Congressional Research Service
Informing the legislative debate since 1914

Supersonic Passenger Flights

Updated November 14, 2018

Congressional Research Service
https://crsreports.congress.gov
R45404

CRS REPORT
Prepared for Members and
Committees of Congress

Congressional Research Service
Informing the legislative debate since 1914

SUMMARY

R45404

November 14, 2018

Rachel Y. Tang, Coordinator
Analyst in Transportation and Industry

Bart Elias
Specialist in Aviation Policy

Linda Luther
Analyst in Environmental Policy

Daniel Morgan
Specialist in Science and Technology Policy

Supersonic Passenger Flights

It has been over 40 years since British Airways' first Concorde passenger flight took off in 1976. So far the Concorde is the only commercial supersonic passenger aircraft to travel at more than twice the speed of sound. It was a technological accomplishment but not a commercial success. In 2003, all Concorde aircraft were taken out of service.

Recent years have seen a revival of interest in supersonic aircraft. Several startup companies are developing new supersonic commercial and business jets, hoping technological advances in materials, design, and engine efficiency will make it possible to produce commercially viable aircraft.

The main regulatory issues related to supersonic flight remain unchanged from the Concorde era: limiting ground-level noise during subsonic flight and sonic booms during supersonic flight. Aircraft noise standards have become much stricter since the Concorde entered service, and the commercial aircraft fleet is considered to be 75% quieter overall than during the 1970s. However, some of the technical approaches used to reduce noise during subsonic flight may hinder efforts to reduce the magnitude of sonic booms in future supersonic aircraft.

In the United States, the FAA Reauthorization Act of 2018 (P.L. 115-254) directs the Federal Aviation Administration (FAA) to take a leadership role in creating federal and international policies, regulations, and standards to certify safe and efficient civil supersonic aircraft operations. It requires FAA to consult with industry stakeholders on noise-certification issues, including operational differences between subsonic and supersonic aircraft. It also requires FAA to develop and issue noise standards for sonic boom over the United States and for takeoff and landing and noise test requirements applicable to civil supersonic aircraft. Furthermore, beginning December 31, 2020, and every two years thereafter, FAA will be required to review available aircraft noise and performance measurements to determine if federal regulations should be amended to remove the current ban on civil supersonic flight over land.

Since new supersonic aircraft are expected to operate internationally, the lack of agreed-upon international standards or agreements is likely to hinder production as well as operations. FAA is already engaged with the International Civil Aviation Organization (ICAO) to develop certification standards for future supersonic aircraft, but this process to produce an international standard may not be completed until 2025. In addition, the United States and other countries prohibit supersonic flights over land except in limited circumstances, and changes in those restrictions may be necessary for supersonic aircraft to be commercially viable.

Contents

Introduction 1
Supersonic Transport (SST) 1
Early SST Development 2
Demise of the Concorde 3
Renewed Interest in Supersonic Passenger Flights 5
Speed and Range 5
Future Aircraft Development 6
Major Issues and Challenges 7
Aircraft Certification Timeline 8
Sonic Boom 8
Aircraft Noise Standards 10
Stage 5 Limits 11
FAA Noise and Sonic Boom Regulations 12
International Harmonization 13

Figures

Figure 1. How Existing Supersonic Aircraft Generate a Sonic Boom 2
Figure 2. Flight Range from New York 6

Contacts

Author Information 14

Introduction

Four decades have passed since the first trans-oceanic supersonic passenger flight took off from London Heathrow Airport in 1976. Subsequently, more than 2.5 million passengers flew supersonically until British Airways and Air France took the Concorde out of service in 2003.[1] Although no supersonic passenger aircraft have flown since then, aviation enthusiasts, aircraft and parts manufacturers, airlines, and some Members of Congress have expressed interest in restarting supersonic air travel. Several U.S. startup companies are now developing supersonic commercial and business jets.

The major issues affecting the introduction of supersonic aircraft appear to remain the same as in the Concorde era—how to translate technological advances into commercial ventures that are economically viable and acceptable to regulators and the public.

Gaining international consensus and approvals to fly supersonically over other countries besides the United States may be a critical element in determining the market viability of future civil supersonic aircraft designs. International agreements would also need to address permissible conditions for supersonic flight operations over water and over polar regions that have opened up to civil aircraft operations over the past decade and offer shorter flights between the United States and Asia.

Supersonic Transport (SST)

Supersonic flight means flight that is faster than the speed of sound. The speed of sound in Earth's atmosphere varies depending on temperature and other atmospheric conditions. Near sea level, it is typically about 760 miles per hour (mph). At the cruising altitude of commercial aircraft, where the air is much colder, it is often less than 700 mph.

The ratio of an aircraft's speed divided by the speed of sound is known as its Mach number

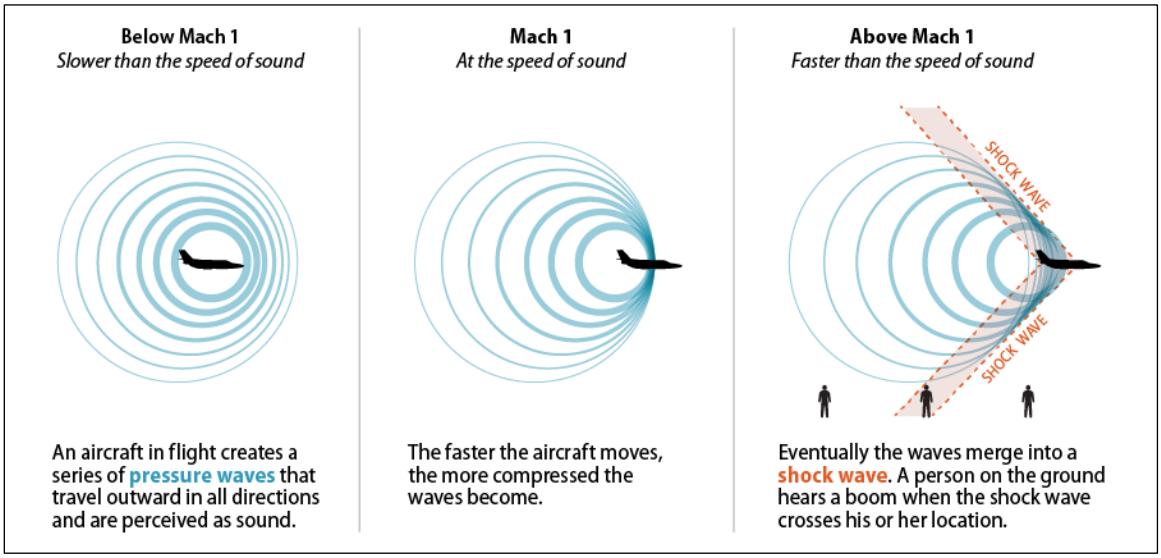
- All current commercial aircraft are subsonic, with Mach number less than 1. For example, the typical cruising speed of a Boeing 777 airliner is Mach 0.84.
- Flight near Mach 1 is called transonic. Aircraft typically fly at such speeds only briefly while they accelerate from subsonic to supersonic or vice versa. They do not cruise near Mach 1 because they would experience high drag.
- Supersonic flight is faster than Mach 1. The Concorde cruised at about Mach 2.02 (roughly twice the speed of sound) when not over land. Some military aircraft fly at even higher supersonic speeds.
- Flight faster than Mach 5 is known as hypersonic. Hypersonic flight is currently limited to experimental aircraft and missiles as well as spacecraft reentering the atmosphere from orbit (the space shuttle during reentry flew at about Mach 25).

