

High Speed Civil Transport

Program Review

Boeing market projections indicate a substantial potential demand for a High Speed Civil Transport (HSCT) to operate in the long-range international market, with service entry early in the next century. To maintain the leadership position in this market, Boeing has undertaken preliminary design and technology development to better understand the requirements and feasibility of this class of aircraft.

To date, marketing studies show that to penetrate the potential market for such an aircraft, the HSCT must be economically competitive with the subsonic fleet while meeting stringent environmental requirements. Our studies show that airplanes designed to fly between Mach 2.0 and 2.5, with 250- to 300-passenger capacity and range of at least 5,000 nautical miles, have the best chance of achieving both the economic and environmental objectives. The studies also indicate that present technology is inadequate to meet these requirements and that early, focused technology development is vital to the timing and ultimate success of the HSCT.

Introduction

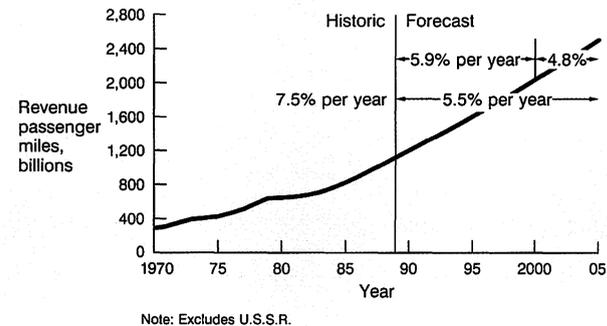
The determination of The Boeing Company to maintain leadership in the commercial aircraft market requires the development of the most appropriate airplanes at the most opportune times to meet domestic and international air travel needs.

Population and economic growth, coupled with lower real travel costs and growing discretionary income, are increasing demand for additional air transport for the international market. At the same time the demand increases, the capability to produce the airplane is increasing as a result of the introduction of new design and manufacturing technology.

The market forecast, based on major market area passenger flows, indicates that world air travel will grow at a rate of 5.9% per year through the year 2000. Studies of the long-range, largely overwater portion of this market indicate that the demand will be

315,000 passengers per day in the year 2000, growing to 607,000 per day in the year 2015. This increase in demand by the year 2015 could require 1,000 to 1,500 HSCTs, certainly a sufficient number to justify studying the supersonic passenger airplane.

Based on encouraging market forecasts and study results, Boeing has increased its design efforts and has initiated the development of HSCT technologies in cooperation with NASA and our suppliers. Current efforts are aimed toward providing the technology and design information necessary for service introduction early in the next century. This brochure provides a review of the Boeing program to date and our view of the future of supersonic travel.



Market Forecast for World Air Travel Through the Year 2005

Background

The Beginning. The first manned supersonic flight occurred in 1947 when the rocket-powered X-1 exceeded the sound barrier. Design of commercial supersonic aircraft began in the early 1960s when U.S. companies coupled experience from military vehicles and commercial jetliner programs to design the prototype U.S. SST. Almost concurrently, the U.S.S.R. initiated its SST program leading to the TU-144, and a British and French consortium initiated work on the Concorde. Boeing continued development of the U.S. SST until 1971, when the U.S. Government canceled the prototype program because of increasing concerns over its economic viability and environmental issues. No U.S. manufacturer was willing to continue the program without Government funding because of the market risks

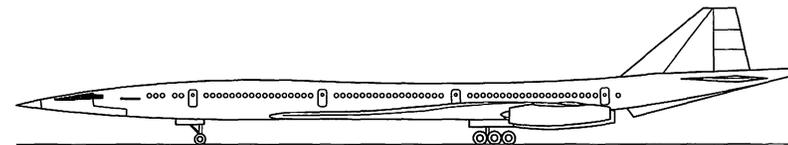
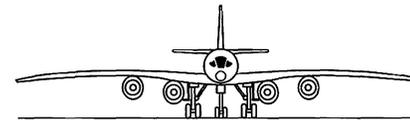
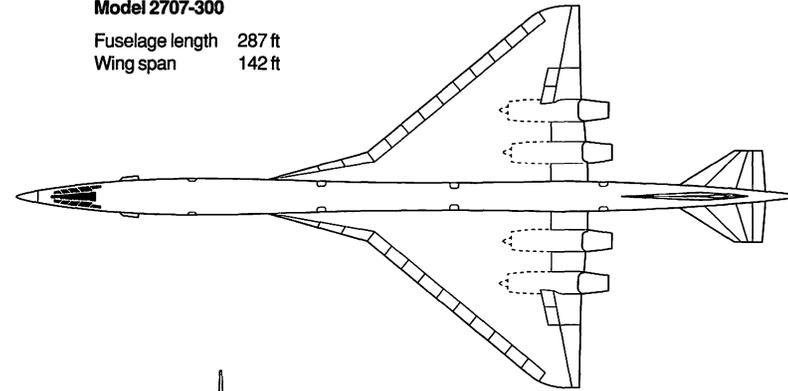
associated with the unsolved problems of poor economics and possible environmental problems.

Although the Concorde has been a technical success, it has not proved to be economically attractive. Hence, production was stopped after only a few airplanes were manufactured. Today, these airplanes are in service, catering to a small segment of the first-class market, where high fares support the substantial operating costs.

Technology studies related to a future SST continued, although at a much lower level, with the NASA Supersonic Cruise Research program.

SST Prototype Airplane Model 2707-300

Fuselage length 287 ft
Wing span 142 ft



U.S. SST Program (1968-1971)

NASA High Speed Research Program. In recognition of the role of the U.S. commercial aircraft industry as the leading exporter of manufactured goods, the U.S. Government's Office of Science and Technology Policy (OSTP) commissioned an aeronautical policy review committee in 1983. (The committee comprised 16 leaders of government, industry, and academia.) In 1985, the OSTP proposed three national goals to focus U.S. aeronautical research and development and to challenge American creativity. One of the goals was technology development for a future long-range supersonic transport. NASA initiated contractual and internal studies of an HSCT in response to OSTP recommendations.

NASA contracts were awarded to McDonnell Douglas and Boeing in 1986 to address the issues of whether or not a second-generation SST could be environmentally acceptable and economically competitive with a new generation of long-range subsonic transports.

Boeing HSCT Development Program. By 1988, the potential shown in the NASA-sponsored studies for environmental, technical, and commercial viability of an HSCT were encouraging. In response, Boeing funding of internal HSCT studies was expanded to build a core HSCT team for preliminary design and technology development.

	Concorde	U.S. SST	HSCT
Year entry into service	1971	1978	2005-2015
Program status	In service	Canceled 1971	Study
Market	North Atlantic	North Atlantic	Worldwide
Range, nmi	3,500	3,500	5,000-6,500
Passengers	100	200	250-300
Takeoff weight, lb	400,000	750,000	700,000
Community noise requirement	None	FAR 36 Stage 2	FAR 36 Stage 3

High Speed Civil Transport Perspective

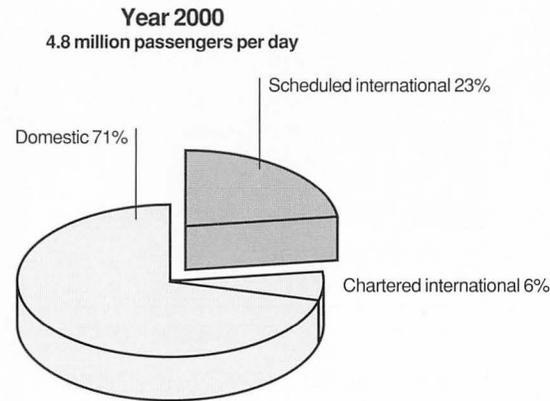
Market Forecast

The market forecast, based on major market area passenger flows, projects that world air travel will roughly double by the year 2000. The scheduled international market is 23% of the total.

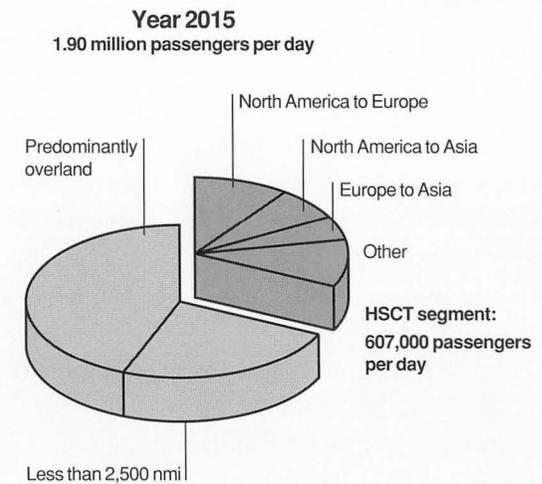
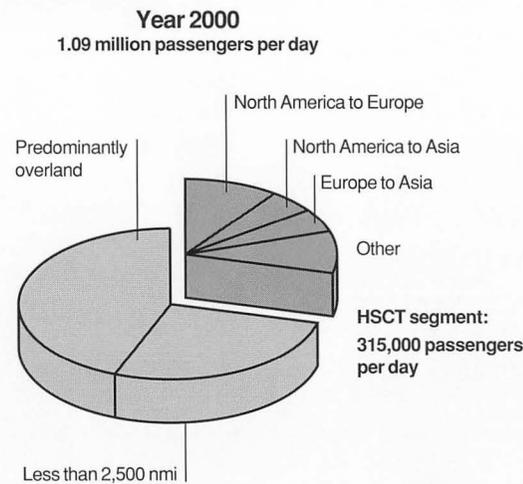
The portions of the international market appropriate to the HSCT include the long-range North America to Asia, North America to Europe, and Europe to Asia markets. (Markets shorter than 2,500 nmi have been eliminated from consideration. Markets predominantly overland are not under consideration because of sonic boom concerns.) Based on this projection, the demand in HSCT markets will be 315,000 passengers per day in the year 2000, growing to 607,000 in the year 2015.

