

WHAT GROSS WEIGHT AND RANGE FOR AN ADVANCED HSCT?

Cornelius Driver
Eagle Engineering, Inc.
Hampton, VA

Abstract

A review of studies conducted in 1986 indicates that a 300 passenger, 5500 nautical mile range aircraft should weigh less than 400,000 pounds. Some data from a British Aerospace SAE paper will be shown that purports to be an advanced Concorde that meets the range payload specifications at a gross weight of 360,000 pounds. Previous studies by Peter Coen of Langley Research Center support these results.

The weight of a supersonic transport is important from the point of view of how much effort should be expended in developing lower sonic boom technologies. It is obvious that a 360,000 pound aircraft can be modified to a more acceptable boom level than a 700,000 pound one.

INTRODUCTION

The HSCT System Studies have confirmed a 30 to 40 percent increase in market penetration of an HSCT that can fly overland compared to one that cannot. This market size factor, like the selection of the proper range-payload and Mach number, deserves all the attention that can be generated for the vehicle to be a success. A review of the HSCT work reported over the past 5 years would suggest that inadequate resources may have contributed to the lack of use of the most advanced technologies. While this perspective may seem harsh, it is difficult to rationalize the configuration gross weights now being shown.

From a sonic boom perspective, a 700 or 800 thousand pound vehicle will be most difficult to modify in such a way as to make its overpressure level low enough to raise the possibility of being acceptable. In fact, the magnitude of this perceived problem may lead to reduced sonic boom research and concentration on over water configurations only. This course could turn out to be disastrous if it turns out to be incorrect.

The question is are there combinations of payload, range, and technology levels that could provide the capability to carry 250 passengers 5500 nautical miles for gross weights of about 360,000 pounds (about half the present study configuration weights). There should be no question that altering a 360,000 pound configuration to attain a specified low boom level is an

easier task than trying to achieve that level with a starting point of 700 or 800 thousand pounds. Fortunately, there are two advanced Concorde studies (Refs. 1 and 2) that support that a 360,000 pound vehicle may be able to carry 250 passengers 5500 nautical miles.

DISCUSSION

The results of several past studies and an array of technology improvements support the contention that present day systems studies should yield lighter weight supersonic cruise transports.

Let us start then with a review of the dollars spent in support of supersonic technologies in the United States (see fig. 1). First, a considerable amount of effort has already been paid for and should be used to the fullest extent. The SCR Program shown spent approximately 130 million dollars over 8 years at an average cost of about \$30,000/man-year; today, three times that amount would have to be spent to generate the man hours expended in that program. It is apparent to me that a lot more resources are required to generate a reasonable level of effort in the supersonic technology area. A major portion of the SCR funds were spent on noise reduction, advanced propulsion, titanium sandwich construction, and sonic boom. Substantial advances were made in each of these areas and should be showing up in the study configurations in terms of reduced takeoff gross weight.

Another primary source of weight reductions is in the advanced subsonic aircraft shown on figure 2. All of these aircraft have technologies not in use when the previous SST Program ended or even when the SCR Program ended in 1980. Technologies, such as the two-man cockpit, advanced engines running at temperatures of 2600°F, carbon brakes, light weight seats and galley, the application of composites in tails and floor beams - each of these technologies have twice the gross weight reduction payoff on an SST compared to a subsonic aircraft. Have we incorporated all the weight reduction items presently in use in the subsonic aircraft in the HSCT study aircraft?

I submit that the competitor to an advanced HSCT are these two-engine, long-range subsonic airplanes that leave from any local airport and fly directly where I wish to go. If I have to fly subsonic to an airport to catch an HSCT flight, then I have forfeited a larger portion of my trip time savings before the SST flight even begins.

Since two studies have been performed applying advanced technology to the Concorde, let us begin with those studies (refs. 1 and 2). The present Concorde in commercial service was designed and prototyped in the 1960's and entered commercial series in 1976. Since it has completed over 50,000 flight cycles in commercial service at $M = 2.05$ it provides a credible base or reference point (see fig. 3).

If the Olympus engine on the Concorde was redesigned today, it would weigh nearly half as much as the original engine and have 1/2 the number of compressor stages and 1/2 the part count (see fig. 4). It would be about 1000 °F hotter and have at least a 15 percent lower SFC.