As an aircraft flies, it disturbs the air through which it moves. The disturbance includes air flow around the aircraft as well as traveling pressure waves that humans perceive as sound. In subsonic flight, sound waves may be emitted in all directions. In supersonic flight, because the aircraft is flying faster than sound travels, all disturbances are behind the aircraft. Instead of sound waves, the pressure waves combine to form a shock wave, which people on the ground perceive as a sudden sonic boom after the aircraft passes (see **Figure 1**). Boom-related environmental impacts

[1] British Airways, "Celebrating Concorde," https://www.britishairways.com/en-us/information/about-ba/history-and-heritage/celebrating-concorde.

and community objections have been major issues for supersonic flight. Companies and government research programs are attempting to address these concerns by designing aircraft so that the shock waves produced by different components (such as the nose, wings, and engine) spread out in space and time, producing a longer but quieter "thump" rather than combining into a single loud boom.

Figure 1. How Existing Supersonic Aircraft Generate a Sonic Boom



Source: Graphic created by CRS.

Early SST Development

Flying faster than the speed of sound is not a novel concept. In 1947, a U.S. Air Force experimental aircraft became the first manned aircraft to exceed Mach 1, breaking the "sound barrier." This represented an important milestone for the burgeoning post-World War II aviation industry and set the stage for fierce international competition for speed and prestige. Notable supersonic developments include the Mach 2 British/Franco Concorde supersonic aircraft and the Mach 3.3 Lockheed SR-71 reconnaissance aircraft.[2]

While early research and development focused on military aircraft, by the early 1960s interest in developing supersonic civil aircraft grew worldwide. The Soviet Union became the first country to fly a supersonic passenger plane, the Tupolev TU-144, in 1968. The aircraft, which was designed to fly at Mach 2.2 and carry 140 passengers, went into production in 1972. However, a fatal crash at the 1973 Paris Air Show ended the Soviet Union's supersonic passenger ambition.

In the United States, the supersonic technology developed in military aircraft programs led to interest in developing a supersonic transport for civilian applications. In June 1963, the government announced a major program to develop a supersonic passenger aircraft under the direction of the Federal Aviation Administration (FAA). However, several serious problems soon surfaced, including the need for considerable federal funding because of a development cost

[2] *Aviation Weekly*, "Faster Than A Speeding Bullet," October 8, 2007. The Concorde made its first noncommercial flight in March 1969; the SR-71's first flight was in December 1964. See https://www.lockheedmartin.com/en-us/news/features/history/blackbird.html.

beyond the capabilities of any aircraft manufacturer, the lack of interest by the airlines due to their heavy investment in subsonic jets and their doubts about the financial viability of supersonic passenger aircraft, and the major challenges of addressing environmental concerns.[3]

The FAA program was eventually terminated by Congress in 1971, amid delays in prototype development and opposition on cost and environmental grounds.[4]

Demise of the Concorde

The Franco-British Concorde was the product of a costly joint project of the British and the French governments. In January 1976, the first flight of the Concorde, also the world's first trans-oceanic supersonic passenger flight, took off from London Heathrow to Bahrain. More than 2.5 million passengers flew supersonically before Concorde was taken out of service in 2003.[5] With a cruising altitude of about 65,000 feet (nearly twice as high as subsonic airliners) and a speed of over twice the speed of sound, a typical journey between London and New York on the Concorde took about three and a half hours, as opposed to about seven hours on a subsonic nonstop flight. Although the Concorde was considered an aeronautical achievement and a symbol of national prestige by many, it did not turn out to be a commercial success for a variety of reasons.

As a government endeavor, the Concorde was a very costly project. Although there has not been an accurate accounting of the costs, it was argued in 1976 that the official figure of £1.46 billion had been a drastic underestimate, and that the program cost of Concorde was nearly £4.26 billion.[6] This was approximately £29.15 billion in 2017 pounds,[7] equivalent to about $37.52 billion in U.S. dollars.[8] Concorde aircraft were also expensive to operate, reportedly using almost three times as much fuel per passenger mile as subsonic aircraft.[9] This drove up operating costs considerably, especially during the period of high oil prices in the 1970s and early 1980s.

High subsonic noise levels during takeoffs and landings and sonic boom impacts from cruise flight generated considerable concern. Many countries banned Concorde flights from their airspace—it was reported that nearly half the planned routes, especially those over land, were prohibited.[10] U.S. civil aviation regulations did and still do prohibit overland supersonic flights in the continental United States. This contributed to Concorde's low utilization rate and effectively limited its flights to a limited number of oceanic routes between big cities, including scheduled trans-Atlantic flights between London and New York.

Providing premium air travel on selected routes, however, failed to make Concorde flights a sustainable business. Even as the development costs of the Concorde were written off by the

[3] F. Edward McLean, "Supersonic Cruise Technology," National Aeronautics and Space Administration (NASA). NASA SP-472, 1985, pp. 12-16.

