From Concorde to Future Supersonic Transport (SST): Designs for Reducing Sonic Boom in Future Supersonic Commercial Aircraft

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***Abstract*—On October 14, 1947, the sound barrier was broken by the Bell X-1, and the possibility of traveling faster than sound was proven. With the development of commercial aircraft, the TU-144 and Concorde showed that the distance between continents was not as far as people had thought. Supersonic commercial aircraft offer the possibility of significantly reduced travel time, but their wider use has been limited by sonic boom. Concorde demonstrated that traveling at Mach 2 was technically possible, but its loud far-field boom restricted its supersonic operation largely to areas above uninhabited regions such as the ocean. This essay examines how future SST aircraft may reduce sonic-boom intensity through aerodynamic and propulsion-integration design and hopefully bring continents closer again. First, the cause of sonic boom is explained through shockwave and the development of the classical N-wave. The quantification of boom intensity is then discussed in terms of peak overpressure, waveform shape, rise time, and perceived loudness level. The essay then considers possible design solutions, including fuselage shaping, wing and lift-distribution control, possible advantages brought by canards, control surfaces and engine placement. Finally, NASA's X-59 is discussed as a modern low-boom prototype that demonstrates how aircraft shaping can transform a loud boom into a quieter sonic thump. The essay argues that future supersonic commercial aircraft must integrate low-boom design at the earliest design stage as a primary design objective, rather than treating noise as a secondary issue.**

***Keywords*—sonic boom, shock wave, SST, aerodynamics**

I. Introduction

SST has been an attractive concept since the sound barrier was broken by the Bell X-1, offering the potential to reduce intercontinental flight times [1]. The most famous example is Concorde, which operated as a commercial supersonic passenger aircraft and became a symbol of that era. However, Concorde also highlighted one of the most important barriers to civil supersonic flight: namely, the sonic boom and the resulting operational restrictions over many inhabited regions [2]. Though it could achieve stable Mach 2 cruising speed and had the capability for low-speed takeoff and landing, it generated intense far-field ground noise.

Thus, the next generation SST cannot be designed only for speed. Public acceptance, environmental impact and following regulations are equally important. This has shifted the design philosophy and objective from simply reaching high speed and efficiency to optimizing the aircraft's complete pressure signature. NASA's X-59 QueSST provides a modern example of this change. Unlike Concorde, it is not yet a passenger aircraft, but a research prototype designed to demonstrate quiet supersonic flight and provide data for future regulations.

The following content discusses how sonic boom is formed, how its intensity could be quantified, and how future aircraft may reduce its noise level. Aerodynamic design features, including fuselage shaping, wing design, control surfaces, and engine placement, are the main aspects discussed.

II. Cause of Sonic Boom and Quantification of Boom Intensity

A sonic boom occurs when an aircraft travels faster than the local speed of sound. In supersonic flight, shock waves are produced due to the compressibility of air around different parts of the aircraft, including the nose, canopy, wings, engine and control surfaces. The pressure behind shocks is normally higher than that before, which causes a sharp increase.

As these shock waves travel down through the atmosphere from cruise altitude to ground level, they merge into a stronger pressure signature. For a supersonic aircraft, the pressure signature is normally N-shaped, as shown in Fig. 1. The N-wave consists of a rapid pressure rise caused by the oblique shock at the nose of the aircraft, a gradual pressure decrease, and a second sharp pressure recovery caused by flow separation and engine-related shock (assuming a cruise speed of Mach 2). This sudden change in pressure is what people on the ground hear as a sonic boom.

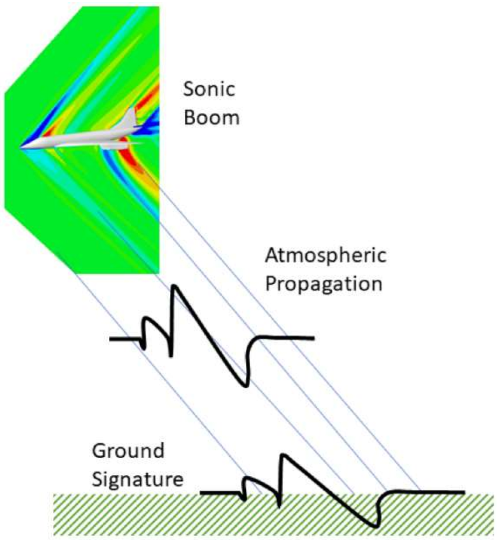

Fig. 1. N-wave pressure signature [3].

Boom intensity could be described with peak overpressure, which is the maximum pressure increase above the atmospheric pressure [4]. However, peak overpressure alone does not fully describe how disturbing a boom is to people on the ground. Human perception also depends on rise time, waveform duration, frequency content, sweep area of the Mach cone and structural vibration. For these reasons, perceived loudness is normally quantified using PLdB, which is often used when assessing the noise level of low-boom aircraft [5]. A sharper N-wave with a short rise time and higher absolute peak values is usually more disturbing than a smoother pressure signature with the same overall pressure change.

