PROSPECTS FOR FUTURE LONG-RANGE AIRCRAFT: FIVE SCENARIOS

Historically, the United States has been the leading producer of commercial aircraft in the free world. The U.S. civil aviation industry (manufacturers and airlines) has dominated the free-world aircraft market for the past 40 years. The industry presently provides more than 80 percent of the free-world's transport aircraft. Although the United States has a competitive advantage in the development and production of commercial jet aircraft, this advantage is now being challenged by Western Europe, where consortia, with strong financial backing from governments, are developing advanced aircraft.

Foreign competition is an extremely important issue for national economics and international trade. For example, the dollar value of all commercial jet aircraft and engines produced and sold in the world to date (excluding the U.S.S.R. and the People's Republic of China) has been about **$50** billion. Of this, the U.S. aircraft manufacturers' share has been about $45 billion, or **90** percent. Approximately one-third of this share has consisted of exports, contributing positively to the U.S. balance of trade. In 1977, exports of aircraft and aircraft parts accounted for a net of $7 billion in the U.S. balance of trade.[1] Figure 11, which compares aircraft with other export commodities in 1977, shows this graphically. Over the next 20 to 30 years, the potential sales of long-range aircraft and parts could amount to $150 billion, depending on the market, of which about half could be exports if U.S. firms continue to capture a predominant market share.[2] Exports amounting to as much as $50 billion to $75 billion would contribute substantially to a favorable balance of payments and would partially counteract the negative impact of petroleum imports. The choice to develop or not to develop an advanced transport with a potential payoff as indicated above involves stakes that are quite high.

Assuming that there will be this potentially very remunerative market, the question comes down to what country or countries, if any, will attempt to exploit it and how any country would do so, developing what kind of aircraft on what kind of a time schedule. This study looked at various answers to these questions and attempted to evaluate the risks and advantages associated with several plausible routes by which advanced high-speed aircraft might enter the worldwide commercial aviation market. As already indicated, the key variables in projecting these possibilities for the aircraft future are who will take the lead in developing a supersonic transport; whether development will proceed under noncompetitive, competitive, or cooperative conditions; how sophisticated an aircraft will be developed; and how the development program and introduction into commercial service will be timed.

Five plausible futures or scenarios are described in greater detail below. In brief, they are: a base case in which no advanced supersonic transport (AST) is developed by either a U.S. or foreign manufacturer and the world commercial fleet continues to consist virtually entirely of subsonic craft; scenario 1 in which an AST is developed by the United States without foreign competition; scenario 2 in which an AST is developed by foreign manufacturers without U.S. competition; scenario 3 in which both U.S. and foreign manufacturers develop ASTs in competition with each other; and scenario 4 in which a consortium of U.S. and foreign manufacturers undertake joint development of an AST.

