Chapter 3

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The feasibility and the optimal form of an advanced supersonic transport (A ST) or advanced subsonic transport (ASUBT) program depend on the attributes of the commercial aircraft industry and, in particular, that segment of the industry which produces air transports, as opposed to commuter or general aviation aircraft. The commercial aircraft industry is a subset of the aerospace industry, which serves three markets: Government (primarily military) aerospace, commercial aerospace, and nonaerospace products. The structure of the aerospace industry—dominated by a small number of large firms—has evolved in response to conditions in the aerospace markets and characteristics of aerospace production. These conditions and characteristics and the industry structure which results from them, described below, may constrain the undertaking of advanced air transport projects.

HISTORICAL OVERVIEW

The history of commercial air transport manufacturing has been marked by market volatility and financial difficulties. Of the many financial losses suffered by major aerospace firms in the postwar period, most have been attributable to commercial operations. Financial distress arising from commercial operations during the 19.50's was largely due to aircraft design flaws and uncertainty about how the commercial air transport market would develop. During the mid and late 1960's, design problems were rare, but financial challenges grew, even for the leading manufacturers, with the cost of doing commercial aerospace business: solving technical problems was expensive; growth in sales volume, inflation, and numbers of accidents raised product liability insurance costs; growth in sales to foreign airlines necessitated investments in global airplane service networks; and input shortages during Viet Nam War mobilization caused operating losses in commercial operations.

Although a new generation of commercial aircraft, the wide-body jets, was launched in the late 1960's, encouraging one firm, Lockheed, to reenter the commercial aircraft market (temporarily, as it proved), only Boeing has profitably produced commercial air transports during the past several years. Consequently, any appeal this market might offer to new entrants has been declining over time,

Because of sharp increases in the costs and risks of aircraft development and production, coupled with slower growth in funding for aeronautical research and development (R&I)), new commercial models have been introduced less frequently over time.[1] The slowdown in technology change for commercial aircraft following the introduction of jets reflects both technological maturation, which makes economical innovations relatively difficult to achieve, and restraint in Government support for aerospace R&D. During the 1970's, industry analysts began to think that rising development, production, and advertising costs raised unit prices so much that competing aircraft programs might no longer be practical.[2] Today, while Boeing is undertaking two (related) new aircraft programs and Lockheed is preparing to leave the commercial air transport market, McDonnell Douglas may concentrate on upgrading its current aircraft models (see table 1).

Although some firms serve only the Government aerospace market, major commercial aircraft producers also depend heavily on Government aerospace business. In 1980, for example,

[1] U.S. Department of Defense, National Aeronautics and Space Administration, and Department of Transportation, *Research and Development Contributions to Aviation Progress (RADCAP)*, 1972.

[2] See, for example Jacques S. Gansier, "The U.S. Aircraft Industry: A Case for Sectoral Planning," in *Challenge*, July-August 1977; and "The Next Commercial Jet . . . It," *Business Week*, Apr. 12, 1976.

Table 1 .—Commercial Air Transport Deliveries: Product Variation and Program Overlap-Among Manufacturers

Year ending 12/31	Boeing					McDonnell Douglas					Lockheed			Convair			Fairchild		Airbus
	707	720	727	737	747	DC-6	DC-7	DC-8	DC-9	DC-10	Constellation	Electra	L-1 011	440	660	890	F-27	FH-227	A-300
1956						39	67				43			57					
1957						44	123				77			79					
1958	7					62	57				29	12		21			25		
1959	73					1		21			5	107		14			41		
1960	63	24						91				24		5	15		14		
1961	11	61						42				21			49		8		
1962	30	30						22							9	22	7		
1963	28	6	6					19							14	15	6		
1964	32	6	95					20									5		
1965	54	9	112					31	5								12		
1966	77	6	135					6	69								3	27	
1967	113	5	115	4				41	155								3	35	
1968	111		160	105				102	193									6	
1969	59		115	114	4			85	122									2	
1970	19		54	37	92			33	51										
1971	10		33	29	89			13	43	13									
1972	3		41	22	30			4	24	52			17						
1973	11		92	17	28				21	57			39						
1974	21		91	41	21				48	46			41						4
1975	7		91	51	20				35	43			25						9
1976	3		61	41	27				44	19			16						13
1977	3		67	25	20				16	12			11						15
1978	3		118	40	32				20	18			8						15
1979	1		136	77	67				39	35			14						25
1980			131	92	73				25	40			24						37
1981			94	108	53				77	19			28						37

