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GENERAL AVIATION TASK FORCE REPORT

“Without innovation enabled by technological advancement, general aviation within the United States will fail to respond to opportunities for expanded use and is destined to continue its decline.

NASA is the most capable and logical source of such enabling technology.”

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Executive Summary	1
Recommendations	4
Chapter I: Introduction	6
NASA Advisory Council	7
Aeronautics Advisory Committee, General Aviation Task Force Membership	7
Chapter 2: Competitive Challenges	8
Chapter 3: Infrastructure	11
Technology Development Tools And Processes	11
Test Facilities	11
Revitalize The Technology Development Process	12
Chapter 4: Technical Disciplines	14
Chapter 4A: Propulsion	14
Community Acoustics	14
Cabin Acoustics	17
Emissions Reduction	18
Simplified Controls And Monitoring Systems	20
Piston Engine Fuel Versatility	22
Small Turbine Components	24
New Concept Evaluation	24
Chapter 4B: Aeronautical Systems	26
Difficulty Of Operation	26
Lack Of Perceived Value	30
Costs	33
Chapter 4C: Structures & Materials	35
Composites And Low-Cost Manufacturing	35
Crashworthiness	37
Interior Noise	37
Chapter 4D: Aerodynamics	39
Performance And Safety	39
Applied Computational Aerodynamics Tools	40
Test Facilities	41

Aerodynamic Data Bases	42
Chapter 5: New Partnerships	44
Government/Industry/University Relationships	44
Research Coordination Mechanisms	46
National General Aviation Consortium	47
Figure 1, Consortia	48
Figure 2, National General Aviation Consortium	50
Appendix A	52
Terms Of Reference For NASA Advisory Council Aeronautics Advisory Committee	52
Appendix B—Alternative Joint-Venture Mechanisms	54
Grants	54
Contracts	54
Space Act Agreements	54
Cooperative Research And Development Agreements (Cradas)	55
Consortia	55
Strategic Partnerships	57
Appendix C—Charts	59

EXECUTIVE SUMMARY

◆ GENERAL AVIATION—AN IMPORTANT ELEMENT OF THE NATIONAL TRANSPORTATION SYSTEM

General aviation covers a wide range of aircraft and related services from two-place trainers used for flight instruction to business jets carrying company personnel internationally at near supersonic speeds. Officially, it is defined as all aviation except scheduled airlines and the military. Business transport (both personnel and freight), flight training, personal transportation, sport aviation, agricultural activities, fire fighting, air ambulance and utility services such as pipeline patrol are important elements.

General aviation is a vital part of the national air transportation system serving over 17,800 airports (nearly 5,250 available for public use). While 669 U.S. airports are certified for commercial service, scheduled air carriers provide some form of service to 578 airports within the United States and only 55 airports account for nearly 75 percent of all airline passenger enplanements. General aviation carries about 120 million people intercity—about 20 percent of all intercity air passengers. Over 540,000 jobs are provided in manufacturing, sales, service, and flight departments. Virtually all pilots learn to fly in a general aviation aircraft. Due to projected decreases of military pilots, future years will see an increased demand on general aviation to provide our nation's commercial pilots.

◆ GENERAL AVIATION CAN MAKE LARGER CONTRIBUTIONS TO THE U.S. AND GLOBAL AIR TRANSPORTATION SYSTEM

General aviation is the only air transportation to many communities throughout the U.S. and the world. New technology such as Global Positioning Satellite (GPS) navigation is facilitating instrument approaches to airports that never before had this capability. The mid-range market of up to 500 miles has large potential, since about 70 percent of intercity trips taken by all forms of transportation are within a radius of 500 statute miles or less from their point of departure.

New business aircraft designs provide increased range and efficiency, thereby expanding the potential market for this form of transportation. General aviation has the capability of serving millions of people throughout the world and becoming even a stronger contributor to U.S. balance of trade.

◆ U.S. INDUSTRY HAS EXPERIENCED SERIOUS DECLINE

Nearly 18,000 new general aviation aircraft were produced in the United States in 1978. In 1992, only 899 new aircraft were shipped, and 1993 shipments will be even lower. In the past 15 years, the turbine segment of general aviation, utilizing newer technologies, has shown less decline in shipments. The piston segment, however, has been decimated. While several factors including U.S. and world economies have influenced general aviation's precipitous decline, a key factor has been the lack of funds and incentives to produce new designs in the existing climate of product liability litigation. Cessna, which produced 9,000 aircraft in 1978, has not manufactured a piston-powered aircraft since 1986. Piper is in bankruptcy. Airframe manufacturing employment has dropped by 50 percent.

◆ **U.S. LEADERSHIP ROLE IS BEING SEVERELY CHALLENGED**

The historical leadership role of U.S. manufacturers in technology, production, marketing, and service support of general aviation aircraft is being severely threatened. Nations such as Canada, France, United Kingdom, Sweden, Brazil, and Indonesia have made the aeronautical industry a high priority for their national economies, and these governments strongly support their aircraft industry. Historically, about 30 percent of U.S. production has been exported. Since 1984, however, the dollar value of imports of general aviation aircraft into the United States has exceeded exports. Aerospatiale of France is now the leading supplier of flight training aircraft in the United States. There are no U.S. aircraft in the 20-100 passenger market. Foreign manufacturers continue to view the U.S. as an important market.

◆ **NASA HAS VIRTUALLY ABANDONED FOCUSED GENERAL AVIATION RESEARCH AND DEVELOPMENT PROGRAMS.**

National Advisory Committee on Aeronautics (NACA) technology and facilities were vitally important to development of early general aviation aircraft. Virtually every new aircraft, both turbine and piston engine, developed in the last 20 years has benefited from use of NASA facilities and personnel (Appendix C—Chart 1). Although there have been no NASA programs or significant funding for general aviation in the last decade, general aviation has utilized NASA expertise and facilities such as wind tunnels and computer codes as well as NASA archives of design data. Applications of NASA research within general aviation are numerous.

◆ **NASA CAN HELP EXPAND U.S. GENERAL AVIATION MARKET THROUGH TECHNOLOGY**

The general aviation fleet contains a wide range of technologies, some of which were developed by NASA. Certain new general aviation aircraft lead the entire civil aviation industry in avionics systems and applications of technology. Foreign built aircraft are also of excellent quality, which makes it imperative that U.S. technological leadership be maintained.

High Performance general aviation designs sometimes lead the transport sector in adopting new technologies. The first civil U.S. airplane certified for operation at 51,000 feet were Learjet models. The Cessna Citation X, now in final design, will enter service as the fastest subsonic civil airplane in the world with a cruising Mach number of .90. NASA can play a major role in evaluating regulatory and certification requirements such as noise and emissions and in providing technology to meet these national and international requirements. General aviation manufacturers are receptive to NASA's technology leadership and will be effective users of NASA-generated technology.

◆ **CONCLUSION**

The U.S. public will benefit from jobs and commerce related to advanced general aviation systems with enhanced transportation capabilities. Future growth in the U.S. and world economy will be facilitated by greater use of general aviation for transportation. Current market positions can be protected and expanded if means are developed to meet increasingly demanding noise and emission standards, many of which are being generated by non U.S. authorities. Without innovation enabled by

technological advancement, general aviation within the United States will fail to respond to opportunities for expanded use and is destined to continue its decline. NASA is the most capable and logical source of such enabling technology.

RECOMMENDATIONS

1. NASA's General Aviation Program should be Revitalized: A dynamic NASA general aviation program can make a substantial contribution to an important U.S. industry and can facilitate economic growth within the U.S. NASA research can be part of the effort to maintain in some areas and regain in others a world leadership position for U.S. general aviation. NASA technology can also stimulate new, potentially very important markets for general aviation. Therefore, general aviation should be included in the NASA strategic plan, and critical programs should be funded on an order of magnitude over present levels.

2. NASA Infrastructure Needs to be Rebuilt and Made Available to the General Aviation Community: "World Class Tools" including wind tunnels, computer simulation capability, engine test cells, and material property labs can greatly assist technology development for general aviation. General aviation should be represented in the National Facility Planning Activities to ensure industry needs are being met.

3. NASA Technology Programs for General Aviation Need to be Balanced: Four areas of technology development are recognized as most important and potentially the most productive:

- A. **Propulsion, Noise and Emissions:** Allow aircraft to meet environmental standards throughout the world and evaluate new technologies for more stringent future environmental requirements, reliability, ease of operation and fuel and cost economies. *The fast pace of regulatory and legislative change in the environmental arena demands the rapid development of noise and emission technologies that will enable U.S. general aviation to operate throughout the world.*
- B. **Aeronautical Systems:** Introduce new technology into the cockpit, to expand the usefulness and acceptance of general aviation, to enhance pilot training and, to improve aviation safety. *Development and application of advanced technology significant potential for a new, expanded general aviation market and for long term, significant growth in general aviation.*
- C. **Structure and Materials:** Transfer available information on advanced metallurgic and composite materials to the private sector. *Because of scaling, general aviation requires technology programs that are unique. Applications of technologies developed in structures and materials for large aircraft are not readily transferable to general aviation designs.*
- D. **Aerodynamics:** Assist in developing greater efficiencies in vehicle speed, carrying capacity, and fuel consumption. *Because of significant differences in Reynolds number between large and small aircraft, the research programs relevant to airline designs do not transfer efficiently or effectively to general aviation.*

Specific recommendations have been developed for each of these areas and are presented with the body of this report.

This does not infer that the referenced areas of general aviation research should be conducted in a serial fashion. Rather, the order reflects a balance between near-term, mid-term and long-term needs of the general aviation community and the anticipated payoffs in user benefits as a function of time.

4. NASA Needs to Coordinate Its Research Efforts with the FAA: NASA should work with the FAA to ensure smooth transfer of general aviation systems and other technology efforts into the ATC system and to facilitate timely and cost-effective certification of new technologies to enhance general aviation utility and safety.

5. Information on NASA Research Should be Disseminated to the U.S. General Aviation Community: A central repository of information should be created to disseminate NASA research as well as other domestic and foreign aeronautical research that has been accomplished, is ongoing or is planned. Universities could help fulfill this need. A user friendly environment should be created.

6. Focal Point and Continuing Advisory Role Need to be Established: General aviation programs cut across different NASA programs. For example, Advanced Subsonic efforts on noise and emissions should be designed toward business aircraft, as well as larger aircraft. A focal point needs to be established at NASA Headquarters and in each of the research centers to ensure that productive programs relative to general aviation are properly funded and executed. A continuing advisory process with industry and universities should be established and maintained.

7. New NASA/Industry/University Partnerships hold Significant Promise and Should be Developed: Recent legislation has provided new ways for industry, government, universities and users to work together on technology programs. Consortia focused on specific problems potentially offer benefits to technology development and transfer. Universities can play major role in the process.

CHAPTER I: INTRODUCTION

In November 1992, representatives of the general aviation community met with NASA Administrator Daniel Goldin. The status of the industry was reviewed, and the involvement of NASA in general aviation technology was discussed. This meeting was prompted by the Administrator's visit to the Experimental Aircraft Association convention at Oshkosh in July 1992.

At the conclusion of the meeting, Administrator Goldin stated that general aviation would be included in NASA's strategic plan for aeronautics and agreed to establish a Task Force under the Aeronautical Advisory Committee.

The Task Force was chartered to address four critical elements:

1. Define technological enhancements necessary in the 1995-2000 period to expand general aviation's contributions to the nation's air transportation system.
2. Recommend a NASA/FAA/Industry action plan for technology development leading to a new generation of safe, economically and environmentally compatible aircraft.
3. Specify the role of U.S. universities in general aviation technology development and technology transfer.
4. Identify critical ground and flight facility requirements to meet the needs of general aviation development.

A copy of the charter and Task Force members is attached in Appendix A.

In addition to numerous conference calls, three meetings of the Task Force were held in the following cities on the following dates: Washington, DC, February 16-17; Langley/Lewis, April 12-14; and Wichita, KS, May 17-18, 1993.

The Task Force very much appreciates the interest and assistance of NASA personnel in this effort. The Task Force is encouraged by the inclusion of a line item for general aviation technology in NASA's FY94 Budget and the attention to general aviation research in others areas of NASA activity.

NASA ADVISORY COUNCIL

AERONAUTICS ADVISORY COMMITTEE, GENERAL AVIATION TASK FORCE,
MEMBERSHIP, MEMBER AFFILIATION

1. Committee Chairman, Edward Stimpson. President, General Aviation Manufacturers Association
2. Philip R. Boob, President, Textron Lycoming
3. R. Craig Christie, President, Bendix/King, AlliedSignal Aerospace
4. John R. Colomy, Flight Standards Manager, Federal Aviation Administration
5. Gary G. Kivela, Director of Engineering, Business and Commuter Aviation Systems, Honeywell, Inc. and AAC/ARTS Guidance and Control Group
6. Paul C. Fiduccia, President, Small Aircraft Manufacturers Association
7. S. Michael Hudson, General Director, Allison Gas Turbine Division
8. David C. Hazen, Chairman, Aerospace Engineering, Embry-Riddle Aeronautical University
9. David A. Hilton, Staff Scientist, Gulfstream Aerospace, Inc.
10. Edward H. Hooper, Senior Principal Engineer, Beech Aircraft Company and AAC/ARTS Structures & Materials Group
11. Paul W. Johnston, Chief Engineer, Cirrus Design, Inc.
12. Dr. John K. Lauber, Member, National Transportation Safety Board and NASA Aeronautics Advisory Committee
13. John W. Olcott, President, National Business Aircraft Association
14. Milt Sills, Vice President, Cessna Aircraft Company
15. Dr. William H. Wentz, Executive Director, National Institute for Aviation Research, Wichita State University and AAC/ARTS Aerodynamics Group

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- ◆ Ray V. Hood, Deputy Director, NASA, Subsonic Transportation Division
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- ◆ Joe W. Elliott, Rotorcraft Program Manager, Subsonic Transportation Division

CHAPTER 2: COMPETITIVE CHALLENGES

INTRODUCTION

General aviation faces two competitive challenges:

1. Increasing competition within a decreasing market for traditional general aviation customers,
2. Inability to appeal to the relative large demand for travel within a radius of 500 miles which, for the sake of this presentation, we will define as the mid-range travel market.

EXISTING MARKET

The traditional U.S. market for general aviation products is mature and flirting with decline. While future demand is shrinking due to increasingly more restrictive entry requirements being placed upon potential customers for general aviation, current demand is being satisfied by existing suppliers. In addition, more stringent environmental requirements are limiting the suitability of existing designs in established markets.

Research and innovation that might have made U.S. general aviation aircraft more competitive has been stifled by two factors: the diversion of manufacturer's funds away from R&D and into self-insurance against product liability costs (many of which were of questionable merit), and the virtual absence of NASA programs in general aviation during the last decade.

During the last 15 years, annual production of general aviation aircraft within the USA has fallen to approximately five percent of its 1978 level (Appendix C—Chart 2). Current production of U.S. manufactured general aviation aircraft is less than 900 per year, which is insufficient to replace the depletion of general aviation aircraft due to age, accident and export. Our nation is experiencing a net loss of aircraft.

Since 1980, the number of licensed pilots has decreased by nearly 10 percent, and student starts have decreased by one third. Only the number of airline transport license holders has grown, reflecting the trend toward more sophistication within aviation as a whole and general aviation in particular.

Hours flown within general aviation have dropped from an estimated high of over 43 million in 1979 to slightly more than 30 million hours, a decrease of approximately 30 percent.

While the U.S. market for general aviation has shrunk in the last 10 to 15 years, worldwide demand has increased. In particular, emerging nations such as China look to general aviation as a means for training future airline pilots and for developing a transportation system to serve locations where adequate roads, rail and service by major airlines are not available.

In addition to losing approximately half the 40,000 U.S. jobs that existed in general aviation airframe manufacturing in 1980 (Appendix C—Chart 3), U.S. companies no longer dominate worldwide general aviation production. Aerospatiale General Aviation, a French company, is today's leader in the production of light, single-engine training aircraft. Two of the three manufacturers of large business jets are non-U.S. companies. More manufacturers of general aviation aircraft now are located off-shore than within the United States of America, reversing a position of dominance recently held by the USA (Appendix C—Charts 4 & 5).

Whereas general aviation in 1980 provided an annual trade surplus of nearly \$300 million, we now have a trade imbalance of over \$800 million per year in this arena even though nearly 40 percent of the value of U.S.-manufactured goods for general aviation are sold outside our borders (Appendix C—Chart 6).

Thus, the U.S. general aviation industry is challenged to remain competitive in a shrinking domestic market and in the potentially expanding worldwide market for general aviation. We have lost the competitive edge to protect current market share within the U.S. and worldwide, and we are ineffective in stimulating demand within the traditional general aviation marketplace.

POTENTIAL MARKET

While diminishing influence within traditional markets for general aviation represents a significant risk to balance-of-trade as well as to U.S. jobs, our industry's failure to compete dramatically in the potentially large and stimulating market for mid-range travel represents a loss of even greater magnitude.