Most of these advances, including digital fuel controls are flying on advanced commercial and military engines today. Coen's analysis (ref. 1) showed that similar technology improvements would reduce the gross weight 150,000 pounds if the range were held constant or the range would increase 1800 nautical miles if the gross weight were held constant. This result was obtained using the original Concorde weights and aerodynamics.

Coen's paper also examined the payoff of advanced aerodynamic features such as planform, thickness, camber and twist, and paying attention to area rule principles in the layout of the configuration. His results were almost as dramatic as the payoffs in propulsion; at a constant range the gross weight was reduced to 280,000 pounds; at constant gross weight the range was increased 1200 nautical miles (see fig. 5).

The recent British aerospace study reported in reference 2 shows a second generation Concorde with many of the features described by Coen in his study done in 1986. The advanced Concorde is a tailless configuration and utilizes fuel transfer for cg control as in the original design. (It uses a small canard to trim the trailing edge flap down configurations for landing and/or takeoff.) Note that it is designed to carry 280 passengers (see fig. 6).

Note that the bars are labeled "Today's" technology, assumed for baseline aircraft, and required for viable aircraft (see fig. 7). Note, also, that they do not mention the engine weight reduction, only the SFC reduction. Finally, note that the Coen study showed larger L/D gains and today's structural weight reduction levels. This figure indicates that most of the necessary technical progress required to provide a viable configuration is already in hand. Only a small further technology increment is required and that may be partially made up by the "extra" aerodynamics available.

The message from figure 8 is that most of the technology required for an advanced SST is already in hand. The figure indicates what is needed is about 1000 miles range at a constant gross weight. From Coen's study, several answers are available. For instance, the L/D improvement of 20 percent shown in the previous chart is only 8.74, 30 percent is 9.49, and 40 percent is 10.22. Certainly 9.5 at Mach 2.05 is feasible today. While the Olympus was, and is, a great supersonic engine, it is still a 25 year old design derived from a predecessor designed in the 1950's. Digital controls and variable bypass offer the promise of at least the 10.22 percent sfc improvement desired.

When Coen (ref. 1) applied all the advances at once, he showed a gross weight of 304,000 pounds to carry 200 passengers 5500 miles. The British Aerospace study indicated 363,000 for 280 passengers 5500 miles (see fig. 9). An advanced Concorde then offers a reasonable way to apply the new technology to an advanced configuration. Certainly we should be working on a sonic boom problem based on a 360,000 pound gross weight not 700,000 to 800,000. Since Δp overpressure is approximately proportional to the \sqrt{w} this reduction in gross weight would reduce the boom by more than 40 percent. The boom reduction available by flying above 60,000 feet instead of about 50,000 feet results in another 40 percent reduction in boom level. Design restrictions, such as NO_x reduction criteria that requires reduced altitude and Mach number

should be fully understood before they commit the country to a false course. In the competitive situation, no risk is greater than pushing a lower Mach number than the competitor.

SUMMARY

- It is probably appropriate that an advanced Concorde be utilized as a reference configuration between the Government and the contractors.
- Attaining a meaningful sonic boom overpressure reduction is tough enough without starting with takeoff gross weights that may be twice as heavy as required to perform the mission.
- Credible data exists that indicates that 250 passengers can be carried 5500 nautical miles with takeoff gross weights of about 360,000 pounds.
- Artificial restraints of altitude or Mach number only make the design decision tougher and may inadvertently lead to the wrong conclusions.

REFERENCES

1. Coen, P. G.: The Effect of Advanced Technology on the Second-Generation SST. NASA Langley Research Center, AIAA/AHS/ASEE Aircraft Systems, Design and Technology Meeting, Dayton, Ohio, 1986.
2. Liddell, Peter W.: Prospects for a Second Generation Supersonic Transport. Presented at the SAE Aerotech 1991 Aerospace Technology Conference and Exposition, September 23-26, 1991, Long Beach, California.

