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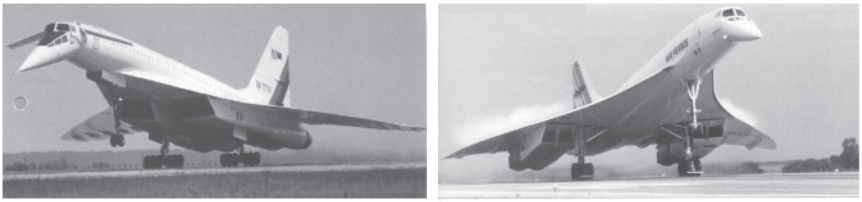
History of Supersonic Transport Aircraft Development

At the end of the 1950s military jet aircraft made routine flights at speeds faster than sound, and the first generation of long-range high-subsonic jet-powered airliners had only just been introduced into service, when it was realized that supersonic airliners could become a reality. The commercial potential for supersonic flight came under serious study in the four nations that fostered their development: France, UK, USA and USSR. Companies in the USA coupled experience obtained from the development of military vehicles during the 1950s (B-58 Hustler, B-70 Valkyrie) with successful jetliner programs in order to develop a supersonic transport (SST) designed to travel at up to three times the speed of sound in the stratosphere. Its funding required direct government sponsorship, with a series of competitions, selecting Boeing as the airframe manufacturer and General Electric as the engine manufacturer. Due to a variety of economic, environmental, and political issues, the development of the Boeing 2707 prototype was discontinued in 1971, nine years behind schedule and 20% above design weights. In 1962 an Anglo-French consortium consisting of the British Aircraft Corporation (BAC) and Sud Aviation started the development of the Concorde. Almost concurrently the Soviets revealed that they were developing a supersonic transport in a manner conventional to their style, with the government assigning the project to Tupolev. Both aircraft (Figure 1.1) were designed to fly at approximately twice the speed of sound (Mach 2). The TU-144 made its first flight in January 1969, was introduced into service in 1977 but suffered from excessive fuel consumption and severe operational difficulties. Since it was apparently unsafe and considered virtually useless, the first TU-144 was withdrawn in June 1978 after 55 scheduled flights. Commercial transport at supersonic speeds was a reality from January 1976, when Concorde entered successful commercial service for 27 years with British Airways and Air France. It is therefore stunning that many “experts” have considered the Concorde a great technical achievement but an economic disaster.

Essentials of Supersonic Commercial Aircraft Conceptual Design, First Edition. Egbert Torenbeek.



Tupolev Tu 144 BAe-Aerospatiale Concorde

Figure 1.1 The only supersonic commercial aircraft serving in commercial operations. Courtesy: Flight International.

1.1 Concorde's Development and Service

Early design studies in the 1950s by the UK industry aimed at a supersonic airliner designed for non-stop flights between London and New York. One concept was equipped with a slender body and very thin straight wings, not unlike the general arrangement of contemporary supersonic bombers. This configuration could not generate an acceptable aerodynamic quality, resulting in an aircraft carrying only fifteen passengers with a take-off weight of 136 metric tons. The large wave drag of its wing was the major obstacle for efficient flight and aerodynamic experts at the Royal Aircraft Establishment (RAE) soon realized that wave drag could be kept low by using a slender wing to keep the leading edge behind the Mach lines from the vertex.

In 1956 the RAE and aircraft manufacturers established the Supersonic Transport Aircraft Committee (STAC) with the intention of taking the lead in designing and producing SST. The STAC concluded that most operational advantages of supersonic long-range flying were secured if the vehicle cruised at a speed near 2000 km h^{-1} (Mach 2), which would enable the airline to fly two transatlantic round trips per day. Moreover, at this speed the kinetic heating of the structure would allow the use of advanced light alloys instead of steel or titanium required for Mach 3. In 1960 Bristol Aircraft was awarded a contract for designing a supersonic commercial transport (SCT) for 130 passengers, which was completed in 1961.

