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NASA'S ROLE IN AERONAUTICS: A Workshop

Volume IV General Aviation

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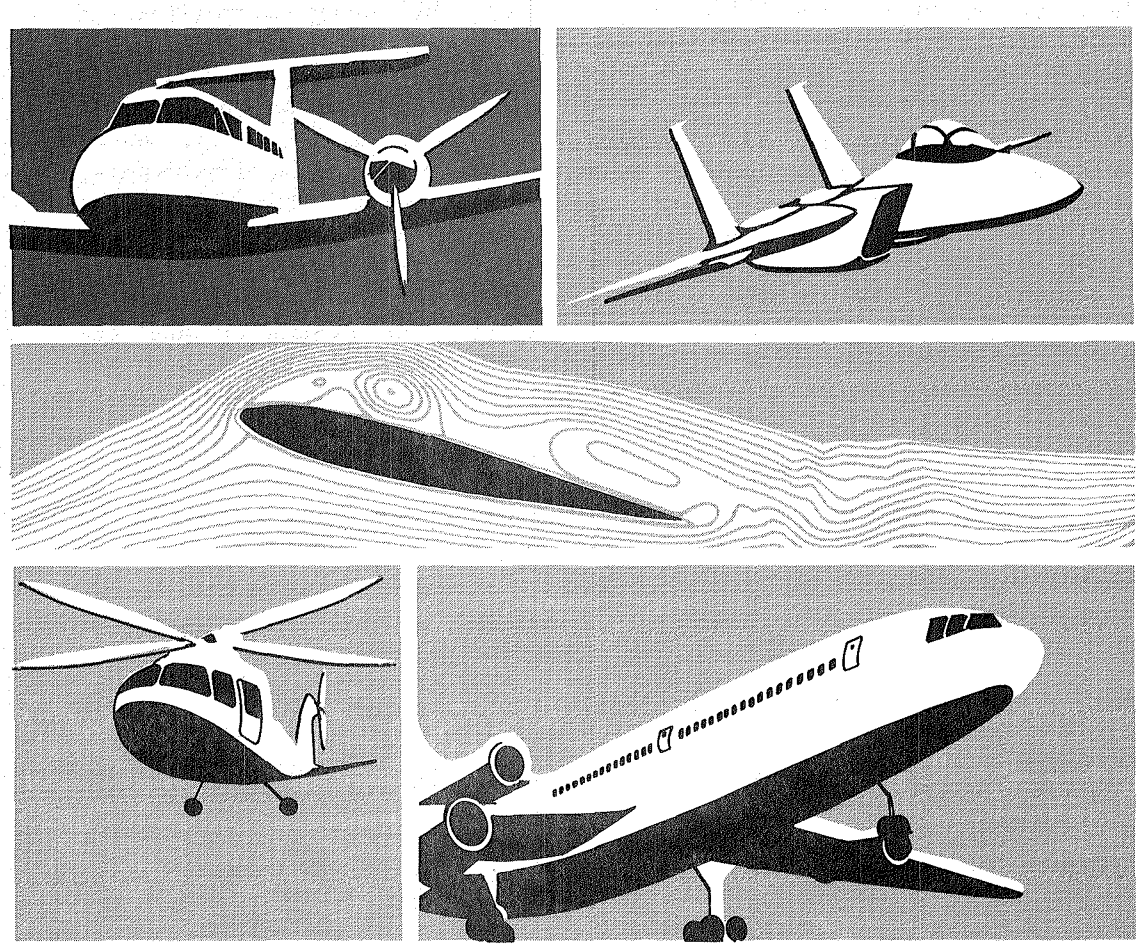

Report to the Workshop by the Panel on General Aviation
Aeronautics and Space Engineering Board
Assembly of Engineering
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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IN MEMORIAM

As this report was nearing completion in October 1980, the workshop participants were saddened by the death of Malcolm S. Harned, Chairman of the Panel on General Aviation Aircraft, a distinguished colleague and a major contributor to their deliberations and conclusions.