[4] U.S. Congress, Office of Technology Assessment, "Impact of Advanced Air Transport Technology; Part 1: Advanced High-Speed Aircraft," April 1980, pp. 30-31.

[5] British Airways, "Celebrating Concorde," https://www.britishairways.com/en-us/information/about-ba/history-and-heritage/celebrating-concorde.

[6] Peter Gillman, *The Atlantic*, "Supersonic Bust," January 1977.

[7] Conversion according to Bank of England, Inflation Calculator. Inflation averaged 4.8% a year between 1976 and 2017. https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator.

[8] Exchange rate was US $0.777 per British £ in 2017, per OECD exchange rates data. https://data.oecd.org/conversion/exchange-rates.htm.

[9] *The Atlantic*, "The Story of Concorde," January 1977.

[10] *The Atlantic*, "The Concorde: A Supersonic Airplane Too Advanced to Survive," July 1, 2015.

British and French governments, few airlines were interested in purchasing a Concorde aircraft. Of the 20 Concordes ever manufactured, 14 were sold to the state-owned carriers of the two countries involved in building the planes: seven to British Airways and seven to Air France. The remainder were built as prototypes and flight test aircraft. All other orders for the Concorde were canceled.

Filling the seats on Concorde flights with paying customers was not easy. Concorde tickets were generally priced at about twice the regular first-class airfare on a comparable subsonic flight. For example, in 2003, a round trip across the Atlantic on the Concorde cost £8,000, equivalent to about $15,475 in 2017 U.S. dollars, almost twice the first-class ticket price on a Boeing 747.[11] Once the attraction of novelty wore off, the airlines found it difficult to fill the seats, often flying at less than half capacity.[12] The plane was also impractical for carrying cargo or mail, given the limited cargo space on the Concorde. The airlines were therefore unable to generate additional revenue from these sources, which are important supplemental revenue streams for subsonic transoceanic passenger flights.

According to figures from the British government, during the first five years of Concorde operations, British Airways recorded a loss of £10.4 million and Air France a loss of £36.7 million.[13] However, the airlines claimed that in some years the SST operations were profitable. This occasional profitability was based on the fact that Concorde's development and capital costs were absorbed by the British and the French governments. In essence, the Concorde was too expensive for the airlines to operate and maintain with consistent profitability, even though they bore none of the cost of designing and building it.

On July 25, 2000, Air France New York-bound flight 4590 took off from Charles de Gaulle airport in Paris. During the take-off acceleration, one of the tires ran over a strip of metal on the runway that had fallen from a previous aircraft. The metal strip shredded the tire. Part of the rubber hit a fuel tank, sending shock waves that burst a valve. Fuel started to pour out and was ignited by sparks from the landing gear damaged by the debris. The aircraft crashed into a hotel in the village of Gonesse, five miles from the runway. All 100 passengers and nine crew members were killed, along with four hotel employees on the ground. This sole fatal accident in the Concorde's operational history generated significant media coverage and damaged the Concorde's reputation for safety.

Following the crash, safety modifications were made. The first test flight of a modified aircraft was completed successfully in July 2001. The first regular Concorde passenger flight after the accident soon followed, on September 11, 2001. That was also the day that terrorist hijackers used civilian aircraft to attack the Pentagon and the World Trade Center. The 9/11 terrorist attacks caused a significant drop in demand for air travel in general and for premium air travel in particular amid a global economic downturn. In 2003 all Concorde flights were discontinued due to financial losses.

[11] Jonathan Glancey, *Concorde: The Rise and Fall of the Supersonic Airliner* (London: Atlantic Books, 2015), p. 5. Adjustment according to Bank of England, Inflation Calculator (https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator). The average exchange rate was US $1.287 per British £1 in 2017; see https://data.oecd.org/conversion/exchange-rates.htm.

[12] *Washington Post*, "Last Liftoff: Concorde Departs Dulles for Good," November 9, 1994.

[13] Jonathan Glancey, *Concorde: The Rise and Fall of the Supersonic Airliner*, p. 161.

Renewed Interest in Supersonic Passenger Flights

The Concorde demonstrated that supersonic passenger travel was technically achievable. But it was not financially successful. A new SST will be commercially viable only if it can offer transportation services at reasonably competitive prices in addition to reducing travel time for passengers over long routes. A supersonic aircraft may gain some advantage from its so-called "speed dividend"—commercial airlines with scheduled flights, charter carriers, and operators of on-demand and business jets would be able to get more trips out of the aircraft, and hence greater asset utilization. However, the speed dividend can be achieved only if the airline can maintain a high load factor while keeping maintenance and ground turnaround time brief.

A supersonic airplane designed for commercial passenger service would face competition from subsonic planes. Modern subsonic widebody aircraft such as the Airbus A 350 and Boeing 787 are able to fly very long distances nonstop, such as the Singapore-Newark route spanning 8,285 nautical miles (about 9,534 miles, or 15,343 kilometers), which Singapore Airlines inaugurated in October 2018. An airline offering SST service would need to identify a city pair between which there are enough passengers willing to pay a high enough fare to turn a profit. It will need to convince its customers that the fare premiums are worth the time saved and worth sacrificing the presumed comfort in premium cabins on competing subsonic flights.

On the other hand, the fact that modern subsonic aircraft are able fly very long distances means flight time gets extended as well, suggesting there could be demand for higher-priced flights offering much shortened travel time. As air travel becomes increasingly commoditized and generic, supersonic flights could be a unique service that would enable an airline to differentiate itself from the crowd.

There may be an entirely separate market for supersonic business jets. Many large corporations fly their top executives aboard private aircraft for security reasons and to minimize wasted time. Supersonic planes could be attractive for this purpose. Several companies (such as NetJets[14] and Flexjet[15]) offer fractional ownership of general aviation aircraft, a shared-ownership model similar to the time-share model in real estate, which would allow potential users to gain access to supersonic flights at considerably lower cost than full ownership.

Speed and Range

Speed is the main attraction of supersonic flight. Due to air traffic constraints, supersonic aircraft would not likely be able to achieve meaningful time savings for flights less than about 800 nautical miles (roughly the distance between New York and Orlando, FL). However, if supersonic flights over land are allowed, flying supersonically could save travelers about one hour on a flight between New York and Los Angeles, for example. Even greater time savings can be achieved on longer flights, but this is constrained by the range of the aircraft (see **Figure 2**).

