



News & Highlights

Supersonic Transport Redux?

Lance A. Davis

Senior Advisor, US National Academy of Engineering

On June 26, 2017, the US National Aeronautics and Space Administration (NASA) announced that it had completed a preliminary design review (PDR) for its Quiet Supersonic Transport (QueSST), designed with the prospect of greatly diminishing the intensity of the sonic boom associated with supersonic flight [1]. A scale model of the plane was tested in an 8 ft (1 ft = 0.3048 m) by 6 ft supersonic wind tunnel at NASA's Glenn Research Center in Cleveland. The lead contractor on the effort was the Lockheed Martin Skunk Works®.

The next step for NASA is to request bids to construct a Low Boom Flight Demonstration (LBFD) X-plane (Fig. 1), which is projected to cost about 390 million USD and be ready for flight testing in 2019 to 2021. The single engine plane will have one pilot, is expected to be 94 ft long and will have a streamlined configuration so that a video camera is required for viewing forward from the cockpit. The results of the PDR will be made available to potential bidders [2].

The ultimate goal of this effort is to again allow supersonic passenger transport, last seen when service on the Concorde was discontinued by Air France and British Airways in 2003 [3]. The compelling feature of the Concorde, cruising at Mach 2.04 [4] (2.04 times the speed of sound, i.e., Mach 1 = 1225 km·h⁻¹; 1354 mi·h⁻¹ or 2180 km·h⁻¹; limited by aerodynamic heating of an Al alloy fuselage), was that it cut the Paris to New York travel time in half. A fatal crash of an Air France flight outside Paris on July 25, 2000, killing 113 people, cast a pall over Concorde service, but it ultimately was discontinued because it was very uneconomical. A major factor in this regard was that the Concorde was banned by the Federal Aviation Administration in 1973 from flying across the continental United States because of its continuous, objectionable, and loud sonic boom. This meant that any possible economies of scale from expanded US service were precluded.

Under supersonic flight, shock waves are generated from any protrusion on the aircraft and propagate into space. As the aircraft approaches Mach 1, the sound waves can no longer run away from the plane and coalesce in large shock waves at the nose and the tail. The shock pressure at the nose drops along the body of the aircraft and then rises again at the tail. This pressure signature is known as the N wave. The rapid increase of pressure at the nose and at the tail creates two sonic booms in close succession, so close that a listener frequently hears only one. For anyone who has not experience a sonic boom, one can typically find examples on the Internet [5].

The sonic boom is in the frequency range of 0.1–100 Hz. On the ground, the boom perceived depends on the distance to the aircraft and the aircraft's shape and speed [6], although the speed plays a diminished role above Mach 1.3. The duration of the boom increases with the size of the aircraft and was 200–300 ms for the Concorde [7]. The width of the sonic boom “carpet” is approximately 5 times the altitude of the aircraft, so a supersonic aircraft flying at 30 000 ft will create a carpet about 5 mi (1 mi = 1.6093 km) wide, continuously, with the loudest boom occurring directly beneath the flight path and diminishing laterally until it is not perceptible. The overpressure from the shock wave on the ground is typically only 1–2 pounds per square foot (psf) (1 psf = 47.8803 Pa), only slightly more than atmospheric pressure of 2116 psf [6]. It is the rapid change of pressure that creates the boom. For the Concorde, flying at 52 000 ft and Mach 2, the over pressure was 1.94 psf.

A critical factor in allowing the PDR to be completed within reasonable time and expense was the availability of high speed computers, not available at the time of the design of the Concorde, to reiterate many complex 3D fluid dynamics simulations. The basic facts were known—the plane should have as large a length to cross-section ratio as possible, with few protrusions, but it is extremely time-consuming and expensive to physically build and test scale models by trial and error. The design goal was to prevent small shock waves generated by flight of the aircraft from coalescing into large shock waves [8]. This would change the pressure signature from an N wave to a more gradual S wave, comprising a series of smaller “rumbling” booms. The notion is that this rumble would be much less offensive to humans and animals on the ground. The noise level for the X-plane traveling at up to Mach 1.42 is projected to be about 75 perceived noise level decibels (PNLdB), about 20 times less than the 105 PNLdB of the Concorde [8]. The level of 75 PNLdB has been likened to the noise that one would perceive inside an automobile moving at highway speeds [2].

