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Aeronautics Research and Technology

A Review of Proposed Reductions in the FY 1983 NASA Program

Committee on NASA Scientific and Technological Program Reviews

Commission on Engineering and Technical Systems

National Research Council

Aeronautics Research and Technology

A Review of Proposed Reductions in the FY 1983 NASA Program

Prepared by a Panel Convened by the
Committee on NASA Scientific and Technological Program Reviews
Commission on Engineering and Technical Systems
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the panel responsible for the report were chosen for their special competences and with regard for appropriate balance.

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

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REVIEW PANEL
REDUCTIONS IN THE FY 1983 NASA AERONAUTICS RESEARCH AND TECHNOLOGY PROGRAM

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Preface

The Committee on NASA Scientific and Technological Program Reviews was created by the National Research Council in June 1981 as a result of a request by the Congress of the United States to the National Aeronautics and Space Administration that it establish an ongoing relationship with the National Academy of Sciences and the National Academy of Engineering for the purpose of providing an independent, objective review of the scientific and technological merits of NASA program changes whenever the Congressional Committees on Appropriations so direct.[1]

When a review is requested, the Committee is called into action to set the terms of reference, select a panel of experts to carry out the task, and review the resulting report before publication.

The panel undertook its first task during the summer months of 1981 when it reviewed alternative versions of the International Solar Polar Mission, a joint venture between NASA and the European Space Agency. A report was issued and the results of the review were presented in briefings to Congress and to NASA in the early part of September 1981.[2]

The second task, which is the subject of this report, resulted from a request by the Congressional Committees on Appropriations to the NASA Administrator (Appendix A) in March 1982 for a review of reductions in NASA's Aeronautics Research and Technology Program. The Committee met on March 27, 1982, to establish terms of reference (Appendix C) for the review based on the congressional request and to nominate a panel combining various areas of industrial, academic, economic, and governmental expertise to undertake the task. In appointing such a group of individuals to make scientific and technical assessments, it is essential that the majority have a high degree of expertise in the subject of the study. It is an almost

[1]Congressional Conference Report 96-1476, November 21, 1980.
[2]The International Solar Polar Mission: A Review and Assessment of Options, National Academy Press, Washington, D.C., September 1981.

impossible task to find individuals totally without potential bias who have the appropriate qualifications. Thus, every effort was made to achieve a balance in backgrounds and attitudes of the panelists in order to present as objective a report as possible.

The short period of time over which the review had to be undertaken put severe demands on the Chairman and members of the panel, who deserve much credit for their effective and timely response.

Norman Hackerman
Chairman, Committee on NASA Scientific
and Technological Program Reviews

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*Proposed new initiative.

Executive Summary

The Committee on NASA Program Reviews of the National Research Council in response to requests from the Congressional Committees on Appropriations formed the Review Panel for Reductions in the FY 1983 NASA Aeronautics Research and Technology Program and provided guidelines for the review on March 27, 1982. The congressional request was for review of reductions in the Fiscal Year 1983 program from the original NASA proposal to the levels of the appropriation request submitted to Congress. The request asked for an assessment of the national criticality of the excluded programs and, for each one, the risk (probability of success) associated with achieving the objectives sought and the degree to which it might be assumed by the private sector.

Based on this request, the NRC Committee on NASA Program Reviews developed a charge comprising an assessment of those aeronautics projects excluded from the NASA FY 1983 budget request to Congress, the likelihood that industry would undertake them, the impact of their not being done, and the more general question of the need for government to "bridge the gap" between the Aeronautics Research and Technology (R&T) Base and early application.[1] The charge further specifies that the assessment is to encompass considerations of safety, national defense, efficient transport, and the national economy.

NATIONAL CRITICALITY AND BRIDGING THE GAP

The issues of national criticality and the need for bridging the gap between the R&T Base and industry raise numerous fundamental questions in economic and political doctrines and policies. Although many of these questions should be addressed in the long run, the panel, in recognition of the relatively near-term nature of the NASA program

[1] The R&T Base consists primarily of discipline-oriented and applied research.

decisions being addressed, judged national criticality in terms of the need to ensure that essential R&D program decisions made now do not foreclose the timely availability of future options to meet national requirements and the need to avoid possible major negative effects on the contributions of NASA and the aerospace industry to the national economy, the national defense, and the national transportation system.

The panel generally accepted the principle expressed by the Office of Management and Budget that "technology development and demonstration projects with relatively near-term commercial applications will be curtailed as an inappropriate federal subsidy." The panel noted, however, the difficulties in the early stages of R&D of separating military from commercial applications, of determining whether innovations will be achieved in the near or the long term, and of defining where in the spectrum of the R&D process particular program activities should be characterized.

