

Originally Processed With FOIA(s):  
2005-0336-F

FOIA Number:  
2005-0336-F

# FOIA MARKER

**This is not a textual record. This is used as an  
administrative marker by the George Bush Presidential  
Library Staff.**

---

**Record Group/Collection:** George H.W. Bush Presidential Records  
**Collection/Office of Origin:** Science and Technology Policy, Office of (OSTP)  
**Series:** O'Neil, John F., Files  
**Subseries:** Government Organization Files

---

**OA/ID Number:** 62097  
**Folder ID Number:** 62097-008

---

**Folder Title:**  
NASA – Aeronautics Policy [1 of 4]

---

**Stack:**

**Row:**

**Section:**

**Shelf:**

**Position:**

**0**

**0**

**0**

**0**

---

"Document Control"

TYPE: INFORMATION

ORIGINATOR: 02

STATUS C

DOCUMENT NUMBER: 9200425

DIRECTORATE STATUS

\*\*\*\*\*

FROM: REIS, Victor H.: DEPARTMENT OF DEFENSE

TO: DR. D.A. BROMLEY

FEB 12 1992

DATE OF  
CORRESPONDENCE: 01/29/92

SUBJECT: A LETTER EXPRESSING HIS OPINION THAT THERE IS NO  
NEED FOR AN AERONAUTICAL R&D POLICY REVIEW AT THIS  
TIME.

\*\*\*\*\*  
DIRECTORATE STAFF  
ASSIGNED: ASSIGNED:

ACTION STAFF  
REQUIRED: ACTION:

\*\*\*\*\*  
SENDER'S DUE DATE:

OSTP DUE DATE: STAFF DUE DATE  
DATE COMPLETED: DATE COMPLETED/DEPT:

\*\*\*\*\*

COPIES TO: D. Allan Bromley  
PHYSICAL SCIENCES  
E. Wang & Rick Yung  
→ Doug Beason  
M Van Cleave

\*\*\*\*\*

WHITE HOUSE TRACKING #: CONTACT PERSON:  
REMARKS: PHONE: EXT:

OSTP RECEIVED: 02/06/92  
FILE: P-PHYSICAL SCIENCES

DEPT RECEIVED:

CENTRAL FILES:





DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

WASHINGTON, DC 20301-3010

RECEIVED

92 FEB 6 AM 11:51

20 JAN 1992

Honorable D. Allan Bromley  
Assistant to the President for  
Science and Technology  
Executive Office of the President  
Washington, DC 20506

MAIL ROOM

Dear Dr. Bromley: *Allan*

I've reviewed your proposed objectives for a reconstituted Aeronautical Policy Review Committee. The formulated questions are good, but I do not believe a policy review is necessary at this time. From a DoD Research and Engineering view, aeronautical policy is under control.

Many of the questions you posed are largely economic in nature and/or not at all unique to aeronautics (i.e., coordinating public and private investment in R&D, implications of foreign investment, ensuring the defense industrial base, vulnerability to supply disruptions). An aeronautical R&D policy review at this time would be unlikely to result in better guidance than is currently available for these questions.

Although there have been many changes since 1987, the previous output of the Committee provides sufficient research strategy guidance for the present.

Sincerely,

*Vic*  
Victor H. Reis

*Morny, am*

NATIONAL RESEARCH COUNCIL

COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS

2101 Constitution Avenue Washington, D.C. 20418

AERONAUTICS AND SPACE  
ENGINEERING BOARD

July 10, 1991  
202/334-3275

Mr. Rick Yannuzzi  
Executive Office of the President  
Office of Science and Technology Policy  
Room 572  
Old Executive Office Building  
Washington, D.C. 20506

Dear Rick:

Following up on our telephone conversation, enclosed is a copy of the Statement of Task for the NRC Aeronautical Technology study, along with a copy of the membership of the Steering Committee and the various technical panels. The study committee has been in an information gathering mode for nearly a year now, including broad looks at all transportation systems for a 20-30 year time frame, an outreach effort for innovative ideas in aeronautical technology, and consideration of various vehicle systems and the technologies that can lead to improvements in those systems. The committee has examined infrastructure constraints and non-technical issues, such as those posed by foreign competition, as well.

We very much appreciate your offer to talk with Bill Phillips about briefing the Steering Committee at its next meeting on July 24-25. We'll provide the members with a copy of the relevant sections of the Report of the National Critical Technologies Panel in advance, and will appreciate learning more about that study and as well as any insight into current activities on this issue.

The meeting will be held July 24-25 in Green Building Room 118 of the NRC Georgetown Facility at 2001 Wisconsin Avenue, N.W. (between the Georgetown Safeway and the Holiday Inn). I will send a preliminary agenda soon.

Thanks for your help.

Sincerely,

  
JoAnn Clayton  
Director

Attachments  
c: E. Covert  
R. Bradley



# **AERONAUTICS AND SPACE ENGINEERING BOARD AERONAUTICAL TECHNOLOGIES STUDY**

## **Statement of Task**

The National Aeronautics and Space Administration/Office of Aeronautics, Exploration and Technology has requested assistance from the NRC Aeronautics and Space Engineering Board in identifying and assessing the status of technologies critical to the maintenance of a strong national aeronautical sector and in assessing how well NASA's aeronautics program is meeting the identified long-term needs. Initially, a small committee will be constituted as a steering committee to outline the course of the study and undertake preliminary investigations into the likely future air transportation systems. Subsequently, panels in the various technical disciplines will be called on for in-depth technical expertise. During the course of the study, the committee and panels will:

1. Consider what the national and worldwide air transportation picture is likely to be 20-30 years hence taking into account the total infrastructure-airports, operations, etc. What mixes of aircraft does one foresee to meet the expected demand for air transportation? What are economic and environmental limitations of these classes of aircraft?
2. Identify the "high leverage" technologies required in order to give U.S. industry and the Department of Defense options for future classes of aircraft noted in item #1 above. Particular attention will be paid to the environmental issues such as the effect of engine emissions on atmospheric ozone and global warming.
3. Examine the current and planned NASA aeronautics program in detail to (1) determine how well it matches the technology requirements identified in the course of the study, and (2) evaluate its likely effectiveness in progressing toward advances that are believed achievable in the next 10 to 20 years.
4. In consonance with NASA's aeronautics mission as stated in the National Aeronautics and Space Act of 1958, address the appropriate role of government in developing these technologies.

A report of findings should be prepared and submitted for National Research Council review by (or before) December of 1991. The steering committee will assume responsibility for integrating the component parts of the report. The final report will be delivered to the NASA Associate Administrator as soon as possible after that date.

TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council  
**COMMITTEE ON AERONAUTICAL TECHNOLOGIES**  
Steering Committee

Dr. Eugene E. Covert, **Chairman**  
Professor, Department of Aeronautics and  
Astronautics  
Room 33-215  
Massachusetts Institute of Technology  
77 Massachusetts Ave.  
Cambridge, MA 02139  
TEL: 617/253-2604  
FAX: 617/253-0051

Dr. Richard G. Bradley, **Vice Chairman**  
Director, Aerospace Technology  
General Dynamics  
Ft. Worth Division/MZ 2888  
P.O. Box 748  
Ft. Worth, TX 76101  
TEL: 817/763-1609  
FAX: 817/777-2115

Mr. Max E. Bleck  
President of the Raytheon Company  
141 Spring Street  
Lexington, MA 02173  
TEL: (617) 860-2207  
FAX: (617) 860-2825

✓ Mr. Edward S. Carter, Jr.  
(Ret., Sikorsky)  
5210 Congress Street  
Fairfield, CT 06430  
TEL: 203/259-9935

✓ Mr. Wolfgang H. Demisch  
Director of Research  
UBS Securities  
299 Park Avenue  
New York, NY 10171  
TEL: 212/230-4292  
FAX: 212/308-4264

Dr. Alexander H. Flax  
Home Secretary  
National Academy of Engineering  
2101 Constitution Ave., NW  
Washington, D.C. 20418  
TEL: 202/334-2438

✓ Mr. Kenneth I. Grina  
(Ret., Boeing Helicopters)  
701 Pine Ridge Road  
Media, PA 19063  
TEL: 215/566-5295

Dr. Robert H. Korkegi  
(Ret., USAF Res. Lab., NRC)  
4418 Springdale Street, NW  
Washington, D.C. 20016  
TEL: 202/686-6918

Mr. Duane T. McRuer  
President and Technical Director  
Systems Technology, Inc.  
13766 South Hawthorne Blvd.  
Hawthorne, CA 90250-7083  
TEL: 213/679-2281

Mr. Garner W. Miller  
(Ret., USAir)  
4901 Gulf Shore Boulevard North  
Meridian 1502  
Naples, FL 33940  
TEL: 813/262-6410

Dr. Mario J. Molina  
Chemistry/Earth & Planetary Sciences  
Massachusetts Institute of Technology  
Bldg. 54, Room 1720  
Cambridge, MA 02139  
TEL: 617/253-5081

✓ Mr. Harvey O. Nay  
Vice President of Engineering  
Piper Aircraft Corporation  
2926 Piper Drive  
Vero Beach, FL 32960  
TEL: 407/567-4361, EXT. 2401

Mr. Robert B. Ormsby, Jr.  
(Ret., Lockheed)  
23961 Wildwood Canyon Road  
Newhall, CA 91321  
TEL: 805/253-1222  
FAX: 805/253-1224



Mr. Hershel Sams  
4342 Holland Drive  
St. Petersburg Beach, FL 33706  
TEL: 813/367-1418

Dr. John D. Warner  
Vice President, Engineering  
Boeing Commercial Airplane Group  
P.O. Box 3707, MS 7Y-73  
Seattle, WA 98124-2207  
TEL: 206/234-9661

Mr. Albertus D. Welliver (Ex Officio)  
Corporate Senior Vice President,  
Engineering and Technology  
The Boeing Company  
P.O. Box 3707, MS 13-35  
Seattle, WA 98124  
206/655-4488  
FAX: 206/655-5981

**Aeronautics and Space Engineering Board Staff:**

Ms. JoAnn C. Clayton  
Director

Dr. Vicki S. Johnson  
Senior Staff Officer

Ms. Ann Farrar  
Administrative Coordinator

Ms. Christina Weinland  
Administrative Secretary

Ms. Susan Coppinger  
Senior Secretary

**Mailing Address:**

Committee on Aeronautical Technologies  
ASEB/HA 292  
2101 Constitution Ave., NW  
Washington, D.C. 20418

TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES**  
**PANEL ON GENERAL SYSTEMS**

Mr. Hershel Sams, **Chairman**  
(Ret., McDonnell Douglas Corporation)  
4342 Holland Drive  
St. Petersburg Beach, FL 33706  
TEL: (813) 367-1418

Mr. William C. Dietz  
Vice President and Program Director,  
Special Products  
General Dynamics Corporation  
Mail Zone 2499  
P.O. Box 748  
Fort Worth, TX 76101  
TEL: (817) 763-3010  
FAX: (817) 777-2115

Mr. Charles W. Ellis  
(Ret., Boeing Helicopters)  
319 Echo Valley Lane  
Newtown Square, PA 19073  
TEL: (215) 356-9126

Dr. Alexander H. Flax  
Home Secretary  
National Academy of Engineering  
2101 Constitution Ave., NW  
Washington, D.C. 20418  
TEL: (202) 334-2438  
FAX: (202) 334-1597

Mr. R. Richard Heppe  
Consultant, Lockheed Aeronautical  
Systems Company and the Lockheed  
Corporation  
1341 Fairlawn Way  
Pasadena, CA 91105  
TEL: (818) 792-0183

Mr. Albertus D. Welliver  
Corporate Senior Vice President,  
Engineering and Technology  
The Boeing Company  
P.O. Box 3707, MS 13-35  
Seattle, WA 98124  
TEL: (206) 655-4488  
FAX: (206) 655-5981

**Technical Advisor:**

Mr. Theodore G. Ayers  
Deputy Director  
NASA Dryden Flight Research Center  
Facility of the Ames Research Center  
P.O. Box 273  
Edwards, CA 93523-5000  
TEL: (805) 258-3103  
FAX: (805) 258-3567



> Maj Song Beason <

• 30 min discussion on the issue

TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES**  
**PANEL ON OPERATIONAL AND ENVIRONMENTAL ISSUES**

Dr. Wesley L. Harris, **Chairman**  
Vice President  
University of Tennessee Space Institute  
Tullahoma, TN 37388  
TEL: (615) 455-0631 ext. 213  
FAX: (615) 454-2354

Mr. Max E. Bleck  
President  
Raytheon Company  
141 Spring Street  
Lexington, MA 02173  
TEL: (617) 860-2207  
FAX: (617) 860-2825

Mr. Wolfgang H. Demisch  
Director of Research  
UBS Securities  
299 Park Avenue  
New York, New York 10171  
TEL: (212) 230-4292  
FAX: (212) 308-4264

Mr. Garner W. Miller  
(Ret., U.S. Air)  
4901 Gulf Shore Blvd. North  
Meridian 1502  
Naples, FL 33940  
TEL: (813) 262-6410

Dr. Mario J. Molina  
Massachusetts Institute of Technology  
Chemistry/Earth & Planetary Sciences  
Cambridge, MA 02139  
TEL: (617) 253-5081  
FAX: (617) 253-0354

**Technical Advisors:**

Dr. Jeremiah F. Creedon  
Director for Flight Systems  
NASA-Langley Research Center  
M/S 113  
Hampton, VA 23665-5225  
TEL: (804) 864-6033  
FAX: (804) 864-6117

Dr. Robert E. Machol  
Chief Scientist  
Federal Aviation Administration  
ASD-4  
800 Independence Ave., SW  
Washington, D.C. 20591  
TEL: (202) 267-9451  
FAX: (202) 267-5117



TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES  
PANEL ON INFORMATION SCIENCES AND HUMAN FACTORS**

Mr. Duane T. McRuer, **Chairman**  
President and Technical Director  
Systems Technology, Inc.  
13766 South Hawthorne Blvd.  
Hawthorne, CA 90250-7083  
TEL: (213) 679-2281  
FAX: (213) 644-3887

Dr. Renwick Curry, President  
Tycho Systems, Inc.  
2661 Riggs Drive  
Atlanta, GA 30344  
TEL: (404) 763-2928 or (404) 631-3032  
FAX: (404) 768-6961

Dr. John Lauber  
Member, National Transportation Safety  
Board  
800 Independence Avenue, S.W.  
Washington, D.C. 20594  
TEL: (202) 382-6504

Dr. Herman Rediess  
Manager, Aerospace Engineering &  
Systems Operation  
Sparta, Inc.  
23041 Carlota, Suite 400  
Laguna Hills, CA 92653  
TEL: (714) 768-8161  
FAX: (714) 583-9114

**Technical Advisor:**

Mr. Tom Snyder  
Director, Aerospace Systems  
NASA-Ames Research Center  
M/S DD 200-3  
Moffett Field, CA 94035  
TEL: (415) 604-5066  
FAX: (415) 604-3786

Dr. Jeremiah Creedon  
(see Panel on Operational  
and Environmental Issues)

TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES**  
**PANEL ON AVIONICS AND CONTROL**

Dr. John D. Warner, Chairman  
Vice President, Engineering  
Boeing Commercial Airplane Company  
P.O. Box 3707, MS 6R-UJ  
Seattle, WA 98124-2207  
TEL: (206) 234-9661  
FAX: (206) 234-9941

Ms. Susan Garing  
Senior Engineer, Air Vehicle  
Software  
CAE-Link Corporation  
Link Flight Simulation Division  
M/S 622  
P.O. Box 1237  
Binghamton, NY 13902-1237  
TEL: (607) 721-4273  
FAX: (607) 771-8477, 8478  
(Voice confirmation (607) 721-4946)

Mr. Joel Kuhlberg  
Manager, Engine Controls Engineering  
Pratt & Whitney  
M/S 162-28  
400 Main Street  
East Hartford, CT 06108  
TEL: (203) 565-5247  
FAX: (203) 565-1345

Mr. Stephen S. Osder  
Chief Scientist  
McDonnell Douglas Helicopter  
Building 530, M/S B345  
5000 E. McDowell Road  
Mesa, AZ 85205  
TEL: (602) 891-6573  
FAX: (602) 891-7671

**Technical Advisor:**

Mr. H. Milton Holt  
Chief, Information Systems Division  
NASA-Langley Research Center  
M/S 469  
Hampton, VA 23665-5225  
TEL: (804) 864-1596  
FAX: (804) 864-7891



TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES  
PANEL ON PROPULSION**

Dr. Frank E. Marble, **Chairman**  
Professor Emeritus  
California Institute of Technology  
Mail Station 205-45  
Pasadena, CA 91125  
TEL: (818) 356-4784  
FAX: (818) 449-2677

Dr. Alan Epstein  
Professor  
Department of Aeronautics and  
Astronautics  
Massachusetts Institute of Technology  
Room 31-266  
Cambridge, MA 02139  
TEL: (617) 253-2485  
FAX: (617) 258-6093

Mr. James N. Krebs  
(Ret., General Electric)  
234 West San Mateo  
Santa Fe, NM 87501  
TEL: (505) 988-3413

Dr. Franklin K. Moore  
Joseph C. Ford Professor of  
Mechanical Engineering  
Cornell University  
Upson Hall  
Ithaca, NY 14853  
TEL: (607) 255-4100  
FAX: (607) 254-4588

Dr. Maurice E. Shank  
Consultant  
2 Enatai Drive  
Bellevue, WA 98004  
TEL: (206) 462-0828

Dr. Montgomerie C. Steele  
Senior Chief Engineer  
Garrett Engine Division  
Building 503 - 3BA  
P.O. Box 5217  
Phoenix, AZ 85010  
TEL: (602) 231-2355  
FAX: (602) 231-7180

Dr. Eugene E. Covert (ex officio)  
Professor  
Department of Aeronautics and  
Astronautics  
Room 33-215  
Massachusetts Institute of Technology  
77 Massachusetts Avenue  
Cambridge, MA 02139-4307  
TEL: (617) 253-2604  
FAX: (617) 253-0051

**Technical Advisor:**

Mr. Neal T. Saunders  
Director of Aeronautics  
NASA-Lewis Research Center  
M/S 3-8  
Cleveland, OH 44135  
TEL: (216) 433-2965  
FAX: (216) 433-5266

TEL: (202) 334-2855  
FAX: (202) 334-2620

July 10, 1991

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES  
PANEL ON MATERIALS AND STRUCTURES**

Dr. Robert G. Loewy, Chairman  
Institute Professor  
Mechanical and Aerospace Sciences  
Rensselaer Polytechnic Institute  
JEC 4010  
Troy, NY 12101  
TEL: (518) 276-6594  
FAX: (518) 276-2623

Mr. Kenneth I. Grina  
(Ret., Boeing Helicopters)  
701 Pine Ridge Road  
Media, PA 19063  
TEL: (215) 566-5295

Dr. Paul A. Lagace  
Associate Professor  
Department of Aeronautics and  
Astronautics  
Massachusetts Institute of Technology  
Room 33-303  
Cambridge, MA 02139  
TEL: (617) 253-3628  
FAX: (617) 253-0361

Mr. Harry L. Lemasters  
Director, Engine Structures, Product  
Integrity,  
Performance and Controls Systems  
Pratt & Whitney  
400 Main Street  
MS/162-31  
East Hartford, CT 06108  
TEL: (203) 565-6799  
FAX: (203) 565-1345

Mr. Harvey O. Nay  
Vice President of Engineering  
Piper Aircraft Corporation  
2926 Piper Drive  
Vero Beach, FL 32960  
TEL: (407) 567-4361 ext 2401  
FAX: (407) 778-2144

**Technical Advisor:**

Mr. Charles P. Blankenship  
Director for Structures  
NASA-Langley Research Center  
M/S 118  
Hampton, VA 23665-5225  
TEL: (804) 864-6005  
FAX: (804) 864-8088



TEL: (202) 334-2855

FAX: (202) 334-2620

Aeronautics and Space Engineering Board  
Commission on Engineering and Technical Systems  
National Research Council

**COMMITTEE ON AERONAUTICAL TECHNOLOGIES**  
**PANEL ON AERODYNAMICS**

Mr. Robert B. Ormsby, Jr., **Chairman**  
(Ret., Lockheed)

23961 Wildwood Canyon Road  
Newhall, CA 91321

TEL: (805) 253-1222

FAX: (805) 253-1224

Mr. Edward S. Carter, Jr.  
(Ret., Sikorsky)

5210 Congress Street  
Fairfield, CT 06430

TEL: (203) 259-9935

Dr. Robert H. Korkegi  
(Ret., National Research Council)

4418 Springdale Street, NW  
Washington, DC 20016

TEL: (202) 686-6918

Dr. Helen L. Reed

Associate Professor  
Department of Mechanical & Aerospace  
Engineering

Arizona State University  
Tempe, AZ 85287-6106

TEL: (602) 965-2823

FAX: (602) 965-1384

Dr. Paul E. Rubbert

Unit Chief, Aerodynamics Research  
The Boeing Company  
M/S 7H-91

P.O. Box 3707

Seattle, WA 98124-2207

TEL: (206) 865-6304

FAX: (206) 865-2776

Dr. Richard G. Bradley (ex officio)

Director, Aerospace Technology  
General Dynamics

Ft. Worth Division/MZ 2888

P.O. Box 748

Ft. Worth, TX 76101

TEL: (817) 763-1609

FAX: (817) 777-2115

**Technical Advisor:**

Mr. Roy V. Harris, Jr.

Director for Aeronautics

NASA Langley Research Center  
M/S 116

Hampton, VA 23665-5225

TEL: (804) 864-6048

FAX: (804) 864-7895

Mr. Victor Peterson

Deputy Director

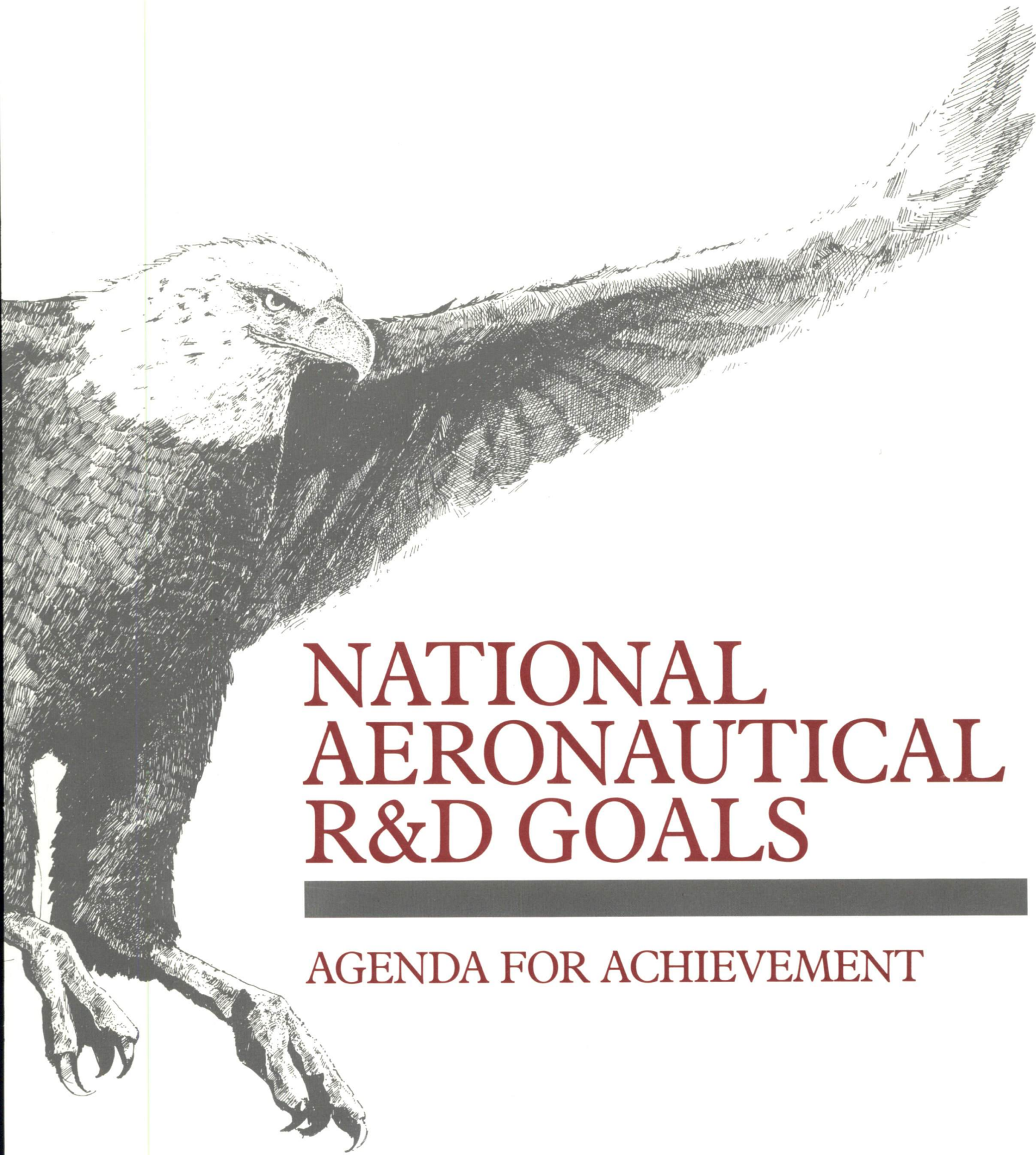
NASA-Ames Research Center

M/S DD 200-2

Moffett Field, CA 94035

TEL: (415) 604-5222

FAX: (415) 604-3786



# NATIONAL AERONAUTICAL R&D GOALS

---

## AGENDA FOR ACHIEVEMENT

Executive Office of the President  
Office of Science and Technology Policy



# ACTION PLAN SUMMARY

The Committee believes that now is the time for the United States to organize a long-term, aggressive, and positive thrust to remain competitive in the world aeronautics marketplace and secure in our national defense. The new era of global competition and the constrained United States fiscal environment pose a national challenge for sustained U.S. leadership. The agenda for achievement of the National Aeronautical R&D Goals will require concerted effort by the Federal Government, industry, and the nation's universities. Specific recommendations for action are:

- 1** Increase innovative industry R&D efforts given the certainty of intensifying global competition and the importance of new technology for U.S. competitiveness.
- 2** Aggressively pursue the National Aero-Space Plane program, assuring maturation of critical technologies leading to an experimental airplane.
- 3** Develop fundamental technology, design, and business foundation for a long-range, supersonic transport in preparation for a potential U.S. industry initiative.
- 4** Expand domestic research and development collaboration by creating an environment that reflects the new era of global competition.
- 5** Encourage government aeronautical research in long-term emerging technology areas which promise high payoffs.
- 6** Strengthen American universities for basic research and science education through enhanced government and aerospace industry support and cooperation.
- 7** Improve the development and integration of advanced design, processing, and computer-integrated manufacturing technologies to transform emerging R&D results into affordable U.S. products.
- 8** Enhance the safety and capacity of the National Airspace System through advanced automation and electronics technology and new vehicle concepts, including vertical and short takeoff and landing aircraft.