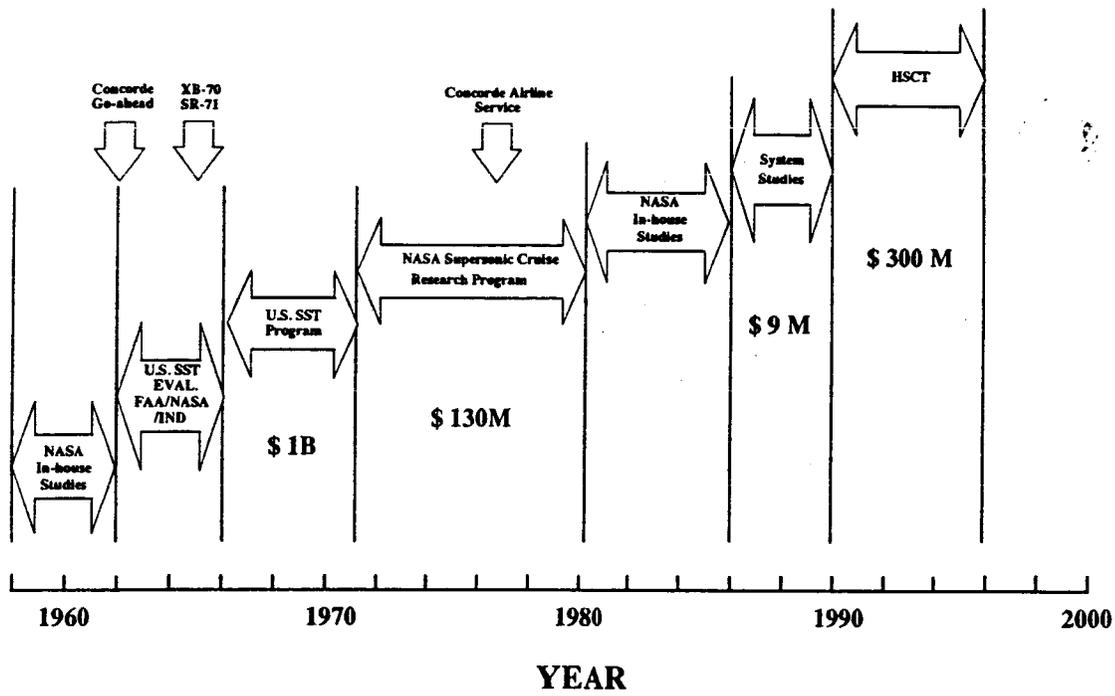


Figure 1. Funding history.