Around the same time the French air ministry requested a proposal from aircraft manufacturers for a medium-range SCT cruising at a Mach number between 2.0 and 2.2 with a capacity of 60–80 passengers. ONERA was selected for basic theoretical and experimental research and the resulting projects by Sud Aviation, Dassault and Nord Aviation were completed in 1961. The French officials concluded that the Sud design was the most promising. Despite the different payload and range requirements, the British and French teams evolved broadly the same aerodynamic design approach and it was realized that they should collaborate in a project that would benefit both industries, and the same applied to the participating British and French engine industries. After consultations with potential customers and governments it was decided that the Anglo-French supersonic transport would carry 130 passengers over the Paris–New York Atlantic range. The formal Anglo/French agreement for development and manufacture with a production line in both countries was signed in November 1962 and prototype construction began in 1965.

The aircraft, baptized "Concorde" produced by BAC and Aerospatiale, made its first flights in early 1969. A total of twenty aircraft were constructed, including two prototypes and two pre-production models. Fourteen of the sixteen series-produced aircraft served mainly on North Atlantic routes, split between British Airways and Air France. They carried their passengers cruising at speeds up to Mach 2 at 18,000 m altitude and thereby saved four of the typical seven hours trip time required by high-subsonic jetliners. However, Concorde was developed just prior to the establishment of FAR 36 noise regulations and – with its afterburners operating during the take-off – the aircraft required a noise rule waiver to allow its operation out of American airports. Moreover, the establishment of FAR 91 rules in 1973 prohibited sonic booms over inhabited areas, making flight at Mach 2 over these areas impossible. It was not until 1980 that Concorde reached the point where it could carry a full load of hundred passengers year-round on the North Atlantic routes.

The Concorde and Boeing SST programs were conceived at a time when fuel prices were coming down. However, supersonic cruise requires more energy per unit of payload and range, and both designs were known to be sensitive to the availability of fuel. Due to the oil crises in the 1970s and the subsequent increase in fuel price as well as the increasing concerns about the effects of supersonic flight on the environment, the interest in supersonic civil aviation decreased and Concorde remained the only SCT in regular airline use during the twentieth century. Scheduled flights were principally London–New York and Paris–New York and they attracted mostly high utilization. During the 27 years of their operational life a fleet of only twelve flying Concordes accumulated some 350,000 hours, most of the time flying at supersonic speed – more than all of the world's military aircraft together – and with high reliability. During the years of Concorde's operational life, it was generally concluded by British Airways and Air France that, despite its high maintenance costs, the technology generally satisfied or exceeded the expectations at the start of the project.

In August 2000 a piece of titanium left on Charles de Gaulle Airport's runway caused Concorde's landing gear tire to explode, damaging its wing fuel tank structure and setting an engine on fire. After lifting off, the plane could not climb out, became uncontrollable, and crashed. Although British Airways and Air France considered the Concorde to be profitable up until the accident, they concluded in 2003 that continuation of its services was no longer commercially justified. In particular, the high fuel costs per seat-kilometer, the maintenance costs of seven times those of a Boeing 747, and the modification costs expected in that year were behind the decision to phase out its operations. Economically, Concorde did not fit into the structure of the air traffic system due to its high operational costs, and the high research and development costs could not be negotiated by the small number of aircraft produced and sold.

In spite of its high cruise speed reducing the time to travel drastically, and the fact that it provided a safe and reliable Atlantic service from 1976, Concorde is sometimes portrayed as a folly and a failure, but this ignores the fact that the USA once viewed it as a threat to its aerospace leadership. The Concorde was a technological and systems integration marvel in its time – an achievement that since its emergence has never been surpassed. Its development, production, and service have enriched the knowledge of European technological cooperation. Apart from the excellent flying qualities demonstrated during its service, the Anglo-French supersonic transport was the first international aerospace program that reshaped industrial and political thinking and it paved the way for most European collaborative programs. Its legacy is today's European aerospace industry Airbus, established in 1970, and the European certification authority EASA.