SOURCES Aerospace Industries Association, Airbus Industrie.

the Government accounted for 59 percent of Lockheed's sales, 56 percent of McDonnell Douglas', and 17 percent of Boeing' s,' Besides aircraft, Government spends on such aerospace products as missiles, helicopters, spacecraft and other space equipment, and also military ships and submarines, some of which are produced by aerospace firms,

Government spending has historically fueled product and market development for the aerospace industry. A recent Government study found that of 51 significant technological advances in U.S. aviation between **1925** and 1972, 35 were sponsored by the military and 45 were funded by military and/or other Government agencies.[4] Government-sponsored aeronautical R&D or production programs contributed to all of the U.S. commercial transports in use during the 1970's, although only about one-fourth of these aircraft were derived from a military plane programs The contribution of Government-sponsored programs to airplanes that will be introduced in the 1980's is believed to be quite small, however, reflecting a slowdown in the development of military aircraft technology that is transferable to commercial aircraft. [6]

The magnitude of Government business is such that the Government effectively controls the number and growth of aerospace firms overall. Moreover, the Federal Government has several times provided extraordinary aid to financially troubled aerospace firms. The Glen L. Martin (now part of Martin Marietta), Northrop, Grumman, and Lockheed companies, for example, have benefited from Government loans or loan guarantees.[7] However, although dollar spending has grown absolutely, financial support by the Federal Government has declined in relative terms.

The Government share of aerospace sales (defined to include Federal expenditures for aerospace R&D and procurement) had declined from **85** percent in 1955 to 44 percent in 1980. * The Govern-

[3]Arnold Bernhard & Co Inc , Value 1 ine Investment Survey.
[4]RADCAP, op cit
[5]RADCAP, op. cit.

[6]Aerospace Industries Association of America, Inc., Aerospace Research Center, *The Challenge of Foreign Competition*, December 1981
[7]Charles B. Bright, *The Jet Makers*, 1978.
*The Government share of aerospace sales ranged between 71 to 84 percent in the 1960's and between 45 to 71 percent in the 1970's.

ment share of aerospace R&D spending has fallen less, from around 90 percent in the early 1960's to around 76 percent in the late 1970's.[8] Finally, the Government also owns large portions of aerospace company plant and equipment used in support of Government aerospace activities, although that proportion, too, has fallen over time.

[8] Aerospace Industries Association of America, Inc, *Aerospace Facts and Figures 1981 82,* July 1981

STRUCTURAL CHANGE

The history of the aerospace industry provides perspective on the prospects for future developments. Since World War II, the structure of the industry has changed dramatically in three ways: firms have diversified and integrated horizontally, vertical integration has declined, and the number of firms has declined.

Diversification is the entering of new lines of business. It is usually a means of reducing financial risk and enhancing the likelihood of firm survival. Through diversification, firms offset cash flow irregularities of one line of business with the different patterns of another line, making cash flow for the firm as a whole less variable and the risk of financial loss for the firm as a whole less than it is for a single line of business. Diversification thus provides insurance for firms undertaking risky projects.

Diversifying within a product class (horizontal integration) and some other forms of diversification also enable more efficient operation, where fixed costs can be allocated across a larger volume of products. Aerospace firms that produce a variety of aircraft can, for example, lower unit costs by spreading shared-cost items over several airplane lines.

Aerospace diversification has taken several forms: increase in the variety of aircraft, aerospace products, and/or defense products manufactured; development of expertise in technologies and manufacturing processes related or similar to aerospace production; and involvement in businesses totally unrelated to aerospace. It has been achieved through firm growth and through mergers and acquisitions.