It is not clear that taming the sonic boom alone will usher in renewed supersonic passenger transport. As noted above, Concorde service (which lasted from 1976 to 2003) was discontinued because it was very uneconomical [9]. A limit to its service routes, both in the continental United States and elsewhere in the world, was one factor, but fuel costs were another. Traveling at supersonic speeds requires 2–3 times the fuel burn. And the limited fuel precluded trans-Pacific flights. The dimensions of the aircraft are a factor as well. The Concorde carried about 100 passengers in a long, narrow



Fig. 1. Illustration of NASA's planned LBF D X-plane as outlined during the project's PDR. Credits: NASA/Lockheed Martin [1].

cabin with two seats on either side of a central aisle. Carrying more passengers in a larger cross-section and longer aircraft would improve economics, but, at 202 ft [10], the Concorde was already slightly longer than a Boeing 747SP (184 ft) [11]. It is also unclear how the economics for a larger aircraft would depend on engines with more thrust and greater fuel consumption. And, the CO₂ signature of the engines is a much more critical factor today than decades ago. But, the lure of cutting travel times in half remains.

References

- [1] NASA completes milestone toward quieter supersonic X-plane [Internet]. Washington, DC: National Aeronautics and Space Administration; [updated 2017 Sep 2; cited 2017 Nov 1]. Available from: <https://www.nasa.gov/press-release/nasa-completes-milestone-toward-quieter-supersonic-x-plane>.
- [2] Black T. NASA has a way to cut your flight time in half [Internet]. New York: Bloomberg L.P.; [updated 2017 Jul 24; cited 2017 Nov 1]. Available from: <https://www.bloomberg.com/news/articles/2017-07-24/nasa-has-a-way-to-cut-your-flight-time-in-half>.
- [3] Keller G. Continental Concord crash conviction overturned by French court [Internet]. Boston: The Christian Science Monitor; [updated 2012 Nov 29; cited 2017 Nov 1]. Available from: <https://www.csmonitor.com/Business/Latest-News-Wires/2012/1129/Continental-Concord-crash-conviction-overturned-by-French-court>.
- [4] Niiler E. NASA thinks it can make a supersonic jet with no boom [Internet]. New York: Condé Nast; [updated 2016 Apr 3; cited 2017 Nov 1]. Available from: <https://www.wired.com/2016/03/nasa-thinks-can-make-supersonic-jet-no-boom/>.
- [5] Pedley T. Watch military jet create sonic boom as it breaks sound barrier in this amazing video [Internet]. London: MGN Limited; c2017 [updated 2015 Jan 4; cited 2017 Nov 1]. Available from: <http://www.mirror.co.uk/news/world-news/watch-military-jet-create-sonic-4915336>.
- [6] NASA Armstrong fact sheet: Sonic booms [Internet]. Washington, DC: National Aeronautics and Space Administration; [updated 2017 Aug 15; cited 2017 Nov 1]. Available from: <https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html>.
- [7] Mertins J. Required technologies for supersonic aircraft. In: Proceedings of the special course on "Fluid dynamic research on supersonic aircraft"; 1998 May 25–29; Rhode-Saint-Genese, Belgium. Neuilly-sur-Seine: Research and Technology Organization; 2012. p. 5.1–16.
- [8] Bennett J. How NASA wants to build a supersonic plane without the boom [Internet]. New York: Hearst Communications, Inc.; c2017 [updated 2017 Jun 13; cited 2017 Nov 1]. Available from: <http://www.popularmechanics.com/flight/a21312/nasas-low-boom-supersonic-aircraft/>.
- [9] Concorde grounded for good [Internet]. London: British Broadcasting Corporation; c2017 [updated 2003 Apr 10; cited 2017 Nov 1]. Available from: http://news.bbc.co.uk/2/hi/uk_news/2934257.stm.
- [10] Yamashita H, Obayashi S. Sonic boom variability due to homogeneous atmospheric turbulence. *J Aircraft* 2009;46(6):1886–93.
- [11] 747SP specifications [Internet]. Boeing 747SP Website; c1996–2017 [cited 2017 Nov 1]. Available from: <http://www.747sp.com/747sp-specification>.