Travel in excess of 100 miles in all forms has grown dramatically since 1974. In 1990, an estimated 661 million journeys exceeding a round-trip distance of 200 sm were conducted by U.S. citizens, up from 281 million in 1974. Approximately 65 percent of all trips taken were less than 600 sm round-trip and 75 percent were less than 1,000 sm, with automobiles (including trucks) and commercial airliners being the dominant forms of transportation used to satisfy that significant demand for mid-range travel.

By providing an aircraft with sufficient user appeal to satisfy travel needs within a 300 to 500 sm radius-of-action, general aviation would follow a new demand curve and thus escape from its present dilemma of being trapped within a mature if not declining market. General aviation would be revitalized by being competitive within an established transportation market of well-defined and significant size.

In addition to finding a new place in an established, mid-range travel market, general aviation aircraft of sufficient appeal could stimulate a new travel demand by increasing the attractiveness of trips within a 300 to 500 sm radius-of-action.

General aviation aircraft with a cruising speed of 200 statute miles per hour (smph) can complete a round-trip flight of 600 miles with two 90-minute legs—1:30 out and 1:30 return. Cruising speeds of approximately 330 smph, well within the capability of several light aircraft designs now flying, would enable 1,000 sm trips to be completed within a similar trip time. Research in the field of travel

preference indicates that one and one-half hours is the practical endurance for routine trips. Since automobiles typically can travel only 80 to 90 sm in an 1.5 hours, a user-friendly general aviation aircraft could be expected to attract those travelers who are using an automobile for travel beyond an 80-to-90 mile radius-of-action, which is estimated to be between two and four times the number of travelers who use commercial airlines for trips less than a 300 mile radius-of-action.

SUMMARY

A significant market exists for general aviation transportation. Aircraft that could achieve greater utility and ease of operation at lower costs than current designs, while maintaining a high level of safety, would help U.S. manufacturers to regain historical market share within traditional markets as well as compete aggressively in the very large and essentially untapped market for mid-range travel via general aviation.

CHAPTER 3: INFRASTRUCTURE

TECHNOLOGY DEVELOPMENT TOOLS AND PROCESSES

INTRODUCTION

When the space program began, NASA's investment in aeronautics research and facilities was curtailed and funding for general aviation activities dropped to insignificant levels. The wave of aeronautical prosperity produced by an investment in aeronautics in the 1930's and 1940's was over. As NASA abandoned programs that had direct relevance to smaller aircraft, the era of U.S. dominance in general aviation also came to an end. To regain preeminence in general aviation as well as in all aspects of aeronautical design, two areas related to the conduct of research must be addressed. They are:

- ◆ Test Facilities
- ◆ Revitalized Technology Development Processes

There must be a massive investment in research, and most importantly, in the construction and operation of world class "tools" for research and development, with adequate capacity for NASA and industry use. Revitalizing the technology development process is also needed to facilitate full utilization of new research tools such as wind tunnels, simulators and computer-aided design tools.

TEST FACILITIES

BACKGROUND AND GOALS

The basic test facilities required for research and development are believed to exist in this country. In many instances, however, they have not been upgraded to take advantage of improved technology in data acquisition or data processing. Some facilities have been allowed to deteriorate and others need more accurate or extended capabilities.

To revitalize the technology development process for commercial aviation and in particular general aviation, facilities must be upgraded in capability and capacity. Furthermore, there must be a change in policy to encourage industry use of facilities for development. In some cases, capacity for the commercial sector may be added by reassigning facilities that were reserved for military use.

Recommendation: To encourage R & D and to accelerate the development of new aircraft, NASA should facilitate the availability and U.S. industry-use of "world-class" tools for aeronautical design, which include:

- ◆ Modern wind tunnels capable of producing inflight Reynolds numbers at subsonic and transonic speeds
- ◆ Spin tunnels with significantly more test capacity

- ◆ Engine test facilities for both low horsepower, low altitude piston powerplants and for turbine engines
- ◆ Facilities to enable sub component and component research in areas of basic technology
- ◆ Facilities to evaluate systems integration and verify concepts for new technologies.
- ◆ Simulators capable of supporting research and development in handling qualities and advanced display technology
- ◆ Simulators capable of supporting research into pilot and systems training
- ◆ Acoustical test facilities
- ◆ Advanced computational facilities

Market forces and the need to revitalize general aviation have resulted in more demanding requirements for precision and efficiency in the design process. Without modern, "world-class" design tools such as those facilities listed above, U.S. manufacturers are at a disadvantage to their non-U.S. competitors. Also, advanced designs require facilities that are capable of specific functions. Although extremely important to the development of all commercial aircraft, advanced handling qualities and cockpit display simulators are virtually nonexistent. Improved facilities for handling quality research and development need to be provided either by NASA or by NASA sponsorship, and must be capable of rapid iteration of stability and control parameters and rapid cockpit display changes. The ability to conduct research into pilot training also is an imperative for these simulators.

Facilities for researching interior and exterior acoustics and evaluating sound-suppression materials are needed to develop more environmentally acceptable aircraft for general aviation.

Advanced analytical computer capability, including fully developed and validated computer codes for aerodynamics, acoustics, structures, systems and crashworthiness, should be provided by NASA to facilitate commercial aircraft development. Super computer capacity available to industry at reduced costs would encourage research and development and would facilitate industry's development of commercial products.

REVITALIZE THE TECHNOLOGY DEVELOPMENT PROCESS

BACKGROUND AND GOALS

NASA's technology development process needs improvement to generate computer codes that are highly capable, user friendly and ready to use. Analytical programs should be validated and constantly improved through extensive NASA participation in industry experiments conducted in NASA facilities. Changing the process to focus on providing the finest codes for industry as well as for NASA,

with the cost born by NASA, would greatly facilitate NASA and industry interaction and would result in a quantum increase of product opportunities.

Recommendation: NASA should reevaluate its procedures for encouraging industry use of its facilities and should support industry use of NASA owned and operated test facilities.

Recommendation: NASA should ensure that computer codes and other design tools are sufficiently user friendly and user ready to result in efficient and cost-effect application by industry.

Recommendation: Additional process improvement actions are proposed as follows:

1. Set Up a Process Improvement Action Team (PIAT) within NASA
 - ◆ Focus on TQM techniques for improvement
 - ◆ Identify ways to produce better results more efficiently.
2. Publish each Active and Planned Project to include:
 - ◆ Who is Doing the Project
 - ◆ How it is Being Done
 - ◆ Schedule and Cost of Each Project
3. Included FAA Sponsorship in Research Projects, assuring Certifiability of Developments
4. Establish NASA as Manager of a National Data Base for Aeronautical Research
 - ◆ Coordinated with DOD
 - ◆ Coordinated with FAA
5. Establish and maintain an analysis of NASA's agency-wide subsonics programs and funding levels to determine their relevance to general aviation.

Specific examples and details of need for facilities and design tools are included in some of the following individual discipline sections.

CHAPTER 4: TECHNICAL DISCIPLINES

CHAPTER 4A: PROPULSION

INTRODUCTION

The Task Force identified propulsion as one area of highest priority for research based on requirements of international competitiveness and product acceptance by both potential future users and the existing general aviation community. NASA technology could address general aviation needs, significantly improve future product effectiveness and make a positive contribution to the general aviation industry, the traveling public and the communities served by general aviation.

Six areas of importance are covered in the following order:

- ◆ Acoustics—Both Community and Cabin
- ◆ Emissions Reduction
- ◆ Simplified Controls and Monitoring Systems
- ◆ Fuel Versatility
- ◆ Small Turbine Component Efficiencies
- ◆ New Concept Evaluation

Common interests exist in some specific technologies between general aviation propulsion and other segments of aviation. However, the Task Force remains concerned that the full requirements of general aviation may not be adequately represented in technology programs that combine the needs of several segments of aviation and therefore recommend that these be reviewed periodically through the advisory committee process. Thus, the Task Force has chosen to include the full technical program in these recommendations.

Recommendation: A clearly defined management structure for general aviation oversight and input into the propulsion program needs to be established at NASA.

COMMUNITY ACOUSTICS

BACKGROUND AND GOALS

The acoustic characteristics of all segments of aviation have attracted considerable attention locally, nationally and internationally as aircraft have become the carrier of choice for distant travel. The general aviation community represents some special cases and opportunities for aviation related noise reduction since they frequently operate from dispersed airports integrated into populated areas, they operate many times outside the “business day” and to some extent their noise signatures are different

from those associated with scheduled air carriers. General aviation recognizes an additional responsibility beyond the statutory requirements to win the support and confidence of the communities in which they operate. The range of the vehicles represented by general aviation, from the piston-powered, propeller-fitted sports and training aircraft through the large corporate turbofan-powered aircraft are all affected since community noise:

- ◆ Directly impacts the use and availability of training aircraft and airports which represent a primary source of pilots and other trained personnel vital to the sustainment and growth of the aviation transportation system.
- ◆ Affects the international competitiveness of the U.S. corporate turbofan aircraft industry (which is the largest financial volume and job producing segment of general aviation) relative to foreign manufactured equipment.
- ◆ Will inhibit accessibility to many geographic areas provided by general aviation, thereby curtailing the potential economic growth of these areas and limiting the viability of general aviation as an important transportation system.

Recommendation: It is recommended that community noise codes for the prediction and design of low noise general aviation propeller and fan propulsors be generated and experimental validations of low noise propellers and fans be conducted.

The technology requirements for general aviation noise control need to be comprehensive and to include both source noise control and operations. However, only source noise control is addressed here. The control of source noise is separated into prop and turbofan noise and is intended to generate a design data base for noise improvements, and conduct proof of concept experiments on selected configurations. This approach intends for the participants to draw heavily on the large quantity of NASA propeller, turbomachinery, jet and jet mixing and general acoustic analytical and experimental research. In shaping the program, the approach must recognize the cost-sensitive nature and current economic conditions of the small aircraft end of general aviation.

Both the Lewis and Langley Centers are recognized as having expertise in the area of aircraft source noise control. It is recommended that one of these centers be identified as the point-of-contact for general aviation noise activities. This center would manage the cataloging of relevant noise experimental work, analytical work and codes, and future plans. It also would guide requests for direct contact with the principal investigators to the appropriate center. It is recommended that the program involve the designers and manufacturers of propellers, engines and airframe propulsion-related components in the applied portions of the program.

Propeller Noise—It is recommended that the propeller community noise programs include the following elements:

1. Compile and assess the applicability of the NASA propeller data base to the reduction of general aviation type propeller aircraft systems.

2. Identify all available and projected aeroacoustic design codes applicable to general aviation propeller systems.
3. Identify any deficiencies existing in the data base and design codes, and determine the appropriate response to rectifying these efficiencies in light of all priorities.
4. Select low-noise configurations for experimental evaluation, and fabricate and evaluate these concepts in full or subscale. This phase of the program should involve the propeller manufacturers so that manufacturing and certification considerations are reflected in the selection and evaluation processes, and so that the transition of the technology to product is expedited.

The participants in the program should include the U.S. airframe manufacturers who utilize the combined engines and propellers, engine manufacturers, propeller manufacturers, universities with expertise in the area and the two NASA centers (Lewis and Langley).

The approach recommended for addressing the propeller noise issue is a combination of work within the NASA centers, direct grants to appropriate universities, and grants passed through a non-profit research consortium comprised of involved manufacturers and the NASA Center. The effort associated with compiling data bases and reviewing of design codes is recommended to be conducted by the Centers or through direct grants to universities. The selection of low-noise configurations would be conducted by manufacturers and universities under the direction of a consortium. Experimental work would be conducted by the manufacturers or by cooperative programs between the manufacturers and the Centers for work to be conducted at the Center. The experimental effort funding would flow through a consortium.

TURBOFAN COMMUNITY NOISE

As part of this effort dealing with turbofan community noise, NASA would compile and continue to refine and make available to industry design codes that are applicable to the prediction of noise characteristics and suppression techniques for turbofan propulsion systems applicable to corporate jet systems. Engine data should be accumulated to compare the codes against actual acoustic levels.

In addition, NASA would conduct periodic workshops on turbofan acoustics and involve the corporate aircraft and engine manufacturers.

The recommended schedule for this effort should be:

- ◆ Compilation of existing design codes should be completed within one year of initiation (approximately October 1994) and maintained on a continuing basis.
- ◆ Within one year of program initiation, comparisons should be made between experimental data and code prediction.

- ♦ Workshops should be annual events, with the first being approximately six months after initiation of this program (March 1994).

Recommendation: It is recommended that NASA compile and continue to refine design codes and that the code verification be made by using test data from small turbofan engines. Following code verification and upgrade, it is recommended that potential design changes of the test engine be identified on the basis of code predictions for lower acoustic levels.

The design and experimental work associated with source noise and suppression should be initiated with the start of the Subsonic Transport Initiative and progress on an expedited basis to have an impact on the next generation of products.

The approach recommended for addressing the turbofan noise issue is a combination of in-house NASA Center work, cooperative industry-NASA-university programs and traditional contracted efforts. The compilation and continued refinement of design codes should be a cooperative effort between NASA and appropriate universities with industry involvement to establish requirements and provide design code expertise as appropriate. The workshops should be conducted by NASA on site at the Center with industry support. The participants for the design studies and experimental verification of concepts for reducing turbofan noise for corporate jet propulsion should be selected based on competitive criteria and contracted under normal NASA procurement procedures.

CABIN ACOUSTICS

BACKGROUND AND GOALS

Cabin interior noise is a competitive element in the acceptability and selection of aircraft. Cabin noise stems primarily from propeller and turbofan propulsion systems. The rear fuselage mounting of turbofan engine is unique to general aviation configurations in this country and therefore is not being addressed in other parts of the NASA program. NASA has been actively involved in interior noise technology relating to advanced turboprops and has generated significant technology in the area of structural analysis and vibration response and transmissibility. The control and reduction of cabin interior noise is viewed as a significant factor in attracting new users to the small general aviation categories and is considered a major competitive feature in the upper range of turbofan-powered aircraft.

Recommendation: It is recommended that cabin noise predictive codes for both general aviation propeller and fan engines be generated and experimental verifications of selected low noise configurations be conducted.

The recommended program is divided into propeller and turbofan segments. Both segments need to be addressed through the generation of predictive tools and experimental validation of approaches to noise reduction.

Propeller Noise—It is recommended that the propeller interior noise program be coordinated with a review of propeller far-field noise codes. The first phase of this program will be a review of past

NASA in-house and sponsored work conducted under the advanced turboprop program and code development. The product of this effort will be design codes that predict interior noise and vibration levels based on discrete engine input vibration levels, propeller characteristics and placement and aircraft structural design. The second phase of the program addresses the definition and experimental evaluation of cabin noise control concepts and validation of the codes generated as part of Phase I. The product of this phase will be validated noise control concepts capable of being committed to the normal product development process.

Phase I code development is considered a precompetitive activity, and it is recommended that this effort be conducted by a cooperative activity between in-house NASA researchers, universities and industry. The second phase of the program may contain industry competitive elements as well as generic work; hence, a mixture of research consortium and individual company and NASA cooperative agreements seem appropriate. These approaches should be tailored to make maximum use of existing facilities, hardware and test equipment.

Turbofan Noise—The turbofan cabin noise program being recommended consists of code development and experimental evaluation elements. It is recommended that the program draw on the similar work being conducted in the NASA Advanced Subsonic Technology Initiative; however, the difference in aircraft-engine installations must be recognized and the general aviation unique features addressed.

Phase I of the turbofan cabin noise effort should start immediately with the initiation of the general aviation program. This is to ensure that general aviation requirements are properly reflected in other programs. The product of this phase is to be design codes that predict interior noise and vibration levels based on discrete engine vibration levels, fan acoustic characteristics and aircraft structural design. The second phase of the program addresses the definition and experimental evaluation of cabin noise control concepts and the validation of the Phase I design codes. The goal of this phase is the generation of noise reduction concepts through adequate demonstration which would permit them to be transitional to a normal development program.

The initial program element of Phase I dealing with code development is viewed as precompetitive and should be addressed using a NASA/university/industry consortium. The second phase may have competitively sensitive information, and it is recommended that this phase be conducted with both consortium and individual company/NASA cooperative arrangements.

EMISSIONS REDUCTION

BACKGROUND AND GOALS

Past studies have shown that emissions from general aviation propulsion systems contribute only a very low percentage of the total pollution produced by transportation systems. It is recognized, however, that the general aviation community should participate in emissions reduction consistent with the improvements being developed for other segments of aviation. Significant concern has been expressed by the community about statutory restrictions in local or national regions which may prohibit

aircraft access without significant reductions in emission from current levels. For the piston engine segment of general aviation propulsion, the sensors and automated control systems being proposed to aid in providing operating simplicity will provide much of the technical capability to make significant gains in emissions control. Basic turbine engine emission technology is being developed as part of other NASA sponsored developments including work on automotive gas turbines, high speed civil transport (HSR) and the subsonic transport initiative (AST). The competitiveness of future U.S. general aviation turbines is directly related to the application of this or comparable technology to this smaller class of engine.