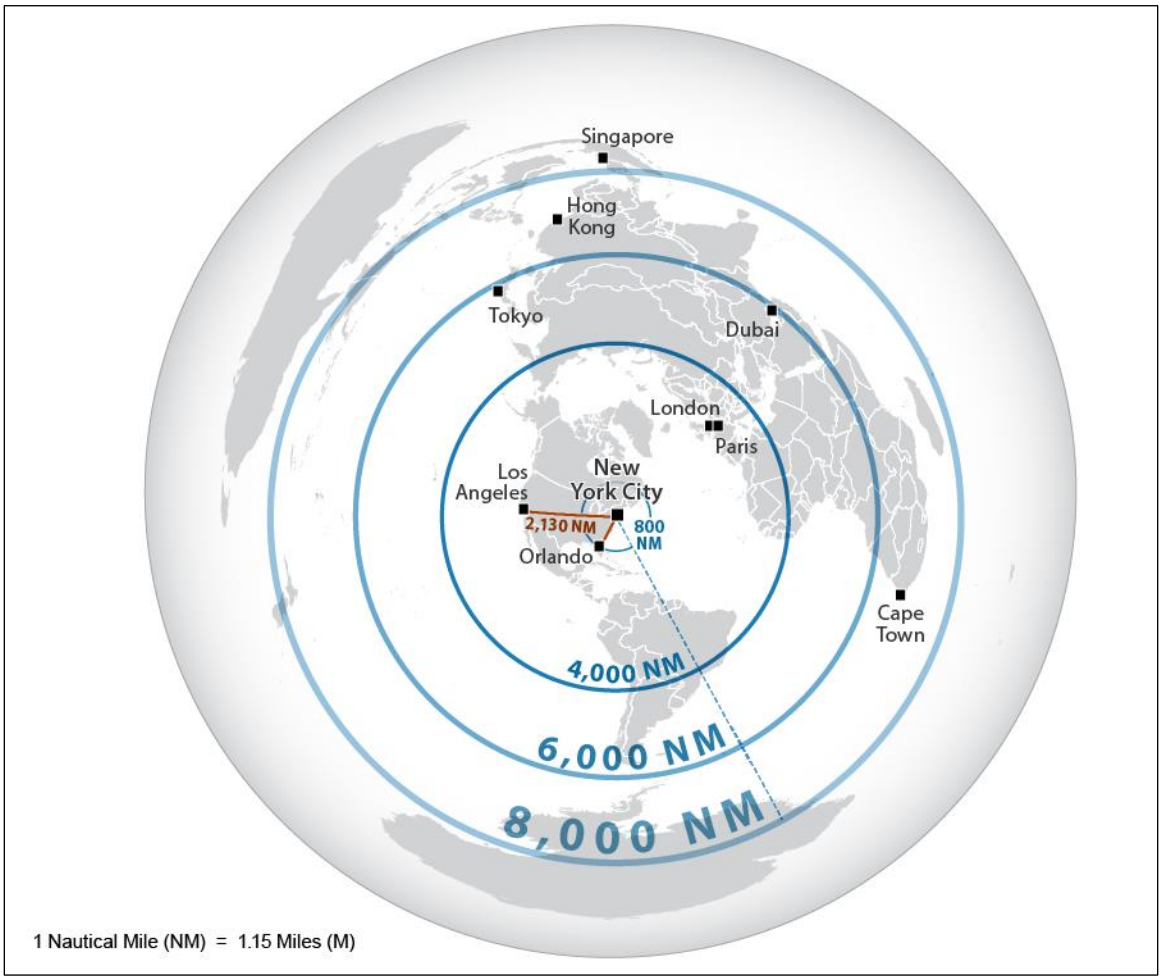
Companies currently developing SSTs have stated that they envision flight ranges of about 4,000 to 6,000 nautical miles. These ranges would comfortably allow for flights between much of the east coast of the United States and key European destinations like London and Paris, with typical time savings of around two hours. However, several trans-Pacific routes, routes from western U.S. cities to Europe, and flights from the United States to Africa or the Middle East would require refueling stops. Developers envision that, even with hour-long service stops to take on

[14] https://www.netjets.com/.

[15] https://www.flexjet.com/.

fuel, the time savings could be substantial, typically cutting about one-third off of total travel time.

Figure 2. Flight Range from New York



Source: Graphic created by CRS.

Note: Map depicts range rings centered on New York City. Most economically viable supersonic flights would be beyond 800 NM. Maximum range with fuel reserves for proposed supersonic civil aircraft are between roughly 4,000NM and 6,000NM, while some long-range subsonic airliners and business jets currently have maximum ranges of about 8000NM (see text for further discussion).

Future Aircraft Development

The revival of interest in supersonic aircraft is the result of technological advances in materials, airframe and engine designs, and aircraft manufacturing that would be able to give the aircraft longer range through improved fuel efficiency and substantial weight savings with advanced composites and aerodynamics.[16] Denver-based Boom Technology has announced plans to test a

[16] For example, according to Boom Technology's website, its supersonic aircraft design includes area-ruled fiber composite fuselage and efficient turbofan engines. See https://boomsupersonic.com/airliner.

supersonic 2-seat demonstrator[17] by the end of 2019, and aims to deliver its first supersonic aircraft to an airline as early as 2025.[18] In November 2016, Virgin Group, an airline operator, took purchase options for 10 of Boom's proposed Mach 2.2 aircraft.[19] Japan Airlines (JAL) invested $10 million in Boom and took purchase options on 20 planes in December 2017.[20] In early 2018, Qatar Airways reportedly expressed interest in supersonic airliners and said it "would not hesitate to be the launch customer."[21]

Nevada-based Aerion Supersonic[22] and Boston-based Spike Aerospace[23] are focusing on smaller jets for private use. In December 2017, Aerion announced a joint venture with Lockheed Martin and GE Aviation, an engine manufacturer, to develop a supersonic business jet, the AS2.[24]

Major Issues and Challenges

The development of supersonic aircraft faces considerable regulatory uncertainty. Because the commercial viability of SSTs will depend on their ability to fly internationally, production of supersonic planes for passenger service is unlikely until the United States and other countries have adopted similar standards.[25] Two types of standards are at issue

- Certification standards pertain to the aircraft itself. At present, there are no agreed-upon international standards for next-generation supersonic aircraft. Current noise standards[26] applicable to new civil aircraft have evolved over the years to reflect existing technology used by subsonic aircraft. Existing standards applicable to supersonic aircraft, however, are now obsolete because they apply only to the Concorde or aircraft with Concorde-type design.[27] The International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection is presently seeking to develop international noise and emissions standards for future supersonic aircraft.[28] ICAO has indicated that it anticipates

[17] https://boomsupersonic.com/xb-1.