This is a potential market for 1,000 to 1,500 HSCTs – sufficient to justify further study.

World Traffic Demand Forecast



High Speed Civil Transport Study Markets



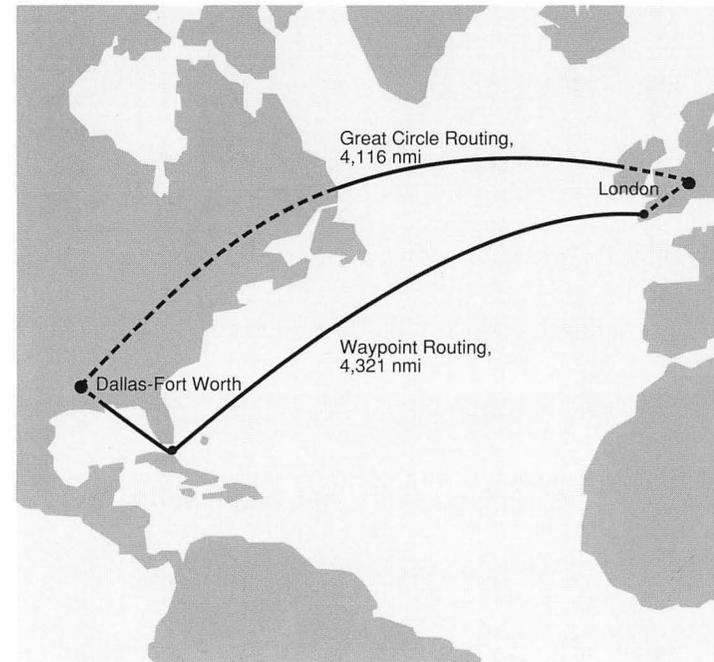
HSCT Fleet Analysis

Since most subsonic jet transport airplanes fly between Mach 0.78 and 0.85, productivity (trips flown per year) is assumed to be equal among all competitors when evaluating subsonic airplanes. Productivity is a key attribute and must be included in the economic evaluation when comparing subsonic airplanes with the HSCT. The comparison shown has been made on a total fleet basis over a scheduled route system to evaluate productivity differences between an HSCT and a comparable subsonic airplane. The evaluation considered applicable routes, turn or through times, airport curfews, and waypoint routing. The markets exclude routes of less than 2,500 nmi, predominantly overland routes, and those where the demand is less than 300 passengers per day. The route system used in the study included 51 cities and 234 city pairs, with about 2,300 flights per day. Subsonic flight over land and waypoint routing to minimize HSCT overland flying were assumed.

The resulting comparison between subsonic and HSCT operation over the route system, using the year 2000 passenger demand of 315,000 passengers per day and a 5,000-nmi design range, is summarized below.

	Subsonic	HSCT
Cruise Mach number	0.84	2.4
Average trip distance, nmi	3,389	3,439
Utilization, trips/year/unit	858	1,552
Average trip time, hr	7.5	4.0
Total system miles flown, billion nmi	2.77	2.91
Fleet required, units (292-seat average)	940	546

The average passenger-trip time savings is approximately 45%. HSCT productivity is approximately 1.8 times that of the subsonic airplane. Total miles flown are about 5% more for the HSCT than for the subsonic airplane because the HSCT will use waypoint routing to reduce subsonic operation.



Example of Waypoint Routing

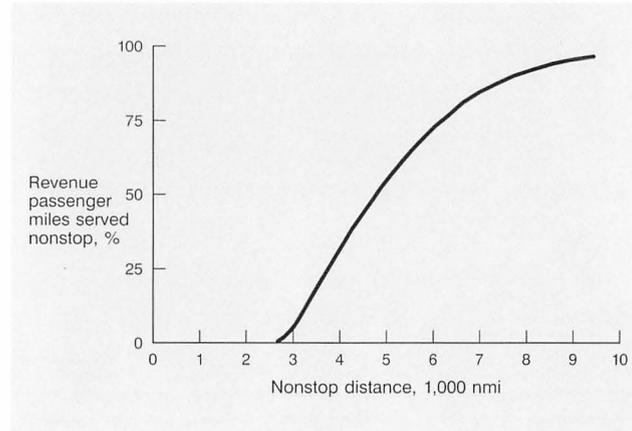


Cities Used in the Study Route System

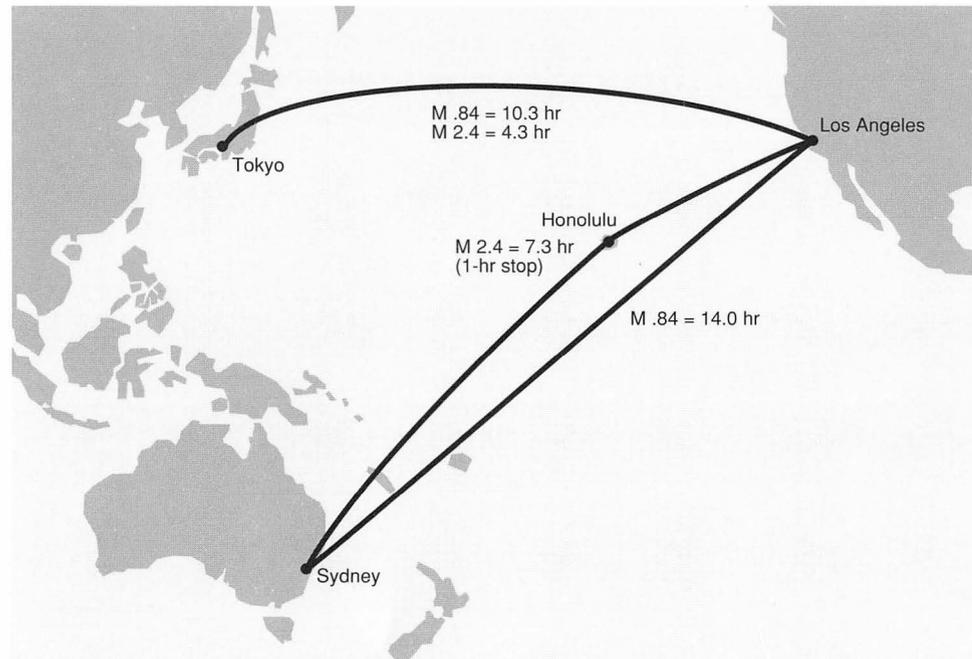
Market-Driven Design Requirements

Design Range. A design range of 5,000 nmi was chosen for the initial baseline airplane in our studies. A 5,000-nmi design will serve more than 50% of the revenue passenger miles in the HSCT nonstop markets. Equally important, the speed of the HSCT will allow the longer range markets to be served on a one-stop basis with significant savings in trip time over a subsonic airplane.

As an example, a 14-hr, nonstop subsonic flight from Los Angeles to Sydney could be replaced by a 7.3 hr, one-stop HSCT flight, including a 1-hr stop in Honolulu. The 5,000-nmi-range airplane will also serve important U.S. west coast-Japan markets nonstop.

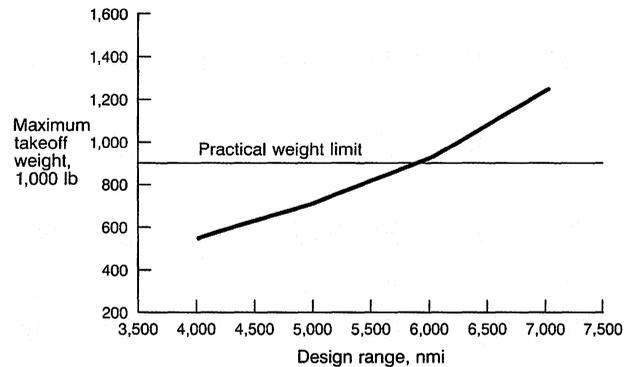


HSCT Market Distribution – Year 2000



HSCT Trip Time Comparison to Subsonic Airplane

A design range of almost 6,500 nmi is required to capture approximately 85% of the non-stop revenue passenger miles in the HSCT markets. However, an initial airplane with a 6,500-nmi range would be heavy and expensive. Downstream improvements in propulsion and structure technologies will allow the HSCT to “grow” into longer nonstop-range markets.



Airport Compatibility. The HSCT must be designed to operate from conventional airports. Surveys of the runway length for the candidate airports indicate that an 11,000-ft runway should be the target for maximum takeoff weight. Runway and taxiway pavement loading should be compatible with contemporary aircraft. Our designs cater to these requirements.

Effect of Design Range on Maximum Takeoff Weight

Comfort Level. Passengers should expect the same comfort levels currently experienced in the cabins of today’s subsonic fleet for flights of comparable duration.