# FOREWORD

Almost two years ago, the Aeronautical Policy Review Committee—composed of sixteen leaders of government, industry, and universities—considered the evolving international scene in aeronautics and America's future in it. In their March 1985 report, "NATIONAL AERONAUTICAL R&D GOALS: TECHNOLOGY FOR AMERICA'S FUTURE," the Committee recommended that all sectors of American aeronautics direct their skills and energies toward the highest-payoff technology areas to sustain the nation's leadership position.

Toward that end, three specific goals—in subsonic, supersonic and transatmospheric flight regimes—were established. In the intervening time, these goals have been accepted by the American aviation community as the centerpiece of national aeronautics strategy, and have attracted global attention. Action on all three goals is in progress.

However, the Committee believes that the depth of foreign aeronautical resolve and the concerted national effort required to preserve American competitiveness are still largely underestimated. Sustained U.S. leadership will require greater achievement by all sectors—government, industry, and academia. Both the opportunity and challenge are unprecedented. Accordingly, the Committee believes that this challenge to our competitiveness is so important—not just to the nation's diverse aeronautics industry, but to the nation as a whole—that it now issues this call to action. This sequel presents a cohesive U.S. strategy and an eight-point action plan to achieve the National Goals and remain a viable competitor in the world aviation marketplace.



**William R. Graham**

Science Advisor to the President and  
Director, Office of Science and Technology Policy

February 1987

## CONTENTS

|                                                                              |           |
|------------------------------------------------------------------------------|-----------|
| <b>U.S. Aeronautics:<br/>A Changing<br/>Perspective</b>                      | <b>2</b>  |
| <b>National<br/>Aeronautical R&amp;D<br/>Goals: Framework<br/>For Action</b> | <b>4</b>  |
| Subsonics Goal                                                               | 4         |
| Supersonics Goal                                                             | 5         |
| Transatmospherics<br>Goal                                                    | 6         |
| <b>The Agenda For<br/>Achievement</b>                                        | <b>8</b>  |
| Action Plan                                                                  | 8         |
| <b>Conclusion</b>                                                            | <b>12</b> |

*"The depth of foreign  
aeronautical resolve and  
the concerted national  
effort required to  
preserve American  
competitiveness are still  
largely underestimated."*



# U.S. AERONAUTICS: A CHANGING PERSPECTIVE

## *The Challenge*

Innovation in science and technology has been the driving force for American growth and power since World War II. It has given us military strength, a high standard of living, and—until recently—a broad range of superior products which dominated world trade.

That picture has changed dramatically over the past decade. We are challenged by a new global economy with technologically equal, well-organized competitors actively backed by foreign governments. European and Pacific Rim nations recognize that science and technology hold the key to their future economic and military well-being, and they are expanding investments in upgrading their capabilities.

Instead of trade surpluses, the United States has huge trade deficits. Most Americans are awakening to the serious dangers in this decline, notably in steel, automobiles, and electronics. The trade deficit has meant slowed economic growth, business failures, and permanent loss of millions of jobs.

Even in high technology, the United States has steadily lost market share since 1980. In 1986, for the first time, high-technology imports exceeded exports. These losses can do enormous damage to our future competitiveness and national security. We must never again take our economic superiority for granted.

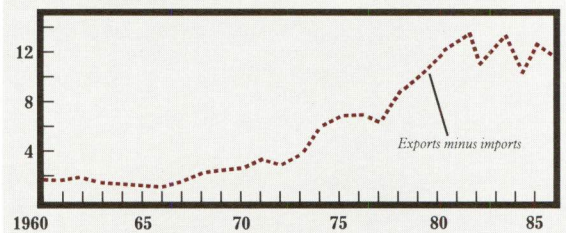
On balance, the United States is still the world leader in aviation. The aeronautics industry has long held a unique position in its contribution to trade and to national security, and as a symbol of U.S. technological power. Aircraft incorporate many advanced technologies and stimulate the development of high technology on a broad front.

Aerospace trade surplus of \$11.8 billion in 1986, the highest of all U.S. export sectors, contrasts to the trade deficit in manufactured goods of \$136 billion. Aircraft and parts comprise over 90 percent of this surplus. These export sales are vital to amortize huge R&D expenditures and to achieve economies of scale. Aerospace total shipments exceeded \$96 billion in 1986.

*"The aeronautics industry has long held a unique position in its contribution to trade and to national security, and as a symbol of U.S. technological power."*

## Aerospace Balance of Trade

Billions of Current Dollars



Source: U.S. Department of Commerce

But that industry today faces profound changes: formidable competition for international and domestic sales, challenges to military superiority requiring technically sophisticated yet more affordable weapons systems, and limitations of capital and skilled workers. The implications are unsettling.

Aeronautics has played a crucial role in national security for more than 40 years. With major R&D investments in advanced technology aircraft, aviation will continue to fulfill a major defense role. Though requirements for civil and military aircraft differ, much of the technology base, the production base which is centered in 15,000 company suppliers supporting the major aircraft manufacturers, and many of the skills and processes used are common. A weakening of the civil industry will ultimately result in more expensive military systems, and the reverse is true as well.

Significant sustained foreign competition exists in all three National Goal areas: subsonics, supersonics, and transatmospherics. In fact, other nations now dominate the world general-aviation and commuter-aircraft markets, account for nearly half the world sales of rotorcraft, and are achieving significant market penetration in the large commercial transport market. The R&D endeavor of the Soviet Union is the largest in the world, and aggressive Soviet aeronautical R&D constantly threatens the U.S. technological margin. Though America is today's world aviation leader, where will we be tomorrow?

## *The Opportunity For Leadership*

Bold new technological thrusts are essential to preserve U.S. aeronautical superiority in the world marketplace and enhance global security through the excellence of our military aircraft.

The National Goals for Aeronautical R&D outline numerous opportunities for dramatic advances in technology that could reshape aviation by the turn of the century. Achievement of these goals will lead to entirely new types of aircraft with vastly superior capabilities. Gains of this order will mean major benefits to our national economy and security, but only if we are the first to exploit them. These opportunities are an equally powerful driving force for foreign competitors.

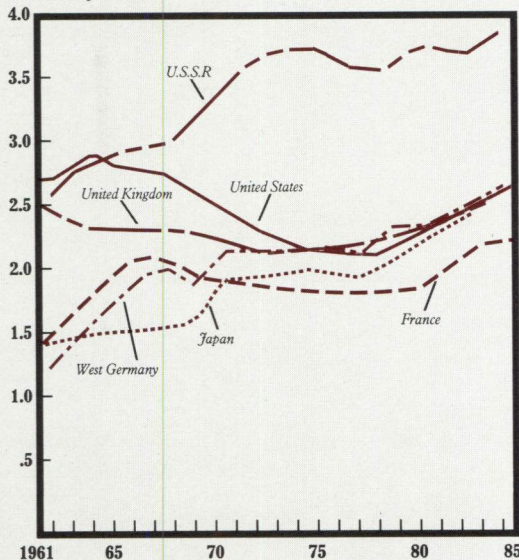
The constrained U.S. fiscal environment, a continuing and difficult problem, requires a cohesive national strategy and a new sense of collective responsibility for achieving the National Goals. This will challenge the resourcefulness and creativity of



the Federal Government, of industry, and of the nation's universities. With their effective cooperation, we must cut the cost of technological advancement and increase the speed at which new aeronautical technologies translate into products and processes. The changes may involve altering traditional approaches. But America holds the key for responding to the challenge: a genius for innovation and a solid foundation in research and development.

### National Expenditures for R&D

Percent of GNP



Source: National Science Foundation Science Indicators—1985

Most important, to preserve America's aeronautical leadership we must accord a higher national priority to research and development. R&D is the highest leverage for revitalization of American economic and strategic competitiveness. These R&D expenditures must be viewed as long-term investments in the nation's productive capacity, and should weigh heavily in government and boardroom decisions even when resources are tight. Underinvestment in R&D and facilities during the 1960's and 1970's has contributed heavily to the current loss of competitiveness in many other U.S. industries.

Greater attention must also be focused on the availability and quality of scientific and engineering manpower. Similarly, higher education must be strengthened. The universities are vital, for both new knowledge and trained minds. Disturbing signs, however, suggest that university research capacity is deteriorating.

Stronger cooperation between government and industry within a free market framework will strengthen American competitiveness. Working together, each must fulfil the role for which it is best suited.

Industry must recognize the certainty of intensifying global competition. It must continue to expand its R&D investment while establishing a more risk-taking approach to world leadership in the commercialization of product and process technology. A strong and healthy Independent Research and Development (IR&D) program, which is the source of much of the innovative work in the industry, is essential in expanding the nation's technology base and strengthening American leadership.

Government, for its part, can best support long-term, high-risk, high-payoff research. Rapid and effective transfer of this technology to the private sector is essential in capitalizing on these results for U.S. competitive advantage. Government must also create a policy environment which fosters U.S. competitiveness.

The National Aeronautics and Space Administration (NASA) is this country's focal point for aeronautical research and technology and national aeronautical facilities. NASA must strengthen its capabilities and take a more assertive leadership role in coordinating and facilitating long-term U.S. research efforts for maximum effectiveness. The health and productivity of our national facilities are fundamental to meeting the country's growing R&D requirements.

America has to compete in the international arena, but it also has to cooperate. To enjoy a high standard of living we need trading partners with healthy economies. The growing trend toward internationalization of aircraft manufacture will require learning how to work effectively with foreign partners while preserving technological leadership. This leadership need not be threatened if we maintain a vigorous program of basic research and technology development. However, the U.S. government and aeronautical firms must pursue equitable arrangements when actual or potential competitors seek to obtain our skills and technical knowledge.

The Committee clearly recognizes that progress on many other issues such as the federal budget deficit, trade and tax policies, and exchange rates are essential to sustained improvements in America's competitive position. But in formulating an implementation strategy for the National Aeronautical R&D Goals, the Committee focused on R&D-related issues. The following pages detail specific recommendations for action.

*"The constrained U.S. fiscal environment requires a cohesive national strategy and a new sense of collective responsibility. . ."*

*"To preserve America's aeronautical leadership we must accord a higher national priority to research and development."*



# NATIONAL AERONAUTICAL R&D GOALS: FRAMEWORK FOR ACTION

## SUBSONICS GOAL: A NEW GENERATION OF SUPERIOR U.S. AIRCRAFT

**S**ubsonic aircraft dominate the world market, exceeding \$35 billion annual sales by U.S. manufacturers alone, and are expected to remain the largest aerospace market into the next century. They include all commercial transport categories, from general aviation and commuter aircraft to inter-continental transports; all military airlifters; and a large array of helicopters and emerging high-speed rotorcraft.

Commercial subsonic aircraft rank first among U.S. manufacturing exports, with a \$9.6 billion average trade surplus over the past five years. The immense subsonic market is the foundation for sustaining the major U.S. airframe manufacturers and their 15,000-company suppliers, who support both civil and military needs. American pre-eminence in this market will be critical to generate capital for investments in modern manufacturing and to exploit opportunities in supersonic and transatmospheric flight. It is in this pivotal worldwide market that foreign competition is having the most impact.

This first National Goal envisions an entirely new generation of fuel-efficient U.S. aircraft operating in a flexible and modernized National Air-space System. Its aim is a safe, congestion-free interstate system, offering superior air transportation at reduced cost. The subsonics goal also envisions the development of advanced military airlift capabilities, tankers, long-endurance aircraft, rotorcraft and other spin-off military requirements. Recent declines in fuel prices have heightened the importance of aircraft affordability. Even with rising fuel prices, cost of ownership, including acquisition, will dominate the economics of the intensely competitive world aircraft markets.

At present, the subsonic industry is busy with advanced R&D activities for next generation systems. Major aircraft and engine manufacturers are accelerating technology readiness for application to new aircraft carrying some 150 passengers for the early 1990's. These aircraft will incorporate revolutionary superbypass engines with 30% better fuel consumption. Flight tests of some of these advanced propulsion systems are already under way.

A new military transport for the early 1990's, the C-17, is also ongoing. This and other developments of advanced military aircraft will have an

important impact on gas turbine engines, composite structures, microelectronics, and fiber-optics technology, and will contribute to future cost superiority.

The Department of Defense (DOD), NASA, and the rotorcraft industry are making substantial investments in revolutionary, high-speed automated rotorcraft now finding their way into military systems. These include the tilt rotor, which combines the advantages of a helicopter and a turboprop. Another is the X-wing, whose X-shaped rotors lift the craft on takeoff and serve as wings in forward flight.

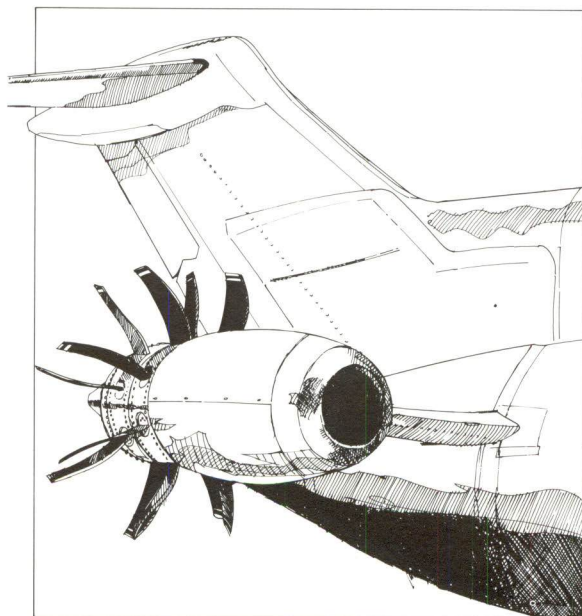
Civil derivatives of some of these high-speed rotorcraft, operating in the vertical or short takeoff modes, are foreseen with the economy, productivity, and maintainability of fixed-wing passenger aircraft. Advanced craft of this kind can provide improved inter-city and inter-region transportation, reducing congestion in U.S. airports without major investments in new runways.

Key advances in drag reduction, composites, and automation must be readied by the early 1990's. Several exciting laminar-flow concepts, that greatly reduce drag by smoothing air flow over wing surfaces, have been successfully tested in NASA wind tunnels and in small-scale flight experiments. However, large-scale flight experiments under realistic conditions and operating environments are needed before introduction in new transport aircraft.

New composite materials offer greater toughness and processability, and a 30-40% potential reduction in structural weight. However, we lack a comprehensive body of knowledge on how these materials will behave in highly loaded structures and in long-term operation. As new materials emerge from the laboratories, significant investment for validation is essential. This endeavor would clearly benefit from joint NASA, DOD, Federal Aviation Administration (FAA), and industry cooperation.

Today's frequent and costly delays at metropolitan airports will become worse with the projected

*"Key advances in drag reduction, composites, and automation must be readied by the early 1990's."*





growth in aviation. Aggressive pursuit of automation, artificial intelligence, and electronic advances for both aircraft and the National Airspace System are vital. Full realization of the National Goals will depend on how fast the National Airspace System can incorporate these advances and accommodate new vehicle capabilities such as tiltrotor, V/STOL, supersonic, and hypersonic aircraft.

Technology validation is currently the weak link in the R&D chain. Validation enables designers to incorporate new advances into a product with confidence in its performance, integrity, and cer-



tificability. It is the longest and most expensive stage in advancing new technology. It is also the point where U.S. R&D momentum has become most vulnerable. Joint industry, NASA, and DOD programs have traditionally played an important role in this area. In this constrained fiscal environment, greater industry mobilization as well as enhanced industry-government cooperation in the subsonic arena is vital. The aviation industry has recently accelerated technology readiness for product application early in the 1990's. This trend must continue if the U.S. is to maintain its competitive momentum into the next century.

NASA should focus primarily on long-term fundamental research. Difficult and demanding decisions must continue to emphasize emerging technology areas that promise major improvements in future aircraft. NASA must also strengthen its capabilities and exert stronger leadership in national research efforts and rapidly disseminate information to U.S. industry. While the potential advancements in range and payload made possible by development of key technologies will have significant benefit to growing military requirements for global operations, the DOD is appropriately channeling much of its current subsonic R&D into more specialized stealth, rotorcraft and cruise missile technology.

Clearly, the nation needs to establish a collective commitment among industry, DOD, NASA, FAA, the universities, and Congress to assure American leadership in this pivotal subsonic area. The huge market can provide the resources for private-sector investment in technology and manu-

facturing innovation for all three goals. We are approaching an important crossroad: one path leading to steady erosion of U.S. participation in world markets; the other to economic growth, and job creation. Industry creativity, leadership, and resolve will be the decisive factors.

### **SUPERSONICS GOAL: LONG-DISTANCE EFFICIENCY AND ENVIRONMENTAL COMPATIBILITY**

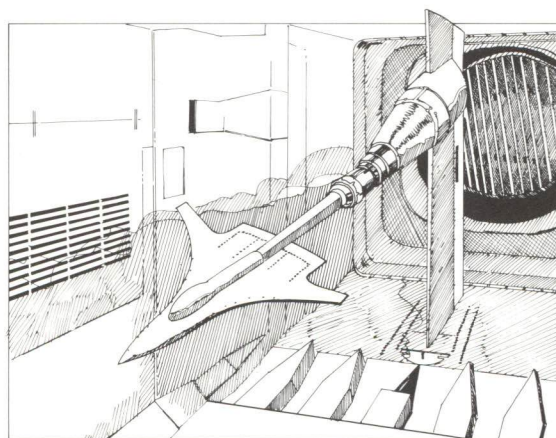
This national goal is a great market-driven opportunity. Trends into the next century almost certainly will brighten the outlook for long-range, high-speed transportation.

One trend is rapid growth of world population. More than 75% of this growth will be in distant developing nations. Another trend sees the axis of global economy and technology shifting farther and farther to East Asia and the Pacific Basin. Mutual security bonds are of increasing importance in this region in light of a potential Soviet buildup.

Yet, U.S. access to the vast Pacific area is constrained by distance. With subsonic planes, travel time between these countries and their major trading partners in the United States and Europe is from 12 to 18 hours. As travel and trade increase, demand is mounting for more productive forms of air travel. Substantial reduction of flying time means great reduction in human fatigue and improved effectiveness at the destination.

Supersonic cruise technology has important application to future combat aircraft as well as to transports. Efficient supersonic cruise, coupled with high maneuver capability, would mean considerable increase in military aircraft effectiveness and survivability. Even though military forerunners are often essential to advanced commercial undertakings, future military requirements will differ significantly from a commercial supersonic transport. Economic and performance considerations, operational requirements such as

*"We are approaching an important crossroad . . . creativity, leadership, and resolve will be the decisive factors."*



airport and community noise levels and sonic boom restrictions, as well as stringent operational life, reliability and safety requirements are vital differences. However, recent military developments have resulted in advances in propulsion, materials and systems which will benefit advanced supersonic transports.



*"By the early 1990's, the U.S. industry could begin design and development, culminating in a new supersonic transport certification around the year 2000."*

The U.S. aeronautics industry must strive to be the leader of the advanced high-speed transport enterprise. It should identify the most promising concepts and the necessary technology for economic competitiveness, safety, and environmental compatibility at reasonable business risk. Decisions must be based on a full understanding of the potential market, economics, environmental implications, the future navigation and air traffic control system, and a wide range of design options such as flight speeds and fuel types. For the airlines, the bottom line for any high-speed transport will be economic performance—competitive earnings capability and operating costs compared with long-range subsonic jets.

As the timing and need for high-speed transport come into better focus, the industry must begin to explore creative ways to assemble the required know-how and capital resources. Because of the risks and the extremely heavy funding, a high-speed transport is probably beyond the capabilities of a single U.S. aircraft or engine company. It may require pooled resources, or perhaps an international consortium. If any arbitrary governmental impediments to such development and production collaboration by major commercial competitors are encountered, they should be identified and eliminated.

On the engineering side, key technologies for advancing supersonic cruise capability have not been aggressively pursued by the U.S. since the 1971 termination of the U.S. Supersonic Transport program. However, the NASA-funded Supersonic Cruise Research program, which ended in 1981, established a constructive base for further advancement. Operational experience with the Concorde and SR-71 also provides a stepping stone for a second-generation supersonic transport.

If the U.S. is to take the lead, a coordinated and disciplined approach by industry and government is necessary. NASA and industry must hasten the development of promising technologies such as supersonic laminar flow, thermoplastics, metal matrix composites, and supersonic through-flow and variable-cycle engine technology. Airport and community noise standards present difficult challenges, but solutions can be found through technology, design and flight management. Further research is urgently needed on the generation, propagation and public perception of low-level sonic booms. The FAA and our air traffic management and control capabilities must keep pace so that new aircraft can be certified in a timely manner and operated efficiently within the National Airspace System.

Without question an economically viable and environmentally compatible supersonic transport, which would cut flying times to the Pacific Rim by 70 to 80 percent, could be available by the late 1990's or early next century. This holds tremendous potential for the American aviation industry, the world airlines, and the traveling public. It will create a multi-billion dollar market for its partici-



pants, not only in the Pacific but by potentially capturing a majority of all long-range intercontinental markets. An efficient supersonic transport represents a logical and essential link between the subsonics of this century and the hypersonics of the next.

The latest Airbus models from Europe are a constant reminder that we have no corner on using advanced technology in competitive aircraft. Japan and European nations are keenly interested and can be expected to expand their R&D investments in this area. Aeronautics remains a dynamic, competitive industry in which those who choose to stand still are quickly left behind.

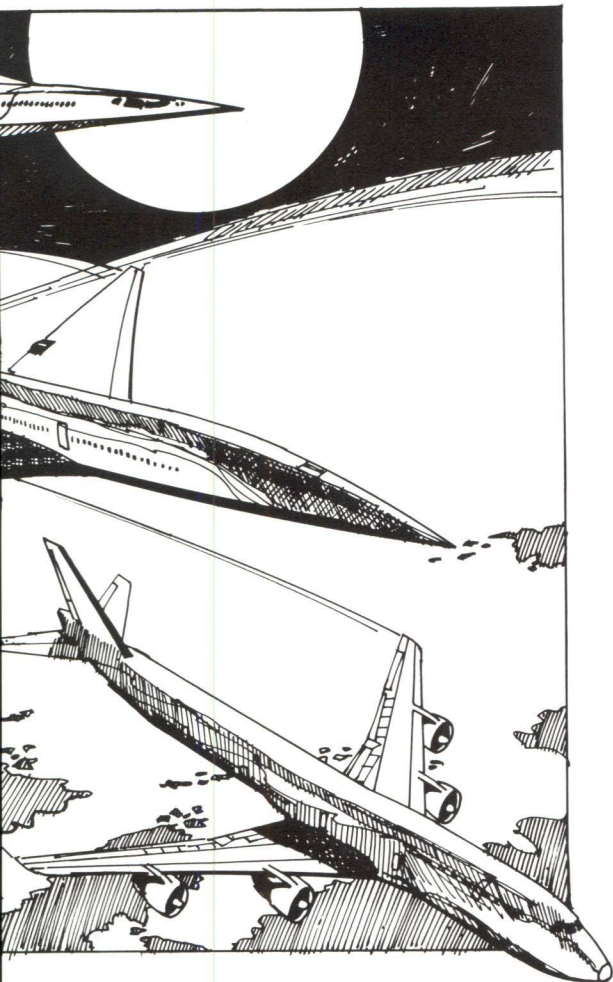
America's first step should be a focused and coordinated basic technology development effort by NASA, industry, and academia including comprehensive preliminary design studies. By the early 1990's, the U.S. industry could begin design and development, culminating in a new commercial supersonic transport certification around the turn of the century.

#### **TRANSATMOSPHERICS GOAL: TO SECURE FUTURE OPTIONS**

Significant progress since the announcement of this goal has brought both its impressive opportunities and its challenges into sharper focus.

By the turn of the century an air-breathing vehicle could take off from an airport runway and fly between 5 and 25 times the speed of sound to the





edge of the earth's atmosphere and into low earth orbit. The plane would return to a conventional runway. Such a new class of aerospace vehicle is foreshadowed by recent technical advances. It would save much weight and cost by using oxygen in the air instead of carrying very large quantities of liquid oxygen as in rocket systems.

A decision to go forward with research on an aerospace plane was announced by President Reagan in his State of the Union address on February 4, 1986. The National Aero-Space Plane program, a bold new technology initiative to carry out the decision, is being conducted jointly by DOD and NASA. These agencies have already stimulated a major expansion of research in all the technologies key to hypersonic and transatmospheric flight. Such rapid mobilization of this degree in both government and industry is unprecedented in recent times. This initiative has reversed more than a decade-long decline in the U.S. hypersonics expertise and technology base in industry and the university community.

The National Aero-Space Plane program is accelerating effort on critical technologies: air-breathing propulsion which must function efficiently from takeoff to near orbital velocities; high-temperature, lightweight materials, and thermal structures that can withstand exposure to ex-

treme heat during ascent and descent or during sustained hypersonic flight in the atmosphere; and new computational tools for analysis of the highly interdependent airframe and propulsion systems. We have the capability to integrate these technologies in the experimental X-30, which should begin validation in actual flight by the early 1990's.

The usefulness of this project is hard to exaggerate. The U.S. military, increasingly dependent on space for communications, intelligence, and early warning, urgently requires such a space vehicle. Transatmospheric craft could place military and civil payloads into orbit and service them more quickly, reliably, and inexpensively than the current Space Shuttle or expendable launch vehicles. Need for massive, fixed launch facilities at a few vulnerable sites would be eliminated. Flexible, fast-turnaround transatmospheric vehicles might cut the cost of delivering payloads into orbit by an order of magnitude.

The extreme altitude and speed capability would make our military aircraft far less vulnerable. Ability to fly to orbit on very short notice while operating from conventional runways would give the advantage of surprise. Flights on unpredicted courses could observe secret installations and activities before they could be hidden. A versatile transatmospheric vehicle could react quickly to any point on the globe in approximately 90 minutes.

A commercial transport derived from this technology could be considered following flight testing of the X-30 research airplane and operational experience with hypersonic military aircraft or space transportation vehicles. It could fly at altitudes of 20 miles or higher and at five times the speed of sound or greater. Travelers would reach most distant destinations within two hours. A hypersonic transport, a major step beyond a supersonic transport, might prove an attractive option for the long-distance market in the next century. The very significant economic, environmental, safety and operational challenges of a public hypersonic transport necessitate extensive research and technology development to exploit the civil transportation potential of hypersonic flight.