Therefore, reducing sonic boom is not simply a matter of flying more slowly or making one part of the aircraft sharper. The main design objective is to control the full pressure signature so that individual shock waves are weakened and separated before they combine into a strong N-wave at ground level.

III. Possible Solutions

The first principle of low-boom design is to control the generation and interaction of shock waves before they reach the ground. Since shock waves are unavoidable in supersonic flight, the objective is to weaken and separate them so that they do not merge into a strong and sharp N-wave. The following discussion presents some possible design solutions.

Aerodynamic shaping is among the most direct ways to reduce sonic boom intensity. In a supersonic aircraft, strong pressure disturbances are generated around the nose, wing, tail and engine. If these pressure disturbances combine during atmospheric propagation, the ground signature—the N-wave shape—becomes sharper and louder.

A. Fuselage Design

Fuselage design has a major effect on sonic-boom formation and affected area because the nose and body produce the first shock wave and pressure disturbance. When an aircraft cruises at supersonic speed, the shock waves it generates spread downward and outward until they intersect with the ground. As the aircraft continues to move forward, this ground intersection sweeps over a large region, often described as the boom carpet [6]. Therefore, sonic-boom impact is not limited to a single point or path below the aircraft but affects a large area along the flight path. A stronger pressure signature can make this swept area more disturbing to people on the ground, while a weaker one can reduce the perceived impact within the same flight corridor.

A longer, sharper nose produces a smaller deflection angle, which can spread the initial shock over a greater distance, thereby reducing the sudden pressure rise and dissipating more energy as the shock wave travels. As shown in Fig. 2, as the geometric angle θ of the nose decreases within a certain range (oblique shock), the shock angle β decreases. Sharper β eventually leads to a smaller boom carpet area and consumes more energy because the shock travels a longer distance. In low-boom aircraft, the fuselage also becomes an acoustic design feature, because its shape influences how pressure waves are formed before they reach the ground.

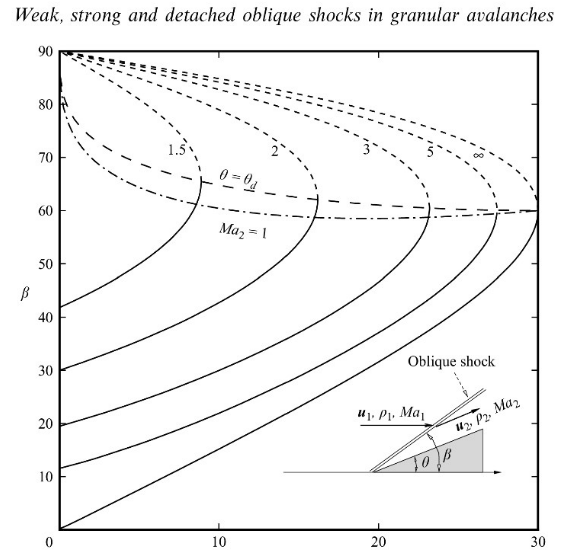

Fig. 2. Relationship between shock angle and deflection angle [7].

Another important factor is the distribution of cross-sectional areas along the aircraft length. Sudden changes in volume can produce stronger shocks and sharper pressure gradients, as well as higher induced drag. A smoother body shape — a wing-body combination, for instance—allows pressure changes to be distributed more gradually, which helps prevent individual shocks from merging into a loud N-wave [8]. This is one reason why future supersonic aircraft may have unusually long noses and slender fuselages compared with subsonic airliners. These may lead to higher ticket prices and more limited comfort, because cabin space is limited compared with subsonic aircraft.

B. Wing Shape and Control Surfaces

Wing shape is also important because lift contributes to the sonic-boom pressure signature. Concorde used an ogival delta wing, which was effective for Mach 2 cruise and provided vortex lift during low-speed take-off and landing. However, this design was not aimed primarily at reducing ground noise. For future aircraft, the wing must be designed not only for aerodynamic efficiency, but also with attention to how its lift distribution affects shock formation.

If lift is concentrated over a short region of the aircraft, it can create stronger local shocks. A possible solution is to distribute lift more gradually along the aircraft length. This may be achieved using carefully shaped wings, canards, tail surfaces or multiple lifting surfaces. Canards can help adjust lift distribution and shock spacing, potentially smoothing the pressure signature and breaking down the N-wave to reduce pressure gradients.

Control surfaces also need to be integrated carefully. Large deflections of control surfaces can create additional local shocks and disturb the ideal pressure distribution. Therefore, future low-boom aircraft may require control surfaces that maintain stability and trim without producing strong local pressure disturbances.

C. Engine Location

Engine location provides another possible solution for reducing sonic-boom intensity. In most subsonic aircraft and the Concorde, under-wing engines or exposed outlets create additional shocks around the inlet and exhaust regions.

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These shocks could contribute to the overall pressure signature and may strengthen the boom heard on the ground.