Environmental Requirements

Three environmental goals must be satisfied for an HSCT to be acceptable:

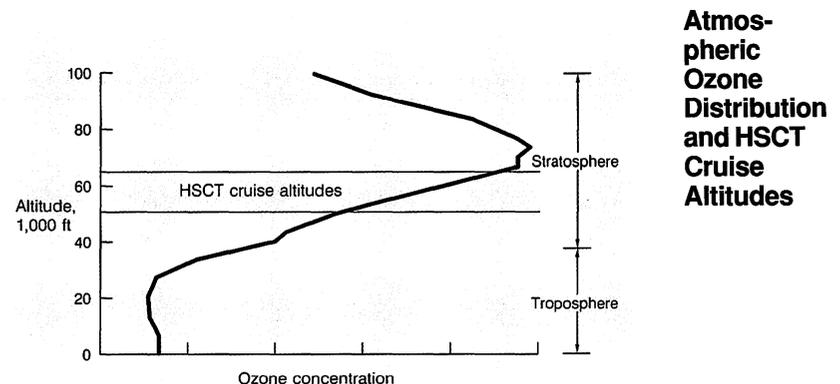
- *The HSCT must have no significant effect on the ozone layer.*
- *HSCT community noise must meet the equivalent of current FAR 36 Stage 3 requirements.*
- *There can be no perceptible boom over populated areas.*

In 1989, NASA launched the \$284 million Industry-Government High Speed Research Program to develop the technology required to realize these goals.

Atmospheric Effects. The HSCT will cruise in the lower region of the ozone layer.

Principal concerns about stratospheric ozone loss have arisen from the discovery that chlorofluorocarbons (CFC) undergo photochemical reactions when transported to the upper atmosphere. This process leads to the catalytic removal of ozone, which protects Earth's atmosphere from potentially damaging ultraviolet light. Oxides of nitrogen, namely nitric oxide (NO) and nitrogen dioxide (NO₂), are also known to reduce stratospheric ozone by catalytic reaction. (These compounds are collectively described as NO_x.) NASA and U.S. engine manufacturers are investigating advanced HSCT engine combustor designs that will markedly reduce NO_x emissions by as much as a factor of 10 while preserving engine efficiency and reliability.

As part of the High Speed Research Program, NASA has funded extensive research to assess the impact of oxides of nitrogen and other products of combustion on the atmosphere. Computer models of atmospheric chemistry and dynamics are being used in conjunction with atmospheric experimental research to predict the effects of supersonic aircraft on the ozone layer. The Atmospheric Advisory Committee, composed of Government and academic experts appointed by NASA, will review the program results and provide the assessment of the atmospheric effects from which emission rules can be developed.

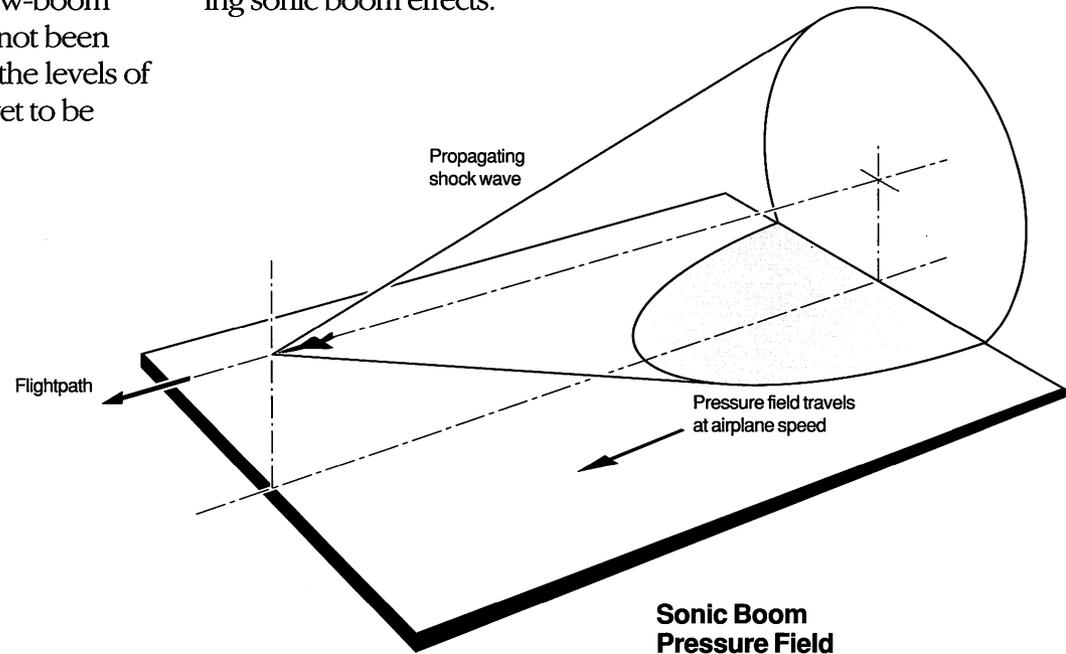


Community Noise. The HSCT will be operated from existing international airports. The community noise it generates will meet the equivalent of current FAR 36 Stage 3 requirements.

Meeting these stringent noise limits is difficult with engines that are required for supersonic flight. These engines produce high-velocity jet exhaust flow and are inherently noisy. Engine and nozzle systems that can entrain and mix ambient air with the engine exhaust flow to reduce the peak flow velocities must be developed. The key objectives are to provide rapid flow mixing within an acoustically treated section while minimizing weight and thrust loss. Research is being conducted by Boeing, the engine companies, and NASA to develop the required technology.

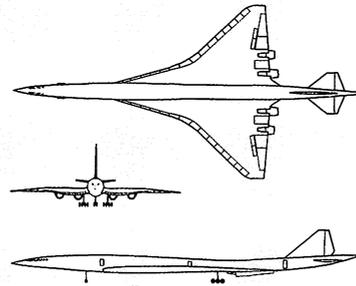
Sonic Boom. Supersonic operation over land would naturally be beneficial to the economics of an HSCT. However, at supersonic speeds, the aircraft produces shock waves that can propagate to the ground, creating sudden pressure changes that can sound loud and offensive to the ear. Aerodynamic theory suggests that the magnitude of the sonic boom levels can be minimized by careful treatment of the aerodynamic design of the aircraft. Nevertheless, the low-boom design process has not been fully validated, and the levels of acceptability have yet to be established.

NASA is conducting human-response studies to establish criteria for sonic boom acceptability. Until clear standards have been established and more confidence has been placed in the low-boom design process, design analysis of our baseline design will assume subsonic overland flight, and the economics of the aircraft will be assessed on that basis. We will continue to research, in conjunction with NASA, the technology of reducing sonic boom effects.

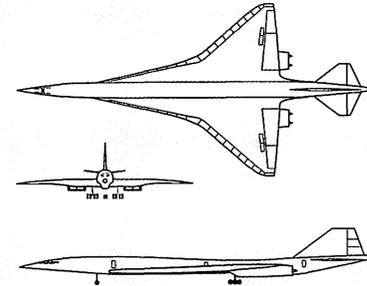


Cruise Speed Studies

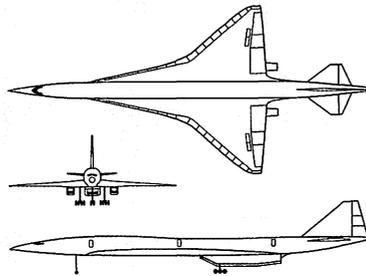
Boeing studies conducted under a NASA contract evaluated 21 configurations designed for Mach numbers between 2.4 and 10.0. A screening process was used to evaluate the concepts on the basis of risk versus benefit. Of the 21 configurations, 6 were further developed and analyzed. These analyses showed that speeds above Mach 3.2 will be impractical. Subsequent studies narrowed the speed range studies to Mach 2.4 to 3.2 for economic commercial vehicles.



