

ECONOMIC BENEFITS OF SUPERSONIC OVERLAND OPERATION

Munir Metwally
New Commercial Programs
McDonnell Douglas
Long Beach, CA

Environmental concerns are likely to impose some restrictions on the next generation of supersonic commercial transport. There is a global concern over the effects of engine emissions on the ozone layer which protects life on Earth from ultraviolet radiation.

There is also some concern over community noise. The High Speed Civil Transport (HSCT) must meet at least the current subsonic noise certification standards to be compatible with the future subsonic fleet. Concerns over sonic boom represent another environmental and marketing challenge to the HSCT program.

The most attractive feature of the supersonic transport is speed, which offers the traveling public significant time savings on long range routes.

The sonic boom issue represents a major environmental and economic challenge as well. Supersonic operation overland produces the most desirable economic results. However, unacceptable overland sonic boom raise levels may force HSCT to use subsonic speeds overland.

These environmental and economic challenges are likely to impose some restrictions on supersonic operation, thus introducing major changes to existing route structures and future supersonic network composition. The current subsonic route structure may have to be altered for supersonic transports to avoid sensitive areas in the stratosphere or to minimize overland flight tracks. It is important to examine the alternative route structure and the impact of these restrictions on the economic viability of the overall supersonic operation.

Future market potential for HSCT fleets must be large enough to enable engine and airframe manufacturers to build the plane at a cost that provides them with an attractive return on investment and to sell it at a price that allows the airlines to operate with a reasonable margin of profit.

Subsonic overland operation of a supersonic aircraft hinders its economic viability for the following reasons:

Reduced time savings

Unrestricted supersonic operation produces optimum economic results. Time savings, the HSCT's most attractive marketing feature, would be maximized. As the percentage of subsonic overland increases, time savings decrease, thus eroding the unique competitive advantage of the HSCT over subsonic aircraft. Figure 1 shows how time savings decline at different levels of mixed operation. The highest time savings of supersonic versus subsonic flight is achieved for routes that are entirely overwater, such as between Honolulu and Sydney, where time savings exceed 5-1/2 hours. As the percentage

TIME PERFORMANCE

AVERAGE STAGE LENGTH — 4,500 NAUTICAL MILES

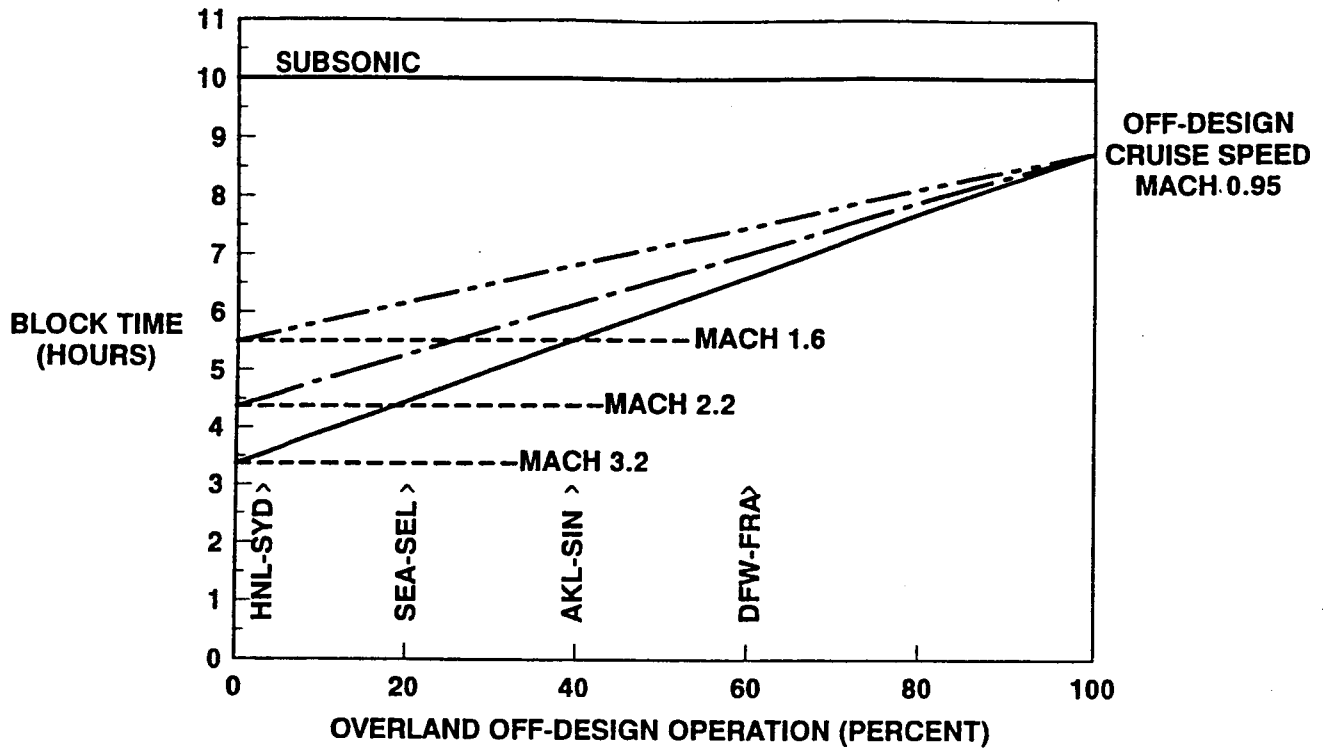


Figure 1

of restricted operation increases, time savings decline, as for example the Dallas Fort Worth-Frankfurt route, where time savings are cut to 3 hours.