Aerospace firms began to diversify in the 1950's as military funding (provided directly through research and production contracts and indirectly through Government investments in plant and equipment) waned in the aftermath of World War II and then the Korean War. The volatility and low profit margins of Government business through the 1960's induced aerospace firms to shift their sales mixes away from military sales and toward commercial and nonaerospace lines (see table 2). During the 1970's, changes in Government procurement activities favorable to aerospace firms apparently dampened that trend. Diversification was also stimulated by the development of new technologies for aircraft and other related defense hardware and systems. Although industry analysts believe that diversification has helped aerospace firms survive and grow, specific efforts have not always been successful. *

After World War II, another major change in the organization of the industry was a decline in vertical integration brought about in response to growth in the costs, risks, and complexity of aircraft manufacture. Vertical integration is in this context the production of inputs (materials, components, parts, subassemblies, systems, etc.) to a firm's principal products.** The more a firm is vertically integrated, the less it relies on suppliers, and vice versa. Suppliers presently conduct about half of the total manufacturing activity involved in airframe manufacturing programs.[9] Thus, for example, there are over 1,300 companies involved

* General Dynamics, for example, has lost millions of dollars on its Quincy (Mass.) shipyards; Grumman has lost money because of problems with its Flxible subsidiary's buses and Boeing has had problems with its Vertol subsidiary's light-rail vehicles

** Integrating supply activities is called backward integration, as contrasted with forward integration or integrating distribution activities. Many firms and industries integrate vertically to reduce costs by gaining better information about inputs; by eliminating costs associated with developing, maintaining, and purchasing from supplier networks; and by enhancing control over their economic environment.

[9] *The Challenge of Foreign Competition* op. cit

Table 2.—Pattern of Diversification, Early 1960's (X) and Later (Y)

	Field of Diversification									
Company	Military aircraft	Missiles	Space	R&D	Electronics/communications	Shipbuilding/marine	Other transportation	Commercial aircraft	Construction	Other
Boeing	X	X	Y	—	Y	Y	Y	X	Y	Y
Douglas[a]	X	X	Y	—	Y	—	—	X	—	Y
Fairchild	Y	[b]	Y	—	Y	—	—	X	—	Y
General Dynamics	X	X	Y	X	X	X	Y	X	X	Y
Grumman	X	Y	Y	—	Y	Y	Y	—	Y	Y
Lockheed	X	X	Y	X	X	X	—	X	—	Y
Northrop	X	[c]	—	X	X	—	—	—	Y	—

[a]Merged with McDonnell in 1967.
[b]Fairchild's missile contracts had been canceled by the sixties.
[c]Northrop abandoned large missiles as a prime after Snark, but does missile avionics now.

SOURCES: Charles D. Bright, *The Jet Makers*, Lawrence, Kans.: The Regents Press of Kansas, 1978; *Moody's Industrial Manual*, 1981.

as primary suppliers in the Boeing 757 program, with many others involved as secondary suppliers (see table 3 and fig. 3). The growth of subcontracting changed the structure of the aerospace industry by adding and strengthening new layers.

Vertical integration in the aerospace industry is not high for several reasons: First, production of many inputs to aircraft manufacture is sufficiently complex that it is more efficient for some suppliers and subcontractors to specialize in the production of particular inputs than for aircraft manufacturers to produce both the inputs and the final products/aircraft, Second, profitable production of some aircraft inputs requires larger volumes than a single manufacturer would demand.

Third, the aircraft business is sufficiently risky and costly that reducing costs and risks by relying on suppliers and subcontractors enables aircraft manufacturers to do more business—take on more risks—than they could do alone. This is one of the reasons that cooperative ventures between manufacturers and subcontractors and among manufacturers have become more common. Fourth, subcontracting also reduces aircraft manufacturing risks by changing the nature of input costs. Buying rather than manufacturing inputs makes some otherwise fixed costs variable (they change with the volume of production), reducing the risk of financial loss in the event that sales volume is less than anticipated.