[18] *Aviation Daily*, "Boom Aims for Supersonic Demo's First Flight in 2019," August 27, 2018; Boom Technology company website, https://boomsupersonic.com/.

[19] *Flight International*, "Boom makes noise over JAL's backing," December 12, 2017-January 1, 2018, p. 11.

[20] *Wall Street Journal*, "Supersonic Jet Gets Boost," December 6, 2017; https://boomsupersonic.com/news/show/our-partnership-with-japan-airlines, as viewed on August 28, 2018.

[21] *Aviation Daily*, "Qatar Airways Ready to Go Supersonic," February 26, 2018.

[22] https://www.aerionsupersonic.com/.

[23] http://www.spikeaerospace.com/.

[24] *The Economist*, "Supersonic jets may be about to make a comeback," January 9, 2018.

[25] For example, see the Japanese Civil Aeronautics Act, http://www.japaneselawtranslation.go.jp/law/detail_main?re=02&vm=02&id=37#en_ch6at44; the European Union noise-related restrictions on aircraft operations at EU airports, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32014R0598; and the EU RUMBLE project aimed at developing standards and compliance measures as well as supporting international regulatory efforts related to future low-sonic-boom SST flights overland, https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/aviation/rumble.

[26] 14 C.F.R. Part 36.

[27] 14 C.F.R. §36.301.

[28] Sandy R. Liu and Bao Tong, "International Civil Aviation Organization Supersonic Task Group Overview and Status," *Journal of the Acoustical Society of America*, Vol. 141, No. 5, May 2017, p. 3566.

reaching a standard for certifying supersonic aircraft in the 2020-2025 timeframe.[29]

- Operational standards pertain to the way an aircraft may be used. Noise standards in the United States and other countries, dating to the early years of the Concorde, prohibit supersonic flight over land. FAA standards prohibit the operation of an aircraft at supersonic speed unless the aircraft is entering or leaving the United States and will not cause a sonic boom to reach the surface, or unless the operation involves a test flight authorized by FAA.[30] Similarly, Japanese law prohibits "extremely high speed flights" over densely populated areas and around airports without specific permission.[31] Aviation authorities will also need to address operational parameters for supersonic flight over water and polar regions on an international basis.

Provisions in the FAA Reauthorization Act of 2018 (P.L. 115-254) require FAA, within one year of the bill's enactment (October 5, 2018), to submit a report to Congress with recommended regulatory changes on a timeline that would permit overland supersonic flights.

Aircraft Certification Timeline

The FAA Reauthorization Act of 2018 directs FAA to take a leadership role in creating federal and international policies, regulations, and standards to certify safe and efficient civil supersonic aircraft operations within U.S. airspace. The legislation requires FAA to consult with industry stakeholders on noise-certification issues, including operational differences between subsonic and supersonic aircraft. It requires FAA to issue a notice of proposed rulemaking (NPRM), no later than December 31, 2019, to revise Part 91 Appendix B regulations to modernize the process for applying to operate civil aircraft at supersonic speeds for flight testing. It further requires FAA to issue an NPRM, no later than March 31, 2020, to develop noise standards for sonic boom over the United States and for takeoff and landing and noise test requirements applicable to civil supersonic aircraft, and to publish the final rule within 18 months after the public comment period closes.

However, FAA may have to move more quickly: if an application for Part 21 certification of a supersonic aircraft is received before the final rule is promulgated, FAA must issue an NPRM no later than 18 months after the submission applicable solely to type certification of that aircraft and its engine. Furthermore, beginning December 31, 2020, and every two years thereafter, FAA would be required to review available aircraft noise and performance measurements to determine if federal regulations should be amended to remove the current ban on civil supersonic flight over land.

Sonic Boom

The principal regulatory concern surrounding supersonic aircraft is the sonic boom, a shock wave of pressure created by compression of sound waves as the air is displaced by the airframe

[29] International Civil Aviation Authority, "Supersonic Aircraft Noise Standards Development," https://www.icao.int/environmental-protection/Pages/Supersonic-Aircraft-Noise-Standards-Development.aspx.

[30] See 14 C.F.R. §91.817; and Appendix B to Part 91—Authorizations To Exceed Mach 1 (§91.817). Compliance with applicable federal standards is determined at aircraft certification. There are no FAA engine emission certification regulations that explicitly apply to supersonic aircraft. Irrespective of whether an engine is used during a supersonic or subsonic flight, emission levels from civil aircraft are regulated according to the amount of thrust generated by an engine, not which aircraft such engine is attached to or how an aircraft operates.

[31] Japanese Civil Aeronautics Act, Article 91.

traveling at or above Mach 1.0. The compressed air molecules form a cone that spreads out from the aircraft and can reach the ground. If these sudden pressure changes reach the ear they will be perceived as booms, similar to the clap of thunder.

The intensity of the boom will depend on the shape, size, and weight of the aircraft, as well as atmospheric factors such as wind, temperature, and humidity. Like explosions and other impulsive sounds, sonic booms are measured in terms of the increase in pressure (or "overpressure") they produce compared to normal pressure of the atmosphere (nominally 14.7 pounds per square inch, or 2,116 pounds per square foot). Humans may tend to find sonic boom overpressures above 1 pound per square foot to be objectionable. Overpressures of 1 to 2 pounds at the surface are typical of current-day supersonic aircraft, including military fighter jets and the retired Concorde supersonic jetliner, flying at typical cruise altitudes of 30,000 to 50,000 feet. Maneuvering during supersonic flight or rare atmospheric anomalies may cause higher boom overpressures to reach the surface. Higher overpressures may increase the likelihood of public reaction and, in very rare instances, may cause physical discomfort and break windows.