As the United States vigorously pursues space transportation systems, foreign nations are not blind to their potential. They, too, are aggressively working on a broad range of reusable spacecraft. These include the French Hermes space transportation system, advanced horizontal takeoff systems such as the British HOTOL and German Sanger vehicles, and the aerospace plane concepts being actively studied in Japan. The Soviets, who already have more responsive space launch capabilities with an annual launch rate many times greater than ours, are well into developments, some of which are beyond anything we have in either operation or design.

Accordingly, the Committee strongly endorses the National Aero-Space Plane initiative in a broad U.S. and global competitive context involving both aerospace leadership and national security.

*"The X-30 experimental airplane should begin technology validation in actual flight by the early 1990's."*



# THE AGENDA FOR ACHIEVEMENT

*"The United States cannot retreat behind protectionist barriers. . ."*

**C**learly, now is the time for the United States to organize a long-term, aggressive, and positive thrust to remain competitive in the world aviation marketplace and secure in our national defense. As the leader of the free world, the United States cannot retreat behind protectionist barriers in the face of formidable economic competitors or military adversaries. America has lost momentum but not its basic capability. In aeronautics, the expertise represented by the government, industry, and university partnership that has evolved since the founding of the National Advisory Committee for Aeronautics in 1915 is unsurpassed anywhere. The most decisive factor in America's favor is the pace of innovation itself.

The current environment with its resource limitations poses a national challenge to our creativity and resolve to make the difficult choices and necessary commitments for U.S. preeminence. The agenda will require concerted effort and greater achievement by the Federal Government, industry, and the nation's universities. The Committee recommends an eight-point action plan to strengthen U.S. competitiveness in the worldwide aerospace marketplace and strategic arenas.

## ACTION PLAN

**1** **Increase innovative industry R&D efforts given the certainty of intensifying global competition and the importance of new technology for U.S. competitiveness.**

The U.S. is challenged by a new global economy. America's ability to compete depends heavily on greater mobilization and commitment of the major aircraft manufacturers and their suppliers. Affordability and quality will be pivotal to the success or failure of U.S. entries in the world markets. With so much of our competitive position dependent on new technology, the Committee recommends that:

- U.S. aeronautics industry continue to expand its own investments in R&D.
- American industry stress affordability and quality during product design, a longer-term perspective in business strategies, and a more risk-taking approach to strengthen American leadership in light of the escalating global competition.
- Government continue to support a healthy Independent Research And Development (IR&D) program as a sound and proven way of stimulating innovative industrial R&D.

**2** **Aggressively pursue the National Aero-Space Plane program, assuring maturation of critical technologies leading to an experimental airplane.**

The Committee strongly endorses the National Aero-Space Plane program. In pursuing this challenging initiative, government and industry partners should strive to:

- Strengthen preliminary design efforts so that attractive vehicle concepts and key technologies can be identified, shaped, and assigned priorities.
- Assure timely development and maturation of the X-30 focused technologies critical to success of the National Aero-Space Plane program.
- Conduct application studies for future operational vehicles of various sizes and missions to provide a comparative assessment with competitive alternatives.
- Assure broadest U.S. technical community involvement consistent with the need to protect certain sensitive information for national security and U.S. competitiveness.
- Broaden the technology base to enable development of a wide range of U.S. hypersonic cruise vehicles.
- Rebuild university expertise base in hypersonics and transatmospherics research.

**3** **Develop fundamental technology, design, and business foundation for a long-range, supersonic transport in preparation for a potential U.S. industry initiative.**

The National Goal for long-distance supersonic efficiency remains a great market-driven opportunity. Second-generation commercial transports which would cut flying times to the Pacific Basin by 70 to 80 percent are possible by the turn of the century. A coordinated and disciplined approach by government and industry is necessary to develop the technology and to mobilize the large capital resources for full-scale development. The Committee recommends that:

- Industry analyze the market needs for an advanced high-speed transport and identify the economic, speed, size, range, and fuel characteristics necessary to become a successful element in international air transportation. Government and industry determine the necessary characteristics for environmental compatibility.



■ Industry and NASA determine the most attractive technical concepts and the necessary technology developments for future long-range, high-speed civil transports.

■ NASA, industry and academia begin a focused and coordinated approach to ready required technology for U.S. industry development and application.

■ Industry provide strong, creative leadership. A high-speed transport will probably require pooled resources of a number of companies, perhaps an international consortium. Arbitrary governmental impediments to collaboration in design, development, and production by major U.S. commercial competitors should be identified and eliminated.

■ The U.S. aeronautics community explore the development and application of new supersonic cruise technologies to advanced technology military aircraft.

## 4 **Expand domestic research and development collaboration by creating an environment that reflects the new era of global competition.**

American companies will have to depend more on themselves and on one another, if they are to stay competitive internationally. Because of changes in the worldwide commercial markets and dramatically rising research and development costs, many U.S. aerospace manufacturers have entered into cooperative relationships with foreign companies to gain market share and reduce financial risk. Collaboration among foreign companies, enabled by less restrictive legal environments overseas, is an increasingly powerful competitive force on the international scene.

Much of the research and development envisioned in this report could benefit from several American firms working collaboratively—sharing the risk while pooling capital, technology, and skilled personnel. The purpose is not to stifle U.S. competition but to enhance international competitiveness. Increased cooperation between federal laboratories and the private sector is also essential. Accordingly, the Committee recommends that:

■ The U.S. aeronautics industry consider the advantages of teaming and other collaborative opportunities now permitted by U.S. law. Research cooperatives that are created by private initiative such as the Microelectronics and Computer Technology Corporation might serve as a model. Associations such as the Aerospace Industries Association are beginning to act as a catalyst.

■ The Federal Government not impose barriers to discussions and teaming between major U.S. Aerospace competitors for development and production projects as well as research. Such team-

ing is already commonplace in major military aviation procurements. This is particularly important for a commercial supersonic transport, since the magnitude and complexity of the required R&D efforts will probably require collaboration of a number of companies.

■ The U.S. increase rate of technology transfer of government funded R&D to the American private sector for commercial development. Rapid transfer and development are essential in preventing significant loss of that technology to foreign companies. Federal agencies must balance the early open publication of research results with need for early domestic technology transfer. Important new discoveries should receive proper intellectual property protection and early domestic dissemination.

■ Industry and the national laboratories expand cooperative research, technology development, and licensing arrangements under the terms of the Federal Technology Transfer Act of 1986. This Act offers a variety of new incentives and mechanisms for cooperation and rapid transfer of government-sponsored technology to the private sector. Government and industry should identify those areas where U.S. industry might be interested in sharing the costs—and benefits—of technology development.

## 5 **Encourage government aeronautical research in long-term emerging technology areas which promise high payoffs.**

Advances in composite materials, propulsion, numerical simulation, and laminar flow will have a profound effect on future vehicles in all three goal areas. NASA provides a unique, central technological resource for this nation's aeronautical preeminence and should now strengthen its capabilities and take a more assertive leadership role in developing the fundamental knowledge base in these emerging areas. Government must also assure the health and availability of critical national facilities to meet the projected increased demands from new aircraft developments across the speed regime.

### *Composites*

Innovative research could yield high-strength, ultra-lightweight, low-cost composite structures for use in advanced subsonic, supersonic and transatmospheric aircraft. To achieve the full potential of composites, the Committee recommends that:

*"A high-speed transport will probably require pooled resources. . ."*



*"NASA should now take a more assertive leadership role in developing the fundamental knowledge base in these emerging areas."*

■ Government, industry, and the universities intensify development and validation of a comprehensive knowledge base to enable the broad application of composite materials to future aircraft and engine systems.

■ NASA and DOD focus research on promising material systems such as thermoplastics and metal matrix composites, and on advanced structural concepts and innovative fabrication techniques to increase damage tolerance and strength and lower cost.

■ Civil and military composite development be made a common, mutually supporting national undertaking.

■ As new composite materials emerge from the research laboratories, government and industry coordinate national technology validation efforts for large, next-generation primary structures. FAA ensure that appropriate certification standards and rules are developed.

#### *Numerical Simulation*

An area of extreme importance for rapid and effective evaluation and optimization of all classes of aircraft and propulsion system designs is numerical simulation, or computer modeling. It is already revolutionizing research in aerodynamics, structures, propulsion, and related areas such as wind shear. The design of highly integrated aerospace vehicles and further improvements in conventional aircraft are dependent on these capabilities. Because these problems involve large numbers of variables, the development of new powerful supercomputers will accelerate progress. To maintain leadership in this vital technology area, the Committee recommends:

■ U.S. fully exploit leadership in supercomputer and numerical simulation technology for improved understanding of fundamental physical phenomena and the optimal, cost-effective design of all future aerospace vehicles. This will require more extensive experimental activity to verify numerical simulation results.

■ U.S. industry and government accelerate development of parallel processing hardware and software technology and artificial intelligence to significantly increase the fidelity and accuracy of computer simulations.

#### *Propulsion*

Ceramic, carbon-carbon, and metal matrix composite materials promise engine operations at extremely high temperatures with improved performance, weight, and life. Successful development of high-temperature materials will spur efficient supersonic cruise propulsion systems and large increases in fighter capability, including short or vertical takeoff and landing aircraft operations. To realize dramatic improvements for subsonic and supersonic propulsion systems, the Committee recommends that:

■ NASA and DOD emphasize high-performance propulsion technology with particular focus on high-temperature composite materials.

■ NASA and DOD explore advanced propulsion cycles and determine the practicality of the most promising concepts.

■ Government and industry develop the fundamental technology base for significant improvements in fuel efficiency, operating life and acoustics of super-bypass subsonic propulsion systems and supersonic variable-cycle engines.

#### *Laminar Flow*

Laminar-flow advances offer dramatic improvements in cruise efficiency of both subsonic and supersonic aircraft. Flight testing of small-scale, subsonic laminar-flow concepts has been completed recently. However, important work remains before these concepts can be introduced in large subsonic transports. Little laminar-flow research has been conducted in the supersonic regime. The Committee recommends that:

■ NASA develop fundamental laminar-flow technology for supersonic aircraft, with potential to double fuel efficiency and reduce skin surface temperatures. This should include research on high-lift devices or techniques for highly-swept leading edges used during the approach and landing phases of flight.

■ NASA and DOD, in conjunction with industry, pursue the validation of promising subsonic concepts in realistic flight conditions and operating environments.

#### *National Facilities*

NASA and DOD are responsible for a large number of unique national facilities that are essential to preserving U.S. leadership in aeronautics. These major government wind tunnels and propulsion facilities, represent the majority of our national aeronautical R&D test capability. They are experiencing significant increases in demand because of new aircraft development programs currently underway across the entire speed range. This demand is expected to grow. Certain of NASA's wind tunnels are aging and in need of modernization. In addition, requirements for higher speeds, higher temperatures, and improved flow and acoustic qualities may require enhanced capabilities. To ensure the health and availability of critical national facilities, the Committee recommends that:

■ NASA, in conjunction with DOD and industry, undertake a national assessment of future wind tunnel use requirements and the adequacy of existing wind tunnels to meet these requirements. This assessment should form the basis for developing and implementing a time-phased plan for modernizing, rehabilitating, or removing current NASA wind tunnels from service and for providing new national capabilities.



## 6 **Strengthen American universities for basic research and science education through enhanced government and aerospace industry support and cooperation.**

As centers of basic research, universities play a vital role in creating the basic technological foundation for achievement of the National Goals. Universities provide the dual benefit of scientific advances and the training of future scientists and engineers. Yet there are disturbing signs that our universities' R&D infrastructure is deteriorating. The U.S. must revitalize the critically important interactions between universities, government and industry that have served this Nation so well in the past. For these reasons, cooperative efforts between government and industry should be encouraged to help:

- Expand, replace and modernize university R&D equipment, facilities, and instrumentation, to keep pace with research and training needs.
- Support U.S. science and engineering students with adequate long-term stipends to encourage our best students to pursue graduate studies in engineering. Challenging graduate level curricula should be established or strengthened in critical aerospace areas.
- Foster aerospace-oriented centers patterned after such successful ventures as NASA's Centers of Excellence, the National Science Foundation's Engineering Research Centers, and the University Research Initiative of the Defense Department. This will help address critical needs for more multi-disciplinary basic research and encourage greater technology transfer to the private sector.

## 7 **Improve the development and integration of advanced design, processing, and computer-integrated manufacturing technologies to transform emerging R&D results into affordable U.S. products.**

Flexible, automated manufacturing technology is a key to affordability and quality in all three goal areas and is a potential major leverage area for U.S. manufacturers. To enhance the U.S. competitive advantage, the Committee recommends that:

- Aerospace industry establish world leadership in advanced processing and computer-integrated manufacturing technology.
- Aerospace industry improve the integration of design with advanced processing techniques and automated factories.

■ Federal agencies, particularly DOD, facilitate U.S. manufacturers' use of advanced manufacturing techniques or concepts sponsored by those agencies.

■ Industry and government strengthen research activities that can lead to new manufacturing techniques and greater productivity.

## 8 **Enhance the safety and capacity of the National Airspace System through advanced automation and electronics technology and new vehicle concepts including vertical and short takeoff and landing aircraft.**

Airport congestion and delay have become substantial problems that will worsen with the expected growth in aviation. New high-performance vehicles will also present significant challenges for the National Airspace System. To realize the benefits of future technology advances, the Committee recommends that:

- Federal Aviation Administration (FAA), in conjunction with NASA, accelerate development and integration of advanced automation and electronics technology into the National Airspace System.
- FAA maintain flexibility for early certification of future aircraft, including supersonic and hypersonic vehicles.
- FAA and NASA provide technology for timely detection and avoidance of hazardous weather such as wind shear, and for computerized aids in handling unavoidable encounters.
- NASA and DOD aggressively pursue advanced automation and electronics technology for future aircraft. Effective integration of humans with these highly-automated systems is pivotal for increased safety and performance.
- Industry explore development of timely and affordable civil derivatives of the new generations of military VTOL and STOL aircraft for inter-city and inter-region transportation.

*"Universities play a vital role in creating the basic technological foundation for achievement of the National Goals."*



# CONCLUSION

**T**he Committee believes that the most crucial problem facing U.S. aeronautics is that government and industry leaders underestimate the depth and determination of foreign aeronautical commitment and the magnitude of the R&D effort required to achieve the National Goals. Real national growth in R&D is essential.

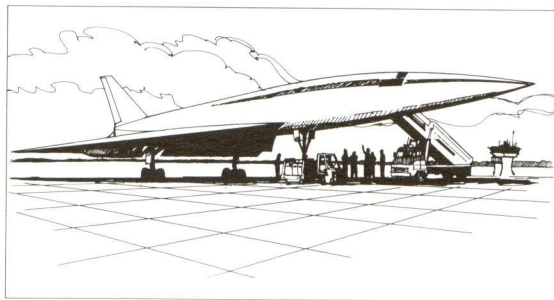
The changing environment requires a new commitment and a new philosophy, characterized by a collective sense of responsibility and a more cooperative relationship among government, industry, and the university community. Government alone cannot guarantee success. America's ability to compete lies primarily within the private sector which must be effectively mobilized. The recommended U.S. strategy will produce both a strengthened defense and a clear-cut product superiority in the international marketplace.

To hold on to American markets while competing in the new global economy requires changes in the aeronautical community's traditional operating procedures. Policies and approaches which were born when U.S. industry was generally preeminent have little place in a world where many competitors are essentially technological equals and actively backed by foreign governments. Major increases in government spending are not required, but necessary outlays will be a prudent investment in America's economic future and national security.

Change is unsettling. Fortunately, many Americans are now recognizing that something different must be done. From education to tax reform, we should be thinking seriously about how to sharpen the country's competitive edge. Otherwise, America's quality of life can only slip relative to the rest of the industrialized world. It is the Committee's hope that all involved will realize that "business as usual" will not carry the U.S. through this world competitive environment successfully.

None of these changes will be easy. The only question is whether they will be made in time with a coherent purpose that will secure lasting U.S. aerospace leadership. Otherwise, far tougher choices will be forced upon us in the heat of a deepening crisis. It is the Committee's firm belief that the central priority for the balance of this century is to regain American competitiveness.

*"The central priority for the balance of this century is to regain American competitiveness."*





# AERONAUTICAL POLICY REVIEW COMMITTEE

**John E. Steiner**  
Chairman

Crawford F. Brubaker  
Deputy Asst. Secretary for Aerospace  
Department of Commerce

John F. Cashen  
Vice President, Advanced Projects  
Northrop Corporation

Raymond S. Colladay  
Associate Administrator for  
Aeronautics and Space Technology  
NASA

Thomas E. Cooper  
Assistant Secretary of the Air Force for  
Research, Development, and Logistics

Eugene E. Covert  
Head, Depart. of Aeronautics and Astronautics  
Massachusetts Institute of Technology

J. Roger Fleming  
Senior Vice President, Technical Services  
Air Transport Association

Bastian Hello  
Senior Vice President, Government Relations  
Rockwell International

Russell L. Hopps  
Vice President, Engineering (Ret.)  
Lockheed Corporation

Charles B. Husick  
Senior Vice President  
Fairchild Industries

Ronald L. Kerber  
Deputy Under Secretary of Defense  
for Research and Advanced Technology

James N. Krebs  
Vice President and General Manager (Ret.)  
General Electric Company

Walter S. Luffsey  
Director, Adv. Aviation System Design Team  
Federal Aviation Administration

Robert R. Lynn  
Senior Vice President of  
Research and Engineering  
Bell Helicopter Textron

Hershel Sams  
Vice President, Engineering Technology  
McDonnell Aircraft Company

John M. Swihart  
Vice President, International Affairs  
The Boeing Company

## **OSTP**

Maurice A. Roesch III  
Former Assistant Director for  
Defense Technology and Systems

David R. Stone  
Executive Secretary



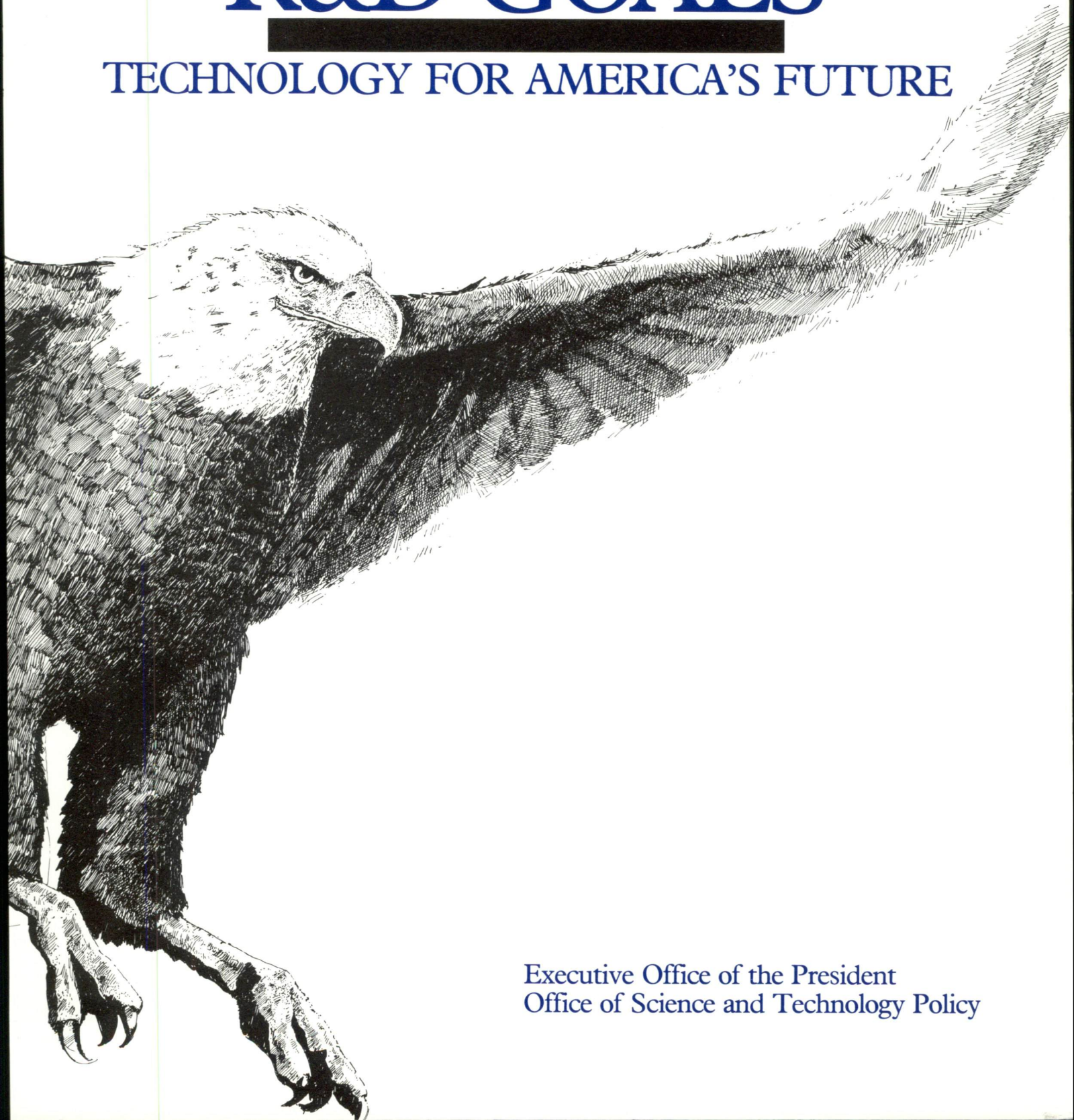


Executive Office of the President  
Office of Science and Technology Policy  
Washington, D.C. 20500



# NATIONAL AERONAUTICAL R&D GOALS

TECHNOLOGY FOR AMERICA'S FUTURE



Executive Office of the President  
Office of Science and Technology Policy







# FOREWORD

In November of 1982 an interagency working group, under the direction of the White House Office of Science and Technology Policy, issued a comprehensive report analyzing the state of aeronautics research and the role of the Federal Government in supporting that research. Among its conclusions were that there are possible today monumental advances in aircraft performance. Due to the nature of the benefits, both military and commercial, the Federal Government and industry must unite to realize that potential.

As a result of that report, I established an Aeronautical Policy Review Committee, composed of government, industry, and academic experts, for the purpose of keeping track of the implementation of the recommendations in the first report. This second report by the Committee points out that, like other industries that rest on strong technological bases, American aeronautics faces tremendous challenges from abroad as well as tremendous opportunities for advances and leadership now and in the future.

The report is comprehensive and addresses specific goals in three areas—subsonics, supersonics, and transatmospherics—that we should be focusing on. It gives clear direction for the Administration's commitment to maintaining and extending our leadership in this field. If the goals are pursued vigorously by industry, academia, and government, U.S. aeronautics, in both the civil and defense sectors, will be able to sustain its preeminence into the next century.

G.A. Keyworth, II  
Science Advisor to the President, and  
Director, Office of Science and Technology Policy

March 1985

## CONTENTS

|                                      |   |
|--------------------------------------|---|
| EXECUTIVE SUMMARY                    | 1 |
| INTRODUCTION                         | 3 |
| NATIONAL AERONAUTICAL R&D GOALS      | 4 |
| SUBSONICS GOAL                       | 4 |
| SUPERSONICS GOAL                     | 5 |
| TRANSATMOSPHERICS GOAL               | 6 |
| REVITALIZATION STRATEGY              | 7 |
| SUMMARY                              | 8 |
| AERONAUTICAL POLICY REVIEW COMMITTEE | 9 |

## EXECUTIVE SUMMARY

### Challenges and Opportunities

U.S. aeronautics is and will remain a decisively forceful influence on the long-term economic and military security of the nation. The technical margins that have long defined U.S. aeronautical preeminence have narrowed significantly in recent years as foreign competition has increased. This trend, if allowed to continue, will evolve into major national weaknesses substantially increasing the vulnerability of America's position in world affairs. Because aeronautics is so integral to our national interest, U.S. national aeronautical policy now stipulates that the nation cannot and will not allow leadership erosion.

Lasting U.S. aeronautical leadership will only be secured by the vigorous renewal of America's traditional strength: pioneering new technology. Aeronautical opportunities are known today which, if actively pursued, would result in 21st century U.S. civil and military aircraft of clear-cut supe-

riority. Their technical excellence and cost advantages could more than overcome foreign competitive approaches.

### Strategy and Goals for U.S. Aeronautics

The high-technology payoffs that result from advances in aeronautics are important national benefits that must be maximized by American enterprise. This maximization requires both government and industry to combine their efforts toward aggressive technological goals with potential for broad future application. In this pursuit, early

*"Lasting leadership will only be secured by the vigorous renewal of America's traditional strength: pioneering new technology."*



*"America's future in aeronautics demands much more than a 'business as usual' attitude."*

applications can help generate the national resources and experience needed to capitalize on the opportunities that will follow. This strategy also supports the more definitive objectives for technically superior U.S. military aircraft.

The Committee proposes three national goals to clarify and focus the direction for U.S. aeronautical R&D. Successful attainment of these goals will challenge American creativity. Within the next 10 years the U.S. must build its research and technology momentum and achieve a trans-century renewal of the nation's total aeronautics capacity. Work must proceed concurrently on all three goals, with early emphasis on the first. The goals are presented here in time-phased order of attainment:

### Subsonics Goal: To Build Trans-Century Renewal

- Envisions technology for an entirely new generation of fuel-efficient, affordable U.S. aircraft operating in a modernized National Airspace System.
- Captures immense civil aircraft market opportunities by technologically superseding foreign competitive challenges.
- Supports development of advanced military aircraft capabilities.
- Requires acceleration of key technology advances for 1995 readiness target. Applications well into the next century.

### Supersonics Goal: To Attain Long-Distance Efficiency

- Develops pacing technologies for sustained supersonic cruise capability.
- Enables linking of farthest reaches of Pacific Rim in four to five hours. Recognizes growing U.S. strategic and economic interests with partnership potential.
- Provides military with enhancements in basing flexibility, long-distance responsiveness, and survivability.
- Applications through much of the next century.

### Transatmospherics Goal: To Secure Future Options

- Pursues research toward capability to routinely cruise and maneuver into and out of the atmosphere with takeoff and landing from conventional runways.

- Builds on progressive subsonic, supersonic, and hypersonic advancements in aeronautics technology as well as Space Shuttle experience.
- Influences long-range options for both aeronautics and space.
- Significant to military and civil 21st century leadership.

Collectively, these goals will focus national energies and creativity on new frontiers and opportunities that are vital for the future success and leadership of America.

## Implementation Challenges

America's future in aeronautics demands much more than a "business as usual" attitude. U.S. industrial companies must work with one another, and with government agencies, to increase *accomplishment* and enhance *affordability*.