The approach for the piston class engines is to experimentally investigate the potential for emission reduction using advanced sensors and controls and fuel system variants. The large turbofan class of engine emission control technology is to be addressed in the smaller (regional airline) portion of the subsonic transport engine initiative. The recommended small turbine engine emission control effort is based on adaptation of technology from other segments to the size and configuration characteristics of this class of engine. In all cases it is recommended that the manufacturers of each of the classes of engines be directly involved in development of low emission research on their engine interest.

The large GA turbofan is subjected to the same rules as those used for large transports, and these rules are becoming more stringent. On the other hand, small classes of engines are essentially uncontrolled. Therefore, there is a relatively high sense of urgency for the large engines, and NASA is urged to provide high priority to this effort in the Subsonic Transport initiative. The work on the small engine issues should proceed through a normal technology program process with its priority established relative to other general aviation propulsion issues.

Recommendation: It is recommended that reduced emission concept design studies and experimental verifications of the most promising concepts be conducted on both turbine and piston general aviation engine configurations.

Emissions control technology for each class of general aviation propulsion systems is unique. The recommended approach is to address each of these classes separately with distinct programs. The priority of emission control for general aviation is related to the regulatory pressures on the class in question.

NASA Lewis Research Center should be the lead in directing the emission reduction efforts. The program should be segmented by size and consists of the following activities:

Large Turbine Engine (>5000 lbs.)—This work should be included as an identifiable and separate part of the Subsonic Transport Initiative and should address near, intermediate and far term goals and requirements indicative of regulatory actions and trends in engine feature evolution. Design studies and engine hardware demonstrations are to be included.

Small Turbine Engine (<5000 lbs.)—This work should be part of the NASA Base Technology Program in combustion research and focus on adapting the lessons learned from this and other

programs such as the large-engine Subsonic Transport Initiative to this class of engine. The end product from this activity will be engine hardware validation of the selected concepts.

Recommendation: NASA should address the research needs of turbine propulsion in the range between 2,000 and 5,000 pounds thrust, especially in the areas of noise and emissions, and provide a clearly defined management structure for general aviation oversight and input into the existing propulsion program at NASA.

Piston Engine—This work should be conducted in a phased program in which the initial effort utilizes the availability of the advanced sensors and controls being configured for simplicity of operation to experimentally investigate emissions reduction. The next phase is used to analyze the results of Phase I and other piston engine emissions work and identify fuel system modifications which have the potential for further emissions reduction. A final part of this phase would experimentally evaluate the prime candidates selected. A third phase would conduct engine configuration design studies and experimental evaluation if further emissions reductions were deemed necessary.

Recommendation: NASA should address the research needs of IC powerplants in the range of 100 to 1,000 hp, with attention to noise, emissions, ease of operation and cost.

Large and Intermediate Engine work should be conducted through normal NASA procurement activities using the BAA approach so that the manufacturers may be more directly involved in the detailed program planning process to address their specific needs considering the requirements. Cooperative NASA-Industry activities are encouraged for the basic research in this area.

The approach recommended for the piston engine work parallels that recommended for the advanced sensor and controls effort. A research consortium of the involved engine manufacturers, component suppliers and universities should be formed to administer the contracts and grants addressing analytical and experimental work.

SIMPLIFIED CONTROLS AND MONITORING SYSTEMS

BACKGROUND AND GOALS

Piston engine control systems used on propeller aircraft date back to the introduction of these systems to aviation. A significant portion of pilot training and operational work load is related to engine and propeller control and monitoring, which directly relates to propulsion reliability. Electronic control and monitoring technology can provide improved fuel consumption, optimized performance on a given fuel grade or alternate fuel type, and greatly simplify pilot workload. Proper fuel management can substantially improve engine reliability and operating costs. Incorporation of these control systems would provide definite benefits in reduced operating costs—justifying the cost of acquisition.

The component technology for these control and monitoring systems exists in the automotive arena and in various areas of aviation. The systems technology is needed for adapting these to general aviation applications. Also needed are design studies to determine the cost-benefit relationship of such

devices, the reliability of the individual components and required system redundancies, and the generation of data and demonstrations needed to provide a certifiable system.

Recommendation: Requirements for a simplified propulsion control system which integrates propeller and engine controls into a minimum number of pilot inputs should be defined and demonstrated in "brass board" engine tests to the point that full scale development and certification may be initiated with low risk.

The technology development process should be one that targets the full range of piston engine propeller propulsion systems. The basic system would be applicable to the simplest of propulsion systems and configured with a control architecture that permits the addition of "modules" to adapt the basic control to more complex systems in larger aircraft with extensive ancillary equipment and features. The program also includes studies to identify requirements and candidate features and concepts, simulations to evaluate effectiveness and design, fabrication and testing of brass board controls and monitoring systems to demonstrate proof of concept.

Lewis Research Center should be the focal point for directing this research with the involvement of other centers to provide the human factors and simulation resources to aid in the cost-benefit analysis of candidate concepts. Also, to be involved are active engine, propeller and fuel system manufacturers and universities with current programs in piston engine controls and sensor technology. Engine-propeller cognizant FAA offices should be involved to assure certification issues are addressed and appropriate data bases are generated.

The recommended program would be conducted in three phases:

Phase I. Systems Studies—Studies are to be conducted to determine various control and monitoring concepts based on existing or near term componentry. These studies are to be sufficiently detailed to define candidate control and monitoring systems that can be incorporated into existing or planned pilot-in-the-loop simulations.

Phase II. Simulation and Evaluation—Control concepts evaluations are recommending using human factors evaluations of piloted simulators. The goal of this phase is to provide cost-benefit data on the various control and monitoring systems to facilitate the selection of configurations for hardware evaluations.

Phase III. Hardware Evaluation—Hardware evaluation and proof of concept type demonstrations of candidate brass board control and monitoring systems are recommended. As envisioned, the design work will include failure mode and effect analysis constructed with help from FAA authorities to facilitate future certification programs. The brass board systems constructed as part of this phase may or may not contain all of the redundancy required of a certifiable system but would be adequately configured to demonstrate engine test stand operation and experimental aircraft demonstrations. The program would culminate in test-stand engine tests to demonstrate the range of control and monitoring features and if deemed appropriate flight demonstrations to confirm operability features.

Testing should be conducted at manufacturers sites or others that may be readily available to minimize program costs and to involve the manufacturers and accelerate transition of the technology into products. Program management and funding is recommended to be through a combination of direct contracts with involved manufacturers, grants to the involved universities and cooperative NASA Center-Industry Agreements to minimize the costs associated with the use of existing NASA simulation facilities and human factors expertise.

PISTON ENGINE FUEL VERSATILITY

BACKGROUND AND GOALS

As economic and environmental pressures reshape fuels availability, the general aviation community must be ready to respond with economically viable technical solutions. This requirement for responsiveness extends beyond the availability of fuels in the U.S. since a significant portion of the potential future U.S. manufacturers' products are in the export market. Fuel versatility could provide a significant competitive advantage for U.S. manufacturers.

Based on past experience, fuel extension programs need to have both a near and longer term phase. For the near term the objective would be the adaptation of existing engine configurations to use near term relaxed specification aviation fuels such as those having the lead additive removed. Longer term activities would address concepts which utilize broader cuts of readily available fuels such as common turbine fuels. This phase of the program would draw upon the intermittent combustion research conducted by NASA, the university community and others. It is envisioned that it will focus on combustion chamber and fuel system design and include approaches such as stratified charge concepts.

Design studies of promising piston engine concepts, including those with multi-fuel capabilities, should be conducted, along with experimental verification of the most promising candidates.

Recommendation: Fuel specification piston engine concept design studies and experimental verifications of the most promising concepts should be conducted, and further design and experimental evaluation on long term concepts should be conducted.

This fuel extension segment of the program is directed at the piston engine propulsion systems used in the smaller end of the general aviation spectrum. It is appropriate that future trends in avgas characteristics be obtained from the fuel suppliers as an initial phase of this effort. This is to be followed by an experimental program conducted primarily by the engine manufacturers addressing gasoline variants. This research will be paced by the availability of advanced sensors and control concepts and should be phased accordingly. It is appropriate that future trends in avgas characteristics be obtained from the fuel suppliers in conjunction with this effort. While the first phase is being conducted, a study of potential concepts for the use of other aviation fuels should be initiated. Joint activities between the manufacturers and university researchers for this part of the activity is recommended. Based on the results of these studies, the most promising concepts will be selected for experimental evaluation. The test vehicles for this effort should be selected to minimize program costs while providing a data base sufficient for evaluations in the context of full engine tests.

The Lewis Center should be the lead Center for this activity. The recommended program consists of the following five phases as noted below:

Phase I—A study of projected fuel availability for the future and the generation of probable specifications will be the deliverable for this phase.

Phase II—Based on the results of the study, a near-to-intermediate term range of gasoline based fuel specifications will be selected for experimental evaluations in engines. Concepts for operating on these fuels over the required general aviation operating range will be selected based on cost benefit analysis.

Phase III—Prime candidates will be evaluated experimentally by the manufacturers using modified equipment. The product of this phase will be reports on the feasibility of utilizing relaxed specification avgas in modified existing and future propulsion systems as well as a plan for exploiting this capability through certification and introduction to production and service.

Phase IV—A review of past concepts which provides potential fuel versatility extending into the turbine fuel area is recommended to initiate this phase. Prime candidates would be selected for experimental evaluation based on this review.

Phase V—Experimental hardware would be fabricated for existing test vehicles and feasibility demonstrations would be conducted. The product of this phase would be an experimental data base from which new concept broad fuel tolerant engines could be designed.

The recommended program would utilize university researchers for the fuel survey work and basic research. The engine manufacturers would be directly involved in all experimental work involving engines. A maximum use will be made of existing facilities and expertise.

The fuel study of Phase I should be started with the initiation of the general aviation initiative with the near term definition appropriately planned. The experimental evaluations should be initiated with the completion of the initial work on advanced controls so that a maximum use may be made of this activity. The research into turbine engine fuel use should follow that of the relaxed specification avgas effort but start no later than two years after the general aviation initiative is launched with the experimental evaluation following.

The proposed program should be structured to provide grants for the university work relating to the fuel availability survey and any basic work on turbine fuel usage. Experimental work on approaches to operation on the modified specification avgas is envisioned as being an extension of the advanced controls and sensor effort and should be contracted as an option to this work with the involved manufacturers. The Phase IV work on extended range operations on turbine fuel should be contracted with the Phase I contractors but with the provision that additional sources may be sought.

SMALL TURBINE COMPONENTS

BACKGROUND AND GOALS

NASA has a history of continued research and accomplishment in the area of basic gas turbines. Much of this effort has been applicable to both large and small engines; however, a significant portion of this effort specifically addressed technologies related to small engine unique features. There is concern that with the increased emphasis on the High Speed Civil Transport and the Subsonic Transport Initiative some of the momentum and continuity of the small engine base technology program may be lost. This technology stream has proved valuable to the U.S. aviation industry in terms of international competitiveness and to the public in the form of improved general aviation and rotorcraft propulsion and to the U. S. military in support of their small engine needs.

Recommendation: The base technology programs should include component technology programs and the generation of design and analysis tools that address the fundamentals of small engine design and application.

The approach to such research should include the continuation of NASA in-house and university work into the fundamentals of engine components and systems integration, cooperative industry/NASA Center work on advanced components, and selective component and system integration work through industry. The Lewis Center should continue to direct all of the turbine engine base technology programs including the small engine portion. Industry participation should be handled using the Broad Agency Announcement approach so that industry may contribute to the detailed planning of the actual program to assure that relevancy and transition-speed to product is maximized. This effort should be based on an apportionment of the overall aviation propulsion budget and should be conducted on an ongoing basis.

NEW CONCEPT EVALUATION

BACKGROUND AND GOALS

NASA's activities on the cutting edge of aviation technology provides an environment for researchers to explore unique and imaginative propulsion concepts.

Recommendation: NASA should allot a portion of its aeronautic budget to the generation of new general aviation propulsion concepts based on evolving technologies and requirements, including low cost piston and small turbine engine development.

The envisioned program would involve both the Langley and Lewis Centers with Lewis directing the propulsion element. The program would include analytical configuration and system studies and address total system cost, environmental impact, public benefit and economic impact as key figures of merit. The Task Force recommends that these studies should include reviews of evolving power systems (such as automotive gas turbines and advanced automotive piston engines) for their direct or derivatives applicability to general aviation propulsion. The effort would include university and industry involvement at appropriate stages. This work would be briefed through the NASA Advisory Committee system and

regular NASA-Industry conferences and reported in formal NASA documents. This work would be used to help guide future program planning and assure a focus on high payoff technologies.

Concept studies should result in an advanced engine concept and the descriptions of the advanced technologies employed in the concept. Component and engine development programs should be defined and estimates made for development of program costs.

CHAPTER 4B: AERONAUTICAL SYSTEMS

INTRODUCTION

For general aviation to achieve its full potential as a transportation system, the highest priority area is to remove the primary inhibitors to general aviation's widespread use, particularly in the mid-range travel market of up to 500 statute miles. Satisfying this demand will create a new generation of general aviation pilots and a new and growing demand curve for general aviation aircraft, thereby providing significant production economies.

The primary inhibitors to broader use of general aviation by the traveling public are:

- ◆ Difficulty of operation
- ◆ Lack of perceived value
- ◆ Costs

Research directed at these inhibitors will enable greater use of general aviation for business as well as personal transportation and for other worthwhile purposes such as training and enhanced quality of life.

Aeronautical systems encompass the displays, controls and navigational, communications, surveillance and hazard avoidance systems with which the pilot operates an aircraft. The capabilities and ease of use of these systems are of critical importance in removing inhibitors to broad GA use. New aeronautical systems—in the aircraft, in space, and on the ground—can result in substantial increases in the utility, safety, affordability and comfort of general aviation aircraft for more people.

DIFFICULTY OF OPERATION

BACKGROUND AND GOALS

Studies of why entry level participants do not remain involved with general aviation find that less than 40 percent of student pilots become private pilots. Only about one of every two private pilots flies more than 100 hours in their total involvement with general aviation, and only about 10 percent of general aviation entrants are still active after 10 years. While the population of licensed pilots in all areas of aviation has decreased in the last decade and currently numbers about 600,000, the number who have held valid licenses but have not maintained a valid medical certificate is approaching 2.5 million.

Difficulty of operation and cost are the principle reasons for this high attrition. Pilots are required to inventory an enormous variety of facts, and they must develop techniques for recalling those facts quickly while engaged in distracting tasks. Pilots also are required to communicate and receive considerable real-time information during periods of high workload. In addition to the knowledge and skill needed for routine operation of general aviation aircraft, considerable mental and physical resources are required during periods of emergency.

While history has shown that with appropriate training, pilots can master the unique and unfamiliar qualities needed to fly safely and to obtain value from general aviation, the high level of dedication to the learning process and the need to continually refresh knowledge and skill have discouraged the growth of general aviation.

Reducing operating difficulties will contribute to revitalization of general aviation in two ways:

- ◆ Attrition of existing pilots will be reduced
- ◆ Attraction of potential pilots will be enhanced

Advanced flight systems that increase the ease of operation of general aviation aircraft will attract a new generation of pilots and aircraft owners by greatly reducing the time and expense required for them to obtain utility, safety and perceived value from this form of transportation. Highly capable systems can reduce the investment necessary for proficiency both in VFR recreational and discretionary personal transportation flying, and in reliable IFR personal and business transportation in almost all weather. Furthermore, advanced systems will have a positive impact on safety.

Several revolutionary and powerful technologies such as today's generation of microprocessors can be used to monitor aircraft systems, diagnose faults, simplify aircraft and engine control, and provide aids in decision making. High-resolution flat-panel color displays are available to provide more capable and user-friendly systems for aircraft management, navigation, weather depiction, situational awareness, ATC monitoring, and collision avoidance. Global Positioning Satellites and Loran-C offer significant opportunities in navigation, communications, and air traffic management and control.

Through the incorporation of these technologies in new aeronautical systems, the time and effort needed to obtain reliable piloting skills can be reduced, and proficiency will be easier to maintain. Safety will be enhanced since the physical coordination as well as multi-task cognitive skills needed to operate a general aviation aircraft will be reduced to levels more consistent with those needed to drive a car. Furthermore, better information flow to the cockpit of a general aviation aircraft also will have a positive impact on operating ease and safety.

Research is needed to determine how advanced microprocessors, displays and navigation communication surveillance technologies can ease the operation of general aviation aircraft. Specific areas to address include:

- ◆ Reduce time and effort required to become proficient in IFR operations
- ◆ Develop less time-consuming and less demanding means for maintaining IFR proficiency
- ◆ Improve passenger and pilot acceptance by improving ride comfort, including reduced interior noise, reduced interior vibration levels and more acceptable vehicle response to turbulence

- ◆ Increase the utility of general aviation as a transportation system while reducing the level of difficulty associated with general aviation use.

