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Research and Technology Program Perspectives for General Aviation and Commuter Aircraft

Final Report

James S. Bauchspies
William E. Simpson

September 1982

Prepared Under Contract No. NASW-3554

for

National Aeronautics and Space Administration
Washington, D.C. 20305

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Silver Spring, Maryland 20910

RESEARCH AND TECHNOLOGY PROGRAM PERSPECTIVES FOR GENERAL AVIATION AND COMMUTER AIRCRAFT

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PREFACE

This report on "Research and Technology Program Perspectives for General Aviation and Commuter Aircraft" presents the results of ORI's data collection efforts and analysis of the uses, benefits and technology needs of the U.S. general aviation industry in light of growing competition from foreign general aviation manufacturers, especially in the commuter and business jet aircraft markets. This work was conducted to support continuing assessments by NASA's Office of Aeronautics and Space Technology (OAST) of factors affecting the need for aeronautical research applicable to general aviation technology and related planning of research and technology (R&T) programs.

The scope of this effort was limited to the review and analysis of available published information. This information was supplemented by discussions with members of the General Aviation Manufacturers Association (GAMA) and the U.S. aircraft industry. However, it became readily apparent more indepth investigation is required especially in the areas of the ability of U.S. manufacturers to conduct needed research in-house and the capabilities of foreign manufacturers as well as the support they receive from their governments.

Conclusions and recommendations for further effort are presented. This effort was accomplished by ORI, Inc. under NASA Contract NASW-3554. Contributions by Dr. Jan Roskam on technology needs and capabilities of U.S. general aviation manufacturers are gratefully acknowledged.

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TABLE OF CONTENTS

TABLE OF CONTENTS
(CONTINUED)

TABLE OF CONTENTS
(CONTINUED)

LIST OF FIGURES

LIST OF FIGURES
(CONTINUED)

LIST OF TABLES

LIST OF TABLES
(CONTINUED)

LIST OF TABLES
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EXECUTIVE SUMMARY

Economic, political and technology changes during the past five years have affected the production, use and future roles of general aviation and commuter aircraft. Escalating fuel costs, airline deregulation, growing foreign competition, and both foreign and domestic government policies have been cited as being the most significant. This report examines these factors as they impact on the general aviation and commuter industry, the needs and opportunities for advanced technologies in this field, and the role of NASA research support.

GENERAL AVIATION -- ITS COMPOSITION, GROWTH, AND USES

General aviation is a broad classification which encompasses all civil aviation activities except those of the certificated air carriers of the nation's commercial airlines. This wide spectrum of elements that make up general aviation includes air transportation services by commuter airlines, air taxi services and rental aircraft, business aviation, agricultural aviation, pilot training and all aspects of personal flying.

The current general aviation fleet includes over 200,000 airplanes consisting of single and multi-engine piston, turboprop and turbojet aircraft. Although the numbers of aircraft in the fleet have continued to increase in all categories, there has been a gradual shift percentage-wise from the piston powered aircraft to turboprop/turbofan powered aircraft.

The historical and forecast growth of general aviation for the years 1975 to 1993 is shown in Table ES.1.

The operators of general aviation aircraft are as varied as the types of aircraft included in this category of aviation. These uses can be grouped into three major categories -- business, commercial and personal flying. Business and commercial operations account for about 77 percent of all general aviation flight hours. The other 23 percent is for personal transportation and proficiency flying.

ECONOMIC FACTORS IN GENERAL AVIATION

General aviation is a large, highly diversified industry which collectively produces an annual contribution of about 10 billion dollars to the national economy. In aggregate, general aviation employment totals over 300,000 people grouped as follows -- 80,000 in sales and services, 20,000 engaged in agricultural flying, 45,000 in corporate flight departments, 15,000 in industrial areas such as aerial mapping and surveillance, 15,000 self-employed instructors and mechanics, 60,000 in manufacturing aircraft and its equipment components and 65,000 in producing materials and subcomponents.* The total annual earnings of these 300,000 employees are about $6.5 billion assuming an average annual wage of $21,711 per full-time employee.**

Figures ES.1 and ES.2 present the trends in aircraft units and sales from 1970 to 1981. Although there was a dramatic 44 percent decline in aircraft shipments since 1979, it is noted that total factory net billings increased to a record high of $2.9 billion. A significant drop (24 percent) in the demand for single and multi-engined aircraft was offset by a 14 percent increase in the sales of the larger higher-value multi-engine turbine-powered aircraft. The continuing growth in the sales of turboprop and turbojet aircraft has been attributed to a strong business aircraft market and the growth in commuter airlines, whereas the decline in the smaller, personal-use aircraft have been attributed to high interest rates, tight credit, the business recession, inflation and rising energy costs.***

*The General Aviation Story, General Aviation Manufacturers Association, 1980.

**National Transportation Statistics, U.S. Department of Transportation, Research and Special Projects Administration, September 1980.

***Based upon 1982 shipments through August 1982 (3,110 units for year to date and billings of $1.3 billion) projected shipments and billings for the full year may fall below 5,000 units and $2.0 billion.

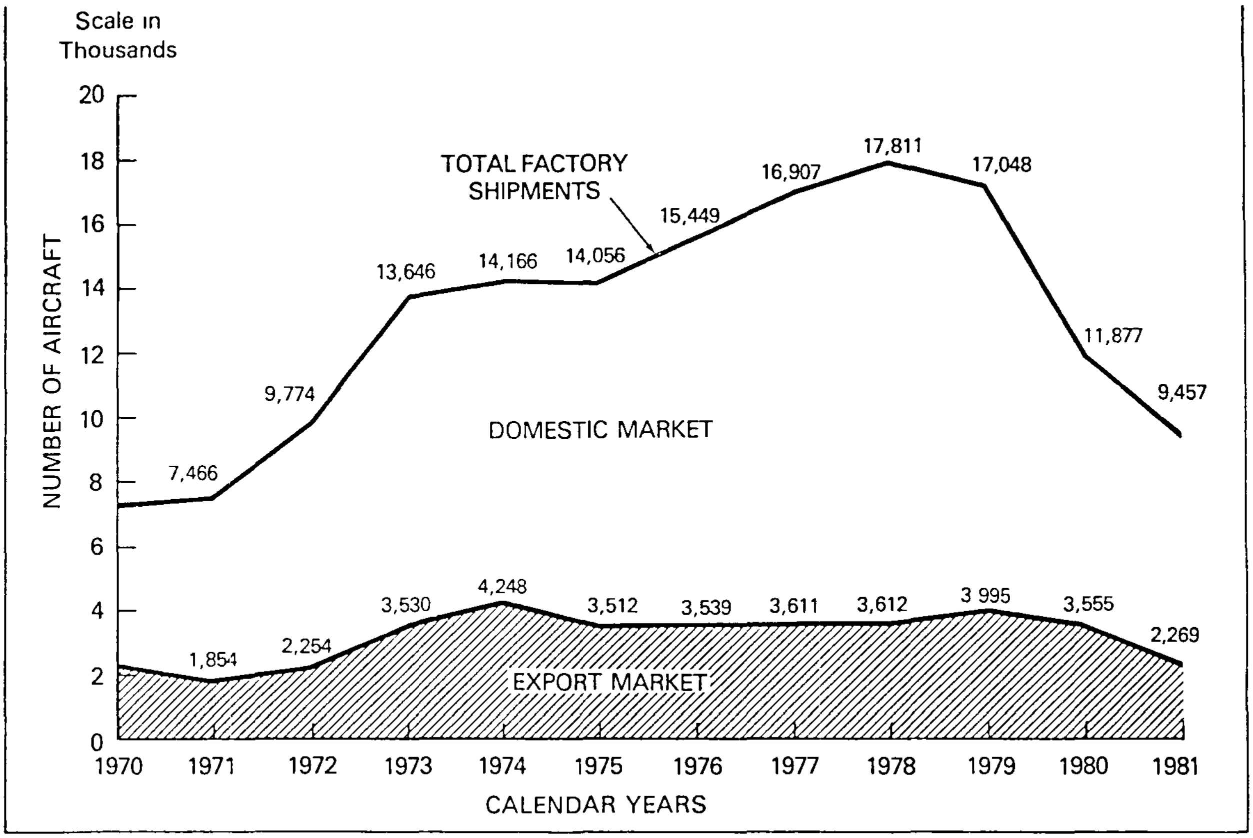
TABLE ES.1

ESTIMATED U.S. GENERAL AVIATION ACTIVE FIXED WING AIRCRAFT
BY AIRCRAFT CATEGORY
(Number in Thousands)

Year as of January 1	Total Fixed Wing	Piston Powered		Turboprop	Turbojet
		Single Engine	Multi-Engine		
Historical					
1975	154.9	131.5	19.7	2.1	1.6
1976	161.1	136.6	20.3	2.5	1.7
1977	170.5	144.8	21.3	2.5	1.9
1978	176.0	149.3	21.5	2.9	2.3
1979	189.5	160.7	23.2	3.1	2.5
1980	199.7	168.4	25.1	3.5	2.7
1981E	203.1	170.2	25.4	4.3	3.2
Forecast					
1982	208.6	173.9	26.6	4.8	3.3
1983	214.2	178.0	27.6	5.2	3.4
1984	220.5	182.7	28.6	5.6	3.6
1985	228.3	188.9	29.6	6.0	3.8
1986	236.3	195.2	30.7	6.4	4.0
1987	245.8	203.0	31.8	6.8	4.2
1988	255.9	211.2	33.1	7.2	4.4
1989	268.0	221.1	34.6	7.6	4.7
1990	282.5	233.0	36.4	8.0	5.1
1991	298.2	245.8	38.4	8.5	5.5
1992	314.3	259.0	40.4	9.0	5.9
1993	330.9	272.7	42.4	9.5	6.3

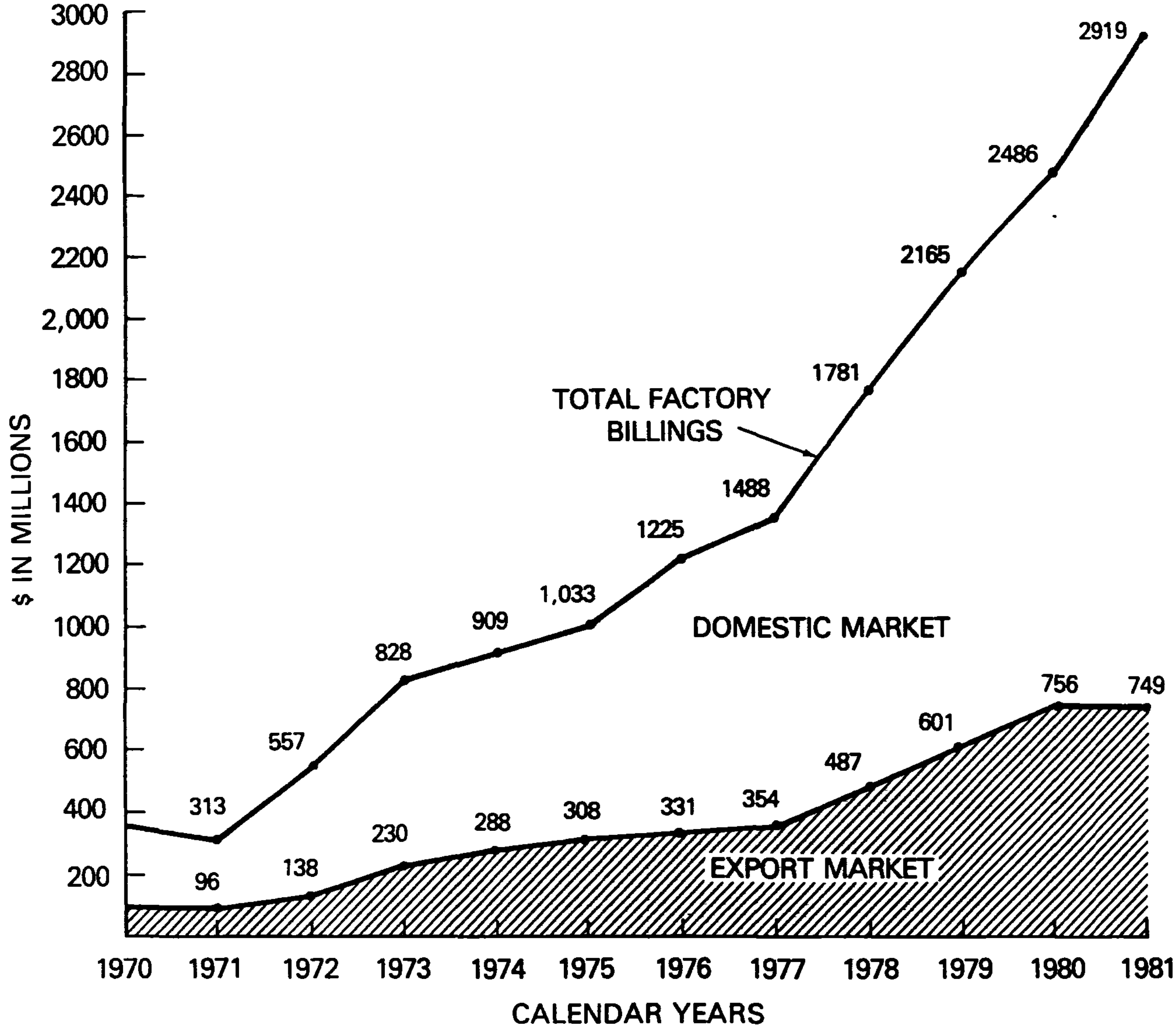
SOURCE: FAA

E - Estimate



Source GAMA

FIGURE ES.1. U.S. GENERAL AVIATION AIRCRAFT
UNIT SHIPMENTS 1970-1981



Source: GAMA

FIGURE ES.2. U.S. GENERAL AVIATION AIRCRAFT FACTORY SALES 1970-1981

SAFETY FACTORS IN GENERAL AVIATION

The accident rate for general aviation (excluding commuter air carriers and air taxi) was 10.0 accidents per 100,000 aircraft flight hours in 1981, an increase from the record low of 9.6 achieved in 1980 ending a continuous decline from 16.8 in 1972 (Table ES.2). In 1981, the National Transportation Safety Board (NTSB) reported commuter air carrier and on-demand air taxi accidents as separate categories from general aviation. The 1981 accident rates for commuter air carriers and air taxis were 2.59 and 3.74, respectively.

Accident rates for commuter air carriers and corporate/executive aircraft flying with professional crews are significantly lower than the totals for all general aviation flying (see Figure ES.3). Personal transportation and aerial application had the highest accident rates.

The cause of general aviation accidents continue to be dominated by weather and pilot error (Tables ES.3 and ES.4). These tables summarize the NTSB findings of the ten most frequently cited factors for both non-fatal and fatal general aviation accidents in 1979, the most recent annual accident data analyzed by the National Transportation Safety Board.

IMPACT OF U.S. GOVERNMENT POLICIES

Airline deregulation and environment controls are two areas where recently enacted government policies have had an impact on the composition of the general aviation fleet and/or needs for improved technology. The greatest impact on general aviation from the Airline Deregulation Act of 1978 is on the high performance segments of the market -- business aviation and the commuter airlines. To some extent the strong market for business aircraft is partially attributed to reduced airline services, but probably more directly related to time efficient direct routings and travel flexibility. The policy changes which have major impact on commuter airlines appear to include the following areas:

- Liberalized process for market entry and exit,
- Essential air services to small communities,
- Increased allowable commuter aircraft size, and
- Guaranteed aircraft loans.

TABLE ES.2

ACCIDENTS, FATALITIES, RATES
U. S. GENERAL AVIATION[1]
1972 - 1981

ACCIDENTS					ACCIDENT RATES PER 100,000 AIRCRAFT HOURS FLOWN	
YEAR	TOTAL[2]	FATAL[2]	FATALITIES	AIRCRAFT[4] HOURS FLOWN	TOTAL	FATAL
1972	4109	653	1305[3]	24,419,000	16.8	2.67
1973	4090	679	1299	26,907,800	15.2	2.52
1974	4234	689	1327	27,773,500	15.2	2.47
1975	4034	638	1247	28,335,700	14.2	2.24
1976	4005	648	1187	29,975,200	13.3	2.15
1977	4069	658	1281	31,584,600	12.9	2.08
1978	4223	723	1563[3]	34,985,399	12.1	2.07
1979	3800	629	1219	38,767,481	9.8	1.62
1980P	3599	629	1264	37,480,076	9.6	1.68
1981P	3634	662	1265	36,280,000	10.0	1.82

P Preliminary Data

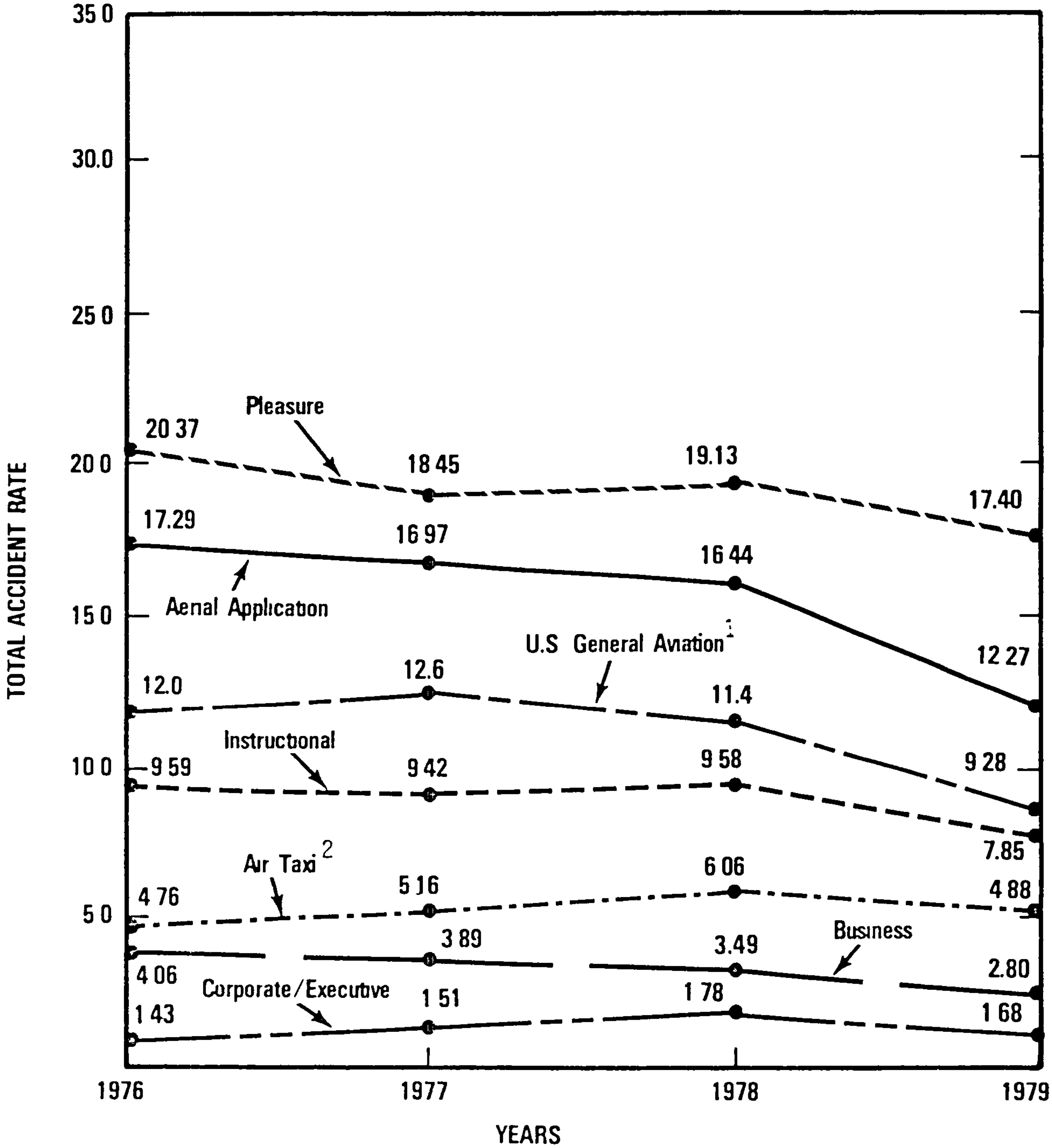
1 Table does not include accidents for Air Taxi and Commuter Air Carrier aircraft.

2 Suicide/sabotage accidents included in all computations except rates (1972-3, 1973-2, 1974-2, 1975-2, 1976-4, 1977-1, 1978-2, 1979-0).

3 Includes air carrier fatalities (1972-5, 1978-142) when in collision with General Aviation aircraft.

4 Source of estimate: FAA

SOURCE: National Transportation Safety Board, Safety Information Release, January 28, 1982.



SOURCE: National Transportation Safety Board, November 5, 1981 Analysis.

[1]Includes Commuter Air Carrier and Air Taxi Accidents.

[2]Includes Commuter Air Carrier Accidents.

FIGURE ES.3. GENERAL AVIATION ACCIDENT RATES PER 100,000 AIRCRAFT - HOURS FLOWN BY KIND OF FLYING 1976 - 1979

TABLE ES.3

TEN MOST FREQUENTLY CITED CAUSE FACTORS OF NONFATAL ACCIDENTS IN 1979

Cause Factors	Frequency	Percent
Pilot - Inadequate Preflight Preparation or Planning	399	11.93
Miscellaneous Acts, Conditions Overload Failure	334	9.99
Terrain - High Obstructions	293	8.76
Weather - Unfavorable Wind Conditions	263	7.86
Pilot - Mismanagement of Fuel	245	7.32
Pilot - Failed to Obtain/Maintain Flying Speed	240	7.17
Pilot - Selected Unsuitable Terrain	224	6.70
Powerplant - Failure for Undetermined Reasons	208	6.22
Miscellaneous Acts, Conditions Fuel Exhaustion	208	6.22
Miscellaneous Acts, Conditions Material Failure	203	6.07

TABLE ES.4

TEN MOST FREQUENTLY CITED CAUSE FACTORS OF FATAL ACCIDENTS IN 1979

Cause Factors	Frequency	Percent
Weather - Low Ceiling	170	25.07
Pilot - Continued VFR Flight Into Adverse Weather Conditions	131	19.32
Pilot - Failed to Obtain/Maintain Flying Speed	131	19.32
Weather - Fog	122	17.99
Pilot - Inadequate Preflight Preparation or Planning	90	13.27
Pilot - Spatial Disorientation	86	12.68
Terrain - High Obstructions	77	11.37
Miscellaneous Acts, Conditions Unwarranted Low Flying	58	8.55
Weather - Rain	49	7.23
Pilot - Improper Inflight Decisions or Planning	44	6.49

SOURCE: National Transportation Safety Board, Annual Review of Aircraft Accident Data-U.S. General Aviation, Calendar Year 1979 Data, Published November 5, 1981.

The principal environmental concern impacting on general aviation is associated with noise. Public objections to high-noise areas near major air carrier airports provided impetus in the 1970's for the Federal government to include noise abatement measures in aircraft airworthiness standards and airport approach and departure paths to reduce the impact of aircraft noise around those airports. Such regulatory measures and implementations of noise reduction technology have been primarily oriented toward reducing the impact of noise around commercial air carriers airports, but general aviation airport noise is also a growing environmental concern.

The FAA has established noise standards (FAR Part 36) to limit the noise levels of new design and new production aircraft, including small propeller-driven aircraft as well as jet aircraft. Although there is a considerable body of aircraft noise technology, with much of this technology based on research and technology sponsored by NASA and other government agencies, it is considered vital that continued progress be made on research efforts for reducing engine noise.

IMPACT OF INCREASING FOREIGN COMPETITION

The United States general aviation industry is experiencing very challenging international competition, particularly in the commuter aircraft and business jet areas. Foreign governments have targeted these areas as matters of national priority. Manufacturers in eleven countries have announced plans for new larger aircraft and are aggressively marketing the U.S. since they see the majority of these sales will be here.

Virtually all foreign manufacturers receive the strong support of their governments. This assistance takes a number of forms -- research and development grants, loans, provision of facilities, funding incentives, etc. Consequently, U.S. manufacturers are competing against foreign manufacturers who, since they are underwritten by their governments, are able to undertake the economic risk in the development of new aircraft types when the market is still ill-defined or when the necessary investment is above that which the U.S. private sector is able or willing to meet.

A review of the current commuter aircraft fleet both U.S. and worldwide indicates the major competitors to the U.S. commuter aircraft industry are France, Great Britain, Spain, Canada, the Netherlands and Brazil. Future commuter aircraft, currently under development, will bring strong competition from Great Britain, Canada, Germany, Brazil, Sweden, a team of France and Italy, and a team of Spain and Indonesia.

A forecast of the market for light transports for the years 1980-2000 is shown in Tables ES.5. The U.S. made up 28 percent of this market in 1978 as shown in Table ES.6. The most dramatic increase in the U.S. commuter market will be in the 20-40 passenger aircraft. Figure ES.4 presents a scattergram of current and future aircraft options for the commuter market by number of seats and year of introduction. U.S. aircraft are shown by a solid circle, foreign aircraft by an open circle and a joint U.S./ Sweden venture by a half circle. It is readily apparent that the larger (>19 seats) market is dominated by the foreign manufacturers with the only new U.S. models envisioned for the eighties being the CAC-100, the Ahrens 404 and the joint U.S./Sweden SF-340. The situation becomes even more serious when one considers there are no confirmed orders for either the CAC-100 or the Ahrens 404.

The business aircraft picture is much more encouraging than the commuters with manufacturers from France, Great Britain, Israel, Canada, and Japan presenting the greatest challenge to the U.S. Of seventeen current and projected turboprops, thirteen are manufactured in the U.S. Of the four foreign aircraft, two will be assembled in the U.S. and one, the Lear Fan, is a U.S. design to be built in Northern Ireland. Half of the turbofan designs available to the business customer are to be built in the U.S. Of the foreign models, the Falcon and Diamond I are to be assembled in the U.S. and the CL-600 is based upon a Lear design.

The production of light general aviation aircraft is dominated by three firms, Cessna Aircraft Company, Beech Aircraft Corporation and Piper Aircraft Corporation. In 1980, these manufacturers accounted for 92 percent of the new aircraft shipped and 67 percent of the net billings. U.S. worldwide sales in 1980 consisted of 11,877 units. France, second to the U.S. in worldwide sales, delivered 591 light piston aircraft in 1980.

TABLE ES.5

U.S./WORLD MARKET FORECAST FOR LIGHT TRANSPORT AIRCRAFT
1980-2000

PASSENGER SEATING CAPACIY	U.S. UNIT SALES	INTERNATIONAL UNIT SALES	TOTAL UNIT WORLDWIDE	VALUE OF SHIPMENTS $ MILLIONS[1]
15-19	1,050	1,137	2,187	3,065
20-40	898	1,098	1,996	6,895
41-60	425	790	1,215	6,685
Total All Aircraft	2,373	3,025	5,398	16,645

[1]CAA Estimated value in constant 1980 U.S. Dollars

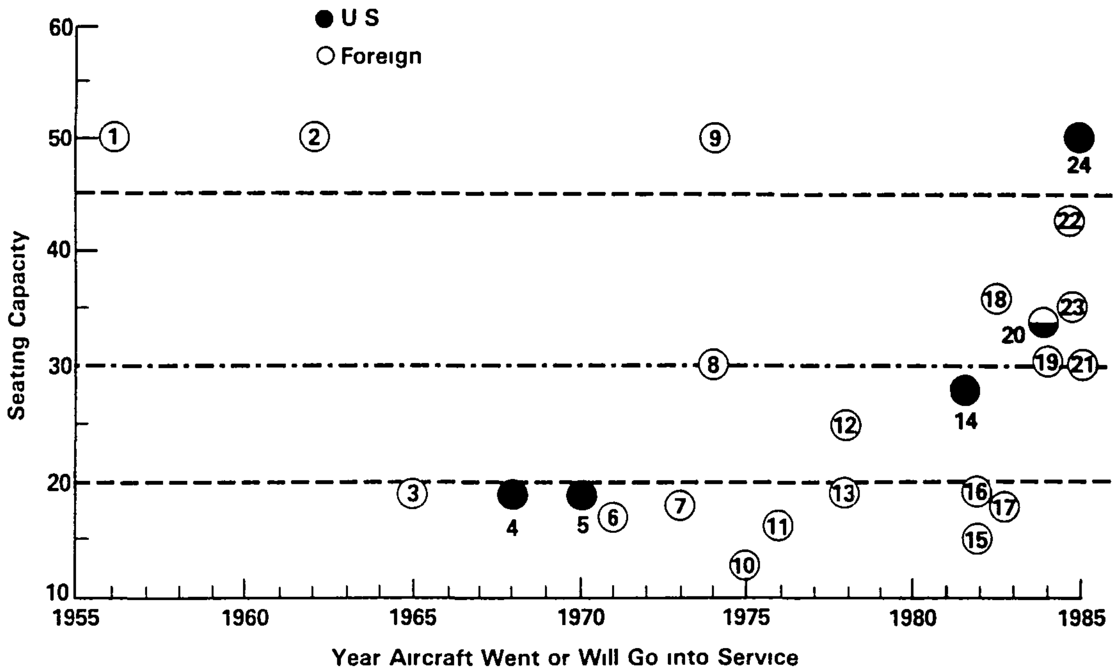
SOURCE: Light Transport Market Forecast Report prepared for the Office Of Aviation Policy, Federal Aviation Administration, Washington, D.C. by the Aerospace Corporation, July 1979.

TABLE ES.6

U.S. MARKET SHARE OF LIGHT TRANSPORT AIRCRAFT
(Percent of Total Units)

Passenger Seating Capacity	1978	1980-2000
15-19	44	48
20-40	25	45
41-60	22	35
TOTAL	28	44

SOURCE: Light Transport Market Forecast Report prepared for the Office of Aviation Policy, Federal Aviation Administration, Washington, D.C. by the Aerospace Corporation, July 1979.