Current regulations prohibit civil aircraft from operating at speeds greater than the speed of sound in U.S. airspace.[32] Exceptions can be authorized on a case-by-case basis, and are generally requested for flight testing of military aircraft types by manufacturers and other civilian organizations supporting Department of Defense flight testing programs. In addition, manufacturers of certain civilian aircraft may petition FAA to obtain authorization to exceed the speed of sound in flight testing. In such a petition, applicants must specify a designated test area, usually over sparsely populated lands, and must demonstrate that the purpose of the flights is for testing to show compliance with aircraft certification requirements, to determine the sonic boom characteristics of the aircraft or establish means to reduce or eliminate the effects of sonic boom, or to establish the parameters under which the aircraft's supersonic flight will not cause measurable sonic boom impacts on the ground. In rare cases, FAA may approve supersonic flights outside of a designated test area if the petitioner can demonstrate that the flights will not produce measurable sonic boom overpressures that reach the ground under all foreseeable operating conditions.[33]

Manufacturers are likely to seek authorization to operate at supersonic speeds over land. The Federal Interagency Committee on Aviation Noise (FICAN) has indicated that, in order to obtain such authorization, a manufacturer will need to demonstrate either that the aircraft is capable of flying at supersonic speeds without its sonic boom reaching the ground (a capability known as Mach cut-off flight) or that the sonic boom impact on the ground is significantly attenuated compared to existing supersonic aircraft designs.[34]

The companies now developing supersonic aircraft believe that they will be able to demonstrate Mach cut-off capabilities or sonic boom signatures that are much quieter and much more acceptable to the public than existing supersonic aircraft. Aerion Supersonic claims its plane will demonstrate a "boomless cruise" at speeds approaching Mach 1.2, depending on atmospheric conditions.[35] The company expects that cruise speeds over land will initially be restricted to below Mach 1.0, and advertises that its plane's envisioned subsonic cruise speed of Mach 0.95 will be faster than current commercial jets and will not produce a sonic boom. The projected

[32] 14 C.F.R. §91.817.

[33] 14 C.F.R. Part 91, Appendix B, Authorization to Exceed Mach 1.

[34] Federal Interagency Committee on Aviation Noise, *Research Review of Selected Aviation Noise Issues*, April 2018, https://fican1.files.wordpress.com/2018/04/fican_research_review_2018.pdf.

[35] https://www.aerionsupersonic.com/as2-mission-planning/.

maximum speed over water is Mach 1.4, about 65% faster than a typical long-range jet airliner. Aerion has had to throttle back on its speed expectations due to noise and heat limitations of existing engine designs. Spike Aerospace anticipates that its Spike S-512 will be able to achieve a supersonic cruise speed of Mach 1.6 with a sonic boom having a perceived loudness of less than 75 decibels (dB) at ground level.[36] Boom Technology seeks to produce a three-engine airliner that will be capable of cruise speeds of Mach 2.2 but will be 30 times quieter than the Concorde at supersonic speed.[37] None of the companies has publicly disclosed the designs and materials that would allow their planes to operate at supersonic speeds with relatively low noise levels.

The National Aeronautics and Space Administration (NASA) Low Boom Flight Demonstrator program is developing the experimental X-59 QueSST (Quiet Supersonic Transport). Delivery of the X-59 is expected in 2021, with test flights planned during 2022. The aircraft is designed to fly at Mach 1.42 while producing a sonic boom with a perceived loudness of 75 dB Comparable to a domestic vacuum cleaner, this would be much less than the Concorde's perceived loudness of 105 dB (comparable to a thunderclap or a loud sports stadium). The nose, wings, engine, and other components of the X-59 will be shaped and positioned so that the individual shock waves they produce do not combine to produce a single loud boom. Instead, they will be spread out in space and time to produce a longer but quieter "thump."

A ground-level sonic boom measurement of 75 dB perceived noise level (PNLdB) has been suggested by some NASA researchers as a potentially acceptable level for unrestricted supersonic flight over land.[38] However, no standard has been established, either in the United States or internationally, and FAA has noted that its ongoing rulemaking efforts to address subsonic noise limits for supersonic aircraft would not rescind the prohibition of flights in excess of Mach 1 over land.[39] However, language in P.L. 115-254 will require FAA to periodically review existing restrictions on supersonic flight of civil aircraft over land in the United States every two years, starting December 31, 2020. The reviews are to determine whether these restrictions may be eased to permit supersonic flight of civil aircraft over land.

Aircraft Noise Standards

Controlling noise generated by supersonic jets during takeoffs and landings raises complex design tradeoffs, because making aircraft engines quieter at subsonic speeds may impact speed and efficiency in supersonic flight. Applying current subsonic noise standards to future supersonic aircraft could affect speed and range as well as aircraft emissions during supersonic phases of flight.

FAA gave the Concorde special consideration with respect to noise certification, so long as developers demonstrated that the subsonic noise levels generated by the aircraft had been "reduced to the lowest levels that are economically reasonable, technologically practicable, and appropriate for the Concorde type design."[40] The Concorde was noticeably louder during takeoff and landing than aircraft meeting ICAO's Stage 2 standards, which were established in 1971 as the original international limits for permissible aircraft noise. Only Concorde airplanes with flight

[36] http://www.spikeaerospace.com/s-512-supersonic-jet/quiet-supersonic-flight/.

[37] https://boomsupersonic.com/contact#faq-section.

[38] Jim Banke, NASA Aeronautics Research Mission Directorate, "Sonic Boom Heads for a Thump," May 8, 2012 (Updated April 3, 2018), https://www.nasa.gov/topics/aeronautics/features/sonic_boom_thump.html.

[39] Federal Aviation Administration, "Fact Sheet – Supersonic Flight," October 10, 2018, https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22754.

[40] 14 C.F.R. §36.301(b).

time prior to January 1, 1980, were granted this special exception.[41] However, as it turned out, no Concorde aircraft were produced after 1979.

In 1976, the Port Authority of New York and New Jersey attempted to ban the Concorde from landing or taking off at John F. Kennedy International Airport (JFK), but a court found that this was preempted by an FAA decision allowing limited Concorde operations in the United States.[42] While a complete ban against the Concorde was struck down by the court's decision, a curfew prohibiting scheduled Concorde flights between 10 p.m. and 7 a.m. was allowed.