1.2 SST Development Program

The efforts in the US to develop a supersonic airliner were preceded by a comprehensive program of supersonic military aircraft development. From the early 1950s the Air Force operated the Convair B-58 Hustler Mach 2 bomber and the North American XB-70 Valkyrie bomber/reconnaissance aircraft (Figure 1.2) was conceived during the late 1950s. The design specifications of the B-70 were influenced by the opinion of military authorities that its high cruise speed should be approximately Mach 3 at 21,000 m altitude, since it was anticipated that the additional research for achieving the same flying qualities as for Mach 2 would be modest. However, aluminum alloys could not be used due to the strong kinetic heating effects of flying at Mach 3 and hence alternative structural materials such as stainless steel and titanium had to be incorporated. Test flying of the XB-70 demonstrated that it had excellent aerodynamic qualities in supersonic flight as well as acceptable low-speed characteristics. Although the B-70 program was canceled for strategic reasons after three prototypes had been built and tested, arguments behind the development of a Mach 3 airliner were dominated by the experience gained during research of the XB-70, and Boeing initiated a design study of an SST, which in 1952 resulted in the Boeing 2707-300.

NACA's supersonic commercial air transport (SCAT) research program was initiated in 1957. Initially there was no government support for a CST development program. However, as soon as the European plans for producing the Concorde

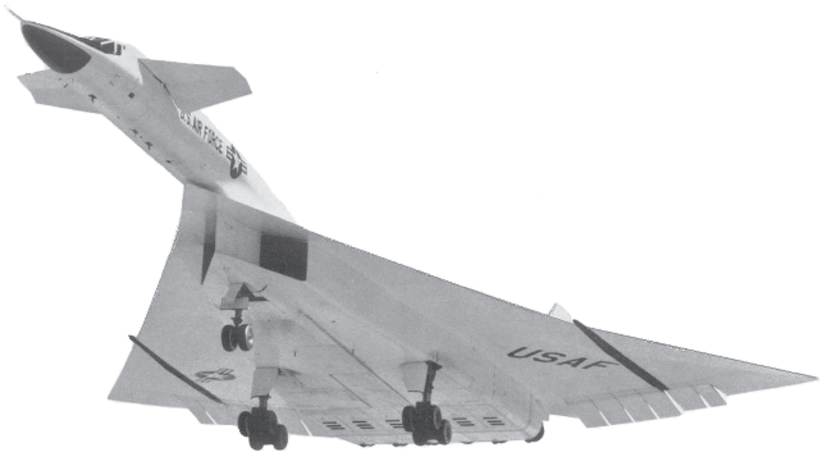


Figure 1.2 The North American XB-70 Valkyrie strategic bomber/reconnaissance aircraft (first flight made in 1964) [4].

appeared to be taken seriously by the airlines, Pan Am wished to be “the first airline to go supersonic” and placed options to buy six aircraft. As one result of this challenge to the “free enterprise American industry”, the development of an SST prototype was addressed by President Kennedy in 1963 as a national objective. The FAA was designated to conduct a design competition between Boeing, Douglas, and Lockheed for a full-scale pre-production SST prototype program. Financial support by the USA government for the project was assured for a program whereby 90% of the funding came from the government and the remaining 10% from the industry. The government’s investment would eventually be returned from the aircraft’s proceeds of sale.

The American SST projects of the late 1960s and early 1970s aimed at carrying more than twice as many passengers as the Anglo-French Concorde over considerably longer distances. Concorde’s competitors initially chose an aggressive Mach 3 cruise regime for the US transport market, similar to the military supersonic cruising vehicles. NASA directed a competition between proposals generated by Boeing, Lockheed, and North American. Featuring a variable-sweep wing and a predominantly titanium structure, the Boeing 2707-200 Mach 2.7 airliner was clearly the most ambitious concept. Having the reputation of the most successful developer of jetliners, Boeing was considered to be capable of solving the foreseen problems of the 2707 program and became the winner of the competition. However, after millions of dollars were spent on advanced development it was concluded that problems with empty weight, load and balance, and aero-elasticity were insurmountable.