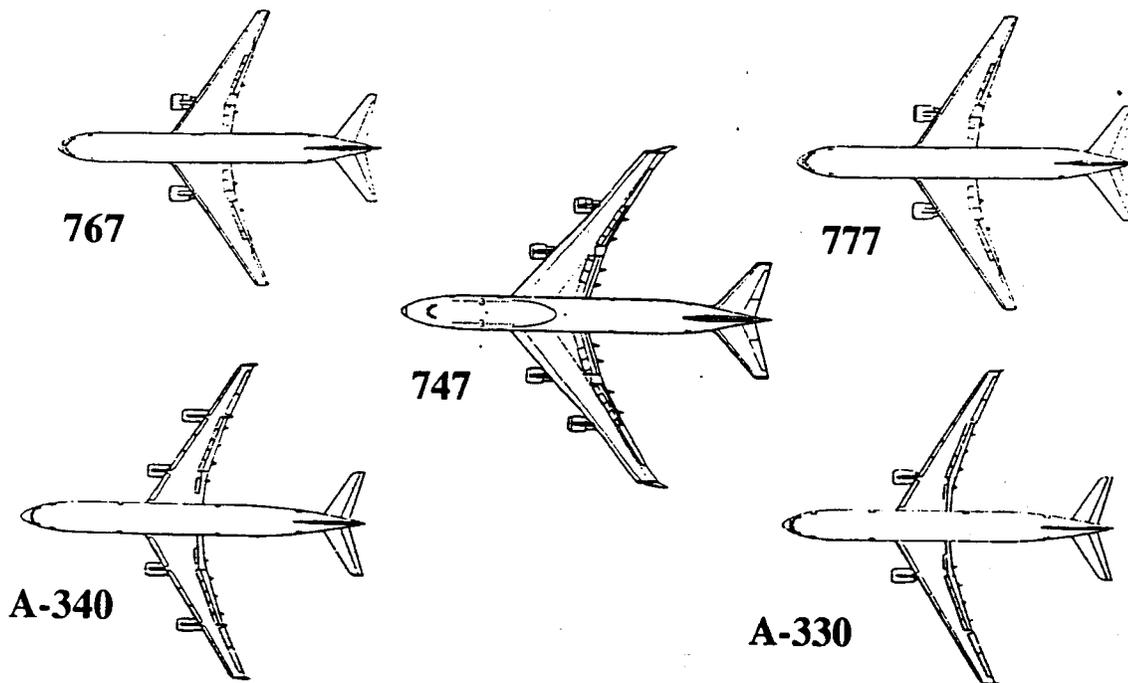
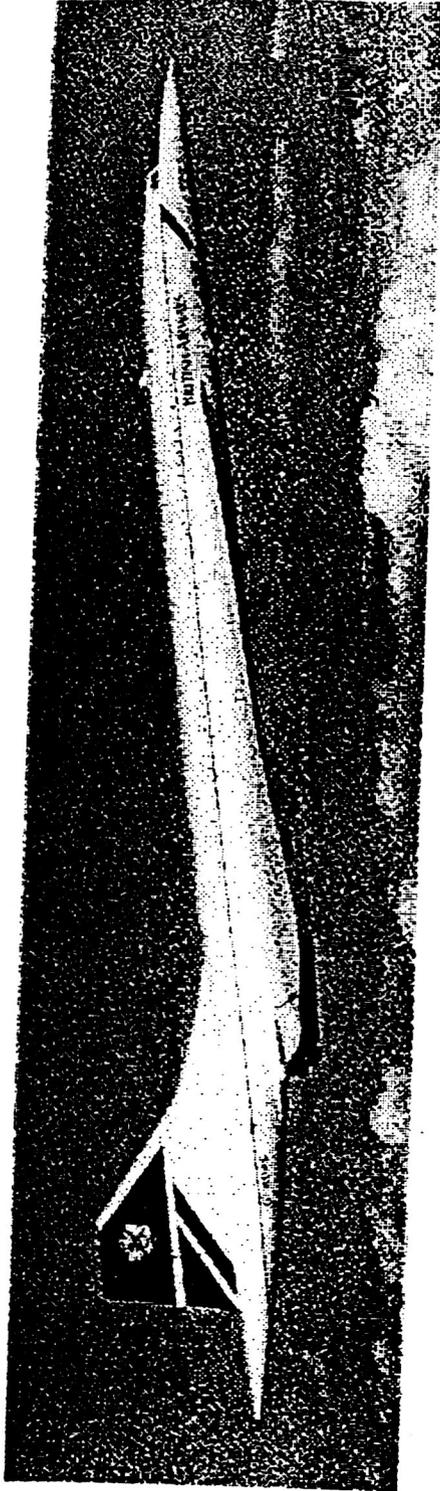
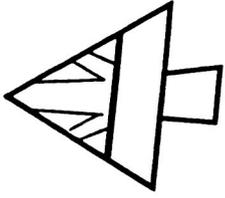


Figure 2. Subsonic aircraft competitors.

Concorde SST



Range 3500 n.m.

T.O.W. 185 Tonnes

Passengers 100 first class

Cruise at $M = 2$

$L/D = 7.3$

s.f.c = 1.2 (installed)

Figure 3. The precursor - Concorde SST.



1971

NOW

3386 kg.	Weight	~ 1814 kg.
15.5	OPR	20+
1350°K	TIT	1811 - 1922°K
14	No. Compressor	6
	Stages	
0.41	h_0	0.5 - 0.55
0.12	SFC	~ 0.10
	Part Count	~ 1/2 of Concorde's
		Olympus Engines

Figure 4. SST propulsion potential.

(Original figure not available at time of publication.)