Historically, a number of barriers have impeded technological advancement in both the public and private sectors. The current environment amplifies the impact of many of these impediments on achieving technology readiness. Appropriate corrective actions exist, and should be pursued without delay:

- Federal contracting procedures should be restructured to reflect a greater distinction between the procurement of research and technology and the procurement of hardware.
- Regulatory policy should encourage cooperative efforts for technology development among U.S. companies (as is now ongoing between U.S. and offshore companies).
- Federal tax legislation should adequately stimulate private investment in timely technology development.
- All branches of the Government with relevant oversight and/or management responsibilities should strive to maintain the continuity of research and technology development activities.

## Planning, Priorities, and Policies For Action

Technical plans for implementing these goals must be developed in close conjunction with the reordering of national R&D priorities and policies. This task challenges both public and private sector creativity to gain real growth in aeronautical technology development. It also challenges government leadership to reconcile policies inhibiting R&D progress and affordability. Toward this national purpose, the Executive Offices and mission-oriented agencies of government must work closely with Congress to ensure that the rich potential in aeronautics is nurtured, encouraged, and firmly secured as an American reality.



# INTRODUCTION

## U.S. Aeronautics in a Global Context

U.S. aircraft have long dominated in civil aircraft markets and in weapon system technical superiority, but there is no guarantee that U.S. leadership in aeronautics will be retained even in the short term. In fact, the U.S. can no longer assume its leadership is secure on any high technology front. Very clearly, the intensity of global competition in high technology poses a serious challenge to U.S. aeronautical preeminence, a situation which also brings into question the economic and strategic future of the United States. Aeronautics has a crucial role both in America's defense capabilities and in the employment, transportation, and exports which strengthen our national economy.

In aeronautics, the U.S. system of private enterprise has developed a unique base of national synergy which affects key parts of the nation's overall competitiveness. Aircraft provide a challenging product focus that stimulates high technology innovation from a broad array of contributing companies and industrial sectors. The success of this aspect of America's aeronautical infrastructure has not gone unnoticed by other nations, and aircraft capacities have become favored targets for foreign technological and industrial expansion over much of the past decade.

While U.S. aircraft still maintain a broad base of technological advantage, the margin of that advantage has narrowed dramatically in recent years. In a growing number of aircraft-related areas, foreign technical capabilities are now comparable, if not superior, to those of the U.S. This is particularly evident for smaller aircraft, where the entry threshold has been within the financial and technical reach of an increasing number of smaller nations or multinational consortia. Foreign military aircraft capacities are now showing a similar trend. Coupled with this, military and civilian aircraft technologies and products have become a politically sensitive aspect of international negotiations and trade. In this respect, the erosion of American preeminence implies major negative consequences for the position of U.S. leadership in global security as well as for the vitality of U.S. industry in a changing global economy.

## An Expanding Perspective

All these factors were recognized in the Administration's 1982 Aeronautical R&T Policy, which established challenging national goals for furthering all aspects of U.S. aeronautical preeminence. Following one of these policy recommendations, the President's Science Advisor formed a senior executive-level committee to review (from a national perspective) the Government's long-range aeronautical plans for consistency with the policy objectives. This is the second report submitted by that policy review committee.

The Committee's first report, submitted to the Executive Office of the President in November

1983, included a number of recommendations to encourage a more aggressive and farsighted national outlook for aeronautics. During 1984, the U.S. aeronautical community reexamined opportunities for technological advancement that could be achieved by the end of this century. This crucial evaluation was conducted with a view toward vehicle concepts that reached beyond the arbitrary time horizon of the turn of the century. The results presented to the Committee both confirmed and expanded many earlier assessments. Very high-leverage payoffs can be expected from interdisciplinary efforts in propulsion, materials, aerodynamics, structures, and avionics. Aggressive technological readiness can produce either a distinct U.S. advantage or, conversely, an advantage to foreign civil and military competitors, depending on where the greatest effort and commitment are made. In considering this dynamic situation, several important factors should be borne in mind:

- Leapfrog advancements are definitely possible which would make obsolete virtually all significant civil and military aircraft operational today (both fixed and rotary wing).
- The range of high-payoff R&T opportunities impacts all classes of aircraft and will far exceed resources available for investment.

*"Very clearly, the intensity of global competition in high technology poses a very serious challenge to U.S. aeronautical preeminence . . . ."*



# NATIONAL AERONAUTICAL R&D GOALS

*"While payoffs will be time-phased in their realization, it is important that work toward all three goals proceed concurrently."*

Three long-range goals are proposed to address all these challenges and opportunities. The Committee believes that the highest potential for revitalizing U.S. competitiveness lies in America's traditional area of strength: the pioneering of new technology. The three goals proposed here are aligned to form a strategy aimed at a decisive strengthening of the U.S. technological foundation and leadership position in world markets and relative to our military adversaries.

The goals are time-phased, with the first goal (subsonics) being crucial as an enabling goal. It must serve to reenergize American R&D momentum, because the product technologies it fosters must generate private sector resources necessary for exploitation of ensuing opportunities in supersonic and transatmospheric flight. While payoffs will be time-phased in their realization, it is important that work toward all three goals proceed concurrently. Emphasis over near-term years, however, must necessarily be focused on the first goal.

## Subsonics Goal: To Build Trans-Century Renewal

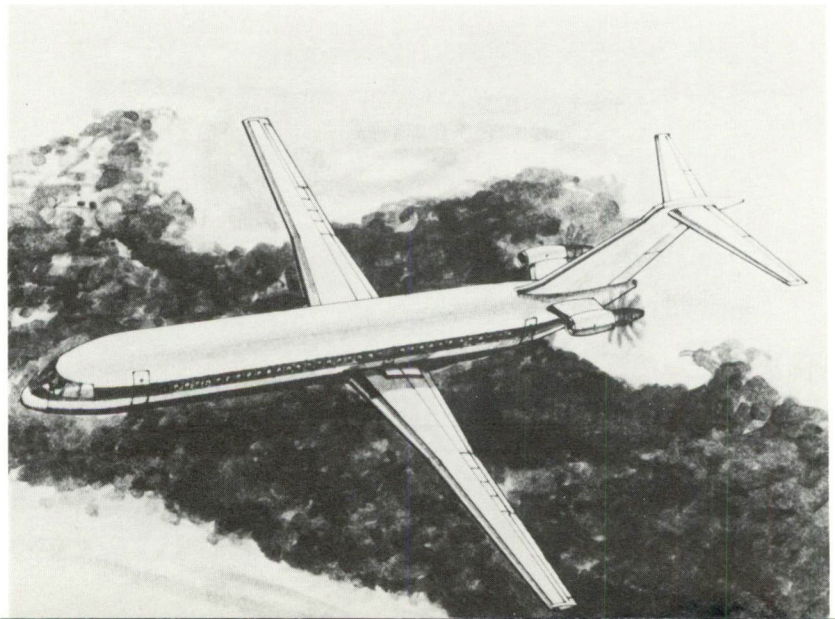
Advancing technology for a new generation of U.S. subsonic aircraft

The past 15 years have seen mostly evolutionary advancements in subsonic aircraft technology, but future possibilities for truly revolutionary advancements far exceed all these. Subsonic opportunities can establish a firm U.S. foundation for technically superior aircraft to carry U.S. aeronautical leadership into the next century. The subsonics goal envisions this with an entirely new generation of fuel-efficient U.S. aircraft operating in a flexible and modernized National Airspace System. Simply stated, its aim is a safe, congestion-free U.S. aeronautical interstate system, offering superior air transportation at half its current cost. The subsonics goal also envisions the development of advanced military airlift capabilities, long endurance aircraft, low observables, rotorcraft, and other spin-off military requirements that are anticipated for the same general time frame.

Accelerating subsonic technology can leverage unique advantages for the United States, by capitalizing on the pioneering efforts in airspace modernization and deregulation already in the national agenda. It also promotes domestic supply for the very large U.S. civil aircraft markets. In this respect, subsonic aircraft also dominate in world market projections, with a variety of requirements extending well into the next century. This immense civil opportunity is the cornerstone for sustaining American aircraft capacities, since civil work generates 60 percent of the total aircraft production business for the 15,000-company supplier base which supports both U.S. civil and military needs. Foreign competition has already placed serious technology readiness pressures on the U.S. supply base, particularly with respect to smaller classes of aircraft (commuters, business aircraft, and rotorcraft) where the position of U.S. products is most endangered today.

Significant national research and technology development is already in progress. However, key subsonic advances contributing to new trans-century aircraft must be accelerated and readied by the mid-1990's to meet crucial competitive applications that will affect U.S. aeronautical momentum into the next century. Technologies that are integral to the development of these subsonic aircraft include: laminar flow control advancements that substantially reduce aircraft drag; all composite high-strain structures; a new generation of super bypass and propfan engines; and fully integrated flight controls and operating systems that interface with National Airspace System modernization. It is essential for the National Airspace System Plan to maintain cohesiveness and flexibility to accommodate and keep pace with these future aircraft technologies. Advanced computational capability is key for both aircraft and air system objectives.

New aircraft in the system will more than double today's best fuel efficiency, as well as being substantially more efficient in operation. U.S. general aviation, rotorcraft, commuters, and transport aircraft that decisively reduce acquisition and operating costs will dominate established world





markets and the new air service expansions of developing nations. U.S. helicopters and V/STOL aircraft will also become increasingly important in both these market areas. Advanced aircraft of this type can reduce congestion in U.S. airports and provide transportation infrastructure unique to the specialized requirements of developing nations.

Achievements of this magnitude could also produce a U.S. advantage in the eventual formation of a globally compatible air system, as well as leadership in other areas of international aviation. This in turn could leverage significant U.S. strategic and economic advantage for other important world agendas, particularly in the developing Pacific region.

Stepping up national research momentum and efficiency is a vital part of this far-reaching goal. In view of this, a broad, trans-century strategy is proposed later in this report that places particular emphasis on revitalizing the nation's capacities for aeronautical innovation over the next decade.

## Supersonics Goal: To Attain Long-Distance Efficiency

Developing technology for efficient, long-distance supersonic cruise

Gaining sustained supersonic cruise capability is of very high priority for future military aircraft survivability, long-distance responsiveness, and basing flexibility. However, this military capability is also aligned with highly constructive civil opportunities that could benefit the U.S. in important non-military areas as well. Supersonic advancement offers the added potential for welding long-term bonds between the U.S. and Pacific partners through possible joint development of the pacing technologies for a new generation of supersonic transports. The key technologies underlying this objective (propulsion, structures, materials, and aerodynamics) are largely generic to future military needs.

Strategically and economically, United States trade and alliances in the Pacific have major implications for the future. The region's dynamic

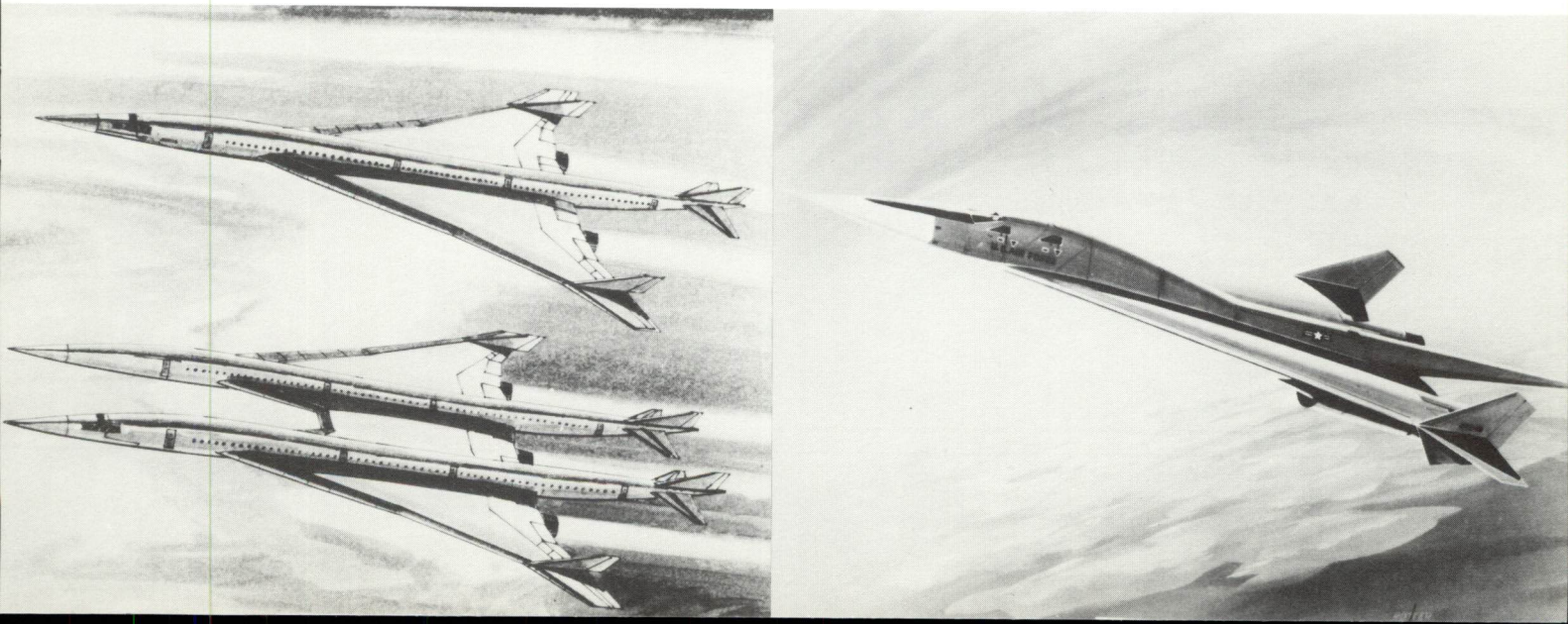
growth and vast potential for development should continue to be influenced and encouraged by American policy and enterprise. U.S. trade with the Pacific community has increased over 75 percent within the last six years, accelerating well beyond the volume of trade with Europe. Mutual security bonds are also of increasing significance in light of a potential major Soviet military buildup in the region. From both the strategic and economic perspectives, the vast Pacific area is constrained by distance, a factor adding significance to a U.S. supersonic goal . . . and contributing to the potential for Pacific Rim development by increasing cooperation and understanding among the nations and peoples of this important region.

The key technologies for advancing supersonic cruise capability have not been aggressively pursued by the U.S. since the 1971 demise of the U.S. Supersonic Transport program. However, the NASA-funded Supersonic Cruise Research program, which ended in 1981, established a constructive base for further advancement. The development of single crystal turbine blades, better coatings, advanced cooling methods, and improved internal aerodynamics has allowed significant improvements in military engine thrust-to-weight ratios. The application of these technologies to a variable cycle engine with reduced noise, and much improved specific fuel consumption over the entire speed regime, forms a starting basis for the Pacific Supersonic Transport.

The application of powder metallurgy technology and superplastic forming techniques to load-carrying structure, along with new thermoplastics, carbon-carbon, and metal matrix materials, will also have significant benefit for all classes of military and civilian supersonic aircraft. Additionally, fault-tolerant computers that provide load alleviation and dynamic damping, coupled with the cooler structure allowed by supersonic laminar flow, will significantly reduce the aircraft weight per pound of payload as compared with earlier supersonic transports.

The advent of powerful computer systems will allow the computation of complex flows and the

*"Key subsonic advances . . . must be accelerated and readied by the mid-1990's to meet crucial competitive applications."*





*"From both the strategic and economic perspectives, the vast Pacific area is constrained by distance, a factor adding significance to a U.S. supersonic goal."*

optimization of configurations that extend the regions of supersonic laminar flow. A complete understanding and verification of the potential for supersonic laminar flow is critical for sustained cruise speeds that would allow both military and civil aircraft operations at triple the fuel efficiency of today's supersonic technologies. Combined with other supersonic advances, it can also substantially reduce the overpressures contributing to sonic booms.

Creative integration of these technologies could provide the U.S. and its Pacific allies with a transportation system linking the farthest reaches of the area in four to five hours, while providing the military with vitally needed mission enhancements in basing, long-distance responsiveness, and survivability.

## Transatmospherics Goal: To Secure Future Options

Exploiting the growing convergence of aeronautics and space technology

U.S. aeronautics and space endeavors share in related constraints and unexploited opportunities in the transatmospheric regime. The capability to routinely cruise and maneuver into and out of the atmosphere, to gain rapid responsiveness for low earth orbit missions (manned or unmanned), or to attain very rapid transport services between earth destinations from conventional runways must be viewed as aerospace options with global importance for the future.

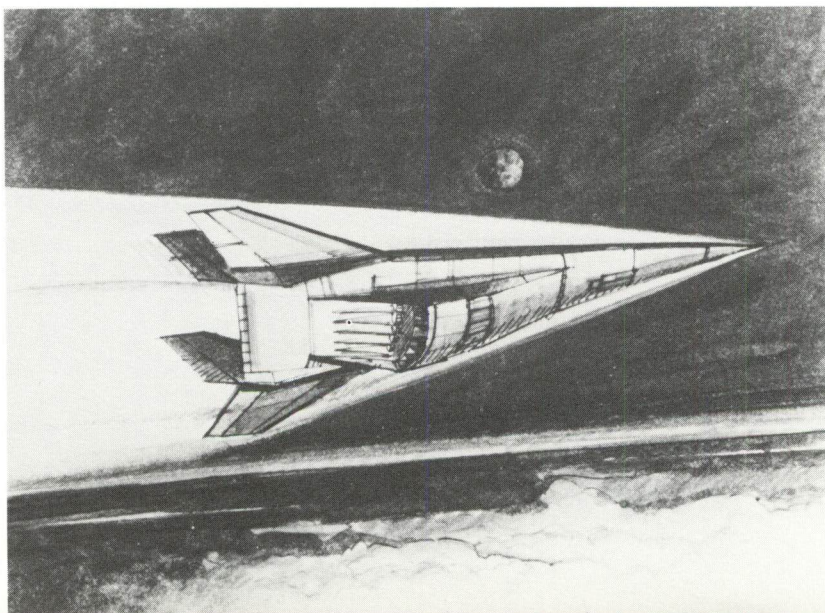
The importance of these capabilities to the U.S. must be underscored, since all these possibilities are also open to foreign military or civil initiatives in either aeronautics or space. The U.S. has largely viewed the transatmosphere as a technical boundary . . . used to define the separate responsibilities between U.S. aeronautics and space. This is a view foreign competitors may not hold, since aeronautics and space technologies are rapidly converging.

This convergence makes it vital for the U.S. to establish a long-range goal for understanding and

better exploiting this important bridging regime. Increased understanding of the transatmospheric environment and its relationship to maneuvering vehicle requirements must be gained within the near term. This knowledge will be highly significant to the selection of high-payoff developments in propulsion, fuels, materials, system concepts, and other areas which may influence future national options in space and/or aeronautics.

Much of the flight vehicle technology base is expected to develop from the progressive subsonic, supersonic, and hypersonic advancements in aeronautics as well as from Space Shuttle experience. Follow-on advancements in lightweight structural and thermal protection concepts involving new materials systems, artificial intelligence advancements, and blended body aerodynamics are also part of the progressive technology development scenario. Hybrid air-breathing propulsion systems, the truly pacing technology for conventional and routine operations from earth, are now viewed as feasible over the long term. Major fuel system/propulsion advancements may also be possible that would extend vehicle capabilities to high earth orbit missions.

The U.S. must seriously consider that the proliferation of world space activities will eventually call for more conventional forms of transport having the earth-based flexibility possible with transatmospheric flight. There are also very important future military options possible. The extreme altitude and speed capabilities this technology makes possible could enhance military survivability in lethal environments and provide flexible basing for global range weapons delivery, reconnaissance, or space support missions.





# REVITALIZATION STRATEGY

If the vital goals outlined here are to be met, research momentum and efficiency must be energized on a national scale. Toward that end, a strategy is proposed that places primary emphasis on efforts that will revitalize the nation's capacities for aeronautical innovation over the next decade.

## Emphasize Basic Research and Technology

A broad-based national program of basic R&T must be supported and sustained to produce the new concepts and ideas essential to technological advancement. A continuous flow of fundamental knowledge from both public and private research is vital if new advances and breakthroughs are to occur.

### Universities

Much of the nation's basic research, as well as the training of scientific and engineering manpower, is performed within the American university system. A significant expansion of industry and government sponsorship of basic research at the university level is needed to encourage and sustain the important university contribution to America's knowledge and skill base. In particular, increased aeronautical research relationships between industry and the university system will provide valuable impetus for overall aeronautical momentum.

### Government and Industry

On another level, highly important aeronautical programs are conducted directly by government and private industry. Basic research and technology at this level forms the bedrock for future technological progress. Government and industry research furthers physical phenomena understandings and the generic technology evolutions that lead to important new aeronautical advances. A continuity of effort on all these fronts — government, industry, and university — must be stressed to maximize the effects of this highly important aspect of trans-century revitalization.

### Time Frame for Progress

A decisive trans-century momentum in national achievement must be established within the next 10 years. This becomes patently clear in view of the fact that only some 25 years elapsed between the DC-3 technology era and the advent of America's first generation of commercial jet transports. By all indications, future leaps in aeronautics technology will be achieved within much shorter time frames. We can also anticipate, from past aeronautical experience, that the acceleration of technology advancement will lead American society into new frontiers of opportunity. America must be fully prepared to take advantage of these opportunities.

## Address the Issue of Affordability

Sustained preeminence will require both cost and technical superiority from U.S. aeronautics. Affordability, or the cost of acquisition, is a major problem confronting both military and civil aircraft programs today. The Committee believes that cost will remain a major impediment to national progress and competitiveness until more concrete steps toward solution are taken.

Partial solutions can be realized in the technologies directly affecting the product level. Advanced manufacturing and product management concepts are all-important in this respect, but partial solutions are not the answer.

### Energizing the R&T Chain

Product costs are highly influenced by the degree of continuity and effort employed at the early stages of research and technology. The most critical area is technology validation, the mid-phase in the R&T chain. This phase takes potentials identified from basic research (the first phase) and advances them into risk-acceptable readiness; the final phase then entails product application and production. National policies and implementing procedures that influence or direct technology have driven unintended barriers into this critical mid-phase of R&T, causing this vital link in the innovation chain for aeronautics to be short-circuited.

There is no question that achieving technology validation and readiness of high-payoff potentials is the most costly and time-consuming aspect of research and development. It requires more time and more money than many persons in program advocacy positions are prepared to recognize or admit to. In truth, significant accomplishment is required before specific system needs are known or program commitments made. It is seldom fully recognized that production failures, program delays, or cost overruns may have been preordained because the risks in critical technologies were not sufficiently understood, and not reduced by appropriate feasibility demonstration experiments, before program commitments were made.

### Civil and Military Synergy

There are highly constructive synergies that can be brought into play to affect affordability. For example, military advancements stress performance; on the other hand, commercial developments tend to emphasize lowered production costs, vehicle operating efficiency, and high availability with low

*"A continuous flow of fundamental knowledge from both public and private research is vital if new advances and breakthroughs are to occur."*



*"In the Committee's view, the question is not whether these advances will be made . . . only when they will be achieved and by whom."*

maintenance . . . all of which are attributes vital to reducing military costs.

At the production level, the civil industry becomes crucially important, because commercial endeavors provide both continuity and private sector funding to sustain industrial innovation. The 15,000 companies supporting both military and civil aircraft programs depend on civil work for about 60 percent of their aircraft production business. This close interrelation of civil and military enterprise should be viewed and utilized as a strong positive force for aeronautical progress and particularly for the achievement of affordability.

#### Strategy for Improvement

To correct problems that have historically impeded technological development, the following actions should be vigorously pursued:

- Federal contracting procedures should be restructured to reflect a greater distinction between the procurement of research and technology and the procurement of hardware.
- Regulatory policy should encourage cooperative efforts for technology developments among U.S. companies (as is now ongoing between U.S. and offshore companies).
- Federal tax legislation should adequately stimulate private investment in timely technology development.
- All branches of the Government with relevant oversight and/or management responsibilities should strive to maintain the continuity of research and technology development activities.

The competitiveness of future U.S. civil and military aircraft will call for all these measures. But it will take more than aggressive government and industry funding at the validation readiness level. It will require smart money and cohesive policies to create a dynamic and flexible capacity to exploit the full circle of synergies that surrounds U.S. aeronautics.

## SUMMARY

### The Challenge for Preeminence

The Committee believes that the single most crucial challenge facing U.S. aeronautics is that much of the nation's leadership, both in government and in industry, underestimates the depth of foreign aeronautical commitment and resolve. U.S. preeminence can be maintained only by focusing a more aggressive national effort on attainment of the proposed national goals for aeronautical R&D. This U.S. strategy would simultaneously produce both a strengthened defense capability and a position of clear-cut product superiority in the international marketplace.

In the Committee's view, the question is not whether these advances will be made . . . only when they will be achieved and by whom. The benefits are too valuable to remain untapped by competitors and adversaries for long. At the present time, the magnitude of world opportunity, and the extent of technology readiness required to decisively exploit this richness, appear to be largely underestimated in the policies and plans affecting U.S. aeronautics.

### The Agenda for Achievement

The agenda for implementing these goals must create real national growth in R&D. Technical plans must reflect this, and the agenda must also emphasize the major issue for today — affordability. Traditional strengths can and must be utilized more cohesively. Affordability *should* challenge U.S. aeronautics to remove costly compartmentalizations from efforts that ready multi-use technologies important to long-term national goals. We must reshape our policies and procedures and posture our efforts toward working more effectively, if the nation is to compete more decisively. National affordability should *again* challenge U.S. aeronautics with the hard fact that military affordability is implicitly linked to the vitality of civil exploitations of technology. In view of this, and in the face of high payoffs and growing dual-use trends, the massive control of critical technologies must be questioned.

The greatest challenge confronting the American realization of the potentials implicit within these goals may be that of redirecting the force of American will into specific, cohesive, and bold steps toward the future.