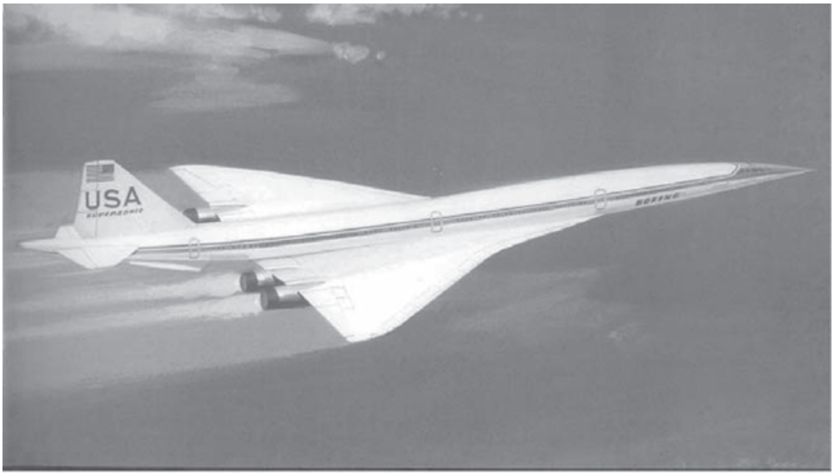


Figure 1.3 Configuration of the Boeing 2707-300. Courtesy: Boeing.

A total design re-think in 1969 resulted in the ultimate Boeing 2707-300 design (Figure 1.3) which was based on application of a fairly highly loaded cropped delta wing in combination with a horizontal tailplane. Different from the generation of lift at low speeds with strong leading edge vortices at Concorde's highly-swept wing, Boeing preferred the 2707 wing lift to be augmented by hinged flaps at the moderate leading edge sweep. The 2707 was an extremely challenging project that never reached the prototype stage as a consequence of the US government program termination in 1971. Among the principal factors that led to this decision were concerns about the possible noise and pollution impacts of SST type aircraft:

- Many countries outlawed supersonic flight over land because of the sonic boom, which would severely restrict the projected market penetration.
- Atmospheric scientists predicted catastrophic depletion of stratospheric ozone from engine emissions, severely limiting fleet size.
- Aircraft regulators wanted the engines designed for supersonic flight to meet subsonic noise certification standards.
- Health officials were concerned about the effects of high-altitude radiation of galactic or solar origin after their observation that, at typical SST cruise altitudes between 15,000 m and 18,000 m, the radiation dose increased to double that of a subsonic jetliner cruising at 10,500 m altitude.

Others held the opinion that economic disadvantages and reordering of US national priorities were the major causes for the cancellation of the SST program. Meanwhile, a new generation of very large transonic airliners was under development in the USA and in fact many considered the Boeing 747 as a direct (in-house) competitor of the 2707.

1.3 Transonic Transport Configuration Studies

The history of near-sonic cruise airliner designs dates back to the late 1950s. One of the concepts discussed by the British STAC was the M-wing layout depicted in Figure 1.4, which was considered as an alternative to the slender wing. This novel configuration was primarily aimed at allowing cruise speeds near Mach 1.2 over land without producing a sonic boom. The M-wing incorporated highly swept thin wing segments with 45° forward sweep inboard and 45° aft sweep outboard in combination with an area-ruled fuselage[1]. Other design aspects were aimed at avoiding the poor aerodynamic efficiency and flying qualities at low speeds of a highly sweptback wing. The unusual inboard forward sweep was intended to compensate for the outboard sweep and the relatively high aspect ratio should contribute to avoiding the high vortex-induced drag of a slender wing. The STAC rejected the M-wing concept since the arguments in favor of a more ambitious Mach 2.0 cruise speed that dominated in the decision-making process. Renewed interest in the development of transonic transport began in the mid 1960s when Boeing and Lockheed generated a series of study layouts based on highly swept wings and area-ruled fuselages. These concepts complied with the principles of transonic flight successfully applied to fighters designed in the 1950s and the technology of supercritical wing sections developed at NASA-Langley. It was also realized that a transport aircraft flying at Mach 1.12 in the standard atmosphere could fly without producing a sonic boom at ground level. Since wind and non-standard temperatures change the boomless cruise speeds between Mach 1.05 and 1.25, a typical cruise speed for transonic flight is Mach 1.20. However, the irregular floor plan due to the mid-cabin body waist made it difficult to configure the cabin according to the manner that individual customers would like, and thus formed an enduring drawback of this airplane concept.