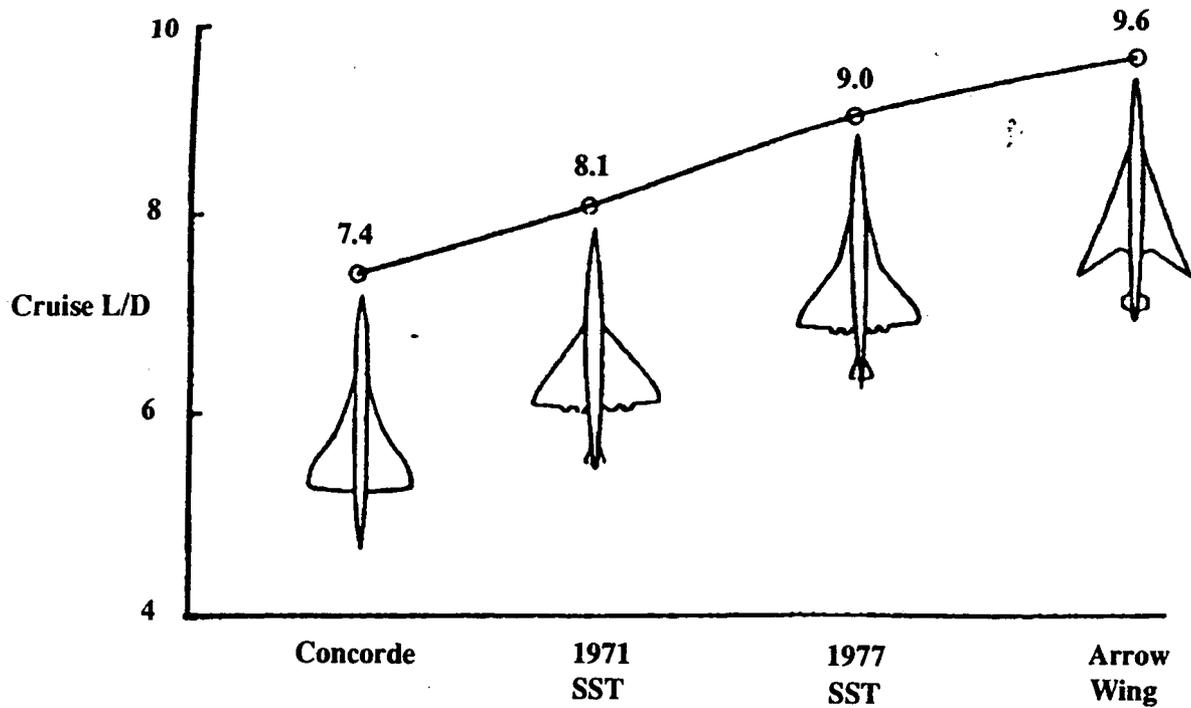


Figure 5. Effect of aerodynamic improvements on lift/drag ratio.

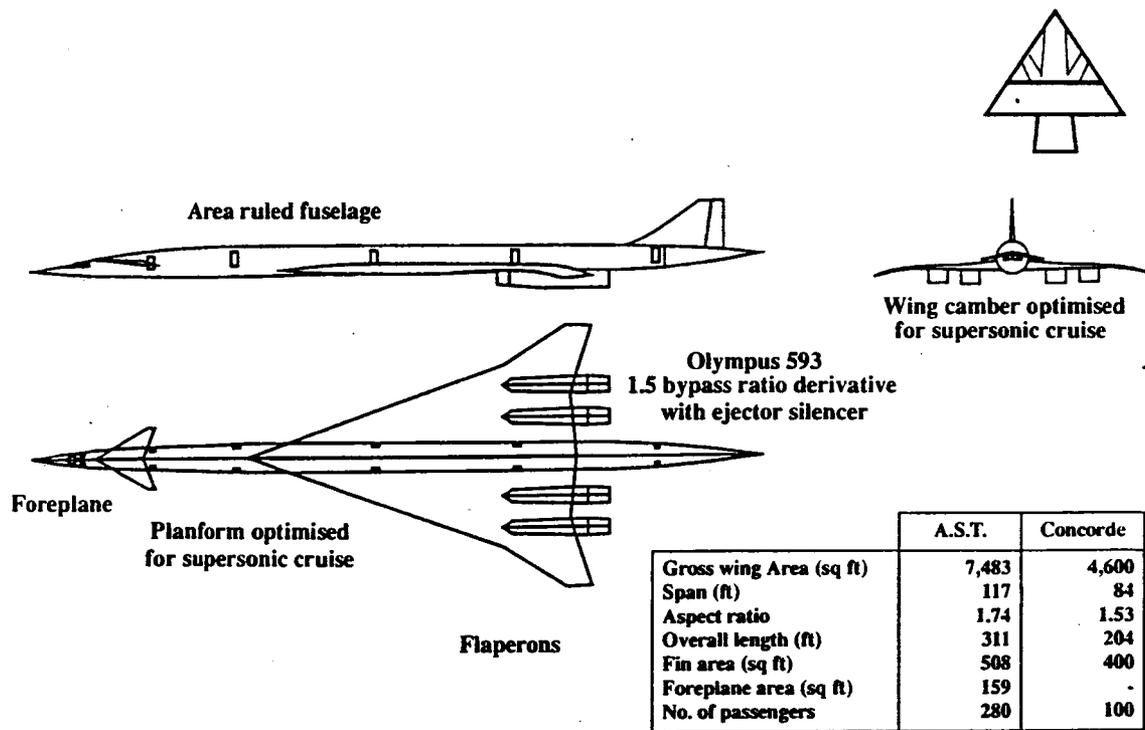


Figure 6. - Advanced supersonic transport study - datum aircraft.