1. Fokker F-27 (Netherlands)
2. BAe 748 (UK)
3. DHC-6 (Canada)
4. Beech 99 (US)
5. Metro (US)
6. BN Trislander (UK)
7. EMB 110 (Brazil)
8. SD 330 (UK)
9. DHC-7 (Canada)
10. Nomad 22B (Australia)
11. Nomad 24A (Australia)
12. CASA 212-200 (Spain)
13. Arava 101B (Israel)
14. AR 404 (US)
15. Do 228-100 (W. Germany)
16. Do 228-200 (W. Germany)
17. BAe Jetstream 31 (UK)
18. SD 360 (UK)
19. DHC-8 (Canada)
20. SF-340 (Sweden/US)
21. EMB 120 (Brazil)
22. ATR 42 (France/Italy)
23. CN 235 (Spain/Indonesia)
24. CAC 100 (US)

FIGURE ES.4. U.S. AND FOREIGN COMMUTER AIRCRAFT IN PRODUCTION OR DEVELOPMENT

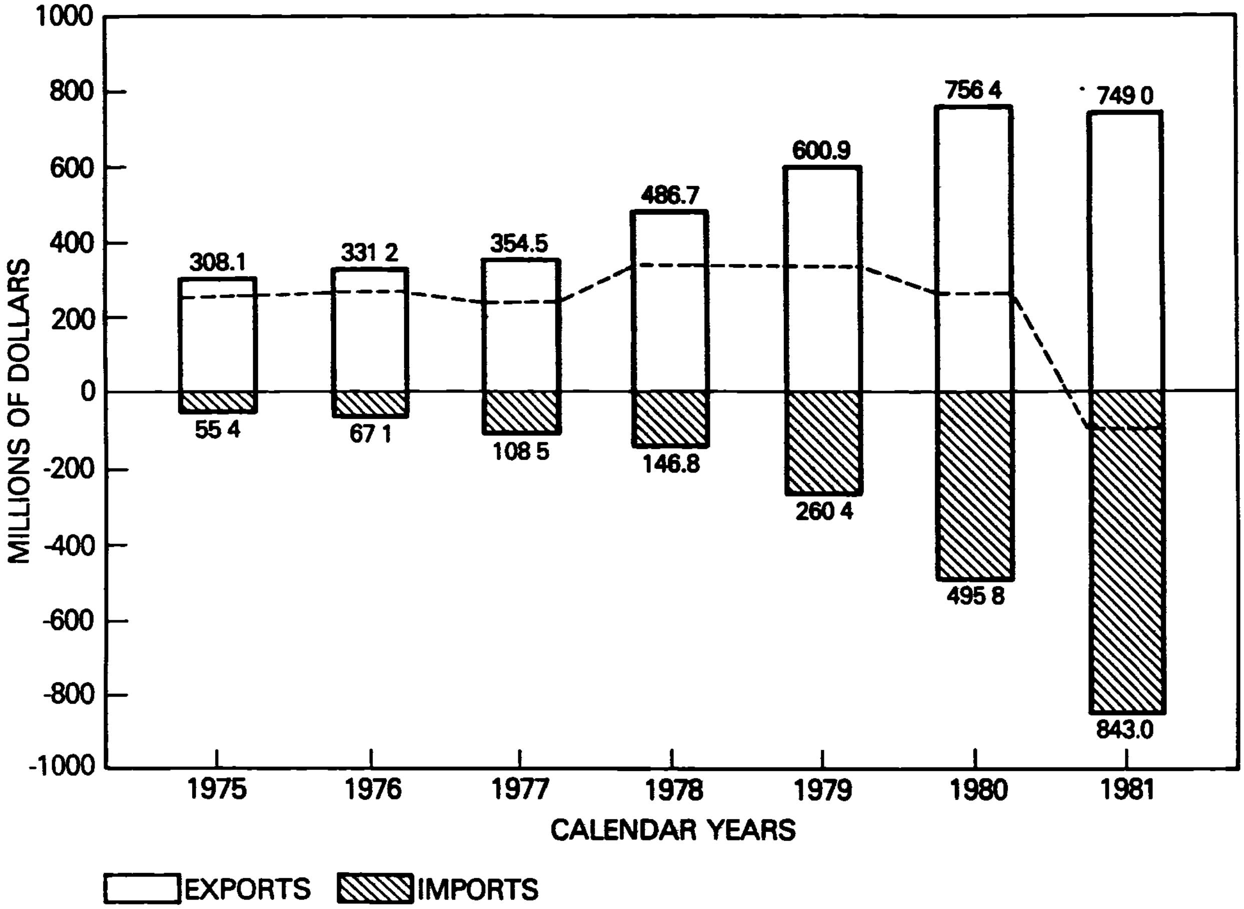
Over 90 percent of the 280,000 general aviation aircraft in the worldwide civil aircraft fleet were manufactured in the United States. In 1981, American manufacturers exported about 24 percent of the general aviation aircraft produced in the United States. The value of these general aviation exports was $749 million in 1981, a slight decrease of about one percent compared to the value of 1980 exports.

General aviation aircraft imports in 1981 reached a record level of $843 million. As indicated in Figure ES.5, general aviation exports contribute to the U.S. trade balance, but in recent years the net value of that contribution has declined from about $340 million in 1978 and 1979 to a deficit in 1981. This decline in trade balance is largely attributed to increases in imported aircraft deliveries to U.S. operators of multi-engine light transport aircraft and business jets which are the high value general aviation aircraft.

An in-depth analysis of the foreign aircraft was considered beyond the scope of this report. However a review of available literature reveals that the technology currently incorporated into the foreign built aircraft does not appear to surpass that which is now incorporated in the U.S. products. Instead, the greatest threat to the U.S. manufacturers is for markets for which the U.S. has previously offered no new developments -- e.g., the 20-40 passenger aircraft for the emerging commuter market. The most common reason given for not venturing into some of the new market areas has been the inability or unwillingness of the U.S. private sector to accept the risk -- preferring instead to stay with proven aircraft concepts or product improvements to existing designs.

U.S. MANUFACTURERS TECHNOLOGY NEEDS

The needs of the general aviation industry for new technology have been identified by industry representatives at Congressional Hearings, industry meetings and workshops. The Workshop on the Role of NASA in Aeronautics which took place at Woods Hole, Massachusetts in 1980 pointed out that the U.S. preeminence in general aviation is being seriously challenged in the 1980's. The report cited several technological developments being



Data Sources· GAMA; Aerospace Facts And Figures;
U.S. Industrial Outlook 1982

FIGURE ES.5. GENERAL AVIATION CONTRIBUTIONS TO U.S. TRADE BALANCE incorporated in the foreign designs and concluded that the U.S. must develop new technology if the U.S. general aviation industry is to produce technically superior aircraft to offset the subsidies granted the foreign manufacturers. The primary requirements for new technology for general aviation aircraft cited by the workshop are significant improvements in the areas of flight safety and fuel efficiency.

In Congressional testimony, the General Aviation Manufacturers Association has highlighted turbine engines, piston engines, propellers, spin research and low speed aerodynamics as critical areas for NASA to provide assistance to the general aviation industry. Avionics research was specifically excluded as being within its members' capability to conduct the needed research.

CAPABILITY OF U.S. MANUFACTURERS TO DEVELOP ADVANCED TECHNOLOGY IN-HOUSE

The U.S. general aviation industry has achieved a position of leadership in producing general aviation aircraft. To a large extent, this position of leadership is attributed to technical superiority achieved by its ability to effectively capitalize on NASA research results and applicable fall-out from military R&D. Further improvements are possible, however, the individual manufacturers have stated they are unable to commit adequate resources to high risk technology programs or to fulfill advanced technology needs due to their lack of the unique facilities and expertise which are available in NASA.

NASA'S ROLE IN GENERAL AVIATION

NASA is the logical organization to conduct general aviation research. It has the facilities, technical expertise and prestige necessary for such programs. Existing NASA facilities are applicable, the expertise is available in all the pertinent disciplines, and the agency has had great success in acting as a catalyst in assembling teams involving industry, government and the academic community to address specific problems of general interest.

The role of NASA in general aviation has diminished over the past few years with reductions in many of the aeronautical research programs directed specifically towards general aviation. A viable program which adequately supports the general aviation industry's needs for advanced technology is required to counter the threat from foreign manufacturers.

CONCLUSIONS

Based on the above, it is concluded that:

1. The U.S. general aviation industry provides a significant contribution to the national transportation system, the national economy, employment, and until last year, the balance of trade.

2. The preeminence of U.S. manufacturers of general aviation aircraft in world competitive markets is being eroded in the high-value business jet and light transport segments by competition from foreign manufacturers stimulated by foreign government support.

3. U.S. general aviation aircraft must incorporate advanced technology in their new developments to compete effectively for future markets at home or abroad.

4. A major problem facing the U.S. general aviation industry is an inability or unwillingness of the private sector to accept substantial risks associated with the development of advanced technology.

5. Available information does not provide a complete understanding of the U.S. general aviation industry's in-house capabilities, but it does indicate that the general aviation industry is unable to meet all of its needs for new technology in-house. Therefore, in order to meet its long term and high risk basic technology needs, this industry will require continued support from NASA's unique facilities and expertise.

6. During the past few years, NASA's aeronautics efforts directed specifically toward general aviation issues and applications have declined, and remaining efforts are not currently adequate to support all known areas of technology needs or opportunities.

7. More extensive analysis is required to fully understand the support foreign governments give to their general aviation industries and its effect on U.S. competition. More analysis is also needed to evaluate properly the factors which may limit the incorporation of advanced technology in future U.S. aircraft.

RECOMMENDATIONS

Based on the above conclusions, it is recommended that:

1. An in-depth analysis be performed of the factors which may limit the U.S. general aviation industry's future use of advanced technology. This analysis would also better identify areas of aeronautical R&T beyond the U.S. general aviation industry's capability to conduct in-house research.

2. An in-depth analysis of the foreign general aviation industry be accomplished to identify the total governmental support provided those manufacturers, the state-of-the-art of their general aviation/commuter aircraft capabilities, and a better assessment of their potential impact on the U.S. general aviation industry.

3. A comprehensive identification be made of the need for and importance of U.S. government (NASA) R&T which specifically addresses unique general aviation and commuter aircraft industry issues and potentials, and which must be supported in order for the U.S. industry to achieve healthy and competitive capabilities for the future.

I. INTRODUCTION

This report presents an analysis of current factors influencing the outlook for general aviation and commuter aircraft, provides an overview of the needs and opportunities for advanced technologies in this field of aeronautics, and addresses the role of the National Aeronautical and Space Administration (NASA) in carrying out research activities oriented toward general aviation and commuter aircraft technology. In 1976, ORI, Inc. performed a general aviation analysis which concentrated on identification of major areas of emphasis for NASA research and technology programs in general aviation.[1] Changes in the economic environment, national policies, and technology during the past six years have affected the production, use, and outlook for general aviation and commuter aircraft. Factors of increasing significance in the 1980s include the cost and availability of aviation fuels, effects of airline deregulation on commuter air carriers and other elements of general aviation, growing foreign competition in business and commuter aircraft development, and both foreign and U.S. government policies which affect general aviation.

This analysis of general aviation, including the growing segment of commuter aircraft, is provided to support continuing assessments by NASA's Office of Aeronautics and Space Technology (OAST) of factors

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[1]General Aviation Advocacy Theme, Office of Aeronautics and Space Administration, National Aeronautics and Space Administration, August 1976.

affecting the need for aeronautical research applicable to general aviation technology and related planning of research and technology (R&T) programs.

This report consists of eight chapters, including the introduction. Chapter II presents an overview of the composition of the various elements, growth, and uses of general aviation. Chapter III discusses economic factors related to general aviation. Chapter IV discusses recent accident statistics and major causes of accidents in general aviation. Chapter V discusses recently enacted government policies which impact on the planning of general aviation technology programs. The impact of increasing foreign competition on the general aviation industry in the United States is discussed in Chapter VI. This section of the report concentrates on the challenge to U.S. industry of foreign airframe manufacturers' developments in new aircraft for the commuter and business aviation markets. Chapter VII discusses the technology needs of U.S. manufacturers, their capabilities to conduct needed research and development in-house, and perceptions on NASA's role in general aviation technology. Conclusions and recommendations are presented in Chapter VIII.

II. MAJOR ELEMENTS IN GENERAL AVIATION

COMPOSITION OF GENERAL AVIATION

As illustrated in Figure 2.1, general aviation is a broad classification which encompasses all civil aviation activities except those of the certificated air carriers of the nation's commercial airlines. The wide spectrum of elements that make-up general aviation includes scheduled air transportation services by commuter airlines, air taxi services and rental aircraft, business aviation, agricultural aviation, pilot training, and all aspects of personal flying.

The types of aircraft used in general aviation activities also cover a wide operational spectrum from multi-engine jet-powered aircraft piloted by professional crews to amateur-built single-engine, piston-powered sport airplanes. Some elements of general aviation also use rotorcraft, but the scope of this report is limited to fixed-wing aircraft. Presently, the active general aviation fleet of over 200,000 airplanes accounts for about 98 percent of the active civil airplanes registered in the United States. A large majority of these aircraft are single-engine piston aircraft which comprise about 84 percent of the general aviation fixed-wing fleet. Higher performance and more costly multi-engine piston and turbine powered aircraft comprise the other 16 percent of the fleet. Table 2.1 presents annual estimates by aircraft categories for the period 1975-1993.

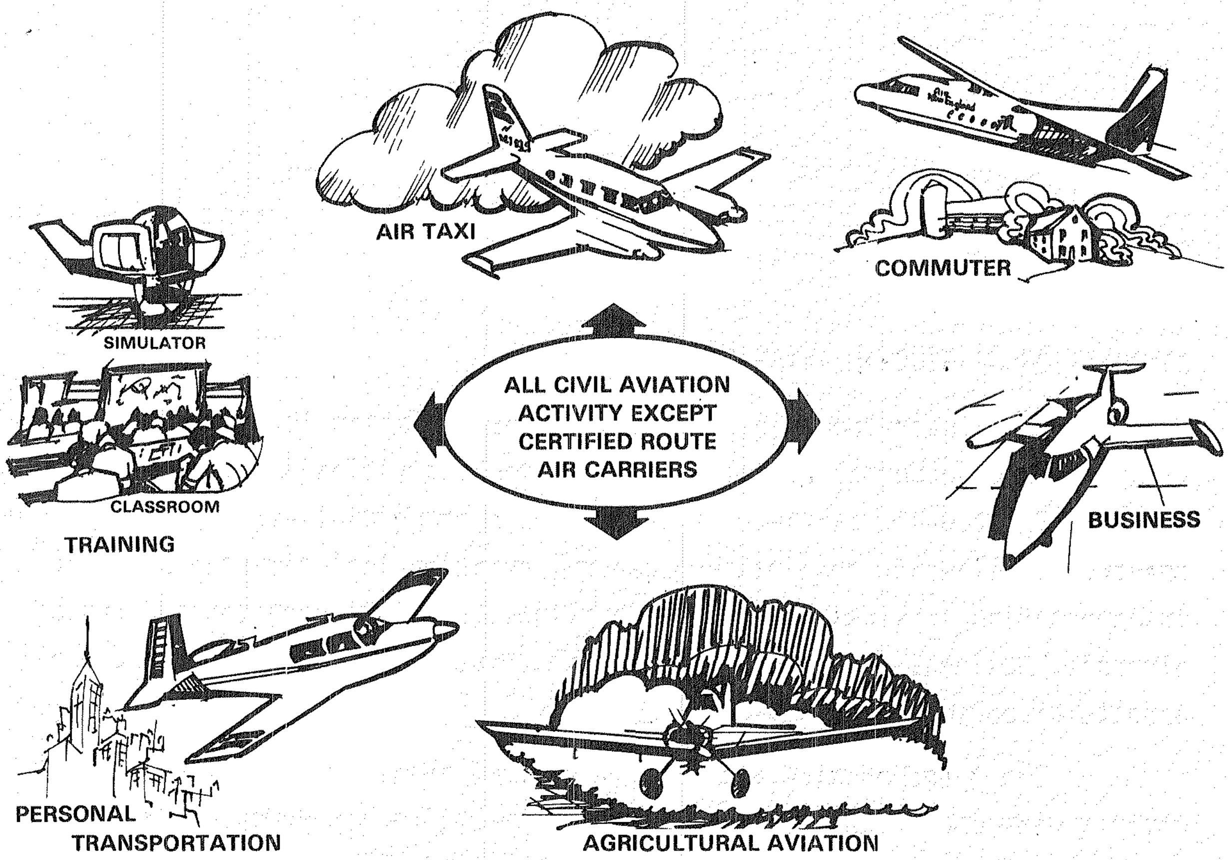

FIGURE 2.1. MAJOR ELEMENTS IN GENERAL AVIATION

TABLE 2.1

ESTIMATED U.S. GENERAL AVIATION ACTIVE FIXED WING AIRCRAFT
BY AIRCRAFT CATEGORY
(Number in Thousands)

Year as of January 1	Total Fixed Wing	Piston Powered		Turboprop	Turbojet
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<u>Forecast</u>					
1982	208.6	173.9	26.6	4.8	3.3
1983	214.2	178.0	27.6	5.2	3.4
1984	220.5	182.7	28.6	5.6	3.6
1985	228.3	188.9	29.6	6.0	3.8
1986	236.3	195.2	30.7	6.4	4.0
1987	245.8	203.0	31.8	6.8	4.2
1988	255.9	211.2	33.1	7.2	4.4
1989	268.0	221.1	34.6	7.6	4.7
1990	282.5	233.0	36.4	8.0	5.1
1991	298.2	245.8	38.4	8.5	5.5
1992	314.3	259.0	40.4	9.0	5.9
1993	330.9	272.7	42.4	9.5	6.3

SOURCE: FAA

E - Estimate

GROWTH OF GENERAL AVIATION

General aviation is growing. Figure 2.2 shows the growth in the aviation fleet and annual hours flown for calendar years 1975-1981. The need for versatile and time efficient transportation is certainly a major factor in the growth of general aviation. It contributes to meeting this need through a variety of operators with access to nearly 13,000 landing facilities (including airports, stolports, and seaplane bases) within the United States and many more in other countries. At the end of 1980, there were 12,788 airports in the United States on record with the FAA.[2] About 32 percent of these airports are publicly owned. Over 5,000 airports have runway lengths of 3,000 feet or more and about 500 have air traffic control towers.

The Federal Aviation Administration estimates that general aviation aircraft (including commuters and air taxis) accounted for about 84 percent of the 59 million civil aircraft operations (landings and takeoffs) conducted during fiscal year 1981 at airports with FAA control towers.[3] In addition, it is estimated that about twice as many more general aviation operations were conducted at the many nontowered airports used by general aviation aircraft. Total civil aviation operations at airports with FAA control towers are expected to increase about 79 percent to 107.9 million operations in fiscal year 1993. During the 1981-1993 time period, general aviation operations (including commuters and air taxis) are expected to increase from 49.5 million operations to 96.2 million operations annually, comprising about 95 percent of the expected growth in civil aircraft operations at airports with FAA traffic control services.

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[2] FAA Statistical Handbook of Aviation, Calendar Year 1980.

[3] FAA Aviation Forecasts, Fiscal Years 1982-1983, FAA, February 1982.

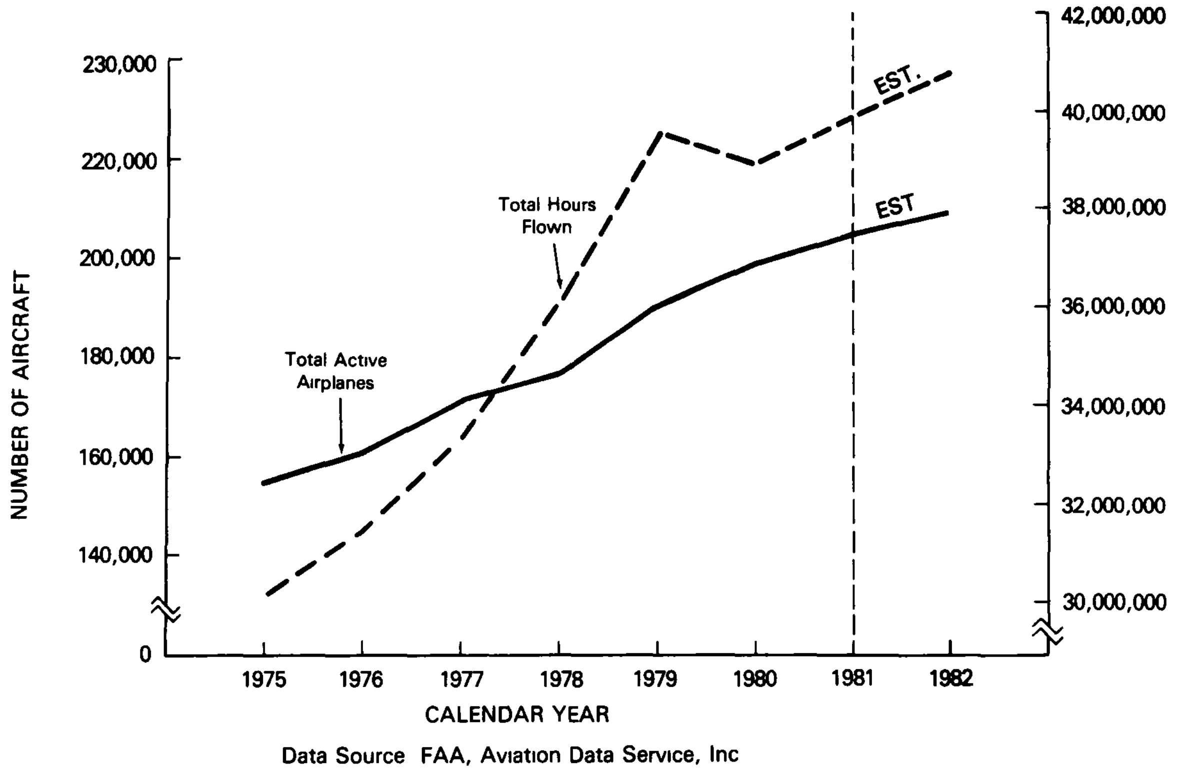

FIGURE 2.2. GROWTH OF GENERAL AVIATION FLEET AND ANNUAL HOURS FLOWN, 1975-1982

USES OF GENERAL AVIATION

General aviation is a diversified industry which includes business, commercial and personal flying. As shown in Figure 2.3, the major uses of general aviation are for business and commercial purposes. Each of the segments of general aviation flying are discussed below.

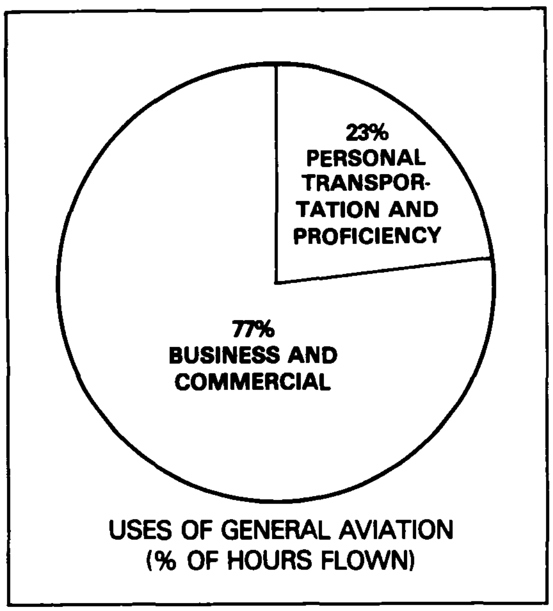

FIGURE 2.3. MAJOR USES OF GENERAL AVIATION

Business Aviation

Business flying, which includes all not-for-hire general aviation operations conducted for business reasons, constitutes the largest segment of general aviation flying. It accounted for about 34 percent of the hours flown in 1980.[4] There are over 62,000 aircraft operated primarily for business reasons. About 22 percent of these business aircraft are corporate aircraft operated by professional crews. Business flying in general aviation aircraft provides flexible air transportation, time and fuel efficient direct routings, and access to many communities that lack adequate airline services.

In 1980, the over 62,000 business aircraft were operated by 36,000 companies. According to the National Business Aircraft Association (NBAA) a majority of the leading industrial companies in the United States operated aircraft as company owned and/or operated transportation vehicles dedicated to business activities.[5] These aircraft range in size from small single-engine piston-powered aircraft to large multi-engine jet transports. Two-thirds of the aircraft are single-engine piston-powered aircraft. While some large corporations operate several aircraft (the highest is 38), more than 60 percent of the 2,500 member companies of NBAA operate one aircraft. The company owned and/or operated aircraft is viewed by the business aviation industry as a practical business investment to provide on-demand transportation services which save time, improve efficiency, and reduce transportation costs.

Table 2.2 presents the number of business aircraft in service for years 1975-1980. The four-seat or more single-engine piston-powered airplane comprises the largest (over half) category of business aircraft, however, the highest rate of growth has been in multi-engine turbine-powered aircraft. During this six-year period the number of turboprop aircraft has doubled and the number of business jets has increased by 97 percent.

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[4] General Aviation Activity and Avionics Survey, Annual Summary Report, (1980 Data), Report No. FAA-MS-81-5, Federal Aviation Administration, December 81.

[5] Business Flying, 1982-Section 1, National Business Aircraft Association, Inc.

TABLE 2.2

NUMBER OF FIXED-WING BUSINESS AIRCRAFT IN SERVICE
BY CALENDAR YEARS 1976-1980

Aircraft Category	1975	1976	1977	1978	1979	1980	6-Year % Change
Single Engine Piston 1 to 3 seats (% of Fleet)	3,532 (7.2)	3,377 (6.5)	3,506 (6.3)	4,386 (8.1)	5,336 (8.7)	4,985 (8.0)	+41%
Single Engine Piston 4 Seats and Over (% of Fleet)	30,428 (62.1)	32,060 (61.4)	34,094 (61.2)	30,378 (56.2)	36,128 (58.6)	36,589 (59 0)	+20%
Multi-Engine Piston (% of Fleet)	12,273 (25.1)	13,193 (25.2)	14,055 (25.2)	14,840 (27.4)	15,277 (24.8)	14,988 (24.1)	+22%
Turboprops (% of Fleet)	1,508 (3.1)	1,942 (3.7)	2,138 (3.9)	2,500 (4.6)	2,800 (4 5)	3,020 (4.9)	+100%
Turbojet/Fan (% of Fleet)	1,249 (2.5)	1,666 (3 2)	1,914 (3.4)	2,028 (3.7)	2,075 (3.4)	2,460 (4.0)	+97%
Total No Aircraft	48,990 (100%)	52,238 (100%)	55,707 (100%)	54,132 (100%)	61,616 (100%)	62,042 (100%)	+27%

Data Source 1978-1980, General Aviation Activity and Avionics, FAA
1975-1977, Aviation Data Service, Inc.

The continued growth in business aviation can be attributed to several factors. Some of the key factors are:

- Industrial decentralization
- Time-efficient, on-demand air transportation
- Effects of deregulation on airline services
- Cost effectiveness of company airplanes.

Industrial Decentralization. For the period 1975-1980, more than 1,000 new planes were located in small communities remote from convenient ground access to the nation's principal transportation hubs. This continuing trend of industrial decentralization to smaller cities and towns is attributed to local government industrial tax incentives, lower investment costs, availability of high quality labor, attractive living environment, and mobility provided by private as well as public conveyances. An important factor in industrial site selection is convenient access to air transportation facilities for business aviation, commercial airlines or both. With greater industrial decentralization the use of a company airplane for business travel becomes an attractive business investment. The business community points out that business aviation can make it possible to bring industrial prosperity to communities remote from principal distribution and communication centers.[6]

Time Efficient Transportation. The company airplane is a flexible business tool that can save time on required business travel. It provides both route and schedule flexibility to meet management priorities for "on-demand" place-to-place transportation.[7]

Effects of Airline Deregulation. Scheduled airline services are attracted to high density routes to facilitate aircraft utilization with high load factors. With airline deregulation the certificated airlines have reduced air services to many communities. Essential air services to small communities are being continued to a large extent by commuter airlines. The effects of these adjustments to commercial airline service patterns appear to be influencing some companies towards expanded use of company aircraft for business travel. The convenience of timely point-to-point flights to a wide variety of airports provides incentives

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[6]Background Report: Business Aviation, National Business Aircraft Association, Inc., January 1981.

[7]Ibid.

for business aviation. But, business aircraft are also extensively used to interconnect passengers with scheduled air carrier services at air transportation hubs. Industry estimates indicate that about 30 percent of all business flights are conducted for this purpose.[8]

Cost Effective Transportation. In 1980, 541 of the 1,000 largest industrial companies identified by Fortune magazine operated business aircraft. At the beginning of 1981, this business fleet had a total of 2,012 aircraft valued at $3.21 billion. Compared to 1979, there was an increase of seventeen companies and 170 aircraft.[9] This growth in the size of the business aircraft fleet (see Table 2.3) and trends toward turbine-powered aircraft give some indication of the cost-effectiveness of these aircraft. An analysis by NBAA of the top 1,000 industrial companies reveals that the 541 companies which operate aircraft out performed the 459 non-operators in such categories as employees, net sales, assets, stockholders equity and net income. NBAA cautions that the use of aircraft is not the only measure of success in business, but notes that those companies which use aircraft do fare better than those companies that do not use aircraft, by whatever standard of measurement is used.[10]

Commercial Air Transportation

Commercial air transportation activities, which include air taxi and commuter airline operations, accounted for about 11 percent of the general aviation hours flown in 1980. These carriers are required to register with the Civil Aeronautics Board (CAB) as commercial operators, but primarily operate small transport aircraft exempted from the CAB certification required for large transports (over 60 passenger seats).

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[8] Ibid.

[9] "Business Aviation and the FORTUNE 1,000 Industries 1980", Business Flying, 1982-Section 1, National Business Aircraft Association, Inc.

[10] "Leading Industrial Aircraft Analysis, the FORTUNE 1,000: 1978 Update", Business Flying, 1980-Section 1, National Business Aircraft Asso., Inc.

Air taxi operators provide services on demand in response to special flight requests. It is estimated that they provided transportation services for about five million passengers in 1980.[11] Most of the aircraft used for air taxi services are small single-engine piston and light twin-engine piston aircraft with less than 10 seats.

The commuter airlines (now termed regional airlines) provide regularly scheduled services. Their route structurers primarily provide connecting services on low-density shorthaul routes from outlying communities to hub air carrier airports in the air transportation system. A typical stage length is a distance of 100 to 300 miles and the route is flown between 5,000 and 14,000 feet predominantly in multi-engine light transport aircraft. Nearly 75 percent of the available seating capacity in the commuter fleet is provided by turbine-powered aircraft which seat 10 or more passengers.[12] Commuter passenger traffic in 1981 was about 12.9 million passenger enplanements.[13]

Although over half (56%) of the commuter airline fleet is piston-powered single-engine and twin-engine aircraft, the trend is toward large capacity multi-engine turboprop aircraft. Table 2.3 lists the top ten aircraft models in the 1981 passenger fleet in terms of commuter airline available seat capacity. The top ten models in all cargo service are listed in Table 2.4 in terms of numbers of aircraft. All-cargo carriers may operate aircraft up to 18,000 pounds payload under Part 298 regulations without route restrictions. They may also operate larger aircraft under a Section 418 certificate established by the Deregulation Act but must comply with additional CAB reporting requirements.

As shown in Figures 2.4 and 2.5 the commuter air carriers have experienced consistent growth in both passenger enplanements and cargo

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[11] "NATA's Burian Eyes the Future for Commercial Operators", Business and Commercial Aviation, 1981 Planning and Purchasing Handbook, April 1982, p. C11.

[12] 1981 Annual Report, Regional/Commuter Airline Industry, Regional Airline Association, February 1982.

[13] FAA Aviation Forecasts, Fiscal years 1982-1993.