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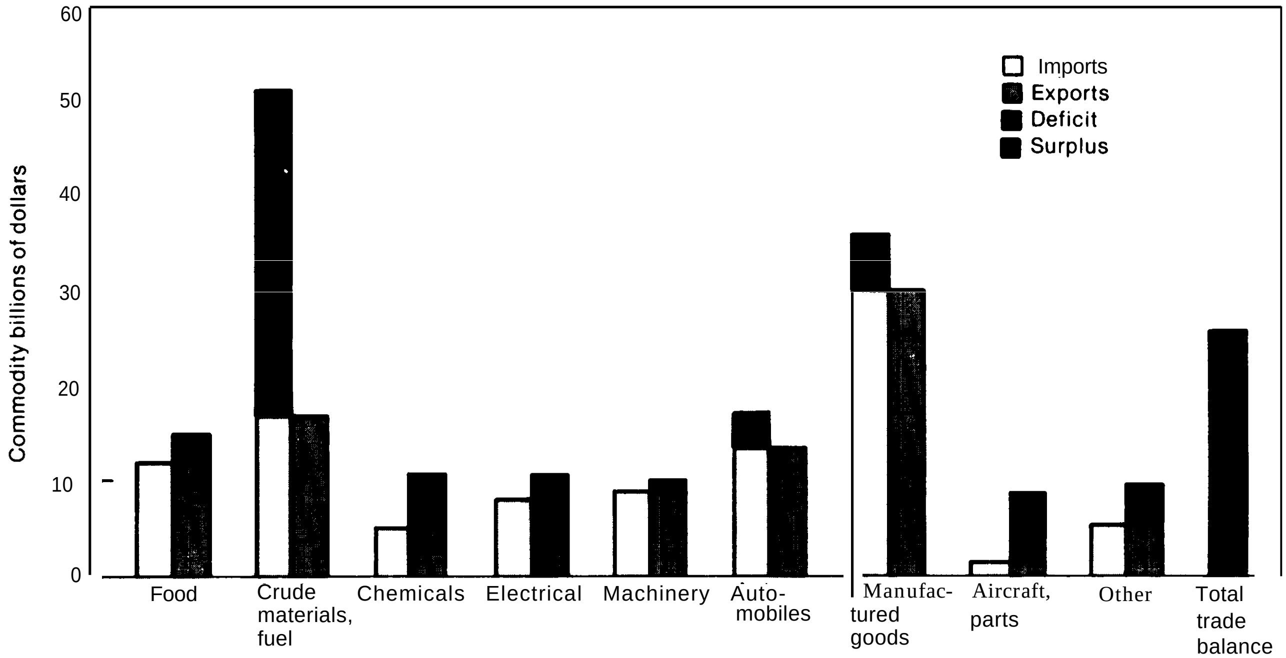
[1] American Institute of Aeronautics and Astronautics, *Astronautics and Aeronautics,* vol. 15, No. 9, September 1978.

[2] OTA Working Paper, Working Group A, "Advanced Hi@-Speed Aircraft, " Douglas Aircraft Co., Task 5, January 1979.

Figure 11.–Commodity Input to U.S. Balance of Trade–1977



SOURCE: F. E. McLean, OTA Working Paper, "Advanced High Speed Aircraft."

PROJECTED FLEET SIZE

To assess the impact of the AST for each scenario, it was necessary to estimate the size of the subsonic and supersonic aircraft fleet in the period from 1980 to 2010.

In 1978, the world passenger jet fleet included about 4,700 aircraft, ranging from small two-engine standard-body aircraft (e.g., B-737, DC-9) to large three- or four-engine, widebody aircraft (e.g., B-747, DC-10, L-1011). With regard to future aircraft requirements, there have been several recent forecasts of fleet size for various years in the period covered in this study.[3-12] The forecasts range from 7,000 to **12,000** aircraft, depending on the assumed growth rate for air travel and the assumed mix of aircraft types and sizes. The estimated world fleet size used in this study to examine the impact of an AST is based on a review of these studies and on working papers prepared by industry participants in Working Group A.[13-15]

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[3]"Studies of the Impact of Advanced Technologies Applied to Supersonic Transport Aircraft," NASA contract No. 11938, Boeing Commercial Airplane Co., April 1973.

[4]"Aviation Futures to the Year 2000," Federal Aviation Administration, February 1977.

[5]R. D. Fitzsimmons, "Market Trends," McDonnell Douglas Corp., November 1976.

[6]E. Q. Bond, E. A. Carroll, and R. A. Flume, "Study of the Impact of Cruise Speed on Scheduling and Productivity of Commercial Transport Aircraft," NASA report No. CR-145189, April 1977.

[7]E. Q. Bond, B. R. Wright, E. A. Carroll, and R. A. Flume, "Impact of Cruise Speed on Productivity of SST's," Jan. 15, 1979.

[8]R. D. Fitzsimmons, "Testing the Market," McDonnell Douglas Corp., August 1974.

[9]A. Dubin, "Supersonic Transport Market Demonstration Model," presented at the AIAA Conference on Air Transportation: Technical Perspectives and Forecasts, Los Angeles, Calif., August 1978.

[10]"Dimensions of Airline Growth," Boeing Commercial Airplane Co., March 1978.