Another important trend in the industry is a decline in the number of major firms whose primary business is aerospace. This trend is consistent with industry domination by large firms. While there were **20** major aerospace firms in the 1950's, there were 15 by the late 1960's and only 7 conducting primarily aerospace business by the late 1970's: Boeing, Lockheed, McDonnell Douglas, Grumman, General Dyamics, Fairchild Industries, and Northrop.[10] While there were five leading commercial aircraft manufacturers in the 1950's, there were two (Boeing and Douglas) in the 1960's. A third (Lockheed), which reentered the commercial aircraft market in the 1970's, is preparing to cease commercial aircraft manufacturing by the mid-1980's. Worldwide, there are only three additional leaders in commercial air-

[10]Hartman L. Butler, Jr., et al., "The Aerospace Industry Re-Revisited," in ***Financial Analysts*** *Journal*, July-August 1977

Table 3.—Manufacturer' Reliance on Subcontractors: The Case of Boeing's 767 and 757 Programs

Component	Subcontractor
767	
Major body sections 43, 45 and 46 Wing to body fairings Main landing gear doors Wing in-spar ribs	Civil Transport Development Corp. Japan
Wing control surfaces Wing trailing edge flaps and leading edge slats Wingtips Elevators Vertical tail rudder and radome	Aeritalia, Italy
Main landing gear	Pneumo Corp.'s Cleveland Pneumatic Co Cleveland, Ohio
Nose landing gear	Colt Industries' Menasco, Inc. Burbank Calif.
Wing center section Adjacent lower fuselage section	Grumman Aerospace Corp. Bethpage N Y
Engine struts	**General Dynamics, Convair** Div. **San Diego, Callf.**
Engine nacelle primary nozzles and plugs	TRE Corp Astech DIV. Santa Ana. Calif.
Rear fuselage of Section 48	Canadair Ltd., Montreal, Canada
Horizontal stabilizer	LTV Corp.'s Vought Corp. Dallas, Tex.
Inertial reference system	Honeywell, Inc., Avionics Div. Minneapolis, Minn.
Ž Autopilot flight system ● Radio distance magnetic indicator ● Electronic fit Instrument system	**Rockwell International** **Collins Air Transport** D iv. South Bend, Ind.
Wheels and brakes	Bendix Corp. Brake and Strut DIV. South Bend, Ind
"Engine thrust management system	General Electric Co Aircraft Equipment Div. Binghamton N Y
Hydraulic flight control actuators	Parker Hannifin Corp.'s Bertea Group Irvine, Calif
Auxiliary power unit	Garrett Corp.'s AlResearch Manufacturing Co. Phoenix, Ariz.
Primary engine Instrument package	**General Electric Co.** **Aircraft** Equipment Div. Wilmington, Maas.
* Flight management computer system * Air data computer "Air data (instruments	Sperry Rand Corp.'s Sperry Flight Systems Phoenix, Ariz.
" Air-conditioning and cabin temperature control system * Cabin pressure control system Pneumatic drive assembly	**Garrett Corp.'s** **AiResearch Manufacturing Co.** **Torrance, Calif.**
Environmental control air supply system	**United Technology Corp.'s** **Hamilton Standard** **Windsor Locks, Corm.**
Autopilot hydraulic servo actuators	**Moog** Inc., **Aerospace Div.** **East Aurora, N.Y.**
* Electric power generating system	**Sundstrand Corp.** **Electric Power Div.** **Rockford, Ill**
Spoiler hydraulic power control actuators	Teijin Seiki Co Gifu, Japan
Wing trailing edge gear boxes	Kawasaki Heavy Industries Ltd. Jet Engine DI.V Akashi, Japan
Wing-leading edge and trailing edge flap rotary actuators Stabilizer trim gear boxes	Western Gear Corp. Lynnwood. Calif.
*Windshield	International Pilkington Group Triplex Safety Glass Birmingham, England
Flight deck side windows	Sierracin Corp. Sylmar Div. Sylmar, Calif.
Thrust-reverser actuator	**Pneumo Corp.'s** **National Water Lift Co** **Kalamazoo, Mich.**
" Ram air turbine	Sundstrand Corp. Sundstrand Aviation Mechanical Rockford, Ill
Stab trim control module	**E. Systems, Salt Lake City, Utah**
Antiskid/autobrake system	Hydro-Aire, Burbank Calif
Proximity switch system	Eldec, Lynnwood Wash
Crew seats, Captain and 1st Officer	Weber Burbank Calif
Evacuation slides	Sargent Industries Los Angeles Calif
Lighted pushbutton switches	Master Special! /es Costa Mesa, Calif
Lights Navigation Navlanti-collision Wing Illum egress Aircraft position indication	Midland Ross Grimes Div. Urbana Ohio
Fuel quantity indication system	Honeywell Minneapolis, Minn.
757	
Wing center Section, keel beam	**Avco** Aerostructures Div. Nashville, Term
Major part of body Section 44	Fairchild Republic Co Farmingdale, N.Y.
Fuselage Sect Ions 43, 46	Rockwell International Corp. Tulsa Div. , Tulsa Okla.
Horizontal stabilizer, including leading edges and stabilizer tips Vertical tail, including leading edge, fuselage Section 48	Vought Corp., Dallas, Texas
Inboard trailing-edge flaps	Short Brothers, Ltd. Belfast Northern Ireland
Wing in-spar ribs	Hawker de Havilland Sydney Austrailia
Outboard wing trailing edge flaps	Construcciones Aeronauticas S A (CASA) Madrid, Spain
Main and nose landing gear	Menasco, Inc. Burbank, Calif.
Electro-hydraulic spoiler actuators	Bendix Corp. Electro-Dynamics DIV. North Hollywood, Calif.
Air supply systems	Garrett Corp. Los Angeles, Calif.
Lights Nav/anti collision Wing illum., egress Aircraft position **indication**	Midland Ross Grimes Div Urbana, Ohio