TABLE 2.3

REGIONAL/COMMUTER PASSENGER AIRCRAFT FLEET IN 1981

TOP TEN MODELS* (B/CA EQPD PRICE)*	TYPE AIRCRAFT	PASSENGER CAPACITY	DATE OF INITIAL PRODUCTION	PERCENT OF TOTAL COMMUTER INDUSTRY SEAT CAPACITY	TOTAL COMMUTER AIRCRAFT IN U.S. OPERATIONS	
1. Swearingen Metro ($1,845,500)	Twin Turbo-prop	19 (Pressurized)	1970	14.0%	135	
2 De Havilland Twin Otter ($1,170,000)	Twin Turbo-prop	19	1966	9.6%	102	
3 De Havilland Dash 7 ($5,020,000)	Multi-Eng Turboprop	50 (Pressurized)	1977	9.1%	30	
4 Shorts 330 SD3-30 ($2,870,000)	Twin Turbo-prop	30	1976	9 0%	51	
5. Beech 99 ($1,335,000)	Twin Turbo-prop	15	1968	8 3%	106	
6 Embraer Bandeirante ($1,495,998)	Twin Turbo-prop	18 (Pressurized)	1973	6 6%	65	
7 Convair 580/ 600	Twin Turbo-prop	40 (Pressurized)	1965	5 9%	33	
8. Fokker F-28, MK4000 ($10,550,000)	Twin-Jet	85 (Pressurized)	1976	4 7%	9	
9. Piper Navajo (PA-31) ($377,620)	Twin Piston	8	1966	4 3%	170	
10 Cessna 402 ($333,606)	Twin Piston	8	1964	4 0%	162	
Total Top Ten Aircraft (By Seats In Service)				75.5%	863	(59%)
Misc. Others* (Includes 20 Helicopters)				24 5%	600	(41%)
TOTAL All Passenger Aircraft (Includes 20 Helicopters)				100%	1463	(100%)

*Notes (1) Ten Top Models are rank by total available passenger seats provided by the Regional/Commuter Airline Industry

(2) B/CA EQPD Price - Business and Commercial Aviation, 1981 Planning and Purchasing Handbook, April 1981

(3) Misc Others 195 Single-Engine Piston, 296 Multi-Engine Piston, 84 Turboprop and 5 Jet aircraft plus 20 helicopters by the following manufacturers Aerospatiale (19), Augusta (3), Beech (38), Bell (10), Bellanca (1), British Aerospace (20), Britten Norman (56), Cessna (175), CASA (11), Convair (8), de Havilland (35), Dornier (3), Douglas (30), Enstrom (1), Fokker/Fairchild (13), Gov't. Aircraft Factories (10), Grumman (16), Helio (2), Lear (4), Martin (19), Mooney (1), Nihon (7), North American Rockwell (8), Piper (106), Shorts (1) and Sikorsky (3)

Source RAA 1981 Annual Report, Regional/Commuter Airline Industry

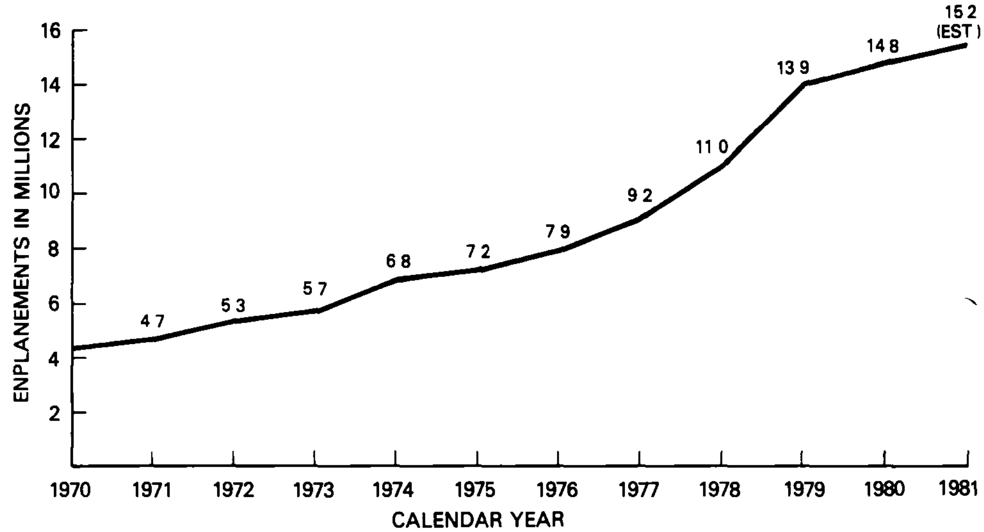
TABLE 2.4

COMMUTER CARGO FLEET IN 1981

TOP TEN AIRCRAFT MODELS*	NUMBER IN FLEET
1. Beech 18	45
2. Convair 580/600	28
3. Douglas DC-3	17
4. Cessna 402	15
5. Aero Commander 680FL	14
6. Nihon YS-11	14
7. Piper Navajo	13
8. Convair 240	12
9. Cessna 207/208	12
10. Piper Cherokee 6 Series	9
Total: Top Ten Models	179 (64%)
Other: Misc. Aircraft	101 (36%)
TOTAL: All Cargo Aircraft	280 (100%)

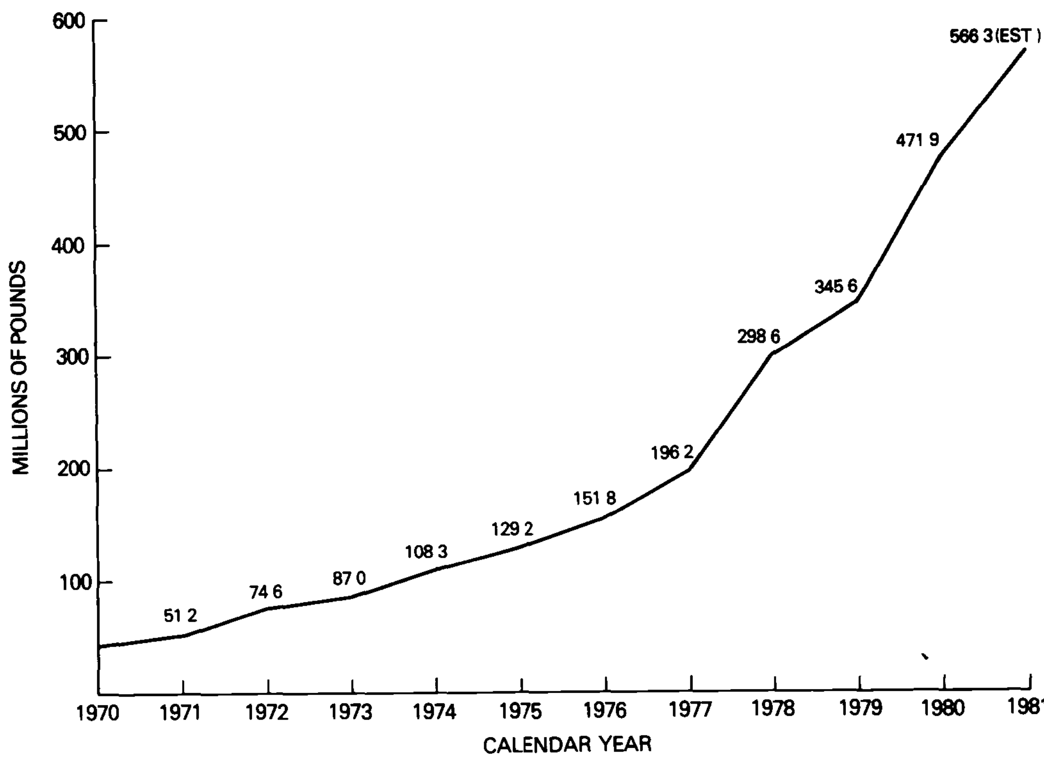
SOURCE: RAA 1981 Annual Report, Regional/Commuter Airline Industry

*Top Ten Models ranked by number in all cargo fleet.



Source Regional Airline Association
1981 Annual Report

FIGURE 2.4. COMMUTER PASSENGER ENPLANEMENTS 1970-1981



Source Regional Airline Association 1981 Annual Report

FIGURE 2.5. COMMUTER CARGO LOADINGS 1970 - 1981

during the past decade. Under deregulation, the commuter airlines have an increasingly important role in providing essential air services to small communities where air services are being abandoned by trunk and local services air carriers equipped with larger jet transport aircraft. The long-term outlook is that commuter passenger enplanements and revenue passenger miles will more than double over the next 10 years to 32 million passenger enplanements and 5.2 billion revenue passenger miles in 1992.[14] The growth in cargo carried is also forecast to double over the next ten years.[15]

Other Commercial Uses

Other commercial flying activities in general aviation include instructional, industrial, and agricultural uses (e.g., aerial applications) and rental aircraft. These uses and other special purpose flights, (e.g., R&D, air shows, sales) are primarily conducted in single-engine aircraft. Most of the flight hours involved rental aircraft (9.7 percent) and instructional flying (14.5 percent).

Personal Use

Personal flying, which includes pilot proficiency and personal transportation comprises another major segment of general aviation. In 1980, personal transportation and proficiency flying accounted for about 23 percent of all general aviation flying. About 95 percent of the aircraft operated for these functions are single-engine piston aircraft. Personal flying increased at an average annual rate of about 4.4 percent to about 9.4 million hours in 1978 but subsequently has declined to 8.7 million hours in 1980.[16] This decrease has been attributed to the increased cost of aviation gasoline and the recession.

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[14] FAA Aviation Forecasts, Fiscal Years 1981-1993.

[15] Commuter Airline Forecast, Final Report, FAA, May 1981.

[16] General Aviation Activity and Avionics Survey, FAA, Op. Cit.

III. ECONOMIC FACTORS IN GENERAL AVIATION

GENERAL AVIATION EMPLOYMENT

General aviation is a large, highly diversified industry which collectively produces an annual contribution of about 10 billion dollars to the national economy. In the aggregate, general aviation employment totals over 300,000 people. According to industry estimates, this total includes 80,000 people in sales and services, 20,000 engaged in agriculture flying, 45,000 in corporate flight departments, and 15,000 in industrial uses such as aerial mapping and surveillance. Self-employed instructors and mechanics are estimated to number about 15,000. On the manufacturing side, 60,000 are employed in manufacturing aircraft and its equipment components and 65,000 others are engaged in producing materials and subcomponents (e.g., aluminum, fuel, oil, and brakes, tires and wheels) used in general aviation aircraft.[17] The total annual earnings of these 300,000 employees are about $6.5 billion based on an average annual earnings per full-time employee in the Air Transportation Sector of $21,711.[18]

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[17] The General Aviation Story, General Aviation Manufacturers Association, 1980.

[18] National Transportation Statistics, U.S. Department of Transportation, Research and Special Projects Administration, September 1980, page 70.

AIRCRAFT PRODUCTION AND SALES

Trends in shipments and sales of general aviation fixed-wing aircraft by U.S. manufacturers are presented in Figures 3.1 and 3.2. In 1981, the market continued to decline by about 20 percent in total shipments to 9,457 units compared to 11,877 units in 1980, but total factory net billings increased to a record high of $2.92 billion. This variance in market trends reflects the change in aircraft sales. Lower sales of the small less expensive aircraft are being offset by growing sales of higher priced turbine-powered aircraft. Since the 1978 production peak of 17,811 general aviation aircraft there has been a significant drop in the market for single-engine piston and light twin-engine piston aircraft. Single-engine aircraft deliveries in 1981 of 6,268 units were about 54 percent below 1978 peak-year shipments of 13,651 single-engine units. The industry attributes the sharp decline in sales of the smaller, personal use type aircraft to high interest rates, business recession and higher energy costs.

Table 3.1 presents a summary of 1981 shipments and billings of general aviation aircraft by manufacturer and type of aircraft. GAMA estimates that total factory billings in 1982 will increase to $3.2 billion for delivery of 8,200 aircraft in all categories.[19] Based on actual 1982 factory deliveries through August of 3,110 units and billings of $1.3 billion, it now appears that full year deliveries will be lower than the GAMA forecast and may fall below a total of 5,000 units and $2.0 billion for 1982.

In contrast to the decline in sales of the small piston airplanes, sales of the larger, higher-value turbine-powered aircraft continued to grow in 1981. Shipments of 198 turboprop aircraft in 1981 by U.S. manufacturers was an increase of about 15 percent over 1980 shipments. Deliveries of jet aircraft also increased by about 19 percent to 389 units. Annual shipments by U.S. manufacturers of turbine-powered business aircraft are expected to increase to about 2,300 units by 1985 and have a sales value of about $3.3 billion.[20]

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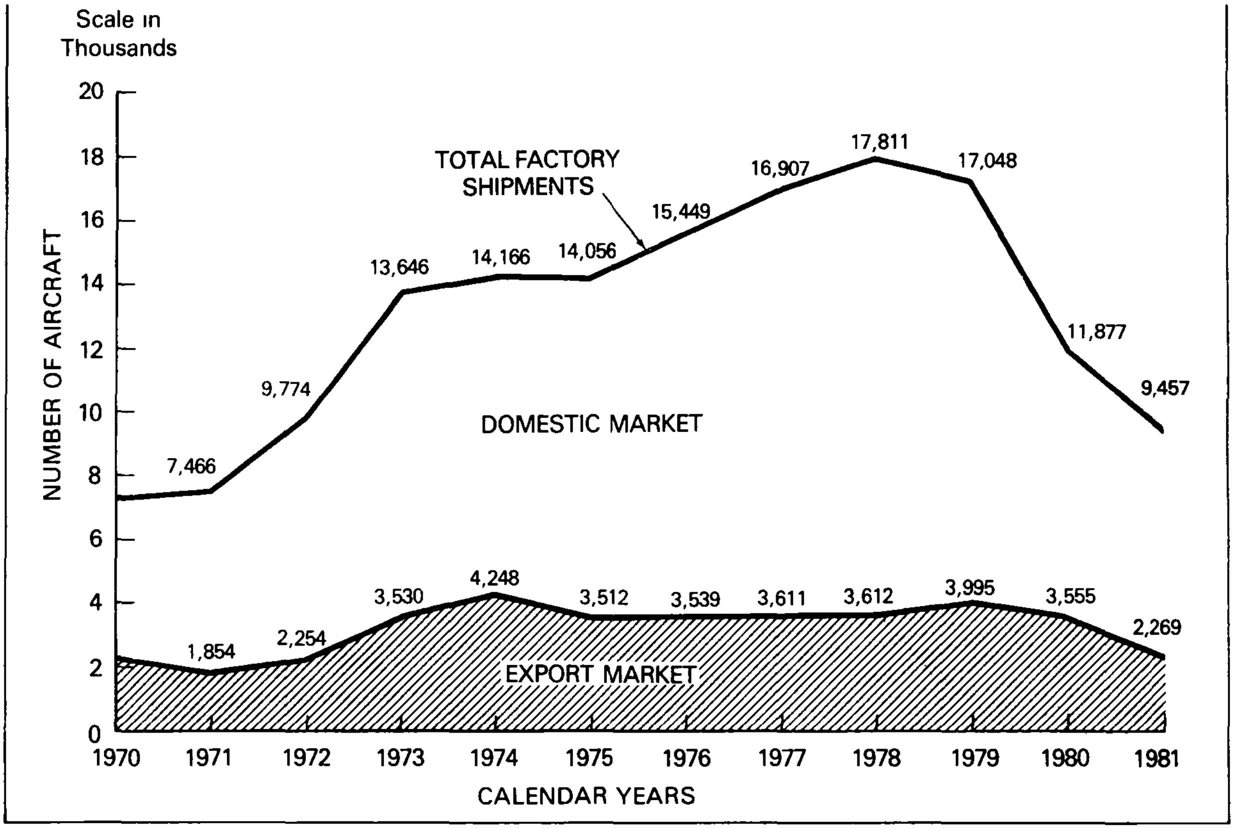
[19] Edward W. Stimpson, President of GAMA, Remarks before the New York Society of Security Analysts, January 4, 1982.

[20] John H. Winant, President of NBAA, Remarks at the International Aerospace Symposium, Le Bourget Airport, Paris, France, June 3, 1982, "An Overview of General Aviation and the Future of the Business Aircraft."



Source GAMA

FIGURE 3.1. U.S. GENERAL AVIATION AIRCRAFT
UNIT SHIPMENTS 1970-1981

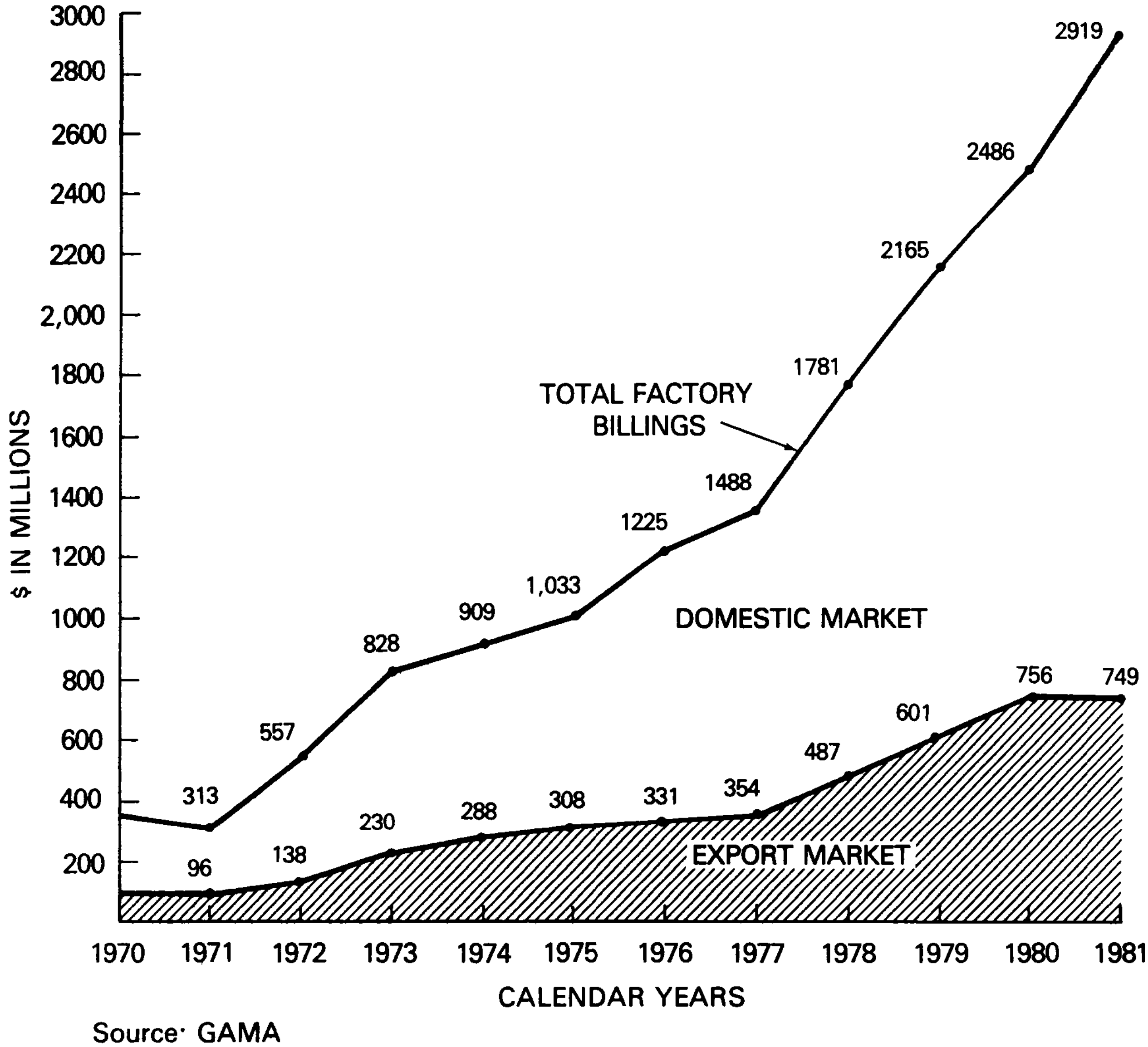


FIGURE 3.2. U.S. GENERAL AVIATION AIRCRAFT FACTORY SALES 1970-1981

TABLE 3.1

SUMMARY OF 1981 SHIPMENTS AND BILLINGS OF
BUSINESS AND UTILITY FIXED-WING AIRCRAFT
U.S. MANUFACTURERS

AIRCRAFT MANUFACTURERS	SINGLE-ENGINE PISTON	MULTI-ENGINE PISTON	AG AIR	TURBO-PROP	JET	TOTAL NUMBER OF UNITS	FACTORY NET BILLINGS (ROUNDED IN MILLIONS)
U S Industry *	6,336	1,542	272	918	389	9,457	$2,920.0M
Ayres	0	0	59	0	0	59	8.7
Beech	5.5	319	0	408	0	1,242	619.7
Cessna	3,698	484	137	165	196	4,680	895.7
Gates Learjet	0	0	0	0	138	138	436.0
Gulfstream Am.	121	2	44	91	26	284	303.8
Lake	52	0	0	0	0	52	4.2
Maule	44	0	0	0	0	44	1.8
Mooney	330	0	0	0	0	330	Not Available
Piper	1,576	737	24	158	0	2,495	368.8
Rockwell Int.	0	0	0	11*	29	40	150.8
Schweizer	0	0	8	0	0	8	0.7
Swearinger	0	0	0	85	0	85	129.8

*Cessna and Piper deliveries and billings include aircraft kits shipped to foreign manufacturers under co-operative production agreements

SOURCE GAMA

The continuing growth in sales of turboprop and jet aircraft is attributed to a strong business aircraft market and growth in commuter airlines. According to GAMA, purchases (including leases) of general aviation aircraft for business purposes account for at least 90 percent of current industry sales. The key reasons attributed to the continued growth in sales for business aviation are dispersal of company plants to smaller communities; need for flexible travel schedules; effect of airline deregulation on airline services and cost efficiency of using business aircraft as a selected mode of transportation for business travel.[21]

FUEL PRICES AND DISTRIBUTION

Current prices for aviation fuels are over four times the average fuel prices in the early 1970's and have more than doubled since 1978. The 10-year trends in average prices for aviation gasoline and Jet A fuel are shown in Figure 3.3. The average retail price in 1978 was about 91 and 79 cents per gallon for 100 octane aviation gasoline and Jet A fuel respectively. According to fuel surveys by the Aircraft Owners and Pilots Association (AOPA) the average retail price in 1981 was $1.92 per gallon for 100 octane aviation gasoline and $1.70 per gallon for Jet A fuel.

In addition to steep increases in fuel prices in recent years, the availability of ample supplies of aviation gasoline has been a concern to general aviation. Spot shortages occur occassionally at some general aviation airports which do not have large storage facilities. More or less chronic shortages of aviation gasoline are expected to become a growing problem at the smaller general aviation airports.[22]

The relatively small market and high production costs for aviation gasoline are key factors which contribute to the supply and distribution problems. The demand for aviation gasoline amounts to only one-half

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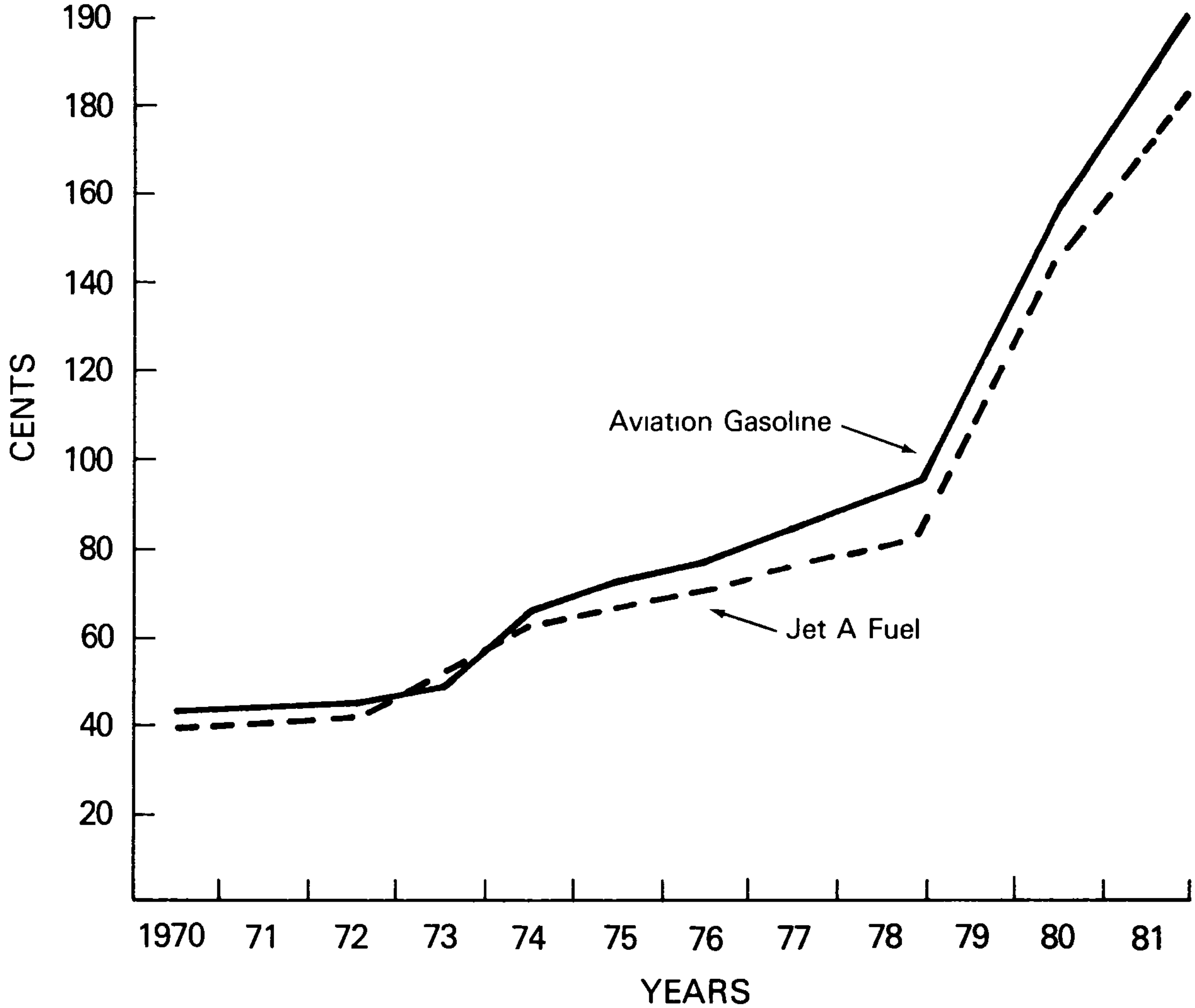
[21] Russell W. Meyer, Jr., Vice Chairman of GAMA, Chairman and President of Cessna Aircraft Co., Remarks before the New York Society of Security Analysts, January 16, 1981.

[22] Airport Services Management, June 1981, page 16.



Source Aviation Data Service, Inc.

FIGURE 3.3. TRENDS IN AVIATION FUEL PRICES

of one percent of the nation's annual usage of all types of gasoline and accounts for only four percent of the domestic consumption of aviation fuels.[23] The relatively low market demand and higher refining costs for aviation gasoline, as compared to jet fuels and automotive gasoline, has resulted in the major oil refiners producing limited supplies for this thin, widely scattered market. This has raised a critical concern to the general aviation industry that its future growth may be constrained by inadequate fuel supplies to meet future demand at reasonable prices. As such, there is a critical need to seek a suitable substitute fuel for aviation gasoline as well as to develop new engine technology for the smaller, piston-powered aircraft segment of the general aviation market.

[23] National Transportation Statistics, Annual Report, September 1980, Research and Special Projects Administration, Transportation Systems Center, Cambridge, MA, page 144.

IV. SAFETY FACTORS IN GENERAL AVIATION

INTRODUCTION

Continued improvements in flight safety are important considerations in planning research and technology programs for general aviation. This section discusses safety factors in general aviation in terms of recent accident statistics and the major causes of accidents.

ACCIDENT STATISTICS

In 1981, the National Transportation Safety Board (NTSB) reported commuter air carrier and on-demand air taxi accidents as separate categories from general aviation.[24] Accident statistics on commuter air carrier, air taxi, and general aviation are presented in Tables 4.1, 4.2 and 4.3, respectively.

In 1981, the commuter air carriers had a total of 28 accidents which included 9 fatal accidents involving 35 fatalities. This resulted in 1981 accident rates of 2.59 accidents per 100,000 aircraft hours flown and 1.64 accidents per 100,000 departures for all scheduled services. Comparable rates over the reported five-year period ranged from a high of 55 accidents in 1978 resulting in rates of 4.27 per 100,000 aircraft hours and

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[24] NTSB Safety Information, SB 82-4, National Transportation Safety Board, January 28, 1982.

TABLE 4.1

ACCIDENTS, FATALITIES AND RATES
COMMUTER AIR CARRIERS[1]
1977 - 1981

Data Element	CALENDAR YEARS 1977	1978	1979	1980	1981
Accidents					
Total	42	55	51	37	28
Fatal	9	13	14	7	9
Fatalities	33	47	65	36	35
Aircraft Hours Flown	1,143,651	1,288,480	1,261,500	1,263,200	1,082,600
Departures	1,728,948	1,978,483	2,005,800	1,895,400	1,708,800
Accident Rate Per 100,000 Hours Flown					
Total	3.67	4.27	4.04	2.93	2.59
Fatal	0.79	1.01	1.11	0.55	0.83
Accident Rate Per 100,000 Departures					
Total	2.43	2.78	2.54	1.95	1.64
Fatal	0.52	0.66	0.70	0.37	0.53

[1]Includes all scheduled service under Part 135, Federal Air Regulations.
All 1981 data is preliminary.

SOURCE: National Transportation Safety Board, January 28, 1982.

TABLE 4.2

ACCIDENTS, FATALITIES, AND RATES
ON-DEMAND AIR TAXIS[1]
1977 - 1981

ACCIDENTS					ACCIDENT RATES PER 100,000 AIRCRAFT HOURS FLOWN	
YEAR	TOTAL	FATAL	FATALITIES	AIRCRAFT HOURS FLOWN	TOTAL	FATAL
1977	175	35	122	3,063,749	5.71	1.14
1978	216	57	160	3,135,121	6.89	1.82
1979	173	36	84	3,373,901	5.13	1.07
1980	164	42	88	3,535,466	4.64	1.19
1981P	138	34	95	3,690,000	3.74	0.92

P Preliminary Data

1 Includes non-scheduled operations by on-demand air-taxi aircraft.

SOURCE: National Transportation Safety Board, January 28, 1982.