By the early 1970s it was recognized that the higher fuel prices and risk of a transonic airplane development outweighed its potential benefits, an opinion that was widely held throughout the mid-1990s. Around the year 2000 Boeing marketed a concept that was designed for extended ranges greater than 17,000 km, flying at cruise speeds of Mach 0.95 or above. It was derived from "slowing down" supersonic configurations rather than "speeding up" conventional subsonic

1 The transonic area rule describes how the variation of the cross-sectional area along the longitudinal axis can be manipulated to reduce the wave drag of a flight vehicle at near-sonic and supersonic flight speeds. The results of this design methodology are often manifest in highly swept wings and "coke bottle" shaped fuselages.

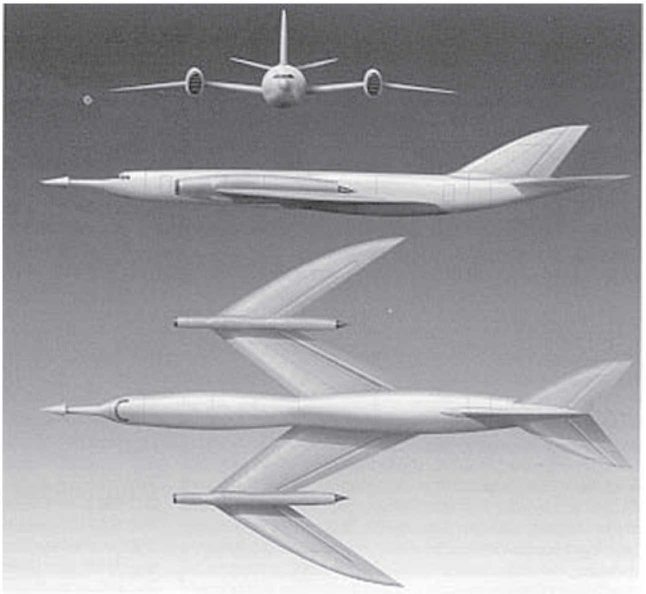


Figure 1.4 The M-wing layout for cruising at Mach 1.20, generated by the STAC in 1956.

configurations and became known as the "Sonic Cruiser". This project came to an end after the events of September 2001, when airlines that were enthusiastic about the Sonic Cruiser initially were struggling for their survival.

1.4 US High Speed Research and Development Programs

During the 1970s and 1980s several projects of the American industry were aimed at investigating applications of NASA research of advanced supersonic configurations. Study projects were part of the supersonic cruise aircraft research (SCAR) program, focusing on a second generation of supersonic airliners transporting some 300 passengers over trans-Pacific routes at speeds up to Mach 2.70. The SCAR Program was brought to an end by the marginal performance and economic potentials that appeared possible with the then available technology base. A resurgence of interest in a second-generation high-speed commercial transport (HSCT) occurred during the 1990s in Europe, the USA and Asia. Projections in 1989 for the 1995–2015 period indicated that the market in terms of passenger miles would increase by a factor of six (relative to 1971–1989) in the North-Mid Pacific and by a factor of seven in the Far East. Based on these projections, a potential market for approximately a thousand HSCT aircraft was foreseen in 1989, well over the minimum needed for a a profitable development program launch. NASA studies concluded that a supersonic transport launched in the early 21st century could be compatible with current airports, use jet fuel, and be within ten to fifteen years' technology reach.

In 1989 NASA and the US industry began investigating the potential of HSCT specifications and required technologies. The original SST of the 1960s was planned for Mach 2.70 but the required titanium structure was too heavy, and the HSCT program of Boeing and McDonnell Douglas converged on a more modest Mach 2.40, 300 seat, 9,270 km range jet A fueled aircraft as a focus for technology development. The challenges facing the HSR program were the extremely restrictive constraints placed on emissions, airfield noise, and operation costs. After approximately five years of research it was concluded that insufficient advancement in technology was available to achieve economic viability and to comply with environmental requirements. In particular an acceptable level of the sonic boom could not be achieved and the program was terminated in 1998.

1.5 European Supersonic Research Program

Similar to the US studies during the 1990s, the European industry indicated a market potential for an aircraft substantially larger and with longer longer range than the Concorde, linking the world's major cities. In 1990 the companies Aerospatiale, British Aerospace, and Deutsche Airbus launched a three-year study into the technical feasibility of a second-generation supersonic transport successor of the Concorde. In 1994 the Supersonic Research Program (ESRP) was established to undertake the research and technology development required to produce the enabling technologies for second generation supersonic commercial transport. The ESRP was supported by a common reference configuration known as the European Supersonic Commercial Transport (ESCT). Its main characteristics are compared with those of the Concorde and the Tu 144 in Table 1.1.