Recommendation: NASA should research advanced applications of modern microprocessor, display and navigation/communications/surveillance technology to identify advanced flight system that will significantly ease the operation of general aviation aircraft, thereby removing a significant inhibitor to growth of general aviation.

Research related to the application of advanced microprocessors and displays should be directed toward providing pilots with information management that minimizes specialized, convoluted procedures and is intuitive. Areas to be addressed include:

- ◆ Terrain and manmade obstacles — displayed on an electronic moving map with appropriate warnings of potential collisions.
- ◆ Other aircraft — displayed in an easy-to-interpret manner (such as a moving map) with appropriate warning, with positions based on GPS.
- ◆ Weather — including ground and air-based weather radar and lightning strike data and ground and air based “vertical slice” data on clouds, precipitation, freezing levels, ice potential turbulence, and wind speed and direction.
- ◆ Navigation fixes, including airports and runways — displayed on a moving map for enroute, terminal, and approach and landing guidance, including conventional navigational aids and controlled and restricted airspace.
- ◆ Aircraft control information — easy to interpret flight data, including attitude, heading, altitude, airspeed, vertical speed, and glide slope.
- ◆ Engine and systems information — operational guidance to provide performance and prefailure monitoring, failure diagnostic and problem resolution advice as well as avoid engine abuse. Such systems would make complex, high-performance powerplants as easy to operate properly as simple, low-performance engines.

The impact of standardized, task-oriented displays should be researched to identify means for reducing the differences in piloting techniques and procedures needed to operate different aircraft models. Standardized presentation of information and display symbology might reduce piloting errors and have a positive impact on training as well as safety. Intelligent, pilot-aiding systems should be explored to reduce workload and increase the effectiveness of decision making. Systems that anticipate piloting requirements and perform reasonability checks related to pilot requests and actions will reduce workload and increase safety. Training programs for learning how to use advanced systems and for maintaining proficiency also need to be researched.

Recommendation: Provide guidelines, data bases, and test facilities for the development of primary flight displays, multi-function navigation displays and weather depiction which meet the objectives stated above.

This effort would in effect create design guidelines for the basic pilot-cockpit interface. These guidelines might be at the level of the "windows" environment now commonplace for personal computers, providing a standardized overall operator interface and allowing applications designers to incorporate display modes and controls appropriate for general aviation applications.

Recommendation: Provide guidelines for task-oriented display optimization for the best possible pilot situational awareness, recognition of action needed, pilot response time, and learning and relearning time.

Such research would address the following issues:

- ◆ How much data are necessary, sufficient, and excessive?
- ◆ How is awareness improved?
- ◆ How does complexity relate to task?
- ◆ How are failures and reversions handled?

Advanced systems that would reduce the complexity of operating general aviation aircraft would contain data generated from the knowledge of expert pilots, expert maintenance personnel, airframe and engine manuals, and other sources of aeronautical knowledge.

Recommendation: Develop and validate concept specifications describing how general aviation expert systems design could be used to minimize the possibility of pilot errors and assist the pilot in responding to aircraft system faults.

Such systems would include a check on the pilot's awareness and performance in high workload IFR environments. Elements to be included are as follows:

- ◆ Flying to waypoints consistent with flight plans
- ◆ Aircraft configurations consistent with task at hand;
- ◆ Aircraft performance consistent with power and configuration
- ◆ Auto-calling of checklist and checks on pilot performance as well as system failure management

Recommendation: Develop guidelines for a desktop computer interactive learning/proficiency program based on expert pilot decision making similar to the program developed by Bell for helicopter operations.

Such guidelines should consider the following elements:

- ◆ visual displays
- ◆ typical piloting tasks
- ◆ Emergency procedures

Recommendation: Develop guidelines for an “operating system” for PC-based pilot and maintenance training that can be easily adapted for different aircraft types, including aircraft systems, instrument training, propulsion, controls, and normal and abnormal procedure training.

Extensive use of simulation will be needed to research optimum applications of advanced microprocessors, displays and navigation/communications/surveillance technology to the goal of reducing the difficulty of operating general aviation aircraft.

Recommendation: Create appropriate ground simulators and where necessary aircraft test beds to facilitate the validation and FAA evaluation of the flight systems enhancements as identified in this report, which together would constitute the Advanced General Aviation Transport Experiment (AGATE). The AGATE would consist of: 1) Simulators to be used for human factors experiments to evaluate systems and display presentations with groups of test subjects and for the development of data needed to obtain FAA certification of these advanced systems; 2) Demonstration aircraft only where needed to provide data not obtainable from ground-based simulation.

The development of single-lever power controls for piston engines, with abuse-prevention operating features, would be effective for low-workload power management as well as optimum engine performance, reliability, and durability. The development of simplified flight path controls would also reduce pilot workload and reduce the time for learning and relearning.

Recommendation: Use AGATE to develop and validate simplified control systems, including decoupled controls, rate-command controls, and simplified integrated (e.g., single-lever power/airspeed) controls, and the guidelines for the characteristics of such systems.

LACK OF PERCEIVED VALUE

BACKGROUND AND GOALS

As the only form of random access, moderately high speed transportation to many locations within the U.S. as well as to other parts of the world, general aviation offers significant value. For potential users, however, its perceived value is low because of the difficulty of using general aviation's capabilities and because of costs associated with its use. Research that increases the utility of general aviation while reducing the difficulty and cost of achieving such utility will stimulate the current market and create a new market for general aviation. Factors that affect utility are as follows:

- ◆ IFR capability in most weather conditions

- ◆ Performance (speed, range, payload, etc.)
- ◆ Ride comfort

Other factors are:

- ◆ Safety
- ◆ Costs

Safety is an important and often misunderstood element in the perceived value of general aviation. Since collision between aircraft currently is a remote possibility (less than 1.0 percent of all general aviation accident result from midair collision) and remaining factors are under the operator's control, general aviation has the potential of being safer than its current state, which has been showing continuing improvement (Appendix C—Chart 7). Turbine-powered general aviation aircraft operated by highly trained two-person crews have the best safety record, on average, for all forms of travel over the last five years—far better than the average for all of general aviation.

The typical general aviation pilot, however, does not have the knowledge, skill or recent experience of a professional aviator operating turbine-powered general aviation aircraft. Nor does he or she anticipate obtaining such high levels of proficiency based upon currently available and affordable training options. Thus, the operator's attitudes toward safety negatively influences perceived value.

Research that leads to ease of operation, retention of adequate skills, higher utility and greater safety will increase perceived value of general aviation and increase demand for this form of transportation. Reductions in acquisition and operating costs also will increase perceived value.

Over 80 percent of general aviation accidents involve pilot error. Thus, research that improves ease of operation, retention of skills and reduced pilot error will contribute measurably to general aviation safety and acceptance.

This report addressed the issue of operating ease in the preceding subsection; the issue of costs is addressed in the Subsection following this presentation. Research that incorporates advanced flight systems leading to enhanced utility and safety for general aviation is discussed below:

To perceive greater value from general aviation, users must be able to operate their aircraft with a high degree of dispatch reliability and safety in most weather conditions. Cross-country flights must be easily accomplished with a high expectation of an enjoyable experience. These goals will be facilitated by providing the general aviation pilot with operational data from ground sources to provide precise navigation, air traffic control, and weather information. Digital data link can provide a mechanism for simplifying the air traffic management system, thereby enhancing ATC's ability to accommodate traffic (general aviation as well as airline and military), assure high levels of safety, and improve utility. Airborne systems and ground-based infrastructure for collecting and distributing high integrity data that are uplinked to general aviation and air carriers, however, require multiple agency planning and guidance.

To devise a data link system that serves the needs of general aviation, data link capacity and configuration must provide the following services:

- ◆ Weather information uplink (weather radar, lightning strikes, surface graphics, and vertical slice graphics based on air and ground data).
- ◆ Airborne weather information downlink.
- ◆ Differential GPS corrections.
- ◆ Route request/ATC clearance.
- ◆ Situational Awareness; aircraft and terrain position data (including GPS position data for automatic dependent surveillance, collision avoidance, and taxi guidance)

Furthermore, research relevant to air traffic management and control, including satellite navigation, communications and surveillance as well as data link features, must be coordinated with other government and quasi government agencies and with private industry.

Recommendation: Using the AGATE described above, develop and validate digital communications systems based on satellite, VHF, UHF, Mode S and other methods of data link.

Such research should determine the optimum data link characteristics for general aviation use. This recommendation should be implemented in consultation with the RTCA Task Forces and Special Committees working on data link issues.

Recommendation: Develop means for ATC to accommodate increased numbers of general aviation aircraft operating with advanced technology systems.

The “autonomous airplane” as conceived by American Airlines suggests that increased numbers of advanced technology general aviation aircraft could be handled by the ATC system without additional expense because many functions now requiring ground controller intervention could be handled by these aircraft autonomously.

Recommendation: Develop interface guidelines for systems/airplane interface, including direct satellite broadcast, VHF, and UHF or other means.

Such research should address the following items:

- ◆ Data link specifications for providing the services listed above.
- ◆ Coordination of data link with voice commands.
- ◆ Power, HIRF, lightning, environmental and other requirements.
- ◆ Requirements in accordance with general aviation affordability.

Recommendation: Establish and foster close coordination with the Federal Aviation Administration on all matters dealing with air traffic management and control, including application of satellite technology and data/voice communications.

Perceived value also can be improved through measures that reduce pilot fatigue and increase passenger comfort. These objectives would be advanced by developing low-cost ride quality improvement system and electronic active noise and vibration control technologies, including vibration-reducing engine operation controls.

Recommendation: Use the AGATE to develop and validate an analytical "tool set" for addressing noise and vibration problems in general aviation aircraft.

Recommendation: Using available analytical tools already developed by NASA wherever possible, develop design tools for alternative methods of reducing noise and vibrations through electronic systems and engine design techniques that reduce the source disturbance.

COSTS

BACKGROUND AND GOALS

Many factors, ranging from the time and funds required for FAA certification to the financial impact of product liability, affect the cost of general aviation. Lack of a broad market that would lead to economies of scale also is a significant contributor to this problem. NASA research can have a beneficial impact on general aviation costs by addressing the following areas:

- ◆ Coordination with FAA to assure that new technology meets certification criteria
- ◆ Increased demand for general aviation by researching systems that increase ease of operation and perceived value
- ◆ Stimulation of enabling technology that has been stifled by the diversion of industry funds from research and development into costs for product liability. (Significant work by NASA is needed to fill the technology vacuum created by diversion of industry resources from general aviation R&D to product liability. Insufficient resources exist within industry to fill the research void quickly even if product liability reform were enacted immediately.)
- ◆ Research ways in which advanced system can reduce operating cost by reducing aircraft and engine wear as well as maintenance requirements

For rapid, cost-effective introduction of the required new generation of aeronautical systems identified in this report, FAA and Joint Aviation Authority (JAA) certification must be accomplished quickly and efficiently. Therefore, NASA's general aviation program must determine levels of integrity,

redundancy, and system reversion appropriate for regulatory compliance. In some cases, NASA must work with the FAA and the JAA to establish appropriate certification standards and procedures. FAA/JAA requirements must be developed concurrent with the product development process, thereby reducing certification cost and cycle time. By collecting all certification criteria and applying them based on system criticality, substantial certification-related cost reduction should result, which is essential to the success of this effort.

Recommendation: Create, with FAA participation, a criticality analysis and data base of proposed new aeronautical systems that describes failure modes and effects and redundancy or backup requirements.

This effort would include hardware (such as internal-battery operated GPS/comm transceivers), software (including pilot operational rules), and liveware (including training) that permit safe operations under all flight conditions with due consideration to cost and the need to avoid expensive, fully redundant systems.

Recommendation: Involve the FAA in the early development of appropriate certification criteria for new systems, including: GPS approaches; GPS-based CAS and ADS systems; Integrated Displays; Data Links; Expert Systems; PC Training Tools; Software; Advanced Controls (e.g., fly-by-light, power-by-wire), including methods and data on reliability, redundancy methods, and backup methods, and including the effects of lightning, HIRF, and EMI, for the FAA to use in certifying new electronic systems.

Recommendation: Develop automated software generation and validation tools for essential systems that yield auto-code and documentation acceptable to the FAA for certification.

Recommendation: Provide pilot, mechanic, and repair station certifications requirements for the new systems described above.

Recommendation: Consider cost of operation as a performance measure in research dealing with aeronautical systems, including systems dealing with powerplant management.

CHAPTER 4C: STRUCTURES & MATERIALS

INTRODUCTION

Because of size and minimum gauge requirement associated with the design and manufacture of general aviation aircraft, NASA programs directed at the needs of the large transport and military communities are not broadly applicable to general aviation. In particular, the following areas are of significant importance to the general aviation community:

- ◆ Composites and low-cost manufacturing
- ◆ Crashworthiness
- ◆ Interior noise and effects of structure on transmission paths

In order to accomplish the objective of substantially reducing production costs of general aviation aircraft, there must be significant reductions in the cost to design, analyze, test, certify, and manufacture a general aviation aircraft. Cost reductions in these areas could be reflected in the initial selling price of the aircraft, thus making the product accessible to more people. When coupled with cost reductions in operating, inspecting, and repairing aircraft, reduced manufacturing costs would have a positive impact on the demand for general aviation.

COMPOSITES AND LOW-COST MANUFACTURING

BACKGROUND AND GOALS

While NASA currently supports significant research in manufacturing technology for composites under the Advanced Composites Technology (ACT) program, little of this research has been useful to general aviation. Much of the effort has been focused upon large airliners and military aircraft that simply have different design construction than general aviation. Minimum gauge structures, in both metals and composites, are very common in general aviation aircraft because of the small size and low loads. Furthermore, the degree of structural optimization desired in large, expensive aircraft is not cost-effective in general aviation.

Recommendation: NASA should initiate a program, patterned after the ACT program, but specifically tailored for general aviation.

Such a program would have three phases:

- ◆ Investigation of feasibility of innovative fabrication of detail parts.
- ◆ Fabrication and testing of components.
- ◆ Full-scale demonstrations.

The goal in manufacturing technology should be to reduce the cost of manufacturing a typical airplane by 25 percent or more.

For many years, the structural properties of aerospace materials have been available from the MIL-Handbook-5. However, this data source is limited to certain metals and most of these are older alloys. New improved alloys need to be included.

Recommendation: An interagency effort should be undertaken to cause inclusion in MIL-Handbook-5 of new data for currently used high tech alloys.

Some of the most promising structural materials today are fibrous composites such as graphite-epoxy. For years, MIL-Handbook-17 has had the goal of providing basic material properties for a large number of composites. However, this simply has not happened. The latest revision contains data for very few composites, most of which are inappropriate for low-cost general aviation aircraft.

Recommendation: NASA should develop a design manual for the use of composite materials including the following areas:

- ◆ Material properties for common composite materials and processes.
- ◆ Manufacturing process controls necessary to use the material properties.
- ◆ Method for suppliers to incorporate new materials and processes into the manual.

The FAA's Technical Center has recently accepted the challenge of assisting the Army in developing a MIL-Handbook-17. An industry-government plan on standardization of advanced composite materials has been developed by a consortium. However, the current level of effort is inadequate to meet the needs of the U.S. general aviation industry. The goal should be to provide a handbook containing useful design data and to do so promptly.

Recommendation: All federal agencies (NASA, FAA, ARPA, DoD, etc.,) should pool their financial resources in composites to accelerate the Army-FAA development of standard test methodology and MIL-Handbook-17 material properties. General aviation should participate in developing the priority list of materials to be characterized.

The general aviation industry could benefit greatly from technology that shortens the development and certification cycle. Today this process typically requires five years and hundreds of thousands of man-hours. Millions of dollars could be saved on each project by reducing development and certification to three years. Dollars and time saved could be invested in the development of a healthier industry.

In the past, NASA engineers have developed a variety of computer programs to the point of demonstration only to discontinue their support prior to commercial status. A no exception is NASTRAN, which has become a mainstay in finite-element analysis.

Recommendation: In the area of structures (as well as in other areas associated with design and analysis), NASA should license selected computer programs to commercial software houses with an agreement for commercialization and on-going support at prices that have widespread affordability.

NASA's program in composites and low-cost manufacturing should be a cooperative effort with other federal agencies and the general aviation industry. NASA should oversee the project and provide material tests, testing facilities and funding. The FAA should coordinate certification issues and provide funding. By means of surveying industry, a list of materials and processes should be established for which an initial composite material data base will be produced. Test samples of materials should be evaluated and then properties defined. Necessary tests to produce material properties and process control documentation could be conducted within universities.

CRASHWORTHINESS

BACKGROUND AND GOALS

A technical discipline open for design improvement is that of crashworthiness. This is especially true for composite aircraft, where little is known about the energy-absorbing characteristics of various design approaches, which vary significantly from the airliner designs that NASA has investigated in recent years. A program is needed for general aviation-specific designs.