TABLE 4.3

ACCIDENTS, FATALITIES, RATES
U. S. GENERAL AVIATION[1]
1972 - 1981

ACCIDENTS					ACCIDENT RATES PER 100,000 AIRCRAFT HOURS FLOWN	
YEAR	TOTAL[2]	FATAL[2]	FATALITIES	AIRCRAFT[4] HOURS FLOWN	TOTAL	FATAL
1972	4109	653	1305[3]	24,419,000	16.8	2.67
1973	4090	679	1299	26,907,800	15.2	2.52
1974	4234	689	1327	27,773,500	15.2	2.47
1975	4034	638	1247	28,335,700	14.2	2.24
1976	4005	648	1187	29,975,200	13.3	2.15
1977	4069	658	1281	31,584,600	12.9	2.08
1978	4223	723	1563[3]	34,985,399	12.1	2.07
1979	3800	629	1219	38,767,481	9.8	1.62
1980P	3599	629	1264	37,480,076	9.6	1.68
1981P	3634	662	1265	36,280,000	10.0	1.82

P Preliminary Data

1 Table does not include accidents for Air Taxi and Commuter Air Carrier aircraft.

2 Suicide/sabotage accidents included in all computations except rates (1972-3, 1973-2, 1974-2, 1975-2, 1976-4, 1977-1, 1978-2, 1979-0).

3 Includes air carrier fatalities (1972-5, 1978-142) when in collision with General Aviation aircraft.

4 Source of estimate: FAA

SOURCE: National Transportation Safety Board, Safety Information Release, January 28, 1982.

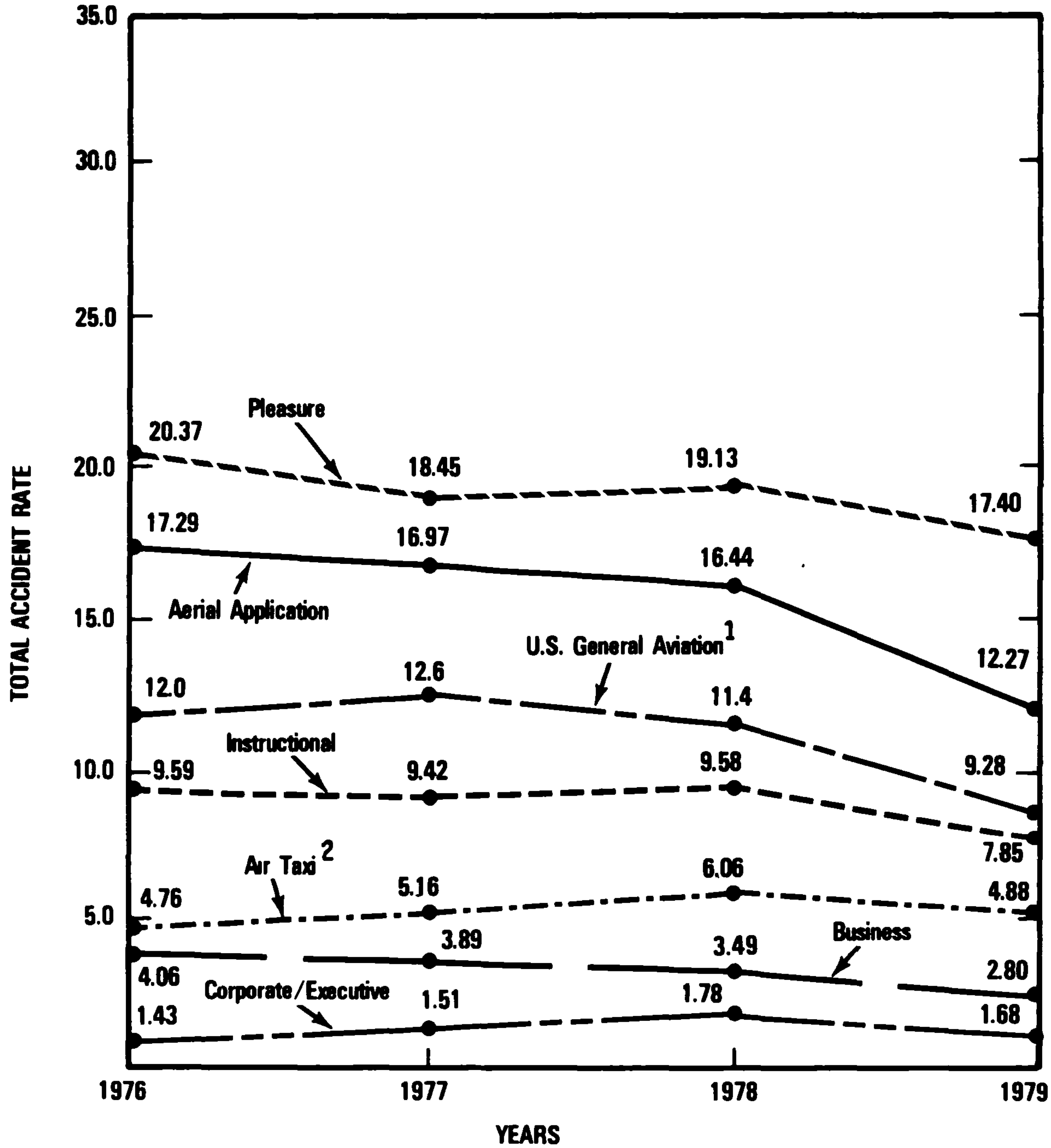
2.78 per 100,000 departures to the low rates achieved in 1981. Annual fatalities for scheduled services ranged from a high of 65 in 1979 to a low of 33 in 1977.

Accident statistics for on-demand (non-scheduled) air taxi operations for the five-year period reported in 1981 by the NTSB are shown in Table 4.2. In 1981, air taxi accidents were low for the five-year period with 138 accidents which included 34 fatal accidents involving 95 fatalities. The accident rates over the five-year period 1977-1981 ranged from a low of 3.74 accidents per 100,000 aircraft flight hours in 1981 to a high of 6.89 accidents per 100,000 aircraft flight hours in 1978.

Accident statistics for the ten-year period 1972-1981 for general aviation (excluding commuter air carriers and air taxi) are shown in Table 4.3. In 1981 general aviation had 3,634 accidents which included 662 fatal accidents with 1,265 fatalities. The accident rate of 10.0 accidents per 100,000 aircraft flight hours in 1981 was up from the record low of 9.6 achieved in 1980 after a continuous decline from 16.8 in 1972.

The annual accident rates for general aviation listed in Table 4.3 presented an overall summary that does not show the wide variations in accident rates attributed to each of the various elements or types of flying in general aviation. The accident rates for corporate executive flying with professional crews are significantly lower than the totals for all general aviation flying. For example, an analysis by the NTSB of accident rates in 1979 for the various types of flying indicated that the personal transportation or so-called pleasure flying sector experienced the highest accident rate involving 17.40 accidents per 100,000 flight-hours as compared to an overall rate of 9.8 in 1979 shown in Table 4.3. Aerial application (includes AgAir spraying) had the second highest rate (12.27), followed by instructional flying (7.85), on-demand air taxi (5.13), commuters (4.04), business (2.80) and corporate/executive (1.68). Figure 4.1 summarizes the NTSB analysis of general aviation accidents by the type of flying for years 1976-1979.[25]

[25] Annual Review of Aircraft Accident Data, U.S. General Aviation, Calendar Year 1979, NTSB-ARG 81-1, National Transportation Safety Board, Washington, D.C., November 5, 1981.



SOURCE: National Transportation Safety Board, November 5, 1981 Analysis.

[1]Includes Commuter Air Carrier and Air Taxi Accidents.

[2]Includes Commuter Air Carrier Accidents.

FIGURE 4.1. GENERAL AVIATION ACCIDENT RATES PER 100,000 AIRCRAFT - HOURS FLOWN BY KIND OF FLYING 1976 - 1979

ACCIDENT CAUSAL FACTORS

The review of 1979 aircraft accident data (most recent NTSB analysis) for U.S. general aviation by the National Transportation Safety Board (NTSB) indicated that weather factors and pilot performance factors continued, as in past reviews, to be predominantly involved in most general aviation accidents. Tables 4.4 and 4.5 summarize the NTSB findings as to the ten most frequently cited cause factors in 3,345 nonfatal accidents and 678 fatal accidents in 1979.[26] The pilot was cited as a causal factor in 482 of the 678 fatal accidents analyzed (71.09 percent cause factor) and 1,108 of the 3,345 nonfatal accidents (33.12 percent cause factor). Weather was cited as a causal factor in 341 of the fatal accidents (50.29 percent cause factor). As noted in the tables, more than one cause can be cited as the major contributing factors in an accident.

The ten most prevalent types of accidents in general aviation are presented in Figures 4.2 for total accidents and Figure 4.3 for fatal accidents. Engine failure or malfunction is the leading type of accident, accounting for about 24 percent of the total accidents recorded. The other most common types of accidents are ground/water loop or swerve, hard landings, or collisions with the ground/water and projecting objects (trees, poles, or wires) near the ground. Stalls and stall-spins also account for a significant number (6.49 percent and 9.90 percent respectively) of the fatal accidents over the 5-year period. Most (over 40 percent) of the total accidents occur during the landing phase of flight while the majority (over 60 percent) of the fatal accidents occur in-flight.

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[26] Ibid.

TABLE 4.4

TEN MOST FREQUENTLY CITED CAUSE FACTORS OF NONFATAL ACCIDENTS IN 1979

Cause Factors	Frequency	Percent
Pilot - Inadequate Preflight Preparation or Planning	399	11.93
Miscellaneous Acts, Conditions Overload Failure	334	9.99
Terrain - High Obstructions	293	8.76
Weather - Unfavorable Wind Conditions	263	7.86
Pilot - Mismanagement of Fuel	245	7.32
Pilot - Failed to Obtain/Maintain Flying Speed	240	7.17
Pilot - Selected Unsuitable Terrain	224	6.70
Powerplant - Failure for Undetermined Reasons	208	6.22
Miscellaneous Acts, Conditions Fuel Exhaustion	208	6.22
Miscellaneous Acts, Conditions Material Failure	203	6.07

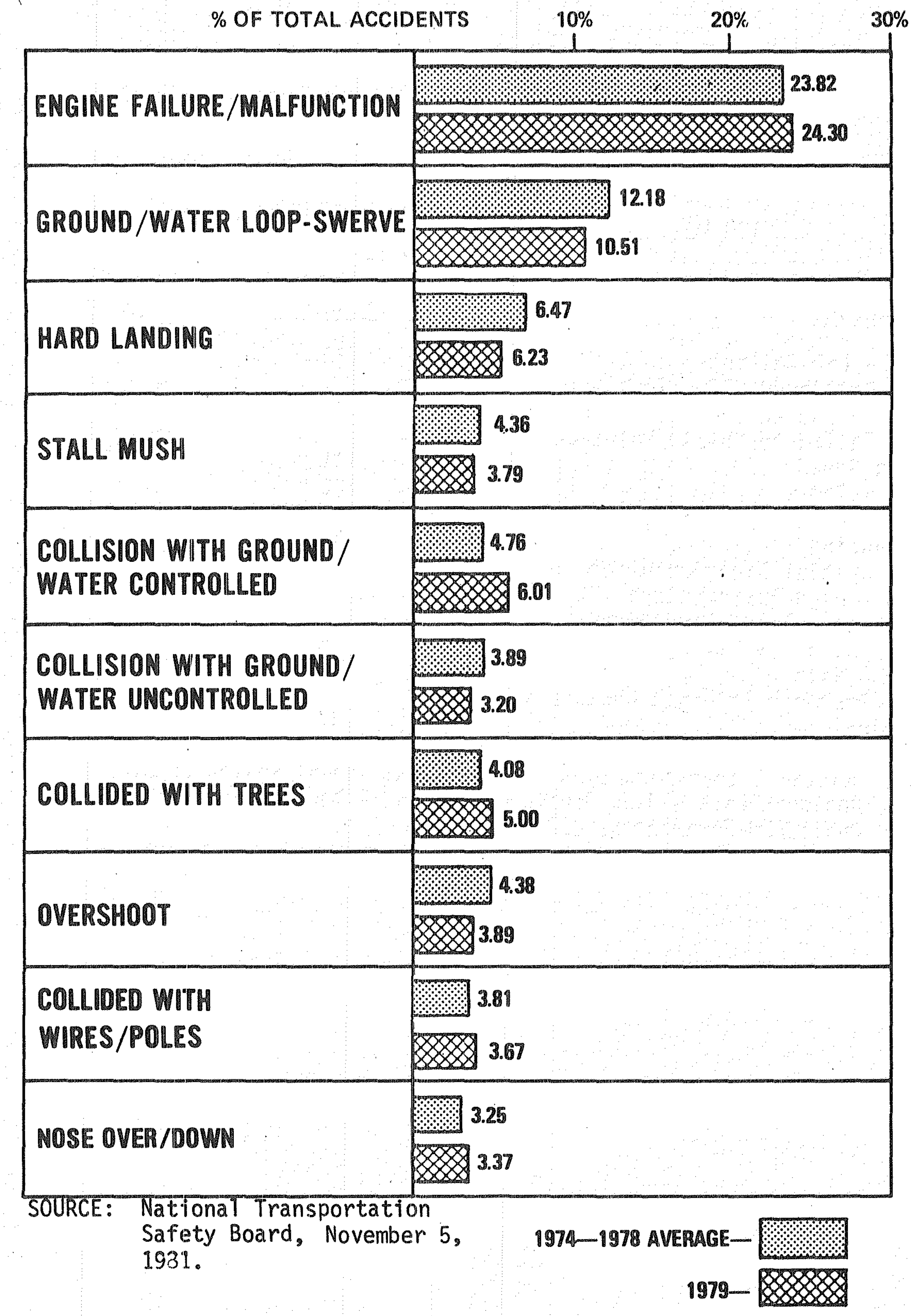
SOURCE: National Transportation Safety Board, Annual Review of Aircraft Accident Data - U.S. General Aviation, Calendar Year 1979 Data, Published November 5, 1981.

TABLE 4.5

TEN MOST FREQUENTLY CITED CAUSE FACTORS OF
FATAL ACCIDENTS IN 1979

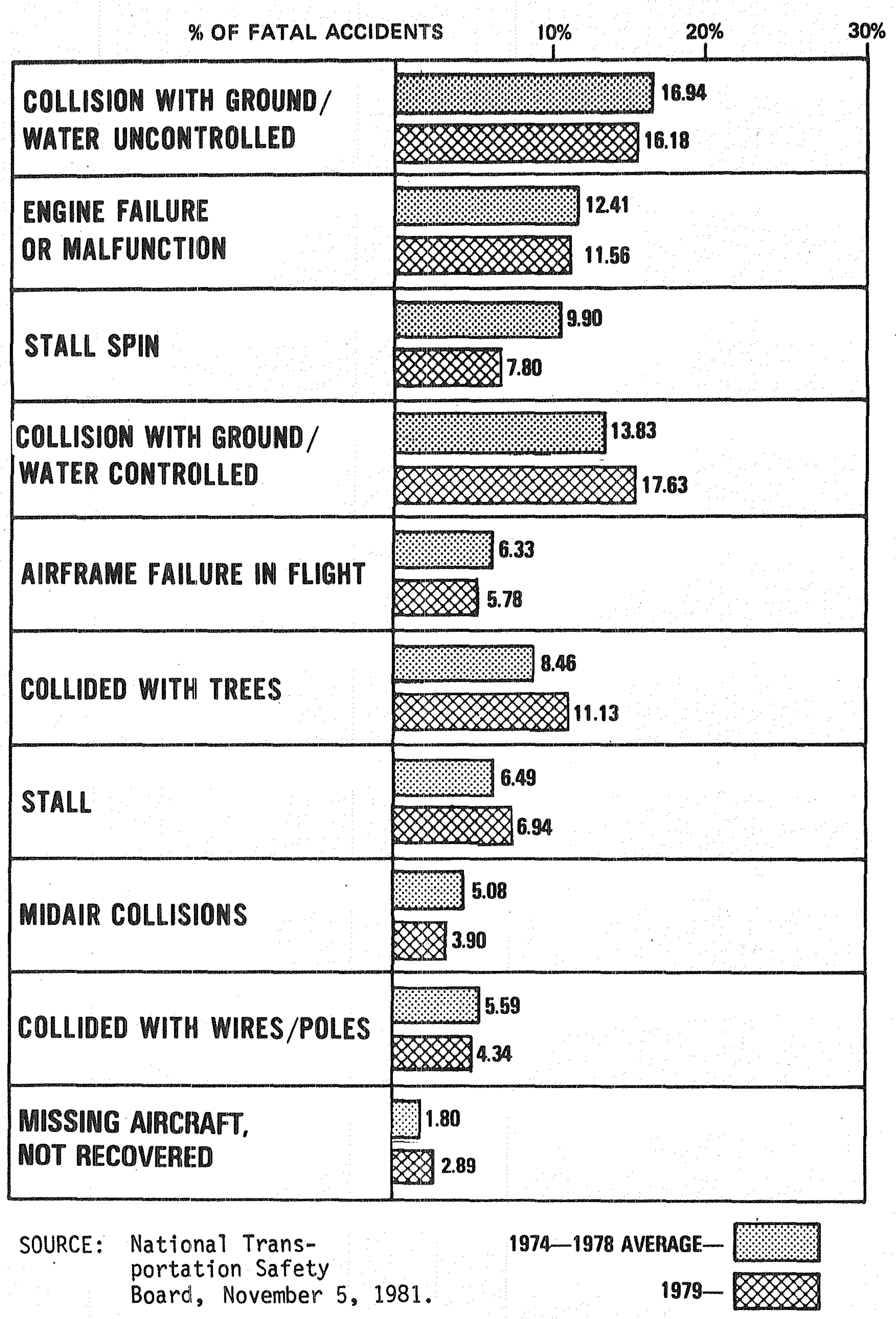
Cause Factors	Frequency	Percent
Weather - Low Ceiling	170	25.07
Pilot - Continued VFR Flight Into Adverse Weather Conditions	131	19.32
Pilot - Failed to Obtain/Maintain Flying Speed	131	19.32
Weather - Fog	122	17.99
Pilot - Inadequate Preflight Preparation or Planning	90	13.27
Pilot - Spatial Disorientation	86	12.68
Terrain - High Obstructions	77	11.37
Miscellaneous Acts, Conditions Unwarranted Low Flying	58	8.55
Weather - Rain	49	7.23
Pilot - Improper Inflight Decisions or Planning	44	6.49

SOURCE: National Transportation Safety Board, Annual Review of Aircraft Accident Data - U.S. General Aviation, Calendar Year 1979 Data, Published November 5, 1981.



SOURCE: National Transportation Safety Board, November 5, 1981.

FIGURE 4.2. TEN MOST PREVALENT ACCIDENT TYPES FOR U.S. GENERAL AVIATION 1979 VS. 5-YEAR AVERAGE



SOURCE: National Transportation Safety Board, November 5, 1981.

FIGURE 4.3. TEN MOST PREVALENT FATAL ACCIDENT TYPES FOR U.S. GENERAL AVIATION 1979 VS. 5-YEAR AVERAGE

V. IMPACT OF U.S. GOVERNMENT POLICIES

Several recently enacted government policies have had an impact on the composition of the general aviation fleet and needs for improved technology. Two of these areas are discussed here -- airline deregulation and environmental controls.

AIRLINE DEREGULATION

The Airline Deregulation Act of 1978 (Public Law 95-504, October 24, 1978) provides for the systematic phase-out by January 1985 of the Civil Aeronautics Board (CAB) and its authority over air transportation fares and the route structure of the domestic airlines. In its implementation of the provisions of the Act, the CAB has taken actions to reduce government restrictions on airline management discretion to make changes in domestic routes, service points, types of service, and ticket prices within a defined zone of reasonableness.[27] During implementation of these competitive oriented policies, the CAB is guided by the Declaration of Policy (Section 102) in the Act also to consider areas that might be adversely affected by

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[27] Graham, D. R. and D. P. Kaplan, Developments in the Deregulated Airline Industry, Office of Economic Analysis, Civil Aeronautics Board, June 1981.

deregulation, such as: safety implications of new services, service to small communities and isolated areas, and monopolistic market concentration.

The greatest impact on general aviation from the Airline Deregulation Act is on the high performance segments of the market -- business aviation and the commuter airlines. To some extent the strong market for business aircraft is partially attributed to reduced airline services, but probably more directly related to time efficient direct routings and travel flexibility. The policy changes which have major impact on commuter airlines appear to include the following areas:

- Liberalized process for market entry and exit,
- Essential air services to small communities,
- Increased allowable commuter aircraft size, and
- Guaranteed aircraft loans.

Liberalized Market Entry and Exit

Provisions under the law reduced constraints on air carriers to enter new markets and to exit markets no longer considered economic for the type of aircraft and route structure preferences of individual airlines. The liberalized market entry and exit policy has permitted economically healthy air carriers to enter new markets and realign routes to better match traffic demands with airline fleet mixes. The general trend during the three year interval since deregulation has been for the major trunk carriers and local service carriers to withdraw from the uneconomic use of their commercial jet fleets on short-haul (less than 200 miles) low-density markets. Commuter airlines have moved in to many of the low-density markets being dropped by the trunk/local service air carriers. Air taxi operators also experienced increases in requests for on-demand air transportation to provide connections with scheduled air carriers as well as to provide point-to-point services.

Small Community Air Service

The Small Community Air Service Program guarantees continuation of essential levels of air transportation for a period of ten years to communities designated as eligible for such service under criteria established under Section 419 of the Act. The CAB guidelines for essential air service guarantee that eligible communities receive at least two well-timed round trips daily to its connecting hub or hubs served by the national air transportation system. This service can be provided by twin-engine commuter aircraft with 8 or more passenger seats. The CAB has certified 560 eligible communities, 337 of which are located in the conterminous United States and Hawaii.[28]

Since passage of the Airline Deregulation Act the structure of the airline industry has been changing in response to market perspectives of individual airlines and essential services determinations. According to the General Accounting Office, various airlines have filed 398 notices with the CAB terminating air services affecting 287 communities, but 139 of these communities were still being served by at least on certificated carrier. Service for the remaining 148 communities is being provided by commuter airlines except for 7 communities where the CAB has required continuation of certificated air carrier service until replacement service is arranged. Essential air services are being supported at 44 of these communities by subsidies under the Small Communities Air Service Program. A review of airline operations subsequent to deregulation concluded that the full impact of deregulation on small communities cannot be judged until the airline industry has more operating experience under deregulation.[29]

Commuter Aircraft Size

Historically, the size of commuter aircraft has been influenced by Federal economic and safety regulation of airlines engaged in providing commercial air transportation as common carriers. Federal Air Regulations applicable to flight safety are discussed later in the section. Economic regulation of the airlines by the Civil Aeronautics Board (CAB) are

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[28]Air Service to Small Communities After Two Years of Deregulation (Level of Service After Two Years)", CAB Chairman, January 1980.

[29]The Changing Airline Industry: A Status Report Through 1980, CED-81-103, U.S. General Accounting Office, June 1, 1981.

established by the Civil Aeronautics Act of 1938. The trunk airlines developed as certificated air carriers under fares and routes regulated by CAB operating certifications granted under Section 401 of the Act.

Small air taxi operators who provided non-scheduled services in small aircraft (gross take-off weight of 10,000 lbs. or less) under Part 298 of the CAB Economic Regulations were exempt from Section 401 operating certificate requirements. In 1969, the CAB amended Part 298 to establish commuter air carriers as a class of operators authorized to use small transports (take-off gross weight of 12,500 lbs. or less) for scheduled services without Section 401 certification requirements. Subsequently, in 1972, the CAB authorized commuter air carriers to operate aircraft with 30 passenger seats and maximum payloads of 7,500 pounds.

Provisions under Section 416 of the Airline Deregulation Act and subsequent CAB actions exempt from CAB certificate requirements under Section 401(a) any air carrier that operates aircraft with 60 passengers seats or less or cargo payload capacity of less than 18,000 pounds. This change in policy modified the former limit of 30 passenger seats imposed on commuter air carriers operating under Part 298 of CAB Economic Regulations. According to the commuter airline industry this policy change has had a beneficial impact on commuter service by improving air carrier efficiency on the denser traffic routes and providing flexibility for use of small aircraft in the fleet to improve service on the less dense routes.[30]

Flexible Fare Pricing

The Airline Deregulation Act provides flexible market pricing of air carrier passenger fares within a zone of reasonableness based upon standard industry fare levels and non-predatory pricing. Initially, the lower limit was set at 50 percent below the standard industry fares in effect on July 1, 1977. The upper limit was set at 5 percent above the standard fare level for the same or essentially similar class of service. The Civil Aeronautics Board (CAB) must adjust the standard industry fare

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[30] RAA 1981 Annual Report, page 22.

level for each class of service at least twice a year by the percentage change, since the previous adjustment, in the industry's average operating cost per available seat-mile for interstate and overseas air transportation. The Board has authority to disallow rates that are considered to be predatory. Under sunset provisions of the Act, CAB authority over domestic fare pricing will expire on January 1, 1983.

Related provisions under the Act and CAB orders require the certificated air carriers to extend joint fare programs to include commuter air carriers. The inclusion of commuter airlines in the industry structure enables joint fares for through-service with single-point ticketing and baggage handling facilities, thereby integrating the commuter air carriers into the national air transportation system.

Guaranteed Commuter Aircraft Loans

Under provisions of the Airline Deregulation Act the commuter air carriers become eligible for Federal guarantees on loans for aircraft acquisitions. A loan guarantee may not exceed 90 percent of the face value of the loan, which can not exceed 90 percent of the purchase price of the aircraft including engines and spare parts. The aircraft loan guarantee program is administered by the Federal Aviation Administration.[31]

Federal Air Regulations

Federal regulations applicable to the flight and safety aspects of aviation are set forth in the Federal Air Regulations (FAR) which are promulgated by the Federal Aviation Administration (FAA). The Federal Air Regulations do not strictly define "general aviation" as a segment of aviation but prescribe aircraft airworthiness standards and operating standards applicable to aircraft of varying sizes and purposes of flight. Thus, in its broadest context, general aviation normally refers to all civil aircraft operations in the United States except for large transport aircraft and helicopers operated under Parts 121 and 127 of the Federal Air Regulations.

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[31] Commuter Air Carrier Loan Guarantee Study, Report No. FAA-AVP-80-1, Federal Aviation Administration, January 1980.

The FAA safety requirements impact most directly on small transport aircraft and operations of the commercial air carrier segments of general aviation, i.e., on-demand air taxi operators and the commuter airlines as specified in Parts 23 and 135 of the Federal Air Regulations. Figure 5.1 presents a matrix of various aircraft sizes used in air taxi and commuter airline operations and related safety regulations. These safety regulations are defined in Federal Air Regulations pertaining to aircraft airworthiness standards applicable to various categories of civil aircraft and to operating procedures for air carriers and other operators engaged in air commerce.

Airworthiness standards have been defined for two basic categories of airplanes: Part 23 for normal, utility and acrobatic category airplanes and Part 25 for the transport type category which has more stringent provisions than Part 23. For many years, the FARs relating to aircraft certification classified civil aircraft as either small or large based on maximum certified take-off weight (MCTW), using 12,500 pounds as the demarcation between small and large airplanes. In addition, the International Civil Aviation Organization (ICAO) uses a similar weight distribution of 5,700 kg (12,566 pounds). As heavier fuel loads increased the take-off weights of business jets and commuters were permitted to use larger aircraft, the FAA took steps to upgrade the safety regulations applicable to small transport aircraft and commuter operations. In 1969, Special Federal Air Regulation 23 established additional airworthiness standards for small multi-engine piston and turboprop airplanes capable of carrying more than 10 occupants including the flight crew. In 1971, the FAA amended Part 23 (amendment 23-10) to limit its applicability to small airplanes by limiting the passenger seating configuration to nine seats or less, excluding pilot seats, rather than using aircraft weight limitation as the demarcation between Part 23 and Part 25.

Special Federal Aviation Regulation 41, was subsequently issued in 1979 to allow type and airworthiness certification of small multiengine propellor-driven airplanes with 10 or more passenger seats (but not more than 19 seats), excluding pilot seats, for use in U.S. domestic commuter services provided the maximum zero fuel weight does not exceed 12,500 pounds. Aircraft

Safety Regulations Related to Aircraft Size / Size of Aircraft	FAR PART 23 APPLIES	SFAR 41 APPLIES	FAR PART 25 APPLIES	FAR PART 135 APPLIES	FAR PART 121 APPLIES	2 PILOTS REQUIRED	FLIGHT ATTENDENT REQUIRED
Single Engine, Under 10 Pass.	●			●			
Multiengine, Under 10 Pass.	●			●			
10-19 Passenger (12,500 MGW)		●	●	●		●	
20-30 Passenger (7,500 lb Payload)			●	●		●	●
Over 30 Passenger or 7,500 lb Pay load			●		●	●	●

FIGURE 5.1. SAFETY REGULATIONS RELATED TO AIRCRAFT SIZE

eligible for compliance with SFAR 41 must have been certified to FAR 23 prior to October 1979 and an application for certification to SFAR 41 filed prior to October 17, 1981. The production of aircraft certified to SFAR 41 are limited to 10 years but no limitation has been established for the operational life of individual aircraft. In addition, aircraft certified under SFAR 41 are required to meet some specific standards of FAR 25 in order to meet ICAO Annex 8 requirements for international acceptance. The objective of SFAR 41 is to allow the design capabilities of certain existing small airplanes to be available for use under Part 135 operations in the domestic commuter market stimulated by enactment of the Airline Deregulation Act of 1978.

It is noted that some of the past relationships between FAA safety regulations and CAB economic regulation of domestic air carriers are undergoing change in the wake of Airline Deregulation. Historically, FAR Part 23 has been applicable to small aircraft operated under Part 135 operating certificates but exempted from the additional complexities of CAB economic regulation. The generally more stringent provisions of FAR 25 applied to larger transport aircraft operated under Part 121 operating certificates applicable to commercial air carriers. Currently, commuter operations can be carried out under FAR Part 135 in aircraft which can seat up to 30 passengers and have maximum payloads of 7,500 pounds. But under economic deregulation the CAB has amended Part 298 of the economic regulations to permit commuter airlines to operate aircraft seating up to 60 passengers and having a maximum payload capacity of 18,000 pounds. The FAA is considering the suitability of modifying Part 25 certification standards to accommodate certain aspects of these medium size commuter transports, such as aisle widths and control system requirements which differ from those needed for wide-body jet transports.[32]

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[32] Aviation Week and Space Technology, Volume 113, Number 19, November 10, 1980, page 25.

ENVIRONMENTAL CONTROL

The principal environmental concern impacting on general aviation is associated with aircraft noise. In 1971, the joint DOT-NASA Civil Aviation Research and Development (CARD) Policy Study highlighted aircraft noise as the most critical environmental problem impeding aviation growth. Public objections to high-noise areas near major air carrier airports provided impetus in the 1970s for the Federal government to include noise abatement measures in aircraft airworthiness standards and airport approach and departure paths to reduce the impact of aircraft noise around those airports. Such regulatory measures and implementations of noise reduction technology have been primarily oriented toward reducing the impact of noise around commercial air carrier airports, but general aviation airport noise is also a growing environmental concern.[33]

Aviation noise abatement efforts have primarily been focused on reducing noise exposure levels in the vicinity of the larger air carrier airports. These efforts have involved both government and industry initiatives to identify sources of aircraft noise, measure the exposure levels around airports, reduce sources of aircraft noise, devise operating procedures to minimize noise impacts, foster land use planning, and develop new noise abatement technology. The FAA has established noise standards (FAR Part 36) to limit the noise levels of new design and new production aircraft, including small propeller-driven aircraft as well as jet aircraft. Through these initiatives in both the public and private sectors, progress has been made in reducing some aspects of aircraft noise, primarily in the vicinity of air carrier airports, but the extent and severity of general aviation contributions to airport noise is an area of growing concern.[34]

There is a considerable body of aircraft noise technology. Much of this technology is based on research and technology sponsored by NASA and other government agencies. The aircraft industry makes use of advances in

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[33] Conference on General Aviation Airport Noise and Land Use Planning, Georgia Institute of Technology, October 3-5, 1979.