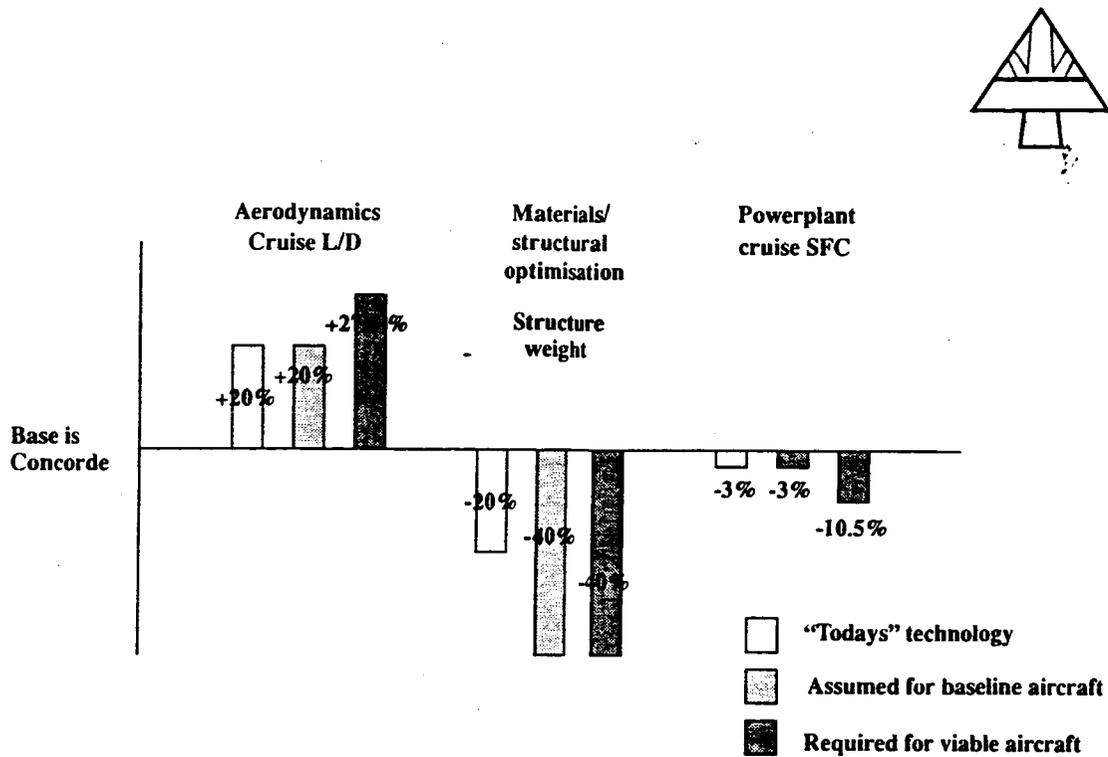


Figure 7. Advanced supersonic transport study technology standards relative to Concorde.

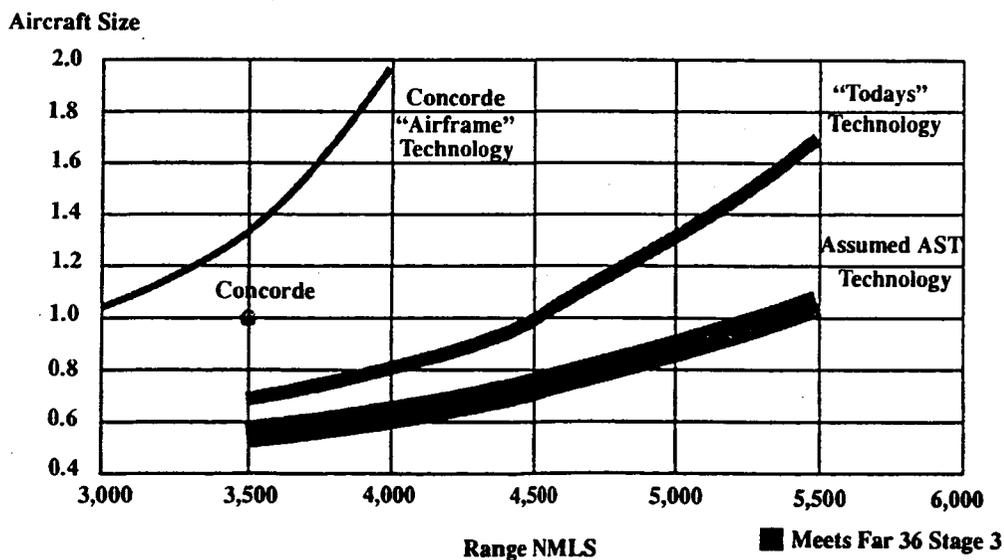


Figure 8. Advanced supersonic transport study-feasibility of achieving AST technology standards.