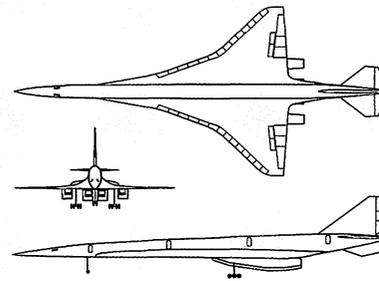
Mach 2.4 Configuration



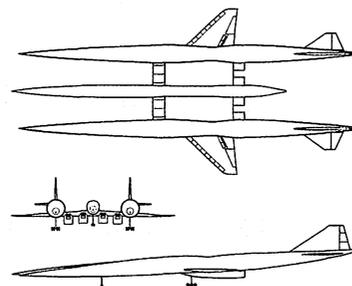
Mach 3.2 Configuration



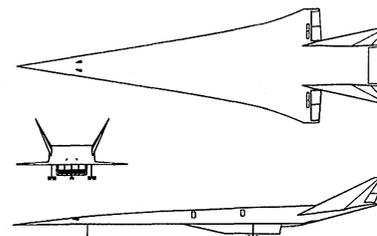
Mach 3.8 Configuration



Mach 4.5 Configuration

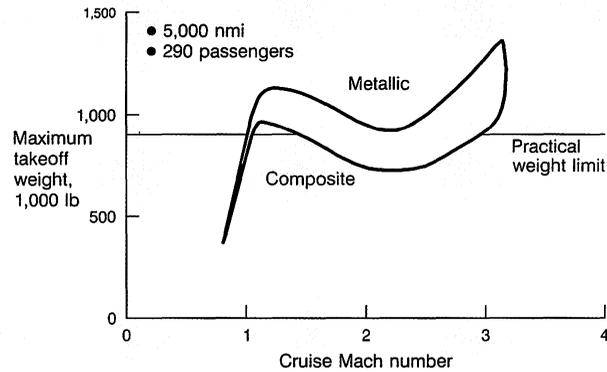


Mach 6.0 Configuration

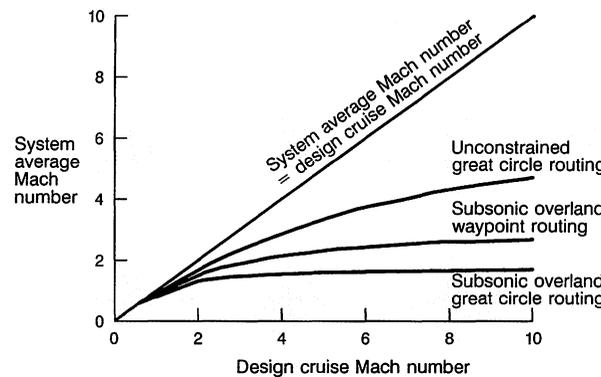


Mach 10.0 Configuration

Aircraft size and complexity increase significantly with increasing Mach number. The practical upper airplane weight limit for turn of the century runways was assumed to be around 900,000 lb. The graph indicates that the region bounded by Mach 2.0 and 2.5 would be optimum for an HSCT. This speed region is further supported by the relationship between the system's average Mach number and cruise Mach number. Constraints on the operation of higher speed airplanes, such as airport curfews, and the added impact of subsonic flight over land practically eliminate any advantage to using cruise speeds above Mach 3.0. Mach 2.4 has been chosen for the current Boeing design studies.



Effect of Cruise Mach Number on Maximum Takeoff Weight

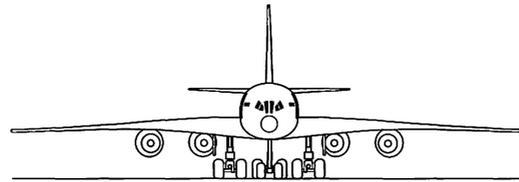
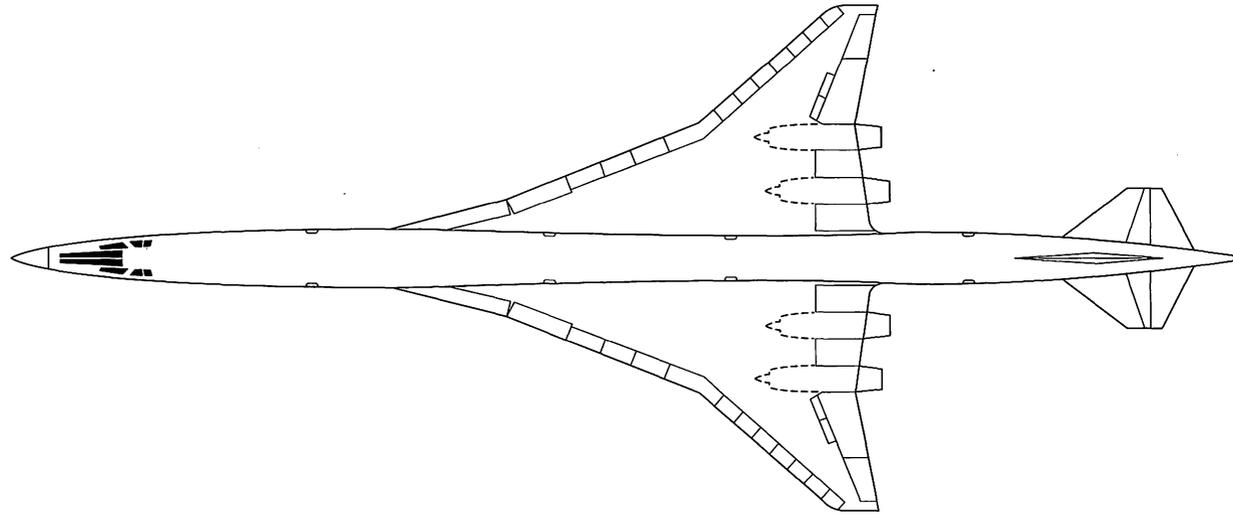


Effect of Increasing Cruise Mach Number on the System Average Mach Number

Baseline Airplane Design

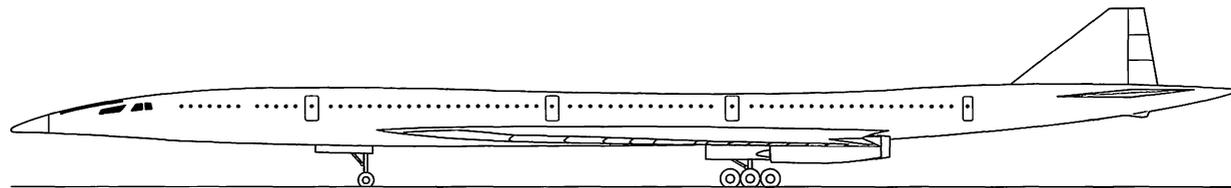
A baseline airplane is continually developed as the logical outgrowth of design studies and technology developments. The baseline is used as the basis for design development, technology development and testing, and evaluation of HSCT operations, economics, and environmental impact.

The current baseline is the result of 4 years of design evolution and meets the market-driven design requirements of 5,000-nmi range and Mach 2.4 cruise speed.



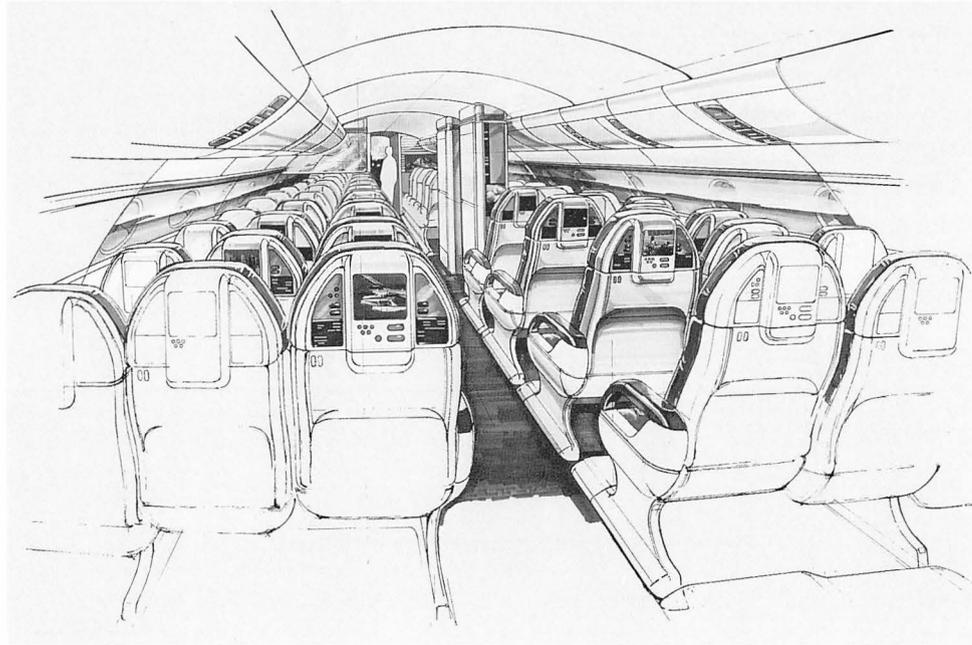
Current Baseline Airplane

Maximum takeoff weight	700,000 lb
Fuselage length	310 ft
Wing span	130 ft
Triclass seating	292 passengers
Cruise speed	Mach 2.4
Design range	5,000 nmi
Takeoff field length	11,000 ft
Approach speed	155 kn



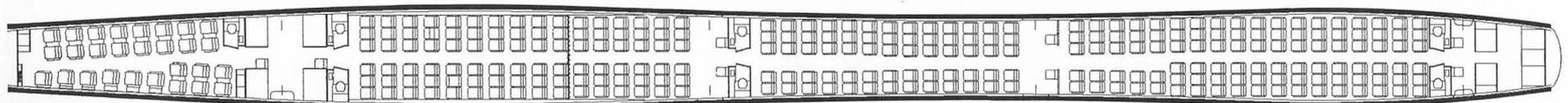
Interiors

Interior arrangement of an area-ruled body creates a challenge different from that of a constant-section fuselage. The baseline interior is triclass with three-, four-, five-, and six-abreast seating, depending on the location.



HSCT Interior Concept

292 Total Passengers



28 first-class passengers
38-in pitch

60 business-class passengers
36-in pitch

204 tourist-class passengers
34-in pitch

Economic Viability Assessment

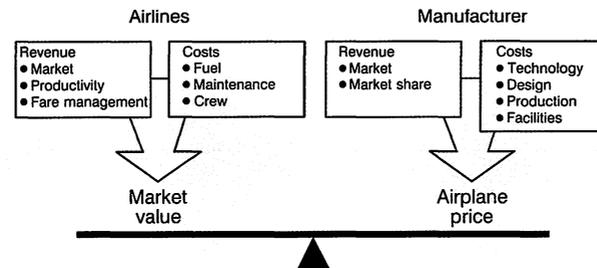
For an airplane to be economically viable, it must offer a value to the airline that is equal to or more than the price charged by the manufacturer to cover manufacturing costs. Economic viability occurs when a market size justifies the investment and risk that both the manufacturer and an airline undertake when deciding to develop or purchase an airplane.

