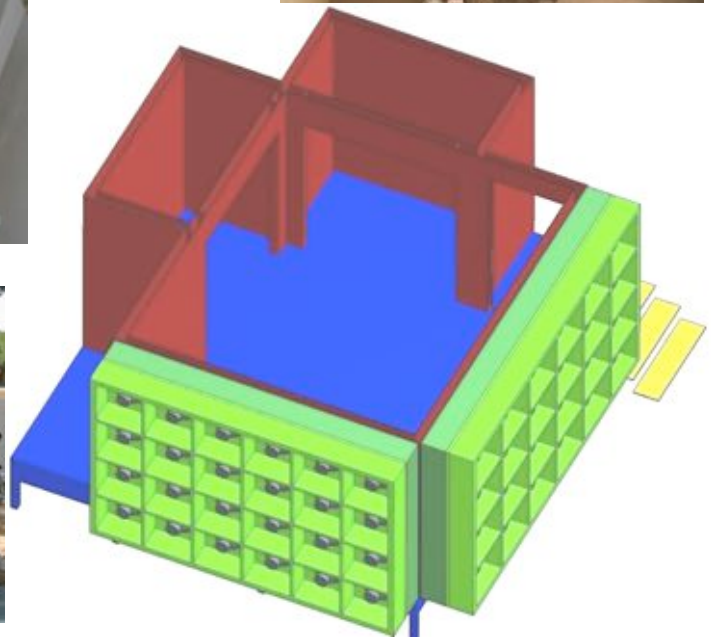








Research on Boom Acceptability



Summary of Sonic Boom Research

- Basics of Sonic Boom creation, propagation and impact are well understood
  - Includes structural damage, avalances, 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
  - Simulataneous design for low boom, high efficiency, light weight, etc.

Future Vision

Efficient, Affordable Supersonic Flight…..

… with little or no sonic boom noise