[34] Report on Conference on General Aviation Airport Noise and Land Use Planning, Georgia Institute of Technology, October 3-5, 1979, Volume II-Prepared Papers.

technology to lower aircraft noise emissions to meet regulatory standards and to improve aircraft performance where economically justifiable. For example, the application of high bypass ratio turbofan engines has reduced noise and improved fuel economy of new jet-powered aircraft. But aircraft noise is still a major public concern and is viewed as a potential impediment to the continued growth of general aviation.

It is considered vital that continued progress be made on research efforts for reducing engine noise. New technology is needed to reduce future aircraft noise levels below the standards specified for FAR 36 (Stage 3). Fruitful areas for research on general aviation noise problems are demonstration of noise reduction concepts in new propeller designs, evaluation of innovative propulsion designs, methods for predicting propellor installation effects and noise of turboshaft engines, and investigation of airframe noise reduction methods.[35]

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[35] Noise Technology Research Needs and the Relative Roles of the Federal Government and the Private Sector, Proceedings of the EPA Noise Technology Research Symposium, January 29-31, 1979, Dallas, Texas.

VI. IMPACT OF INCREASING FOREIGN COMPETITION

In the past, U.S. manufacturers of general aviation aircraft dominated the world market largely because of technical superiority, pricing policies, marketing techniques, and after sales support of their products. This technical superiority was due in great part to the large bank of available R&D data that existed at the end of World War II and which the aircraft and component manufacturers were able to develop quickly and economically into commercial products.[36]

Today, the dominant position of the United States general aviation industry is being challenged by the dynamic efforts of international competitors, particularly Canada, the United Kingdom, France, Spain, Italy, Germany, Israel, Australia, Japan, Brazil and Indonesia. The greatest challenge has been in the areas of commuter and business jet aircraft. Foreign governments have targeted these areas as matters of national priority. A primary target for the foreign competitors marketing efforts has been the United States since they see that the majority of future sales will be here.

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[36] Civil Aviation Research and Development Policy Study, DOT TST-10-4, NASA SP-265, a Joint DOT-NASA Report, March 1971.

This section examines the impact of increasing foreign competition in the general aviation and commuter industries. Its objective is to determine the implications to the U.S. industry's current and future posture. The section includes an overview of current and projected general aviation and commuter markets and the impact foreign competition is having on the historical U.S. market share. Individual foreign manufacturers of general aviation are discussed with respect to their current and future products and the amount of advanced technology incorporated into their aircraft designs. In view of the limited scope of this effort, areas requiring a more in-depth analysis have been highlighted. The impact of foreign government aviation policies have been investigated and their influence on general aviation and commuter aircraft development, technology levels and marketing are reported.

OVERVIEW OF CURRENT AND PROJECTED GENERAL AVIATION AND COMMUTER MARKETS

The 1981 world-wide sales of 20 manufacturers of general aviation and commuter aircraft consisted of about 9,800 units of various sizes and uses.[37] Historically, the U.S. manufacturers have held a 90 percent share of this market. Foreign manufacturers now dominate the 15-60 passenger light transport segment and new competitors, i.e., Japan and Canada have entered the business jet market. The U.S. continues to dominate the light single- and multi-engine piston aircraft markets.

Commuter Market

Table 6.1 presents the 1978 distribution of the worldwide inventory for light transport in terms of units and percent of the market. It is readily apparent that the United States contains the largest share

[37] Business Aviation, January 11, 1982, page 13.

TABLE 6.1

LIGHT TRANSPORT MARKET SHARE
(Percent of Total)

	15-19	20-40	41-60	TOTAL
United States	255(44)	124(25)	353(22)	732(28)
West Europe	63(11)	80(16)	208(13)	351(13)
South Asia	63(12)	29(6)	223(15)	315(12)
Latin America	75(13)	65(13)	143(9)	283(11)
Africa	33(6)	62(13)	161(10)	256(10)
Canada	41(7)	79(16)	102(6)	222(9)
East Asia	2(1)	10(2)	158(10)	170(6)
South Pacific	14(2)	18(4)	102(7)	134(5)
Middle East	24(4)	11(2)	50(3)	85(3)
South Atlantic	8(1)	13(3)	41(3)	62(2)
East Europe	0(0)	0(0)	39(2)	39(1)
TOTAL	578(100)	491(100)	1580(100)	2649(100)

SOURCE: Light Transport Market Forecast Report prepared for the Office of Aviation Policy, Federal Aviation Administration, Washington, D.C. by the Aerospace Corporation, July 1979.

of this market (28 percent) especially in the 15-19 seat category where 44 percent of the aircraft are located.

The units shown in Table 6.1 include the aircraft used for such missions as commuter, regional and supplemental airlines; government and military; as well as other operators (corporate, lease companies, manufacturers, etc.). Since the same basic aircraft is used for these various missions, it is important that the manufacturers consider the entire potential market in determining whether or not to proceed with a new aircraft development. The demand for the larger light transport aircraft is greater in the non-U.S. markets for regional and supplemental airlines missions where limited runway lengths preclude the use of jet aircraft. This market is currently serviced in the U.S. by B 737 and DC 9-type aircraft. As the commuter airlines establish themselves and take over the routes previously serviced by the air carrier airlines prior to deregulation, the market for larger light transports in the U.S. will increase.

The forecast for light transports for the years 1980-2000 is shown in Table 6.2. The trend towards a larger share of the world market of larger light transport aircraft is evident in Table 6.3 with the most dramatic increase in the 20-40 passenger range. This potential 1996[38] aircraft market is the target of several new commuter aircraft such as the de Havilland Dash 8, the Saab-Fairchild 340, EMBRAER Brasilia (EMB-120), Shorts SD 360 and CASA-Nurtanio CN-235. Of these aircraft only the Saab-Fairchild 340 can claim some U.S. origin.

[38] This is a composite of many manufacturers forecasts. For example: CASA-Nurtanio forecasts a requirement for 1800 of the 30-40 seat aircraft between 1984 and 1994 plus 600 for military applications. Saab-Fairchild forecasts a minimum of 1600 and de Havilland 2000 of these aircraft to meet the worldwide market. SOURCE: Interavia, 8/1981, p. 819.

TABLE 6.2

U.S./WORLD MARKET FORECAST FOR LIGHT TRANSPORT AIRCRAFT 1980-2000

PASSENGER SEATING CAPACIY	U.S. UNIT SALES	INTERNATIONAL UNIT SALES	TOTAL UNIT WORLDWIDE	VALUE OF SHIPMENTS $ MILLIONS[1]
15-19	1,050	1,137	2,187	3,065
20-40	898	1,098	1,996	6,895
41-60	425	790	1,215	6,685
Total All Aircraft	2,373	3,025	5,398	16,645

[1] CAAA Estimated value in constant 1980 U.S. dollars.

SOURCE: Light Transport Market Forecast Report prepared for the Office Of Aviation Policy, Federal Aviation Administration, Washington, D.C. by the Aerospace Corporation, July 1979.

TABLE 6.3

U.S. MARKET SHARE OF LIGHT TRANSPORT AIRCRAFT (Percent of Total Units)

Passenger Seating Capacity	1978	1980-2000
15-19	44	48
20-40	25	45
41-60	22	35
TOTAL	28	44

SOURCE: Light Transport Market Forecast Report prepared for the Office of Aviation Policy, Federal Aviation Administration, Washington, D.C. by the Aerospace Corporation, July 1979.

Business Jet Market

The United States also represents the largest segment of the business aircraft market comprising 69 percent of all business aircraft in service around the world. Europe makes up 18 percent of the market with 13 percent distributed among other countries. However, unlike the commuter market, American manufactured aircraft dominate with nearly 66 percent of the business aircraft in service today produced in the United States.

In the past ten years, the sale of business jets has skyrocketed. In 1978, 270 new business jets built by U.S. and European manufacturers joined the some 4,000 business aircraft in service around the world. The 1979 deliveries showed a 38 percent growth rate compared to 1978 with 280 U.S. and 50 European aircraft placed into service. The 1980 deliveries rose by 15 percent compared with 1979 despite the fact the world was in a relatively severe recession.

Current market forecasts envision particular strength in the turboprop field as well as for slightly less dramatic yet steady growth in turbojets. One recent long-range market forecast[39] revealed that sales of U.S. manufactured business turboprops and turbojets are expected to double from 1980 totals of 1,100 to about 2,300 by 1985 with a value of $3.3 billion. All aircraft manufacturers, however, are not in agreement and at least one manufacturer believes sales will actually drop in the near future with the increase in deliveries an illusionary figure resulting from aircraft ordered several years ago.

Other General Aviation Aircraft

The production of general aviation aircraft (other than the commuter and business aircraft described above), is dominated by three firms, Cessna Aircraft Company, Beech Aircraft Corporation (a subsidiary of Raytheon) and Piper Aircraft Corporation (a subsidiary of Bangor Punta). In

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[39] John H. Winant, President of NBAA, Remarks at the International Aerospace Symposium, Le Bourget Airport, Paris, France, June 3, 1981.

1980, these manufacturers accounted for 92 percent of the new aircraft shipped and 67 percent of the net billings. Cessna had the largest share of the market with 57 percent of all shipments and 32 percent of net billings. Piper and Beech had 27 and 9 percent of unit shipments, respectively. Historically, Cessna and Piper have been the major producers of the light, less costly, single-engine and multi-engine piston aircraft -- Beech has had the major share of the market for the larger, more sophisticated, aircraft. In 1980, Cessna produced 62 percent of the single-engine piston aircraft, Piper built 22 percent. In other categories, Cessna, Piper, and Beech accounted for 98 percent of the twin-engine piston units shipped.

Foreign Trade Balanace

Over 90 percent of the 280,000 general aviation aircraft in the world-wide civil aircraft fleet were manufactured in the United States. In 1981, American manufacturers exported about 24 percent of the general aviation aircraft produced in the United States. The value of these general aviation exports were $749 million in 1981, a slight decrease of about one percent compared to the value of 1980 exports.

General aviation aircraft imports in 1981 reached a record level of $843 million. As indicated in Figure 6.1, general aviation exports contribute to the U.S. trade balance, but in recent years the net value of that contribution has declined from about $340 million in 1978 and 1979 to a deficit in 1981. This decline in trade balance is largely attributed to increases in imported aircraft deliveries to U.S. operators of multi-engine light transport aircraft and business jets which are the high value general aviation aircraft.

Of course these figures give only an indication of the true balance of payments situation. A more accurate accounting of the impact from the sales of foreign general aviation aircraft requires an in-depth analysis of each aircraft to determine the degree to which it incorporates U.S. technology, labor and components. The effort required for such an analysis is beyond the scope of this study; however, an indication of the complexity is illustrated by the many situations which now exist. These situations are presented below:

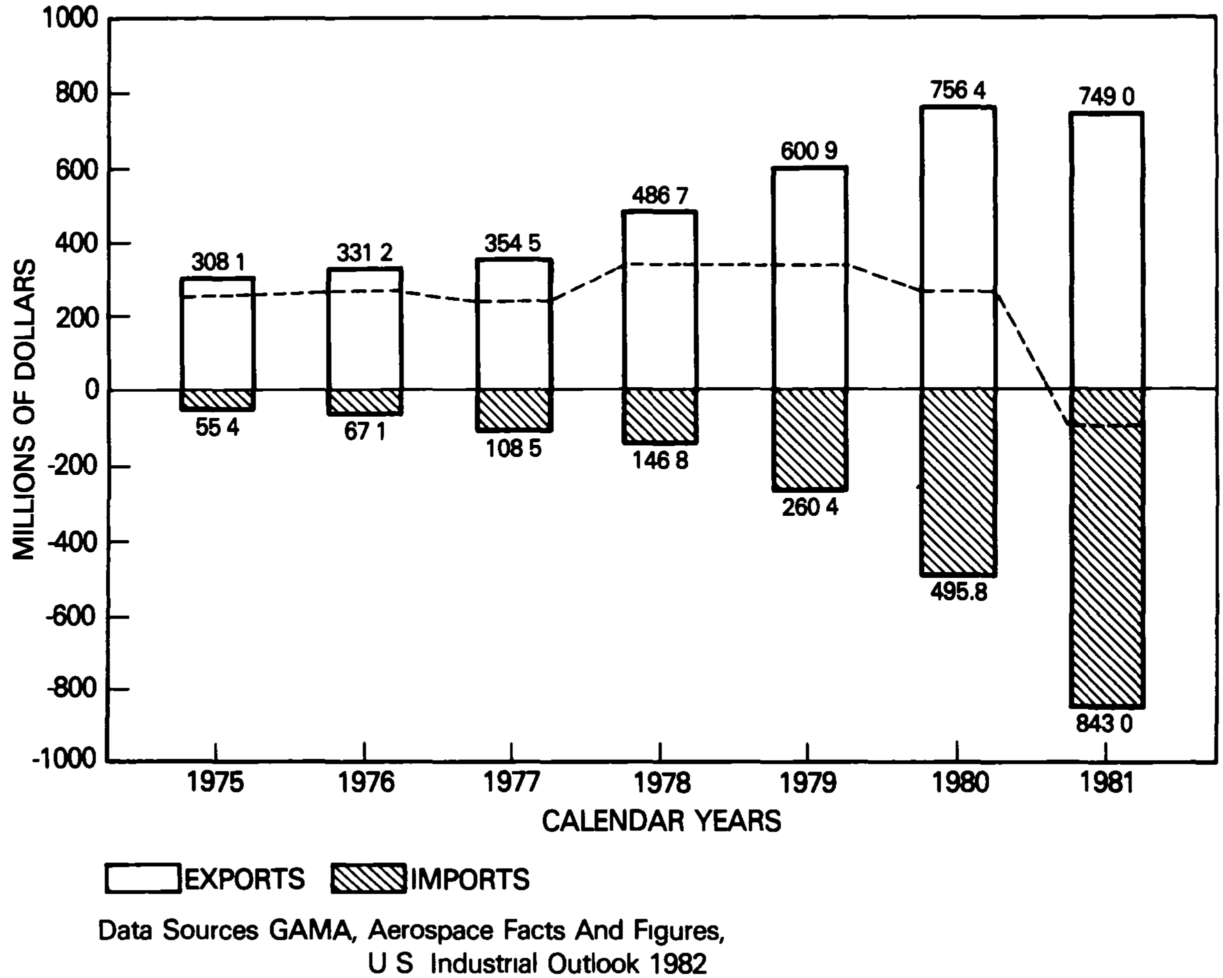

FIGURE 6.1. GENERAL AVIATION CONTRIBUTIONS TO U.S. TRADE BALANCE

- U.S. product: the aircraft and all its components are designed, built and assembled in the United States (e.g., Cessna aircraft).
- U.S. product with foreign components: the aircraft is designed and assembled in the United States but some components are built outside the U.S. (e.g., aircraft with P&WAC PT6 engines).
- U.S. product assembled in a foreign country: the aircraft is designed and the components built in the U.S. but the aircraft is assembled in a foreign country (e.g., Piper a/c kits assembled in Brazil).
- Joint production: the design, manufacture and assembly of the aircraft is a joint venture with a foreign country (e.g., SF 340).
- Foreign product assembled under license in U.S. using components made primarily in a foreign country (e.g., Dassault Falcons).
- Product designed in the U.S. but built in a foreign country (e.g., Lear Fan in Ireland).
- Foreign product assembled outside the U.S. using many U.S. components (e.g., EMBRAER Bandeirante).
- Foreign product designed, built and assembled using all foreign parts (e.g., none identified since at least the avionics package is manufactured in the U.S.).
- U.S. design modified as a different aircraft and built in a foreign country (e.g., Aero Commander in Israel) using many U.S. components.

FOREIGN GENERAL AVIATION AIRCRAFT

A review of the current commuter aircraft, both U.S. and foreign, indicates that the major competitors to the U.S. commuter aircraft industry are France, Great Britain, Spain, Canada, the Netherlands and Brazil. Future commuter aircraft, currently under development will bring strong competition from Great Britain, Canada, Germany, Brazil, a team of France and Italy, a team of Spain and Indonesia, and Sweden who is in a joint venture with Fairchild. The European Communist Bloc Countries, particularly Czechoslvakia and the USSR, appear content to market within their own sphere of influence. However, the Czech LET L-410 UVP twin-turboprop is reported to be aimed at the Western market and the Third World countries although it is principally intended for the European Communist Bloc countries.[40] Japan appears to be concentrating on business jets with the emerging nations building small personal type aircraft.

Current and Projected Commuter Aircraft

Figure 6.2 presents a scattergram of current and future aircraft options for the commuter market by number of seats and year of introduction. U.S. aircraft are shown by a solid circle, foreign aircraft by an open circle and the joint U.S./Sweden venture by a half circle. It is readily apparent that the larger (>19 seats) market is dominated by the foreign manufacturers with the only new U.S. models envisioned for the eighties being the CAC 100, the Ahrens 404 and the joint U.S./Sweden SF 340. The situation becomes even more serious when one considers there are no confirmed orders for either the CAC 100 or the Ahrens 404.

The major characteristics and performance parameters for each of these aircraft are shown in Table 6.4.

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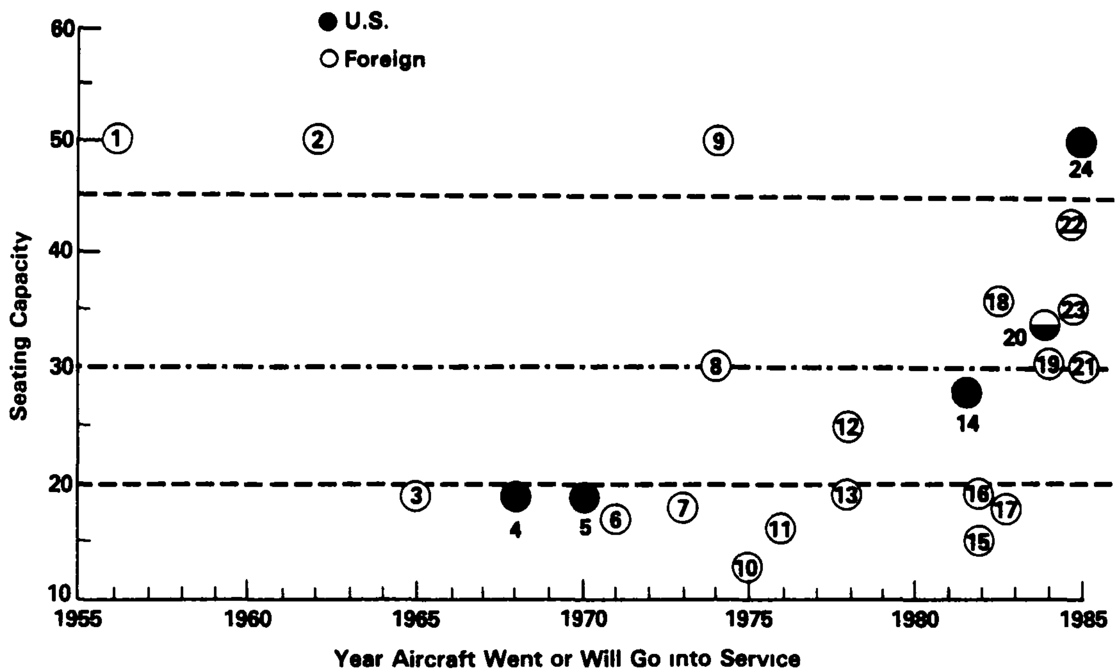
[40] Interavia, 9/1979.



1. Fokker F-27 (Netherlands)
2. BAe 748 (UK)
3. DHC-6 (Canada)
4. Beech 99 (US)
5. Metro (US)
6. BN Trislander (UK)
7. EMB 110 (Brazil)
8. SD 330 (UK)
9. DHC-7 (Canada)
10. Nomad 22B (Australia)
11. Nomad 24A (Australia)
12. CASA 212-200 (Spain)
13. Arava 101B (Israel)
14. AR 404 (US)
15. Do 228-100 (W. Germany)
16. Do 228-200 (W. Germany)
17. BAe Jetstream 31 (UK)
18. SD 360 (UK)
19. DHC-8 (Canada)
20. SF-340 (Sweden/US)
21. EMB 120 (Brazil)
22. ATR 42 (France/Italy)
23. CN 235 (Spain/Indonesia)
24. CAC 100 (US)

FIGURE 6.2. U.S. AND FOREIGN COMMUTER AIRCRAFT IN PRODUCTION OR DEVELOPMENT

TABLE 6.4

COMMUTERS

MANUFACTURER	AIRCRAFT	COST	SEATING	CABIN L/H/W	ENGINES	WEIGHT MAX TO	CRUISE SPEED	CEILING	BREAK EVEN 100% LF	EST DEL DATE	PRESS
PILATUS B-N	BN-2B-[illegible] Islander	$ 301,930	2+8	10/3 9/3 6	(2) Lyc IO-540-K1B5 300 hp ea	6,600	137	18,000	0 217		No
CESSNA	CE-402C Ultraliner	$ 333,606	2+8	15 8/4 2/4 7	(2) Cont TSIO-502VB 325 hp ea	6,850	174	26,900	0 245		No
PIPER	PA 31-350 Navajo Chiefter	$ 377,620	2+8	18 1/4 3/4 2	(2) LYC TIO-540-J2BD 350 hp ea	7 000	163	24,000	0 242		No
CESSNA	CE 404 Titan Courier II	$ 478,910	2+9	13 8/4 3/4 7	(2) Cont GTSIO-520M 375 hp ea	8 400	174	26,000	0 262		No
PILATUS B-N	BN-2A-111-2 Trislander	$ 514,120	2+16	21 5/3 9/3 6	(3) Lyc O-540-E4-C5 260 hp ea	10,000	145	12,400	0 144		No
de HAVILLAND	DHC-6-300 Twin Otter	$ 1,170,000	2+19	18 4/4 9/5 3	(2) P&W PT6A-27 620 shp ea	12,500	172	26,700	0 187		No
GAF	N24A Nomad	$ 1,196,308	2+16	21 3/5 2/4 3	(2) All 250-B-17C 385 shp ea	9,400	163	20,500	0 239		No
BEECH	BE-C99 CB 99	$ 1,335,000	2+15	18 7/4 8/4 5	(2) P&W PT6A-36 750 shp ea	11,300	249	28,080	0 209		No
EMBRAER	EMB-110P1 Bandierante	$ 1,495,998	2+18	31 2/5 3/5 3	(2) P&W PT6A-34 750 shp ea	12,500	224	22,500	0 244		No
ISRAEL AIRCRAFT IND	1A1-1018 Arava	$ 1,650,000	2+18	22 4/5 8/7 7	(2) P&W PT6A-36 750 shp ea	15,140	139	23,600	0 268		No
SWEARINGEN	SA227-AC Metro III	$ 1,845,000	2+19	25 4/4 8/5 2	(2) AR TPE-331-110 1,000 shp ea	14,000	280	30,000	0 221		Yes
CASA	C212-200 Commuter	$ 2 121,700	3+26	26 1/5 9/6 8	(2) AR TPE 331-10 900 shp ea	16,427	185	25,000	0 216		No
SHORT BROS LTD	SD 3-30 Shorts 330	$ 2,870,000	3+30	31 0/6 5/6 5	(2) P&W PT6A-45B 1,156 shp ea	22,900	165	20,000	0 212		No
GULFSTREAM AM	Gulfstream 1C	$ 3,000,000	3+37	41 0/6 1/7 5	(2) RR Dart 7 MK 529-8x 1,910 shp ea	36,000	300	30,000	0 218		Yes
de HAVILLAND	DHC-7 Dash 7	$ 5,020,000	3+50	39 5/6 4/7 0	(4) P&W PT6A-50 1,120 shp ea	44,000	230	21,000	0 180		Yes
FOKKER	F27 MK 500 Friendship	$ 6,350,000	3+50	52 4/6 8/8 5	(2) RR Dart 7 MK 535-7 2,020 shp ea	45,000	259	20,000	0 193		Yes
BRITISH AEROSPACE	HS 748-2B Intercity	$ 6,500,000	3+48	46 6/6 3/8 1	(2) RR Dart 7 MK 535-2 2,280 shp ea	46,500	234	25,000	0 227		Yes
FOKKER	F28 MK 4000 Fellowship	$10,550,000	4+85	50 3/6 7/10 2	(2) RR RB 183-MK 555-15 9,900 lbs ea	73,000	437	35 000	0 133		Yes
AHRENS	402	$ 2,000,000	+27	N/A	(2) AR TPE 331-11 1,100 shp ea	16,000	170	NA	NA	1982	No
AHRENS	404	$ 1,8-2,000 000	+30	28 0/6 0/6 0	(4) All 250-B17B 440 shp ea	17,000	170	18,000	NA	1981	No
BRITISH AEROSPACE	Jetstream 31	$ 1,800,000	+19	24 0/6 0/5 9	(2) AR TPE 331-10 900 shp ea	14,110	263	31,000	NA	1982	Yes
BEECH	1900	$ 1,600,000	+19	N/A	(2) P&W PT6A 1,000 shp ea	15,245	263	NA	NA	1983	Yes
COMMUTER AIRCRAFT CORP	CAC-100	$ 3,000,000	+44	N/A	(4) P&W PT6A-41 850 shp ea	28,900	287			1982	No
de HAVILLAND	Dash 8	$ 4,000,000	+32-36	N/A	(2) P&W PT 7A-1 1,700 shp ea	29 000	260	25,000	NA	1984	Yes
DORNIER	228-100	$ 1,400,000	+15	2 8/4 5/5 3	(2) AR TPE 331-5 715 shp ea	12,568	233	29,600	NA	1981	Yes
DORNIER	228-200	$ 1,500,000	+19	2 6/4 5/5 3	(2) AR TPE 331-5 715 shp ea	14,500	233	27,600	NA	1981	Yes
EMBRAER	110P-3 Bandierante	$1 550 000	+19	N/A	(2) P&W PT6A-65 1,17[illegible] shp ea	15 440	300	NA	NA	1983	Yes
EMBRAER	120 Brasilia	$ 3 200,000	+30	29 8/7 1/5 7	(2) P&W PT 7A-1 1 500 shp ea	20,000	287	35,500	NA	1985	Yes
FAIRCHILD/ SAAB	SF 340 Commuter	$ 3,450,000	3 +34	33 7/7 1/6 0	(2) GE CT 7-5 1 650 shp ea	25 000	360	NA	NA	1984	Yes
SHORT BROS LTD	360	$ 3 400 000	3 +26	36 1/6 3/6 3	(2) P&W PT6A-65R 1 294 shp ea	25 700	190	NA	NA	1982	No
AERO-SPATIALE/ AGRITALIA	AS 35	$ 5 000 000	+40-46	NA	NA	NA	NA	NA	NA	1985	NA
BRITISH AEROSPACE	BAE 146-100	$10 000 000	4/5+ 71	50 5/11 0/6 2	4 Lyc ALF 502 R-3 6,700 lbs ea	78 850	434	22 000	NA	1982	Yes
BRITISH Aerospace	BAE 146-200	NA	4/5+ 100	58 5/11 0/6 2	4 Lyc AFL 502 R-3 6 700 lbs ea	87 500	424	24,000	NA	1983	Yes

Current and Projected Business Aircraft

In the business aircraft field, products from France, Great Britain, Israel, Canada and shortly Japan are making inroads into the U.S. business turbojet fleet. Japan is already a factor in the turboprop field.

Of the 1680 turbojets operated by the 2500 member companies of NBAA, 31 percent were manufactured outside the U.S. Three aircraft types made up this 31 percent: the several models of Falcons produced in France; the British Aerospace HS lines manufactured in Great Britain and the Jet Commander/Westwind series from Israel. New products will come in the form of the Challenger lines from Canada and the Diamond I turbojets from Japan.

The British report that the 125 series is a sellout in the U.S. market for the next two years. Canadair has delivered 16 Challengers to completion centers in the U.S. and reports its on order backlog lists 125 Standard models, 75 "E"[41] (extended models), along with 11 GE powered standard models.

Israel expects to have placed 400 Westwind aircraft in the U.S. by 1985. By that time they hope to introduce their new Astra model.

Falcon looks for an increase in the monthly production rate from 8 to 10 units consisting of Models 10, 20, 200 and 50.

Japan has 121 orders for the Diamond I and regards the Diamond II as a natural follow-on by mid 1985.

Table 6.5 presents the principal characteristics and performance parameters for the current and projected business turbojet/turbofan aircraft. Here over half of the options available to the potential business jet customer are manufactured in the U.S. of the foreign models, the Falcon and the Diamond I are, or will be, assembled in the U.S. In addition, the CL 600 is a Lear designed aircraft.

The U.S. turboprop market is brighter with 87 percent of the 1029 aircraft registered to NBAA members manufactured in the U.S., Japan and Canada are the only notable foreign competitors.

[41] Canadair has recently announced cancellation of the "E" model. Canadair hopes to convert these "E" model orders to orders for standard models.