Such a program should study energy-absorbing seats, subfloor structures, innovative restraint systems, and the possible application of airbags. Full-scale crash simulations conducted in the past have been informative and should be included.

The FAA Technical Center has an interest and active program in both commuter and general aviation crashworthiness. It is a program directed toward occupant protection issues such as energy-absorbing seats, restraint systems and engines. Joint NASA/FAA Efforts have been initiated in crashworthiness testing.

Recommendation: NASA and FAA efforts on a joint program should continue with participation by industry.

Recommendation: A user friendly validated computer program should be developed for showing compliance with the new dynamic crashworthiness criteria for both Part 23 and Part 25.

INTERIOR NOISE

BACKGROUND AND GOALS

In recent years, significant noise reductions have been accomplished in autos, factories, and airliners without corresponding reductions in the interior noise levels of small airplanes. By comparison, the public finds these noise levels in general aviation to be undesirable and even

uncomfortable. It is generally accepted that the training environment is compromised in many of today's entry-level aircraft.

A major impediment to incorporating some of the passive noise treatments currently being used in larger aircraft is their weight. These smaller aircraft cannot add significant barrier and damping materials without detrimentally affecting payload. In addition, these small aircraft have a disproportionate amount of window area compared to larger aircraft, and it is very difficult to reduce the noise transmitted through windows. The development of lightweight noise treatments and materials would be very desirable, as would the continued research into active noise cancellation which is being conducted at NASA/Langley.

Recommendation: NASA should undertake a research program that identifies acoustic transmission characteristics of composite aircraft, develop lightweight noise-attenuation materials, and relate its finding with the benefits that come from broad-band active noise cancellation.

CHAPTER 4D: AERODYNAMICS

INTRODUCTION

Continued competitiveness in the area of aerodynamics requires performance and safety improvements, as well as computational, wind tunnel, simulation, flight research, and testing tools that are more accurate, faster and lower cost. The smaller size and higher altitudes of business jets places them in operation at Reynolds numbers much lower than transport aircraft, even though the Mach numbers are comparable to transports. Trainer and commuter aircraft operate at lower altitudes and speeds, and require greater tolerance to turbulence, rain and other weather phenomena. Thus general aviation's needs in the area of aerodynamics fall into the following areas:

- ◆ Performance and safety
- ◆ Applied computational aerodynamics tools
- ◆ Aerodynamic test facilities
- ◆ Aerodynamic data bases

In particular, Reynolds number considerations cause general aviation research in the area of aerodynamics to be unique and not readily obtainable from other NASA efforts in the areas of large transports or military aircraft.

PERFORMANCE AND SAFETY

BACKGROUND AND GOALS

Drag: Airplane fuel mileage and thus payload and range performance are related directly to drag. Each percentage drag reduction results in comparable fuel saving, or alternatively in increased range or payload. Manufacturing processes are improving, and further improvements are expected, making possible more widespread realization of laminar flow than was practical only a few years ago. Unfortunately, some high-lift systems are incompatible with maintenance of natural laminar flow. As new materials and fabrication processes are adopted, freedom in shaping will allow better fairing, with the potential for reducing interference drag associated with wing-fuselage, wing-nacelle or fuselage-nacelle intersections.

High-Lift: Improved high-lift systems are considered essential to future transport aircraft, to permit increasing airplane size (super-jumbo jets) without increasing runway size. High-lift research is also important to general aviation, but for different reasons. While current runways are adequate for general aviation airplanes, improved high-lift capability (in particular, reduced drag at high-lift) will reduce ground noise associated with takeoff and landing for general aviation aircraft. Current and proposed noise restrictions are extremely important in general aviation airplane design. Additionally, improved high-lift will reduce wing area, permitting better optimization and fuel saving at cruise.

Planform Advances: Sheared wing tips, winglets, integration of nacelles, and reducing wing-fuselage interference continue to be important areas for overall drag reduction. Design methodologies for these and other devices are needed.

Handling Qualities/Stall and Spin Resistance: Design of control surfaces is complicated by gaps, balance, and uncertainties about the boundary layer characteristics approaching and flowing over these devices. Large deflections are often used, and resulting control characteristics are non-linear. Modern CFD analytic techniques should be applied to these problems, coupled with careful experiments for validation.

Spin Resistance: Spin characteristics are a function of a number of aerodynamic variables, including airfoils, wing planform, tail geometry and control authority. Certain leading edge devices have been shown in flight to improve spin resistance, but traditional analytic tools do not predict their performance with adequate accuracy to permit rapid and confident design. Tailplane geometry guidelines were published by the NACA to assist designers in the 1930's. Although these guidelines have subsequently been shown to be inadequate for assuring good spin behavior, more comprehensive guidelines have not been published.

Review of past and current practice, coupled with modern analysis and testing (including rotary balance testing) could produce summary information of high value to designers. Wing planform add-on devices such as stall strips, fences, vortex generators, etc. are still applied by trial and error. CFD code creators need to focus on developing understanding and practical methods for design application of such devices.

Recommendation: NASA should conduct analyses and experiments at Reynolds and Mach numbers which are appropriate to general aviation to achieve drag reduction through additional laminar flow and/or reduction of separation and turbulent drag.

Recommendation: NASA should conduct analyses and experiments to determine potential gains (noise reduction, shorter runway requirements, lower landing speeds and improved safety) associated with improved high-lift systems.

Recommendation: NASA should utilize industry-FAA-NASA advisory groups such as the AAC's Aeronautical Research and Technology Subcommittee to establish aerodynamics performance and safety goals for general aviation.

APPLIED COMPUTATIONAL AERODYNAMICS TOOLS

BACKGROUND AND GOALS

The rapid growth of computing capability and the low cost of computational studies have resulted in a bewildering array of computational fluid dynamics (CFD) codes, both within NASA and in the private and educational sectors. Unfortunately, early predictions that fast, powerful computers coupled with CFD codes would make experimentation unnecessary have proven overly optimistic. In fact, the full viscous Navier-Stokes codes, even running on super-computers, require weeks or months to

prepare input grids. The results are inconsistent, proving sensitive to the turbulence eddy-viscosity model as well as to the grid. These codes require experts not only to prepare input, but also to interpret the results.

On the other hand, simpler inviscid techniques, using surface singularity or Euler formulations can be run on "work stations," or even on personal computers with a resolution adequate for many configuration design purposes. The current generation of "486-class" personal computers are available to even the smallest company. Graphics capabilities have similarly increased dramatically, making possible rapid interpretation of computer code results.

General aviation design teams need access to codes which are intended to produce useful analyses in time to affect configuration design. Time to produce useful answers must be in hours or days rather than weeks or months. Such codes must have credibility with the FAA if flight test and certification times are to be reduced.

Recommendation: Review and catalog CFD codes which are available, calibrated and appropriate for general aviation design studies.

Recommendation: Make codes "designer-friendly" by simplifying and standardizing input and output.

Recommendation: Develop interfaces and compatible input and output so that programs can be interfaced.

Recommendation: Provide better access of general aviation designers to NASA CFD supercomputing capabilities, where supercomputing power is appropriate.

Recommendation: Conduct workshops to demonstrate code capabilities to industry, university and FAA personnel, and to determine future needs.

Recommendation: Establish an Applied Computational Aerodynamics group with joint industry-university-NASA-FAA oversight to select, develop and maintain computational aerodynamics codes which are cost and time effective for general aviation airplane designers.

TEST FACILITIES

Wind Tunnels — Wind tunnel have been, and will continue to be primary tool for the aerodynamicist and configuration designer. While wind tunnel and model costs have risen dramatically in recent years, advances have also been made in data acquisition and processing. Unfortunately, the full potential of improvements in the processing of experimental data have not been realized, because of recent trends to invest in advanced computing rather than improved experimental capabilities. Special facilities like the vertical spin tunnel and flow visualization tunnels have emerged in recent years as viable tools for tailoring geometry to provide good high angle of attack behavior. Existing facilities must be upgraded with modern data acquisition systems, and access to these facilities should be provided.

Instrumentation — Real-time data processing is leading to advances in instrumentation. The computer has relieved the instrumentation specialist from the burden of needing linearity between measured quantity and output signal. Rapid data acquisition and processing make possible meaningful measurement and interpretation of dynamic processes such as turbulence. Many advances in instrumentation have application to flight testing as well as to ground-based wind tunnel tests.

Flight Testing — While flight testing costs have increased over the past decade, the cost of flight testing in the general aviation arena remains much lower than flight testing of large transports. Progress in laminar flow research was substantially accelerated by joint NASA-university-industry (general aviation and transport company) participation in the 1980's. Airfoil shapes and instrumentation techniques developed in NASA and university wind tunnels were flight-test proven at very low cost on piston-engine aircraft, and later on high-performance business jet general aviation airplanes.

Similar progress was accomplished in this same time period in the development of a new ice removal technique, called Electro-Impulse-De-Icing. In this program, the FAA, NASA, university and industry team members collaborated. Low-cost proof-of-concept flight tests were successfully conducted on general aviation airplanes.

All major general aviation manufacturers, a number of private firms and several universities have very capable general aviation flight test organizations. These units represent an under-utilized resource to foster advances in aerodynamics. Coupling new computing, instrumentation and data processing capabilities with wind tunnel and low-cost flight testing will often produce major reductions in time between concept and certified product.

Handling Quality Simulations — An effort should be made to develop and refine handling quality simulations for development of product stability and control characteristics in advance of actual product construction. This effort should enable a more precise product definition and identification of satisfactory flight performance early in the design phase.

Recommendation: Review NASA, industry and university test facilities (wind tunnels, flow visualization facilities, spin tunnels, handling quality simulation, flight test capabilities, etc.) for relevancy to general aviation, and recommend upgrades or changes in capabilities, operations, and accessibility, as appropriate.

AERODYNAMIC DATA BASES

BACKGROUND AND GOALS

NASA and its predecessor, the NACA, have generated a treasure trove of experimental aerodynamic data, spanning 75 years of research. Most of this information resides in hard copy reports, many of which are still key references for designers, especially at the conceptual stages. Unfortunately, many of the reports are available only from micro-fisch forms. There has been only occasional application of computer information technology to the process of reporting and information storage, and retrieval. Specific effort should be mounted to identify key reports and data, to digitize these data, and to

make the data available though compact disk ROMs or other appropriate media. New reports should provide easily accessible, computer-readable media as well as hard copy, to enable researchers and designers to rapidly create graphic presentations suited to their particular needs. This activity will benefit not only general aviation, but the entire aviation community, as well as educational institutions.

Recommendation: Establish standards and formats for NASA technical aerodynamic data, making use of electronic data base software and CD-ROM media.

Recommendation: Review older NASA and NACA reports to identify those which should be converted to the new media, and implement a conversion process. (NASA Contractor Report No. 1484 by F. O.Smetana, 1970, "A Study of NACA and NASA Published Information of Pertinence in the Design of Light Aircraft will provide a starting point for this study.)

Recommendation: Cross-reference the information in a "hyper-text" format as used by many CD-ROM data bases today.

Recommendation: Distribute the CD-ROMs in a manner similar to NASA Tech Brief CD-ROMS.

Recommendation: Establish computerized data bases using CD-ROMs to make current and historic aerodynamic information available to general aviation designers and design reviewers (FAA) in a timely manner.

CHAPTER 5: NEW PARTNERSHIPS

GOVERNMENT/INDUSTRY/UNIVERSITY RELATIONSHIPS

INTRODUCTION

In the effort to identify the factors that will assist the U.S. general aviation community in meeting the present and future competitive challenges of both traditional and emerging markets, as well as developing the approaches that will provide the means to address these factors, it is useful to conceive of each of them as costs that must be overcome. Real or imagined, actual or anticipated, the cost that one perceives involved is the major factor underlying most decisions to select one course of action over another. This perceived cost is comprised of many more elements than just the economic one and is highly dependent upon the evaluation of individual who is weighing the decision.

Although it is difficult, if not completely impossible, to quantify its component parts, the concept of total perceived cost as the basis of choice between competing modes of transportation is a useful one. The hypothesis is that an individual will select the mode that appears to offer what he perceives to be the lowest total cost for the trip. In making this assessment the traveler, consciously or unconsciously, assigns values, or costs, to the various characteristics of competing modes; their direct economic cost, i.e. the cost of ownership and operation versus the cost of charter versus the cost of common carriage; the cost of unproductive time involved in the trip, of critical importance to the business executive, but much less so to the vacation traveler; the cost of discomfort from cramped quarters, noise, vibration, or the pressure of crowds; the cost of inconvenience arising from having to transfer between transportation modes with all the resulting hassle involved; the cost of unreliability arising from transportation not being available when required owing to traffic, weather or other causes; and finally the cost of the risk, or lack of safety, involved, real or imagined.

To be competitive, it can be argued that general aviation must appear to provide a solution with a lower perceived total cost than any of the other modes that might be available. It may, and frequently will, be more expensive, in the strictly economic sense, than competing forms of transportation, but will more than compensate when the values of speed, convenience, comfort and reliability are considered, making it the mode of choice of firms wishing not only to utilize the time of their executives efficiently but to do so in a manner exposing them to the least possible wear and tear. Actually this is the case only to the extent that one restricts attention to those elements of general aviation that do in fact primarily provide an alternative transportation mode rather than serving a training function. Nonetheless, it is clear that the cost, real or perceived, is a matter of overwhelming importance to the success of all aspects of general aviation, and that the future of the field depends critically upon the degree to which all elements contributing to that cost can be addressed and minimized.

BACKGROUND AND GOALS

In face of the demonstrated strength of foreign competition, it is important not only that these perceived cost elements be addressed, but that this be done in the most expeditious and efficient manner

possible. One of the great difficulties confronting government laboratories such as the NASA Centers is the fact that their work must be planned, budgeted and scheduled well in advance. Thus any new initiative, regardless of how important or critical, can take several years from concept to realization. At the present time the United States' general aviation community is in a position to regain its world leadership role if it can move rapidly to perform the R&D necessary to take full advantage of the opportunities being presented by the advent of new technologies such as onboard computing power, flat panels and GPS. The window of opportunity is not large. Estimates seem to indicate it may be less than five years before the competition reaps the benefits of taking full advantage of the possibilities these technologies so present. Thus it is urgent that the country develop new methods by which resources such as the talent and facilities available both within NASA and other organizations—industrial, nonprofit and academic—can be brought to bear upon the task in a timely manner.

No less important than the need to reduce the time required to plan, fund and conduct the research required to minimize the perceived costs of general aviation is the need to find ways of reducing the time and cost of certifying the products of this research for commercial use. To this end it is essential that the FAA be a full partner in the process from the very beginning so that certification requirements can be identified and addressed in the most economical and expeditious manner. New approaches to the certification process are as critical to the recovery of this nation's general aviation industry as they are to the R&D process.

Since many of the elements affecting perceived cost—manufacturing and operational expense; speed; cabin noise levels; take off and landing performance; all-weather performance; crashworthiness; etc.—are all characteristics which will require research and development to achieve substantial improvement, it would appear reasonable to require that the R&D costs associated with reducing each perceived cost be kept low enough that a net gain can be realized. Appealing as the logic is, it comes to naught because of the impossibility of actually quantifying the elements of perceived cost; but it is clear that it is necessary to conduct the required work in an economical manner, which in turn implies that efficiency in the identification and conduct of the specific work required is vital.

To keep the costs low there have been attempts in the past for the general aviation community to utilize portions of the work performed as part of the research and development of both military and large commercial aircraft. Because of the wide range of requirements of general aviation aircraft (some more advanced than airliners entertaining main-line commercial service and others—primary trainers and sport aircraft), this practice has been found to be less than ideal, the scope and range of parameters measured often rendering otherwise potentially important research virtually useless to much of the community. Although a few general aviation manufacturers, typically those producing high performance business jets, possess the facilities and staff required to generate much of the specific research and development needed to meet their needs, others do not.

Even those with substantial in-house capabilities occasionally need access to facilities available only within the national laboratories. Unfortunately obtaining this access and designing the required program is often such a lengthy and frustrating process that many find it necessary to eschew potentially promising technologies and stick with more traditional approaches. Thus it appears that a new mechanism is required that will allow the entire spectrum of general aviation manufacturers to let their

range of needs be known, to participate in the planning of programs to meet them, and to see that they are conducted in a timely and economic manner.

RESEARCH COORDINATION MECHANISMS

Clearly, in research of the nature required, NASA must obviously play a leading, but not necessarily exclusive, role. Not only are there many other organizations with major stakes in the well-being of general aviation, but there has been much useful work done in many other places both within the United States and abroad that could have direct application to general aviation if the community was but aware of it. There are also numerous other entities within the country, such as universities and non-profit research organizations, capable of performing useful work whose talents have not yet been tapped or have been diverted to other areas.