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WORKSHOP ON
THE ROLE OF NASA IN AERONAUTICS

GENERAL AVIATION PANEL

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PREFACE

Aeronautics is changing in many significant respects. The implications of this are so far-reaching as to call into question the future position of the United States in world aviation.

The magnitude of this question, with its possible consequences for the nation's economy and security, led the National Aeronautics and Space Administration (NASA) to seek an independent evaluation from the Aeronautics and Space Engineering Board (ASEB) of the National Research Council's Assembly of Engineering. Specifically, the ASEB was asked to assess the nature and implications of the current state of U.S. aviation in a world setting and their significance for NASA's role in the nation's aeronautical future.

The ASEB responded by convening a workshop July 27 through August 2, 1980, at the National Academy of Sciences' Woods Hole Study Center. The workshop was structured into four panels covering military aviation, transport aircraft, general aviation, and rotorcraft. In addition, an overview panel was formed to consider NASA's role in research as well as its relationships with other elements of the aeronautics community.

The central task of the workshop was to examine the relationship of NASA's aeronautical research capabilities to the state of U.S. aviation and to make recommendations about NASA's future roles in aeronautics.

NASA and its predecessor, the National Advisory Committee for Aeronautics (NACA), traditionally have maintained a cooperative relationship with the aeronautical industry, with other government agencies concerned with aircraft operations and regulations, and with the academic community engaged in aerospace research. This triumvirate was taken into account in planning the workshop and selecting the participants. Thus, representatives from each part of the aeronautical community were invited, and information on NASA's relationship with each was the subject of special presentations prior to the working sessions. Representation from industry was predominant because industry's relationship with NASA is considered to be a key element in examining the present and future roles of NASA.

The members of the workshop panels represented, in total expertise and experience, all of the important sectors of aeronautics: military aircraft and missiles; commercial air transports; general aviation;

rotorcraft; university and private research; airline operations; and government regulatory agencies. In addition, the participants also included representatives of other industries--notably, automotive, electronics, and steel. Including the speakers and other non-panel members, close to 80 individuals participated.

The participants were asked to address the issue of NASA's role in the context of a wider discussion concerning: the status and dimensions of U.S. aeronautics; the key aeronautical problems and opportunities that are likely to be amenable to research and technology development; the historical evolution and accomplishments of NASA in aeronautical research and technology development; and possible alternatives to NASA. Each of these subjects is discussed thoroughly in separate panel reports.

The report of the workshop consists of seven volumes:

I -- Summary

II -- Report of the Panel on Military Aviation

III -- Report of the Panel on Transport Aircraft

IV -- Report of the Panel on General Aviation

V -- Report of the Panel on Rotorcraft

VI -- Report of the Overview Panel on Aeronautical Research

VII -- Background Papers--The Outlook for Aeronautics and Relevant Areas

In order to help focus the discussion, NASA officials developed and provided a concise set of definitions of eight possible roles for NASA: National Facilities and Expertise; Research; Generic Technology Evolution; Vehicle Class Technology Evolution; Technology Demonstration; Technology Validation; Prototype Development; and, Operations Feasibility. Because some of these roles differ, depending on the aeronautical discipline involved, the roles are assessed within six principal aeronautical disciplines: aerodynamics, structures and materials, propulsion, electronics and avionics, vehicle operations, and human engineering. Definitions of these roles and disciplines are contained in Appendix A. The matching of the roles and disciplines is treated in Volumes II-VI and summarized in Section II of Volume I.

The workshop participants were extensively briefed by officials from NASA, the Department of Defense (DOD), and the Federal Aviation Administration (FAA), by leaders from the aviation manufacturing and operating industries, and by a member of Congress. The briefings are to be found in Volume VII.