While our goal is for the HSCT to operate profitably on the same fare base as the subsonic fleet, configuration assessments show that some increase in fare may be necessary.

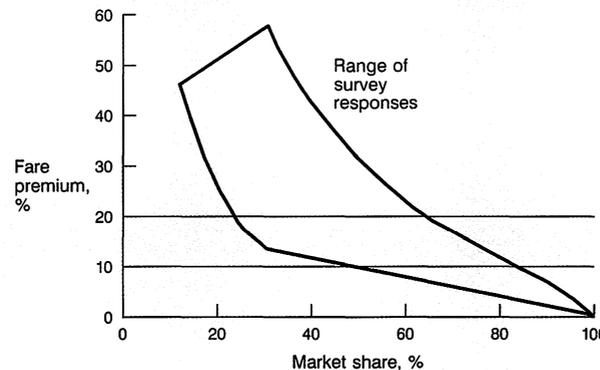
The willingness to pay a fare premium is subject to a great deal of uncertainty. Nevertheless, airline surveys have shown that, from a passenger point of view, the time savings offered by an HSCT can justify a fare premium.

Optimistic assessments show that if fare premiums for HSCT flights averaged 20% over the fares of subsonic flights, nearly 65% of the potential HSCT market could be obtained, and if fares averaged only 10% over,

nearly 85% of the market could be obtained. Conservative assessments at the same fare premium levels yield respective market share estimates of 25% and 50%.



Economic Viability



Passenger Willingness To Pay a Fare Premium

Technology Development

Successful development of the HSCT is dependent on advanced technology.

For environmental and economic viability, the highest near-term priorities for technology development are low-emission engine combustors, engine noise suppressors, variable-cycle engines, high-temperature composite structural materials, high-lift aerodynamics, and high-temperature metals. Other efforts in technology development include high-speed aerodynamics, supersonic engine inlets, aircraft systems, avionics, and flight deck requirements.

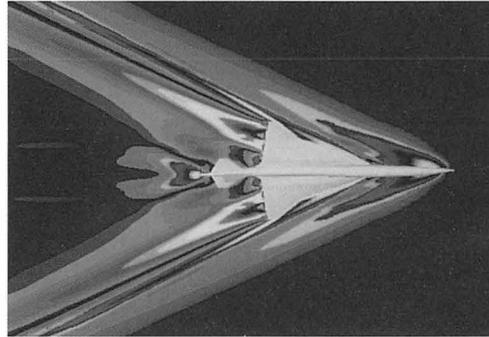
Boeing, along with engine companies, other suppliers, and NASA, is pursuing both enabling and key high-leverage technologies.

Aerodynamics Technology Development

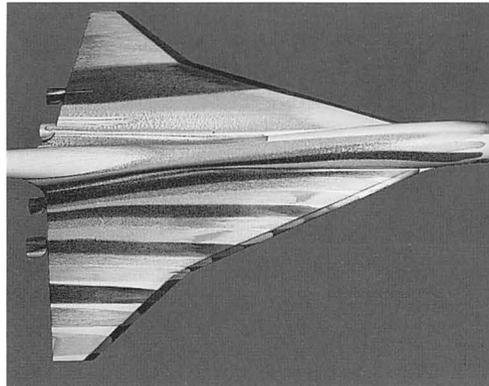
Cruise Efficiency. Computational fluid dynamics (CFD) is used extensively in the high-speed aerodynamic design of the HSCT. A major advantage of the new CFD methods is the ability to obtain detailed information about the airflow away from the airplane as well as on its surface. These analyses are being used to investigate the formation and interactions of shock waves produced by the wing, body, and nacelles and their effects on performance.

We are currently conducting tests in our supersonic and transonic wind tunnels to validate our new designs and to verify information obtained from CFD analyses. Force and moment data, surface pressures, and flow visualization data include conditions for which current CFD methods are inadequate. (This is particularly true for high angles of attack, where large regions of separated flow are present.)

Much progress has been made since 1970 in improving the aerodynamic efficiency of the

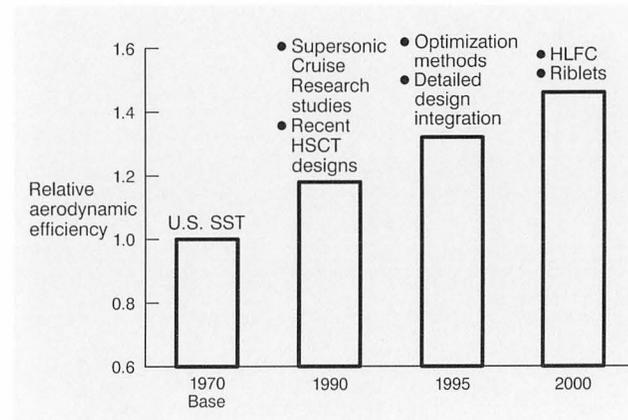


CFD Representation of the HSCT During Cruise



Oil Flows From Wind Tunnel Tests at Cruise Mach

HSCT. Our new and emerging design, analysis, and test methods will allow us to continue to improve the aerodynamic efficiency of the HSCT.



Aerodynamic Efficiency Improvement Projections

Low-Speed Performance.

We are pursuing research on improving low-speed performance by increasing vortex lift as the airplane lifts off and as it prepares to touch down. (Vortex lift is increased by amplifying the vortex separation from the wing's highly swept leading edges. Leaving the leading edge flaps undeflected, or even raising them, directly increases lift.)

Other devices, such as vortex fences, shown with smoke visualization in this wind tunnel test, increase lift and help to control the airplane.

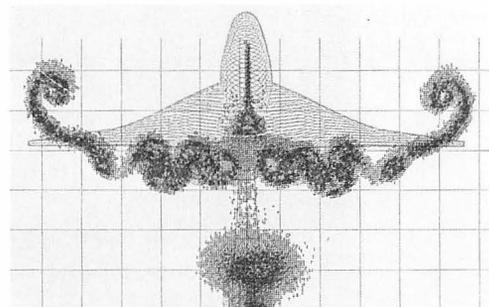
Retaining attached flow on the wing upper surface by suppressing the leading edge vortex improves the lift-to-drag ratio. This will lower community noise levels by making a steeper climb possible or by allowing the engines to be operated at lower thrust settings. Optimum lift-to-drag ratio will be maintained after liftoff and throughout the takeoff profile and again during the landing approach by adjusting flap position.



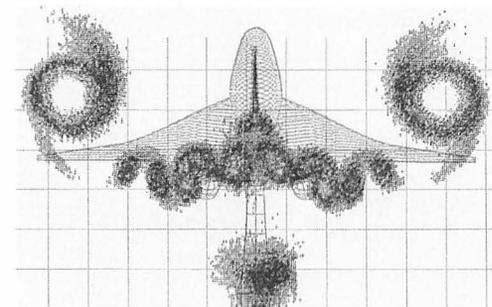
**Vortex
Fence
Testing**

Wake imaging of the flow-field behind the wing illustrates the difference between a low-drag, attached flow configuration and a high-lift, vortex-generating configuration. Flow attachment results in a smaller wake behind the wing, with less

loss of kinetic energy and lower drag. A strong vortex forming over the wing causes suction pressures that add to the lifting force. Amplifying or suppressing the vortex will be controlled by changing flap deflection.



**Wing Wake With Attached
Flow (Less Drag)**



**Wing Wake With Vortex
Generation (More Lift)**

Boeing-NASA Supersonic Laminar Flow Control Studies.

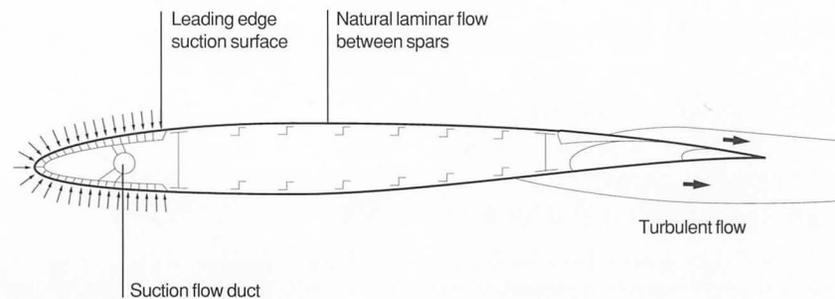
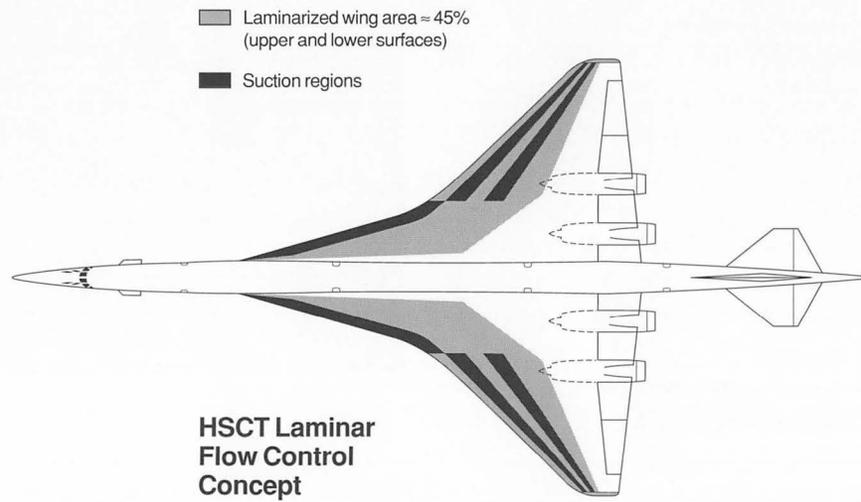
An HSCT has greater sensitivity to aerodynamic drag reduction than its subsonic counterpart. Any reduction in aerodynamic drag leads directly to a reduction in airplane size and fuel requirements.