A group of particular importance, partly because of the value of the research it can perform and partly because it is the source of technical manpower that will be required in the future, is comprised of the universities and engineering schools of the nation. Unfortunately, except for those institutions that because of geographic location or historical precedent have maintained close ties with one or more specific manufacturer, as a group these schools have drifted further and further away from the general aviation field. In part this is because the high costs associated with the conduct of experimental research have driven them to concentrate increasingly upon theoretical analysis generally far from practical application, and, in part, because their research funding largely comes from agencies and organizations not overly concerned with the problems of general aviation.

This has not always been the case. At one time, for example, there were as many as two dozen engineering school programs conducting active flight research involving general aviation aircraft. This has dwindled to but three at the present time, and one of these is largely funded from foreign sources. It is important that the pool of talent and ideas represented by these institutions again be tapped for the benefit of the general aviation field. While obviously not possessing experimental facilities that can rival those of the national laboratories, there are many areas of specialization in such fields as materials, human factors, simulation and the like in which they can make invaluable contributions if properly organized and funded.

Ideally, to assist in bringing diverse potential contributors to bear on the problems of the field, a focal point for general aviation research should be created, that focal point should be an organization that could serve not only as a central repository of information about research that has been performed, or is under way, but could also plan and conduct substantial research programs in support of the field in general as well as respond to the needs of specific manufacturers. Such an organization might well be a consortium or other joint venture comprised of non-profit institutions, industrial organizations and universities with major interests in the well-being and future of general aviation, with NASA and the FAA participating in its direction in an active but non-voting role. This private sector consortium, having decided the nature of the work to be performed, could then form appropriate partnerships with other organizations, including federal agencies, to conduct the necessary research programs.

Although such a consortium with broad oversight over all aspects of research conducted in support of general aviation is highly desirable, it may well prove to be too great a departure from current practice to be immediately practical, so the formation of smaller, more narrowly specialized organizations representing important elements of the entity eventually desired should be considered as a means of getting much of the needed research initiated in the shortest possible time. These organizations might themselves take the form of more limited consortia dealing with specific areas of concern such as materials or simulation engineering. They would not only serve as focal points for the planning and conduct of important research programs, but would also provide the participating groups with much needed experience with this type of cooperative endeavor. If the idea of covering specialized areas in this manner proves workable, these consortia might be extended or combined to become divisions of a larger more general organization. With this in mind, the following description of the umbrella organization has been developed.

NATIONAL GENERAL AVIATION CONSORTIUM

Regardless of the organizational arrangements employed, this focal point organization, tentatively titled the National General Aviation Consortium, must serve as a facilitator in both proactive and reactive roles; a facilitator in that it must provide the means to conduct the needed research in the most expeditious and economical manner; proactive in that it must foresee the generic research needs of the general aviation community and establish programs to address them; and reactive in that it must respond to the needs of industry to use national facilities for the conduct of research with proprietary data protection requirements.

The consortium has been selected as probably the best legal vehicle to serve the purpose of forming a cohesive group with pooled resources. In this model the collaborating members establish the consortium as an official entity (typically a non-profit organization registered with the Department of Justice) that can receive funding both from its cooperating members and outside sources. It can equally well dispense funds to its cooperating members and/or outside organizations.

Figure 1 presents an illustration of such a consortium. In this case it has been assumed that a group consisting of general aviation manufacturers, suppliers, and advocacy groups has joined with interested universities, and non-profit organizations to form the National General Aviation Consortium. The funding arrangements in this particular illustration have been shown as coming exclusively from NASA through the various funding mechanisms it currently has in place—Grants, Cooperative Agreements, Space Act Agreements and/or Contracts. Funding from other sources using other or similar mechanisms, however, is both possible and intended. Under such an arrangement, NASA can provide funds and expertise to the consortium as well as participate in the conduct of the research. Additionally, NASA can indirectly further the objectives of the Consortium through the support of appropriate Small Business Innovation Research initiatives.

A consortium, be it a large omnibus organization or a small specialized one, may be organized in a number of different manners, but will have to have a Board of Directors or a Steering Committee comprised of a representative from each of the cooperating organizations, each member having an equal vote, charged with the responsibility of providing overall policy guidance. To deal in an expeditious

POTENTIAL APPLICATION TO GENERAL AVIATION

CONSORTIA

Consortia offer opportunities to form cohesive groups and pool resources.

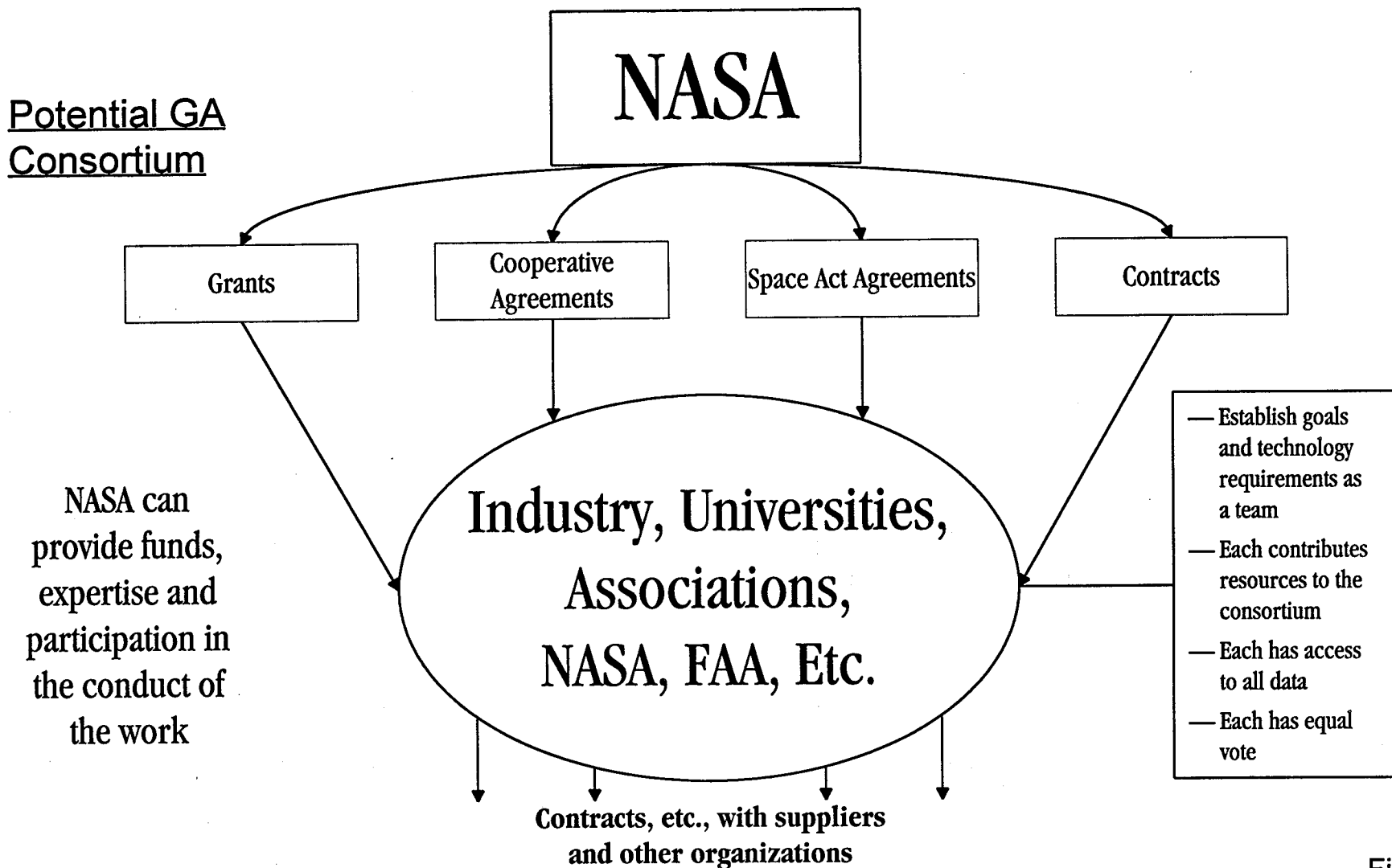


Figure 1

manner with matters requiring Board attention, it is likely that a small Executive Committee will provide guidance between Board meetings. The immediate administration of the Consortium's activities will be handled by an administrative staff reporting directly to this Executive Committee. Since it is important that expenses be kept to a minimum, care must be taken not to set up an organizational framework of more complexity than is required. One proposed model for an idealized National General Aviation Consortium is shown in Figure 2.

In Figure 2 the action arm of the Consortium is shown as organized in a number of divisions addressing the disciplines of flight systems, structures and materials, propulsion, acoustics and aerodynamics, and supported by an on-line aviation library service. While these divisions in practice may be nothing more than administrative desks within the Consortium offices, they serve to focus the work in particular areas of concern, and may in fact be the first pilot consortia to be formed later to be subsumed into the larger organization. The topics related to each division listed in the Figure are simply meant to be illustrative and are in no way exhaustive.

In regard to an on-line aviation library service, it should be pointed out that much valuable information for the design of new general aviation aircraft resides in the old NACA technical reports, notes and memoranda, but goes unused because of inadequate distribution and storage of this material. As part of the on-line aviation library, it is suggested that this dated, but still valuable, material be converted to CD-ROM, appropriately cross referenced, and made available.

To fulfill its responsibility to address areas of research of general interest to the entire field, the Consortium, through its Steering Committee, must outline a program covering the topics defined in the procurement arrangements between the government and the Consortium and request proposals relating to them. In determining the nature of this program it is important that close communication be maintained with all of the impacted parties; the operators, users, community and environmental associations, as well as groups representing the manufacturers. Depending upon the nature of the tasks required, the requests for proposals may vary from general to highly specific and may be addressed to Consortium members, outside organizations or both. Selection of the proposals to be funded will be the responsibility of the Steering Committee or an appropriate group designated by it. Funding may be through the mechanism of Grants, Cooperative Agreements or contracts. Appendix B taken from the Wharton report "NASA-Industry Cooperative Research Arrangement Options" shows the advantages and disadvantages of each type of arrangement.

In the case of programs involving the generation of data of potential proprietary interest, the role of the Consortium will be that of a facilitator, helping industrial organizations to make arrangements with NASA for the use of its facilities, expertise and personnel in exchange for industry supplied models, hardware, computer codes, personnel, and the like. The tests are conducted under a Space Act Agreement with each partner funding their own efforts. The data generated are protected from disclosure for up to 5 years, and are available to all participants in the agreement, although industry can buy exclusive rights to them if desired.

Even though by the time it, or something like it, becomes a reality the nature of the operation and organization of the National General Aviation Consortium will undoubtedly differ in detail from that

NATIONAL GENERAL AVIATION CONSORTIUM

CONSORTIUM

BOARD OF DIRECTORS

- Member Senior Management
- Institute Directors

TECHNOLOGIES SHARED

- Infrastructure Technologies
- Certification of New Technologies
- Safety
- Selected Proprietary Technologies

DISCIPLINE INSTITUTES

INSTITUTE DIRECTORS

TECHNOLOGY MANAGERS

OPERATING MODES

- CONTRACTS
- GRANTS
- SPACE ACT AGREEMENTS
- COOPERATIVE AGREEMENTS

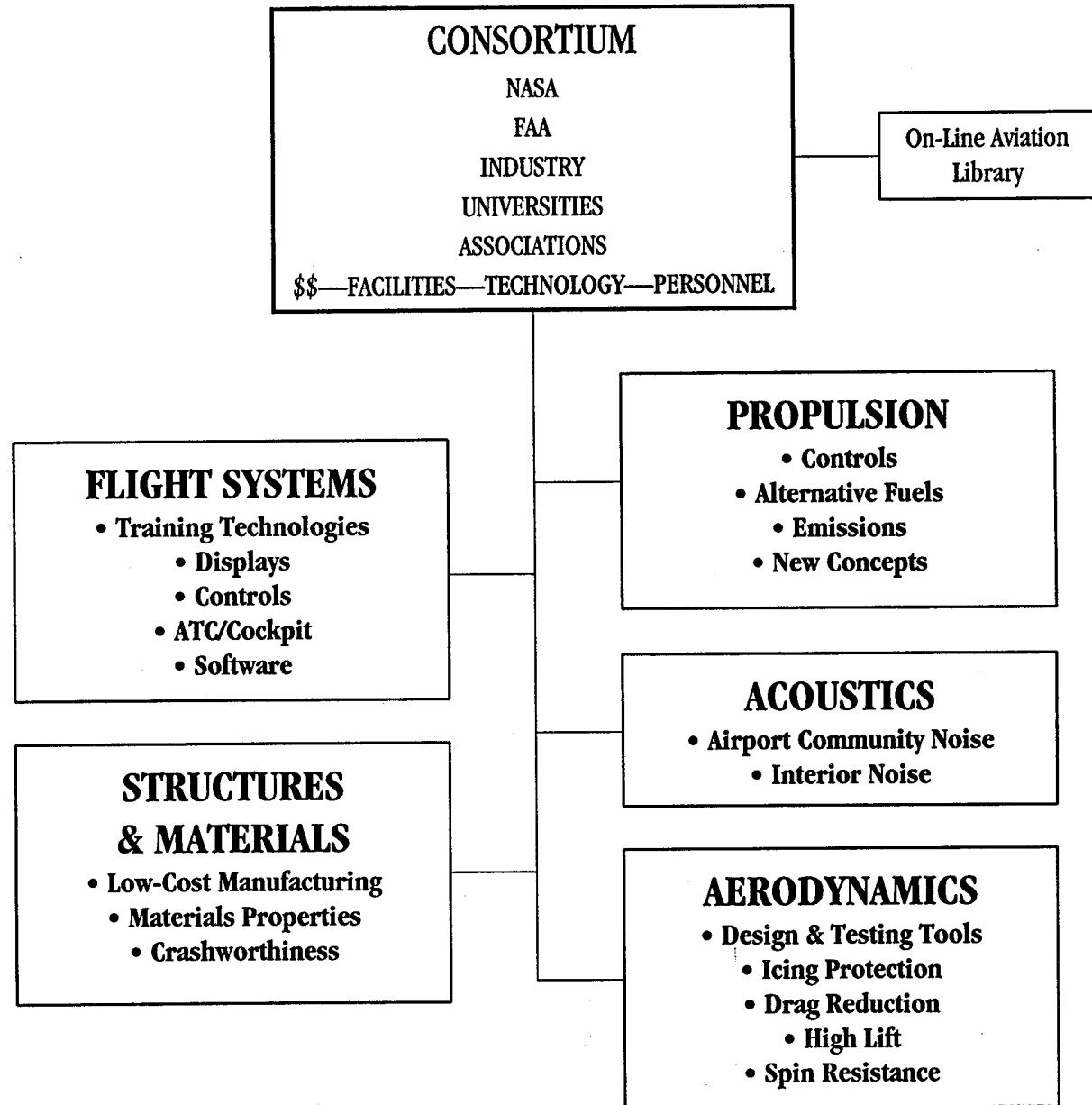


Figure 2

described herein, the important point is that there currently exist the legal arrangements by which the goals set forth can be achieved once the decision to proceed is made.

Recommendation: In order for general aviation to take advantage of the opportunities provided by the application of new technologies in a manner that will improve the United States' competitive posture in the world market, it will be necessary for NASA to take a leadership role in bringing the diverse elements represented not only by its and other agencies' laboratories and capabilities, but also be industrial, university and nonprofit organizations, to bear on the problems of the field in the most timely manner possible.

The following recommendations are made with the intent that if followed they will result in the eventual formation of a National General Aviation Consortium.

Recommendation: NASA should support the formation of a National On-Line Aviation Library and library service with particular emphasis on the concerns of the general aviation community. Included in this support should be the conversion and distribution of NACA material in CD-ROM form.

Recommendation: NASA should support the formation of consortia consisting of industrial, university, and nonprofit members designed to address specific areas of concern to general aviation in one or more of the fields of aeronautical systems, propulsion, structures and materials, and aerodynamics.

Recommendation: Based on experience gained with these consortia, NASA should consider the desirability of forming a National General Aviation Consortium in cooperation with similar industrial, university, nonprofit organizations and the FAA.

APPENDIX A

TERMS OF REFERENCE FOR NASA ADVISORY COUNCIL AERONAUTICS ADVISORY COMMITTEE, TASK FORCE ON GENERAL AVIATION TRANSPORTATION

The purpose of the Task Force is to develop a national strategy to: 1) increase system capacity by expanding the role of general aviation in the national airspace system through higher utilization of the airspace and the large network of general aviation public-use airports; and 2) revitalize the general aviation industry through the development and application of new technology to improve the safety and expand the utility and use of U.S.-produced general aviation aircraft domestically and internationally. The strategy will address the key opportunities and principle inhibitors to a revitalization of general aviation and a significantly expanded use of general aviation aircraft (commuter, corporate, business, personal) in the National Aviation System and establish a plan of action for technology development and application to achieve these goals.