Also similar to the US studies during the 1990s, the European industry indicated a market potential for an aircraft substantially larger and with longer range than the Concorde, linking the world's major cities. The ESCT could be economically viable and environmentally friendly, in particular due to its capacity to carry 250 passengers over distances up to 10,000 km and its much improved take-off field performance compared to the Concorde. Figure 1.5 depicts a three view drawing of one of the designs studied in the framework of the ESCT.

Due to the widely divergent requirements at supersonic and low-subsonic flight conditions it is unavoidable that the engines for the ESCT will have a variable geometry and/or operating cycle. Figure 1.6 depicts the mid tandem fan (MTF) power plant selected for the ESCT, generated by Roll-Royce and SNECMA

Table 1.1 Characteristics of the first generation supersonic transport and the ESCT

		Concorde	**Tu-144**	**ESCT**
Maximum take-off mass	tonnes	185	200	320
Range	km	6,200	3,500	10,000
Span	m	25.6	28.8	42.0
Length	m	61.7	65.7	89.0
Passengers		90	150	250
Supersonic cruise Mach number		2.0	2.35	2.0

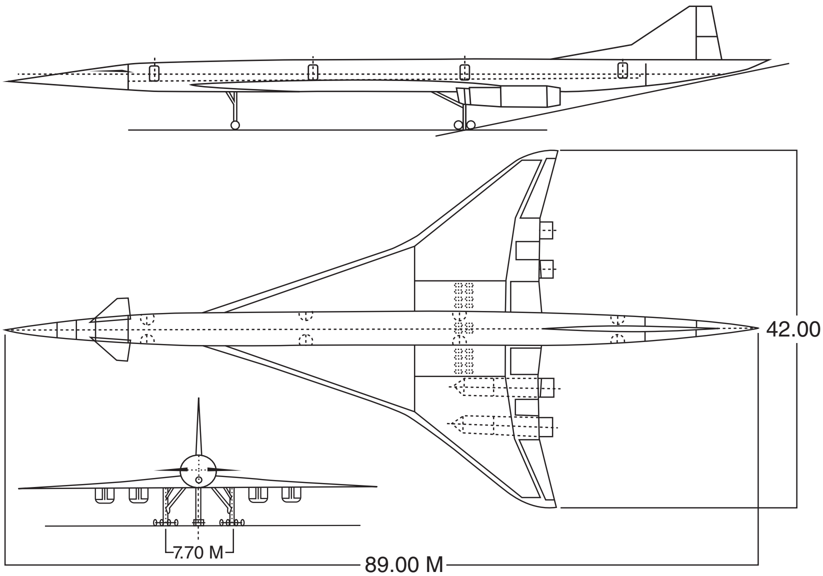


Figure 1.5 Design study of the European Supersonic Commercial Transport.

in cooperation. This engine concept is equipped with a secondary fan coupled to the secondary body. During take-off and climb the air enters the engine via auxiliary inlets. This double flow path allows very low specific fuel consumption during subsonic operation with a bypass ratio of 12 at Mach 0.8 and an exhaust velocity less than 400 m s^{-1} at the converging nozzle outlet. Auxiliary inlets are closed during the supersonic cruise at Mach 1.6 and the variable inlet mid-fan guide vanes reduce frontal airflow to the bypass duct. The bypass ratio is then 2.5 and the exhaust jet velocity 620 m s^{-1}.

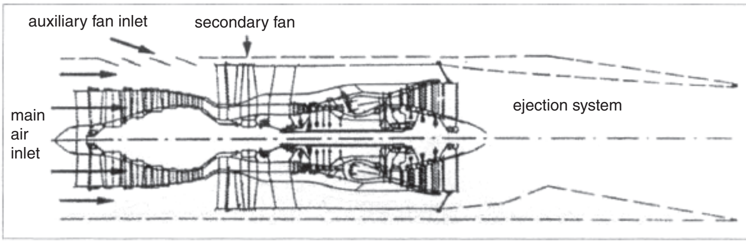


Figure 1.6 Single spool MTF in operating mode for take-off (top) and cruise (bottom).