Each panel separately considered the national benefits produced within the dimensions of its sector and the relative state of the sector's world position; each considered the evolution of NASA's role, as well as a rationale for NASA's aeronautical support of its sector; and, finally, each panel produced sector-oriented conclusions and recommendations for NASA's roles for the future. Although there are obvious overlaps, the similarities and differences in each of the panels' findings are preserved in the separate reports of the sector-oriented panels, Volumes II-V.

This document, Volume IV, presents the findings and recommendations of the Panel on General Aviation.

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C O N T E N T S

INTRODUCTION

General aviation is defined as all aviation except the military and the large air carrier operations. It therefore includes business, air taxi, commuter, agricultural, training, and personal aircraft.

During the past decade, general aviation has experienced rapid growth and become an essential part of the nation's air transportation system. Such growth is due principally to the expansion and decentralization of many American corporations. Without business aircraft, the rapid industrial expansion of the past 20 years could have been considerably more difficult.

In addition, a continuing decline in airline service to smaller communities is evident since the quadrupling of the cost of fuel and, particularly, since airline deregulation. Of the nation's 14,000 airports, fewer than 350 are served by the larger airlines, and only an additional 360 receive any type of commuter service.[1] About 70 percent of the passengers enplane at the 30 major hub airports, and one-third enplane at the top five terminals. Also, in the last 20 years, service has been discontinued to over one-third of the cities served by the airlines. This year, general aviation will transport more than 110 million passengers in inter-city travel, in contrast to about 300 million transported by the scheduled airlines.

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STATUS AND DIMENSIONS OF GENERAL AVIATION

The general aviation domestic fleet includes more than 200,000 aircraft; this accounts for 98 percent of the U.S. civil fleet. The worldwide general aviation fleet numbers about 300,000 aircraft.[2] Approximately three-quarters of the hours flown by the nation's 800,000 pilots are related to business and commercial activities. The dimensions of the industry are illustrated by the growth in sales of new aircraft over the past 10 years, as shown in Figure 1. A forecast of fleet growth for the next 10 years is shown in Table 1.

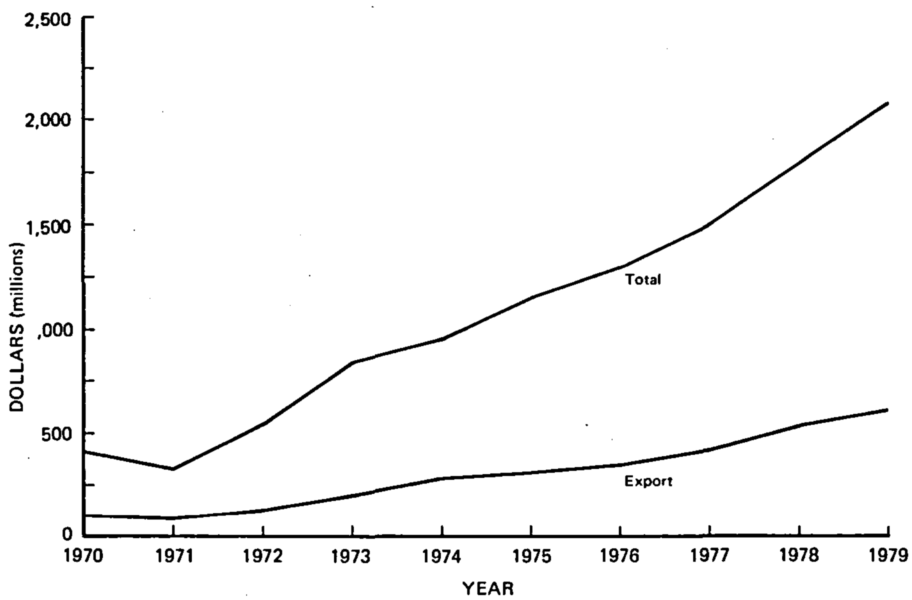


FIGURE 1 New General Aviation Aircraft Sales

TABLE 1 General Aviation Fleet Forecast

	1980	1990
Single-Engine	167,800	245,000
Multi-Engine	25,400	45,000
Turbo-Prop	3,700	7,300
Turbo-Jet	2,600	6,000

Source: General Aviation Manufacturers Association.