The NASA Administrator's Aeronautics Policy Address of December 9, 1992, expressed a vision of a future National Aviation System with greatly increased capacity, utility and safety. This vision includes a significant role for general aviation, from turbofan-powered corporate aircraft to piston single-engine business and personal aircraft. In general, the major elements of the vision are:

- ◆ improved safety
- ◆ environmentally acceptable aircraft (noise and emissions),
- ◆ enhanced cockpit displays of flight, navigation, weather, and traffic information
- ◆ advanced flight and propulsion controls,
- ◆ high efficiency propulsion and aerodynamics,
- ◆ lower initial and operating costs.

A point-of-departure briefing document will be provided to the Task Force summarizing the information which supported the general aviation content in the NASA Administrator's December, 1992 U.S. Aeronautics Strategy Address.

The Task Force's report to the Aeronautics Advisory Committee should address four elements:

1. The definition of the air transportation system enhancements necessary in the 1995 to 2005 time frame that will enable the expanded general aviation transportation system. The enabling technologies necessary for the success of this general aviation transportation system. The impact of expanded use of general aviation aircraft on the vitality of the U.S. aeronautics industry, the overall National Aviation System, and the nation's economy.

2. Recommendations for a NASA/FAA/industry/university action plan for technology development, transfer, certification, and application to create a new generation of safe, economical, and environmentally compatible aircraft. Existing NASA research efforts which can be adapted to the general aviation transportation system. NASA/FAA/industry/university cooperative activities required to develop new technology and to transfer existing NASA technology to industry. Government/industry cooperative processes to speed the transfer of new technologies to enable improvements in utility, safety, affordability, and environmental compatibility of future general aviation aircraft.
3. The specific roles for U.S. universities in general aviation technology development and transfer.
4. The critical ground and flight facilities requirements to meet general aviation industry needs in the future.

The Task Force report to the Aeronautics Advisory Committee is due in September, 1993.

APPENDIX B—ALTERNATIVE JOINT-VENTURE MECHANISMS

GRANTS

A grant consists of a noncompetitive government award to an organization to support or stimulate activity in a field of research, and very little involvement is anticipated between the government and the recipient of the grant during the performance of the activity. In general, the intent is to advance the state of knowledge or investigate new concepts or innovations. A primary purpose of most grants is to provide a source of funding and support over a period of time so that research continuity and excellence can be achieved and maintained. The specific activities to be performed are not defined in detail, and goods and services are not provided to the government. Reporting requirements are minimal, and as a result, inventions and intellectual property created during the performance of the grant are not provided to the government and remain the property of the grant performer.

CONTRACTS

Contracts typically specify very clearly the conditions under which the work is to be performed, what is to be investigated, the property or services to be provided and the schedule for delivery, and the nature and details of the compensation. If changes become necessary, the contract must be amended through a formal amendment to the contract. The contract reporting requirements are also specified in detail.

SPACE ACT AGREEMENTS

Space Act Agreements are specifically authorized for NASA by the Space Act of 1958 as amended, and are cooperative research and technology agreements between NASA Centers and other organizations (government, industry, and universities). Typically, NASA contributes researcher time, facilities, and equipment to the agreement. The incentive for a NASA Center to enter into such an agreement is that it leverages NASA funding through the resources of industry and it keeps NASA researchers in touch with a company's interests. For companies party to a Space Act Agreement, they receive access to NASA Center research and facilities and may obtain some rights to any findings which develop from the agreement.

The Space Act authorizes the use of government funds to support Space Act Agreements "as appropriate." However, this provision has not been implemented although a pilot program to fund Space Act Agreements has been initiated. The Space Act also provides for reimbursement of government expenses by the cooperative agreement partner, as appropriate.

As a result of the amendment to the NASA Space Act of 1958 enacted by the Fiscal Year 1993 NASA Authorization Act, NASA has statutory authority to protect trade secret or commercial or financial information obtained from a non-Federal party to a Space Act Agreement from disclosure for a period of up to five years. This is a significant provision that makes Space Act Agreements particularly attractive from an industry point-of-view. It allows the proprietary interests of a company to be protected and

provides the company with a competitive advantage in applying information developed through the agreement to a commercial product.

Space Act Agreements are applicable to both early and later technology development and both component and system technology. Since data developed during the activity can be protected, we believe that the potential for the transfer of technology is high. In addition, since Space Act Agreements can be both funded and offer protection for proprietary data, they provide a unique opportunity to establish cooperative NASA-Industry activities tailored to expedite the transfer of technology into commercial products.

COOPERATIVE RESEARCH AND DEVELOPMENT AGREEMENTS (CRADAS)

CRADAs are similar to Space Act Agreements in nature and intent but authorize and encourage all federal laboratories to enter into cooperative research and development agreements with outside organizations. CRADAs permit the government to provide personnel, services, facilities use, and equipment to support the agreement but do not permit government funding to be provided to non-government partners.

Since the primary objective of the act that authorized the establishment of CRADAs was to provide a process to help transition government laboratory technology into industry and into commercialization, significant provisions were made to encourage this process to take place. Specifically, laboratory directors can make advance agreements on the licensing of inventions created under CRADAs. In addition, innovations brought into and created through CRADAs (by both government and non-government parties) can be protected from disclosure for up to five years.

CRADAs have application to both the early and late stages of technology development and can be used for both component and systems technology. Since CRADAs provide for the protection of information and the government is actively involved in the activity, we believe that the probability of technology transfer is high. Unfortunately, the inability of the government to provide funds is a factor that limits the use of CRADAs to very select areas of technology very near to product commercialization. CRADAs do not encourage cooperative research arrangements in areas of complex technologies where the required investments and technical risk are high.

CONSORTIA

Research and development consortia represent a new organizational form for U.S. managers (Evan and Olk, 1990). Encouraged by the National Cooperative Research Act of 1984, these arrangements are horizontal collaborations addressing precompetitive research. As such, they are primarily focused on the early stages of technology development, mostly used for the applied and technology development stages.

Depending on the scope of the research, a consortium is effective for working on component technology as well as system technology. For example, the United States Automobile Battery Consortium is focusing on developing a new battery, not the entire car. The Software Productivity Consortium seeks

to improve the general system of software development for defense contractors, not write a particular program.

Finally, the probability of technology transfer is high but will vary by the consortium's structure. Some consortia are designed as stand-alone entities with minimal contact with company representatives. For these, technology transfer will be low. Other consortia are much more interactive with member companies (research is conducted in both the consortium and in member companies, and researchers are exchanged quite frequently) and should have greater technology transfer.

The functioning of a consortium, and the government's role and participation either in or with a consortium, is dictated by whether or not the government provides funding to the consortium and if so, the process by which government funding is provided. Options range from no government funding, government funding through a grant, government funding through a cooperative agreement, and government funding through a contract. Each of these options is discussed very briefly and examples of existing consortia are presented.

A. CONSORTIUM—NO GOVERNMENT FUNDING

With no government funding, a consortium is independent of the government. The consortium members determine their goals, objectives, and procedures, and all information is the property of the consortium. The government can participate as a member of the consortium but has no management control or oversight. Examples of consortia of this type are the Microelectronics and Computer Technology Corporation (MCC) and the Software Productivity Consortium (SPC).

B. CONSORTIUM—FUNDING THROUGH GRANTS

Since the purpose of a grant is to provide funding to accomplish a public purpose of support or stimulation and not to acquire goods or services, a government grant to a consortium is provided for the same reason. Very little direction and guidance are provided, and government involvement and participation are minimal. Information generated by the consortium does not have to be provided to the government. Once the government has provided the grant, the consortium is responsible for the activity. The consortium can use the grant funds to support contract activity or can enter into CRADAs with government laboratories. Data generated through these CRADAs then have the same statutory protection as a standard CRADA. Examples of consortia of this type are the National Center for Manufacturing Sciences and the Semiconductor Manufacturing Technology Consortium.

C. CONSORTIUM—FUNDING THROUGH COOPERATIVE AGREEMENTS

This option is similar to that of a grant to a consortium since the funding is provided to accomplish a public purpose of support or stimulation and not to acquire goods and services. The primary difference is that significant government involvement and participation is expected with a Space Act Agreement. In this case, the government is an active participant in the consortium activity. If a Space Act Agreement is used as the basis for NASA involvement with a consortium, then the data developed by the consortium can be withheld from disclosure for up to five years. An example of this type of

consortium is the United States Automobile Battery Consortium, which is funded through a cooperative agreement with the DOE.

D. CONSORTIUM—FUNDING THROUGH CONTRACTS

Government contract funding of a consortium involves a competitive procurement process where the purpose is to fund the consortium to provide a specific product or service to the government. In this case, the relationship is one of buyer and seller and normal procurement regulations apply. The relationship is not a true partnership since the consortium must perform as required in the contract and has little ability to change as the situation changes. Information generated during the contract is in the public domain and can be protected only as specified in “data rights” clauses specified in the contract. Examples of this type of arrangement are the National Aero-Space Plane Program (NASP) and the NASA Guide program.

STRATEGIC PARTNERSHIPS

Recently advocated by the DOC Office of Technology Policy, Strategic Partnerships consist of a team of vertically integrated, non-competing firms seeking to develop and commercialize large-scale, enabling technologies (e.g., advance composites, microelectronics). The firms in a Strategic Partnership would include firms from the various phases of technology development—suppliers, producers, and end-users. Because Strategic Partnerships consist of vertically integrated companies from all phases of the technology development process, they partially emulate the Keiretsu form found in Japan (Gerlach, 1987).

They differ in principle from consortia in the following ways. First, Strategic Partnerships are vertically integrated, non-competing companies, whereas consortia are horizontally integrated, competing companies. Second, Strategic Partnerships are best suited for large-scale technologies which have potential application in multiple products and multiple industries. Consortia are typically focused on specific technologies aimed at one product and one industry. Functionally a Strategic Partnership is very similar to a consortium. The government role in participating and funding a Strategic Partnership is analogous to any consortium. That is, they can provide grants, contracts, enter into cooperative agreements and provide other resources, expertise, or facilities.

As defined by the DOC, the primary function of a Strategic Partnership is to carry enabling technologies from the basic research phase through the product commercialization phase. The advantage is that all phases of the technology development process are addressed simultaneously, and upon program completion the results can be immediately applied in multiple products and industries. The Strategic Partnership is an effective mechanism for managing a system technology. Bringing together vertically related companies permits the application of concurrent engineering in which decisions about materials and product design are made in conjunction with marketing issues. This structure permits all parties to coordinate their research activities. Finally, because companies are working together on the research at the same time, there is a high probability of transferring technology among the organizations.

The role of the DOC is to serve as a catalyst in the formation of Strategic Partnerships; it does not fund any research. However, there are no provisions against the government functioning in a different role. Because there are only a very limited number of Strategic Partnerships—all in their infancy—the role of the government is not yet well established.

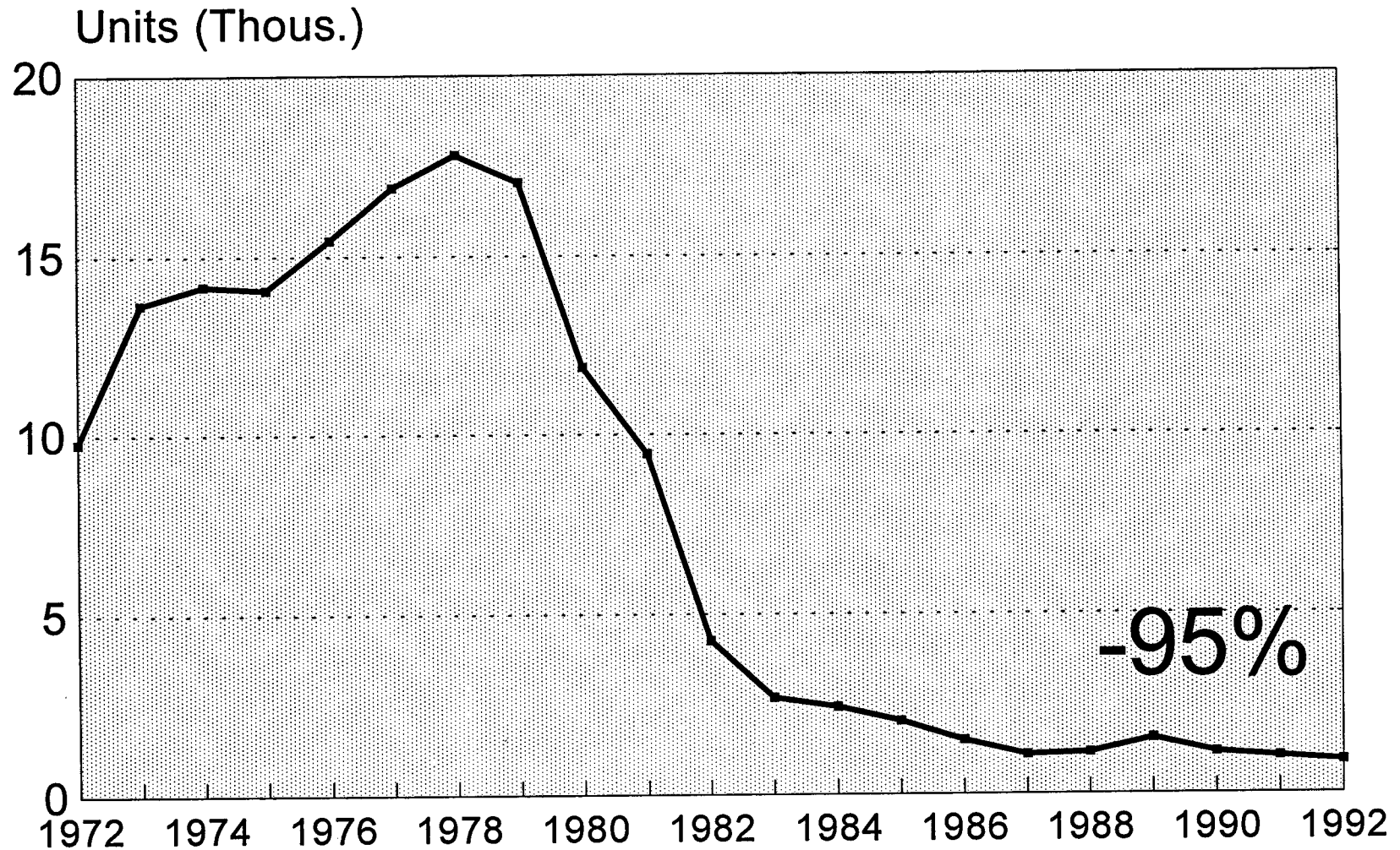
APPENDIX C—CHARTS

EXAMPLES OF NASA TECHNOLOGY UTILIZED IN PRODUCTS

American General Trainer	Enhanced Safety Through Spin Research
Beech Bonanza	Enhanced Safety Through Spin Research
Piper Malibu	Computer Aided Design And Manufacturing
Mooney	Cooling Drag Improvements
Cessna Caravan	Occupant Protection From Crash Dynamic Research, Fatigue Research
Cessna Citation Jet	Wing/Fuselage Interface, Drag Reduction
Cessna Citation II	Whitcomb Wing
Cessna Citation X	Advanced Wing
Beech Starship	Advance Aircraft Configuration And Composites
Learjet 60	Advanced Configuration Design, Fuselage Shape, Aft Body Strakes
Learjet 35	Leading Edge For Safety
Gulfstream	Winglets, Advanced Metals, Composites, Advanced Wing
Garrett	731-5 Engine Fan Blade Design