Stage 5 Limits

The United States completely phased out Stage 2 jets at the end of 2015, and those aircraft can no longer operate in U.S. airspace without special permission. Most jets today meet either Stage 3 or Stage 4 standards, which require much quieter engines. These standards, which vary based on aircraft weight, are known internationally as Chapter 3 and Chapter 4 noise standards in reference to the applicable chapters in ICAO Annex 16 (Environmental Protection), Volume 1 (Aircraft Noise).

Newly designed aircraft certified after December 31, 2017, must meet U.S. "Stage 5" standards (internationally known as Chapter 14 standards, in reference to Chapter 14 of ICAO Annex 16).[43] Stage 5 standards require aircraft to be at least 7 dB quieter than required by the previous Stage 4 noise standards, or 17 dB less than required by Stage 3 standards, cumulatively across three noise measurements (flyover, sideline, and approach).[44] The sound produced by aircraft under the new standard will be on the order of one-fourth of the sound intensity of aircraft operating in the 1970s under Stage 2 noise limits. Many recent commercial jet models already meet the Stage 5 requirements, and in general, the subsonic commercial aircraft fleet is considered to be 75% quieter overall than aircraft produced in the 1970s.[45] The Stage 5 standards apply to both commercial aircraft and general aviation aircraft such as business and private jets.

Supersonic aircraft developers argue that the Stage 5 standard was finalized after significant design work on some new supersonic designs had already been completed, and, consequently, significant design changes may be required to pass noise certification tests, including changes that may substantially limit aircraft characteristics such as payload capacity and range. Some critics assert that requiring compliance with stringent Stage 5 noise standards may put supersonic designs at a competitive disadvantage while having little effect on reducing community noise around airports, as SSTs are likely to be produced in comparatively small numbers and subsonic Stage 3 and Stage 4 aircraft will continue to make up most of the air traffic around airports.[46]

---

[41] 14 C.F.R. §91.821.

[42] *British Airways Board and Compagnie Nationale Air France v. Port Authority of New York and New Jersey*, 564 F. 2d 1002 (2nd Cir. 1977); Joshua A. Muss, "Aircraft Noise: Federal Pre-Emption of Local Control, Concorde and Other Recent Cases," *Journal of Air Law and Commerce*, vol. 43, p. 753 (1977), https://scholar.smu.edu/jalc/vol43/iss4/6; Robert B. Donin, "British Airways V. Port Authority: Its Impact on Aircraft Noise Regulation," *Journal of Air Law and Commerce*, vol. 43, p. 691, https://scholar.smu.edu/jalc/vol43/iss4/4.

[43] Federal Aviation Administration, "Stage 5 Airplane Noise Standards," 82 *Federal Register* 46123-46132, October 4, 2017.

[44] International Civil Aviation Organization, "Reduction of Noise at Source," https://www.icao.int/environmental-protection/Pages/Reduction-of-Noise-at-Source.aspx.

[45] See, e.g., Neil Dickson, "Aircraft Noise Technology and International Standards," International Civil Aviation Organization Air Transport Bureau, Environment, https://www.icao.int/Meetings/EnvironmentalWorkshops/Documents/2015-Warsaw/3_2_Aircraft-Noise-Technology-and-International-Noise-Standards.pdf.

[46] Eli Dourado and Samuel Hammond, "Make America Boom Again: How to Bring Back Supersonic Transport,"

At this point, aircraft manufacturers are generally employing higher bypass engines to achieve Stage 5 standards. These engines have large diameters, which can significantly increase drag and reduce fuel efficiency during supersonic flight. According to some studies, these engine designs could increase fuel consumption and carbon emissions by about 20% during supersonic flight. In addition, the increased wave drag of higher bypass engine designs is anticipated to reduce supersonic cruise speeds and aircraft range.[47]

FAA reauthorization language offered in the Senate (S. 1405, 115th Congress) would have required that noise certification standards for future supersonic aircraft be no more stringent than standards that were in place for large subsonic aircraft on January 1, 2017. This would have had the effect of applying the Stage 4 noise standards in place on that date, and not the more stringent Stage 5 standards, to supersonic aircraft in development. This language was not included in the enacted FAA Reauthorization Act, thus leaving it to FAA to set appropriate noise limits as part of its mandated rulemaking activities to address noise certification of supersonic aircraft.

FAA Noise and Sonic Boom Regulations

U.S.-registered civil aircraft are required to meet airworthiness requirements that include, among other criteria, the FAA noise standards in 14 C.F.R. Part 36. FAA established Part 36, as well as additional operating standards applicable to aircraft noise, pursuant to the Control and Abatement of Aircraft Noise and Sonic Boom Act of 1968 (P.L. 90-411, as amended). That act required the FAA Administrator to prescribe standards and regulations to "afford present and future relief and protection to the public from unnecessary aircraft noise and sonic boom."[48]

FAA prohibited supersonic flights over land in 1973, based on the expectation that such flights would cause a sonic boom to reach the ground. FAA amended its operating standards in 1989 to allow for the authorization of supersonic flights in a designated test area if the flight is necessary to determine the sonic boom characteristics of an airplane or to establish means of reducing or eliminating the effects of sonic boom; or to demonstrate the conditions and limitations under which flight at supersonic speeds will not cause a measurable sonic boom overpressure to reach the surface.[49]

In 2008, FAA issued a statement updating its policy on noise limits for future civil supersonic aircraft to reflect then-current noise limits. The statement acknowledged that designers and prospective manufacturers of supersonic aircraft had approached FAA and ICAO for guidance on the feasibility of changing operational limitations that prohibited civil supersonic aircraft flight over land. In response, the agency stated, in part,

> Before the FAA can address a change in operational restrictions, it needs thorough research to serve as a basis for any regulatory decisions. Public involvement will be essential in defining an acceptable sonic boom requirement, and public participation would be part of any potential rulemaking process.

Mercatus Center, George Mason University, Arlington, VA, October 2016, https://www.mercatus.org/system/files/mercatus-dourado-supersonic-transport-v1.pdf.

[47] Guy Norris and Graham Warwick, "Noise and Emissions Are Central Issues for Resurgent Supersonics," *Aviation Week & Space Technology*, July 27, 2018, http://aviationweek.com/commercial-aviation/noise-and-emissions-are-central-issues-resurgent-supersonics.