Skin friction drag accounts for approximately 40% of the total aerodynamic drag on an HSCT at cruise conditions. A powerful way to reduce skin friction drag is to maintain the airflow in the vicinity of the aircraft surface in the laminar state and delay its transition to the turbulent state. In regions where laminar flow is maintained, skin friction drag is reduced as much as 80% to 90%. Laminar flow is achieved by sucking away a small amount of flow through tiny skin perforations on the wing surface. The possibility of maintaining laminar flow over a large area of the wing surface

by this method is currently being studied by Boeing.

To assess net performance and economics, the benefits of aerodynamic drag reduction must be balanced against the weight, fuel displacement, and cost penalties of a laminar flow control (LFC) system installation. Systems studies have shown a potential for significant benefits of LFC implementation on HSCTs.

Subsonic technology development and validation work continues through flight testing of the LFC concept on a Boeing 757 aircraft. The flight test program is a joint effort of Boeing, NASA, and the U.S. Air Force. The results will be of value to the supersonic transport program.



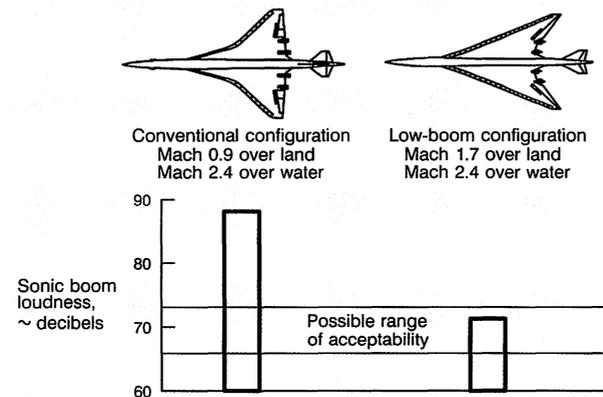
Low Sonic Boom Studies.

Supersonic operation over land would have a beneficial impact on fleet economics. The level of sonic boom acceptable to the public is as yet unknown. NASA is conducting human-response studies to establish criteria for sonic boom acceptability.

Sonic boom may be reduced by precise shaping of the fuselage and the wing. The design process is complex and has not yet been completely validated. In addition, there are a number of unknowns, such as the effects of variations in wind shear, turbulence, temperature gradients, water vapor, and ground surface conditions, that can strongly affect the perceived noise level.

Boeing is working with NASA to develop low sonic boom technology that will incorporate emerging analysis methods and wind tunnel testing to see whether a satisfactory low sonic boom aircraft design is achievable. In addition, we are

conducting detailed airplane systems studies to assess the economic viability and technical feasibility of our low-boom configuration designs. Clearly, the HSCT must not become an unacceptable source of noise. If low sonic boom technology does not achieve expectations, overland flight will be limited to subsonic speeds.



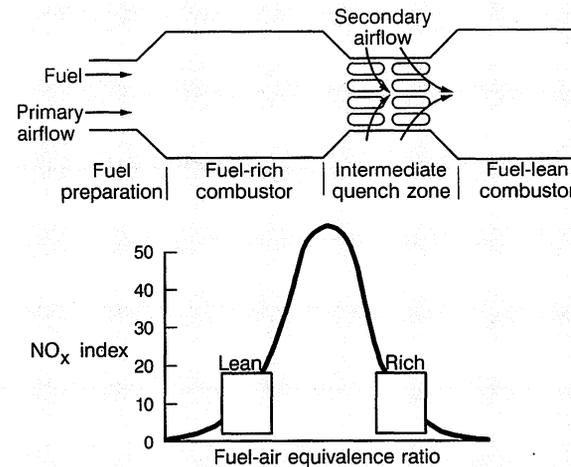
Design for Reduced Sonic Boom

Propulsion Technology Development

Emissions – Low NO_x Combustors. To ensure that the emissions from the engines will not harm the ozone layer, the engine combustor will be designed for low production of NO_x (oxides of nitrogen – NO and NO₂). Both Pratt & Whitney and General Electric have identified combustor concepts that appear to have the potential to reduce the NO_x levels by 80% to 90%.

The low NO_x combustor of the future will achieve low emission levels through precise control of the burning process and the combustion time during each stage of the process. One candidate is shown in the illustration. The combustion occurs in two stages: first in a fuel-rich zone, then in a fuel-lean zone. This avoids the high rate of NO_x production that occurs when the fuel burns in one stage. All

combustion air is either pre-mixed with the fuel on entering the first-stage fuel-rich zone or introduced into the intermediate quench zone. The fuel-rich condition is accomplished by not permitting cooling air through the combustion zone walls as in conventional combustors. Without this cooling air, the combustor liner must be designed to work at higher temperatures, requiring application of new, higher temperature materials.



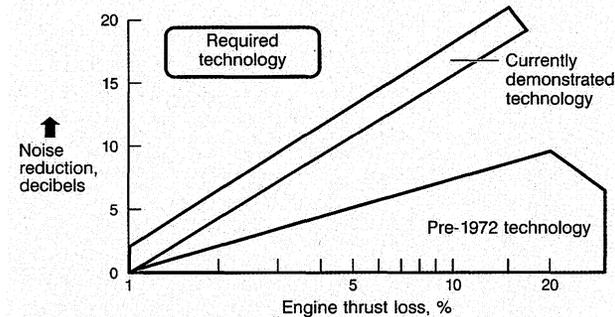
**Low NO_x
Combustor
Concept**

Noise. The HSCT must be a good neighbor around airports. Accordingly, it will be designed to meet the equivalent of current FAR 36 Stage 3 noise requirements. Advanced-technology ejector-suppressor nozzles will be required to reduce the two main contributors to jet noise – mixing and shock cell noise – which result from the very high jet velocities characteristic of supersonic engines. High-velocity jet mixing noise can be reduced by mixing the propulsive jet with large amounts of entrained outside air within an acoustically lined nozzle duct. Shock cell noise can be reduced by properly controlling the rate of expansion of the high-pressure jet prior to mixing with the aspirated air.

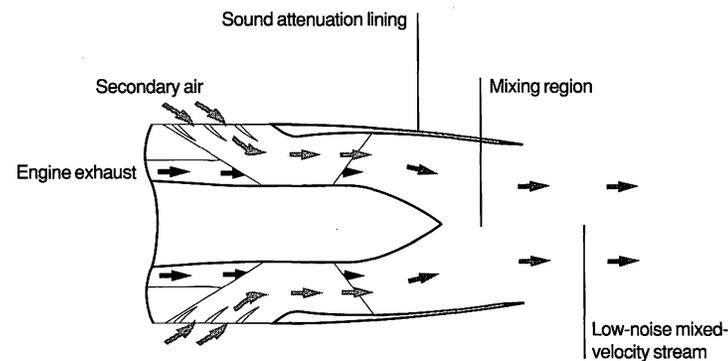
A low-bypass-ratio turbofan and a turbojet are the leading HSCT propulsion candidates today because of their good supersonic and subsonic performance. These engines require a noise suppression

nozzle that will provide a reduction of at least 18 decibels in jet noise with little loss in thrust. Results from wind tunnel testing show promise for achieving the noise and performance goals using nozzle designs that combine aspirated freestream air with the core flow to produce a low mixed-jet velocity.

Current studies suggest that meeting the noise goals will be a difficult but achievable task that will require innovation and technology advancements in engines, noise suppressors, aircraft design, and flightpath management.



Suppressor Technology History and Requirements



Internally Mixed Ejector-Suppressor Nozzle Concept

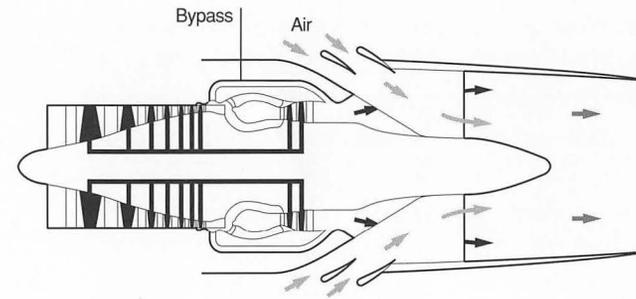
Variable-Cycle Engines.

Considerable effort has been devoted to improvement of engine specific fuel consumption (SFC) at subsonic conditions over the past 20 years. The U.S. SST had very poor subsonic SFC. Poor subsonic SFC penalizes the mission performance by reducing the efficiency during subsonic mission legs and by requiring larger amounts of reserve fuel. The key to good subsonic and supersonic SFC is a variable-cycle engine. The major objective for a future HSCT application is to provide some degree of engine cycle variability that will not significantly increase the cost, the maintenance requirements, or the overall complexity of the engine. The variable-cycle engine must have a good economic payoff for the airline while still providing more mission flexibility and reducing the reserve fuel requirements so that more payload can be carried.