AIRPLANE SHIPMENTS DOWN 95% SINCE 1978

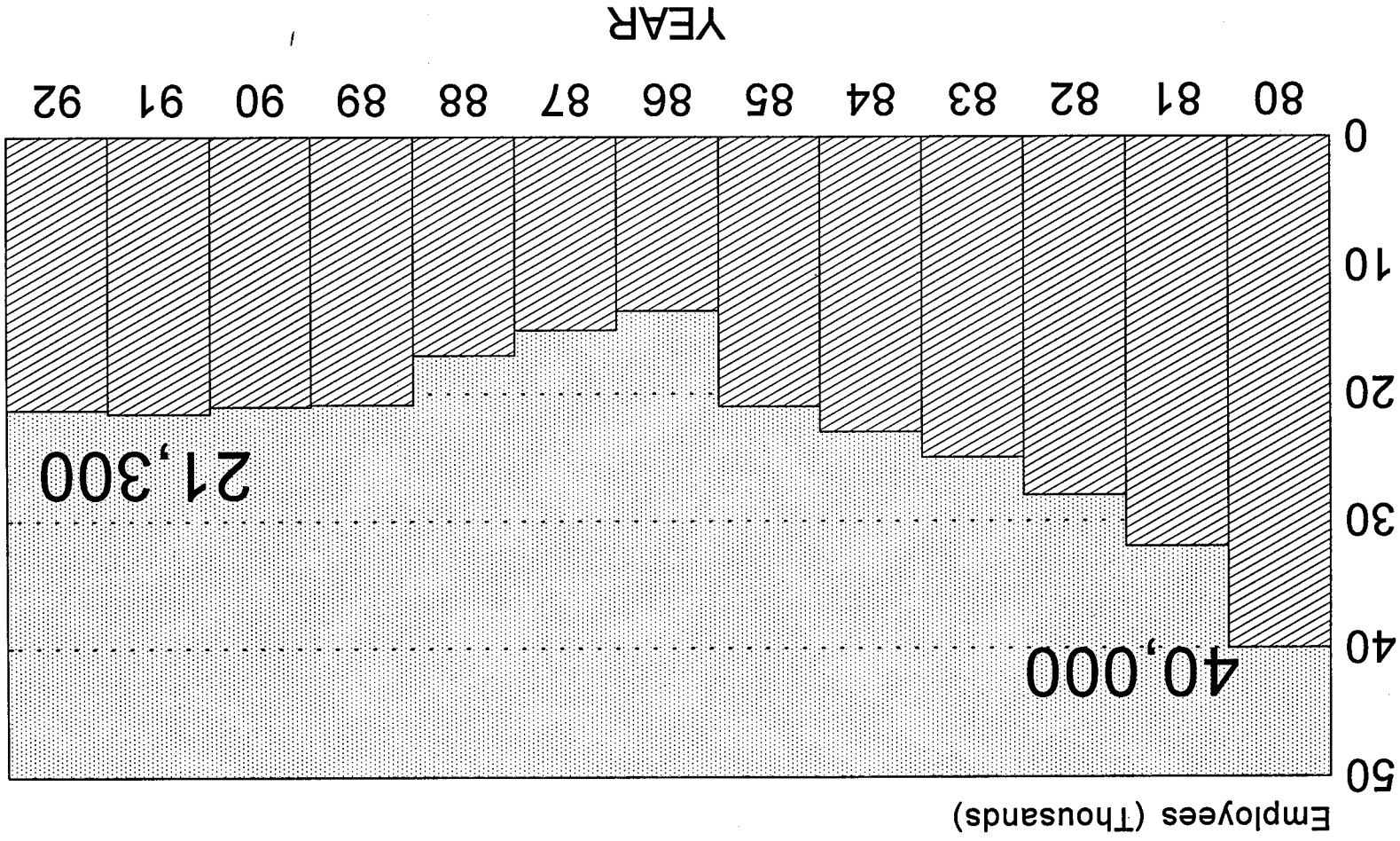
U.S. FACTORY SHIPMENTS OF GENERAL AVIATION AIRPLANES



Source: GAMA

Chart 2

U.S. AIRPLANE MANUFACTURING EMPLOYMENT DOWN 46 PERCENT



General Aviation Only

Chart 3

PISTON AIRPLANE PRODUCTION HAS MOVED OUT OF THE U.S.

Number of Piston Airplane Manufacturers - Foreign and Domestic

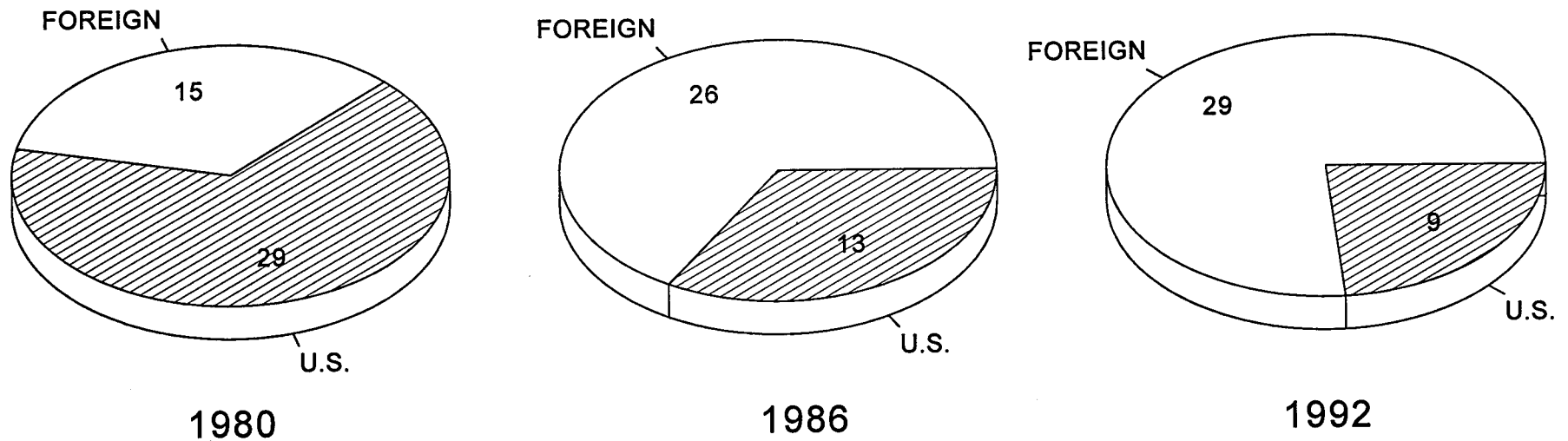
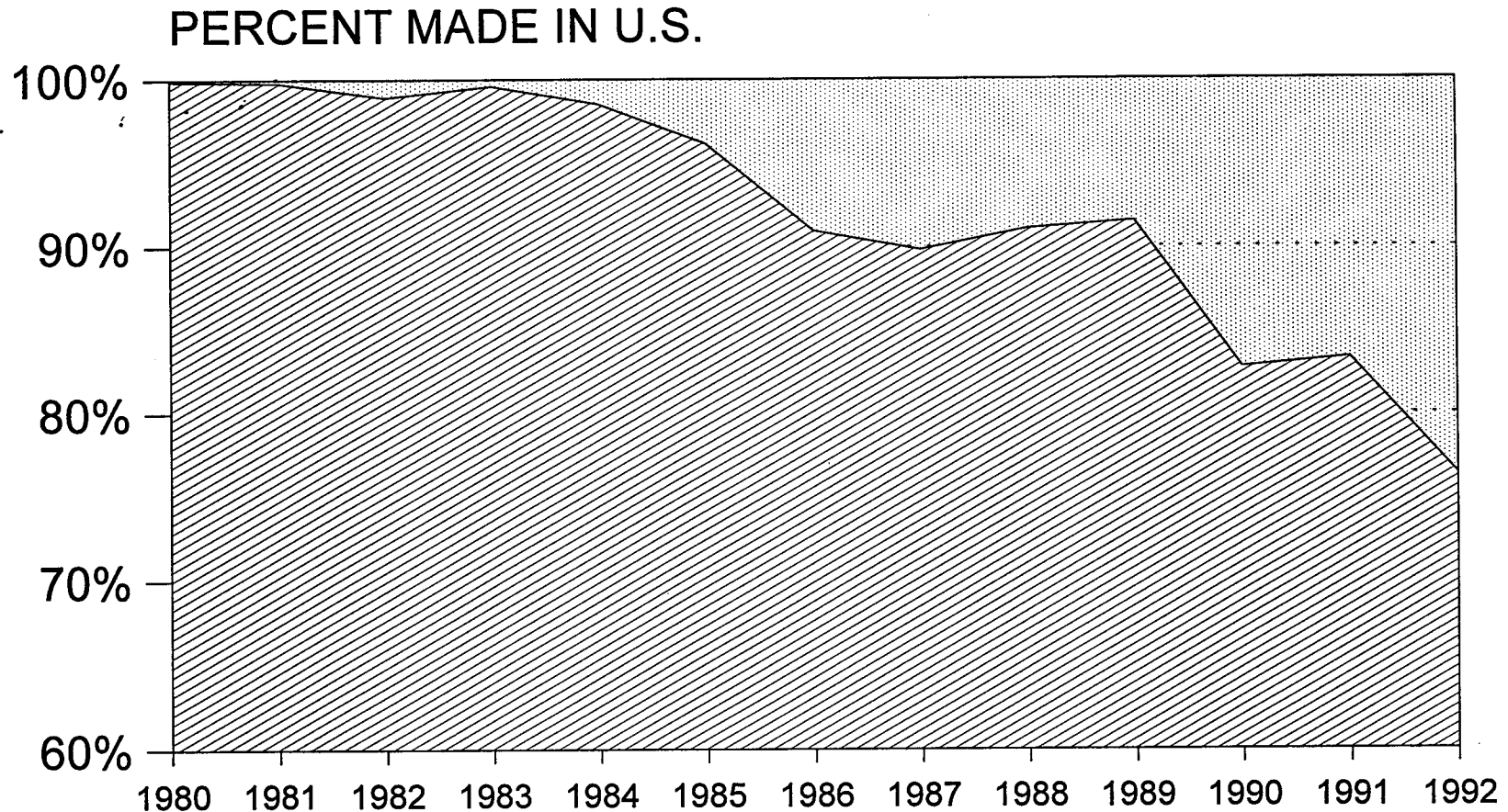


Chart 4

U.S. MARKET SHARE ERODING

SINGLE-ENGINE PISTON AIRPLANES SHIPPED TO THE U.S.

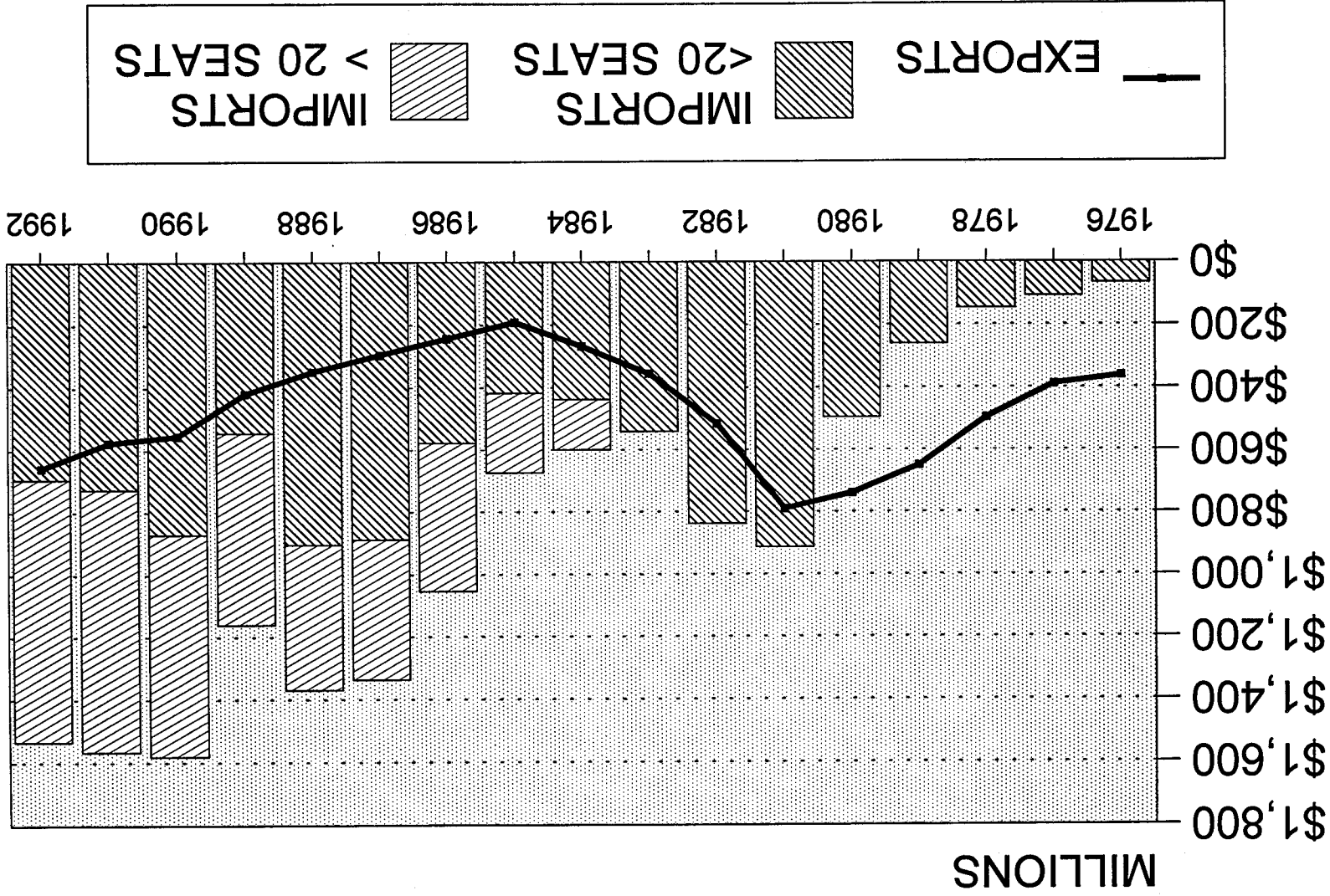


Source: GAMA & U.S. Dept. of Commerce
(1992 Estimated)

Chart 5

U.S. TRADE IN GENERAL AVIATION AIRPLANES

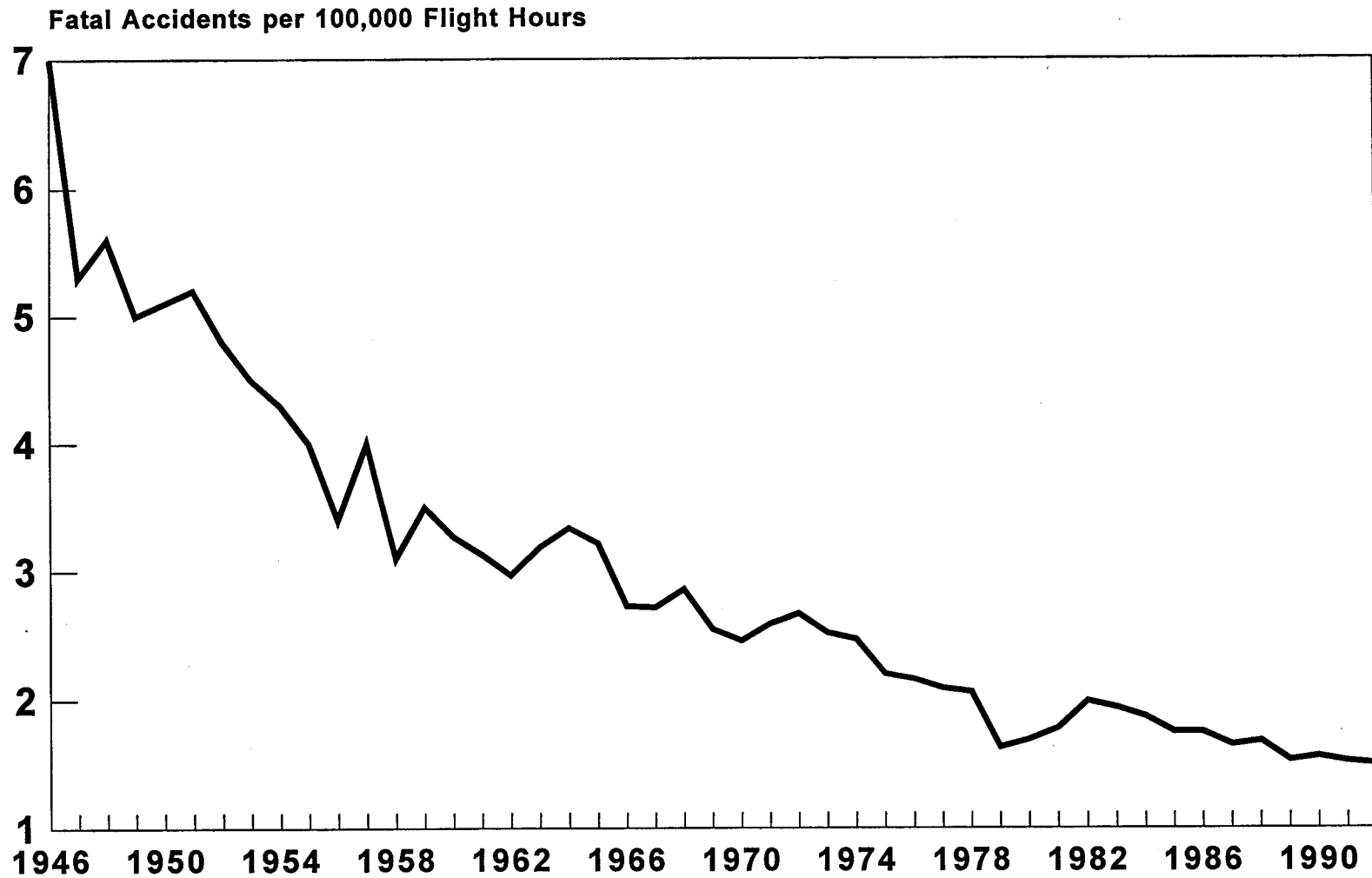
New, Civil Airplanes Under 33,000 lbs.



Source: U.S. Dept. of Commerce; GAMA

Chart 6

GEN'L AVIATION'S IMPROVING SAFETY RECORD 1946 - 1992



Source: NTSB

Chart 7