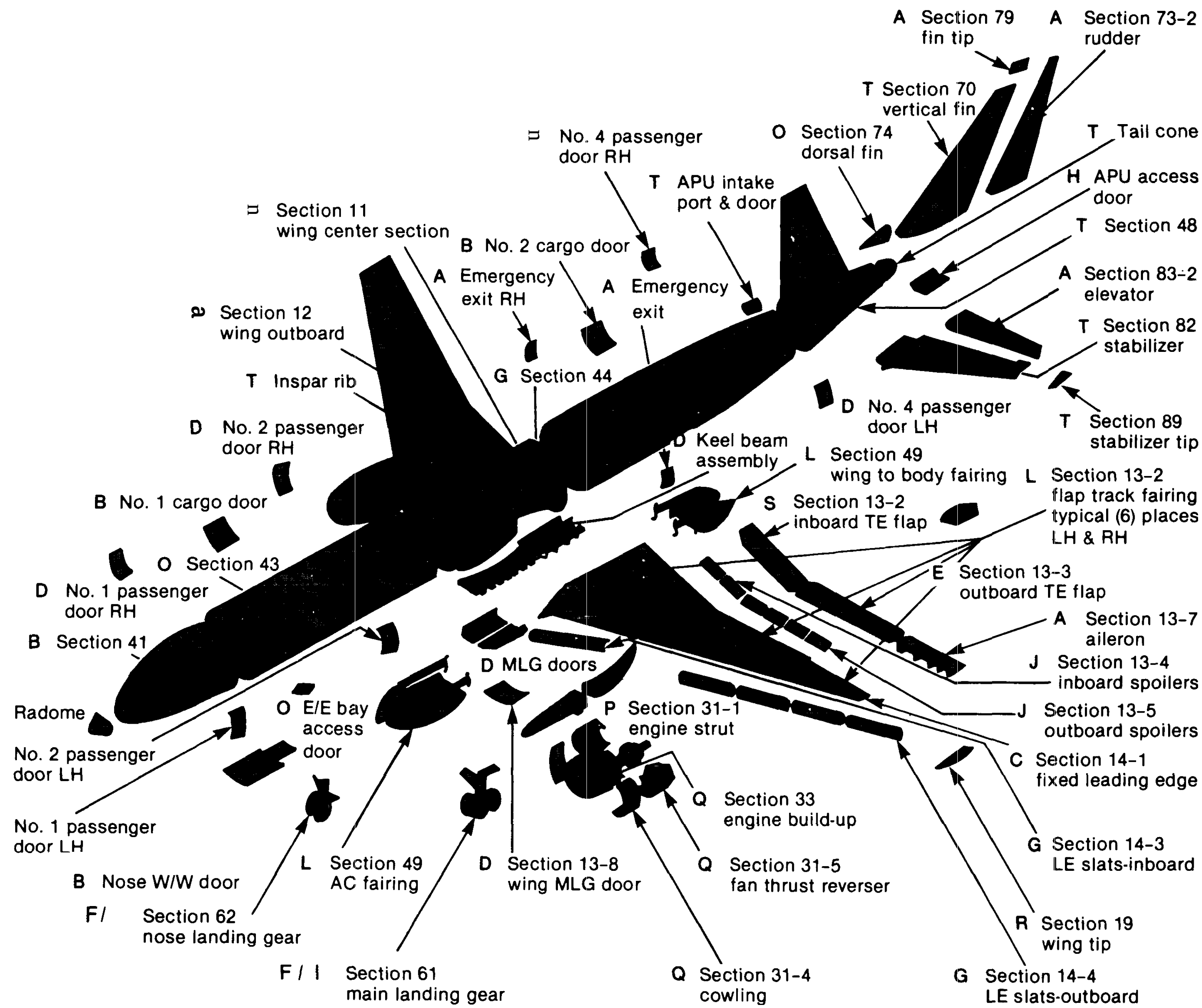
'Agreements cover items common, and ordered for, both the 757 and 767