[11]G. G. Kayten, "A View of the Future—Constraints and Opportunities," National Aeronautics and Space Administration, August 1977.

[12]"Potential for Advanced Air Transport —Preliminary Economic and Market Analysis," Working Paper for Impact of Advanced Air Transport Technology Assessment, deButts Associates, Nov. 15, 1978.

[13]OTA working paper, Working Group A, "Advanced High-Speed Aircraft," Boeing Commercial Airplane Co., January 1979.

[14]OTA Working Paper, Working Group A, "Advanced High-Speed Aircraft," Lockheed California Co., January 1979.

[15]OTA Working Paper, Working Group A, "Advanced High-Speed Aircraft," Douglas Aircraft Co., January 1979.

Using the estimate that approximately 8,000 to 9,000 subsonic commercial jet aircraft would be needed to satisfy demand in the period 1980 to 2010, approximately one-fourth of these aircraft (2,000 to 2,200) would then be required to satisfy the long-range travel demand; the remainder would serve the medium- and short-haul markets.

If an AST were introduced, U.S. restrictions on sonic booms would allow it to compete with subsonic aircraft only on long-distance over water routes. On the basis of stage lengths and city pairs appropriate to the AST and assuming that no additional travel would be induced by its introduction, * a market for as many as 300 to 500 ASTs in the world commercial fleet by the year 2010 has been predicted. In examining the impact of the AST below, a round value of 400 ASTs was used.

The AST, because of its speed, would be approximately twice as productive as a subsonic aircraft of equivalent size. Thus, the introduction of 400 ASTs would eliminate the need for 800 to 850 subsonics and advanced subsonics of comparable capacity on long-distance over water routes. Table 4 shows one possible detailed estimate of fleet size and composition by the year 2010, with and without ASTs: ASTs could replace 850 subsonic aircraft, reducing the total subsonic aircraft fleet to about 7,250.

In the scenarios which follow and in the analyses in later chapters, fleet estimates are limited to the portion of the market for which ASTs might compete with subsonics. Thus, the overshadowing effects of short- and medium-haul subsonic aircraft are removed from the analysis and attention is focused sharply on the central question: the impact of the U.S. or foreign manufacturers introducing ASTs into the world fleet during the next 30 years.

*In fact, some travel may be created by the higher speed service of an AST. However, to simplify the analysis, all such induced travel was excluded. The estimated impacts of the AST are, therefore, limited to those that would result from the single substitution of supersonic for subsonic aircraft.

Table 4.—Free-World Commercial Jet Fleet With and Without ASTs—Year 2010

Aircraft type[a]	Passenger seats	World fleet		Number of subsonic aircraft replaced by AST
		Without AST	With AST	
Short and medium haul				
2S	100	150	150	—
3S	130	700	700	—
2S	160	1,200	1,200	—
2W,	200	2,000	2,000	—
3W	250	1,550	1,550	—
3W	290	400	400	—
Long haul				
3W	200 LR[b]	150	100	50
3W	250 LR	400	200	200
4W	420 LR	750	350	400
4W ... ,	530 LR	500	400	100
4W ,	600 LR	300	200	100
4AST	330	—	400	—
Totals		8,100	7,250 subsonic 400 supersonic	850

[a]Aircraft are classified by the number of engines (2, 3, or 4) and by body (S= standard, W = wide); AST = advanced supersonic transport.
bLR = seating configuration for long-range flights

SOURCE: OTA Working Paper, Boeing Commercial Airplane Co., Jan 22, 1979.

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TYPES OF AIRCRAFT

Constructing the scenarios required a projection of types of aircraft that might be in service from 1980 to 2010. Four possible types were used in the scenarios—one advanced subsonic transport (ASUBT) and three ASTs. Table 5 lists the characteristics of the possible types. The supersonic aircraft are designated AST-I, AST-11, and AST-III in order of their sophistication in technology and performance. However, the designations are not to be regarded as successive generations of supersonic transports. It is assumed that U.S. or foreign manufacturers will each develop at least one model of supersonic aircraft during the period considered in this study, if either develops a supersonic at all. It should also be realized that, as indicated in chapter II, the real choice comes down to a **200-** passenger, Mach-2 aluminum aircraft with a better design than the Concorde (along the lines of the AST-I in the scenarios) or a **200-** to **450-** passenger advanced titanium aircraft to fly at Mach **2.4** or faster (like the AST-III of the scenarios).