General aviation's most significant segment is business transportation. This area includes aircraft ranging from intercontinental business jets to single-engine, two-place aircraft. Of Fortune's top 1000 companies, 522 owned aircraft in 1978; these were the larger corporations, accounting for 85 percent of the sales and assets of the top 1000.[3] Many more aircraft, however, are flown by smaller companies and businessmen. In fact, more than 56,000 aircraft are flown solely for business purposes.

Business transportation is expected to continue as one of the fastest growing segments of general aviation. As industry continues to decentralize and as airlines continue to reduce service to smaller communities, general aviation will become an ever more essential form of transportation for business.

The Airline Deregulation Act of 1977 accelerated the growth of the commuter air carrier services as well as business flying. Last year, this segment of general aviation carried more than 13 million passengers and provided scheduled air transportation to more than 630 airports. Since the deregulation of airline fares and routes, the commuters have replaced services abandoned by the larger airlines at approximately 60 airports.[1] Service to these airports and the communities they serve is heavily dependent on the availability of safe, efficient general aviation aircraft.

Currently, many manufacturers are preparing to meet the needs of this expanding market, and several new commuter aircraft have already been announced. It is significant that most of these designs are being developed by foreign manufacturers that receive financial and technical support from their governments.

Another aspect of general aviation involves air taxis, which provide "on demand" air transportation to smaller cities for many business people and for others who cannot justify aircraft ownership. Today, there are approximately 2500 air taxi companies operating 7000 aircraft.[2]

General aviation aircraft also are used for agricultural and industrial purposes. In the United States, there are 9000 aircraft that seed, fertilize, and spray more than one-quarter of a billion acres of crops per year and use one-ninth of the fuel that tractors would consume in covering the same farmland.[2]

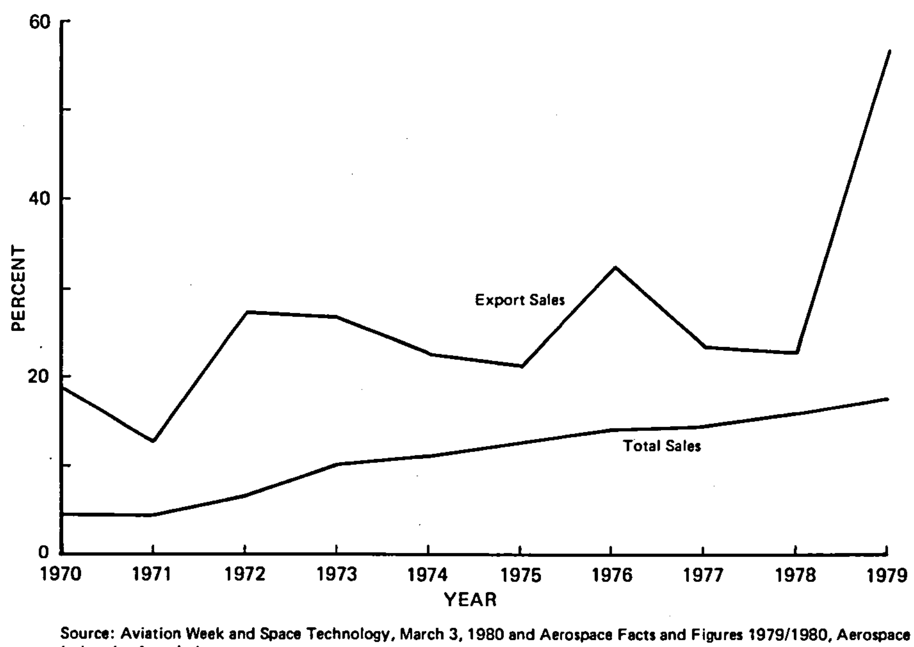
In addition, industrial and special-use general aviation aircraft provide such vital public services as emergency air ambulances, forest fire fighting, pipeline patrol, fish spotting, and law enforcement.