TABLE 6.5

TURBOPROP BUSINESS AIRCRAFT

MANUFACTURER	AIRCRAFT	COST	SEATING	CABIN	ENGINES	WEIGHT MAX TO	CRUISE SPEED	CEILING
Piper	PA31T-500TI Cheyenne I	$ 845,165	1+6	8 4/4.3/4.2	(2) P&W PT6A-11 500 shp ea	8,700	247	28,200
Cessna	CE-425 Corsair	914,329	1+6	10 6/4 3/4.6	(2) P&W PT6A-112 450 shp ea	8,200	264	34,700
Beech	BE-C90 King Air	988,540	1+7	12 7/4 8/4 5	(2) P&W PT6A-21 550 shp ea	9,650	222	30,700
Piaggio	P 166-DS3 P 166-DL3	1,050,000	1+5	10 5/5 8/	(2) Lyc LTP-101-600 600 shp ea	9,480	160	20,000
Piper	PA-31T-620 Cheyenne II	1,055,640	1+7	8 4/4 3/4 2	(2) P&W PT6A-28 620 shp ea	9,000	281	31,600
Gulfstream AM	AE-840 Commander 840	1,157,715	1+7	9 5/4 5/4 0	(2) AR TPE-331-5-254K 718 shp ea	10,325	287	31,000
Piper	PA-31T2XL Cheyenne II XL	1,168,450	1+7	10 0/4 3/4 2	(2) P&W PT6A-135 620 shp ea	9,474	268	32,400
Cessna	CE-441 Conquest	1,174,470	1+8	12 7/4 3/4 6	(2) AR TPE331-8-402S 636 shp ea	9,850	293	35,000
Beech	BE-E90 King Air	1,198,105	1+7	12 7/4 8/4 5	(2) P&W PT6A-28 550 shp ea	10,100	249	27,620
Mitsubishi	MU-2B-40 Solitaire	1,198,900	1+7	8 0/4 3/4 9	(2) AR TPE 331-10 665 shp ea	10,470	313	33,500
Piper	PA-42 Cheyenne III	1,347,930	1+8	14 9/4 4/4 3	(2) P&W PT6A-41 720 shp ea	11,200	291	32,800
Beech	BE-F90 King Air	1,349,025	1+6	12 7/4 8/4 5	(2) P&W PT6A-135 750 shp ea	10,950	267	29,802
Gulfstream Ar	AE-980 Commander 980	1,357,715	1+7	9 5/4 5/4 0	(2) AR TPE331-10 733 shp ea	10,325	304	31,000
Beech	BE-B100 King Air	1,367,493	1+8	16 7/4 8/4 5	(2) AR TPE 331-6 715 shp ea	11,800	268	28,138
Mitsubishi	MU-2B-60 Marquise	1,475,815	1+8	11 8/4 3/4 9	(2) AR TPE331-10-501 715 shp ea	11,575	296	29,750
Gulfstream Am	AE-1000 Commander 1000	1,500,075	1+7	12 4/4 8/4 1	(2) AR TPE331-10 820 shp ea	11,200	307	35,000
Lear Avia	LF 2100 Lear Fan	1,650,000	1+7	12 8/4 7/4 8	(2) P&W PT6B-35F 650 shp ea	7,200	358	41,000
Beech	BE-200 King Air	1,655,380	1+8	16 7/4 8/4 5	(2) P&W PT6A-41 850 shp ea	12,500	287	32,880
Swearingen	SA227-TT Merlin III C	1,849,320	1+7	10 6/4 8/5 2	(2) AR TPE 331-10U 900 shp ea	13,230	300	27,000
Swearingen	SA227-AT Merlin IVC	2,071,180	1+11	25 4/4 8/5 2	(2) AR TPE 331-11U 1100 shp ea	14,000	283	30,000
Embrarer	Xingu	NA	2+6	NA	(2) P&W PT6A-28 680 shp ea	12,500	182	NA
Embrarer	Bandierante	NA	2+7	NA	(2) P&W PT6A-27 680 shp ea	30,500	259	NA
SIAI-Marchetti	SF600 Canguro	NA	2+9	NA	(2) All 250-B176 420 shp ea	9,480	218	NA

Table 6.6 presents the principal characteristics and performance paremeters of the current and projected business turboprop aircraft. It is readily apparent that sixteen of the aircfaft are manufactured in the U.S. whereas only seven are foreign built. Of these seven, two are assembled in the U.S. and one, the Lear Fan, is a U.S. design to be built in Ireland.

Use of Advanced Technology

An examination was made of available information to determine the extent of advanced technology incorporated into the foreign general aviation aircraft. The major difficulty in identifying this data was in deriving an acceptable definition for "advanced technology". Aircraft are currently being touted as having "advanced technology" by one manufacturer whereas another manufacturer may have been incorporating this same technology for years.

The report by the panel on General Aviation presented at the Workshop on the Role of NASA in Aeronautics[42] cited the technical developments in advanced airfoils being made through the work of Eppler and Wortman for use in the Dornier TNT wing on the Do 228-100 and -200. Also mentioned were the use of computer-aided design and supercritical aerodynamics by Dassault in its Falcon 50 and Dowty Rotol's advanced technology propellers now standard equipment on several U.S. turboprops. Examples of technology by discipline which were included in ORI's definition as advanced technology include:

- Aerodynamics
  - Supercritical wing
  - Winglets
  - Natural Laminar Flow
  - TNT wing (Dornier)
  - Canards and multiple surface configurations
  - Forward swept wing configurations.

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[42] NASA's Role in Aeronautics: A Workshop, Volume IV, General Aviation, Aeronautics and Engineering Board, National Research Council, 1981.

TABLE 6.6

TURBOJET/TURBOFAN BUSINESS AIRCRAFT

MANUFACTURER	AIRCRAFT	COST	SE'TING	CABIN L/H/W	ENGINES	WEIGHT MAX TO	CRUISE SPEED	CEILING
Aerospatiale	SN 601 Corvette	$1,750,000	2+12	18 9/5 0/5 2	(2) P&W JT15D-4 2500 lbs ea	15,430	389	36,000
Cessna Jet	CE 500 Citation I	1,947,525	2+6	12 7/4 3/4 9	(2) P&W JT15D-1A 2200 lbs ea	11,850	347	41,000
Gates	LR-25D Learjet	2,131,000	2+7	12 1/4 3/49	(2) GE CJ610-8A 2950 lbs ea	15,000	437	51,000
Gates	LR-28 Learjet	2,336,400	2+7	12 1/4 3/4 9	(2) GE CJ610-8A 2950 lbs ea	15,000	440	51,000
Cessna Jet	CE 550 Citation II	2,518,475	2+7	16 2/4 8/4 9	(2) P&W JT15D-4 2500 lbs ea	13,300	377	43,000
Dassalt	AD MY-10 Falcon 10	3,200,000	2+7	12 8/4 7/4 8	(2) AR TFE731-2-1C 3230 lbs ea	18,740	430	45,000
Gates	LR-35A Learjet	3,325,485	2+7	12 9/4 3/4 9	(2) AR TFE731-2-2B 3500 lbs ea	17,000	432	45,000
Israel Aircraft	IA-1124 Westwind I	3,428,710	2+7	15 3/4 9/4 8	(2) AR TFE731-3-1G 3700 lbs ea	22,850	424	45,000
Gates	LR-55 Learjet	3,529,785	2+7	13 9/5 7/5 9	(2) AR TFE731-3A-2B 3700 lbs ea	19,500	441	51,000
Gates	LR-36A Learjet	3,545,485	2+5	10 8/4 3/4 9	(2) AR TFE731-2-2B 3500 lbs ea	18,300	432	45,000
Gates	LR-56 Learjet	3,614,785	2+6	11 0/5 7/5 9	(2) AR TFE731-3A-2B 3700 lbs ea	20,500	441	51,000
Israel Aircraft	IA-1124A Westwind II	3,828,060	2+7	15 3/4 9/4 8	(2) AR TFE731-3-1G 3700 lbs ea	23,500	415	45,000
Cessna Jet	CE-650XR Citation III X	4,237,925	2+8	18 6/5 8/5 7	(2) AR TFE731-3B-100 3650 lbs ea	19,500	465	51,000
Cessna Jet	CE-650 Citation III	4,298,400	2+8	18 6/5 8/5 7	(2) AR TFE731-3B-100 3650 lbs ea	19,500	464	51,000
Rockwell Int'l	NA-265-65 Sabreliner	5,100,000	2+8	19 0/5 5/5 2	(2) AR TFE731-3R-1D 3700 lbs ea	23,800	441	45,000
British Aerospace	HS 125-700 HS 125 Srs 700	5,845,000	2+8	21 3/5 8/5 9	(2) AR TFE 731-3R-1H 3700 lbs ea	24,800	427	41,000
Dassault	AD MY-20F Falcon 20	5,960,000	2+9	24 4/5 5/6 2	(2) GE CF700-2D2 4500 lbs ea	28,660	410	42,000
Dassault	AD MY-50 Falcon 50	8,750,000	2+9	23 5/5 9/6 1	(3) AR TFE731-3-K 3700 lbs ea	38,800	430	45,000
Canadair	CL 600 Challenger	9,000,000	2+11	28 3/6 1/8 2	(2) LYC ALF502-L 7500 lbs ea	40,400	443	45,000
Canadair	CL 600GE Challenger (GE)	9,900,000	2+11	28 3/6 1/8 2	(2) GE CF34-1A 8650 lbs ea	41,450	450	45,000
Gulfstream Am	G-1159A Gulfstream III	11,000,000	2+14	24 3/6 1/7 0	(2) RR SPEY MK 511-8 11400 lbs ea	68,200	459	45,000
Dassault	AD MY-20H Falcon 20H	NA	2+8	NA	(2) AR- NA NA	30,000 to 32,000	NA	NA
Mitsubishi	MU 300 Diamond I	2,381,710	2+7	15 7/4 8/4 9	(2) P&W JT15D-4 2500 lbs ea	14,100	423	41,000
Gates	LR-29 Learjet	2,388,300	2+5	9 9/4 4/4 9	(2) GE CJ610-8A 2950 lbs ea	15,000	440	51,000

- Propulsion
  - High By Pass Ratio engines
  - Rotary engines
  - Diesel engines
  - Internal combustion engines for multiple fuels
  - Improved SFC.
- Materials and Structures
  - Composites
  - Advanced metals and metal composite hybrids.
- Propellers
  - Advanced designs (propfans)
  - Improved materials (composites).
  - Others
- Avionics and Controls
  - Combined flight and propulsion controls
  - Automatic flight performance management
  - Digital Controls
  - Advanced displays
  - Ride control.
- Subsystems
  - All electric (e.g., no hydraulics or pneumatics).

It is noted that much of this technology had its beginnings in the NASA Aircraft Energy Efficiency (ACEE) program but has found initial application in general aviation aircraft (e.g., composites and winglets).

Those commuter and business aircraft which appear to contain some advanced technology in their designs are listed in Table 6.7. The absence of an aircraft from the list does not imply that it does not incorporate advanced technology, only that available literature does not highlight any of the items identified above. An indepth investigation of each aircraft is suggested to assure that an accurate listing is presented.

TABLE 6.7

SURVEY OF CURRENT AND PROTOTYPE FOREIGN COMMUTER AIRCRAFT

COUNTRY	MANUFACTURER	AIRCRAFT	ADVANCED TECHNOLOGY
Brazil	Embraer	Brasilia (EMB-120)	Keep as simple as possible, avoid technical risks involved in adopting advanced features because of planned operations in out of way places.
Canada	Canadair	Challenger CL 600	Advanced technology wing section, high-bypass ratio turbofan engines.
Canada	De Havilland	Dash 8 (DHC-8)	Advanced technology turboprop engine.
France	Dessault-Brequet	Falcon-10	Supercritical wing section.
		Falcon-50	High lift devices, supercritical wing sections
Germany	Dornier	Do 228-100 Do 228-100	Low drag/high lift TNT (new technology) wing 20/30% improvement in performance.
Israel	Israel Aircraft Industries	Arava 101B/ 102 ±	Advanced construction techniques, weight saving composites, fuel efficient turboprop.
Israel	IAI	Westwind I Westwind II	Sigma supercritical wing with NACA64A-212 section winglets
Japan	Mitsubishi	Diamond I	Separate surface stability augmentation.
Netherlands	Fokker	F-27	Bonded metal primary construction.

SOURCE ORI, Inc

An analysis of the foreign aircraft reveals that currently the technology being incorporated into the foreign built aircraft does not appear to surpass that which is now incorporated in the U.S. produced aircraft. Instead, the areas posing the greatest threat to the U.S. manufacturers are in markets for which the U.S. has previously offered no new developments -- e.g., the 20-40 passenger aircraft for the emerging commuter market. The most common reason given for not venturing into some of the new market areas has been the inability of the U.S. financial community to accept the risk -- preferring instead to stay with proven aircraft concepts or product improvements to existing designs.

Two new aircraft sharing a common heritage are the Challenger and the Lear Fan -- both designed by the U.S. aeronautical innovator, William Lear. Both aircraft are departures from current designs. The Challenger offers the business executive the comforts of a wide body for his business travel. By building the Challenger to the strict standards of FAR 25, Canadair was required to increase the weight, thereby lowering the anticipated performance from the attractive specifications first offered in the initial design. Whether the Challenger can overcome these deficiencies remains to be seen.

The second aircraft is the Lear Fan. The British government has taken over the manufacture and marketing of this twin-engine, single-pusher-propeller, all composite business turboprop to bring much needed industry into Northern Ireland. Although preproduction sales have been encouraging, the aircraft has yet to be proven successful.

If these two aircraft succeed, the point will not be the lack of technology but non-availability of risk capital within the U.S.

FOREIGN GOVERNMENT SUPPORT

Many of the foreign manufacturers are government owned and virtually all receive strong support from their governments. This support takes a number of forms -- research and development grants, loans, provision of facilities, funding incentives, etc.

Government support has enabled the foreign manufacturers to undertake the development of new aircraft, particularly in the commuter field, at a time when the market was still ill-defined and the necessary investment risk was beyond that which the U.S. private sector was able or willing to meet. As a result several new foreign commuter aircraft are expected to enter service during the mide-1980's, when the market is expected to peak.

The impact of the U.S. default to the light transport market could have far reaching effects since airlines are prone to commit to a particular aircraft and then build a fleet of various sized aircraft around it. An example is the de Havilland of Canada offering a full spectrum of commuter aircraft consisting of the popular 19-passenger Twin Otter (DHC-6), the mid-sized, 32-passenger Dash 8 (DHC-8), and the 50-passenger Dash 7 (DHC-7).

Another area which has caused great concern to the U.S. general aviation industry has been the ability of foreign governments to offer attractive financing for their products. The country most cited for this practice is Brazil which made large inroads into the U.S. market with the sale of their Bandeirante (EMP 110P) by offering financing at 7½ to 8½ percent interest with an 8- to 10-year payback period, often with no down payment.

Table 6.8 presents an overview of the support foreign manufacturers receive from their governments in the areas of development, technology and marketing. Table 6.9 presents a synopsis of the various foreign aviation industries. A more detailed discussion is included in Appendix A.

TABLE 6.8

FOREIGN COMMUTER AIRCRAFT MANUFACTURERS AND THE NATURE OF THEIR GOVERNMENT AVIATION POLICIES AND INFLUENCE

Country	Corporation	Status	Government Influence		
			Development	Technology Levels	Marketing
Australia	Government Aircraft Factories	Government Corporation	x	x	x
Brazil	EMBRAER	51% controlled Brazilian Government	x	x	x
Canada	Canadair	Government Owned Corp.	x	x	-
	de Havilland	Government Owned Corporation	x	x	-
France	Aerospatiale	Government Owned Corp.	x	x	-
	Dassault	21% Stock Owned by Government	x	x	-
Germany	Dornier	Privately Owned	-	-	-
Indonesia	P.T. Nurtanio	Government Owned Corp.	x	x	x
Israel	Israel Aircraft Industries	Government Owned Corporation	x	x	x
Italy	Siai Marchetti Subsidiary of Agusta	51% Government Owned	x	x	-
	Partenavia	Privately Owned, Subsidiary	-	-	-
		Aeritalia	x	x	-

TABLE 6.8

(Continued)

Country	Corporation	Status	Government Influenced: Development	Government Influenced: Technology Levels	Government Influenced: Marketing
Italy (Continued)	Aeritalia	Government Owned	x	x	-
Japan	Mitsubishi	Privately Owned	-	-	x
Nether-lands	Fokker	49-51% Government Owned	x	x	?
Puerto Rico	Ahrens	Privately Owned	-	-	-
Spain	CASA	65.5% Government Owned	x	x	-
Sweden	Saab-Scania	Privately Owned	-	-	-
United Kingdom	British Aerospace Corporation	Government Owned	x	x	-
	Pilatus Britten-Norman	Privately Owned	-	-	-
	Short Brothers	Government Owned	x	x	-
	Lear Avia	49% Government Owned	x	x	-

TABLE 6.9

GOVERNMENT PARTICIPATION IN FOREIGN AERONAUTICS INDUSTRIES

	AUSTRALIA	CANADA	FRANCE
Government Ownership	The Government Aircraft Factories are wholly owned by the Australian Government	Canadair Ltd. and de Havilland are government owned companies	Aerospatiale 75% Government 25% private Dassault-Breguet, 46% Government, 54% private, R Reims Aviation, 10% government SOCATA, GA Division of Aerospatiale
Government Encouraged Consolidations	There is no information available pertaining to a possible consolidation of aircraft companies in Australia.	There is no indication of government encouraged consolidation of the aircraft industry with de Havilland concentrating on commuter aircraft and Canadair on business jets.	In January 1970, the nationalized Sud-aviation and Nord-aviation merged with the nationalized SEREB to form Societe National Industrial Aerospatiale Brequet aviation merged with Avions Marcel Dassault in 1967 after government pressure The current government objective appears to be to gain control of Dassault-Breguet. The government controlled SNECMA holds 10 percent interest in Reims Aviation.
Multinational Projects	Most sales to Australia require an offset in the form of aircraft subcontract work. As such, GAF is performing subcontract work for Boeing (B727) and Fokker (F-28).	Canada gave some thought to participation in the joint development of new commuter aircraft with Aerospatiale but no agreement could be reached. Canadair produces the U.S. Lear designed Challenger	Aerospatiale has joined with Aeritalia in a joint development of the ATR 42, a 42 passenger commuter aircraft based on the earlier French AS 35 and Italian AIT 230 designs. Dassault Breguet Falcons are assembled in the United States Reims Aviation builds single- and multiengine piston aircraft under license from Cessna which has a 49 percent holding
Government Subsidies	The Nomad program was financed by the Australian government, however, lack of government financial support has hurt the industry, e.g., the cancellation of production of the Vista Airtouer.	$70 million (1978) guaranteed by Canadian government for development of CL 600.	France and Italy will share the development costs of the ATR 42.
R&D	Not available	Not available.	93% of the R&D is controlled by the government. The government aid to the aeronautical industry exceeded $15 billion from 1970 to 1979 on an average of $1.67 billion per year
Marketing Assistance	Domestic orders of the Nomad have suffered because GAF has not been able to offer civil customers at home terms competitive with foreign types. Government supports sales through foreign aid programmers	Not available	Not available.
State As A Customer	Most sales have been exports however, domestic sales have been primarily to Australia government and military customers	Most of Canada's production is for export.	Most (76%) of France's general aviation production is for export

TABLE 6.9

(Continued)

	ISRAEL	INDONESIA	BRAZIL
Government Ownership	Israel Aircraft Industries is government owned	PT Nurtanio is a State-owned company	54 5% of EMBRAER's voting shares are owned by the Brazilian government although 89 2% of the subscribed capital is held by private shareholders Neiva is a wholly owned subsidiary of EMBRAER Aerotec is a private company
Government Encouraged Consolidations	Israel's aircraft industry is embodied in IAI which consists of several divisions, plants and subsidiary companies.	Nurtanio was established by a government decree and is the only aeronautics company in Indonesia	EMBRAER is the nucleus of Brazil's aircraft industry with Neiva a wholly owned subsidiary and Aerotec a subcontractor.
Multinational Projects	The Israeli business jet effort began when IAI bought the rights to manufacture and market the Rockwell Aero Commander.	Nurtanio is in joint development with CASA of Spain of the 34-38 passenger CN 235 commuter aircraft. The cost of development, estimated at $80 million, will be shared equally.	EMBRAER and Neiva produce a line of light general aviation aircraft under license to Piper. The U.S., Canada and Europe participate in the EMB 110 and EMB 120 programs 20%, 15%, and 5% respectively.
Government Subsidies	Not available.	The government provides the fullest possible support to Nurtanio, estimated at $100 million per year.	Government loans
R&D	Not available	The government is providing the funds to build the Nurtanio II facilities (estimated at $175 million) as well as training the workforce estimated to increase to 10,000 by 1986	R&D costs are carried out through the Air Ministry
Marketing Assistance	Not available	The Indonesian government has placed a ban on imports of aircraft which compete with any built by Nurtanio	Although EMBRAER claims there is no Brazilian government participation in marketing and promotion costs, the government offers loans at 15% down with interest at 7-8% for 7 to 9 years
State As A Customer	Not available	Nurtanio has a captive market of about 150 civil versions of the CN 235 and a similar number likely to be required by the military	The government prevents imports to Brazil through the "Law of Similars" The State is one of the aircraft industry's major customers

TABLE 6.9

(Continued)

	SPAIN	JAPAN	ITALY
Government Ownership	The government is the majority shareholder of Construcciones Aeronauticas SA (CASA).	The aircraft industry in Japan is privately owned.	Aeritalia-100% government Partenavia-absorbed by Aeritalia in 1981.
Government Encouraged Consolidations	The bulk of Spanish aerospace industry activity is undertaken by CASA. In 1972/73 the company absorbed Hispano Aviacion, another aircraft company, and ENMASA, an engine company	The Japanese government encourages the private companies to join together for the development of new aircraft and forms a project organization (e.g., CTDC for the YS-11 program) to oversee the concerted effort.	Italian Aerospace industry was divided into two groups in July 1981. Aeritalia was assigned the responsibility for heavy aircraft and Agusta responsibility for helicopters and light aircraft.
Multinational Projects	Joint development, with Nurtanio of the CN 235. Member of Airbus Industries Subcontract and overhaul of aircraft.	Japan encourages multinational projects to reduce risk and gain needed technology. Projects include joint ventures (e.g., B767) and production of aircraft under license. The MU2 and MU300 are assembled in the U S. from kits produced in Japan	Aeritalia has joined with Aerospatiale to build the ATR 42.
Government Subsidies	Not available.	Japan limits its support to the development stage considering the funding a loan rather than a subsidy to be paid back if the venture is successful.	France and Italy will share the development costs for the ATR 42.
R&D	Not available.	R&D is conducted through the National Aerospace Laboratory, the Research Coordination Bureau, and the National Research Institute for Metals	Not available.
Marketing Assistance	Not available.	Japan considers the ultimate commercial risk to be that of business and does not provide funds for marketing.	A law was passed in 1978 to provide assistance for aerospace exports.
State As A Customer	The State is a principal customer of CASA's products.	The State is a major customer of the aircraft industry.	Aeritalia is a nationalized company and military, government funded business currently accounts for between 60 and 70 percent of total production.

TABLE 6.9

(Continued)

	UNITED KINGDOM		
Government Ownership	British Aerospace-50% Government, 50% private Short Brothers-100% Government owned. Pilatus Britten/Norman-100% private owned. Lear Fan Ltd.-49% Government owned.		
Government Encouraged Consoli-dations	In the late fifties and early sixties, the British began nationalizing their aerospace industry. The trend appears to be reversing with the recent offering of stock in British Aerospace with the aim to divest 50% of the shares.		
Multi-national Projects	Concorde with France and participation in Airbus Industries.		
Government Subsidies	Not available.		
R&D	Not available.		
Marketing Assistance	Not available.		
State As A Customer	Not available		

VII. U.S. MANUFACTURERS TECHNOLOGICAL NEEDS AND CAPABILITIES

The preceding sections of this report discussed factors in economics, safety and both U.S. and foreign government policies which influence technology needs for general aviation. This section addresses the capability of U.S. general aviation manufacturers to meet these needs as well as NASA's role in those areas beyond the manufacturers capabilities.

U.S. MANUFACTURERS TECHNOLOGY NEEDS

The needs of the general aviation industry for new technology have been identified by industry representatives at Congressional Hearings, industry meetings and workshops. In testimony at Congressional Hearings, GAMA witnesses have identified areas where NASA assistance is needed in general aviation technology. These areas are:

- Turbine engines,
- Piston engines,
- Propellers,
- Spin research, and
- Low speed aerodynamics.

GAMA specifically excluded avionics as being within its members capability to conduct needed research.

In testimony before a joint Senate and House of Representatives Subcommittee hearing on general aviation and commuter aircraft at Wichita, Kansas, August 27, 1981, industry witnesses stressed the need for Federally sponsored research in high risk technology programs that could help U.S. manufacturers meet strong competition from nationalized or subsidized foreign manufacturers. Interactions between the manufacturers and NASA were mentioned as necessary to facilitate the application of advanced technologies in aircraft developments. The application of area rule and winglet technology were cited as examples. Specific needs for research identified in the Wichita hearings were:

- Research in composites, including techniques in fabrication of composite structural components, properties and physical characteristics of composite materials, environmental impact and long-term effects, as well as suitability for use as primary structures of transport type aircraft,
- Investigation of alternative aircraft fuels such as hydrogen and alcohol, and
- Improvements in propulsion energy efficiency.

During the summer of 1980, the National Research Council's Aeronautics and Space Engineering Board (ASEB) convened a workshop at the Woods Hole Study Center to examine the status of U.S. aviation relative to foreign activities and NASA's role in aeronautics. The report of the general aviation panel asserted that the U.S. general aviation industry must produce technically superior aircraft to offset subsidy advantages of foreign manufacturers in world market competition. Among its conclusions, the panel concluded that the general aviation industry cannot generate the required technology by itself.

The primary requirements for new technology for general aviation aircraft cited by the workshop are significant improvements in the areas of flight safety and fuel efficiency. Other important objectives cited for general aviation technology are:[43]

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[43] Report by the Panel on General Aviation to the Workshop on NASA's Role in Aeronautics, Volume IV, National Academy Press, Washington, D.C., 1981.

- Reduced interior and exterior noise levels,
- Reduced maintenance,
- Reduced cost of ownership, particularly operating costs, and
- Improved reliability.

U.S. MANUFACTURERS CAPABILITIES TO CONDUCT NEEDED RESEARCH AND DEVELOPMENT IN-HOUSE

The U.S. general aviation industry has achieved a position of leadership in producing general aviation aircraft through the ability to effectively capitalize on NASA research results and applicable fall-out from military R&D. An area of current interest is industry's ability to maintain its dominant position in general aviation in an atmosphere of increasing foreign competition and reduced government research and technology programs.

The scope of effort of this report prevented an in-depth analysis of industry's capabilities to meet this challenge; however, review of available industry reports did provide some insight into the nature of R&D activities being pursued as part of the U.S. manufacturers' in-house initiatives. For example, one manufacturer has stated that his company spent approximately $50 million on research and development over the past five years. This representated more than 3.3 percent of the company's annual sales.

The nature of the in-house R&D activities appear to be oriented towards improving the safety, comfort, reliability, fuel efficiency and sound levels of existing designs as well as future products. Specific IR&D efforts include:

- Use of computer graphics for conceptual definition of new products.
- Use of comprehensive wind-tunnel testing utilizing scale models to provide data which is assimulated to form a basis for refinement and development of configurations to achieve performance and fuel-efficiency goals.

- Use of a flight simulator as a design aid to provide accurate aircraft response throughout the flight regime with cockpit instruments in the simulator. This enables airplane parameters to be changed to permit testing of various model configurations.
- Use of rotary balance scaled models in wind tunnel tests to define spin characteristics.
- Use of a ground vibration survey to obtain critical vibration resonance in order to accurately define the flight test envelope prior to initial flight of new models.
- Development of sophisticated printed circuit board arrangements.

In addition to reviewing available industry literature, ORI queried several of the primary general aviation aircraft manufacturers to obtain specific answers to questions relating to their technological capabilities, the extent of their in-house R&D activities, the use and need for NASA technological assistance and their view of foreign competition. The responses to these questions are summarized below.

Key Factors Limiting Industry's Ability to Incorporate Advanced Technology

U.S. industry is limited in its ability to expeditiously incorporate technological advances in aircraft developments because of a lack of complete data, lack of time and/or the cost required to develop sufficient data needed to adequately address the:

- Evaluation of risk (i.e., is the risk acceptable),
- Safety aspects of new technology applications,
- Airworthiness certification requirements, and/or
- Manufacturing variables.

Extent of the U.S. Industry's Activities

The primary focus of the IR&D efforts are directed towards product improvement of existing designs and manufacturing methods/tooling. Major efforts are on near-term projects which have reasonably good assurance of being successful as product or manufacturing improvements. No basic research is conducted.

Investment figures vary by company and from year to year, and are considered proprietory. Orders of magnitude allocations for IR&D represent a range of three to ten percent of sales and approximately ten percent of the company's personnel.

Use and Need of NASA Research

Manufacturers make use of NASA research and technology efforts in their developments of new product lines. Key factors in the use of technology advances are cost and product development risks. Specific examples of benefits from NASA research include winglets, supercritical airfoil, GAW airfoil, and propeller technology.

Future NASA research activities required for the U.S. manufacturers to maintain a strong competitive position relative to foreign manufacturers include:

- Composites and materials,
- Airframe and propulsion aerodynamics, and
- Propulsion.

NASA'S ROLE IN GENERAL AVIATION TECHNOLOGY

NASA is the logical organization to conduct general aviation research. It has the facilities, technical expertise and prestige necessary for such programs. Existing NASA facilities are applicable, the expertise is available in all the pertinent disciplines, and the agency has had great success in acting as a catalyst in assembling teams involving industry, government, and academe to address specific problems of general interest.

The general aviation panel at the Woods Hole Workshop recommended that NASA develop a strategic plan for, and aggressively pursue, a technology program to assure U.S. supremacy in general aviation. Excerpts from the panel's report addressing specific technology needs and related NASA activities are included as Appendix D of this report.

The role of NASA in general aviation has diminished over the past few years. NASA's aeronautics research efforts directed specifically toward general aviation issues and applications have been reduced and a recent reorganization at NASA Headquarters has eliminated general aviation as a separate aeronautics technology office.

In the past, the general aviation industry faced negligible foreign competition and U.S. firms were able to successfully market their products without a need for advancing the state-of-the-art. Two new factors -- heavily subsidized foreign competition and quintupling of the cost of fuel -- now require significant technological advances in U.S. aircraft if they are to compete effectively in the future, either at home or abroad. These advances will not take place without the active participation of NASA using their unique facilities and expertise.

VIII. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the information presented in this report of factors influencing the current and future status of general aviation, it is concluded that:

1. The U.S. general aviation industry provides a significant contribution to the national transportation system, the national economy, employment and until last year, the balance of trade.

2. The preeminence of U.S. manufacturers of general aviation aircraft in world competitive markets is being erroded in the high-value business jet and light transport segments by competition from foreign manufacturers stimulated by foreign government support.

3. U.S. general aviation aircraft must incorporate advanced technology in their new developments to compete effectively for future markets at home or abroad.

4. A major problem facing the U.S. general aviation industry is an inability or unwillingness of the private sector to accept substantial risks associated with the development of advanced technology.

5. Available information does not provide a complete understanding of the U.S. general aviation industry's in-house capabilities, but it does indicate that the general aviation industry is unable to meet all of its needs for new technology in-house. Therefore, in order to meet its long term and high risk basic technology needs, this industry will require continued support from NASA's unique facilities and expertise.

6. During the past few years, NASA's aeronautics efforts directed specifically toward general aviation issues and applications have declined and remaining efforts are not currently adequate to support all known areas of technology needs or opportunities.

7. More extensive analysis is required to fully understand the support foreign governments give to their general aviation industries and its effect on U.S. competition. More analysis is also needed to evaluate properly the factors which may limit the incorporation of advanced technology in future U.S. aircraft.

RECOMMENDATIONS

Based on the above conclusions, it is recommended that:

1. An in-depth analysis be performed of the factors which may limit the U.S. general aviation industry's future use of advanced technology. This analysis would also better identify areas of aeronautical R&T beyond the U.S. general aviation industry's capability to conduct in-house research.

2. An in-depth analysis of the foreign general aviation industry be accomplished to identify the total governmental support provided those manufacturers, the state-of-the-art of their general aviation/commuter aircraft capabilities, and a better assessment of their potential impact on the U.S. general aviation industry.