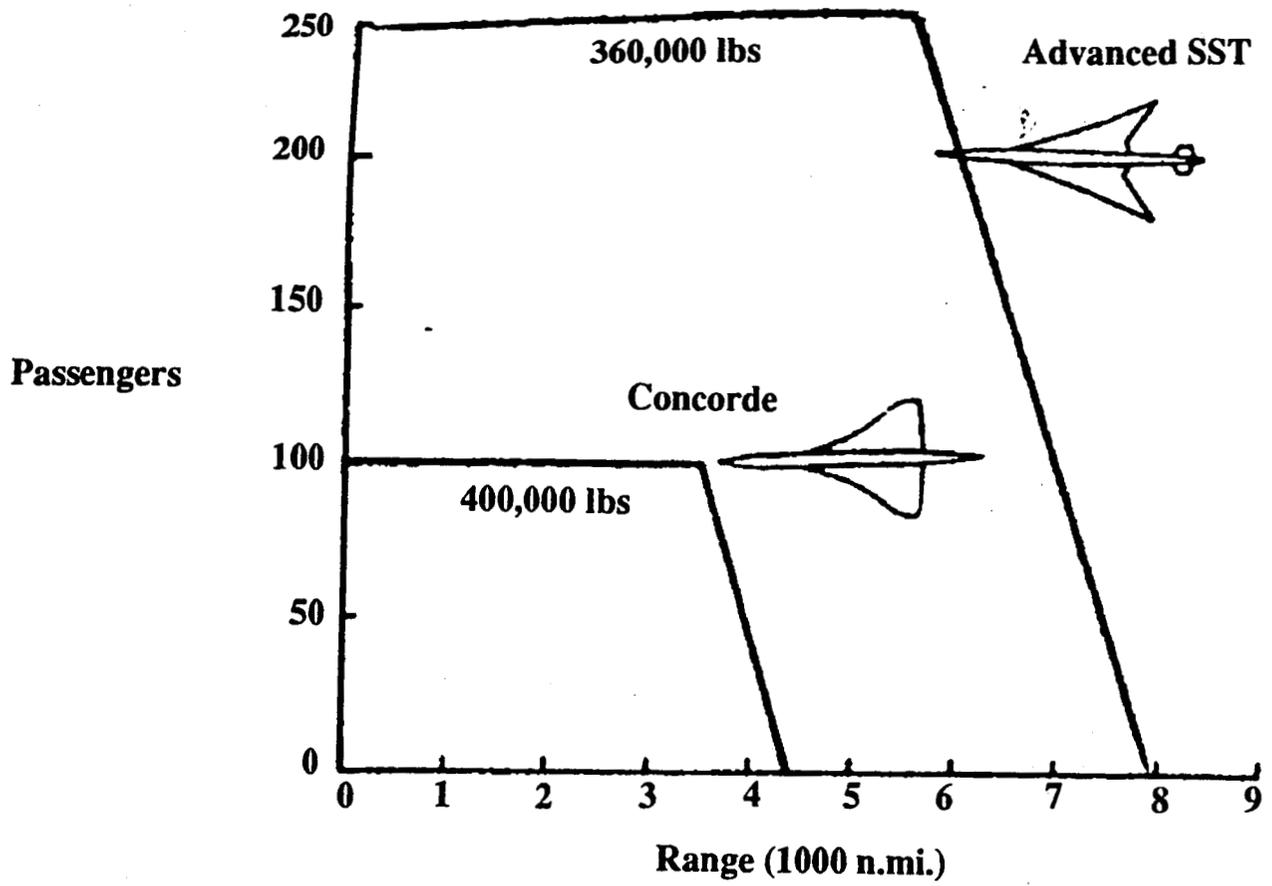


Figure 9. Range-payload curve for advanced two-engine SST.