The vast majority of the nation's pilots come from the ranks of general aviation. In 1980, approximately 55,000 people will receive private pilot licenses. A large number of these will continue their training to receive advanced ratings, and they will serve as a manpower pool for the airlines, corporate aviation, and the military.

The Economic Contribution of General Aviation

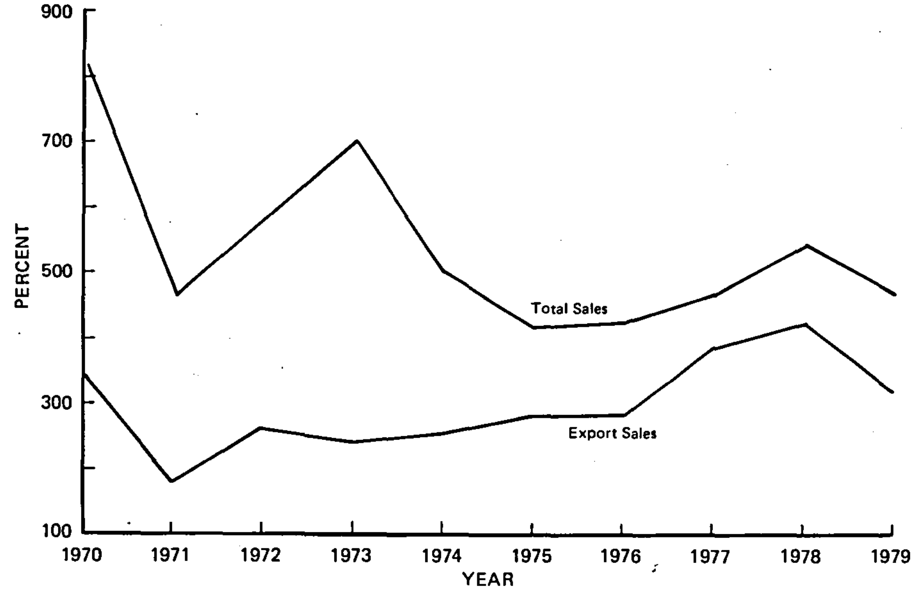
General aviation is an essential element in establishing and maintaining U.S. preeminence in aeronautics. Because of the diverse and important roles general aviation plays in business transportation, utility services, agriculture, training, and short haul travel, this segment of aeronautics shares equally with airline and military aircraft in contributing to U.S. economic strength and political prestige throughout the world.

The economic value of general aviation can be expressed in several ways. More than $3 billion dollars of aircraft and equipment were sold last year. General aviation contributed nearly $1 billion to the U.S. balance of payments. The general aviation industry provides jobs for 300,000 people in the U.S., one-third of them in manufacturing. Its total contribution to the U.S. economy is approximately $10 billion per year.[2] Its growth relative to the other segments of aviation is shown in Figures 2, 3, and 4. The figures present general aviation sales as percentages of the military, helicopter, and transport sales, respectively.