SOURCES: Richard **D. O'Lone, "Boeing Facing New Set of Challenges,"** ***Aviation Week and Space Technology, Nov. 12, 1979.***

Figure 3.—Many Subcontractors and Suppliers Work on a Single Program: Some Major Subcontracts for the Boeing 757

Legend

- A Boeing BCAC)
- Boeing (BMAC)
- C Boeing (Vertol)
- D O
- E ASA
- F Dunlop
- Fairchild
- H Fleet Industries
- Goodrich
- J Grumman
- K Hawker De Havilland
- L Heath
- M HITCO
- N M
- O R w
- P Rohr
- Q Rolls-Royce/ Pratt & Whitney
- Schweizer
- Short Brothers
- T Vought



SOURCE: "757 Effort Involves 1,300 Companies," *Aviation Week and Space Technology*, Feb. 22, 1982.

craft manufacturing: British Aerospace, Fokker, and the Airbus Industrie consortium.[11]

The number of subcontractors has also fallen as subcontractor firms— typically smaller companies—have gone out of business or been acquired by larger companies. Many smaller subcontractors have left the aerospace business because they could not afford to modernize facilities, train personnel, or operate profitably given the unstable flow of aerospace work and, according to some, the requirements of Government regulations.[12]

The Standard and Poor's Aerospace Industry Survey provides a measure of the number of major firms in the U.S. aerospace industry. It lists 5 airframe manufacturers, 15 subcontractors and systems suppliers, 2 propulsion and engine suppliers, 6 diversified firms, 3 general aviation firms and 3 shipbuilders.[13] Several hundred more firms, primarily small suppliers, make up the rest of the industry. *

The number of firms that can efficiently supply a product depends on production costs and market size. The commercial aircraft market is relatively small in terms of annual unit sales volume, with limited potential for growth. On average, U.S. manufacturers sell fewer than 350 commercial transports annually. Production of aircraft is sufficiently costly that during the several years when a model is produced, 200 to 500 airplanes—a large number relative to annual demand —must be sold (at or above a model-specific annual rate) for a manufacturer just to break even on a given model.