# AERONAUTICAL POLICY REVIEW COMMITTEE

John E. Steiner  
(Chairman)

Harold D. Altis  
Executive Vice President  
McDonnell Aircraft Company

John Boppart  
Vice President of Engineering  
Garrett Turbine Engine Company

Crawford F. Brubaker  
Deputy Asst. Secretary for Aerospace  
Department of Commerce

Raymond S. Colladay  
Deputy Associate Administrator for  
Aeronautics & Space Technology  
NASA

Robert S. Cooper  
Director, Defense Advanced Research  
Projects Agency — DoD

Thomas D. Cooper  
Assistant Secretary of the Air Force  
for Research, Development, and Logistics

Eugene E. Covert  
Director, Gas Turbine and Plasma Dynamics Laboratory  
MIT

J. Roger Fleming  
Vice President, Operations  
Air Transport Association

Bastian Hello  
President, North American Aircraft Operations  
Rockwell International

Charles B. Husick  
Senior Vice President  
Fairchild Industries

James N. Krebs  
Vice President, Technology and Management Assessment  
General Electric Company

Walter S. Luffsey  
Associate Administrator for  
Aviation Standards — FAA

Robert R. Lynn  
Senior Vice President of Research and Engineering  
Bell Helicopter Textron

Robert B. Ormsby  
President  
Lockheed Aeronautical Systems Group

John M. Swihart  
Vice President  
Government Technical Liaison  
The Boeing Company

## OSTP

Maurice A. Roesch, III  
Assistant Director  
National Security and Space

Robert T. Williams  
Executive Secretary





Executive Office of the President  
Office of Science and Technology Policy  
Washington, D.C. 20500



# **AERONAUTICAL RESEARCH AND TECHNOLOGY POLICY**

## **VOLUME I: SUMMARY REPORT**



Executive Office of the President  
Office of Science and Technology Policy  
November 1982



# AERONAUTICAL RESEARCH AND TECHNOLOGY POLICY

## VOLUME I: SUMMARY REPORT



Executive Office of the President  
Office of Science and Technology Policy  
November 1982



## CONTENTS

|                                                                                        | <u>Page</u> |
|----------------------------------------------------------------------------------------|-------------|
| I. INTRODUCTION . . . . .                                                              | 1           |
| II. KEY TERMINOLOGY . . . . .                                                          | 3           |
| III. FINDINGS AND RECOMMENDATIONS . . . . .                                            | 9           |
| IV. ORIGINS AND HISTORY . . . . .                                                      | 13          |
| V. FOREIGN CHALLENGES: CIVIL COMPETITION<br>AND MILITARY THREAT . . . . .              | 15          |
| VI. NEEDS AND OPPORTUNITIES . . . . .                                                  | 17          |
| VII. NATIONAL GOALS IN AERONAUTICS . . . . .                                           | 21          |
| VIII. GOVERNMENT ROLES IN AERONAUTICAL<br>RESEARCH AND TECHNOLOGY . . . . .            | 25          |
| IX. AERONAUTICAL FACILITIES . . . . .                                                  | 33          |
| X. TECHNOLOGY TRANSFER . . . . .                                                       | 35          |
| APPENDIX A--Steering Group Members . . . . .                                           | 37          |
| APPENDIX B--Working Group Members . . . . .                                            | 39          |
| APPENDIX C--Industry Responders to OSTP<br>Questionnaire Dated 18 March 1982 . . . . . | 41          |



## I. INTRODUCTION

Since 1915, the U.S. government has provided national leadership and significant financial support for the development of aeronautical research and technology (R&T). Approximately one-third of the U.S. defense budget is spent on aeronautical products and their support, and commercial aircraft sales contribute the largest positive balance of trade among U.S. manufactured goods. Superior aeronautical R&T has been essential to the current U.S. preeminence in both military and civil aviation. Given the ever-increasing Soviet military pressures and foreign commercial aviation competition, future preeminence depends on effective U.S. R&T programs. Significant questions have been raised concerning the appropriateness and effectiveness of current U.S. aeronautical R&T policies, and the U.S. government's role in support of aeronautical R&T.

In response to these questions, the Office of Science and Technology Policy (OSTP), in the Executive Office of the President, chaired a multi-agency study group that reviewed national aeronautical R&T policy. The following central issues and/or questions were addressed:

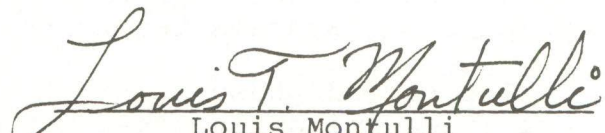
- o Is aeronautics a mature technology and is continued investment justified by potential benefits?
- o What are the proper government roles in aeronautical R&T and does the present institutional framework satisfy these roles or should it be changed?

The study was conducted from February 1982 through August 1982 by an interagency working group and a senior-level steering group consisting of individuals from: OSTP (chair), the Office of Management and Budget (OMB), Council of Economic Advisors (CEA), Department of Defense (DOD), National Aeronautics and Space Administration (NASA), Department of Transportation [Federal Aviation Administration (FAA)], and Department of Commerce (DOC). Two observers, one from industry and one from the university community, also participated. Further data were acquired from an extensive questionnaire sent to aeronautical industry leaders and from interviews with their representatives. While considering the broad range of aeronautics and aeronautical R&T, the study group concentrated on the air vehicle and only peripherally addressed external weapon systems and air traffic control systems. The study



group reviewed past and current government policies on aeronautical research, and extensively addressed current and future needs, capabilities, and incentives for such research in both government and private industry. Analysis of policy options and alternatives resulted in specific findings and recommendations. This summary report, Volume I, provides the study findings and recommendations in brief, and a summary of the major rationale that led to these results. Volume II provides analyses and data to support the results. Volume I was fully reviewed and approved by all agencies represented on the Steering Group (OSTP, OMB, CEA, DOD, NASA, FAA, DOC) and further reviewed and approved by the National Security Council (NSC) and the Office of the U.S. Trade Representatives (USTR). Volume II was reviewed and approved by members and agency support staff on the working group. This study was accomplished to aid senior Administration officials in establishing and implementing policies affecting aeronautical R&T.

  
Victor Reis  
Steering Group Chairman

  
Louis Montulli  
Working Group Chairman



## II. KEY TERMINOLOGY

The following definitions have been developed to aid in the understanding of the study recommendations, particularly with respect to government roles. The following definitions differ from those used in previous studies. The present definitions divide the research and development (R&D) process into three major, sequential phases: R&T development, technology demonstration, and system development. As defined here, R&T consists of the first two phases.

The initial phase, R&T development, consists of activities primarily aimed at producing physical understanding, new concepts, design data, and validated design procedures for aircraft systems, subsystems, and components. It consists of activities ranging from theoretical analysis to laboratory investigations to flight-testing experimental aircraft. These activities tend to have a large degree of uncertainty in their outcome. They are typified by the activities conducted in DOD budget categories 6.1, 6.2, and some of 6.3A, and in NASA budget categories "R&T Base" and, with some exceptions, "Systems Technology."

The second phase, technology demonstration, consists of activities primarily aimed at demonstrating improved subsystem or system characteristics to provide the development and manufacturing decisionmaker with the confidence that the anticipated improved level of performance is indeed achievable in a new system. The technology demonstration efforts are characterized by testing configurations similar to the intended applications and by a modest degree of uncertainty in outcome. These efforts are the final technology activity before system development, but before a decision to develop a specific system is made. A transition activity, which occurs during some of the large-scale testing stages of technology development and during technology demonstration, ensures effective and efficient handoff to industry for military and civil development.

The third phase, system development, consists of activities aimed at producing a specific aircraft or specific aircraft system for operational use (beginning with DOD budget category 6.3B).

The key criterion in applying the definitions of technology development and technology demonstration is the nature of the intended results, not the physical mechanisms selected to



conduct the effort. Because a single program may be intended for more than one purpose, categorizing an activity as either technology development or technology demonstration therefore requires the exercise of informed judgment, with emphasis on the intended output (understanding, design data, validated design procedures versus demonstrated system/subsystem performance) and on the technical risk or the research questions being addressed.

The following examples\* of DOD, NASA, and industry current or recent activities show the broad range of R&T development:

- o DOD [6.1] propulsion programs in fundamental internal aerothermodynamics, combustion processes, turbo-machinery turbulence studies, and analytical methods development
- o NASA [R&T Base] exploration of the mechanical breakup of boundary layer eddies to reduce turbulent drag
- o NASA [R&T Base] analytical and experimental examination of aeroelastic behavior of new structural concepts, including flight tests on remotely piloted vehicles
- o DOD [6.2] development and testing of propulsion components, including compressors, turbines, and combustors, and similar [6.2] activities on structural components and aerodynamic configurations
- o NASA [R&T Base] analytical and experimental investigations of bearings, gears, and lubricants, including studies of friction and wear, and determination of dynamic loading effects on material behavior
- o DOD [6.3A] exploration and improved understanding of interrelationships between life and performance in advanced high-temperature engines (as part of Joint Technology Demonstrator Engine program)
- o NASA [Systems Technology] program to generate and test new concepts for practical systems to maintain laminar

---

\*These examples are presented to clarify the scope and character of aeronautical R&T development and technology demonstration phases. They are not intended to imply any assessment of the merit of these programs.



flow on large subsonic aircraft, including: analytical derivation of airfoils, suction requirements, and structural systems; and wind-tunnel and flight-testing of promising concepts

- o Joint DOD/NASA [6.3A/Systems Technology] experimental flight tests on tilt-rotor concepts to generate a design data base and to validate aeroelastic analysis and design procedures for future tilt-rotor vehicles
- o Joint DOD/NASA [6.3A/Systems Technology] flight-testing on modified fighter to investigate experimental mission-oriented subsystems, including coupled flight control and fire control, and independent mode motion/direction control
- o NASA [Systems Technology] construction of and flight research on an upper-surface-blowing research airplane to develop handling qualities and design criteria, basic design data, and validated analysis and engineering procedures for propulsive-lift aircraft
- o NASA [Systems Technology] program to develop data base and design criteria for small- and medium-size composite primary aircraft structures, including: analysis, design, and testing of components; generation of data on design procedures, fabrication techniques, and operational environment effects; service-life testing of representative transport rudders, elevators, and ailerons; and flight-testing of transport horizontal stabilizer
- o NASA [Systems Technology] program investigating new energy-efficiency concepts in aerodynamics and active controls technology for application to future transport or patrol aircraft, including analysis, wind-tunnel testing, and flight research on high-aspect-ratio supercritical wings, winglets, nacelle/airframe integration, and active control system concepts
- o Industry development of proprietary structural analysis and design techniques.

The following are examples of technology demonstration:

- o DOD [6.3A] performance demonstration of complete engine systems (as part of Joint Technology Demonstrator Engine program)



- o NASA [Systems Technology] flight demonstration of an active-control wing load alleviation system designed for a specific wide-body transport (a phase of transport energy-efficient technology development program)
- o DOD [6.3A] design, fabrication, and flight demonstration of an all-composite fuselage using a nonmilitary helicopter to provide confidence in projected cost, weight, and manufacturability
- o NASA [Systems Technology] performance demonstration portion of integrated-core/low-spool assembly testing that incorporated advanced high-efficiency turbofan engine components as final 10 percent of energy-efficient engine technology development program
- o NASA [Systems Technology] program in which a modified JT8D engine (with larger fan diameter to increase bypass ratio and reduce noise) was installed and demonstrated on a DC-9 airplane to assist the FAA in considering the application of more stringent noise regulations to existing transport aircraft
- o Joint DOD/NASA [6.3A/Systems Technology] flight-testing to investigate and demonstrate performance of aileron-rudder-interconnect flight control system modification on an operational fighter to improve handling qualities in tracking and at high angles of attack
- o Industry flight-testing of multiple engine and nacelle combinations on a B-747 test-bed aircraft.

The following are examples of systems development:

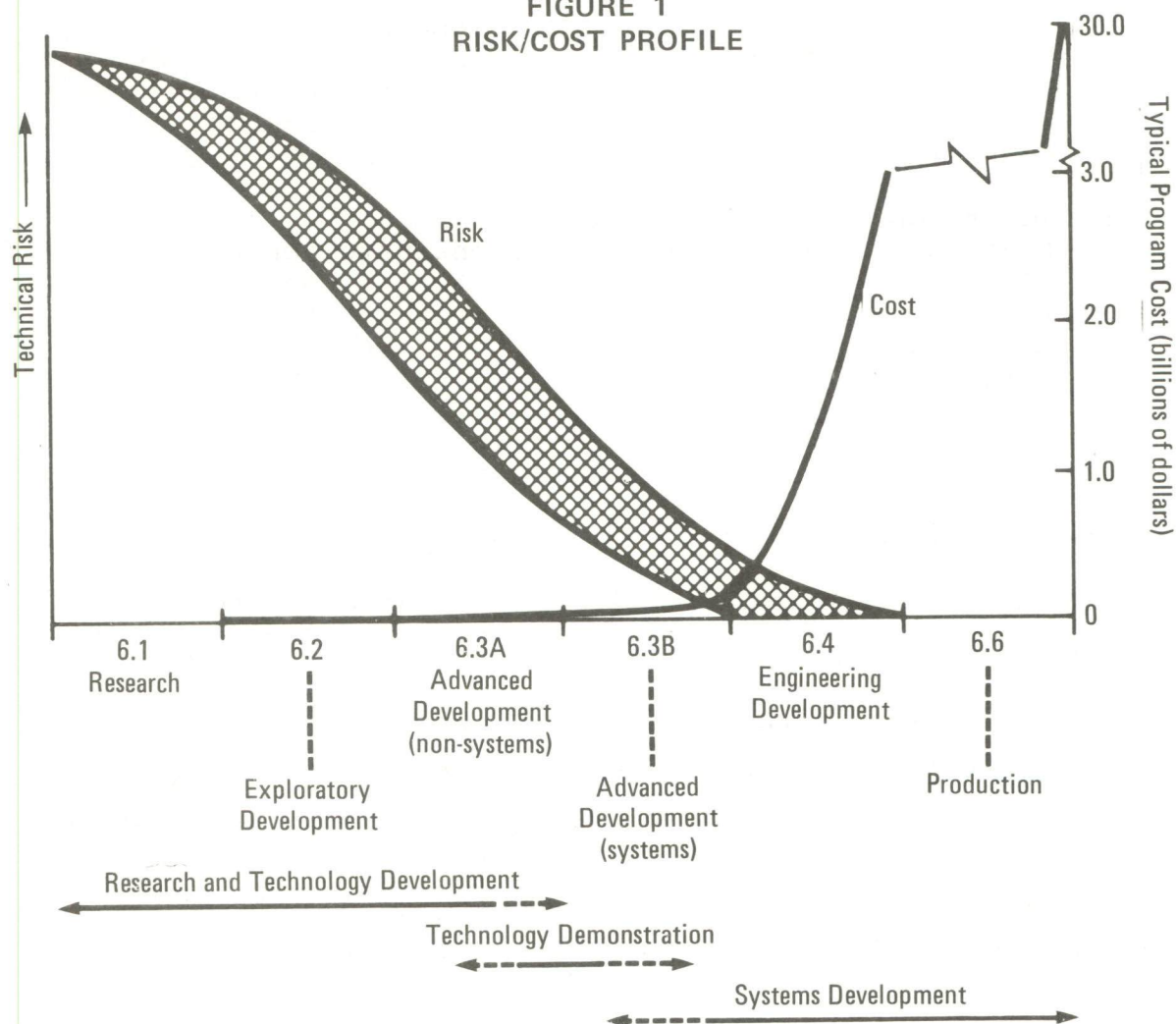
- o DOD [6.3B] advanced tactical fighter activity, the first phase of a development program for a new fighter aircraft system
- o DOD [6.4] B-1 full-scale development and prototype testing
- o Industry full-scale development and prototype testing of B-757 and B-767.

The three phases represent a continuous spectrum of related activities in the R&D process, in which technology



is generated, demonstrated, and transferred into system development. Figure 1 illustrates the typical cost variation of a single program in the category listed, not the cost of a single aircraft program as it proceeds through the R&D spectrum. As expected, development and production costs dominate R&T costs. Superimposed is a notional representation of the technical risk associated with the development of new technology. This is presented to illustrate that in the early research stages--i.e., 6.1, 6.2--the emerging concept is generally a high technical risk from the development manager's perspective. As successful technology programs proceed through the advanced development and demonstration phases, the technical risk is lowered by providing the evidence required to prudently accept the advanced technology into engineering development.

FIGURE 1  
RISK/COST PROFILE





### III. FINDINGS AND RECOMMENDATIONS

This chapter presents the study group's findings and principal recommendations.

#### Findings

The study group presented the following findings:

##### 1. Importance of Aeronautics

- o The United States depends heavily on technical superiority of military aircraft for national defense--approximately one-third of the DOD budget is for procurement, maintenance, and operation of aeronautical systems.
- o Civil aircraft are the dominant common carrier mode of inter-city travel in the United States. The U.S. government is responsible for air traffic control and safety.

##### 2. Nature of Aeronautics Industry

- o A healthy, competitive civil aeronautics manufacturing industry reduces the cost of providing an essential military industrial base and wartime mobilization surge capacity.
- o A successful aeronautics industry requires a continuous input of multidisciplined advanced technologies from both inside and outside the aeronautical industry.
- o The capital investment required to develop a new aircraft often exceeds the net worth of the sponsoring company.
- o Antitrust laws have constrained U.S. companies from domestic joint ventures but have often allowed international joint ventures. However, industry has not yet attempted to take full advantage of recent relaxation of some antitrust constraints.
- o Aeronautics industry prosperity is influenced by worldwide economic conditions, foreign trade policies, and government policies, as well as R&T.



### 3. Aeronautical R&T

- o Large gains are expected from continued aeronautical R&T.
- o Continued strong advancement in aeronautical R&T is essential for national security and for continued success of the U.S. civil aeronautics industry.
- o The aeronautical R&T development activities in support of future military and civil applications are largely common, thereby compounding the value of the resulting research.
- o Industry-funded aeronautical R&T is predominantly near-term focused. Private companies have been generally unable to effectively capture the benefits of internally funded aeronautical R&T development. As a result, a market disincentive exists for such R&T activities.

### Recommendations

The study group made the following recommendations:

#### 1. National Goals in Aeronautics and Aeronautical R&T

Recognizing aviation's unique role in national defense and its significance in the U.S. transportation system, the study group recommends the following goals for industry and government:

- o In Aeronautics
  - Maintain a superior military aeronautical capability.
  - Provide for the safe and efficient use of the national airspace system, vehicles operated within the system, and facilities required for those operations.
  - Maintain an environment in which civil aviation services and manufacturing can flourish.
  - Ensure that the U.S. aeronautical industry has access to and is able to compete fairly in domestic and international markets, consistent with U.S. export policy.



o In Aeronautical R&T

- Ensure the timely provision of a proven technology base to support future development of superior U.S. aircraft.
- Ensure the timely provision of a proven technology base for a safe, efficient, and environmentally compatible air transportation system.

2. U.S. Government Role

After considering alternative policies consistent with national needs, objectives, and the U.S. economic system, the study group recommends:

- o Government support for aeronautical R&T development and for military aeronautical technology demonstration, consistent with overall government priorities and the availability of funds.

3. Government Agency Roles

The study group recommends that the government maintain the present institutional framework in which

- o DOD funds, directs, and implements aeronautical technology development and demonstration programs directed specifically toward military applications.
- o NASA funds, directs, and implements aeronautical R&T development programs and supports military aeronautical technology demonstration programs.
- o NASA and DOD encourage transfer of aeronautical research results to and within U.S. industry.
- o Both DOD and NASA manage, maintain, and operate aeronautical research, development, test, and evaluation facilities.
- o The FAA, with NASA and DOD support, is responsible for air traffic control and safety-related aeronautical R&T.

The study group found the general coordination of NASA and DOD programs to be both frequent and highly professional. However, since the creation of NASA in 1958 and the elimination of the NACA Advisory Board, senior aeronautical policy coordination



between NASA, DOD, and industry has been weakened. The panel recommends

- o The reinstitution of a high-level NASA, DOD, and industry committee, which would meet at least once a year to review and coordinate all aeronautical R&T policies.

#### 4. Facilities

The study group examined the capabilities and limitations of the existing and developing aeronautical facilities and concluded that present and planned major facilities are adequate. However, continued maintenance and modernization will be required. Specifically, improvements to and expansion of computational capability should be considered.

Disparity in approach to user charges between DOD and NASA facilities creates a significant potential for inappropriate program distribution and use of some facilities. It is recommended that

- o NASA and DOD develop a common framework of appropriate incentives and proper joint management coordinating mechanisms to ensure that the use of NASA and DOD aeronautical facilities is consistent with government priorities and the needs of the user programs.

#### 5. Technology Transfer

The study group viewed the rapid, uncontrolled dissemination of unclassified aeronautical R&T data by the United States to foreign parties as detrimental to U.S. preeminence in military and civil aviation. The group further determined that significant, high-quality aeronautical R&T is being accomplished by many developed countries. The United States is not now fully collecting and utilizing this available, unclassified foreign technology. After a study of technology transfer, including a review by DOD and other agencies, the study group recommends that

- o NASA and DOD, in conjunction with other U.S. government and non-government agencies, review the procedures for disseminating aeronautical R&T documents.
- o NASA provide a plan for a centralized means of collecting unclassified aeronautical R&T documents, conference proceedings, and meeting results.



#### IV. ORIGINS AND HISTORY

An historical review provides an insight into the major government policies and world events that influenced the development of U.S. aeronautics. The government's concern for military aeronautical needs repeatedly inspired major advances in the aeronautics industry. The following summarizes this evolutionary and cyclic process.

The period from the first powered flight in 1903 to 1914 can be characterized by aggressive European aviation development and U.S. government lack of interest. By 1914, only 23 of the 3,700 airplanes in the world were U.S. owned. With the imminence of World War I, the Aviation Section of the Signal Corps was formed in 1914-15, and the National Advisory Committee for Aeronautics (NACA) was established to conduct aerodynamic research. The services and industry were assigned responsibility for research on aircraft structures and engines.

At the end of World War I, the government employed several methods to sustain the momentum of the newly formed aviation industry for military aircraft production. In 1925, President Coolidge appointed a board to study the problems of aircraft development for national defense. The board determined that development of a strong civil aviation industry was important to maintain a sound manufacturing base to meet national defense aircraft production needs. Their conclusions cited several impediments to air transportation progress, including the excessive burden on private capital for developing aircraft and facilities and the uncertainties regarding civil and military demand and government regulation. One key result was that, in 1926, the Department of Commerce was chartered to regulate and encourage civil aviation and to establish the civil airways systems. Subsequent proliferation of airlines as a form of public transportation resulted in the Civil Aeronautics Act of 1938, which established the Civil Aeronautics Board (CAB).

In the late 1930s, the more aggressive research efforts in Europe, particularly in Germany as reported in 1939 by Charles Lindbergh, were again recognized as having successfully provided a substantial European lead in military aviation, particularly through advanced propulsion and structural systems. The U.S. response was to form two additional laboratories, the NACA Ames Aeronautical Laboratory, established in 1940, and the NACA Aircraft Engine Research



Laboratory (now Lewis Research Center), which became functional in 1942.

NACA's large growth during World War II and the demands of the war effort made the roles of military, industry, and NACA difficult to distinguish. However, early postwar policy defined the NACA role as fundamental research: industry was responsible for development and the military for evaluation. In 1949, Congress passed the Unitary Wind Tunnel Act, which created a cooperative program for jet-age aircraft R&D among NACA, the military, and the aircraft industry.

Throughout the 1950s, NACA, the military services, and industry teams jointly conducted long-range research, much of which centered around the X-series of research aircraft. The military procured these vehicles, built by industry to government specifications, for joint NACA/DOD research programs.

With the formation of NASA in 1958, incorporating NACA and its laboratories, the NACA/NASA manpower devoted to aeronautical research dropped from 5,700 in 1957 to under 1,400 in 1963. Much of the NASA aeronautical research was deferred and its manpower transferred to support the space activity. The major burden for providing R&T to meet the continuing military needs was shifted to DOD, although at a significantly decreased level. Aeronautical research in NASA began to resurge in the late 1960s, inspired by aircraft noise problems, a growing concern for future energy shortages, and recognized military requirements. This renewed growth gave fresh impetus to government/industry cooperative research, produced direct results, and brought NASA aeronautics manpower to its current level of approximately 3,800.

The aerospace industry is a high-technology industry that has evolved into a major U.S. enterprise that provided about 1.2 million jobs in the United States in 1981; development and production of aircraft, engines, and parts accounted for 657,000 jobs in 1981. Approximately one-third of the U.S. defense budget is now spent on aeronautical products and their support. In 1981, U.S. manufacturers' direct sales of aircraft, engines, and parts totaled \$34.7 billion and produced a positive trade balance of about \$13 billion, the largest for any U.S. industry group. Major factors influencing the future prospects of U.S. manufacturers to sustain market growth include worldwide economic conditions, foreign trade policies and practices, government policies, and the sustained development and availability of new and advanced technology.



## V. FOREIGN CHALLENGES: CIVIL COMPETITION AND MILITARY THREAT

The U.S. aeronautics industry was preeminent at the end of World War II, after which aeronautical capabilities gradually reemerged in each of the major European countries, paced by the Soviet Union. Very aggressive R&D efforts across the spectrum of aeronautics and space were nationally supported in both Eastern and Western Europe. The Western Allies initially concentrated on military systems in concert with, and heavily supported by, U.S. R&T and co-production agreements.

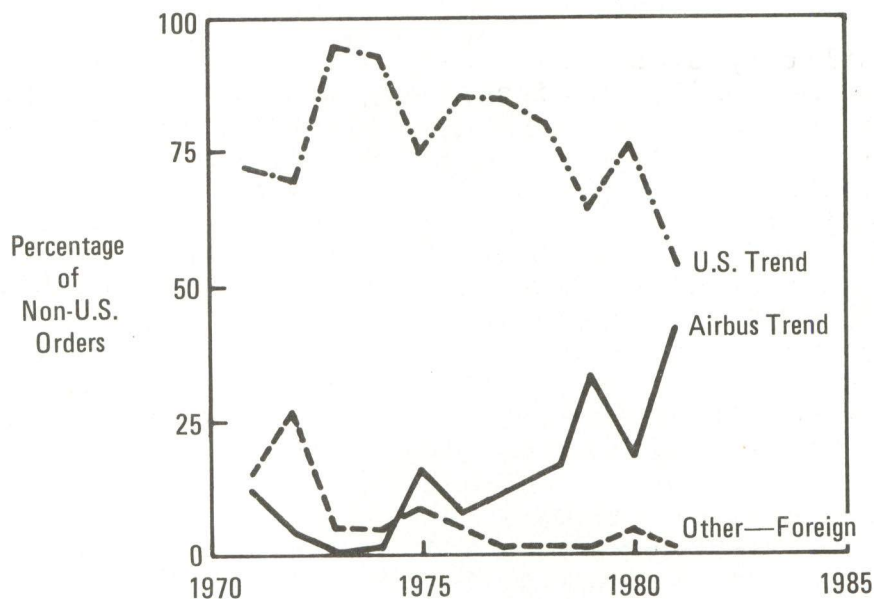
Based on the military-derived technology and production base, application to civil products slowly developed in Western Europe. The United Kingdom had an initial lead after World War II as a result of their work in jet engine technology. The British Comet led the market in the application of advanced technology until structural problems slowed progress. The French Caravelle set the initial pace for aft-fuselage-mounted engines on jet transports, but it was overtaken by the U.S. industry as market requirements evolved to larger size aircraft. Initial market selections by the European manufacturers usually avoided direct competition with the dominant U.S. industry, which had captured approximately 90 percent of the world civil market in 1970. Ultimate formation of the multinational consortia in Western Europe, underwritten by large government subsidization, has resulted in substantial competition in today's world aviation market. Figure 2 illustrates the degree of recent European success in the civil transport market competition.