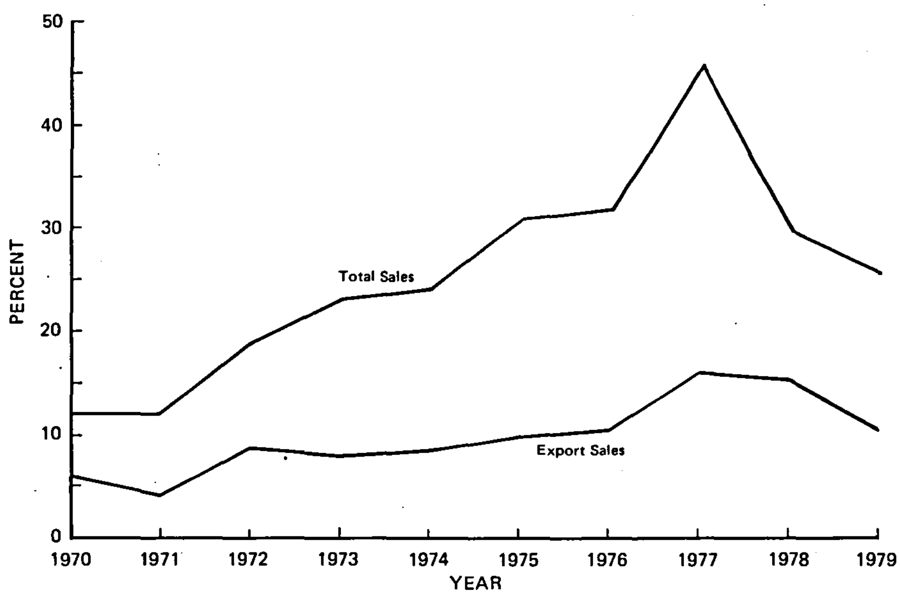
Source: Aviation Week and Space Technology, March 3, 1980 and Aerospace Facts and Figures 1979/1980, Aerospace Industries Association.

FIGURE 2 Percent General Aviation Sales to Military Aircraft Sales



Source: Aviation Week and Space Technology, March 3, 1980 and Aerospace Facts and Figures 1979/1980, Aerospace Industries Association.

FIGURE 3 Percent General Aviation Sales to Helicopter Sales



Source: Aviation Week and Space Technology, March 3, 1980 and Aerospace Facts and Figures 1979/1980, Aerospace Industries Association.

FIGURE 4 Percent General Aviation Sales to Transport Aircraft Sales

The U.S. general aviation fleet is expected to grow to more than 300,000 aircraft by 1990. (See Table 1.) The business jet fleet alone is expected to reach 6000 aircraft. This is twice the projected size of the scheduled airline fleet. It is anticipated that the turboprop fleet will grow from 3700 aircraft in 1980 to 7300 by 1990. Thus, there will be more than 13,000 turbine-powered aircraft in general aviation. In 1980, the hours flown in general aviation are expected to exceed 41 million, five times the number flown by the scheduled airlines, and the Federal Aviation Administration (FAA) forecasts that 62 million hours will be flown in general aviation by 1990.[4]

General aviation is one of the few industries that exports 25 to 30 percent of its production. The United States currently accounts for 85 to 90 percent of the world market in general aviation aircraft units and 75 percent in dollar volume.[2] It is anticipated that the international market will grow significantly as airlines throughout the world react to the rising costs of fuel and labor by consolidating service between the major city-pairs that guarantee high load factors.

The expanding export market throughout the 1980s will be aided by the developing nations as they turn more toward the use of general aviation. Emerging nations also represent a valuable export market, because general aviation aircraft often are used to develop business and provide transportation systems where road and rail networks do not exist.

The Future

Traditionally, aviation has held an importance that extends beyond its measurable economic value. It is a highly visible and effective expression of a nation's technical capability. Often a country selects aviation as a primary means for announcing its technical and economic growth by establishing a national airline and an aircraft manufacturing capability.

Because of their greater numbers and more diverse roles, general aviation aircraft are visible to more people throughout the world than are airliners and military aircraft. Consequently, general aviation is at least an equal partner with the other elements in the aeronautical community in establishing and maintaining U.S. prestige abroad. But U.S. preeminence in general aviation is being seriously challenged in the 1980s. Major technical developments in advanced airfoils are being made in West Germany through the work of Eppler and Wortmann, and these are being used in aircraft designed at Dornier. The use of computer-aided design and supercritical aerodynamics by Dassault in France in its Falcon 50 is widely respected throughout the business aircraft community. Dowty Rotol of Great Britain has incorporated advanced technology in its new propellers, and these are now standard equipment on several U.S. turboprop aircraft. The British government is underwriting much of the costs of Learfan's efforts in Northern Ireland to manufacture a business aircraft built entirely from graphite epoxy composite material.