One possible solution is to place the engine above the fuselage or use shielding underneath to reflect the shock wave produced [9]. A top-mounted engine can reduce the direct propagation of propulsion-related shocks toward the ground because the fuselage and wing act as a shielding surface. This approach is used on NASA's X-59, with the engine mounted on the upper part of the aircraft. The intention is to reduce the effect of inlet and nozzle disturbances on the ground-level acoustic signature.

However, engine placement also introduces design trade-offs. A top-mounted engine may experience inlet distortion because the incoming airflow is already affected by the aircraft body. It may also create structural complexity, maintenance difficulties and possible aerodynamic penalties.

IV. Discussion on Existing Prototype

NASA's X-59 QueSST exemplifies many of the low-boom design principles discussed above. Unlike Concorde, the X-59 is not designed as a passenger aircraft. Its main purpose is to demonstrate the possibility that supersonic flights can produce a quieter ground signature and to provide data for future noise regulations. The main differences in design philosophy are summarized in Table 1 as shown below.

Table 1. Comparison between Concorde and X-59

Comparison Dimensions	Concorde	X-59	Optimization Logic
Core Design Objective	Supersonic cruising speed and passenger delivery	Minimizing noise caused by sonic boom	Design priority changes from speed-first to speed and low-boom-first
Fuselage Design Objective	Minimizing wave drag	Minimizing ground noise level	Smooth volume distribution weakens and separates shocks
Wing and Control Surface Profile	Minimizing drag and provide enough lift at low-speed scenarios	Distributing lift, minimizing noise, and enhance maneuverability	Lift distribution affects the pressure signature
Engine Location	Underneath main wing structure	Both inlet and engine placed above fuselage	Airframe shielding reduces propulsion-related ground noise

A. Low Boom Aerodynamic Configuration of X-59

The most noticeable feature of the X-59 is its long sharp nose. This shape helps spread the forward pressure rise and prevents the bow shock from becoming a strong single disturbance. The aircraft also has a carefully shaped fuselage, which is designed to control the spacing and strength of the shock waves. Instead of allowing the shocks to merge into a traditional N-wave, the pressure signature is more spread out and slows the rate of pressure change, as shown in Fig. 3.

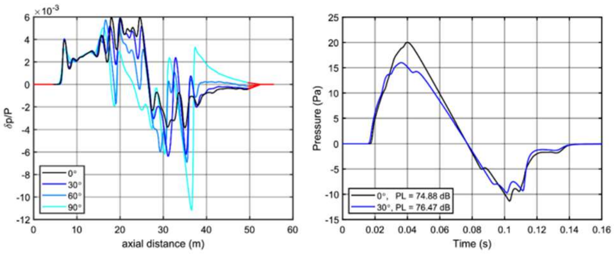

Fig. 3. Pressure signature of X-59 [10].

B. Propulsion Integration Design of X-59

The X-59 also demonstrates the importance of propulsion integration. Its top-mounted engine helps shield propulsion-related shocks from the ground. In addition, the aircraft has no conventional forward cockpit window, as the long nose blocks direct forward visibility and helps to perfect the aerodynamic smoothness.

Compared with Concorde, the X-59 represents a major change in design philosophy. Concorde was designed mainly for efficient supersonic passenger transport, whereas the X-59 is designed around acoustic acceptability. This difference is significant for future SSTs. A future commercial aircraft cannot simply replicate Concorde by using improved engines and materials. It must include low-boom shaping from the earliest design stage.

V. Conclusion

Sonic boom remains a key barrier to the return of commercial supersonic aircraft. Concorde proved that passenger flights at supersonic speed were technically possible and helped advance commercial aircraft technology, especially in areas such as high-speed aerodynamics, digital fly-by-wire, intake design and thermal structural considerations. However, its loud ground-level boom also revealed major social and regulatory problems. Routine supersonic operation over land was restricted because the noise disturbance was unacceptable to communities below the flight path. Therefore, future SST must not only achieve high cruise speed but also address ground noise, along with fuel efficiency, emissions, and operating cost.

Integrated low-boom design offers the most promise. Fuselage shaping, wing planform, lift distribution, control-surface integration and engine location can all be used to control the aircraft's pressure signature. Instead of allowing individual shock waves to merge into a strong N-wave, future designs should spread and weaken the pressure changes before they reach the ground. NASA's X-59 demonstrates how these principles can be applied in practice through a long sharp nose, shaped fuselage and top-mounted engine. Although the X-59 is not a passenger aircraft, it serves as an important prototype for understanding how the N-wave can be split and weakened.

However, further development is required before these ideas can be applied to a large commercial aircraft. Future SSTs must combine low-boom aerodynamics with efficient propulsion, acceptable airport noise, environmental performance, passenger comfort and regulatory approval. In this sense, the future of SST depends on both faster flight and making supersonic flight acceptable to people on the ground.

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Conflict of Interest

The author declares no conflict of interest.

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