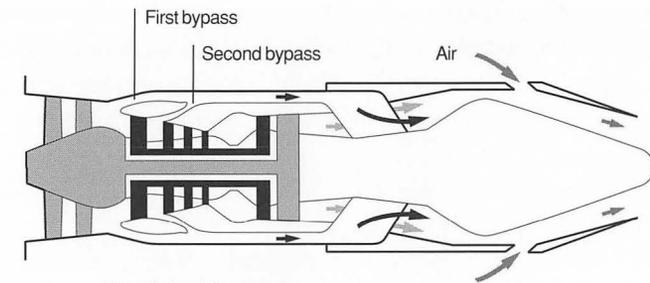
In the past, variable-cycle engines were designed with large variations in bypass ratio

to provide jet noise reduction. However, these types were complicated and did not perform well. Today, the trend is toward turbojets or low-bypass engines that have the ability to improve off-design performance by adjustment of compressor bleed or by relatively small variation in bypass ratio. The current engine offerings from Pratt & Whitney and General Electric fall into this category. Both of these engines will require an effective jet noise suppressor.

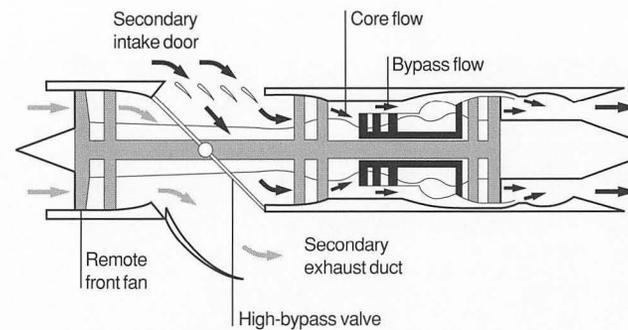
Rolls-Royce/SNECMA favors other approaches. One is a tandem fan that operates as a turbojet cycle for cruise but opens a bypass inlet and nozzle for higher flow at subsonic speeds. A second approach is to increase the bypass ratio by incorporating an additional fan and turbine stream into the flow path at subsonic speeds.



Turbine-Bypass Turbojet Engine



Double-Bypass Turbofan Engine



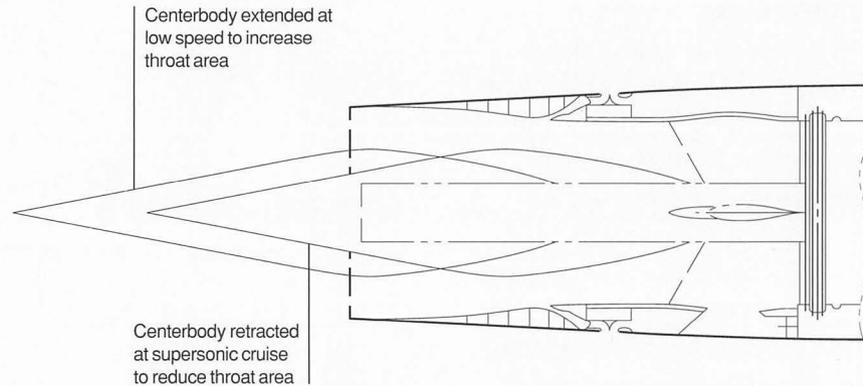
Tandem Fan Concept – High-Bypass Mode

Supersonic Engine Inlet

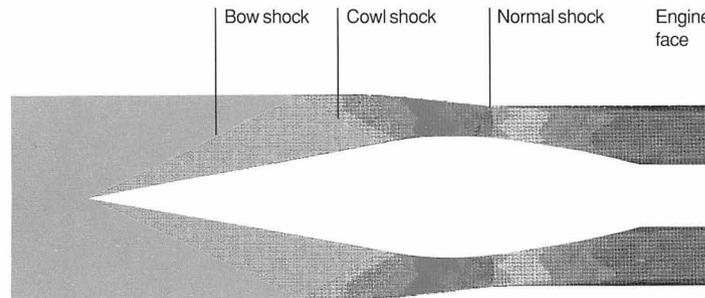
Design. At supersonic flight speeds, the air to the engine must be slowed to subsonic speeds before entering the engine. The flow must be supplied efficiently to obtain optimum engine operation. An inlet is required that can vary the geometry of the air supply duct to accelerate the flow during takeoff and low-speed flight and decelerate the flow during transonic and supersonic flight. A digital electronic control system is required to provide stable operation at all flight conditions.

Extensive analyses (using modern computational fluid dynamic methods) and test programs are continuing to show that such an inlet system can be designed with the required high-performance, reliability, and stability characteristics required on a commercial airplane.

Other inlet concepts with different characteristics are also being studied. Installed aerodynamic efficiency and stability, weight, initial costs, and operating costs will be the basis for selecting the final inlet design.



Variable Geometry Inlet Concept



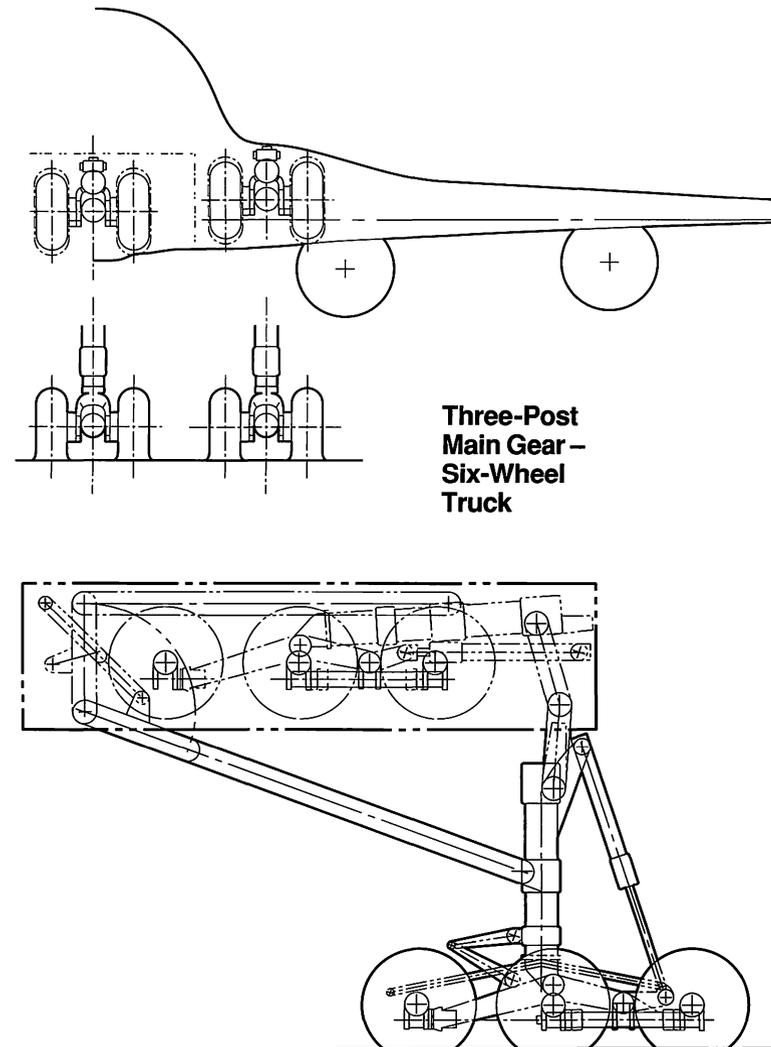
CFD Representation of the Inlet Operating at Mach 2.4

Systems Technology Development

When compared with those existing on today's subsonic commercial airplanes, the mechanical, electrical, and avionic flight systems for the HSCT will require substantial development. Some systems will require change to cater to the greater range in flight speeds and altitudes and to the corresponding increases in operating temperatures. Other systems will require development to address the higher levels of system complexity and automation required to optimize the performance and hence the economics of this type of airplane.

Landing Gear. A typical mechanical system requiring development is the landing gear. Factors influencing main landing gear designs include runway loading requirements, spatial separation of the gear elements from the engine inlets to prevent ingestion of foreign objects, and critical requirements for stowing gear elements efficiently in the thin, supersonic wing contours.

Conceptual design studies are addressing all these problem issues. Technology advances in wheels, tires, and brakes will aid in providing minimum weight and minimum volume gear designs compatible with the stowage requirements.



Flight Deck. Advanced flight deck designs will take maximum advantage of new technologies and human factors design principles to create a safe, efficient, and highly capable flight deck. The pilot's situational awareness and operating capabilities will be increased, and automation will be optimized to reduce the potential for pilot error.

Over-the-nose forward vision on past supersonic transport designs required a heavy and expensive retractable visor and droop nose. Synthetic vision, using a combination of optical and other sensors, could eliminate the need for a droop nose by providing the necessary forward view on a cockpit display. A display of this type has the added advantages of being unaffected by poor visibility in bad weather or night operations.

HSCT flight deck capabilities will be influenced by automation philosophy. This philosophy recognizes that human capabilities surpass those of automated systems in certain areas, while automation outperforms human capabilities in others. Boeing will create a system that optimizes the contribution of each of these elements and functions well in both normal and emergency situations.

Flight deck management information systems may include the portrayal of a pathway-in-the-sky that will allow a pilot to fly or monitor complex curved flightpaths in the landing and takeoff phases of flight.