1.6 A Market for a Supersonic Commercial Aircraft?

Ever since jet-powered airliners made their introduction into service during the 1950s, passengers on medium to long range routes have been transported at cruising speeds up to 900 km h^{-1} (Mach 0.85) in the stratosphere. Military aircraft have been able to pass the so-called "sound barrier" in routine flights since about 1960. A few exceptional types achieved continuous speeds higher than Mach 3 at altitudes above 20 km. It is therefore not surprising that after 1975 the development of a second generation supersonic airliner became a challenge to the aeronautical community. Since then, a huge amount of money has been spent on R&D programs aimed at developing advanced technology for a new generation of HSCT aircraft. *Arguably it is stunning that, despite 27 years of Concorde's satisfactory passenger service and so many technological advancements applied in all sectors of civil aviation, none of these programs have resulted in a viable development project for the near future aimed at producing an advanced supersonic commercial aircraft.*

1.6.1 Why Fly Supersonically?

Although wide-body seating during long-distance flights of a long-range subsonic airliner offers high spatial comfort, the high-priced tickets of first class and business class seating do not compensate in the form of significantly reduced boarding and traveling times. The essential economic issue is the air traveler's value of time. Some SST economic studies base the value of time on the actual earning rate for business travel and on one half the earning rate for personal travel. Concorde's concept of flying at Mach 2.0 across the Atlantic was a technical success and high-speed flying has remained attractive, especially to hasty officials.

Concordes were flagship aircraft flying at premium fares giving prestige to their passengers and operators. However, its substantial operating costs made high fares necessary: in the year 2000 the return ticket price London–New York was roughly 10,000 US dollars compared to 8,000 dollars for first class and 5,000 dollars for business class tickets of subsonic airliners. Nevertheless, Concorde's relatively high load factors and the fact that the ticket prices at the turn of the century were increasing by approximately 15% per year showed that a niche market existed for much faster passenger transport than any subsonic airliner can offer. It seems fair to assume that today a significant percentage of airline passengers is prepared to pay a premium fare, making this type of executive traveling commercially attractive to airlines. The unique achievements of the Concorde program justified sustained supersonic cruising from the technical viewpoint during its lifetime. Although technology has progressed steadily since Concorde was conceived, it was decades ahead of its time and nowadays we cannot do significantly better. Nevertheless, new technical innovations and organizational approaches will be mandatory to develop and operate a second generation SCT in the economic and regulatory environment of the 21st century.

Having surveyed the abundance of research achievements and project proposals generated during the half century after Concorde's first flight, one could anticipate that significantly improved concepts have become available in most aeronautical disciplines and production capabilities that could lead to a realistic program for development, production, and operation of an environmentally acceptable and economically viable second generation supersonic airliner. A crucial condition for such a program is that a new HSCT will be developed and produced by a consortium of R&D institutes and companies in America, Europe, and East-Asia. Since all engineers involved in the first generation supersonic airliners are no longer available to apply their knowledge to such a development, considerable effort will be required to bring together and educate sufficiently experienced staff. The availability of relevant progress reports of previous projects will be indispensable to make such an international project team manageable and effective.

1.6.2 Requirements and Operations

Arguments in favor of developing and producing a modernized version of the Concorde would not immediately get acclaim from airlines. In the present commercial aviation market its 110 passenger cabin would be too small, its transatlantic design range too short, its fuel economy too low, and its engines too noisy when taking off. Although Concorde's technical complexity made it a very costly aircraft to purchase, its high operating costs were associated primarily with its poor fuel efficiency, high maintenance, and upgrading costs.

A new high-speed transport aircraft would fly over the Atlantic, the Pacific, and uninhabited areas, covering about 80% of the most attractive long-range routes where supersonic flight is legally permitted. The size of the market, estimated as being between 500 and 1,000 aircraft, suggests that there will only be room for a single development program and only international cooperation would make such a program feasible. Enabling a potential trip time reduction of 50% or more when compared to current subsonic flights, supersonic air travel is the one technology that offers a large step forward in functional capability and a large increase in service. This increased productivity potential could result in SCT that is economically viable and environmentally acceptable and thereby could capture a significant portion of the long-range travel market.