Exclusion of some major city-pairs for the global super network.

Some of the major high density routes are mostly overland. Restricted supersonic operation overland will result in excluding the trans-continental U.S. routes such as New York-Los Angeles. This will reduce the traffic demand base of the supersonic operation, thus having an impact on HSCT fleet size.

Subsonic operation of a supersonic configuration imposes a penalty on its operating cost.

There is a significant reduction in aircraft economic performance and productivities when a mixed mode of operation is gradually introduced. The impact of wholly supersonic versus mixed subsonic and supersonic flight on the vehicle's operating economics is illustrated in Figure 2. The data presented compares the operating profit for a vehicle with all Mach 2.2 operation versus vehicles with a mixed Mach number operation of Mach 2.2 overwater and 0.95 overland, or Mach 2.2 overwater and 1.6 overland. These comparisons are made with 10, 20, and 30 percent of the operation flown at the lower Mach number. Using an all Mach 2.2 operation as baseline, at a 30:70 ratio of over land (Mach 1.6) to overwater (Mach 2.2) operation, there is a decrease of 12 percent in operating profit. When the overland portion is flown at Mach 0.95, the reduction in operating profit amounts to 20 percent.

Increase airline dependence on fare surcharge.

The higher operating cost of the mixed mode of operation may force the airlines to impose a fare premium on supersonic travelers. Higher fares will reduce the HSCT's potential market share and fleet size. Figure 3 shows fleet projections based on traffic demands at different levels of fare premium. As fleet requirement declines, less aircraft will be produced, resulting in a higher unit price. A reduced HSCT fleet size may make launching the program financially unattractive to airframe manufacturers.

An increase in the market potential of supersonic operation can be achieved by making progress in the following areas:

ROUTE DIVERSION

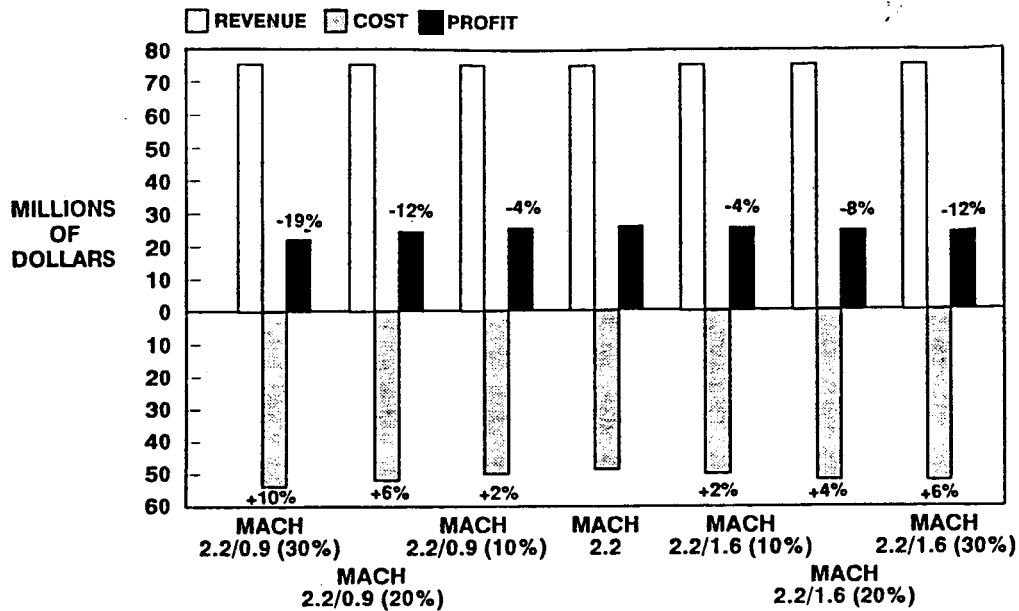
Supersonic restrictions overland and other environmental concerns require changes from current subsonic global air route systems. Supersonic network scenarios were developed to assess the impact of environmental restrictions on the HSCT's market potential and economics. Attention is focussed on reaching an optimum supersonic route structure to facilitate evaluation of different technical, operational, environmental, economic, and marketing scenarios that may ultimately influence the design of the HSCT. Until a satisfactory solution to the sonic boom problem is obtained, supersonic flight overland will be restricted. Modifications to great circle routes are required to find an alternative flight path that eliminates or minimizes overland flight to unpopulated land masses. Candidate supersonic city-pairs were each analyzed for possible diversion to eliminate or reduce overland tracks.

The results of the route diversion analysis show that some of the routes are all overwater, with no diversion required. Others become all overwater through diversion. Still others exhibit various degrees of overland reduction through diversion. However, some are all overland, with no feasible diversion.

These routes are strong candidates for removal from possible HSCT service.