HSCT Flight Deck Concept

Structures Technology Development

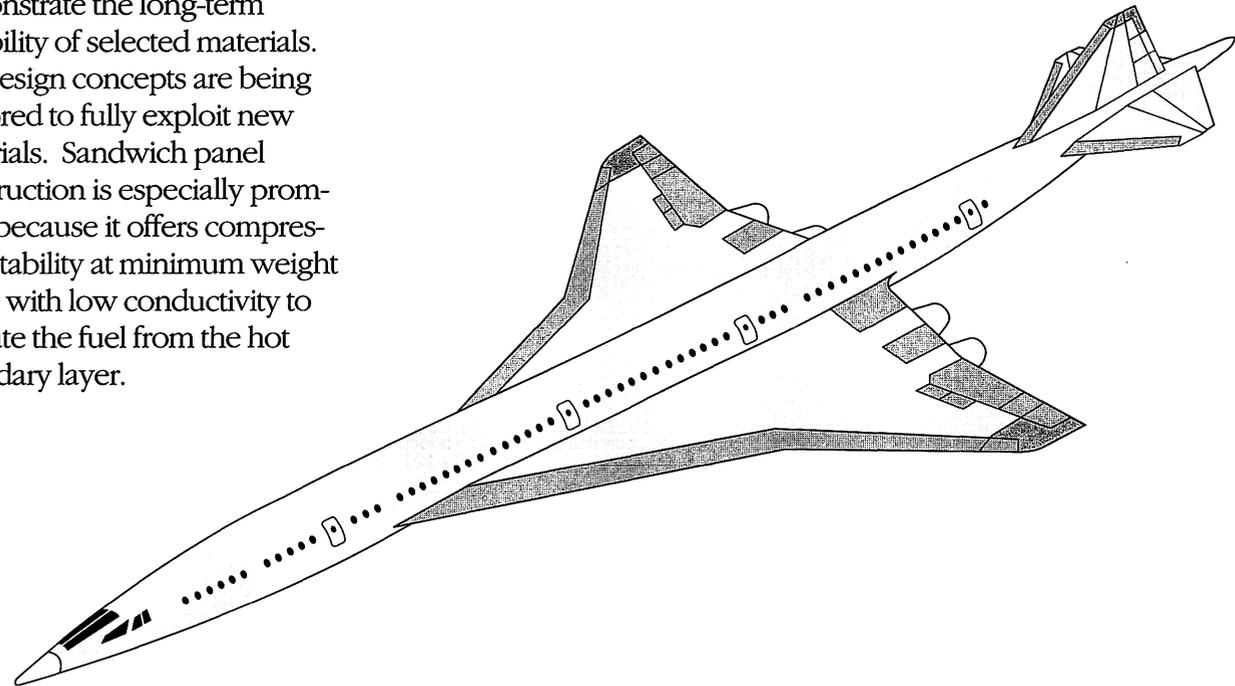
To satisfy strength and stiffness requirements for proposed airplane configurations, structural sizing is being established through the application of finite-element analysis and high-speed computers. Results are incorporated into airplane performance predictions.

Major structural design features, such as landing gear support, engine location, and wing-to-body intersection, are undergoing indepth studies to achieve optimum performance with maximum reliability.

New high-temperature, graphite-fiber composite materials and advanced aluminum alloys are being evaluated for lightweight and cost-effective aircraft structure. Real-time

exposure to expected HSCT load and temperature profiles on test samples and structural elements is being used to demonstrate the long-term durability of selected materials.

Design concepts are being explored to fully exploit new materials. Sandwich panel construction is especially promising because it offers compression stability at minimum weight along with low conductivity to insulate the fuel from the hot boundary layer.



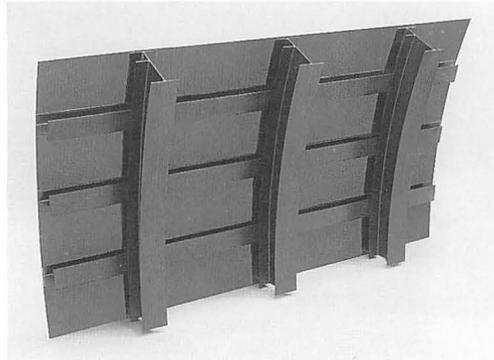
**Proposed Usage
of Materials for
the HSCT**

-  Composite honeycomb skin panels with composite substructure
-  Titanium honeycomb skin panels with composite substructure
-  Full-depth composite honeycomb panels

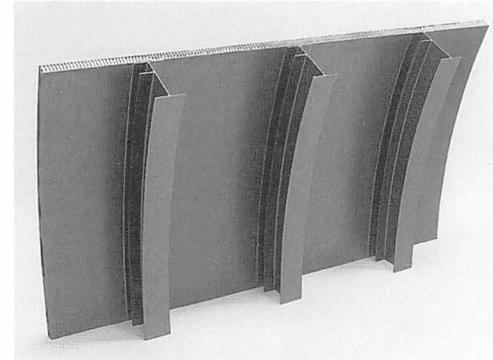
Manufacturing Technology Development

The HSCT will require development of many new designs, materials, and processes. Manufacturing Research and Development in the HSCT program is providing manufacturing, tooling, and assembly support as the development of the design progresses. This design-build team approach will ensure that the materials and structural design will result in an efficient, producible, cost-effective aircraft.

Typical body structural panels are being produced using new manufacturing process technologies to establish the producibility of the design and to assess process costs.



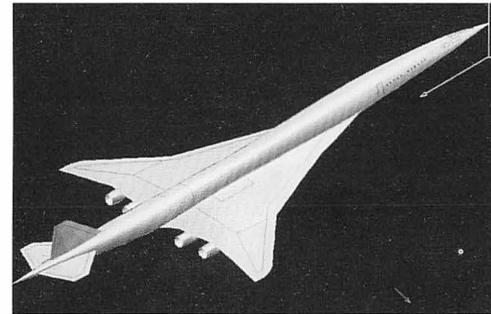
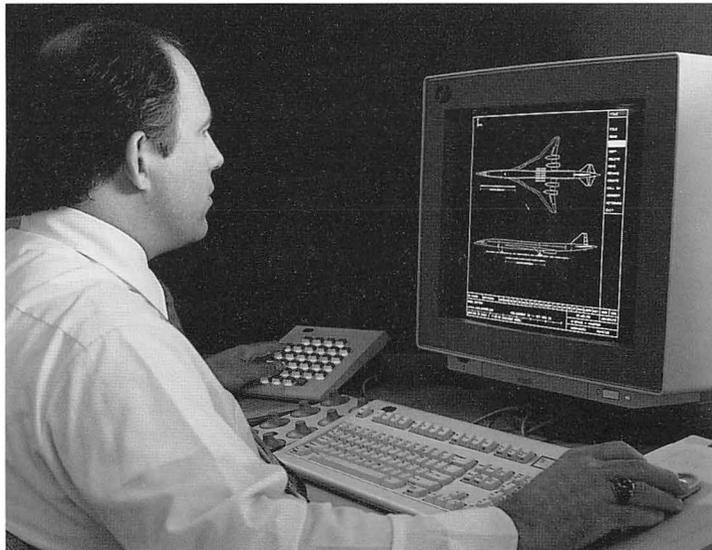
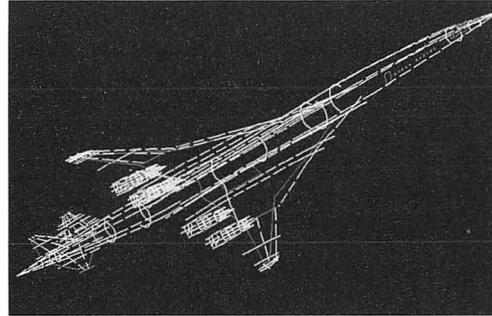
**Graphite/Bismaleimide Tape,
Stiffened Skin Panel, Precured
Stringers, and Frames Cobonded
to the Skin**



**Graphite/Bismaleimide Tape,
Sandwich Panel With Titanium
Honeycomb Core, and Precured
Frames With Fail-Safe Chord**

Digital Design Technology

Digital design will be a major contributor to the cost-effective design and manufacture of the HSCT. Design of component parts, assembly checks, and manufacturing processes will be performed through digital definition of the airplane by using computer-aided graphics and shared digital databases.



HSCT Operations

The addition of a new supersonic aircraft type with markedly different operating characteristics will require changes in the Air Traffic Control (ATC) infrastructure. Current National Airspace System plans will provide for worldwide navigation and communication coverage, automatic data linking, and strategic control. The problems foreseen are the control and efficient use of airspace, transition operations, and the impact of HSCT airplanes on airport capacity. Planned changes made for a future subsonic fleet will cover most of the needs of a supersonic fleet. HSCT takeoff and approach speeds are similar to those of the 747 and will not have a significant impact on ATC operations.

The HSCT will take off and land on existing international airport runways. Runway strengths will be adequate if they now can accommodate the high-gross-weight 747s. Some attention to taxi operations and taxiway design and, in many cases, new gates will be required because of the extreme length of the HSCT.

Boeing has initiated a High Speed Civil Transport program that integrates technology development, aircraft design, manufacturing research, and airline requirements. Boeing is teamed with NASA, engine manufacturers, and many other suppliers in technology development.

The goals of the program are to continue to assess the commercial and environmental viability of such an aircraft and to develop the technology that will allow Boeing to be a leader in this market if the HSCT proves feasible. Technology development is aimed at protecting the ability to launch an HSCT late this century.

Boeing will build an HSCT when it becomes commercially viable.

BOEING

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