Aggressive programs for the development of competitive positions in the world market for aeronautical products are emerging in several areas of the world. Embraer, in Brazil, has become a major factor in the light transport or commuter market. Japan, under the guidance of the Ministry of International Trade and Industry (MITI), clearly intends to become a major partner in world aviation sales. In Europe, multinational consortia, as well as individual national efforts, now provide competitive products in nearly all fields of military and commercial aviation.

The numerical superiority of our principal military adversary, the Soviet Union, is unquestioned, as is the fact that Soviet production rates for all classes of military aircraft continue to be much higher than their western counterparts.



FIGURE 2  
CIVIL TRANSPORT AIRCRAFT MARKET POSITION



★ It is estimated that Soviet production rates for tactical aircraft alone are twice those of the United States.

The nine Soviet research institutes working with the eight design bureaus under centralized direction continue to significantly improve existing production aircraft and a range of new aircraft concepts, some of which appear to be nearing production status. Recent introduction into the Soviet military fleet of such aircraft as the YAK-36 (Forger) vertical takeoff and landing (VTOL) combat aircraft, the MI-24 (Hind) helicopter, and the identification of a new variable-sweep bomber larger than either the TU-26 (Backfire) or the U.S. B-1, all indicate an intense concentration on continued improvement of military capability.

Soviet dedication of substantial resources to improved aeronautical research capabilities is evidenced by major high-Mach-number facility construction projects at several Soviet research institutes. Aggressive Soviet R&T programs are a constant challenge to the margin the United States now maintains through technically superior equipment. To preserve that margin, continued advancement in U.S. technological capability in many areas such as aerodynamics, structures, propulsion, avionics, radar, and missiles--as well as in range, payload, speed, altitude, and maneuver capability--is a critical requirement.



## VI. NEEDS AND OPPORTUNITIES

U.S. military strategists depend on offsetting Soviet numerical superiority in aircraft by producing fewer yet technologically superior vehicles combined with improved tactics and training. This policy is believed to be advantageous both tactically and economically. However, margins of technical superiority are highly perishable and must constantly be reestablished. Examination of alternatives yields a range of continuing R&T requirements. For example, higher speeds, enhanced high-speed maneuverability, and low observable or stealth technology are key areas strongly supported by military planners. A constant goal of both military and civil aircraft designers is an aircraft with longer range and greater payload for less cost,

Although a vital national security imperative exists and future economic success of a vital U.S. industry is involved, it is appropriate to question whether, after 80 years of intense aircraft development, there are enough potential improvement gains to warrant future aggressive research investment. The study group has strongly concluded that the answer is yes.

To support this conclusion, Volume II of this study documents a broad range of technological advancements possible through a continued strong aeronautical R&T effort. While the improvements in individual aeronautical disciplines can be significant, multiple technologies, when integrated synergistically, can provide much larger improvements in system capability. The following examples illustrate the scope and magnitude of the potential advances in key technical disciplines and some of the resulting system benefits, achievable by the 1990s as related to the current state of the art:

### o Aerodynamics

- Double the supersonic lift to drag ratio
- Laminar flow control for a 20- to 40-percent reduction in friction drag
- Continuously variable camber-wing design to optimize aerodynamic performance and significantly increase range and maneuverability



- Optimized configurations to reduce radar cross section
- o Structures and material
  - Composite materials to reduce structural weight by 20 to 30 percent
  - Aeroelastic tailoring of aerodynamic surfaces to reduce weight and improve maneuver performance
  - Superplastic forming and diffusion bonding of metals to reduce fabrication costs
- o Propulsion
  - Increased thrust-to-weight ratios by 20 percent
  - Reduced specific fuel consumption by 15 to 20 percent
- o Flight Control/Electronics
  - Active controls to increase fuel efficiency by 10 to 15 percent
  - Ultra-reliable systems with  $10^{-9}$  failure rates.

For fighter aircraft, combining advanced aerodynamics, structures, and propulsion technology can enable tactical aircraft to achieve

- ✓ o Significantly reduced detection range against threat radars and sensors for infrared and other observables
- o Small ship deck operations
- ✓ o Wider missile launch envelopes
- o Operation from short/damaged runways
- o 25- to 40-percent reduction in design gross weight for the same mission range
- o 15- to 25-percent life-cycle-cost reduction compared to current costs.



For strategic bombers, survivability, weapon effectiveness, and range/payload are vital to mission success. Advanced aeronautical technologies applied to both the airframe and the weapon can yield a strategic system with

- o Increased survivability through increased speed, decreased operating altitude, extended range, and decreased observables
- ★ o Ability to launch super/hypersonic long-range stand-off weapons to attack time critical targets
- o 25-percent reduction in design gross weight for the same mission range.

For large military and civil transport aircraft, productivity and direct operating costs are figures of merit. Integrating advanced aeronautical technologies will provide

- o Rapid worldwide deployment with 30-percent increase in productivity
- o Twice the range/payload of the C-5A with only one-third more takeoff weight
- o 20- to 40-percent reduction in maintenance hours per flight-hour
- o 50- to 100-percent increase in fuel efficiency
- o 30- to 45-percent reduction in direct operating costs
- o 10- to 15-percent reduction in acquisition cost.

Applying advanced integrated technologies to military and civil rotorcraft will allow

- o 100-percent speed and range increase
- o Worldwide self-deployment capability
- o 50-percent decrease in noise and vibration
- o 25-percent reduction in fuel used for same mission
- o 25- to 50-percent life-cycle-cost savings.

For cruise missiles and remotely piloted vehicles, survivability and range/payload are critical to mission success. Applying advanced integrated aeronautical technologies will provide

- o 60-percent increase in range for the same launch weight
- o 50-percent decrease in weight for the same range
- o Greatly increased survivability due to higher speed and lower observability
- o Viable intercontinental range cruise missiles.

The current projection of the Free World market for all civil aircraft is estimated to be \$185 billion (FY 1982 dollars) in the next decade. U.S. military aviation procurement demands in the next decade are estimated to exceed \$350 billion (FY 1982 dollars). Incorporation of these advanced technologies is expected to produce, by the year 2000, an increased military capability equivalent to \$20 billion annually invested in additional units, as well as provide a continuing civil market advantage.

Our potential military adversaries and U.S. industries' commercial competitors are aggressively pursuing these and other opportunities. The U.S. government and industry must continue to maintain their leadership in aeronautical R&T or lose current military and economic advantages.



## VII. NATIONAL GOALS IN AERONAUTICS

From the study group's examination of aeronautics--historical, current, and future--it is clear that a superior capability in aeronautics is a unique and vital asset to the national security and significantly influences U.S. international negotiating power. The critical reliance on superior aircraft for national defense and the position of civil aeronautics as a key manufacturing group for wartime mobilization and international travel, coupled with the aggressive foreign challenges in every aspect of aviation, warrant serious national attention. A review of policy statements and recommendations (contained in Chapter VII of Volume II) over the past 15 years shows consistent agreement with this finding.

A statement of national goals relative to aeronautics and aeronautical R&T forms a useful basis for the subsequent establishment and implementation of these R&T policies. The study group recommends the following national aeronautics and aeronautical R&T goals for government and industry.

### Aeronautics

#### 1. Maintain a superior military aeronautical capability.

The design, development, manufacture, and operation of military aircraft and their weapon systems are vital to the national defense. The constant ensurance of aeronautical superiority in terms of operational and combat effectiveness, survivability, dependability, and affordability for all types of military aircraft is a high-priority national goal.

#### 2. Provide for the safe and efficient use of the national airspace system, vehicles operated within the system, and facilities required for those operations.

The air mode is a major component of the U.S. public transportation system. It is essential that the national air traffic control and navigation systems be equipped and operated effectively, and that aircraft airworthiness, airline operations, crew qualifications, and airport facilities be certified with paramount concern for public safety.

3. Maintain an environment in which civil aviation services and manufacturing can flourish.

A healthy, competitive industry for both military and civil products ensures the most cost-effective, technically advanced products and supports a healthy, up-to-date industrial base for military surge capability.

4. Ensure that the U.S. aeronautical industry has access to and is able to compete fairly in domestic and international markets consistent with U.S. export policy.

U.S. aeronautical products compete in a marketplace that is international and characterized by strong government involvement. Such government involvement is based on a need to protect the military and industrial base of individual countries. Foreign companies are generally wholly or partially government owned and are strongly influenced by government policymakers. Foreign government support takes the form of development subsidies, or low-interest loans, attractive sales financing and other sales inducements, directed flag airline procurement, embassy sales assistance, and direct support of research, technology, and development.

The U.S. government provides support for the U.S. aeronautics industry through the development and procurement of military aeronautical systems and funding of NASA and DOD aeronautical R&T, but it has traditionally avoided direct subsidies. Rather than try to match the form and substance of foreign government subsidies for the aeronautics industry, the U.S. government has, in addition to military procurement and R&T support, employed direct reactive actions, including EXIM Bank assistance for exporters, threat of/or imposition of countervailing duties in appropriate cases of trade distortive import penetration, and attempts to discipline the trading activities of other countries through the negotiation of international trade agreements and understandings. The GATT Agreement on Trade in Civil Aircraft is one such agreement; the OECD Arrangement on Official Export Credits (including its side agreements called the "Standstill" and the "Commonline") is another.



## Aeronautical R&T

1. Ensure the timely provision of a proven technology base to support future development of superior U.S. aircraft.

Achievement of the stated goals of military superiority, a safe and efficient air transport system, and a favorable environment for civil aviation depends on improved productivity and advanced aeronautical technology.

2. Ensure the timely provision of a proven technology base for a safe, efficient, and environmentally compatible air transportation system.

This goal relates to the technology and technical data base required to operate the national airspace system and certify aircraft airworthiness. It includes the R&T required to improve and operate air traffic control and navigation systems equipment, and that required to establish a base of understanding to meet government responsibilities regarding airworthiness certification of new U.S. or foreign aircraft, including structural concepts and materials, advanced aerodynamics, propulsion, controls, and terminal-area operating systems.

### VIII. GOVERNMENT ROLES IN AERONAUTICAL RESEARCH AND TECHNOLOGY

The analyses and formulation of policy regarding government roles in aeronautical R&T must be guided by the general policies for all government R&T as well as specific, pertinent considerations. Current administration policy guidance for direct government support of any form of R&T requires that

- o The results of the project are required to support clearly established government responsibility.
- o The benefits of the R&T are not likely to be appropriate by private firms, and such firms are not likely to undertake the project without additional incentive, and direct support is the most effective and efficient means of providing the needed incentive.
- o Its priority is sufficiently high for it to successfully compete for available federal funds.

The panel, in formulating its recommendations, considered each of these general R&T policy criteria.

1. Is aeronautical R&T required to support a clearly established government responsibility?

Yes.

The United States relies heavily on aircraft for its national defense. The magnitude of this dependency is illustrated by the fact that approximately one-third of the DOD budget is for procurement, maintenance, and operation of aeronautical systems. In addition to its economic value, this civilian industry infrastructure provides an in-place (non-government funded) wartime mobilization capability important for national security. U.S. military planners have long depended on offsetting Soviet numerical superiority with fewer yet technologically superior vehicles. It is important to have the continued capability to support this dependence, since DOD believes this to be tactically and economically advantageous, thus providing the country with the best, most economical defense. Further, the national responsibility to provide a safe national airspace system requires continued R&T to meet changing requirements and needs.



The panel has chosen to express its recognition of this clear national responsibility through its recommendation for national aeronautical R&T goals.

2. Are the benefits of aeronautical R&T likely to be non-appropriable by private firms, and are such firms unlikely to undertake such research without additional incentive, and is direct support of aeronautical R&T the most effective and efficient means of providing adequate incentive for the foreseeable future?

Yes.

The U.S. aeronautics industry has generally been able to capture the benefits of aeronautical R&T, as is apparent from the success of the products resulting from superior technology, such as the development of large commercial transports and U.S. military aircraft. Most of the civil aeronautical products now on the market are the result of development investments by industry. However, U.S. government investments have supported most aeronautical R&T on which industry has depended. For example, major aeronautical firms, such as Boeing, spend less than 1.0 to 1.5 percent of their privately funded R&D budget on aeronautical R&T development activities, which is defined as research ending 2 to 3 years before start of system development. Industry is, however, being further encouraged to increase their private R&D by the specific tax reductions and tax credits in the Reagan Administration's Economic Recovery Program. This is expected to motivate the growth of corporate sales and profits, which, in turn, is a principal means and motivation for further corporate investments in R&T.

However, some factors limit the extent of the aeronautics industry's private investment in R&T:

- o There are commercially attractive investments that, even with the additional incentives provided by the Economic Recovery Program, may require financial resources that are beyond the ability of individual firms to generate or borrow.
- o The benefits of some R&T development may be so widespread that specific applications may not be readily foreseen or the full value of the benefits may not be captured by individual firms within the characteristically long-time horizons typical of aeronautical R&T investments.

- o The results of aeronautical R&T are often knowledge or expertise based and, therefore, very difficult to patent and protect for very long periods of time.

An obvious approach to the problem of wide application is for two or more firms to share the cost of the required R&T. However, many firms perceive ambiguities in the interpretation of antitrust statutes that inhibit attempts to establish joint ventures among domestic firms. These ambiguities lead to a risk that a joint venture, once initiated, may have to terminate if it is later judged to not comply with the requirements of the antitrust statutes. However, these inhibitions to domestic cooperative ventures in aeronautical R&T may be increasingly offset by recent federal guidelines that attempt to reduce the uncertainty surrounding the permissible conditions for cooperative R&T by domestic firms. Also, ongoing government efforts to examine changes to existing antitrust statutes may encourage greater cooperative investments by domestic firms in the future. The present condition that prevails, however, is that little or no domestic joint aeronautical R&T venturing exists.

Existing patent laws do not provide sufficient protection to enable private firms to dependably capture the value of private aeronautical R&T investments. The Reagan Administration is already considering strengthening U.S. patent laws, and these efforts may eventually encourage greater private investment in all research. The benefits of these proposed changes in patent laws will take many years to come to fruition, but the study group believes these efforts are worthwhile and should be encouraged.

The long time horizons, typical of aeronautical R&T investments, are also a key factor that makes private investment in aeronautical R&T unattractive to U.S. firms. These long times make it difficult to protect the research, plan and focus it for maximum results, and internally fund it against competing short-term corporate alternatives.

In summary, the study group recognizes that the preferred form of government support for industry generally, including the civil aeronautics industry, is the efforts reflected in the Economic Recovery Plan and long-range antitrust and patent law changes. These efforts will eventually allow reduced taxes and lower inflation, lower interest rates, increase economic growth, and provide greater patent protection, so that industry will have the means and incentive to make greater R&T investments that are in both the corporate



and national interest. However, for many reasons, as well as the above, it was concluded that aeronautical R&T is sufficiently inappropriate to cause significantly lower private investment in such R&T than would be in the best national interest. Therefore, since leadership in aeronautical R&T is essential to our national security, U.S. government help is required to ensure that adequate national investments are made in aeronautical R&T.

The study group also notes the long and successful history of government-assisted aeronautical R&T now encompassed primarily by NASA's aeronautical R&T programs, and believes that there are currently no better nondirect and no other direct budgetary means for appropriate government support to aeronautics that would be superior to the current system. (See Chapter V and Appendix C of Volume II.)

3. Is the priority for government support of aeronautical R&T sufficiently high to compete for available federal funds?

Yes.

While the study group recognizes the urgent need to reduce government spending to achieve the objectives of the Economic Recovery Program, it unanimously concludes that a continued strong, government-budgeted program of aeronautical R&T is consistent with overall government priorities and should be maintained.

Funding stability is important to the long-term productivity of research in general and of aeronautics in particular. This should be an important consideration in developing future aeronautical R&T budgets.

Policy Alternatives

Using the above rationale, the study group considered alternatives for government roles in aeronautical R&T. For convenience, policy alternatives were separated into two areas: aircraft R&T and air transportation system R&T.

1. Aircraft R&T

Although the theoretical policy options range from no government role at all to complete government funding and conduct, three alternatives were considered in detail:

- o Government support for military aeronautical R&T
- o Government support for aeronautical R&T development and military aeronautical technology demonstration consistent with overall government priorities and availability of funds
- o Government support for military and civil technology development and technology demonstration.

A key question has centered around a definition that would describe the type of R&T that is properly supported by the U.S. government, as distinguished from R&T that is properly supported privately. This distinction is not usually important in large-scale, defense-oriented aeronautical programs, because of the fundamental need for the taxpayers to provide for the common defense. When R&T programs become more applied in nature, however, many with experience in economics and government policy caution that careful distinctions are necessary for the U.S. government to avoid activities that are more properly done by the private sector.

The study group concluded that grounds for government support are more apparent where the aeronautical R&T is long term and/or high risk, and/or offers a potentially high payoff in areas of clear government priority and responsibility, such as national defense. The group also concluded that civil and military aeronautical R&T development was largely common. For these reasons and those discussed earlier, the study group concluded that aeronautical R&T development projects, for which the benefits are unlikely to be appropriable by private industry, are candidates for government support, subject to the overall needs and priorities of the government and the availability of funds.

The study group viewed government support of civil technology demonstration as generally inappropriate, if the work is within sight of near-term application and the benefits can be generally captured. Consequently, the study group recommended the second alternative, government support for aeronautical R&T development and military aeronautical technology demonstration, consistent with overall government priorities and availability of funds.

## 2. Air Transportation System R&T

The government has statutory responsibility to ensure the safety of the air transportation system. The FAA performs



this function and also supports R&T programs involving national airspace activities.

As discussed in Chapter I of Volume II, the national air-space activities, although important, are excluded from this study because they can be conducted almost exclusive of the air vehicle. This study focuses on the vehicle aspects of air transportation R&T.

The Administrator of the FAA has described the requirement for a data base on this subject and the FAA's reliance on NASA to provide it. (See Chapter VII of Volume II.) Therefore, the current policy regarding aeronautical and air transportation system R&T is completely consistent with the preferred government goal and role in aeronautical R&T.

#### Alternative Methods of Implementing Government Roles

Preliminary analyses resulted in the following alternatives.

1. DOD, as the Customer, Conducts All Aeronautics R&T.

This alternative was not recommended, because DOD is a mission-oriented "requirements" agency with a focus on near-term projects. Resources would be concentrated in this area to the detriment of both the long-range military aeronautical and civil aviation R&T needs.

2. Establish a Separate, Government Aeronautical R&T Agency.

The study group found very little duplication between NASA and DOD R&T programs and facilities, and concluded that the advantages of combining major elements of the present DOD/NASA aeronautical R&T organizations were minimal. Further, there would be strong pressure from DOD to address military applications, with the result that the new agency would soon become dominated by DOD and thus experience the shortcomings discussed in Alternative 1.

3. Privatize Programs and Facilities.

The key problem with privatization is designing and administering a subsidy/incentive scheme that would encourage sufficient long-term and broad-based aeronautical R&T, disseminate the results, and avoid unwarranted and costly duplication. Also, a significant reason for establishing DOD laboratories is to maintain in-house expertise so that the

military can be "smart buyers" of technically complex aircraft weapon systems. It is not possible to develop a competent technical staff through contract monitoring alone.

4. Maintain Present Institutional Framework.

Under this alternative, the U.S. government role is implemented by the following:

- o DOD funds, directs, and implements technology development and demonstration programs directed specifically toward military applications.
- o NASA funds, directs, and implements R&T development programs and supports military technology demonstration programs.
- o NASA and DOD encourage transfer of aeronautical research results to and within U.S. industry as effectively as possible.
- o Both DOD and NASA manage, maintain, and operate aeronautical research, development, test, and evaluation facilities.
- o FAA, with NASA and DOD support, is responsible for air traffic control and safety-related R&T.

The following arguments favor this approach:

- o Specific and timely military aeronautical R&T needs are provided by DOD technology development and demonstration programs.
- o A broad technology base is provided by NASA R&T development programs, the results of which can be used by industry in meeting both military and civil aeronautical vehicle needs, as appropriate.
- o NASA's reservoir of technical expertise and research infrastructure would be preserved. The independent research framework provides the necessary stimulus and incentives to sustain a cadre of researchers. Incentives in the other approaches would ultimately be based more on near-term cost-schedule-performance criteria, which would cause a decrease in research and technical development output and eventual loss of skilled staff.



- o NASA's independence is an asset that enables free transfer of information among government and industry and provides a long-term perspective free from short-term development and operational pressures.

The study group recommends maintaining the present institutional framework to implement the U.S. government role in developing aeronautical R&T. Only this approach can ensure all of the following:

- o DOD needs will be met.
- o Aeronautics results will be freely interchanged within the U.S. industrial community.
- o Technology required to meet the long-term requirements of both civil and military aircraft is developed.
- o The United States will more nearly maximize the productivity of aeronautical R&T.

## IX. AERONAUTICAL FACILITIES

The foundation for advancement in aeronautical science has been the development of continually improving research and test facilities. From its origin, research in aeronautics has depended on the ability to simulate flight conditions in a controlled, realistic, stable manner in order to measure and understand the phenomena being investigated.

The capital investment required for necessary aeronautical facilities has grown to such magnitude in terms of complexity and sophistication as to require centralization. This contrasts with most other high-technology endeavors in which the basic tools required for research and design are much less costly and thus proliferate through the private sector.

Although individual, privately owned wind tunnels and propulsion test facilities do exist, only the federal laboratory system now has the composite capability sufficient to support the full requirements of research, design, and testing for a state-of-the-art aeronautical system. The current replacement value of DOD and NASA facilities is estimated to be 8 to 10 billion dollars. When combined with the researchers associated with the facilities, the federal laboratory system forms a national asset that is the foundation for maintaining U.S. preeminence in aeronautics.

The study group examined the capability, capacity, and limitations of the U.S. aeronautical facilities and is convinced that, with minor exceptions, existing and planned major facilities are adequate and will not require replacements in the near future. Continued maintenance, improved productivity, and modernization will be required. Improvements to computational capability should be specifically considered.

An area of concern surfaced during the examination of the aeronautical facilities. The approach to operational funding support for the wind tunnels and the corresponding user charges that are imposed by DOD has resulted in reduced activity in certain DOD facilities. The policy of direct cost recovery from users of DOD facilities when compared to the NASA policy of no charge to any user except for proprietary industrial testing has caused a migration, when possible, to NASA facilities.



The study group strongly believes that selecting the most appropriate facility for either research or system development testing should be based on mission priorities and/or technical requirements and not on the funding policies. High-quality R&T requires more support, and low-quality R&T should be eliminated. Consequently, the group recommends that

- o NASA and DOD develop a common framework of appropriate incentives and proper joint management coordinating mechanisms to ensure that the use of NASA and DOD aeronautical facilities is consistent with government priorities and the needs of the user programs.

## X. TECHNOLOGY TRANSFER

Because identification of specific application is lacking, the majority of R&T development is carried out and reported openly in the United States. Significance to a military system, the primary basis for classification and control, is usually identified only after the basic concepts have been discussed openly.

The Soviets and our commercial competitors expend significant effort on the acquisition, analysis, and internal distribution of U.S. aeronautical technical data. The superb efficiency of the U.S. secondary distribution systems in worldwide dissemination of U.S. government-sponsored reports and the potential application of this valuable technology to a critical foreign military or civil system suggest a need to reassess policies regarding the dissemination of aeronautical technical data.

Several procedures exist to control dissemination of unclassified but critical dual-use technology, such as the commodity control list maintained by the Department of Commerce for export control and the munitions control list maintained by the Department of State. The most appropriate application of these procedures or the development of a new process more precisely tuned to controlling the DOD/NASA unclassified technology data will require further analysis. The study group strongly concluded that such a study be undertaken as rapidly as possible to recommend a national policy on this subject. Such policy should not inhibit or discourage government-approved international cooperation or research exchanges at the university level. To facilitate definition of the policy, the study group recommends that

- o NASA and DOD, in conjunction with other government and non-government agencies, review the procedures for disseminating aeronautical R&T documents.

The study group recognized that foreign countries are developing a considerable amount of aeronautical R&T. The U.S. government currently has no central organization to collect the best unclassified foreign R&T and disseminate it to both government and industry users, a role formerly performed by NACA. The collection, translation, and analysis requires expert knowledge. Therefore, the study group further recommended that



- o NASA provide a plan for a centralized means of collecting unclassified aeronautical R&T documents, conference proceedings, and meeting results.