OTHER CONSIDERATIONS AFFECTING THE REVIEW

The panel's assessments were based on the following additional considerations:

o The history of undisputed success in aeronautics research and technology under existing divisions of labor among NASA, the Department of Defense, and the private sector (universities and industry) and the effective dissemination of research ideas among the nation's research teams.

o The multipurpose nature of much of NASA's research and the difficulty in identifying programs and technologies with exclusively military or commercial applicability. Much aeronautical technology in transports, in the engine field, and in helicopters is equally applicable to defense as to civil aviation needs.

o The nature of the transport aircraft and engine manufacturing industry, whose commercial product bears a very high price tag and whose product development costs are of the order of the worth of a large company (typically $2 billion for the development of a new transport and $1 billion for the development of a new engine). These industries engage in near-term technology demonstration to extend the state-of-the-art into improved products.

The crucial element in determining which products of NASA research will be developed is confidence in a technical base. This is essential before a manufacturer can responsibly commit the enormous funding needed for development of a new product.

o The good long-term economic performance of the U.S. aircraft and aircraft engine industries in both the civil and military sectors (these industries account for 10 percent of U.S. exports in the nonagricultural sector) and the growing and increasingly effective competition from foreign competitors who are heavily government subsidized.

In judging the importance and priority of specific demonstration programs, the panel laid heaviest emphasis on the degree of innovation involved, the breadth of applicability possible, and the extent of development, demonstration, verification of concept, and validation in an operational environment required before the new concept, component, material, or device could be incorporated with acceptable technical risk in production of civil or military aircraft.

FINDINGS

Although only seven Systems Technology projects were retained in the FY 1983 budget request to Congress because they were judged to support military needs, several of the nineteen excluded projects (see Table 2 on pages 8 and 9) were found by the panel to have medium to high impact on national defense.

Of the excluded ongoing projects and new initiatives, the following nine programs spanning the three major technology areas in aeronautics were judged to be of the highest priority.

o In the area of structures, the three programs in composites--Composite Primary Aircraft Structures (CPAS), Transport Aircraft Composite Structures (TACS), and Advanced Composite Materials R&T--are regarded as having the highest priority, with high potential impact on safety, efficient transport, and the national economy and moderate impact on national defense. The outlook for technical success is good. Although industry is using some composite structures in new aircraft and is doing considerable near-term R&D for further application, it is not likely to take on in the near future such programs as CPAS and TACS, which represent long-term objectives with broad applicability.

o In the propulsion area, the Energy Efficient Engine (E^3) and the Advanced Turboprop Program (ATP) were judged to be of high priority. The E^3 program has high potential impact on efficient transport, the national economy, and national defense. The outlook for technical success is good, but it is unlikely that industry would undertake such a program in the near future.

The ground test phase of the Advanced Turboprop Program (ATP), in which aerodynamic, structural, and acoustic characteristics will be defined, is seen as having high priority along with some effort in preparing for the flight test program (Phase III), which will eventually be required for an adequate data base. The full implementation of Phase III is also of high priority and represents a very desirable acceleration of the program but is rated below the other programs in urgency. Successful technological development of the advanced turboprop will have high potential impact on efficient transport, the national economy, and national defense. The outlook for technical success is fair to good, and it is improbable that industry would undertake this work in the near future.

o In the area of aerodynamics, three activities were singled out as high priority programs--Energy Efficient Transport (EET), High

Performance Military R&T, and Productivity Improvement. Completion of the remaining work in the EET program should result in benefits to efficient transport and the national economy. High Performance Military R&T will provide a basis for NASA to continue its strong role in technology developments to improve future military aircraft. Productivity Improvement is grouped with the aerodynamic activities because it will improve facilities that are used primarily for aerodynamic investigations.

The panel believes that the implementation of these high-priority activities will result in a focused and balanced program, enabling advances in all three major divisions of aeronautical technology--structures, propulsion, and aerodynamics.

Some degree of support within the R&T Base is regarded as appropriate for several ongoing projects, as well as for the new initiative Small Engine Components. These projects include three that NASA itself has proposed for the R&T Base.

The excluded Systems Technology projects and new initiatives assigned a high priority are projected by NASA to cost somewhere between $48 million and $79 million, depending on the level of support allocated the ATP Phase III. (Three of these high-priority programs totaling $14 million are new initiatives in the R&T Base.)

A further increase in the R&T Base of between $10 million and $20 million would appear to account for the inclusion of some level of effort for the R&T Base components of Systems Technology projects being terminated and deemed appropriate for funding within this category.

OTHER CONCERNS

Several issues arose in the panel's deliberations about which its members wish to express concern.

New Initiatives

The panel views with great concern the deferral of NASA's new initiatives in aeronautics for the past two years. The absence of such long-term R&D programs, while not felt in the near term, may result in severe setbacks in the U.S. defense and economic posture in the long term.