Costs of producing aircraft are minimized when individual manufacturers can produce in large volumes because of scale economies and learning-curve effects. Production is said to involve economies of scale when unit costs decline as the rate of production is increased, either for a particular product or within a particular plant or set of plants. Production is said to involve learning-curve effects where experience with a particular product or production process enables unit costs to fall as accumulated production volume increases. Unit aircraft costs may fall by up to 15 to 20 percent after initial production volume is doubled. Learning-curve effects in aircraft manufacture depend largely on learning by labor, because there are many intricate labor operations in aircraft production, with which workers become proficient over time, and because both technical and production staffs are often learning how to work with new technologies. Finally, individual firms overall learn and benefit through involvement in aircraft manufacture over time, a phenomenon that advantages older aerospace firms.

The trends and circumstances described above have supported the evolution of a concentrated industry led by a group of large firms. Scale economies and learning-curve effects enable large firms to produce with lower unit costs than small firms; large firms involved in several lines of business require large amounts of capital; and scale economies, large capital needs, high risks, and intertemporal learning benefits all inhibit new firms from entering into aircraft manufacturing.

In addition to these factors, growth in foreign competition also serves to promote an industry characterized by relatively few large firms or other economic entities, including consortia. Growth in foreign aircraft competition, particularly from foreign production consortia such as Airbus Industrie, is a major concern of U.S. aerospace firms. Foreign commercial aircraft sales have diminished U.S. aircraft sales to foreign airlines and, to a smaller extent, to U.S. airlines. Sales of aircraft to foreign customers are a major concern of domestic aircraft manufacturers, because since the early 1970's over half of both unit and dollar sales of U.S.-made aircraft have been for export. s

[11] *The Challenge of Foreign Competition,"* op. cit

[12] Alton K Marsh, "Subcontractors Shrinking Base of Industry," in *Aviation Week and Space Technology*, July 20, 1981

[13] Robert Spremulli, "Aerospace Industry Survey: Basic Analysis," for Standard & Poor's, Apr. 3, 1980.

*According to the 1977 Census of Manufacture, there are 151 companies in the "Aircraft Industry" (SIC 3721), 226 in the "Aircraft Engines and Engine Parts Industry" (SIC 3724), 678 in the "Aircraft Equipment, Not Elsewhere Classified, Industry" (SIC 3728) and 78 in the three industries devoted to missiles and space equipment

[14] *The Jet Makers*, Op. cit with reference to data and analysis compiled by the RAND Corp.

[15] U. S Department of Commerce, *U S Industrial Outlook 1981*, January 1981

Industry representatives maintain that the loss of sales to foreign manufacturers reflects at least in part the efforts of foreign governments to promote sales of foreign-made aircraft within their countries of origin and within other countries through trade agreements and other arrangements. These practices may become less common with implementation of the Civil Aircraft Agreement, which came out of the recent Tokyo Round of Multilateral Trade Negotiations.[16]

Regardless of the reasons behind the growth in sales of foreign aircraft, increased competition in aircraft sales raises market risks for all aircraft programs and reduces the number likely to be viable. U.S. manufacturers of aircraft and aircraft engines have begun to participate in cooperative research and production ventures with foreign firms to improve access to foreign customers as well as to share costs and risks (see ch. 4). U.S. firms not only undertake new projects with foreign partners (e. g., the General Electric and SNECMA (France) engine production partnership, CFM International), they also work with foreign firms in lesser subcontractor and supplier roles (see table 3).

The U.S. commercial aircraft industry may contract further because of growth in manufacturing costs, competition from foreign manufacturers, and continued financial problems, Firms in a small, or smaller, industry may be more efficient and financially healthier, but they may not command enough resources to pursue an especially high-cost, high-risk commercial air transport program alone, The current trend toward cooperative ventures between U.S. and foreign aerospace firms suggests that individual firms may be unable to manage even more conventional programs on their own.

[16] *The Challenge of Foreign Competition,* op. cit,