## APPENDIX A

### OSTP STUDY GROUP ON AERONAUTICAL RESEARCH AND TECHNOLOGY POLICY

#### STEERING GROUP MEMBERS

Victor Reis (Chairman)  
Assistant Director, Office  
of Science & Technology Policy

Allan V. Burman  
Chief, Air Force  
National Security Division  
Office of Management and  
Budget

Robert S. Cooper  
Director, Defense Advanced  
Research Projects Agency

Charles R. Foster  
Director - FAA  
Northwest Mountain Region

Jack L. Kerrebrock  
Associate Administrator for  
Aeronautics & Space Technology  
NASA

Louis Montulli  
(Working Group Chairman)  
Senior Policy Analyst  
Office of Science and  
Technology Policy

William H. Morris, Jr.  
Assistant Secretary for  
Trade Development  
U.S. Department of Commerce

Allen Parkman  
Senior Economist, Council  
of Economic Advisors

Jeffrey L. Struthers  
Chief, Science & Space Program  
Branch  
Energy and Space Division  
Office of Management and  
Budget

#### OBSERVERS

Eugene E. Covert  
Director, Gas Turbine and  
Plasma Dynamics Laboratory  
Massachusetts Institute of  
Technology

John E. Steiner  
Vice President, Corporate  
Product Development  
The Boeing Company



## APPENDIX B

### OSTP STUDY GROUP ON AERONAUTICAL RESEARCH AND TECHNOLOGY POLICY

#### WORKING GROUP MEMBERS

Louis T. Montulli (Chairman)  
Senior Policy Analyst  
Office of Science & Technology Policy

William S. Aiken, Jr.  
Director, Aeronautical Systems  
Division - NASA

Richard Ballard  
Chief, Technology & Support Team  
Aviation Systems Division  
Department of the Army

Sally H. Bath  
Industry Specialist, Aircraft  
U.S. Department of Commerce

Anthony J. Broderick  
Deputy Associate Administrator  
for Aviation Standards - FAA

Gregory A. Carter  
Operations Research Analyst  
Office of Management and  
Budget

Donald Dix  
Staff Specialist for Propulsion  
Office of Engineering Technology  
OUSD - The Pentagon

Bernard A. Kulp  
Chief Scientist  
Air Force Systems Command - DLZ

Gerald G. Kayten  
Deputy Director, Aeronautical  
Systems Division - NASA

Kshitij Mohan  
Operations Research Analyst  
Office of Management and  
Budget

Louis V. Schmidt  
Assistant for Engineering  
Technology  
Office of Assistant Secretary  
of the Navy for Research,  
Engineering & Systems  
The Pentagon

Raymond Siewert  
Director of Engineering  
Technology  
OUSD - The Pentagon

Roger L. Winblade  
Manager, Transport Aircraft  
Office  
Aeronautical Systems Division  
NASA

#### OSTP - STAFF

George F. Unger  
Staff Assistant

John J. McCarthy  
Staff Assistant

APPENDIX C

INDUSTRY RESPONDERS TO OSTP  
QUESTIONNAIRE DATED 18 MARCH 1982

|                    |                     |
|--------------------|---------------------|
| AIAA (Society)     | General Electric    |
| AOPA (Association) | Gulfstream American |
| ATA (Association)  | Grumman             |
| Beech              | Lockheed            |
| Bell Helicopter    | McDonnell           |
| Boeing Company     | Northrop            |
| Detroit Allison    | Pratt and Whitney   |
| Fairchild          | Rockwell            |
| Garrett            | Sikorsky            |
| Gates Learjet      | Teledyne            |
| General Dynamics   | Vought              |



REPORT OF THE  
AERONAUTICAL POLICY REVIEW COMMITTEE  
AUGUST 1988

## CONTENTS

|                                                                      | PAGE |
|----------------------------------------------------------------------|------|
| EXECUTIVE SUMMARY .....                                              | 2    |
| I. INTRODUCTION .....                                                | 3    |
| II. HISTORY AND OVERVIEW .....                                       | 3    |
| III. PROGRESS ON NATIONAL R&D GOALS .....                            | 5    |
| IV. ISSUES AND RECOMMENDATIONS .....                                 | 8    |
| APPENDIX A: DISCIPLINE TECHNOLOGY STATUS .....                       | 16   |
| APPENDIX B: AERONAUTICAL POLICY REVIEW<br>COMMITTEE MEMBERSHIP ..... | 29   |



## EXECUTIVE SUMMARY

During the 1980's, aeronautics has provided this nation a strong positive balance of trade far outstripping other industrial sectors. However, global indicators now show a weakening trend in U.S. market share due to emerging competition from Europe, France, and Japan. This disturbing trend needs to be halted. Innovative technology and its application to new aviation products are key to competitiveness.

The Aeronautical Policy Review Committee in 1985 recommended national technological goals in the three regimes of flight: Subsonics, Supersonics and Hypersonics. Progress is occurring in all three areas: most notably, the emergence of the advanced propfan propulsion technology in Subsonics and the National Aero-Space Plane program in Hypersonics.

The Committee believes the current time period is critical to securing a lasting position of world leadership that the United States has traditionally occupied in this industry. Indeed, the international competitiveness of this nation in broad areas of technical and scientific enterprise is at stake. Accordingly, the Committee urges that major issues affecting the nation's future posture in global aviation be addressed on a priority basis by senior levels of national leadership. Specific recommendations are provided in the following areas.

- Stimulation of United States Research and Development
- Domestic and International Consortia
- Engineering Education
- The X-30 Aero-Space Plane Technology Demonstrator
- National Facilities
- High-Speed Civil Transport
- Recovery of Global Market Share in Vertical Takeoff and Landing Aircraft
- Revitalization of the General Aviation Industry
- Stimulation of Favorable Trade Balance
- Global Air Traffic Control

Several of the issues such as Engineering Education and Stimulation of Research and Development affect broad segments of the economy, not just aviation. Perhaps the most pressing issue is Global Air Traffic Control. Our recommendation calls for a Presidential Commission to formulate a national strategy and implementation plan. This report also provides a concise status and needs of those aeronautical technologies key to future aviation leadership.

## I. INTRODUCTION

The aeronautics industry has long held an important position in its contributions to the well-being of the United States in terms of trade, transportation, national security and as a symbol of U.S. technological power. The aeronautics manufacturing sector, civil and military, account for almost one million jobs at the principal manufacturers and their supplier base of 15,000 companies. Over the past five years, the positive balance of trade has grown to over \$15 billion per year which exceeds agriculture and is far above any other manufacturing sector. The U.S. aviation sector also provides a vital domestic and international transportation infrastructure which has major economic and competitive implications. In addition, the industry generates enormous advanced technology output, the spin-off from which affects many other industrial sectors. The industry's products and services are very visible to world populations and influence the manner in which the United States is regarded from a world leadership standpoint.

However, the aeronautics industry is in the midst of escalating challenge by government-supported foreign manufacturers, and the U.S. share of the world market is eroding. In addition, the U.S. aviation system is facing mounting pressures. Advanced technology, which is emerging at a rate unmatched since the 1950s, offers effective options for superior U.S. aircraft and enhancement our national air transportation system for the next century. This report recounts a very extensive study of the industry that resulted in a Policy statement in November 1982, plus the subsequent efforts of a senior-level committee of industry, government and academia experts. Major findings and recommendations of the Aeronautical Policy Review Committee are summarized and the 10 most pertinent issues with Committee recommendations are presented. The recommendations are directed to government, industry and academia, not to government alone.

The Committee perceives the current time period as one which is critical to the position of world leadership that the United States has occupied in this industry and is also critical to the international competitiveness of this nation in areas of technical and scientific enterprise.

## II. HISTORY AND OVERVIEW

Current Federal policy, pertaining to aeronautics in general and aeronautical research and development (R&D) in particular, is the product of a series of in-depth assessments from a national perspective undertaken over the past seven years. This section summarizes the major outputs of that effort.



## **Aeronautical Research and Technology Policy -- November 1982.**

A new Federal Policy for Aeronautics emerged from a thorough and pragmatic examination by the Administration of the role of government in the highly-successful government, industry and academia partnership that had evolved over the many years since the establishment of the National Advisory Committee on Aeronautics (NACA) in 1915. The policy reaffirmed that aeronautical capabilities are a vital and unique part of America's economic and national security strength. It also underscored the importance of the government role in providing the technology base in high-priority areas of Federal responsibility where private sector incentives would lead to underinvestment in needed research and technology development. Finally, the policy provided a clearly defined framework of roles and responsibilities of government, industry and universities to secure lasting U.S. preeminence in aeronautics.

In response to the Aeronautical Policy recommendations, a senior-level Aeronautical Policy Review Committee was formed in 1983 to oversee the implementation of the aeronautics policy. It included representatives of industry, the Department of Defense, NASA, Federal Aviation Administration (FAA), the Department of Commerce, and academia and was asked to review national R&D plans for consistency with the policy and to make recommendations where appropriate.

### **First Report of the Committee -- November 1983**

From its review of the nation's long-range R&D plans, the Committee concluded that the leadership spirit expressed in the policy would require a more aggressive, adventurous and risk-taking approach. This report particularly stressed the need for a cohesive and imaginative national vision for aeronautics -- one that would extend the time horizon of aeronautical R&D for both civil and military uses.

### **National Aeronautical R&D Goals : Technology for America's Future**

This major report, prepared by the Committee and released for national distribution in March 1985, identified both the emerging challenge of foreign competition to the nation's aeronautics industry, and the tremendous opportunities for technological advances and leadership open to the country both then and into the future.

To maximize the high-technology payoffs inherent in advances in aeronautical research and technology development, the report--now widely known as "Birdbook I"--outlined three national goals:

- **Subsonics:** To build "trans-century" renewal--advancing technology for a new generation of fuel-efficient U.S. aircraft operating in a modernized National Airspace System.



- **Supersonics:** To attain long-distance efficiency--and enable the development of civil and military aircraft featuring sustained supersonic cruise capabilities.
- **Transatmospherics:** To secure future options--and exploit the merging of aeronautics and space technology in developing the capability to routinely cruise and maneuver into and out of the atmosphere, with take-off from and landing on conventional runways.

The report also highlighted some of the key challenges in achieving these goals, and concluded with a broad strategy for revitalizing the nation's capacities for innovation in aeronautical research and technology development.

### **National Aeronautical R&D Goals: Agenda for Achievement**

Birdbook I was well received, and became the focal point of a number of new initiatives in aeronautical research and technology development. The Committee, however, believed that--in spite of such progress--the depth of foreign aeronautical resolve and the concerted national effort required to preserve American competitiveness were still largely underestimated. Consequently, in February of 1987, the Committee released "Birdbook II" to reemphasize the importance of aeronautical technology to the nation and the challenge of sustaining U.S. leadership in a fiscally constrained environment.

This report updated the competitive situation with respect to each of the three National Goals, and provided a detailed an eight-point action plan for coordinating the efforts of U.S. industry, academia, and the Federal government to achieve the National Goals proposed in Birdbook I and to ensure that U.S. industry remained a viable competitor in the world aviation marketplace.

## **III. PROGRESS ON NATIONAL R&D GOALS**

The Committee's March 1985 report--National Aeronautical R&D Goals--set forth three critical national goals, the achievement of which would contribute to a safer and more efficient national air transportation system, ensure a secure national defense, and solidify U.S. competitiveness in the global aviation marketplace well into the next century. This section highlights each of those three national goals and summarizes their present status.



### Subsonics Goal: To Build Trans-Century Renewal

The free world market for large, subsonic jet transports is immense--over \$34 billion worth of orders in 1987--and growing at a rapid pace: world revenue passenger miles are forecast to double by the year 2000 and quadruple by 2015. U.S. industry currently supplies about two-thirds of the total shipments to that market, and the positive net trade balance generated by our aerospace industry--over \$15 billion in 1987--is the largest such balance contributed by any U.S. industrial sector.

To maintain that economic leadership, and to address the safety and airspace capacity problems associated with dramatic increases in air traffic, the Subsonics Goal envisions the development of advanced technology for an entirely new generation of fuel-efficient, affordable U.S. aircraft operating in a modernized National Airspace System.

Major progress has been made in several subsonic technologies. For example, following years of research and technology development on the part of both government and industry, the advanced turboprop--offering a 20-30 percent reduction in fuel consumption--is being introduced into the commercial jet transport market. Tiltrotor technology, a potential solution to help alleviate both airspace and airport congestion, has been developed to the point where a military version is ready for flight testing, and work continues toward developing a civil version. And, advances in guidance and control, human factors, and related technologies promise near-term improvements in aviation safety and efficiency.

Much remains to be done, however. U.S. manufacturers have experienced a constant erosion of market share as foreign manufacturers have aggressively applied advanced technologies into their products. In the last fifteen years, the United States has lost one-third of a world market that it once dominated as European competitors moved toward technological parity and in several key areas to a position of leadership.

One major problem has been industry's inability to take full advantage of government research and technology development. Commercial programs are normally built without a separately-tooled and tested prototype, and are typically built on short lead times. Industry is extremely reluctant, therefore, to incorporate any new technology that is unproven, or not "validated". In fact, industry--faced with the increased market risks deriving from airline deregulation and subsidized foreign competition--became increasingly risk-averse at exactly the same time the government reduced its role in carrying research and technology development into the validation phase.

As a result, several important subsonic technologies have not been sufficiently validated for incorporation into commercial aircraft development programs at acceptable levels of risk. To address this situation, in 1987 the Senate Committee on Commerce, Science, and



Transportation directed NASA to prepare--in close cooperation with industry--a multi-year technology development and validation plan to "help the United States retain its leadership in aeronautics research and technology and compete in the international marketplace for future civil aircraft." This plan was completed and submitted as requested. The Committee strongly supports the recommended plan and the urgency implicit in its formulation.

In sum, trans-century renewal still requires major efforts on the part of the government, industry, and academia. Present efforts in the basic disciplines of aerodynamics, propulsion, structures and materials, systems management, and process and manufacturing technology are inadequate, and a further deterioration of U.S. market share, with resulting loss of jobs, tax base, and contribution to balance of trade should be expected.

#### Supersonics Goal: To Attain Long-Distance Efficiency

As outlined in the Committee's 1985 Goals Report, the nation's goal with respect to the supersonic flight regime is to develop the pacing technologies required to enable a sustained supersonic cruise capability. Following the release of that report, NASA initiated a High-Speed Civil Transport study effort with Boeing and McDonnell Douglas, to identify specific technology requirements that would enable the development--by industry--of an environmentally compatible and economically viable high-speed commercial transport.

To date, that study effort has indicated that the market opportunity for an economically viable high-speed trans-Pacific transportation system is very large. For example, market demand for a fleet of up to 300 supersonic transport aircraft is envisioned by the year 2000, and a fleet of 1,500 by the year 2025.

The studies also indicate, however, that substantial research and technology development remains to be undertaken to enable the development of an environmentally-sound, economical high-speed civil transport. Government and industry progress to-date is but a bare bones start by the United States in what may be one of the world's most rewarding markets. The loss of this significant market to aggressive foreign competitors from Europe and Japan would severely damage the future U.S. position in aerospace sales, balance of trade, and technology leadership.

#### Trans-Atmospherics Goal: To Secure Future Options

The merging of aeronautics and space technologies provides the potential for an entirely new class of vehicles for the next century, ranging from hypersonic aircraft to a single-stage-to-orbit space transportation system. The national Transatmospheric Goal is to develop and mature technologies that will provide the capability to routinely cruise and maneuver into and



out of the atmosphere with take-off and landing from conventional runways.

The funding of the National Aero-Space Plane (NASP) program, which culminates in the X-30 flight research vehicle, was in part a result of this goal statement. The NASP program, a combined government and industry effort, has resulted in significant accomplishments in aerodynamic, propulsion, and materials technology. It is too early to tell, however, if it will be possible to fully meet the ambitious objectives of this program.

Technologically, this is the most demanding of the three goals. It is also the goal which, if realized, will place the United States in the strongest position of technological leadership. It is the Committee's opinion that initial steps with regard to both the NASP program and generic hypersonics research have been very worthwhile, and that a successful result will be attained--providing the seriousness of the effort involved is recognized.

The Committee believes that Congress, the Administration, U.S. industry, and perhaps academia continue to underestimate the effort required to be world-competitive in these three technology areas. We have watched as other U.S. industries have lost their technological lead. We also know that a lead, once lost, is often impossible to regain. The Committee believes that the United States is at a pivotal decision point. Either we increase the national effort and achievement in the three goals, or accept the deterioration of the U.S. position with respect to other world powers.

#### IV. ISSUES AND RECOMMENDATIONS

The Committee believes that the following are the ten most important issues facing U.S. aeronautics today. Specific recommendations in each area follow. All are important. They are not necessarily listed in order of priority.

##### 1. Stimulation of United States Research and Development

**ISSUE:** The present U.S. aeronautical research and technology environment will not assure future technology leadership in aviation. A solid base of fundamental research coupled with appropriate validation of key emerging technologies has been the foundation for sustained U.S. leadership in aviation during the three decades following World War II. Technology validation is currently the weak link in the U.S. research and development (R&D) chain.

Present Department of Defense practices are severely constraining the capital of many aeronautics contractors. The impact is most severe at the

second and third tier suppliers. Capital constraints have already reduced contractor-funded R&D investment, forced substitution of "safe" low technology product alternatives, slowed production and research facility modernization, and diminished industry assistance to the universities. Left unchecked, this situation could undermine our long-term competitiveness in the world marketplace.

Foreign competitors, particularly in the commercial marketplace, now pose a serious challenge. Europe and Japan have very vigorous technology development programs culminating with prototype validations which accelerate application of new technologies to highly-competitive products. The USSR investments in research outstrip ours and are narrowing the margins of U.S. technological superiority.

RECOMMENDATIONS: U.S. Government policy should:

- a. Foster steady growth in national R&D focused on key technology areas. Wider participation in the Department of Defense's Independent Research and Development (IR&D) program by second and third tier suppliers should be an immediate priority.
- b. Revitalize the incentives for investment of corporate profits in industrial research through revised government procurement policies which more equitably balance program risk and reward.
- c. Increase the technology transfer from U.S. military to U.S. civil sectors through classified forums or other means.
- d. Encourage the aeronautical industry to invest a fixed fraction of their R&D budget in university research.
- e. Strengthen NASA and DOD basic and applied research and technology demonstrations; this is central to future technology leadership.

## **2. Domestic and International Consortia**

ISSUE: A consortium of U.S. prime contractors is normally required for military or other government programs. For civil programs, anti-trust laws generally prevent U.S. consortia, except for recently permitted ones pertaining to basic research. As a result, U.S. manufacturers have frequently teamed with foreign partners in addressing world and U.S. markets. Such teaming is sometimes criticized as losing U.S. jobs and other national benefits. Anti-trust legislation, although its objectives were laudable, was enacted before the present international competitive environment had grown to its present size or severity.



## RECOMMENDATIONS:

- a. Modernize U.S. anti-trust legislation to permit U.S. commercial consortia when this will result in national benefits.
- b. Avoid legislation limiting U.S.-foreign collaboration. Such collaboration often is required to maintain U.S. market share, and technology transfer is now often toward the U.S. rather than away from it.
- c. Develop U.S. policies to limit the dependency of the U.S. aviation industry upon critical components from foreign sources.

### **3. Engineering Education**

ISSUE: The key to global leadership in aeronautics is the quality and quantity of engineering talent. Engineers trained during the space race period (1957-1967) are nearing retirement. It is crucial that newly graduated engineers at all degree levels enter the aviation field during the next decade. Demographics will result in a 15 percent decline in U.S. college-age students from now to 1994, and the continuing national trend away from engineering education will aggravate this shortage. Security constraints prohibit most foreign-born, and even many U.S.-born, engineering graduates from working in highly-classified military aeronautics programs. The average foreign enrollment in U.S. engineering graduate schools (Masters and Ph.D.) is 60 percent, and in a number of key aviation disciplines it is greater than 80 percent. The availability of skilled engineers presents a most serious challenge to American leadership. Improved science education at the primary and secondary levels is essential to progress in higher education.

## RECOMMENDATIONS:

- a. Reestablish a national focus of pride and need for superior technology and innovation in our aeronautical industry. A sense of competitive urgency and a visible national commitment much like the "missile gap and space race" periods is needed to encourage young people to enter science and engineering.
- b. The aviation industry should establish an "Education Enhancement Council" to work with state and local governments and school districts to develop ways that the industry can assist in providing mathematical and physical science education from the primary grades through college.
- c. Government and industry should enhance support for U.S. science and engineering students to encourage our best students to pursue graduate studies in engineering. Challenging graduate level

curricula should be established or strengthened in critical aerospace disciplines.

- d. Industry should encourage an exchange of employees, especially in engineering and mathematical and physical sciences with teachers and professors on a one or two-year basis. Industry scholarships, job assistance and cooperative programs should be encouraged.
- e. Support training in the teaching of elementary science through grants, incentives and symposia.

#### **4. The X-30 Aero-Space Plane Technology Demonstrators**

**ISSUE:** The X-30 National Aerospace Plane (NASP) program is providing the U.S. technology base for a whole new generation of hypersonic (Mach 5 to 25) vehicles. This highly focused program has already made significant technology advances. A continued aggressive commitment of government and industrial resources is needed to assure that the technology is developed at the best possible rate. Both the Europeans and the Japanese have announced plans for their own hypersonic programs and the Soviets have had an aggressive program for a number of years. Recently, the Soviets announced the achievement of a major technology milestone with flight testing of a large hydrogen-fueled aircraft engine.

The U.S. is in a global technological competition in both single-stage-to-orbit and atmospheric cruise hypersonics. The issue is whether the present effort is adequate to insure U.S. international competitiveness.

#### **RECOMMENDATION:**

- a. The X-30 NASP should be focused and supported at the maximum rate consistent with availability of advancing technology.
- b. Key supporting technical resources such as research in materials, propulsion, and computational fluid dynamics should be encouraged in universities, government and industrial laboratories.
- c. The X-30 technology demonstrators should be considered as a start of a technology line of programs, not as ends in themselves.

#### **5. National Facilities**

**ISSUE:** International competitiveness in aeronautics requires major test facilities, including wind tunnels, propulsion facilities, computational facilities, and special-purpose facilities (e.g. radar cross-section, icing, rain erosion, acoustical, etc.) Many of these critical facilities are government-owned as they are so expensive as to preclude private ownership. In many



cases, particularly in government-owned facilities, maintenance and modernization have been inadequately funded over the years, resulting in a degradation in their health and productivity.

#### RECOMMENDATIONS:

- a. Assure proper maintenance and modernization of existing national facilities, which are important to U.S. international competitiveness. This includes NASA, DOD, other government agencies, and universities.
- b. Develop and implement specific plans such as the 1987 "Major NASA Wind Tunnel Revitalization Program" to assure the health and productivity of required government facilities.
- c. Formulate a plan for identification and construction of critical new national facilities.

#### **6. High-Speed Civil Transport**

ISSUE: One of the major elements in the 1985 National Aeronautical R&D Goals Report was the development of technology for an advanced high-speed civil transport. NASA studies with Boeing and McDonnell Douglas have indicated a strong market for higher speed, long-haul travel. Over 300 high-speed civil transport aircraft by the year 2000, and 1,500 by 2025 are envisioned. A European consortium has announced its intention to start a program, and Japan has announced its intention to seek funding for supersonic transport research and technology development. Foreign success would severely damage the U.S. position in aerospace sales and balance of trade. Strong U.S. government encouragement is necessary. We need to assure a strong market position in this emerging opportunity.

#### RECOMMENDATIONS:

- a. The Senate Committee on Commerce, Science and Transportation asked NASA for a civil technology development and validation plan in mid-1987. It was submitted in early 1988, and contains a high-speed transport technology plan which addresses the pacing technology requirements. NASA should continue to accelerate research efforts on the critical technology and environmental issues identified in this plan as funds become available.
- b. A business strategy featuring private sector management and funding of a potential aircraft development program should be developed. U.S. industrial leadership of a multi-company consortium should be a principle focus.

- c. The importance and cost of this program justify specific anti-trust legislation to permit a consortium of U.S. manufacturers.

## **7. Recovery of Global Market Share in Vertical Takeoff and Landing Aircraft**

**ISSUE:** The U.S. has lost its leadership position in the worldwide rotorcraft market. At the same time, rotorcraft continue to be the cornerstone for meeting the day-to-day vertical lift requirements in both military and civil applications. Strong commitments are also being made towards helicopter applications for the foreseeable future. Emerging vertical takeoff and landing (VTOL) technologies, such as the tiltrotor, provide the opportunity to offset the intensifying global industrial and military competition.

### **RECOMMENDATIONS:**

- a. Accelerate the commercialization of tiltrotor technology through NASA/FAA/industry efforts leading to an early commercial demonstrator vehicle.
- b. Conduct an indepth study of innovative VTOL systems having potential economic viability within the national and world airways system. This should include but not be limited to the tiltrotor.

## **8. Revitalization of the General Aviation Industry**

**ISSUE:** The current product liability situation which faces the U.S. General Aviation Industry has resulted in costs which price products out of the market. It poses a serious deterrent to new product development and production, virtually eliminating such activity in the United States. A foreign producer suffers very limited product liability exposure when participating in the U.S. market while the U.S. producer is at risk under the U.S. tort system regardless of where the product is sold. As a result, foreign producers have displaced a major portion of the once dominant U.S. General Aviation Industry.

### **RECOMMENDATION:**

- a. Change the legal product liability practice in the United States to permit a resumption of new product innovation and development in the U.S. General Aviation Industry. These changes should include: allowance of "state-of-the-art" as a defense; institution of a reasonable Statute of Repose; and elimination of joint-and-several liability.



## 9. Stimulation of Favorable Trade Balance

**ISSUE:** The best stimulation of a favorable trade balance is technological superiority. However, in many cases, this alone is not adequate because foreign governments provide their manufacturers with financing terms which are more favorable than any privately owned U.S. company can offer. The EXIM (Export Import) Bank has played a critical role in offsetting competitive foreign export-financing extended by government-supported export credit agencies. Moreover, EXIM's financial guarantee is essential to gain support of private banks in creating export-financing programs that permit third world carriers to acquire newer aircraft types to replace their aging and less-productive fleets.

### RECOMMENDATIONS:

- a. EXIM should adapt its export-financing programs to conform to new aircraft financing techniques, such as leasing, or equipment trusts. These are often referred to as "asset-based" financing. EXIM should become more active in using the value of the aircraft as prime security to provide its financing guarantee.
- b. EXIM should develop a political risk insurance program which supplements the private sector in the area of expropriation by a host country.

## 10. Global Air Traffic Control

**ISSUE:** The 1978 deregulation of the airlines accomplished the objective Congress desired-- lower air fares. However, it resulted in a much larger number of smaller airplanes for the major airlines, and a proliferation of commuter airlines with even smaller aircraft. The impact has been to hasten the saturation of national airspace. Between 1982 and 1987, near collisions recorded by the FAA increased by three times. In the next twelve years, U.S. air traffic in terms of revenue passenger miles will double. It will double again by 2015. Thus, in a little over 25 years the U.S. will be faced with four times the current traffic levels. The deregulation and crowded airspace situation that came to the U.S. in the early to mid-1980s is now coming to Europe at a rate which is causing enormously expensive delays, and the various other risks that accompany overcrowding. The Committee views the present situation, therefore, as being world scale.

The 1970 Airport and Airways Development Act and its 1976 modifications provided a ticket and way bill tax which sustains an aviation trust fund. This trust fund is the source of about \$4 billion to \$5 billion per year for FAA R&D, air traffic control (ATC) system modernization and expansion, airport matching grants to municipalities and states, and 50 percent of ATC operating costs. The trust fund originally was for airport and airways modernization and expansion, not for day-to-day operations.



In 1982, the National Airspace System Plan was initiated with an additional annual allocation aggregating to \$1.2 billion over ten years. It is still ongoing, but it appears grossly inadequate considering the global character of the aviation system problem. The FAA formed an Advanced Aviation System Design Team two years ago with the participation of NASA and DoD. The team interfaces with Europe, Japan, Canada, Australia, and the USSR. Reports are currently unpublished, but the team, it is believed, will recommend extensive use of data link, a global system of 24 navigation satellites, a series of ground stations, communications satellites, and a worldwide computerized system with associated ground-based and airborne displays and subsystem interfaces. The implications of the global interfaces with the domestic aviation system are beyond anything the FAA might be expected to accomplish. Attempts to separate the U.S. domestic portions of the world system and to deal with it at a local level, the Committee believes, would be unwise and detrimental to U.S. aviation leadership.

The USSR recently unveiled their global navigation satellite (Glonass) system aiming at a similar 24 navigation satellite system. Nine are now in orbit, 10 to 12 will be in orbit by 1989/90, and the full 24 will be in orbit between 1991 and 1995. Such a system would duplicate a potential U.S.-led Western system, and might lead to U.S. and free world dependency upon USSR satellites.