[48] This language appears in Section 611 of the Federal Aviation Act of 1958; with subsequent amendments, it is codified in 49 U.S.C. §44715.

[49] 14 C.F.R. Part 91, App. B, Section 2(a)(2)-(3).

> While technological advances in supersonic aircraft technology continue, many factors still will need to be addressed. At present, the FAA's guidance for supersonic aircraft is the same as for subsonic, that the same noise certification limits apply for supersonic aircraft *when flown in subsonic flight configurations*.[50] [Emphasis added.]

The final policy statement notes FAA's expectation that any rulemaking affecting noise operating rules would propose that any future supersonic airplane produce no greater noise impact on a community than a subsonic airplane. Further, FAA stated that "noise standards for supersonic operation will be developed as the unique operational flight characteristics of supersonic designs become known and the noise impacts of supersonic flight are shown to be acceptable."

Between 2009 and 2011, FAA held public meetings and solicited technical information from other federal agencies, industries, universities, and other interested parties on the mitigation of sonic boom from supersonic aircraft. According to FAA, it did so in an effort to determine whether there are sufficient new data supported by flight over land.[51]

On October 10, 2018, FAA announced it is initiating two rulemakings relevant to supersonic flights, one to amend domestic noise certification standards for supersonic aircraft[52] and the other to update the operating standards applicable to supersonic flight testing.[53] FAA anticipates issuing both proposed rules in 2019. FAA stated that the proposals are intended to streamline and clarify the procedures to obtain FAA authorization. According to FAA, neither of these two rulemaking activities would rescind the prohibition of flight in excess of Mach 1 over land.[54]

International Harmonization

The potential success of supersonic aircraft likely hinges not only on U.S. certification and the ability to operate in U.S. airspace, but also on certification and operational acceptance of supersonic flight internationally.

Noise certification standards and sonic boom are reportedly both points of contention between the United States and Europe. Following the legislative mandate in P.L. 115-254 requiring FAA to periodically review and amend as appropriate existing restrictions on supersonic flights over land beginning by 2021, there is likely to be mounting international pressure to develop consensus sonic boom standards through ICAO in a timely manner. Reportedly, "[t]here are concerns that a U.S.-only standard for sonic boom could be higher than NASA's 75 PNLdB target, which compares to the Concordes's 110 PNLdB, and could jeopardize public acceptance of supersonic travel."[55] If other countries insist that supersonic aircraft meet Chapter 14/Stage 5 subsonic noise standards, engine options may be more limited, potentially impacting speed, range, and emissions characteristics of supersonic designs.

---

[50] Federal Aviation Administration, Statement of Policy, "Civil Supersonic Airplane Noise Type Certification Standards and Operating," 73 *Federal Register* 62872, October 22, 2008.

[51] See FAA's "Supersonic Aircraft Noise" web page at https://www.faa.gov/about/office_org/headquarters_offices/apl/noise_emissions/supersonic_aircraft_noise/.

[52] https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201810&RIN=2120-AL29.

[53] https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201810&RIN=2120-AL30.

[54] https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=22754.

[55] Guy Norris and Graham Warwick, "Noise and Emissions Are Central Issues for Resurgent Supersonics," *Aviation Week & Space Technology*, July 27, 2018, http://aviationweek.com/commercial-aviation/noise-and-emissions-are-central-issues-resurgent-supersonics.

Reportedly, efforts to move forward with international certification standards for supersonic aircraft are facing resistance from European nations that want the aircraft to adhere to strict noise guidelines, particularly for landing and takeoff phases of flight. Developers of supersonic aircraft have cautioned that a protracted debate to set international standards could delay progress on development, and FAA has urged agreement on standards as soon as practicable so that manufacturers can have certainty regarding certification requirements.[56]

Gaining international consensus and approvals to fly supersonically over other countries besides the United States may be a critical element in determining the market viability of future civil supersonic aircraft designs. International agreements would also need to address permissible conditions for supersonic flight operations over water and over polar regions.

Polar flights may be a first step for future supersonic aircraft operations if supersonic flight over land is not immediately authorized. Polar airspace has become increasingly important to aviation as polar routes offering shorter flights between the United States and Asia have opened up to civil aircraft operations over the past decade. Approvals to fly at supersonic speeds along these polar routes and along transoceanic routes would generally fall under the purview of countries' delegated authority to oversee the management of airspace in these regions, pursuant to ICAO standards and guidelines. The United States has been delegated authority to oversee air traffic over large areas of the northern Pacific and northern Atlantic oceans and portions of the Arctic, while Canada, Iceland, and Russia control much of the airspace overlying the polar regions of the Arctic Circle under international agreement. As the main selling point of supersonic flight is speed, access to these time-saving international routes could be a critical factor in the potential commercial success of future civil supersonic aircraft.

Author Information

Rachel Y. Tang, Coordinator
Analyst in Transportation and Industry

Linda Luther
Analyst in Environmental Policy

Bart Elias
Specialist in Aviation Policy

Daniel Morgan
Specialist in Science and Technology Policy

Acknowledgments

The authors wish to thank Lena Gomez for providing research assistance and Amber Wilhelm, Hannah Fischer, and James Uzel for creating the graphics in this report.

Disclaimer

This document was prepared by the Congressional Research Service (CRS). CRS serves as nonpartisan shared staff to congressional committees and Members of Congress. It operates solely at the behest of and under the direction of Congress. Information in a CRS Report should not be relied upon for purposes other

[56] Allison Lampert and Jamie Freed, "Exclusive: U.S. and Europe Clash over Global Supersonic Jet Noise Standards," *Reuters*, July 12, 2018, https://www.reuters.com/article/us-airplane-supersonic-usa-exclusive/exclusive-u-s-and-europe-clash-over-global-supersonic-jet-noise-standards-idUSKBN1K21YQ.

than public understanding of information that has been provided by CRS to Members of Congress in connection with CRS's institutional role. CRS Reports, as a work of the United States Government, are not subject to copyright protection in the United States. Any CRS Report may be reproduced and distributed in its entirety without permission from CRS. However, as a CRS Report may include copyrighted images or material from a third party, you may need to obtain the permission of the copyright holder if you wish to copy or otherwise use copyrighted material.