Adequacy and Balance of R&T Base Program

Finally, the panel wishes to express its concern over the generally declining trend in support of NASA aeronautical R&D over the past several years and the even steeper decline in out-of-house effort relative to in-house effort (see Figure 2 in Chapter 6). It is especially concerned about the decline in support of university programs in a period when universities are experiencing severe financial stresses and when the need for educating scientists and engineers to meet national requirements is of great importance. In the panel's view, the continuation of these trends would be most unfortunate for future progress in aeronautics in the United States, having serious adverse effects on the national economy and national defense.

1

Introduction

NASA's Aeronautics Research and Technology Program is divided into two major elements, the Research and Technology Base and Systems Technology. The Research and Technology Base consists primarily of discipline-oriented research and applied research. Systems Technology, as described by NASA, consists predominantly of technology demonstration/proof-of-concept activities and, to a much lesser extent, technology validation in those research areas that have shown promise.

The FY 1983 budget submitted to Congress for NASA's Aeronautics Research and Technology Program is substantially lower than its level of prior years in constant dollars, as shown in Table 1 and Figure 1. While that part of the budget allocated to the Research and Technology Base is slightly higher than in past years, the Systems Technology budget is only 25-30 percent of its level in the 1973-1981 period. The budget excludes any new initiatives and retains only those programs that had been judged to support military needs (see the Office of Management and Budget's Special Analysis K in Appendix D). The Systems Technology projects proposed for termination are those that had been viewed as supporting primarily civil aviation. Table 2, derived from NASA-furnished information, shows the FY 1983 budget for NASA's Aeronautics Research and Technology Program. The three columns reflect the originally proposed NASA program, a reduced program proposed by NASA, and the appropriations request to Congress.

The congressional request (Appendix A) is for an assessment of the national criticality of excluded programs, the risk associated with achieving the objectives sought by each one, and the degree to which each one might be assumed by the private sector.

The charge to the panel from the Committee on NASA Program Reviews (Appendix C) calls for an assessment of those projects excluded from the proposed FY 83 budget, the likelihood that industry would undertake them, the impact of their not being done, and the more general issue of government support for aeronautics beyond the research phase.

TABLE 1 Aeronautics R&T Profile, Fiscal Years 1973-1983
(in FY 1983 dollars)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Aeronautics R&D	371.8	388.2	345.8	334.5	327.2	364.1	385.1	406.0	322.4	254.0	232.0
Research and Technology Base	184.7	184.9	173.5	161.5	156.1	156.2	160.0	159.1	158.9	177.1	182.0
Systems Technology	187.1	203.3	172.3	173.0	171.1	207.9	225.1	246.9	163.5	76.9	50.0