#### RECOMMENDATION:

- a. The Committee strongly recommends that a Presidential Commission be set up as soon as feasible to examine the domestic and global problem and its implications for our transportation infrastructure. The Commission should recommend a national strategy and implementation plan.
- b. FAA-led improvements in the National Airspace system and Advanced Aviation System Design should proceed while the Commission completes its study. However, the study should be accelerated to assure that major resource expenditures by all nations involved will be compatible with long-range directions for a global system architecture.



## APPENDIX A

### DISCIPLINE TECHNOLOGY STATUS

The Committee is in agreement with the Aerospace Industries Association of America report, "Key Technologies for the 1990s" and the road maps for advanced technologies that are contained therein. Unless such road maps are followed, the United States will not remain competitive in world military and civil aviation. Organizations and facilities are in place in the combined NASA, DOD, and industry U.S. complex. However, we are still underestimating the effort and money that will be required to remain world competitive. Since some crucial efforts are of a very long-term nature, it will be very difficult for industry to carry them into production without increased emphasis in government research and technology validation activities. America is generally not competing with private industry outside of the United States, but in many cases with aggressive government objectives and budgets.

#### **A. Aerodynamics**

The science of aerodynamics is immensely more complex than it once was. Optimum solutions for subsonic, transonic, supersonic and hypersonic flight regimes are needed. In many programs and systems, optimum performance in more than one region is required.

New tools in Computational Fluid Dynamics (CFD) are being successfully used within our present limitations of computer capacity and validated design and analysis codes. Such codes take a large effort to develop and, for validation, require instrumentation and wind tunnel facilities that are either non-existent or only partially usable. While we may someday be able to decrease wind tunnel usage for a given system design by using CFD, today, meeting the necessary standards of design excellence requires use of both. In addition, we have not solved CFD codes applicable to flow within the boundary layer and particularly in boundary layer transition. Such flow become of much large importance as we increase speeds to transonic, supersonic and hypersonic levels. In addition to aerodynamics affecting the vehicle performance, we now need more extensive information on heat transfer since skin temperatures are of critical importance in determining what materials can be used for supersonic and hypersonic flight. This becomes especially true as performance optimization requires materials under the general heading of composites.



In the area of computational fluid dynamics we are becoming limited by two things--the size of our computing capabilities and our knowledge of the fundamental physics of turbulent flow. NASA and DOD need to conduct fundamental experiments to provide basic data for CFD development and to validate the resulting CFD codes. Because this needs a detailed understanding of the flow field including the structure of laminar and turbulent boundary layers, it is important that NASA revitalize its capabilities to provide innovative diagnostic instrumentation. The specific problems that need detailed attention include confluent boundary layers of high lift devices, leading and trailing edge separation of high lift wings and shock boundary layer interactions including shock induced separation of high speed airfoils.

To a large extent, the long term health of the aeronautics industry is dependent upon the health of NASA wind tunnels and NASA and DOD sponsored computational fluid dynamics development. Unfortunately, NASA wind tunnels are not healthy because of continued long-term deferment of routine maintenance and technology-driven upgrades. A significant NASA initiative in 1987 focuses on rehabilitation and upgrade of existing facilities. This initiative is critical and must be continued in the new administration.

Airplane design is at a stage of maturity where the design and tailoring of configurations, at flight Reynolds numbers, has become very important. Unfortunately, this comes at a time when NASA facilities are least able to provide capabilities that should keep the United States at the forefront of aerodynamics. The world's premiere low-speed high Reynolds number facility, NASA Ames' 12-foot pressure tunnel, is inoperative because of defective welds in the pressure shell of that tunnel. Again a 1987 NASA initiative was begun to repair and refurbish that tunnel. This initiative must be supported with the highest priority. Furthermore, additional studies should be undertaken to improve the productivity of that tunnel and to extend its Reynolds number capabilities towards full scale through the use of freon as an alternate working fluid.

The United States has the premiere high Reynolds number high-speed wind tunnel in the National Transonic Facility (NTF). Unfortunately, NTF is undergoing severe start-up problems that have significantly reduced its productivity from what was expected during its conceptual development a decade ago. NASA must continue to direct meaningful resources towards making NTF productive.

Some specific comments within areas of the three National Goals follows:

#### Subsonics

Since approximately 50% of the cruise drag of a commercial transport is due to skin friction, it is imperative that initiatives begun at NASA to evaluate the practical application of hybrid laminar flow control continue.



In those applications where hybrid laminar flow control is not the best solution, further development of turbulent skin friction reduction ideas should be encouraged. Those ideas include riblet materials similar to that currently being flight tested by industry and large eddy breakup devices for which the first generation of exploratory tests are underway at NASA Langley.

A third of the cruise drag of an airplane results from lift-induced drag. Again, innovative ideas need to be pursued as means of reducing lift-induced drag while providing for basic payload and lift requirements through a minimum amount of wetted area and a maximum amount of effective wing span.

The physics of a rotorcraft rotor system represents a significant challenge to achieving the aerodynamic definition necessary to tighten the design allowable. However, emerging computational fluid dynamics (CFD) techniques, as well as computational structural mechanics (CSM) methods, are just beginning to treat the rotor physics in the detail necessary to effectively define three dimensional, unsteady flows at high angles of attack and/or transonic speeds. The research efforts necessary to bring both CFD and CSM technologies, as applied to rotorcraft to a state of validated design tools, is essential. The improved physical modeling combined with experimental validation will lead to vehicles which are more efficient, aerodynamically are quieter and aeroelastically stable having reduced vibration.

### Supersonics

In the area of supersonic aircraft design, renewed emphasis needs to be placed on the development of supersonic design codes and analysis codes, and the development of quiet wind tunnels for the design of airplanes with supersonic hybrid laminar flow control.

### Hypersonics

In the area of hypersonics, Mach 3 to 25 regime, increased emphasis needs to be placed on development of hypersonic testing and analysis CFD codes and code validation with test data. The feasibility of increasing the capabilities for tunnel testing in the hypersonic regime should be investigated. The X-30 flight research vehicle, planned as part of the NASP Program, will fly throughout the hypersonic speed regime up to Mach 25. This experimental program is a technology program to develop the technological base for a whole new generation of hypersonic vehicles. The NASP Program is important to the U.S. in maintaining a position of preeminence in aeronautics. This program needs full support and reasoned high-level guidance to compete with the British, French, German, Japanese and Soviet hypersonic programs.



The complexity of modern requirements leads to wind tunnels and computational facilities that are not only very expensive but that take a very long time to design, build and bring online. The industry itself has built some excellent facilities, and an increasing capability exists in non-US world areas. However, the nation and the world face aerodynamic complexities of a very large magnitude. For the United States to remain world competitive, there must be a very large cooperative NASA, DOD, industry, and academia program, balanced among the three speed regimes of our National Goals, to develop new test facilities.

The above addresses only technical aerodynamic development. It does not address validation through flight test. Some such validation is absolutely required, and the process is a costly one. The United States has demonstrated great research ability and great ability to put large programs together once technology demonstration or validation has been obtained. The intermediate phase has proven to be much more difficult for our system and requires national leadership if program risks (commercial and military) are to be held to an acceptable level.

## **B. Propulsion**

Air breathing propulsion technology for military and commercial systems is progressing on a broad front. In the high performance military combat category, current aircraft are being fitted with improved versions of existing engines, growth derivatives are being qualified, for example, for the F-16, F-18, A-12, and B-2 and all-new engines are being developed for the Advanced Tactical Fighter.

In the military transport category, new high bypass engines have been certified and ultra-high concepts have been defined and demonstrated. Development of turbo-shaft engines is underway for new rotorcraft, such as the tiltrotor V-22 and advanced concepts for cruise missile engines are in process.

In the commercial arena, industry and NASA through cooperative proof-of-concept testing programs have demonstrated the viability of prop fan and ultra high-bypass ratio propulsion systems in ground and flight testing of first-generation geared and nongearred systems. These new concepts have the potential to allow design of new and derivative aircraft of the early 1990s that will offer significant economic benefits to the operators.

### Subsonics

Substantial opportunities exist for improving ultra high-bypass engines for fixed wing transport aircraft beyond the first generation recently tested. For the late nineties period further breakthroughs yielding at least 20% in specific fuel consumption, 10-15% in installed thrust to weight ratio, and lower noise, emissions, and cost are possible. The goals can be achieved by



application of enhanced CFD methods for improved configuration definition; utilization of advanced materials which permit reduced structural weight fraction or offer realization of new propulsion concepts; and component innovations that achieve higher thermal efficiency through increased overall pressure ratio and turbine temperature. Validation of these concepts by engine demonstrator testing is crucial to assure preeminence or even competitiveness. Early demonstration will provide the confidence to assure the successful and timely introduction of new products.

Technology superiority must be reestablished for rotorcraft engines by leadership in overall performance, durability and cost. Again component and material advancements must be defined and validated recognizing the unique requirements for small engines. Radically new system concepts should be evolved and critical features proven.

### Supersonics

NASA and industry are conducting studies aimed at defining an economically attractive, environmentally compatible high-speed commercial transport for nonstop trans-Pacific operation in the 2000 to 2005 period. The initial questions center on the speed, altitude, fuel, noise, and emission characteristics required. Technologies to be developed are advanced variable cycles, materials, noise suppression, emission controls and unique thermal management systems. In parallel, advocacy needs to be established on a national basis to assure that the commercial benefits are understood and accepted. The Technology program over the next five years should be led by NASA with strong industry involvement and needs continued sustained support for another five years--including a ground based engine demonstration.

### Transatmospherics

The NASP program is pursuing the technology required for a Mach 25 transatmospheric flight research vehicle. Overall propulsion system definition and component validation is in process as capability of ground based facilities, analytical methods, and material availability permits.

Parallel to NASP, a long-range plan needs to be formulated for sustaining development of the critical hypersonic technologies on a broad basis. The benefits of military hypersonic missions in the atmosphere at various Mach numbers from 4 to 12 and flight durations need to be determined. Critical decisions are speed fuel type, mission impact on the type of propulsion system, facilities for validation testing, and data to verify analytical codes over critical parts of the flight envelope. New types of engines such as turboramjets and turbosramjets are likely to be required with special emphasis on inlet and exhaust systems as well.



Opportunities in the field of propulsion are extremely large. Goals within 10-20 year periods of time would include subsonic engines having 30% greater efficiency, economic commercial supersonic engines in the Mach 2.5 to 4 range, and military aircraft with sustained cruise capability well above Mach 4.

### C. Structures and Materials

Development has been proceeding rapidly in many areas applicable to both aircraft structures and to propulsion systems. Applications change with cruise speed and therefore skin temperature. In addition, as noted earlier, until we attain a more complete understanding of supersonic and hypersonic boundary air conditions we cannot precisely predict the location of peak temperatures, except at the nose and wing leading edges. We thus must stay on the safe and therefore the heavy side. To cover all developments would require more space than is here available. We have thus chosen to limit our discussion to that of composite technology.

Composite materials for aerospace vehicles have been in the forefront of technology development for over 20 years. The introduction of this technology to aerospace vehicles has intentionally been slow and deliberate, beginning with secondary structure applications, and progressing to primary structure. Current generation fighter airframes employ up to 40% composite materials. New and innovative processes and procedures are being developed to reduce the cost of composite structures. Cost is a central issue to more widespread use of composites, particularly on commercial vehicles. Projections of 40% to 90% composites on the next generation fighter airframes are being forecast.

Most composite developments have taken place with organic thermoset composites using epoxy matrices. They have lived up to their promise of saving weight, improving fatigue life, and having outstanding corrosion resistance. Epoxy matrix composites have limited elevated temperature capability (approximately 250° F maximum).

A number of composite technologies are being developed for higher temperature applications, for improvement in strength, stiffness, and damage tolerance, and for low-observable applications. These are:

1. Advanced fibers
2. Toughened/high temperature thermoset composites
3. Electrically conductive polymers
4. Thermoplastic matrix composites
5. Ceramic matrix, carbon/carbon composites
6. Metal matrix composites

A number of improvements are being made in fibers to improve strength, stiffness, elevated temperature properties, and electrical properties. Significant improvements have been made in carbon fiber and both the



technology base and capacity of the U.S. industry are rapidly increasing. Significant development work is also ongoing in ceramic fibers and other fibers for use in both organic, metal, and ceramic matrix composites.

Toughened epoxies are now available which offer significant improvement in damage tolerance. Bismaleimides are being used for elevated temperature applications up to 450°F.

Conductive polymers are in emerging technology which promises to offer advantages in new "stealth technology" applications, however, they need substantial development before they can be considered in any aerospace application.

True thermoplastic composites offer potential advantages because they have indefinite shelf life, do not require refrigeration, and can be joined by self-infusion. Manufacturing processes are being developed which offer acquisition cost reduction potential. They generally exhibit good toughness, damage tolerance and repairability. Thermoplastic polyimides have good elevated temperature properties up to approximately 600°F, but processing is more complex and development work is ongoing.

Ceramic matrix and carbon/carbon composites are in limited use on high performance vehicles like the Space Shuttle. They are extremely advantageous in very high temperature applications such as engine exhaust nozzles and fire zones in aerospace vehicles. With present state-of-the-art materials, ceramic matrix composites are very brittle and essentially impractical in a primary aerospace structure. Carbon/carbon materials require development of better oxidation resistance coatings to allow their use in long life vehicles.

Ceramic matrix and carbon/carbon composites require major development. Their high temperature resistance could mean substantial improvements in the performance of propulsion systems as well as fire safety in aerospace vehicles. They require the development of a more elastic material than exists today. Currently they are useable on short life vehicles, but will not perform satisfactorily on systems requiring extended vehicle life. Major thrust in the development of ceramic matrix and carbon/carbon composites and coatings are being pursued to accomplish these goals.

Metal matrix composites lie in the temperature region between organic composites and ceramics. Some metal matrix composites have been used in high payoff applications such as the space shuttle where their cost per pound can be justified. They are expensive to fabricate because of the nature of their processing; however, newer techniques are being developed to cut their cost.



Metal matrix composites are critical to the development of reusable hypersonic aircraft and spacecraft such as the X-30. Although organic composites have better properties at low temperatures and ceramic composites are useable at higher temperatures, metal matrix composites have the highest specific strength in the 800 to 1800°F, which includes most of the surface of a typical hypersonic vehicle. If the U.S. is to remain a leader in the next area of aerospace development, we must develop matrix materials, fibers, manufacturing processes and structural concepts for metal matrix composite hypersonic vehicles. Both U.S. and foreign industries are presently engaged in the development of organic matrix, ceramic matrix, and carbon/carbon materials. The leaders, however, seem to be overseas with thermoplastics advancements being made in Britain, and ceramics in France. Japan also has development programs in these areas, particularly in ceramics.

The U.S. is not the leader in several important composite materials areas. We must establish a mechanism to stimulate development of these highly advantageous materials and provide the incentive for their manufacture to maintain and reestablish U.S. leadership in these technologies.

#### **D. Systems Management**

Aircraft of the future will be fully managed by on-board computer systems. Sensors deployed to monitor all on-board functions and the off-board environment will provide the computers with a continuous flow of data on the flight status, conditions of the external environment and the health of all on-board systems.

The aircraft crew monitors the displays that are updated in real time by the management systems and programs the computers in real time to query and command the systems. The system translates the crew's commands into fault-free operation of all the aircraft's subsystems. The subsystems themselves are integral to the overall architecture such that the entire aircraft system is controlled in an optimum energy and time efficient manner. The crew becomes the overall system executive overseeing a highly self-managed electronic system. This approach allows the crew to give efficient executive level attention to the critical elements of air vehicle operation.

Key technologies that will provide this new aircraft system management capability are: (1) Ultra-reliable electronics; (2) Advanced sensors; and (3) Artificial Intelligence and advanced system concepts.

#### Ultrareliable Electronic Systems

The most promising approach to achieving cost effective fault-tolerance involves the maximization of assignable digital processing resources with the minimization of dedicated equipment that can only achieve fault-tolerance through multiple redundancy. This can be succinctly envisioned



as common distributed processing elements networked together with primitive sensor elements, actuators, and input/output devices. This approach is a substantial rethinking of how functions can be implemented as part of a system, instead of the traditional microsystem philosophy -- specifically use of a shared instead of dedicated processing resource. Critical to this will be the development of standard processing elements, networks, operating systems, and interfaces.

To achieve ultrareliability through the fault-tolerant capability of this distributed processing architecture requires:

1. An ability to communicate data and status between processing elements in a fault-tolerant manner.
2. Knowledge, identification, and isolation of the fault within the system architecture.
3. An ability to reassign resources to assume the functions of the failed system element(s).

The distributed processing architecture poses demanding requirements on the interprocessor communication networking mechanism. These include a versatile set of communication services to support the real-time distribution of data throughout the system and fault-tolerance. Fiberoptic based networks being developed by international and national standards organizations both meet these requirements and provide a basis of commercial and military aerospace standards. Use of fiber-optics as a transmission medium provides the bandwidth to quickly transfer large data bases required for operation of a distributed processing system and reconfiguration to overcome faults in processing elements. The use of network protocols instead of the simpler bus protocols will substantially simplify the interface with system elements and provide an autonomous fault-tolerance within the network. Fiber optics greatly reduces electromagnetic interference (EMI) susceptibility relative to past avionics systems.

To maintain fault-tolerant operation of a system that utilizes reallocation of processing resources instead of multiple redundancy requires the knowledge, identification and isolation of the fault with the system. Unlike the voting system employed in multiple redundant systems more indirect approaches are required to ascertain the existence of a fault in the non-redundant or partially redundant distributed processing architectures. The evolving artificial intelligence technology is developing tools and methodologies that may be uniquely applicable to the problem of identifying anomalies in large data bases of partially related data. This would then provide the information required to identify the source of the fault for reassignment of its impacted functions.



The ability to reassign functions of a failed unit is dependent on the availability of an equivalent alternative. For elements of the distributed processing architecture functions of identified failed elements can be reallocated among the remaining processing elements that are functionally equivalent. For this, and cost reasons, it is desirable to structure the processing elements that are functionally equivalent. For this, and cost reasons, it is desirable to structure the processing architecture out of common processing elements. Again, as also in the case of the network, a set of standard modules should be developed to implement these data and signal processing elements.

### Advanced Sensors

The issue in sensors today is reducing cost of acquisition and production and the integration of multi-sensor systems. The emphasis in future R&D should be placed in reducing size, weight and cost and increasing reliability. The area of automatic target recognition and pattern recognition concepts for imaging sensors is an extremely fruitful technology that needs to be employed in the next generation of such sensors. Not enough attention, on a national scale, is being paid to commonization or modularization to provide reduced cost through economy of scale. Each sensor concept tends to stand on its own.

Developing sensors may provide the visionics to operate a VTOL in a self-contained IFR mode. Automated flight control and information processing through artificial intelligence/expert system provides a great opportunity and challenge to enhance the safety of VTOL operations by reducing the pilot workload and increasing situational awareness. To achieve this, the total cockpit information transfer and display process requires a concerted effort to integrate the mission critical systems, information displays and activation systems into a balanced configuration capable of dealing with more demanding missions with increased safety.

New avionics architecture, which can share computer systems and make overall systems integration more redundant and lower cost, need to be addressed with openness and foresight for future systems. We tend to standardize and live by those standards too long. Avionics architecture is a rapidly expanding field, benefiting from the explosion of computing networking and the common data processing applications in the commercial sector. These new architectures are a key to true multi-sensor integration. This area requires aeronautics R&D attention and focus if the true value of advanced avionics sensors are to be fully realized in the next decade.

### Artificial Intelligence

Artificial Intelligence (AI) is a technology which has many applications in the cockpit and is even more valuable in unmanned systems. Current DOD activities such as Pilot's Associate and Super Cockpit will explore the



capabilities of "AI" during the next decade for aircraft application. Catastrophic accidents due to pilot error can be reduced and perhaps eliminated if the pilot is "backed up" by intelligent computers. Future emphasis should be towards demonstrations of AI's capability in the cockpit. Pilot community confidence in its capabilities will not come easy and a great deal of testing will be required.

AI's utility in aircraft system operations other than pilot "backup" will be easier to transition. These applications include, but are not limited to, subsystem failure analysis and correction, real-time remote sensing data/image analysis, maintenance fault locating and correction.

There should be a focus on research to bring AI into aircraft applications as soon as possible. The payoff is great.

### **E. Processing and Manufacturing Technology**

Technology trends within the context of manufacturing methods development can be considered in two categories: 1) manufacturing improvements which will be applicable regardless of technology development in the materials, processes and product design area, and 2) other manufacturing changes which are driven by the attendant technology advancements in materials and end product or system design changes.

#### **Equipment and Process Development Which is Independent of Material and Design Improvements**

Industry experts agree that the use of Artificial Intelligence, AI, as a means of process control will have significant impact on reducing manufacturing costs and improving product integrity. AI can be applied to a broad range of manufacturing operations which rely on machine or equipment response to real time measurements of some physical attribute. One of the present widespread areas of research involves the application of these principles to the control of heat curing of thermosetting resin matrix composites. This development will lead to significant changes in the control of temperature and pressure dependent processes which include polymerization reactions, thermal treatment of metals and welding. By the turn of the century, applications of AI are expected to revolutionize the way in which both military and civilian aerospace system products are manufactured. The timetable and extent of AI technology development will be dependent on the availability of other newly emerging key technologies which include advanced computer software, very large scale integrated circuitry and optical information processing.

All aspects of composite material fabrication which are commonly practiced could be improved by general automation. This includes material cutting, handling, positioning and compacting. Precision fiber placement involves the use of robotic principles to accurately place continuous lengths



of uncured composite materials onto a forming tool. The complexities of actual structures such as compound curvatures and variable thickness introduce a need for a high level of machine sophistication.

The aerospace and military aircraft industries generally employ batch production methods. The extensive use of robotics can be expected to follow the widespread use in more commercialized sectors. Conversely, the flexible manufacturing systems appear to offer the greatest promise in the aerospace/aircraft environment. Flexible manufacturing systems and other computer-controlled and integrated machines, work stations, transfer mechanisms and tooling allow production of a wide CIM, has great benefit and will be a major technology thrust for the aircraft industry.

#### Equipment and Process Development Which Coincides With New Materials

There will be many innovative, low cost manufacturing methods which will be developed as the direct result of the introduction of a new material or new material form,. One near term example is the use of thermoplastic resin matrix composites. Although the fully processed structure retains the general design characteristics of a corresponding thermosetting resin matrix composites structure, the manufacturing processes involved are vastly different. The initial usage of thermoplastic composites in major production is expected to occur within the next five years. the development of the manufacturing methods for this new class materials has progressed to the state where the preferred processes and equipment are generally known and these vary depending upon the part size and complexity .

Joining is one aspect of the manufacturing with thermoplastics that will serve as an example of a major product and producability improvement which will be realized. These materials can be joined by heat fusion, i.e., welding, due to the ability to melt and resolidify the matrix material without affecting the material itself. Therefore, an overlapping joint can be made which cannot be distinguished from the surrounding material. This development will lead to production of "unitized" assemblies and eliminate the need for many fasteners or adhesives. The significance of this is apparent since approximately one-half of all touch labor required in typical aircraft fabrication involves fastener installation and related operations.

There is compelling need for materials which can withstand extreme temperature. Metal matrix composites, carbon/carbon composites and ceramic materials in all forms provide the high temperature characteristics which are sought. The inherent thermal stability of these materials presents a strong challenge to the manufacturing community. In the past, material characteristics for many high temperature materials have limited their use to very small detail parts. As these and other unconventional materials are developed for larger structural applications, the manufacturing engineers will be called upon to evolve the large scale, innovative manufacturing methods for the difficult to process materials.



## F. Overall Status

The current status of the manufacturing technology in the United States aerospace and aircraft industries is keeping pace with the developments of new materials. The time required for a material supplier to formulate and fully characterize a new material is several years. These years are generally sufficient to develop the processes and equipment for production utilization.

On the other hand, product changes and improvements can happen rapidly giving little time for the manufacturing engineers to respond. This results in short term manufacturing inefficiencies until the manufacturing improvements can be introduced into the production environment. The need for an effective product design and manufacturing engineering interface is well known. Despite its recognition and importance, this has been difficult to achieve. The use of centralized computing does not alleviate, but can actually exaggerate the situation by speeding up the design change process and reducing the personal interaction.

The United States leads the world in AI technology. The aerospace/aircraft industry will be among the first users. Conversely, heavy robotic utilization will follow the highly repetitive production environments such as the automobile industry. The one common factor which applies to all areas of technology advancement is that more highly skilled engineering resources are needed. The role of universities and the industry-university interaction can be increased to ring new technologies and trained graduates to industry.

In summary, the future manufacturing trends will focus in the following major areas:

1. Computerized Management/Information Systems (e.g., MRP)
2. Artificial Intelligence
3. Robotics
4. Automation of Present Tough Labor Intensive Processes
5. Equipment and Process Development which Coincides with the Introduction of New Materials and Material Forms

APPENDIX B  
AERONAUTICAL POLICY REVIEW COMMITTEE

MEMBERSHIP

John E. Steiner (Chairman)  
Vice President, Corporate  
Product Development (Retired)  
The Boeing Company

William F. Ballhaus, Jr.  
Acting Associate Administrator for  
Aeronautics & Space Technology  
National Aeronautics and Space Admin.

John F. Cashen (Deputy Chairman)  
Vice President, Advanced Projects  
Northrop Corporation

Raymond S. Colladay  
Director  
Defense Advanced Research Projects  
Agency

Eugene E. Covert  
Department Head, Aeronautics &  
Astronautics  
Massachusetts Institute of Technology

J. Roger Fleming  
Sr. Vice President, Technical Services  
Air Transport Association

Bastian (Buz) Hello  
Senior Vice President, Government  
Relations  
Rockwell International Corporation

Russell L. Hopps  
Vice President Engineering (Ret.)  
Lockheed Corporation

Charles B. Husick  
Executive Vice President, Operations  
Advanced Technology & Research, Inc.

James N. Krebs  
Vice President & General Mgr. (Ret.)  
General Electric Company

Walter Luffsey  
Director, Advanced Aviation Systems  
Design Team  
Federal Aviation Administration

Robert R. Lynn  
Senior Vice President, Research &  
Engineering  
Bell Helicopter Textron

Benard Paiewonsky  
Deputy for Advanced Technology  
Office of the Assistant Secretary of  
the Air Force for Acquisition

Hershel Sams  
Vice President, Engineering Technology  
McDonnell Aircraft Company

John M. Swihart  
Vice President, International Affairs  
The Boeing Company

**OSIP**

Thomas P. Rona  
Deputy Director

Alan Chambers  
Executive Secretary