Since an SCT will have to comply with the same international regulations as the contemporary subsonic fleets, take-off performance and engine design must be improved considerably relative to Concorde's capabilities. Cruise speed is a major factor affecting the operating costs and it is the primary performance characteristic that has to be considered in drawing up the top level specifications, and its choice has far-reaching consequences for the design and development as well as the operation of the aircraft.

- The Boeing 2707-200 was designed to achieve a range of 6,600 km, similar to the trans-Atlantic routes served by Concorde. Such a maximum range would be of limited interest for the market of a future SCT since the most important part of its market will be the long distances over water, in particular the trans-Pacific routes with ranges of more than 10,000 km.
- The SCT must be able to take-off from and land on existing airfields and comply with the associated noise criteria applicable to present-day jetliners and the plane's dimensions must be compatible with the existing infrastructure of the relevant airports. Accordingly, the accessibility to the aircraft must allow for parallel embark and disembark, service, and fueling in order to enable rapid turn-around.
- In order to serve the many routes that have overland legs, subsonic/transonic flight performance must be at least as good as supersonic cruising and the plane should be able to cruise at speeds up to Mach 1.2 without producing an offensive sonic boom, thereby enabling increasing the cruise speed over land by 50% relative to present-day jetliners.

1.6.3 Block Speed, Productivity, and Complexity

- The block time for intercontinental supersonic flight rapidly improves through the low Mach number region; it levels out at speeds above Mach 3.0. Greater speeds will not be paid off with appreciable time saving to the passenger as well as increased productivity to the airliner, and the cost of cruising faster than Mach 2.0 can be large since it complicates the airframe and systems development effort. In particular, the structure of a high Mach number aircraft is subject to kinetic heating of the airframe skin. This requires a complicated air conditioning system and the usage of expensive heat-resisting structural materials, whereas the combination of materials having different coefficients of expansion may increase structural stresses.

- Complicated variable-geometry engines are required when flying at high Mach numbers and, since the best cruise altitude increases as well, the installed power plant becomes heavier and more costly. Moreover, a heavier fuselage structure is required to cope with the higher cabin pressure differential and increased fuel tank pressurization to prevent fuel boil-off.
- A cruise speed lower than Mach 2.0 leads to less wing sweep than Concorde's 60° leading edge sweep, which is better suited to low speed operation, higher bypass ratio engines that reduce take-off noise, and cruise altitudes that reduce global impact of emissions. A cruise speed of Mach 1.6 to Mach 1.8 offers a practical possibility for increasing the block speed to about twice that of present-day jetliners.

These considerations demonstrate that a considerable development effort is required to combine the need for high fuel efficiency in supersonic cruising flight with acceptable development costs and friendliness to the airfield environment during take-off, climb-away, approach, and landing. This means a major dilemma for the design team of any SST: there is a fundamental discrepancy between design characteristics acting in favor of efficient high-speed cruising and acceptable flight characteristics at subsonic speeds, in particular take-off and landing. A solution may be immanent in a market analysis indicating the effect of increasing the block speed on the aircraft's productivity and economy on a particular route network.

The industrial activities aimed at development of new SCT applications were concentrated in the time frame 1960–1990 but, in spite of the long history of technological research and development on civil supersonic aircraft, little systematic information required to initiate a realistic conceptual design of a supersonic transport or executive jet has been published. Remarkable exceptions are Corning's textbook [2] appearing first in 1960 with later versions up to 1976, and [3] published in 1978. Küchemann's authoritative book is dedicated to the aerodynamic design of transport aircraft in general and Concorde's aerodynamic development in particular.

The Concorde would not be able to successfully comply with the requirements of commercial air transport in the 21st century but with the present-day technologies a much more efficient supersonic transport than the Concorde could be built. Many projects have been started to investigate the viability of a second generation SCT, resulting in a wealth of articles written by investigators from all continents, together forming a deluge for (teams of) engineers who are supposed to create a design concept based on a realistic set of top level requirements. It is the intention of the present author to present a synthesis of classical analysis models as well as methodologies generated by recent technological research and project studies that can be considered as an essential guidance to conceive an initial configuration design.

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