In evaluating flight performance, the ground track profile becomes important. If the overland segments of the route occur at the beginning and end of the flight, performance is

OPERATING PERFORMANCE (REVENUE - COST = PROFIT) MACH 2.2, MACH 2.2/1.6, MACH 2.2/0.9 (PER AIRCRAFT)



PERCENTAGE OF OVERLAND OPERATION

Figure 2

HSCT FLEET PROJECTIONS BASED ON TRAFFIC DEMAND

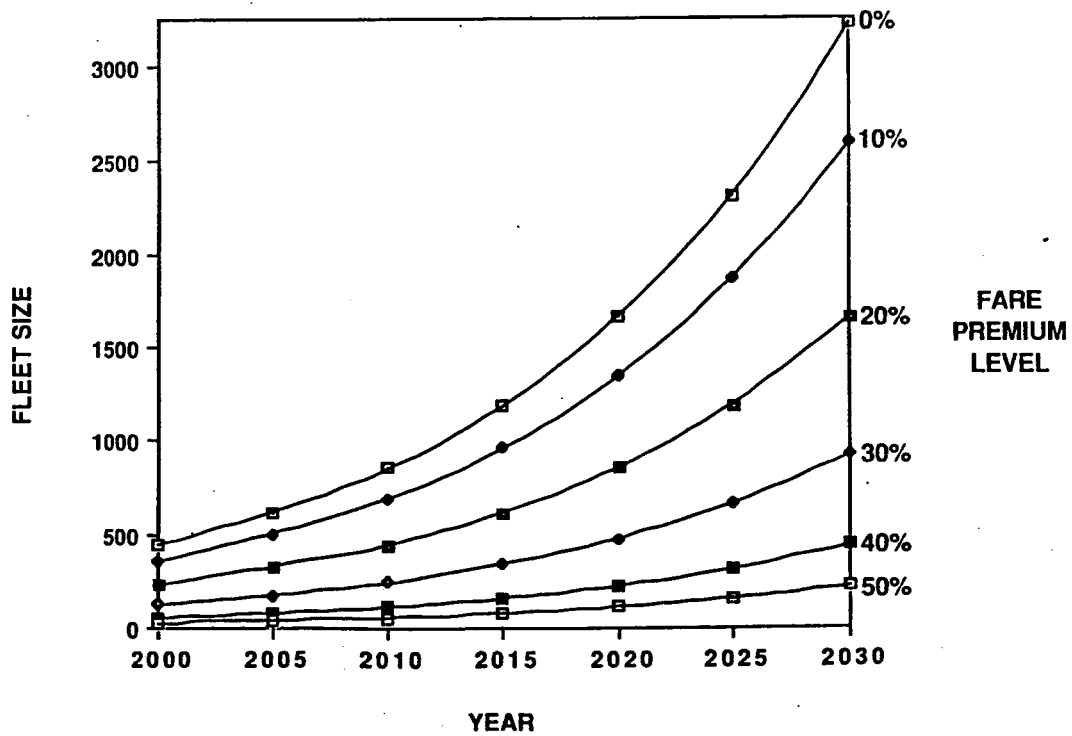


Figure 3

least affected. However, if the overland segments happen to fall anywhere along the track after cruise speed has been reached, there would be additional penalties. The aircraft must fly lower and slower over the land segment, and then climb back up to higher cruise altitude. An example of route diversion and optimization is depicted in Figure 4 for the New York - Tokyo route. The Great Circle Distance between JFK Airport and Narita Airport is 5845 N.Mi., with 88 percent of the ground track overland. By rerouting the flight via Seattle, distance is increased by 693 n miles, and the percentage overland declined from 88 to 35 percent as illustrated in Figure 4A. By diverting the route through the Arctic Ocean, Bering Strait, and North Pacific, the percentage of overland flight was further reduced to 20 percent at a lower cost of 227 extra nautical miles, as shown in Figure 4B.

Few candidate global airline network scenarios for HSCT have been assembled. Creative rerouting was conducted to minimize overland segments and to lessen the impact of the environmental restrictions that may be imposed on future supersonic operation. The data on these network scenarios represents an assembly of global routes from which HSCT global traffic networks can be constructed. The network scenarios provide examples on how supersonic service may bring some changes to the current global route structure. Some of these supersonic network scenarios show good potential for capturing more than half the market share of long-range traffic.

DEDICATED CORRIDORS

Few dedicated corridors were selected for unrestricted supersonic flight between high density traffic regions. Whenever possible, supersonic flight corridors are mostly over unpopulated land or regions with very low population density. The sole purpose for selecting these corridors was to examine the impact on network productivity, with no intention of recommending their use. Figure 5 shows some of the corridors used in the analysis. In general, the introduction of corridors would add some improvement over route diversion. Corridors appear to be more effective where they serve the regional flow from Europe to the Middle and Far East, and less effective between Europe and the Americas. The Asian and Australian tracks provided about 90% reduction in the subsonic operation as compared to 30% reduction achieved by route diversion. Figure 6 illustrates this comparison.

The Europe-Americas tracks provided about 49% reduction in the subsonic operation as compared to 71% reduction achieved by route diversion. Figure 7 illustrates the subsonic reduction between Europe and the Americas.