3. A comprehensive identification be made of the need for and importance of U.S. government (NASA) R&T which specifically addresses unique general aviation and commuter aircraft industry issues and potentials, and which must be supported in order for the U.S. industry to achieve healthy and competitive capabilities for the future.

APPENDIX A

OVERVIEW OF FOREIGN GENERAL AVIATION AIRCRAFT MANUFACTURERS

APPENDIX A

OVERVIEW OF FOREIGN GENERAL AVIATION AIRCRAFT MANUFACTURERS

This Appendix provides an overview of the major foreign general aviation aircraft manufacturers. The material supplements the information summarized in Chapter VI.

The manufacturers have been listed by country in alphabetical order. The extent of material provided for each country is based upon the availability of information and does not reflect an in-depth assessment of the subject.

AUSTRALIA

<u>Government Aircraft Factories</u>

The Government Aircraft Factories (GAF) are units of the Defense Production facilities owned by the Australian government and operated by the Department of Productivity with a work force of approximately 2,500 persons. Their functions include the design, development, manufacture, assembly, maintenance and modification of aircraft, target drones and guided weapons. At Avalon airfield, subassembly of components, final assembly, modification, repair and test-flying of jet and other aircraft are undertaken.

Current general aviation activity consists of development and production of the Nomad twin turboprop STOL aircraft.

BRAZIL

EMBRAER

EMBRAER (Empresa Brasileira de Aeronautica, S.A.), a joint government/private company was created by the Presidential Decree No. 770 dated August 19, 1969 "to promote the development of the Brazilian aircraft industry and of similar activities, including the design and construction of aircraft."

The company officially began its activities in January 1970 and by 1973 had produced its 100th aircraft. At that time, it occupied over 2.4 million square feet of area near Sao Jose dos Compos airfield with 670,000 square feet of buildings and 2,400 employees. Production has now increased to over 2,700 aircraft consisting of twelve models as shown in Table A.1. There are now (1981) 6,582 employees with 1,562,180 square feet of building area. The growth of EMBRAER is shown in Table A.2 EMBRAER's forecast production for the years 1981-1985 are shown in Table A.3.

Brazil's EMBRAER has emerged as a significant supplier of commuter and training aircraft to the international market. However, the rise in international sales is causing delays in the development of aircraft programs already underway. The primary slippage in the Brasilia 30-passenger commuter and Xingu 2 business aircraft programs has been attributed to the inability of the engineering workforce to assimulate all the new programs.

Countering the international growth is the general economic climate in Brazil that is holding production of EMBRAER agricultural, single-, and twin-engine general aviation aircraft to fewer than 35 per month. Sales of these aircraft are less than the production rate and the company is considering whether a reduction is in order.

The workload on EMBRAER's engineering team as well as the large buy of Xingu 1's by the French has delayed introduction of the PT6A-42 powered Xingu 2 by at least six months. The Xingu 2 is flying in Brazil but with a production rate of two Xingu 1's per month, the Xingu 2 is not expected to be ready for production until early 1983. EMBPAER expects to

TABLE A.1

EMBRAER AIRCRAFT PRODUCTION

MODELS \ YEARS	1970 1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981**	TOTAL
EMB-110	1*	-	13	28	44	46	30	37	54	73	73	399
EMB-121	-	-	-	-	-	1*	03	05	11	25	16	61
EMB-200	1*	14	32	54	78	101	94	15	-	32	17	438
EMB-312	-	-	-	-	-	-	-	-	-	02*	-	02
EMB-326	05	23	20	23	25	15	21	17	13	05	15	182
EMB-710	-	-	-	-	49	90	88	29	11	04	10	281
EMB-711	-	-	-	-	31	82	103	30	19	75	50	390
EMB-712	-	-	-	-	-	-	-	12	18	50	21	101
EMB-720	-	-	-	-	21	27	29	07	26	35	17	162
EMB-721	-	-	-	-	-	52	68	11	14	24	17	186
EMB-810	-	-	-	-	27	58	90	50	89	80	38	432
EMB-820	-	-	-	-	04	43	30	09	24	14	07	131
TOTAL	07	37	65	105	279	515	556	222	279	419	281	2.765
ACCUMULATED	07	44	109	214	493	1.008	1.564	1.786	2.065	2.484	2.765	2.765

* PROTOTYPES

** ESTIMATE

TABLE A.2

EMBRAER'S EVOLUTION (1970-1981)

ITENS / YEARS	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981*
1. PRODUCTION	2	5	37	65	105	279	515	556	222	279	419	281
2. SALES (Cr$ millions)	2,7	30,9	172,9	222,5	363,7	643,9	1.198,9	1.453,5	2.078,2	4.624,5	9.028,8	21.935,9
3. EXPORT (US$ millions)	-	-	-	-	-	5,039	20,700	12,676	38,287	70,004	84,128	100,000
4. Capital Stock (Cr$ millions)	6,1	56,3	101,1	145,7	193,7	198,3	283,7	359,0	842,1	1.285,3	2.678,1	6.015,4
5. Shareholders'equity (Cr$ millions)	5,2	57,6	123,3	216,8	423,7	736,4	1.159,7	1.360,0	2.353,4	4.150,4	6.988,1	15.403,2
6. Net Income (Cr$ millions)	-	2,3	16,7	21,4	49,7	61,1	55,6	-	63,7	252,8	(257,5)	1.697,2
7. Personnel	589	1.128	2.031	2.621	3.323	3.553	4.225	4.104	4.300	4.887	5.957	6.582
8. Constructed Area (m^2)	18.366	46.185	53.616	63.206	67.480	96.340	111.014	116.426	117.821	124.219	132.260	144.560
9. Number of Stock-holders	1.035	45.509	73.029	95.462	117.932	117.504	126.156	162.276	176.758	183.997	222.481	246.953
10. Income per Share	-	0,04	0,17	0,15	0,26	0,31	0,20	-	0,08	0,20	-	0,98

* ESTIMATE

TABLE A.3

EMBRAER PRODUCTION FORECAST
(SUMMARY FOR 1981-1985)

PROGRAM	1981	1982	1983	1984	1985
EMB-110	73	70	70	70	70
EMB-120					10
EMB-121 A	16	28	28	12	12
EMB-121 B			6	12	12
SUB-TOTAL	89	98	104	94	104
EMB-810	38	60	60	60	60
EMB-820	7	6	8	8	8
SUB-TOTAL	45	66	68	68	68
EMB-312		13	56	84	84
EMB-326	15				
SUB-TOTAL	15	13	56	84	84
EMB-720	17	30	30	30	30
EMB-721	17	24	24	24	24
SUB-TOTAL	34	54	54	54	54
EMB-710	10	18	18	18	18
EMB-711	50	50	50	50	50
EMB-712	21	24	24	24	24
SUB-TOTAL	81	92	92	92	92
EMB-201	17	36	36	36	36
TOTAL	281	359	410	428	438

keep the Xingu production line at two per month until it can better define the market for the six- to nine-place turboprop.

EMBRAER's new EMB-120 Brasilia is being delayed by at least one year from recent estimates and more than two years from the optimistic schedule established at the onset of the program. Contributing to the delay of the 30-passenger commuter aircraft from an expected production in 1982 to an estimate now of early 1985 has been the slow development of the Pratt and Whitney of Canada PW-100 series turboprop engines. The configuration of the Brasilia wing and fuselage are being defined and EMBRAER has settled on the avionics packages it will offer with the aircraft. The aircraft will be built to FAA Regulation, Part 25 in light of the FAA's decision to scrap a proposed Part 24 covering commuter aircraft.

At the end of December 1980, EMBRAER held 120 options for the Brasilia of which 25 have been converted into paid options by international operators and 15 into paid options by Brazilian commuter operators. These options were from operators in the United States, the United Kingdom, Canada, France, Australia, New Guina and Brazil. The largest orders are from the Brazilian Air Force. EMBRAER sees a market of from 600 to 800 EMB-120's over the next twenty years.

The most successful aircraft program at Embraer in terms of production rate and sales remains the EMB-110 Bandeirante commuter aircraft. Launched with a production rate of two units per month in 1973, the figure rose to three per month in 1976. The Bandeirante has now sold 399 units worldwide and is flying in more than 22 countries. It is being produced at a rate of six aircraft per month.

The largest market for the 19-passenger commuter aircraft has been the U.S. with 45 Bandeirantes in service, followed by the United Kingdom with 23 in operation. EMB-110's are also flying in Australia, France, North Africa, Fiji and other countries.

A plan to produce a pressurized version of the EMB-110 has been put on hold both because of the engineering workload and the concern for the higher fuel flows for a heavier aircraft that might rarely fly the stage lengths required for higher altitudes.

Brazil, as part of its effort to reduce its trade imbalance, imposes barriers to the sale of U.S. general aviation aircraft. Though a signator to the general agreements of the Multilateral Trade Negotiations, but not the aircraft agreement, Brazil is able to sell EMBRAER aircraft in the U.S. without restraints.

Financing for the commuter aircraft consists of 15 percent down, with semi-annual payments for seven to nine years. The minimum financing interest rate is 7-5/9 percent for well-qualified customers.

EMBRAER delivered 436 aircraft in 1979, 388 to the domestic market and 48 for export. Single engine piston aircraft accounted for the largest percentage of deliveries with 329 EMB 201 Ipanema agricultural aircraft and Piper aircraft delivered to the domestic market. One single-engine aircraft was delivered for export.

Twin engine piston aircraft, the Piper Navajo and Seneca 2, assembled in Brazil, accounted for 125 domestic sales. Embraer also delivered 62 Xavante EMB-326 trainers to the Brazilian Air Force and three for the export market.

All versions of the EMB-110, such as the Bandeirante, the maritime partrol EMB-111, and the Xingu, accounted for 56 aircraft, 12 for the domestic market and 44 for the export market. The Brazilian market is almost totally protected against rival imports, yet out of the 6,000-strong Brazilian general aviation fleet, only about one-third are Pipers. EMBRAER claims to have only 33 unsold Pipers on its hands in April.

Despite the downturn in the sale of light, single engined aircraft in Brazil, EMBRAER is looking at the possibility of producing the Piper Tomahawk at San Jose dos Campos. One aircraft is already there.

Aerotec

The smallest of the Brazilian aircraft industries is Sociedade Aerotec Limitada with headquarters and production facilities in Sao Jose dos Compos. The company occupies a covered area of 61,350 square feet and employees about 200 people. Its first project to achieve series manufacture was the A-122 Uirapuru two-seat, all-metal lightplane, the prototype of which flew for the first time on June 2, 1965.

Another Aerotec activity is the subcontract work it does for EMBRAER, e.g., fuselages for the Seneca and Lance as well as wings for the Ipanema. Despite the subcontract work, Aerotec is continuing with its own designs and is now half way through the development of the new A-132 Tangara which first flew on February 27, 1981. When the aircraft enters production, a peak rate for four aircraft per month is planned.

Though resembling the earlier Uirapuru, the Tangara is a completely new side-by-side two-seat fully aerobatic trainer powered by a 160 HP Lycoming O-320 engine with fixed-pitch propeller. The Tangara wing is a parallel-chord NASA 2415 section with flaps and two integral fuel tanks. The rear fuselage has been designed with flap sides and top to improve spin characteristics and a smoothly rounded sliding canopy.

CANADA

de Havilland Aircraft of Canada

de Havilland is Canada's oldest and largest aircraft producer. The company was incorporated in 1928 as a subsidiary of the de Havilland Aircraft Company of England and has become one of Canada's major exporters. On 26 June 1974 ownership was transferred to the Canadian government. De Havilland of Canada has built and delivered more than 3,500 aircraft of its own design to 96 countries throughout the world since 1946.

A recently completed expansion program at de Havilland's Downview facilities has increased the company's manufacturing and office space to 1.4 million sq. ft. A new facility will be added to handle production of the Dash 8. DHC currently employs 5,000 people. When the Dash 8 program is in full swing, the company plans to increase the work force by between 2,500 and 3,000 people even though there will be a slight cutback in production of the Twin Otter.

De Havilland's sales for 1980 totalled about $250 million and are expected to double over the next several years and exceed $900 million annually by 1990.

Current production of the DHC-6 is running at seven units per month. For the last fifteen years, de Havilland has dominated the commuter aircraft market with the popular 19-seat Twin Otter turboprop. Almost 780 Twin Otters have been sold to date. During the past two years de Havilland has improved its sales position even more with the introduction of the four-engined, 50-seat Dash 7 which has already won over 130 orders and options. The Dash 7 has captured about 45 percent of total sales in the 50-seat category and production has recently increased from two to three aircraft per month.

De Havilland has stated its desire to become to the commuter market what Boeing is to the trunk airlines. Being fully aware of a gap between the Twin Otter and Dash 7 and that the regional carriers wanted a 30-40 seat aircraft, de Havilland began development of the Dash 8 in 1979. De Havilland estimates that between now and 1995 the potential sales of commuter aircraft will reach 1,300 units, not the 2,000 envisioned by the competitors, who base their figures on a recent study by the RAND corporation. DHC hopes to capture 40-45 percent of this market. The planned rate of production of the Dash 8 is six aircraft per month, to begin one and a half years after the start up of production, at end-1985. DHC is also studying the possibilities for increasing the rate to eight per month in July 1986 in order to meet the expected demand. It is highly likely DHC will opt for the higher production rate given the expansion of the commuter market and the necessity of reducing delivery deadlines to a minimum to avoid missing potential sales.

De Havilland is not involved in any joint development ventures although during one period they had numerous discussions with Aerospatiale which was also planning development of a commuter aircraft in the same category - the AS 35 - but no common agreement could be met.

De Havilland also sees potential for the Dash 8 for the top of the range twin turboprop business aircraft with a 12-16 seat version developed by Innotech in Montreal for executive transportation. The cabin of the Dash 8 has practically the same dimensions as the Canadair Challenger twin business jet. DHC is relying upon the expected economy of the turboprop to appear to customers for routes less than 1000 km.

Other potential markets envisioned by DHC for the Dash 8 include personal transport (for example the oil companies or mining research and prospecting companies which have to send their technicians to out-of-the-way regions with unprepared airstrips) and various military requirements. DHC visualizes as many as 200 units for the military during the next 20 years.

De Havilland believes sales of the Dash 8 could climb as high as 650 units with the main customers as follows:

U.S. commuter airlines	32%
Canada	12%
Africa	12%
South America	16%
Far East	11%
Europe	10%
Middle East	7%

There are currently 93 orders and options for the Dash 8 from 26 operators in the U.S., Canada, Europe and Australasia.

For the future, DHC does not exclude the possibility of a stretched version of the Dash 8 during the second half of the decade, which would carry 40-50 passengers. But to maintain the right size in relation to the other models in the range, such a decision would imply the development of a stretched version of the Dash 7, designed to carry 70-75 passengers.

FRANCE

Aerospatiale

Aerospatiale was formed on 1 January 1970 as a result of the merger of the former Sud Aviation, Nord Aviation, and SEREB companies. It is the largest aerospace company in the Common Market with a registered capital of 447,400,000 francs, facilities extending over a total area of 9,790,000 sq. meters (105,380,000 sq. feet) of which 1,778,000 square meters (19,138,000 sq. feet) are covered, and a staff of 38,173 persons at the beginning of 1980.*

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*Jane's, 1980-81.

Aerospatiale is divided into four divisions -- Aircraft Division, Helicopter Division, Tactical Missiles Division, and Space and Ballistic Systems Division. France has made investments recently in two principal sectors: the general computerization of the firms activities, not only in the area of computation and administration, but also computer-assisted design and manufacture. The second sector was the re-equipment of their machine shops with replacement of old machines and increasing adoption of numerically controlled machines.**

In the autumn of 1981 the French and Italian governments signed an agreement for the joint development and production of the ATR 42, a 42 seat commuter turboprop aircraft.

Dassault-Breguet

Formed as a result of a merger of the Avionics Marcel Dassault and Breguet Aviation companies on 14 December 1971, 21 percent of the stock was transferred to the French Government* on 1 January 1979. The current government favors nationalization of the company in part because of its monopoly on the development of fighter aircraft.**

Dassault-Breguet is engaged in the development and production of military and civil aircraft, guided missiles and servo control equipment. Series production of its aircraft is undertaken under a widespread subcontracting program with final assembly and flight testing handled by the company. Its 16 separate works and facilities covers 620,800 square meters (6,682,300 sq. feet) with a total of 15,553 employees, including 2,259 engineers at the beginning of 1980.*

Light Aviation

The French light aviation industry is made up of four manufacturers -- SOCATA, Avions Pierre Robin, Avions Mudry and the Cessna associate Reimes Aviation. Reims Aviation, a Cessna subsidiary, is the largest light aircraft

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* Jane's, 1980-1981.

**Interavia, 5/1981.

manufacturer in France. It produces two single-engined models, the FA152 and FR172, together with the twin engined FTB 337 exporting 85 percent of its output.

Avions Robins produced 104 aircraft in 1980. Among its products, are the R1180, DR 400, R 2160, and R2212. It is currently developing the R3140, a new economical four-seater with a T-tail and fixed under carriage. It will be powered by a 143 HP engine with a projected payload of 1050 pounds.

Avions Mudry is currently developing the CAP, a low-cost single-engined aircraft with two side by side seats built largely from composite materials to help keep down maintenance costs. With a fuel consumption of 4-5 gal. per hr, Avions Mudry hopes to discover a new market slot which the CAP could fill. The low-wing aircraft is intended primarily for use by flying schools with an expected performance of 102 km/hr cruise speed and 405 nmi range.

In cooperation with the Buchoux Company, Mudry is developing the MB-4-80 engine, an air cooled four-stroke piston power-plant developing 80 HP destined to power both the CAP and another projected design, an economy optimized aerobatic single-seater designated the Mini-CAP. The new engine will run on either 100 octane AvGas or on "Super" automobile gasoline.

ISRAEL

Israel Aircraft Industries

Israel Aircraft Industries (IAI) entered the business aircraft market in 1976 as a result of U.S. antitrust legislation which required North American Rockwell to give up one of the business jets previously produced by North American Aviation and Rockwell-Standard Corporation at the time the two corporations merged. The new corporation opted for North American's Sabreliner and IAI bought the rights to manufacture and market Rockwell's Aero Commander.

Renamed variously the Commodore Jet and Jet Commander 1121, the former Aero Commander was subsequently developed into the 1122 and 1123 versions. A total of 186 of these various units were sold. In 1976, IAI launched the Westwind 1124 with turbofan engines and an enlarged fuselage. In 1978 this aircraft was succeeded by the Westwind I and in 1979 IAI commenced fullscale development of the Westwind II (the winglet Westwind).

Israel Aircraft Industries ranks only sixth in the world in numbers of business jets delivered. The long Arab-Israeli war closed much of the European market and IAI looks at the United States and Latin American as their prime sales areas.

ITALY

The Italian aerospace industry employs 40,700 people of whom 39 percent are in the South of the peninsula* and achieved a turnover of 1,500,000 hire in 1980.* 1981 sales were probably in the region of 2,000,000 Lire with exports representing 60 percent of the total.* Italy ranks fourth in terms of aerospace employment in Europe.

Most of the Italian aerospace industry is controlled by two holding companies:

IRI - Finmeccanica
EFIM

The Italian government stepped in to bring order to the "open warfare" between IFI and ERIM and defined the aerospace business into two sectors:

IRI - Aeritalia -- Heavy aircraft
EFIM - Agusta -- Helicopters and Light Aircraft.

IRI is a 100 percent government owned holding company which, according to the Italian embassy, makes Aeritalia 100 percent government owned. Although Aeritalia absorbed Partenavia in 1981, it and all other aerospace companies are considered to be privately owned.

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*Interavia 2/82.

Aeritalia

Formed on 12 November 1969 to combine Fiat's aerospace activities (except those which concerned aero-engines) with those of Aerfer and Salmoiraghi of the Finmeccanica group. The company consists of four groups:

Combat Aircraft Group
Transport Aircraft Group
Equipment Group
Space and Alternative Energy Group

The company employs 11,500 people and operates six plants -- three at Turin, two at Naples, one at Milan. Considerations are being given to opening a plant in Southern Italy at Foggia.

Aeritalia engineers have worked closely with the Boeing research department to define the B767 specification and to incorporate advanced technology in the aircraft.* Their work consists of 15 percent of the total value of the project.

An Italian team of engineers, headed by S. Ruocco has developed the high-lift devices (flaps, etc.) for the B767 wing.

One third of Aeritalia's workforce is engaged in the production of B767 components with responsibility for the tailfin, rudder inner and outer spoilers, outer aelerions and the inner and outer trailing edge flaps.

Aeritalia plans to invest up to $100 million by 1985 on factory modernization, the purchase of new numerically - controlled machine tools, and on other improvements to the production plant. Over the past few months, the firm has become highly skilled in the production of epoxy/carbon fiber components. It produces the six-meters-long B767 rudder which is currently the worlds largest aircraft component made from composite materials.*

Agusta

Formed in 1907 by Giovanni Agusta, Agusta is now part of the Agusta group consisting of helicopter, aircraft and other groups under the control of two holding companies, Agusta and SIAI.

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*Interavia, 7/1981.

The company employs 9,500 people. The helicopter division consists of Costruzioni Aeronautiche Giovanni Agusta, Elicotteri Meridionali, Agusta Aviation, the subsidiary representing Agusta helicopters in North America, and European Helicopter Industries.*

According to Mr. Pietro Fascione (Vice President of Agusta), a reoreganization of the Italian helicopter industry is being planned.

During the early 1970's Agusta considerably improved its production facilities making for greater use of numerically controlled machine tools. At that time they planned to expand the EMA facilities to about 100,000 square meters for production of light helicopters.**

Between now and 1984, the Agusta Group plans to devote 214,000 million Lire to the improvement of the present range of products. The company plans a systematic program of modernization to meet current market requirements.*

Partenavia

Founded in 1957 by Prof. Ing Luigi Pascale and his brother Ing Nino Pascale, Partenavia occupies a 129,165 square ft. facility on Capodichino Airport, Naples. In 1981, Partenavia was absorbed by Aeritalia.* Partenavia has one of the finest facilities in the Naples area employing about 160 people.*

JAPAN

Mitsubishi Heavy Industries Ltd.

Mitsubishi Aircraft International, Inc. is a wholly-owned subsidiary of Mitsubishi Heavy Industries, Ltd. of Japan. It was established in 1965 at San Angelo, Texas to undertake final assembly and flight testing of the MU-2 twin turboprop STOL multi-purpose transport aircraft designed by the parent company. The head office was moved to Dallas in 1977.

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*Interavia, 2/1974.

**Interavia, 2/1982.

Two MU-2's are currently being assembled in San Angelo - the Marquise (MU-2B-40) and Solitaire (MU-2B-60). The aircraft are manufactured in the parent company's Komaki plant and shipped in semi-completed form to MAI for assembly and delivery to customers in the U.S., Canada and Latin America. By 1 January 1980 total orders for all versions of the MU-2 had reached 623 including 574 for export and 49 for Japanese customers.

MAI will also be responsible for assembly of the New Diamond I (MU-300).

WEST GERMANY

Dornier

Dornier's market analysis reveals that the need for 30+ commuter aircraft will not materialize until the mid 1980's but that the need for the 15-19 seat aircraft is now. Therefore Dornier accelerated its efforts to enter its two contenders, the DO-228-100 and Do-228-200 into the market in 1981. The aircraft incorporate the new TNT (Tragfeügel Neuer Technologie) advanced wing and fuselage cross section of the Skyservant.

Dornier has been flying the low drag/high lift TNT wing since June 1979 and claims a 20 to 30 percent fuel saving on a typical commuter stage length. With the German government research establishment, DFVLR, Dornier is developing an Open Loop Gust Alleviation (OLGA) system. Gusts are sensed by an angle of attack vane at the nose, pitch rate gyro and vertical accelerometer. Gust responses are damped by moving both ailerons up or down simultaneously in association with the elevator. Successful gust alleviation, particularly damping G-cycles occurring at between one Hertz and five Hertz, can go a long way towards avoiding airsickness in aircraft forced to operate in the turbulent airspace.

Dornier claims three firm sales and 35 paid options. The initial production will be 10 to 15 units split half and half -100's and -200's. A production rate of two per month is planned with tooling for three.

In addition to the above, Dornier claims to be using new advanced production techniques which will result in weight savings, smoother surface and less maintenance.

Dornier will also offer a special support program, training and turn-key operating consultancy.

APPENDIX B

AIRCRAFT CHARACTERISTICS AND PERFORMANCE FACTORS

APPENDIX B

AIRCRAFT CHARACTERISTICS AND PERFORMANCE FACTORS

Tables B.1 through B.3 present the key parameters of those aircraft which currently dominate or are expected to enter the commuter and business jet/turboprop markets. Each of the tables presents the manufacturer, aircraft name and designator, cost, seating (both crew and passengers), cabin dimensions - length, height and width (in feet), number and type of engines as well as thrust or shaft horsepower, maximum takeoff weight, cruise speed, and service ceiling. The commuter chart also shows the breakeven point (in cents per seat mile) assuming a 100 percent load factor. This value was determined by Business and Commercial Aviation as reported in their April 1981 issue. The breakeven yield was determined by taking the total operating costs for a block segment (B/CA used 100 sm) and calculating what it would cost per passenger seat per statute mile to break even on the segment.

Direct operating costs were established by assuming that each aircraft was in its first year of operation, a four-airplane fleet and that most of the maintenance was performed in-house. Each aircraft was equipped to meet FAA Part 135 requirements. The aircraft was depreciated over ten years to a 15-percent residual value. The downpayment is ten percent with 90 percent financed over ten years at 12.5 percent interest and the first year's principal is deferred.

Crew salaries were $36 per block hour for unpressurized turboprops with up to 19 passenger seats; $40 per hour for pressurized turboprops with up to 19 passenger seats; $50 per hour for aircraft with 20-19 passenger seats; $70 per hour for aircraft with 30 to 49 passenger seats; $85 per hour for aircraft with 50 or more passenger seats and $120 per hour for turbojet aircraft.

Personnel expenses, employee benefits and payroll taxes totaled 38.7 percent of salaries, while annual insurance costs and taxes on the aircraft amounted to 3.5 percent of the airframe price. For aircraft supplies B/CA charged $1 per seat for up to 19 passengers and $1.25 per seat for 20 or more passengers. Into-plane contract fuel was estimated at $1.25 per gallon for jet A and $1.30 per gallon for avgas.

Maintenance costs were actual costs determined through conversations with aircraft operations plus a 25 percent maintenance burden.

Indirect operating costs were 50 percent of direct operating costs.

New aircraft do not have breakeven costs shown.