More than 20 companies in 17 nations are competing with U.S.

industry for the growing worldwide market in general aviation. Among the foreign competitors, it is the general practice for their governments to provide financial incentives for all phases of aircraft production and sales, including research and development, tooling, and fabrication, as well as the provision of attractive financing for marketing. Several foreign companies are pursuing aggressively the advantages of new technology in their aircraft designs, and these high-technology airplanes are likely to represent a competitive threat to U.S. aircraft. Thus, unless U.S. aircraft are technically superior, the nation's general aviation industry cannot demand the higher prices required to overcome the subsidies granted the foreign manufacturers.

No longer can the U.S. general aviation industry rely on its present designs to sustain the leadership position the nation has enjoyed worldwide. General aviation must develop new technology if the industry and the nation are to counter increasing foreign competition and maintain worldwide supremacy.

RESEARCH AND TECHNOLOGY NEEDS IN 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 SP	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:

- Reduce interior and exterior noise levels;
- Reduce maintenance;
- Reduce cost of ownership, particularly operating costs; and
- 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	PROPULSION: TURBINE ENGINES	PROPULSION: INT. COMBUST. ENGINES	PROPULSION: PROPELLERS	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:

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

- o Improved fuel economy and performance;
- o Increased reliability and safety;
- o Lower manufacturing cost;
- o Improved material technology; and
- o 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:

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

The panel concludes that:

- The U.S. general aviation industry makes a significant contribution to:

  -The national transportation system;
  -The balance of trade;
  -The national economy;
  -U.S. international prestige; and
  -Employment.

- U.S. preeminence in general aviation has been eroded by foreign aircraft manufacturers. Foreign manufacturers presently have the majority of orders for heavy business jets and commuter aircraft, and their market share is increasing dramatically.

- A substantially improved flow of new technology is imperative if the general aviation industry is to maintain a strong world position.

- The general aviation industry cannot generate the required technology by itself.

- NASA is the most eminently suited entity available to carry out the necessary research and technology development effort. It has the facilities, the proven expertise, and the endorsement of industry to execute this work.

- Current levels of NASA research and technology (R&T) funding are inadequate to provide the timely enactment of enabling technologies for general aviation.

- NASA does not have a strategic plan dedicated to general aviation consistent with industry goals.

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RECOMMENDATIONS

Recognizing that maintenance of a healthy general aviation industry is in the national interest, the panel recommends that:

- o A technology program, particularly one that focuses on improving fuel efficiency and safety, be agressively pursued by NASA to assure U.S. supremacy in general aviation.

- o NASA be assigned the role of leading the basic research and technology effort in general aviation up through Technology Demonstration.

- o A strategic plan be developed by NASA, in association with the general aviation industry, and implemented as soon as possible, certainly in time for the 1982 budget cycle.

- o A NASA R&T budget be allocated for general aviation adequate to support the proposed plan. Funding needs to be several times the present level.

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APPENDIX A

DEFINITIONS OF ROLES AND DISCIPLINES

To facilitate the task undertaken by the participants in the ASEB workshop, a series of definitions of possible roles for NASA was developed. The roles represent steps in the hierarchy of the research and development process, beginning with a desire for knowledge and an understanding of basic phenomena, an idea, or technical concept, and ending with the design and construction of a vehicle, a vehicle component, or a new operational system.

Definitions of Possible Roles for NASA

Each of the following eight roles as defined by NASA was reviewed by the participants, and the panels considered the extent to which NASA should carry out these roles.