In fuel economy and noise characteristics, the ASUBT aircraft are expected to be more advanced than the generation of subsonic aircraft (such as the B-757 and **B-767)** scheduled for introduction by the mid-1980's. The model ASUBTs, used for analysis in the scenarios, would have a range of **3,600** to 5,500 nautical miles and a payload of from 400 to 800 passengers. The ASUBT family could make its first appearance by the late 1980's or early 1990's and, if so, reach full deployment in the world fleet by about 2005.

The three model versions of supersonic aircraft considered in the scenarios vary in speed, range, payload, structural material, and type of engine. They represent a spectrum of technological possibilities, from an advanced Concorde to an advanced Mach 2.4, 300-passenger, titanium aircraft with a range of up to 5,500 nautical miles that might enter service in the mid-1990's. Figure 12 indicates a schedule postulated for the introduction and deployment of the aircraft in the several scenarios. The rationale for the aircraft used in each scenario is provided below.

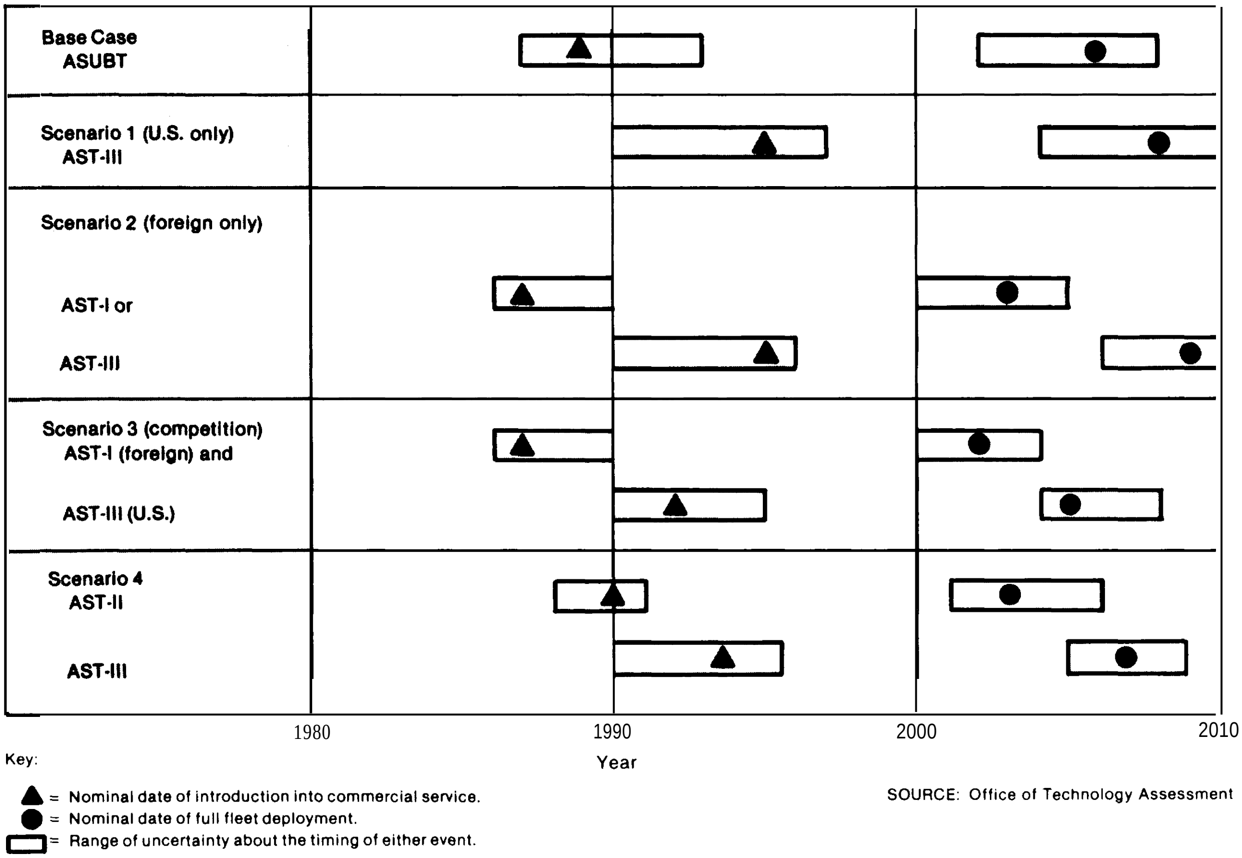
Table 5.—Characteristics of Four Projected Aircraft Types