LOW SONIC BOOM DESIGN

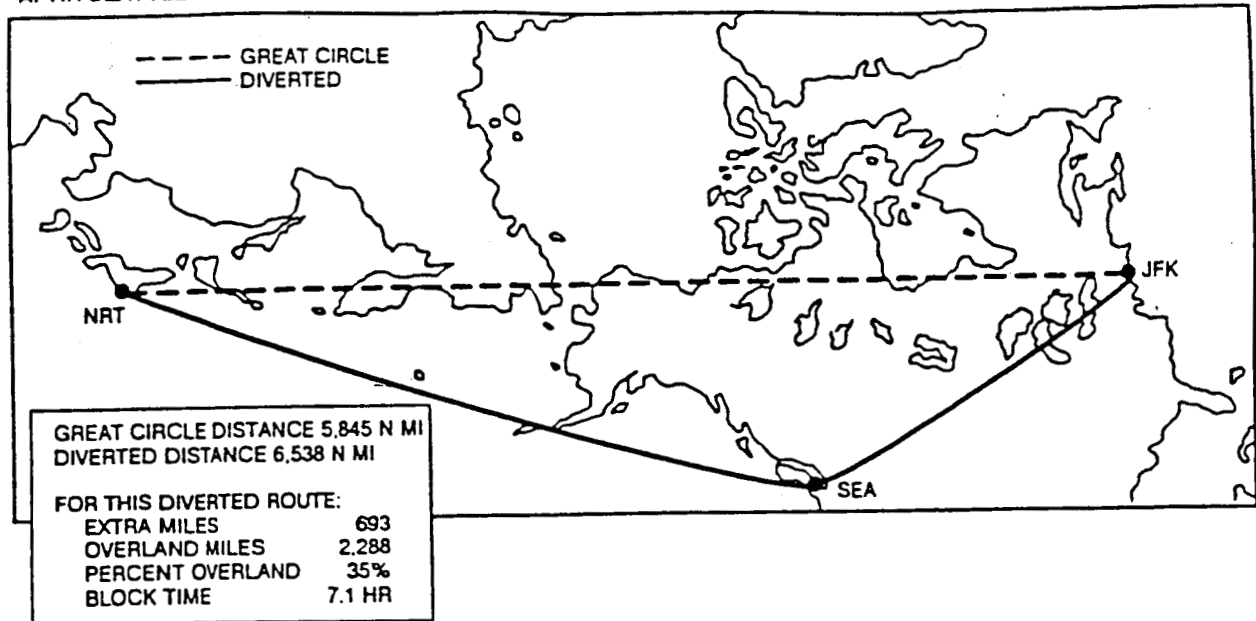
The economic benefits of low sonic boom design can be attributed largely to its ability to capture a much larger market. An aircraft that can fly supersonically overland will be able to operate those high density routes that are mostly overland, such as "coast to coast" routes in North America and the routes between Europe and the Far East. The penetration of additional major traffic markets will impact the fleet requirements, the development and production costs, the operating cost, and the profitability of both the airline and the manufacturer. It will also improve the productivity in terms of Mach speed per block hour.

MARKET CAPTURE

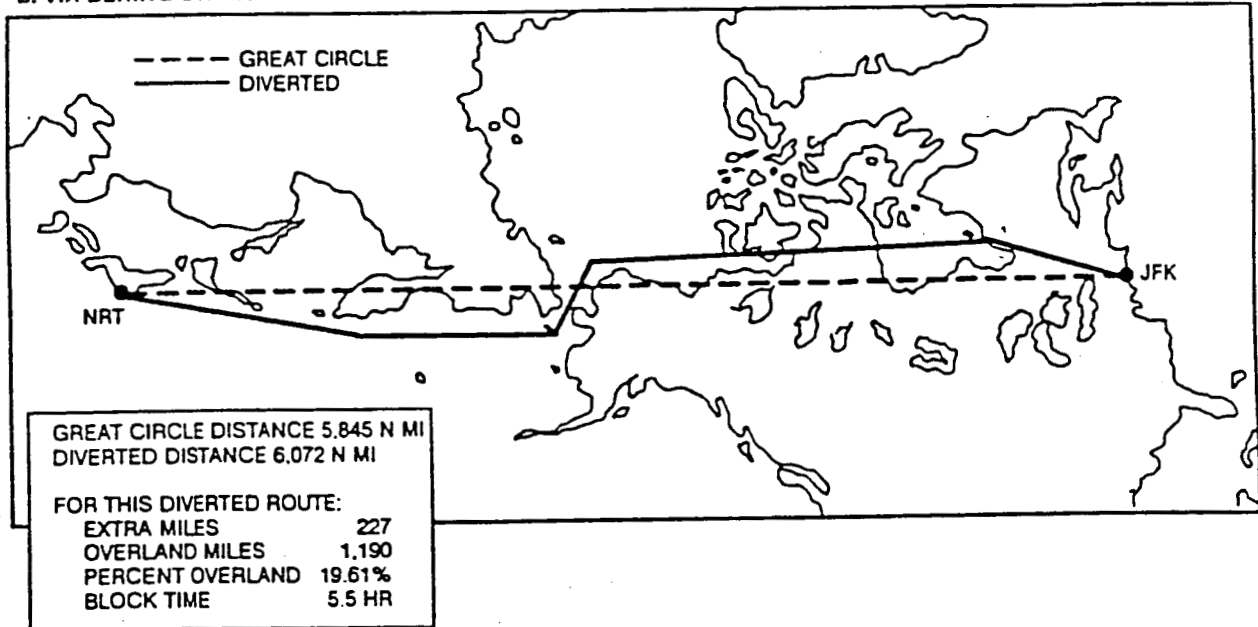
An HSCT with a mixed mode of operation will be operating in a restricted supersonic network. The criteria used for selecting city pairs for the restricted network are as follows:

- Route distance should be over 2,000 N MI.
- Overland portion should not exceed 50% of individual route distance.
- Average overland distance of total restricted network should not exceed 25%.