National Facilities and Expertise

This category comprises the development and maintenance of test facilities, including wind tunnels, simulators, and computers, as well as the maintenance of personnel with specialized skills, technical knowledge, and expertise in the field of aeronautics.

Research

Programs in this category are designed to gain basic knowledge and understanding of physical phenomena and processes in all discipline areas relevant to aeronautics. The work is fundamental in character and is performed within NASA, at universities, in industry, and by independent research organizations.

Generic Technology Evolution

This category involves the pursuit of the results of specific lines of basic research that show promise of generating technology broadly applicable to a number of classes of vehicles. The work is evolutionary in nature and leads to the continued advancement of technology.

Such advances generally precede focused technology development in support of specific vehicle class needs. The work is conducted primarily within NASA, with appropriate university and industry support.

Vehicle Class Technology Evolution

NASA programs in this category concentrate on specific vehicle classes and on the preparation of the unique technology data base required to improve the design and development of certain classes of aircraft. Activities include generating and evaluating new concepts and configuration approaches for the vehicle classes. Examples include V/STOL and supersonic cruise vehicles. In both cases, the technologies unique to those classes of aircraft are examined with regard to design feasibility, benefits, costs, etc. Then tailored data bases are developed.

Technology Demonstration

This category includes programs that are conducted to demonstrate the technical feasibility of a technology advance or concept. Activities may include flight testing and component or systems demonstrations. Specific examples in the current NASA program are: Tilt-Rotor Research Aircraft, Energy Efficient Engine, Quiet Short-Haul Research Aircraft, and Terminal Configured Vehicle. Future modifications and tests on an aircraft to demonstrate the feasibility of Laminar Flow Control and flight tests of an Advanced Turboprop would be included in Technology Demonstration.

Technology Validation

This comprises programs that include large-scale ground or flight validation as a necessary step to assure technology transfer. The purpose is to make possible, with minimal risk and without additional technology development, the practical utilization of high-benefit, high-risk conceptual, component, or subsystem technology advances. Specific examples in the present NASA program are: Composite Primary Aircraft Structure (CPAS), Materials for Advanced Turbine Engine (MATE), and Engine Component Improvement (ECI).

Prototype Development

This category consists of design, development, construction, and testing of an aircraft, engine, or system that is sufficiently representative of a planned final product to serve as a production prototype. An example of such a program for the civil sector would be the supersonic transport (SST) program conducted by the FAA during the 1960s. Current NASA programs do not include any prototype developments, and none is currently planned.

Operations Feasibility

This refers to operations conducted as research directed toward evaluating the feasibility or practicality of aircraft system operations to meet special needs or requirements or to demonstrate that a total, integrated operational system (e.g., new aircraft or simulated new aircraft, advanced integrated flight systems, approach and landing techniques, wake vortex alleviation, etc.) provides a service or benefit. The economic, environmental, and/or social aspects are considered.

Definitions of Disciplines

Aerodynamics

Aerodynamics is the science dealing with the motion of air and other gases and with the effects of such motion on objects moving through such media.

Structures and Materials

This is the portion of aeronautical research and technology development dealing with the design of structures (the part of the aircraft, missiles and/or their components whose function is to carry loads in the broadest sense) and the materials used in aircraft and missile construction.

Propulsion

This disciplinary heading includes the part of aeronautical research and technology development relating to the various methods and systems for generating and delivering power for propelling and/or lifting aircraft and missiles.

Electronics and Avionics

Electronics refers to that aircraft and missile electrical equipment that is required for the basic operation of the vehicles--e.g., flight and engine controls. Avionics means the electrical equipment used for mission functions, such as air-to-ground communications and navigation. In military aircraft and missiles, the latter category includes offensive and defensive equipment and weapons control systems.

Vehicle Operations

This area deals directly with operational problems encountered by aircraft and missiles, such as icing, detection and dissemination of weather information, and air traffic control systems.

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