TABLE B.1

COMMUTERS

MANUFACTURER	AIRCRAFT	COST	SEAT-ING	CABIN L/H/W	ENGINES	WEIGHT MAX TO	CRUISE SPEED	CEILING	BREAK EVEN 100% LF	EST DEL DATE	PRESS
PILATUS B-N	BN-2B-20 Islander	$ 301,930	2+8	10/3 9/3 6	(2) Lyc IO-540-K1B5 300 hp ea	6,600	137	18,000	0 217		No
CESSNA	CE-402C Ultraliner	$ 333,606	2+8	15 8/4 2/4 7	(2) Cont TSIO-502VB 325 hp ea	6 850	174	26,900	0 245		No
PIPER	PA 31-350 Navajo Chieften	$ 377 620	2+8	13 1/4 3/4 2	(2) LYC TIO-540-J2BD 350 hp ea	7 000	163	24 000	0 242		No
CESSNA	CE 404 Titan Courier II	$ 478,910	2+9	13 8/4 3/4 7	(2) Cont GTSIO-520M 375 hp ea	8 400	174	26,000	0 262		No
PILATUS B-N	BN-2A-111-2 Trislander	$ 514,120	2+16	21 5/3 9/3 6	(3) Lyc O-540-E4-C5 260 hp ea	10,000	145	12,400	0 144		No
de HAVILLAND	DITL-6-300 Twin Otter	$ 1,170,000	2+19	18 4/4 9/5 3	(2) P&W PT6A-27 620 shp ea	12,500	172	26,700	0 187		No
GAF	N24A Nomad	$ 1,196,308	2+16	21 3/5 2/4 3	(2) All 250-B-17C 385 shp ea	9,400	163	20,500	0 239		No
BEECH	BE-C99 CB 99	$ 1,335,000	2+15	18 7/4 8/4 5	(2) P&W PT6A-36 750 shp ea	11,300	249	28,080	0 209		No
EMBRAER	EMB-110P1 Bandierante	$ 1 495,998	2+18	31 2/5 3/5 3	(2) P&W PT6A-34 750 shp ea	12,500	224	22,500	0 244		No
ISRAEL AIRCRAFT IND	1A1-101B Arava	$ 1,650,000	2+18	22 4/5 8/7 7	(2) P&W PT6A-36 750 shp ea	15 140	139	23,600	0 268		No
SWEARINGEN	SA227-AC Metro III	$ 1,845,000	2+19	25 4/4 8/5 2	(2) AR TPE-331-110 1,000 shp ea	14,000	280	30,000	0 221		Yes
CASA	C212-200 Commuter	$ 2 121,700	3+26	26 1/5 9/6 8	(2) AR TPE 331-10 900 shp ea	16,427	185	25,000	0 216		No
SHORT BROS LTD	SD 3-30 Shorts 330	$ 2,870,000	3+30	31 0/6 5/6 5	(2) P&W PT6A-45B 1,156 shp ea	22,900	165	20,000	0 212		No
GULFSTREAM AM	Gulfstream 1C	$ 3,000,000	3+37	41 0/6 1/7 5	(2) RR Dart 7 MK 529-8x 1 910 shp ea	36,000	300	30,000	0 218		Yes
de HAVILLAND	DHC-7 Dash 7	$ 5 020,000	3+50	39 5/6 4/7 0	(4) P&W PT6A-50 1,120 shp ea	44,000	230	21,000	0 180		Yes
FOKKER	F27 MK 500 Friendship	$ 6,350,000	3+50	52 4/6 8/8 5	(2) RR Dart 7 MK 535-7 2,020 shp ea	45,000	259	20,000	0 193		Yes
BRITISH AEROSPACE	HS 748-2B Intercity	$ 6 500 000	3+48	46 6/6 3/8 1	(2) RR Dart 7 MK 535-2 2,280 shp ea	46,500	234	25,000	0 227		Yes
FOKKER	F28 MK 4000 Fellowship	$10,550,000	4+85	50 3/6 7/10 2	(2) RR RB 183-MK 555-15 9,900 lbs ea	73,000	437	35,000	0 133		Yes
AHRENS	402	$ 2 000 000	+27	N/A	(2) AR TPE 331-11 1,100 shp ea	16,000	170	NA	NA	1982	No
AHRENS	404	$.,8- 2,000,000	+30	28 0/6 0/6 0	(4) All 250-B17B 440 shp ea	17,000	170	18,000	NA	1981	No
BRITISH AEROSPACE	Jetstream 31	$.,800,000	+19	24 0/6 0/5 9	(2) AR TPE 331-10 900 shp ea	14,110	263	31,000	NA	1982	Yes
BEECH	1900	$,600,000	+19	N/A	(2) P&W PT6A 1,000 shp ea	15,245	263	NA	NA	1983	Yes
COMMUTER AIRCRAFT CORP	CAC-100	$ 3 000 000	+44	N/A	(4) P&W PT6A-41 850 shp ea	28,900	287			1982	No
de HAVILLAND	Dash 8	$ 4 000,000	+32-36	N/A	(2) P&W PT 7A-1 1,700 shp ea	29,000	260	25,000	NA	1984	Yes
DORNIER	228-100	$ 1 400 000	+15	2 8/4 5/5 3	(2) AR TPE 331-5 715 shp ea	12,568	233	29,600	NA	1981	Yes
DORNIER	228-200	$ 1,500 000	+19	[illegible] 6/4 5/5 3	(2) AR TPE 331-5 715 shp ea	14,500	233	27,60C	NA	1981	Yes
EMBRAER	110P-3 Bandierante	$1 550 000	+19	N/A	(2) P&W PT6A-65 1 17[illegible] shp ea	15,440	300	NA	NA	1983	Yes
EMBRAER	120 Brasilia	$ 3 200 000	+30	29 8/7 1/5 7	(2) P&W PT 7A-1 1,500 shp ea	20 000	287	35,500	NA	1985	Yes
FAIRCHILD/ SAAB	SF 340 Commuter	$ 3 450,000	3 +34	33 7/7 1/6 0	(2) GE CT 7-5 1,650 shp ea	25,000	360	NA	NA	1984	Yes
SHORT BROS LTD	360	$ 3 400,000	3 +26	36 1/6 3/6 3	(2) P&W PT6A-65R 1,294 shp ea	25,700	190	NA	NA	1982	No
AERO-SPATIALE/ AGRITALIA	AS 35	$ 5 000 000	+40-46	NA	NA	NA	NA	NA	NA	1985	NA
BRITISH AEROSPACE	BAE 146-100	$10 000 000	4/5+ 71	50 5/11 0/6 2	4 Lyc ALF 502 R-3 6,700 lbs ea	78,850	434	22,000	NA	1982	Yes
BRITISH Aerospace	BAE 146-200	NA	4/5+ 100	58 5/11 0/6 2	4 Lyc AFL 502 R-3 6 700 lbs ea	87,500	424	24,000	NA	1983	Yes

TABLE B.2

TURBOPROP BUSINESS AIRCRAFT

MANUFACTURER	AIRCRAFT	COST	SEATING	CABIN	ENGINES		WEIGHT MAX TO	CRUISE SPEED	CEILING
Piper	PA31T-500TI Cheyenne I	$ 845,165	1+6	8 4/4 3/4 2	(2) P&W PT6A-11	500 shp ea	8,700	247	28,200
Cessna	CE-425 Corsair	914,329	1+6	10 6/4 3/4 6	(2) P&W PT6A-112	450 shp ea	8,200	264	34,700
Beech	BE-C90 King Air	988,540	1+7	12 7/4 8/4 5	(2) P&W PT6A-21	550 shp ea	9,650	222	30,700
Piaggio	P 166-DS3 P 166-DL3	1,050,000	1+5	10 5/5 8/	(2) Lyc LTP-101-600	600 shp ea	9,480	160	20,000
Piper	PA-31T-620 Cheyenne II	1,055,640	1+7	8 4/4 3/4 2	(2) P&W PT6A-28	620 shp ea	9,000	281	31,600
Gulfstream AM	AE-840 Commander 840	1,157,715	1+7	9 5/4 5/4 0	(2) AR TPE-331-5-254K	718 shp ea	10,325	287	31,000
Piper	PA-31T2XL Cheyenne II XL	1,168,450	1+7	10 0/4 3/4 2	(2) P&W PT6A-135	620 shp ea	9,474	268	32,400
Cessna	CE-441 Conquest	1,174,470	1+8	12 7/4 3/4 6	(2) AR TPE331-8-402S	636 shp ea	9,850	293	35,000
Beech	BE-E90 King Air	1,198,105	1+7	12 7/4 8/4 5	(2) P&W PT6A-28	550 shp ea	10,100	249	27,620
Mitsubishi	MU-2B-40 Solitaire	1,198,900	1+7	8 0/4 3/4 9	(2) AR TPE 331-10	665 shp ea	10,470	313	33,500
Piper	PA-42 Cheyenne III	1,347,930	1+8	14 9/4 4/4 3	(2) P&W PT6A-41	720 shp ea	11,200	291	32,800
Beech	BE-F90 King Air	1,349,025	1+6	12 7/4 8/4 5	(2) P&W PT6A-I35	750 shp ea	10,950	267	29,802
Gulfstream Ar	AE-980 Commander 980	1,357,715	1+7	9 5/4 5/4 0	(2) AR TPE331-10	733 shp ea	10,325	304	31,000
Beech	BE-B100 King Air	1,367,493	1+8	16 7/4 8/4 5	(2) AR TPE 331-6	715 shp ea	11,800	268	28,138
Mitsubishi	MU-2B-60 Marquise	1,475,815	1+8	11 8/4 3/4 9	(2) AR TPE331-10-501	715 shp ea	11,575	296	29,750
Gulfstream Am	AE-1000 Commander 1000	1,500,075	1+7	12 4/4 8/4 1	(2) AR TPE331-10	820 shp ea	11,200	307	35,000
Lear Avia	LF 2100 Lear Fan	1,650,000	1+7	12 8/4 7/4 8	(2) P&W PT6B-35F	650 shp ea	7,200	358	41,000
Beech	BE-200 King Air	1,655,380	1+8	16 7/4 8/4 5	(2) P&W PT6A-41	850 shp ea	12,500	287	32,880
Swearingen	SA227-TT Merlin III C	1,849,320	1+7	10 6/4 8/5 2	(2) AR TPE 331-10U	900 shp ea	13,230	300	27,000
Swearingen	SA227-AT Merlin IVC	2,071,180	1+11	25 4/4 8/5 2	(2) AR TPE 331-11U	1100 shp ea	14,000	283	30,000
Embrarer	Xingu	NA	2+6	NA	(2) P&W PT6A-28	680 shp ea	12,500	182	NA
Embrarer	Bandierante	NA	2+7	NA	(2) P&W PT6A-27	680 shp ea	30,500	259	NA
SIAI-Marchetti	SF600 Canguro	NA	2+9	NA	(2) All 250-B176	420 shp ea	9,480	218	NA

TABLE B.3

TURBOJET/TURBOFAN BUSINESS AIRCRAFT

MANUFACTURER	AIRCRAFT	COST	SE*TING	CABIN L/H/W	ENGINES	WEIGHT MAX TO	CRUISE SPEED	CEILING
Aerospatiale	SN 601 Corvette	$1,750,000	2+12	18 9/5 0/5 2	(2) P&W JT15D-4 2500 lbs ea	15,430	389	36,000
Cessna Jet	CE 500 Citation I	1,947,525	2+6	12 7/4 3/4 9	(2) P&W JT15D-1A ?200 lbs ea	11,850	347	41,000
Gates	LR-25D Learjet	2,131,000	2+7	12 1/4 3/49	(2) GE CJ610-8A 2950 lbs ea	15,000	437	51,000
Gates	LR-28 Learjet	2,336,400	2+7	12 1/4 3/4 9	(2) GE CJ610-8A 2950 lbs ea	15,000	440	51,000
Cessna Jet	CE 550 Citation II	2,518,475	2+7	16 2/4 8/4 9	(2) P&W JT15D-4 2500 lbs ea	13,300	377	43,000
Dassalt	AD MY-10 Falcon 10	3,200,000	2+7	12 8/4 7/4 8	(2) AR TFE731-2-1C 3?30 lbs ea	18,740	430	45,000
Gates	LR-35A Learjet	3,325,485	2+7	12 9/4 3/4 9	(2) AR TFE731-2-2B 3500 lbs ea	17,000	432	45,000
Israel Aircraft	IA-1124 Westwind I	3,428,710	2+7	15 3/4 9/4 8	(2) AR TFE731-3-1G 3700 lbs ea	22,850	424	45,000
Gates	LR-55 Learjet	3,529,785	2+7	13 9/5 7/5 9	(2) AR TFE731-3A-2B 3700 lbs ea	19,500	441	51,000
Gates	LR-36A Learjet	3,545,485	2+5	10 8/4 3/4 9	(2) AR TFE731-2-2B 3500 lbs ea	18,300	432	45,000
Gates	LR-56 Learjet	3,614,785	2+6	11 0/5 7/5 9	(2) AR TFE731-3A-2B 3700 lbs ea	20,500	441	51,000
Israel Aircraft	IA-1124A Westwind II	3,828,060	2+7	15 3/4 9/4 8	(2) AR TFE731-3-1G 3700 lbs ea	23,500	415	45,000
Cessna Jet	CE-650XR Citation III X?	4,237,925	2+8	18 6/5 8/5 7	(2) AR TFE731-3B-100 3650 lbs ea	19,500	465	51,000
Cessna Jet	CE-650 Citation III	4,298,400	2+8	18 6/5 8/5 7	(2) AR TFE731-3B-100 3650 lbs ea	19,500	464	51,000
Rockwell Int'l	NA-265-65 Sabreliner	5,100,000	2+8	19 0/5 5/5 2	(2) AR TFE731-?R-1D 3700 lbs ea	23,800	441	45,000
British Aerospace	HS 125-700 HS 125 Srs 700	5,845,000	2+8	21 3/5 8/5 9	(2) AR TFE 731-3R-1H 3700 lbs ea	24,800	427	41,000
Dassault	AD MY-20F Falcon 20	5,960,000	2+9	24 4/5 5/6 2	(2) GE CF700-2D2 4500 lbs ea	28,660	410	42,000
Dassault	AD MY-50 Falcon 50	8,750,000	2+9	23 5/5 9/6 1	(3) AR TFE731-3-K 3700 lbs ea	38,800	430	45,000
Canadair	CL 600 Challenger	9,000,000	2+11	28 3/6 1/8 2	(2) LYC ALF502-L 7500 lbs ea	40,400	443	45,000
Canadair	CL 600GE Challenger (GE)	9,900,000	2+11	28 3/6 1/8 2	(2) GE CF34-1A 8650 lbs ea	41,450	450	45,000
Gulfstream Am	G-1159A Gulfstream III	11,000,000	2+14	24 3/6 1/7 0	(2) RR SPEY MK 511-8 11400 lbs ea	68,200	459	45,000
Dassault	AD MY-20H Falcon 20H	NA	2+8	NA	(2) AR- NA NA	30,000 to 32,000	NA	NA
Mitsubishi	MU 300 Diamond I	2,381,710	2+7	15 7/4 8/4 9	(2) P&W JT15D-4 2500 lbs ea	14,100	423	41,000
Gates	LR-29 Learjet	2,388,300	2+5	9 9/4 4/4 9	(2) GE CJ610-8A 2950 lbs ea	15,000	440	51,000

APPENDIX C

GROUP FOR AERONAUTICAL RESEARCH AND TECHNOLOGY -- EUROPE (GARTEUR)

Group for Aeronautical Research and Technology-Europe (GARTEUR)

In a recent article in the Dutch magazine, Avia, some insight into the realization of a European effort to pool their aeronautical R&D resources was presented. Although this subject has been mentioned for some time, this article presented the first details of the proposed organization.

GARTEUR is a cooperative group composed of representatives from France, Germany, England and the Netherlands. It had its start in 1973 with three members -- Germany, France and England. The Netherlands became a member in 1977.

GARTEUR consists of three elements -- a Council, Groups of Responsibles and Working Groups.

The members of the Council are appointed by the various governments and set policy for the organization.

The Groups of Responsibles (literal translation from the Dutch) determine the details of the effort to be performed. Four areas have been highlighted:

- Aerodynamics
- Flight Mechanics
- Strength and Materials
- Helicopters.

It is of interest to note helicopters having such a prominent position in the organization. This can be attributed to Europe's opinion that they are number one in rotorcraft technology and plan to stay there.

Under the Groups of Responsibles are the Working Groups. These can be likened to the Branches within NASA. The Working Groups perform the actual research. Areas in which the article claims strong activities are underway include:

- Wing/body aerodynamics, especially at transonic speeds.
- Impact damage and tolerance studies-especially composite materials. The article highlighted the aluminum alloy

7010 which has a high strength to weight ratio and fatigue resistance.

SOURCE: Jan Roskam, 15 August 1981.

APPENDIX D

EXCERPT FROM THE REPORT TO THE
WORKSHOP BY THE PANEL ON GENERAL
AVIATION, AERONAUTICS AND SPACE
ENGINEERING BOARD, ASSEMBLY OF ENGINEERING
NATIONAL RESEARCH COUNCIL, ENTITLED:

NASA's Role in Aeronautics: A Workshop
Volume IV - General Aviation

The primary requirements of general aviation aircraft are significant improvements in flight safety and fuel efficiency. The need for safety is clearly indicated because fatality rates are worse in general aviation than motor vehicle fatality rates and are two orders of magnitude poorer than the safety record of the trunk airlines. Even though corporate and business flying is an order of magnitude better than the overall general aviation record, it also should be significantly improved.

Fuel economy is important for general aviation. Representative fuel efficiency data, as reported by individual manufacturers, are shown in Table 2. The "mpg" ratings compare favorably with domestic cars and commercial airplanes in use today, but not with the automobiles and aircraft that are under development.

TABLE 2 General Aviation Fuel Efficiency Typical 1980 Aircraft

Model	Statute Miles per Gallon	Seat Miles per Gallon
Mooney 201	19 5	78
Cessna P210	14 7	88
Beech A36	14 4	86
Piper Saratoga 5P	12 6	76
Cessna 421	7 0	49
Cessna 441	5 5	55
Gates Learjet 35A	3 5	28

Source Each manufacturer

Additional important objectives for general aviation aircraft are:

- o Reduce interior and exterior noise levels;
- o Reduce maintenance;
- o Reduce cost of ownership, particularly operating costs; and
- o Improve reliability.

The new technologies required to achieve these critical objectives are briefly described below.

Aerodynamics

Enhanced flight characteristics to improve operational safety and new configurations to reduce the propulsive energy requirements of small aircraft are the most critical aerodynamic needs of general aviation.

New or improved airfoils, coupled with developments in wing and wing/body configurations and/or control capabilities, will improve aerodynamic efficiency while reducing requirements for piloting skills in general aviation aircraft. Such achievements, which are applicable to single- and multi-engine aircraft, also will improve safety.

Structures and Materials

The dominant need in new structural technology is to develop the ncessary knowledge to make full use of advanced composite materials for general aviation, with special emphasis on Kevlar or aramid fibers. It is feasible to obtain a 35 percent reduction in structural weight, plus reduced interior noise, improved structural life and cleaner contours for reduced drag. The greater use of Kevlar in tires in 10 to 20 years, if the material proves successful, should reduce its price, making it practical for wider use in aircraft and resulting in higher quality aircraft.

Crashworthiness design also is an important requirement in general aviation aircraft. Such technology will be particularly necessary when composite structures are widely incorporated into general aviation aircraft - the knowledge base for crashworthy design using the materials does not exist today.

Propulsion: Turbine

Because general aviation turbine engines are small in comparison to transport and military power plants, unique technologies are required to achieve higher pressure ratios and higher efficiency centrifugal compressors, as well as higher turbine-inlet temperature capabilities with lower cost turbine construction. The technologies are essential to achieving reduced fuel consumption and lower cost engines, and they should be obtained while maintaining a multi-fuel capability.

Propulsion: Intermittent Combustion Engines

The dominant need in general aviation is improved fuel efficiency; increased reliability and the ability to use middle distillates are secondary objectives, though important. Since several years will be needed to achieve these goals by developing new engine types, improvements are needed in current engines.

Electronic fuel controls, as well as turbochargers with improved durability, higher pressure ratios, higher efficiency, and lighter weight will improve fuel efficiency and increase reliability. Fabrication and design methods employing lightweight materials should be developed, with the goal being a 30 percent reduction in engine weight.

Propulsion: Propellers

Because of their inherent propulsive efficiency, propellers will be used on nearly 95 percent of present and future general aviation aircraft.

Yet, little advancement in general aviation propeller technology has been evident in this country since World War II, in spite of the serious need for propellers of higher efficiency for commuter and business aircraft. The need for propeller research has been stimulated by the high cost of fuel, more stringent noise requirements, and increasing emphasis on safety.

High propeller efficiency must be developed over a wide range of operating conditions. Lower noise levels, longer structural life for blades, lower cost (including maintenance costs), and lower weight are required if the United States is to retain its competitive edge in the world market for general aviation products.

Electronics and Avionics

Most general aviation flying is done by businessmen-pilots. Since they must operate in the same complex air traffic environment as professional executive and air transport crews, a special need exists in general aviation to reduce the pilot's workload and to simplify the pilot's flight control, navigation, communications, and weather-related tasks. Improvements in reduced workload will apply equally to personal pilots and to the two-person crews for commuter airlines.

Operations

To improve general aviation safety, research is needed to detect and disseminate real-time weather information, particularly thunderstorm information, winds aloft, and atmospheric icing conditions. Improved technologies also are needed to protect the general aviation airframe, propeller, and engine from the accumulation of ice in flight.

Research should be conducted to improve the operational efficiency of Air Traffic Control (ATC) systems. Inefficiencies in ATC systems can cause delays that could offset the gains in fuel efficiency made possible by research in NASA's traditional areas of work.

Human Engineering

Because general aviation aircraft are flown by the most diverse and often least experienced members of the aviation community, a unique need exists for advances in human engineering. Enhanced general aviation safety and efficiency will result from simplifying cockpits, improving the readability of instruments, and improving avionics, controls, and displays that reduce pilot workload and the consequences of human error. Easier means for accurate fuel management and improved flight control systems, including stability augmentation, also will lead to higher levels of flight safety and fuel efficiency. Human engineering research should be conducted in the area of designs for maintenance simplicity, including maintenance monitoring and diagnostic techniques, particularly because the industry anticipates increasing shortages in the number of skilled mechanics.

EVOLUTION OF NASA'S ROLE IN GENERAL AVIATION AERONAUTICS

From its inception in 1915 to the start of World War II, the research work of the National Advisory Committee for Aeronautics (NACA) was of great benefit to the entire aeronautical community - although primarily conducted to support military aviation. In many cases, the performance of military and commercial aircraft was nearly identical, the problems confronted in the development of each were quite similar, and not infrequently both types were designed by the same staff.

With World War II came an immense expansion of aeronautical development in the United States. By 1945, aircraft production capacity had increased vastly, and a network of airfields with paved runways had been constructed. Technology had advanced to the point where airliners could fly at speeds that only five years earlier were the sole province of fighter aircraft, and some fighter planes were flirting with the speed of sound. During the next decade, the jet engine pushed military aircraft to supersonic speeds, and the airlines wrested the long-range passenger market from trains and ocean liners. The airframe companies found it desirable to split their activities into commercial and military divisions. The NACA found that the frontiers of aerodynamics and propulsion technology for military aircraft, pressing into the realm of supersonic flight, had extended beyond commercial aviation. For the first time, the research and development needs of the two segments of the industry were substantially different.

In the 1950s, general aviation began to emerge as a significant mode of transportation. Even so, the technology for general aviation was far from the aeronautical frontiers being explored in the 1950s and 1960s. The 1971 Civil Aviation Research and Development (CARD) study, conducted jointly by the Department of Transportation (DOT) and NASA, recommended that NASA limit its research in general aviation to factors relating to safety. Consequently, NASA's attempts to introduce other research activities related to general aviation were unsuccessful.

As important as safety is, product improvement in general aviation demands both the application of existing advanced technologies and the generation of new research relating especially to airfoils, propellers, materials, and propulsion systems. Without the necessary in-house capability, and without specific NASA assistance, the general aviation industry's development of these technologies has been a slow and difficult process. The result has been that today's general aviation products have yet to reach their full potential.

NASA'S ROLE IN GENERAL AVIATION AERONAUTICS: 1980 AND BEYOND

General aviation needs substantial new technology development to fulfill the technology needs previously outlined. In particular, an order of magnitude improvement in safety and a 50 percent increase in mpg are needed for future models.

NASA aerodynamics and avionics research on commercial airliners benefits business-jet technology. That is about the only benefit obtained from the NASA research conducted for large airliners and military aircraft. The great differences in size between general aviation aircraft and the wide-body transports result in almost completely different structural design parameters. Moreover, the bulk of general aviation aircraft will always be propeller driven and smaller than the commercial transport, necessitating entirely different lines of research.

NASA's general aviation effort, in 1980, is less than 3 percent of its aeronautical research and technology (R&T) budget and only 175 out of 4000 people working in aeronautics were devoted to general aviation research.

The panel's recommendations regarding the roles that NASA should play in the 1980s and beyond are summarized in Figure 5. The following sections describe the types of effort that NASA could provide for the future design and development of general aviation aircraft, within the context of the general technology needs previously outlined.

Aerodynamics

Because flight safety and fuel efficiency are of primary concern, the aerodynamics research and development requirements for general aviation fall into three major categories: high-lift considerations (including control systems), low drag, and handling qualities. The small size and configurations of typical general aviation machines present particular aerodynamic conditions that require special consideration.

Operational experience has demonstrated a strong relationship between flight safety and the aircraft's ability to fly slowly while maintaining strong, positive control during landing approach

NASA ROLE CODE
1 Major Role
*2 Moderate Role
*3 Minor Role
*– No Role

ROLES \ DISCIPLINES	AERODYNAMICS	STRUCTURES & MATERIALS	TURBINE ENGINES (PROPULSION)	INT COMBUST ENGINES (PROPULSION)	PROPELLERS (PROPULSION)	ELECTRONICS & AVIONICS	VEHICLE OPERATIONS	HUMAN ENGINEERING
NATIONAL FACILITIES & EXPERTISE	1	1	1	1	1	3	1	1
RESEARCH	1	1	1	1	1	–	1	1
GENERIC TECHNOLOGY EVOLUTION	1	1	1	1	1	3	1	–
VEHICLE CLASS TECHNOLOGY EVOLUTION	2	1	1	1	1	3	1	1
TECHNOLOGY DEMONSTRATION	1	1	1	1	1	3	1	–
TECHNOLOGY VALIDATION	–	2	2	2	2	–	1	–
PROTOTYPE DEVELOPMENT	–	–	–	–	–	–	–	–
OPERATIONS FEASIBILITY	–	–	–	–	–	–	–	–

*If a proposed project or program initially falls in a recommended moderate minor, or no-role category but following review of its merits on an individual case basis is deemed to be a desirable undertaking by virtue of its being in the national interest or mandated by the Congress or as a result of review it is concluded there are other overriding circumstances then NASA s role for that project or program would be elevated to a major one (i e Category 1)

FIGURE 5 GENERAL AVIATION Role/Discipline Matrix

maneuvers. Nearly 50 percent of all general aviation accidents occur during the final phase of flight. Thus, particular interest is focused on the development of high-lift systems that can be utilized with high-aspect-ratio wings employing low-drag airfoils. Such airfoils are typical of those that will be employed by energy-efficient aircraft.

Low-drag research must be directed toward systems that increase the extent of laminar flow over both wing and fuselage surfaces, toward interference between wing and body surfaces, and toward powerplant/airframe integration (particularly engine cooling drag and boundary layer-slipstream or propeller inflow interactions). Vortex modifiers such as winglets also need continued development.

Much still remains to be done to improve the handling qualities of general aviation aircraft in order to simplify piloting tasks. Systems that provide stall-avoidance and improve flight-path control also are needed.

Structures and Materials

The timely development of advanced composite technology for general aviation is dependent on NASA's performance of the following types of efforts:

- Improve the compressive strength of Kevlar;
- Find a new matrix material that will cure well below 350° F and as close to room temperature as possible;
- Develop improved design approaches for using advanced composites;
- Reduce manufacturing costs;
- Develop low cost and effective inspection techniques;
- Develop strength analysis techniques; and
- Establish data on fatigue and damage tolerance.

NASA's investigations of the applications of composites should include not only major airframe structures but also propellers and landing gear. In addition, extensive research is needed in the area of the crashworthiness characteristics of composite structures, because such materials are significantly different from aluminum. Full-scale structural mockup testing will be required, as well as material and component testing. In doing this, the research will need to extend through the Technology Validation phase, with extensive NASA work in-house and contract projects with universities and the industry.

Propulsion: Turbine

General aviation propulsion systems must meet the following challenges in the 1990s:

- Improved fuel economy and performance;
- Increased reliability and safety;
- Lower manufacturing cost;
- Improved material technology; and
- Durability and lower maintenance.

NASA can best contribute to finding answers to these challenges in small propulsion turbines for general aviation by conducting programs in the following areas:

- Component technology of compressors, combustors, turbines, seals, and nozzles;
- Materials for advance turbine engines;
- Alternative fuels;

- Low-cost manufacturing technology, such as laminated turbine construction;
- Ceramics for turbines;
- Engine aeroelastic and aerodynamic measurement techniques; and
- Advanced codes and numerical methods.

The U.S. gas turbine manufacturers have a significant share of the worldwide turboprop market and dominate the turbofan market. If this position is to be maintained, it is necessary to maintain a superior technical capability in these disciplines. NASA has the requisite skills and facilities that, together with the universities and industry, can contribute significantly to the technical superiority of small aircraft propulsion systems.

Propulsion: Intermittent Combustion Engines

The current concern for fuel cost and fuel availability is a motivating force in the pursuit of technological leads toward engines with substantially better fuel efficiency and broad-specification fuel capability. All known alternative engine systems should be analyzed for the most promising concepts. The alternatives already identified are a diesel engine, a rotary engine, and an advanced concept spark-ignition engine. Turbochargers of higher pressure ratio and higher overall efficiency with lower weight also are required. The basic technologies essential to the success of the selected systems should be developed to the level that soundness is demonstrated.

The properties of engine components fabricated in advanced materials need to be determined; in addition, manufacturing and design methods need to be developed. Weight reductions of 30 percent might be achieved using fiber composite structures and powder metallurgy developments.

The cost of airplane maintenance can be reduced and safety improved by electronic diagnostic systems, which could be applied to indicate engine condition. This will help alleviate a future maintenance problem that is likely to occur with the expected shortage of mechanics in the next decade.

Propulsion: Propellers

Studies conducted by NASA and the industry show that the application of advanced technology to general aviation propellers could result in reducing fuel consumption by approximately 10 percent. This benefit will be sought by utilizing new aerodynamic technology such as improved airfoils; proper thickness distribution and planform; and propeller innovations such as proplets, smooth surface finishes, and suitable propeller/nacelle integration. Furthermore, noise levels can be considerably lowered (approximately 5 dB) by proper acoustic design. Lower weight, lower manufacturing cost, and enhanced safety are achievable by replacing the present aluminum blades with new materials such as advanced composites. NASA has a role in the development and demonstration of such technologies. In developing the technologies, flight tests are essential. Ground and wind-tunnel tests cannot fully demonstrate propeller characteristics because of flow interference effects.

Electronics and Avionics

The general aviation avionics industry, spurred by active competition and breakthroughs in digital electronics technology (e.g., large-scale integrated circuits, microprocessors, and microcomputers), has demonstrated an aggressive and effective responsiveness to the increasing needs of pilots for the integrated and simplified display of weather and operational data in today's complex air traffic system.

While NASA is unlikely to make major contributions in avionics for general aviation, the avionics community has limited capability to develop basic sensors and display components vital to optimum use of the technology. In the area of basic sensors that measure such things as altitude, pressure, engine temperatures and vibration, NASA should provide research help in developing low-cost, reliable units with digital outputs.

Vehicle Operations

NASA scientists and facilities could be important in developing an improved definition of atmospheric icing conditions in detectable and reportable gradations of severity. The agency also should place a high priority on enhancing the technology of in-flight ice protection for use on general aviation aircraft.

Moreover, NASA should maintain its existing facilities and expertise and undertake basic research toward improving the efficiency of the Air Traffic Control (ATC) system. NASA's technical capabilities can be of value to Federal Aviation Administration (FAA).

To enhance safety and aid pilots in lowering fuel consumption, NASA should provide information to the National Oceanic and Atmospheric Administration (NOAA) and the FAA on techniques for measuring and disseminating winds-aloft data and other real-time weather information.

Human Engineering

The field of human engineering is increasingly important in the design of all categories of aircraft. This technology can have a particularly significant impact in general aviation because many general aviation pilots have limited opportunities to maintain their proficiency. To increase the safety of flight under these circumstances, NASA should conduct investigations of cockpit controls and displays from basic Research through Technology Evolution to reduce the pilot's workload significantly.

The efficiency and operating costs of general aviation aircraft can be improved significantly by designs that use human engineering to achieve maintenance simplicity. Improved aircraft maintenance may be expected from the development of monitoring and diagnostic equipment and techniques.

Why NASA?

The last few years have seen a loss of U.S. dominance in some industries in which, at one time, the nation was the world leader. Many reasons have been advanced, post facto, including inadequate productivity, increasing labor costs, loss of U.S. innovation capacity and/or ability to bring new or improved products to market, real or alleged predatory practices on the part of foreign governments with mixed economies, rapidly escalating social programs and large social costs. Whatever the reason, the effects are real. The United States can no longer expect to maintain superiority, or, in some cases, parity in world markets in all fields through the efforts of individual companies.

Foreign competitors have made impressive inroads in U.S. international and domestic markets by focusing on selected fields and products. The most current example is the rapid rise in imports of Japanese cars.

How does this apply to general aviation? This industry has always been a very difficult business in which the few have succeeded, principally because these companies have been able to run austere operations. Based on sales of aircraft models, the industry is characterized as low-volume and subject to cyclic fluctuations in demand. Investment in tooling, along with the most straightforward design development for a new model, can pose a risk to a company's existence. Consequently, technological risk has been avoided and only well-proven technology has been used. Almost all "new" models have been derivatives of previous aircraft, which retained much of the previous engineering and tooling. Even the successful companies have limited facilities and technical expertise for developing advanced designs. These companies simply cannot afford the risk of incorporating unproven new technology in their products.

NASA is the logical organization to conduct general aviation research. It has the facilities, expertise, and prestige necessary for such programs. Existing NASA facilities are applicable; the expertise is available in all of the pertinent disciplines; and the agency has experience in assembling an efficient team involving industry, government, and academe. Whatever questions have been asked about NASA's role in aeronautics in the past, it is imperative to maximize utilization of the agency in support of the domestic industry immediately.

Also, in the past, facing negligible foreign competition, U.S. firms have been able to proceed without advancing the state of the art. However, two new factors -- heavily subsidized foreign competition and quintupling of the cost of fuel -- require significant technological advances in order for U.S. aircraft to compete effectively in the future, either at home or abroad.

In the past, general aviation has benefited from data generated by NACA and NASA for the military and for commercial transports. At present, general aviation requires new NASA technology specifically for general aviation. The industry accepts foreign competition; but, in view of heavy foreign government subsidies and the realities of the marketplace, advanced technology to retain the U.S. lead in general aviation is imperative.

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