	Subsonic	Supersonic		
	Advanced subsonic transport (ASUBT)	Advanced Concorde (AST-I)	Advanced supersonic transport-II (AST-II)	Advanced supersonic transport-III (AST-III)
Passengers	400 (600) 800	200	225	200 (300) 450
Design range (nautical miles)	**3,600** to 5,500	4,200	4,800	5,500
Speed (Mach)	0.85	2.0	2.2	2.2 2.4 2.7
Material (primary structure)	Aluminum	Aluminum	Titanium	Titanium
Engine type	Advanced turbofan	Low bypass w/ mechanical suppressor	Low bypass w/ mechanical suppressor	Variable-cycle engine
Noise	Satisfy legal requirements at time of introduction	Stage 2a	Stage 2a	No more than other comparable aircraft introduced at that time
Sonic boom	NA	← No over land boom →		

ªAt Introduction
( )Nominal value

SOURCE Office of Technology Assessment

Figure 12.— Scenario Timetables



SOURCE: Office of Technology Assessment

SCENARIOS

The base case assumes that there will be no further development of supersonic transport aircraft by either U.S. or foreign manufacturers prior to **2010.** The base case thus serves as a reference for comparing the impacts of other scenarios involving some form of supersonic transport aircraft.

The market in the base case consists of only those **850** subsonic aircraft which, as shown in table 4, would have been competing with or replaced by supersonic transport in the case of the other scenarios. It is assumed that, without any additional supersonic transports (besides the existing Concords), ASUBTs will be developed and introduced into commercial service by the late 1980's or early 1990's with full fleet deployment around 2005.

Scenario 1 projects that the United States is the sole developer of an AST and that the aircraft is an AST-III, the most technologically advanced of the transports considered. It is assumed that, given an orderly development program in the absence of foreign competition, the United States will not elect to undertake to produce an aircraft of lower capability and dimmer economic promise. Thus, this scenario allows the examination of the impact of the United States alone developing the most technologically advanced, economically viable, and environmentally acceptable supersonic transport achievable within the period considered in this study.

The market in scenario 1 consists of 400 AST-111 aircraft that replace 850 of the subsonic aircraft in the base case. Introduction into commercial service is assumed to take place in the mid-1990's, with full deployment around **2005.**

Scenario 2 projects that the United States does not participate in the development of an AST and that foreign manufacturers do develop and introduce it. It is assumed that, depending on how foreign manufacturers exploit the technical advantage of Concorde experience, they will develop either an AST-I or AST-III. This scenario allows the examination of the consequences of a U.S. decision not to become involved in a supersonic transport program.

If the foreign countries elect to develop an AST-III, it is expected that the market will be satisfied by the same number of supersonic aircraft **(400) as** in scenario 1. Because it is anticipated that U.S. airlines will buy some of these AST-IIIs instead of American-built subsonic aircraft, this scenario will involve a significant impact on the U.S. economy. If foreign countries adopt a different strategy—early development of an AST-I based on existing technology in order to solidify their competitive position—the market for aircraft sales will be different. Although it is estimated that there could be a market for perhaps 400 AST-Is, the number of subsonic aircraft replaced by the AST-I will be less than in scenario 1, because the size of the AST-I will be smaller than that of an AST-III.