A. VIA SEATTLE



B. VIA BERING STRAIT



DIVERTED ROUTING — NEW YORK-TOKYO

Figure 4

POSSIBLE SUPERSONIC FLIGHT CORRIDORS

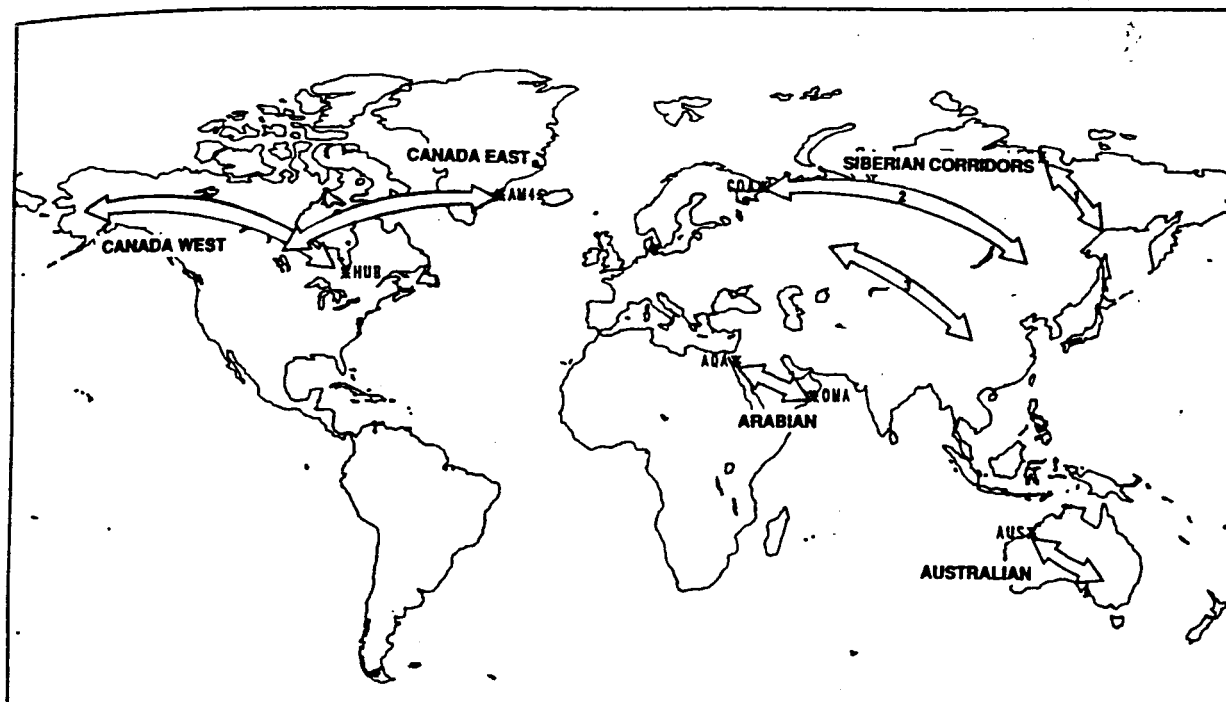


Figure 5

Comparison Asian And Australian Tracks

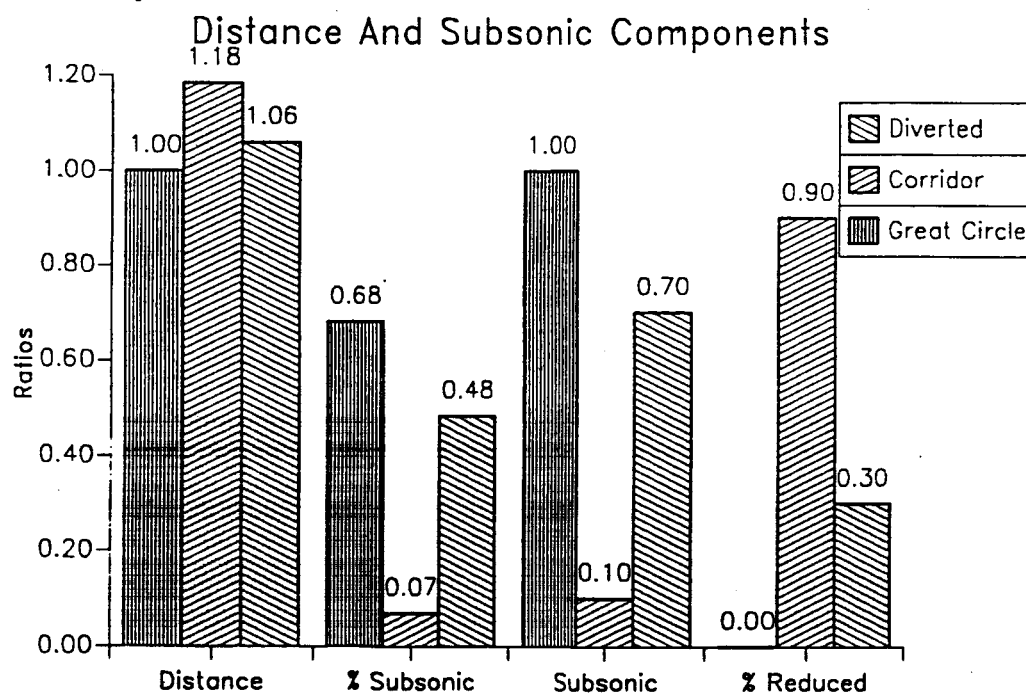


Figure 6

Comparison Europe-Americas Tracks

Distance And Subsonic Components

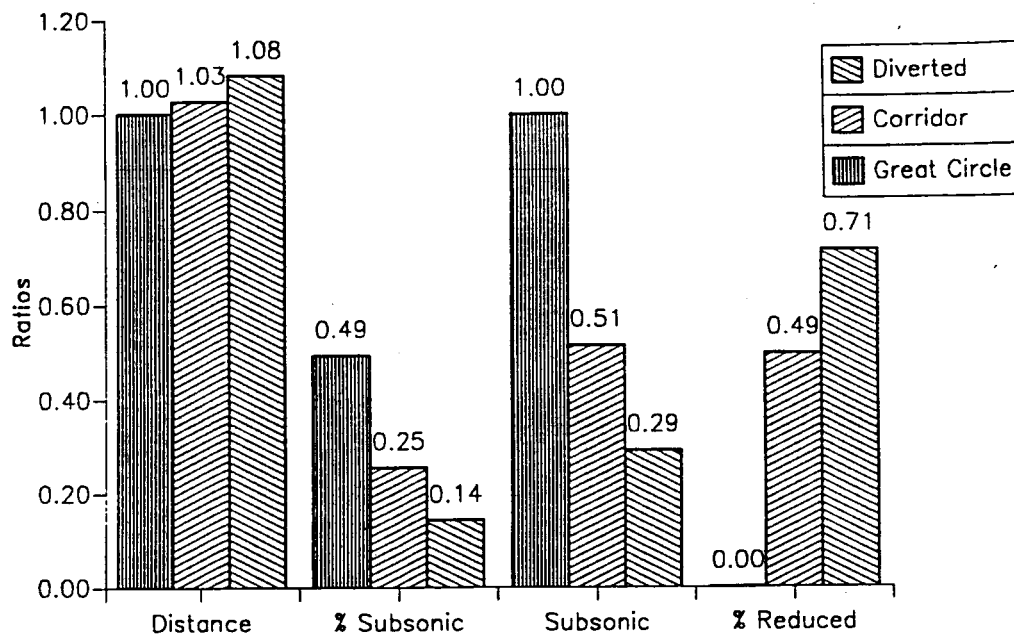


Figure 7

250 City pairs have qualified for membership in the restricted network.

On the other hand, the low sonic boom design will be operating in an unrestricted supersonic network which will include all routes greater than 2,000 N MI, whether they are over water or overland; 918 city pairs have qualified for membership in the unrestricted network. Figure 8 shows the relationship between the restricted and the unrestricted supersonic networks in terms of airport pairs.

Assuming that a mature fleet of HSCT does exist in the year 2005, 975 (Mach 2.2) and 1142 (Mach 1.6) aircraft will be required to serve the 918 city pairs of the unrestricted network.

For the restricted network, the 250 city pairs represent only 40% of the ASM. Therefore, the fleet requirement is estimated to be between 386 for Mach 2.2 / 0.95 and 450 for Mach 1.6/0.95. Figure 9 shows relative ASM for both the restricted and the unrestricted supersonic networks. Figure 10 illustrates the fleet size projection for restricted and unrestricted networks.

HSCT FLYAWAY COSTS

Unit flyaway cost is a function of production quantity. The flyaway cost includes all design and development cost amortized over the production quantity. HSCT will have higher development and production cost because of the advanced technology incorporated in its material, propulsion system, and manufacturing techniques. A