Scenario 3 examines the possibility of super-sonic transports being developed and introduced by U.S. and foreign manufacturers in competition with each other. Given the existing technology bases here and abroad and the differing degrees of readiness to produce a significantly advanced supersonic aircraft, it is assumed that the competition takes the form of a less advanced, foreign-built supersonic aircraft (AST-1) developed rather early (by the late 1980's) pitted against a U.S.-built AST-III introduced about 5 years later. The foreign strategy would be to take advantage of Concorde experience to capture sales that would otherwise go to a more advanced aircraft that will not be available until later. The U.S. strategy would be to attempt to win a large market by the promise of a technologically advanced aircraft with significantly higher productivity and lower operating costs than the foreign-built AST-I available earlier.

This scenario depicts the effects of competition on the market. It is projected that a total of **250** AST-Is and **250** AST-IIIs are sold. Thus, both the U.S. and the foreign participants realize a smaller share of the market than if there is no competition. However, the total supersonic market is larger because there are two versions of supersonic transports available. Nonetheless, the total number of subsonic aircraft replaced by the two versions of supersonic transport is about the same as in the other scenarios—850—because the AST-I is not as productive as the AST-III. Hence, the market share—in terms of passenger trips diverted to supersonic aircraft—does not change significantly even though more supersonic aircraft are in use.

The consortium scenario (scenario 4) assumes that a supersonic transport is developed and introduced into commercial service around **1990** through a joint venture by a consortium of U.S. and foreign manufacturers. The joint effort reduces the economic risk for each party, but at the cost of diminished returns for each because the revenues from sales must be shared. Furthermore, a joint program may cost more than a program run by a single manufacturer as a result of the extra expense of coordinating more than one supplier and utilizing duplicate facilities and production lines.

Two possible consortium scenarios have been projected, one leading to an AST-II and the other leading to an AST-III.

The consortium scenario leading to an AST-II assumes that the United States has pursued only a modest technological advancement program and lacks technology for an AST-III and that the consortium results from foreign initiative. It is projected that the aircraft produced is an AST-11, of a design reflecting the differences in the technological bases of the participants. In range and payload the AST-II falls about midway between the AST-I and the AST-III. It is assumed titanium is used for many structural components and the aircraft has a cruise speed of Mach 2.2.

The market for such an aircraft is estimated at **450,** slightly larger than the market for the AST-111, partly because of the lower productivity of the aircraft and partly because of the stimulation of sales to airlines by the cooperative aspects of the venture. For the purpose of examining one possible joint undertaking, it is assumed that the contribution of each party is determined by its experience and technological capability and, more particularly, that the U.S. share of the program is about **30** percent and the foreign share, the remaining **70** percent. It is assumed these percentages are reflected in sales to world airlines (30 percent to U.S. carriers and 70 percent to foreign ones) and in apportionment of the revenues from sales.[16]

The consortium scenario leading to an AST-111 assumes that the United States has pursued the technology for an AST-III and initiates a consortium effort to help solidify a world market as well as to reduce the financial risk. The ratio of U.S. and foreign contributions is assumed to be **50/50,** although a larger U.S. proportion is possible. Likewise, sales to world airlines and apportionment of sales revenues are assumed to be 50/50.

The AST-III assumed for this scenario is the same aircraft envisioned in scenarios 1, **2,** and 3. However, its introduction is projected as earlier than an AST-III's introduction under a single manufacturing effort (scenarios 1 and 2) and later than an AST-III's introduction under a competitive venture (scenario 3). The rationale behind this projection is that a joint venture would produce the aircraft faster than would one manufacturer but would most likely not be able to produce it as fast as would occur in the competitive situation. However, as shown in figure 12, the projected ranges for introduction and deployment are quite broad.

The market for such an aircraft is estimated to be **400,** the same number used for the AST-III in the other scenarios.

[16]Boeing Commercial Airplane Co., "Prototype Make or Buy," SST Industrial Engineering Planning Group, 1977.