large production quantity will enable the manufacturer to recoup its higher development and production costs. It will also reduce the flyaway cost, making the market-based selling price for HSCT very attractive. Figure 11 shows the flyaway cost data as a function of production quantity. Higher fleet size for serving the unrestricted network will take advantage of the lower unit flyaway cost.

DIRECT OPERATING COST (DOC)

The ownership related DOC components such as depreciation for aircraft and spares, interest, and insurance, represent the major items in DOC calculation. The higher the HSCT price, the higher will be the ownership cost. Figure 12 shows the DOC comparison between baseline M2.2/0.95 and low sonic boom M2.2/1.6 design. Due to the smaller fleet size required to serve the restricted network, the production quantity of the M2.2/0.95 is relatively small. The higher price of the baseline aircraft is reflected in .31 percent higher ownership cost. The larger fleet size of the low sonic boom Mach 2.2/1.6 design that is required for serving the unrestricted network has resulted in higher production quantity, lower unit price, and a reduction in ownership cost percentage. Overall reduction in direct operating cost amounts to 19 percent in favor of the low sonic boom Mach 2.2/1.6 design.

HIGHER PRODUCTIVITY MACH PER BLOCK HOUR

The weighted average network block Mach number for the restricted network is much lower for the low sonic boom unrestricted network. This is due to the higher percentage of overland distances flown at subsonic speeds. The unrestricted network is the more efficient supersonic network. Due to its single mode of operation, the unrestricted network shows a higher block to design cruise/speed ratio.

RESTRICTED Vs UNRESTRICTED Supersonic Network

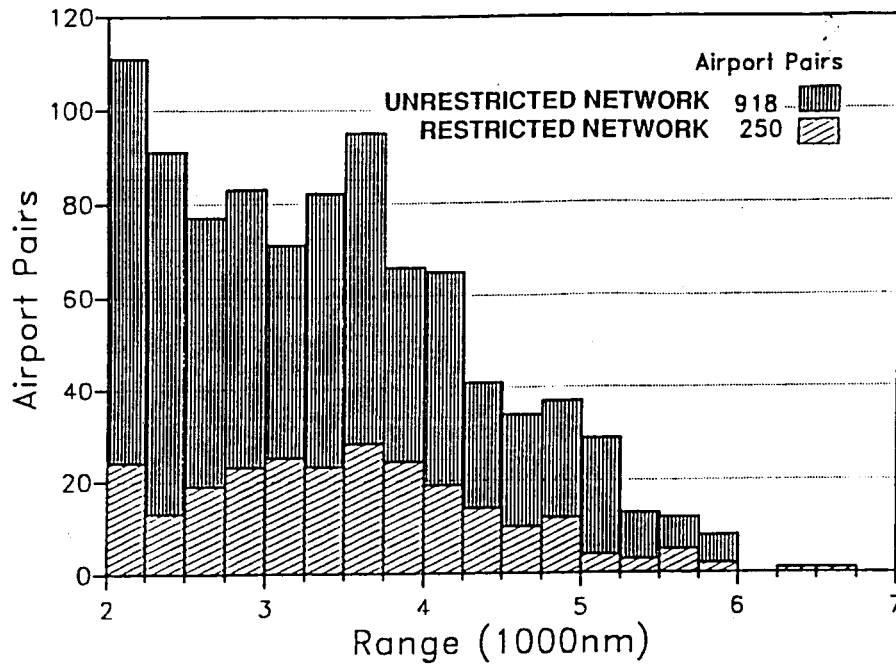


Figure 8

Supersonic Network

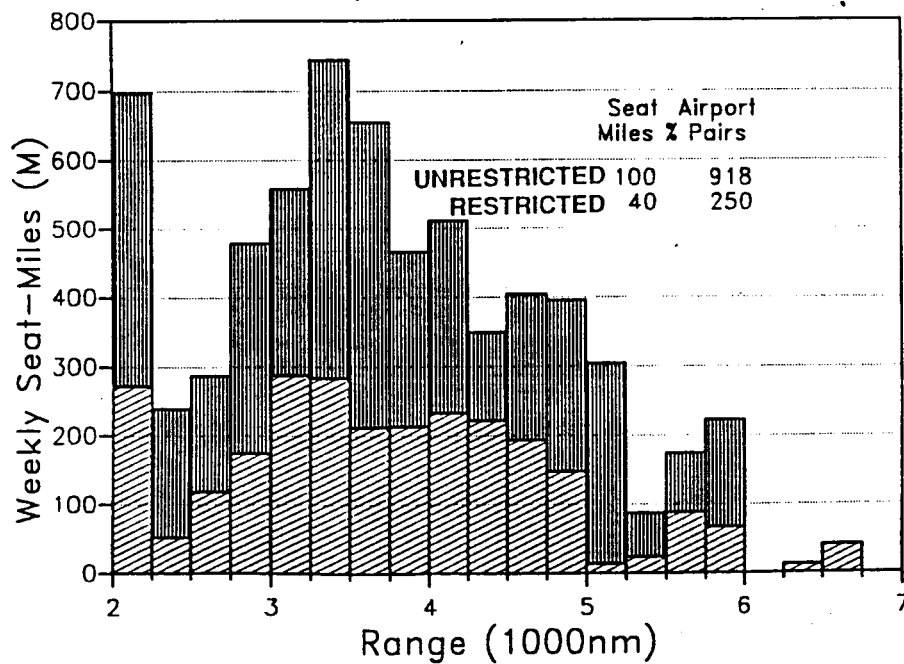


Figure 9

FLEET SIZE PROJECTION FOR RESTRICTED AND UNRESTRICTED NETWORKS

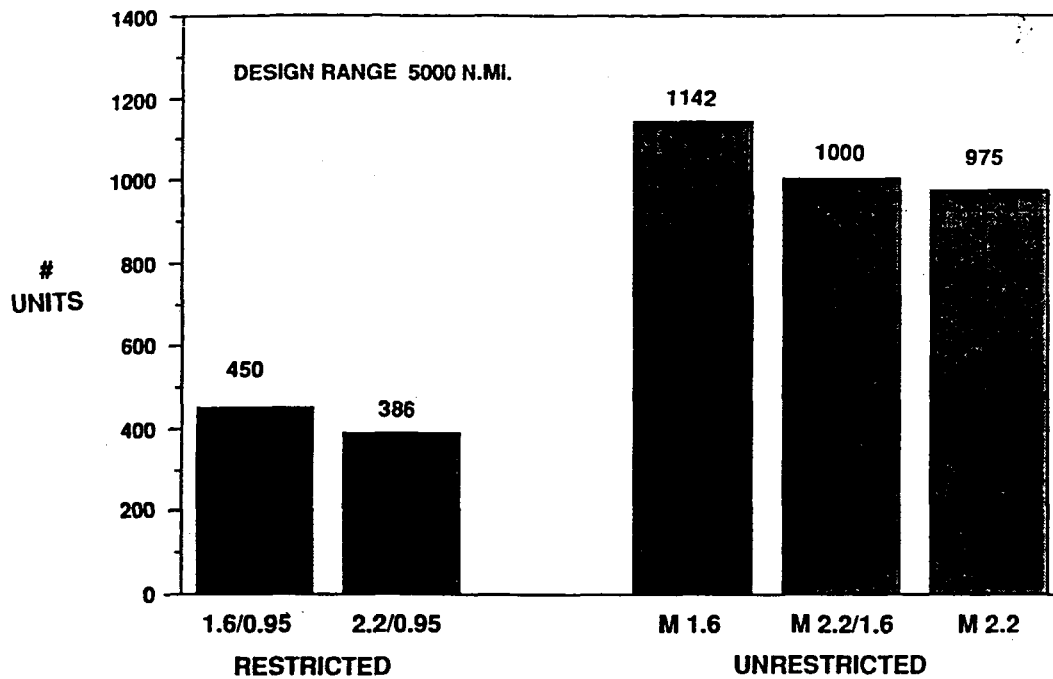


Figure 10

COMPARATIVE HSCT FLYAWAY COSTS Development Costs Included Cum Average Basis, 1990 Dollars

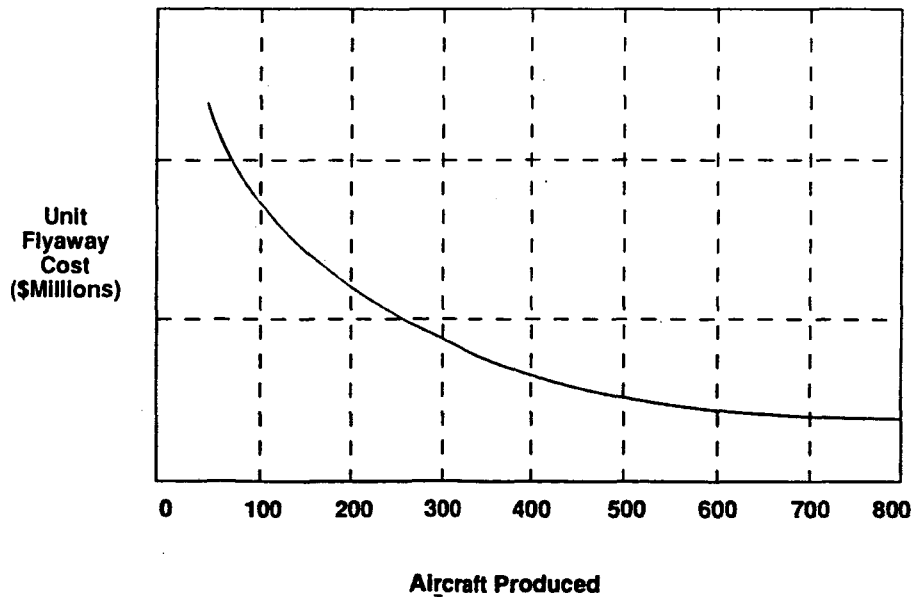


Figure 11

DOC COMPARISON (4000N.M. TRIP)

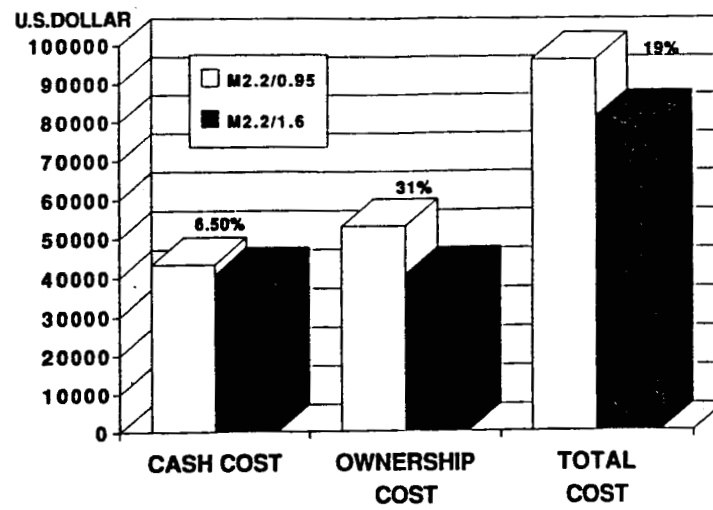


Figure 12

AIRLINE PROFITABILITY

Any reduction in operating cost is commensurate with higher profit to the airline. Airlines may elect to reduce or eliminate fare premium, thus improving the overall commercial viability of the HSCT program.

CONCLUSION

Low boom design is a high risk challenge with very rewarding payoffs. Eliminating the sonic boom problem will be difficult. However, any breakthrough will improve the efficiency of the supersonic operation and enhance the market potential for the HSCT. A reasonable reduction in sonic boom may not be good enough for completely unrestricted operation, but it can be adequate for corridor operation. In general, full supersonic operation is highly attractive to all concerned. It provides better economics for the airlines, the passengers, and the manufacturers. It is readily apparent that there are substantial economic and marketing benefits in full supersonic operation, hence the importance of achieving a low-sonic-boom configuration.