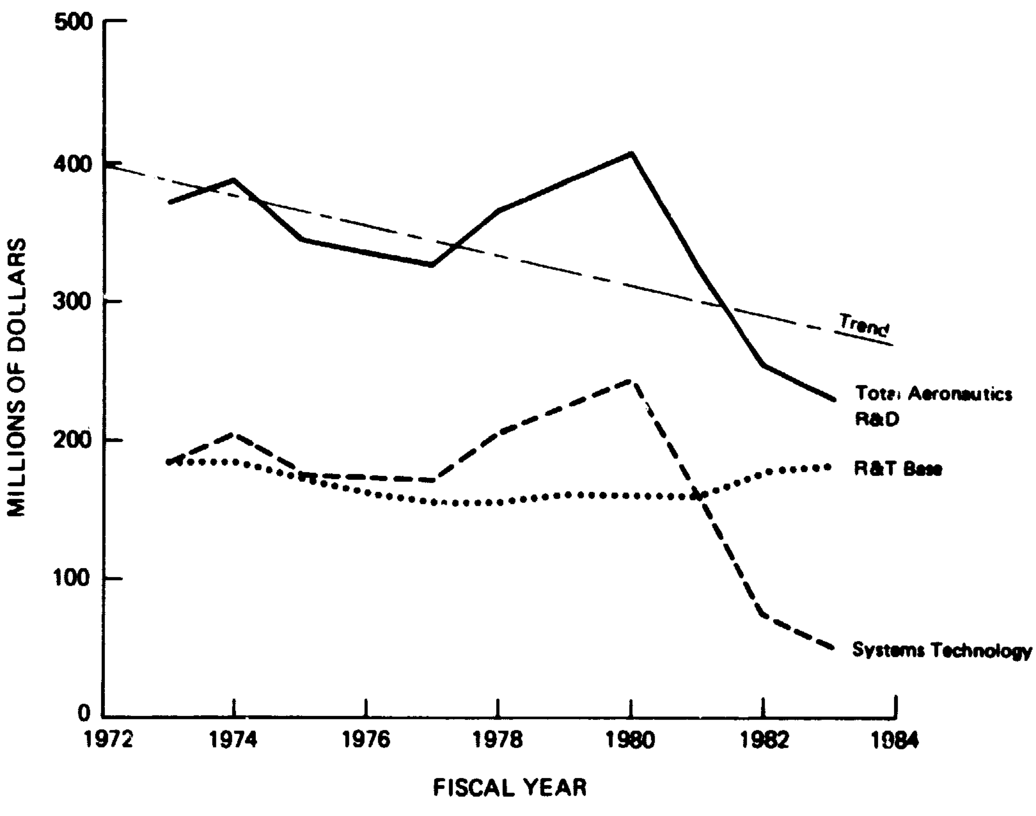

FIGURE 1 Aeronautics R&T Profile, Fiscal Years 1973-1983
(in FY 1983 dollars)

TABLE 2 NASA Aeronautics R&T FY 1983 Budget

Program	Request to OMB	NASA Reduced Budget	Request to Congress
R&T Base	217.8	203.5	182.0
Aerodynamics	49.2	45.2	42.3
Propulsion	46.8	49.8	43.0
Materials and Structures	28.5	31.8	31.3
Aircraft Controls and Guidance	9.9	13.9	12.9
Human Factors	9.6	10.6	9.6
Multidisciplinary Research	6.6	6.6	3.5
General Aviation/Commuter	8.5	--	--
Low-Speed	12.4	13.4	12.4
High-Speed	36.5	32.2	27.0
Transport	9.8	--	--
Productivity Improvement*	(6.0)[a]	(--)	(--)
Advanced Composite Materials R&T*	(4.0)	(--)	(--)
High-Performance Military R&T*	(4.0)	(--)	(--)
Systems Technology	153.2	92.5	50.0
Systems Studies	2.9	2.9	--
Materials and Structures	3.1	0.1	--
Integrated Program for Aerospace Vehicle Design (IPAD)	1.6	0.1	--
Aeroelasticity of Turbine Engines	1.5	--	--
Propulsion	8.7	4.2	--
Helicopter Transmission Technology	1.5	--	--
Critical Aircraft Resources/Broad Property Fuels	4.2	4.2	--
Small Engine Technology*	3.0	--	--
Advanced Propulsion	57.8	16.8	--
Energy Efficient Engine	17.0	7.0	--
Advanced Turboprop Systems	9.8	9.8	--
Advanced Turboprop Systems Phase III*	31.0	--	--
Low-Speed	38.8	38.3	30.0
Rotorcraft Operating Systems	1.5	1.5	1.5
Powered Lift Technology	2.0	2.0	--
Advanced Rotor System Technology	5.6	5.6	5.6
TRRA Systems Technology	1.8	1.8	--

*New Initiative

[a]Non-Add--Included in R&T Base figures

TABLE 2 (Continued)

Program	Request to OMB	NASA Reduced Budget	Request to Congress
Advanced Rotorcraft Technology	18.0	18.0	13.5
Low-Speed Simulation and Flight Systems Support	9.9	9.4	9.4
High-Speed	20.5	19.5	20.0
High-Performance Flight Research	9.1	8.1	13.3
Highly-Maneuverable Aircraft Technology	1.1	1.1	1.1
Turbine Engine Hot Section Technology	10.3**	10.3**	5.6
Transport	21.4	10.7	--
Laminar Flow Control (LFC)	6.7	--	--
Energy Efficient Transport (EET)	1.1	1.1	--
Composite Primary Aircraft Structures	2.0	2.0	--
Terminal Configured Vehicle	7.6	7.6	--
Transport Aircraft Composite Structures*	4.0	--	--
TOTAL	371.0	296.0	232.0

*New Initiative
**Transferred from Materials and Structures

2

Approach

The panel met on April 15-16, April 30-May 1, and June 9-10, 1982. A team of NASA engineering executives briefed the panel and participated in discussions with the members (Appendix E). The panel also received briefings from representatives of the Aerospace Industries Association, the General Aviation Manufacturers Association, the Department of Defense, and the Federal Aviation Administration (FAA), and it held informal discussions with representatives of the Office of Management and Budget and the White House Office of Science and Technology Policy (Appendix F).

The panel took account of other National Research Council studies that dealt with NASA's aeronautics program, which include the Aeronautics and Space Engineering Board's seven volumes on *NASA's Role in Aeronautics: A Workshop* (1981) and its reports *NASA's Aeronautics Research and Technology Base* (1979) and *NASA's Aeronautics Program: Systems Technology and Experimental Programs* (1980) as well as the current Review of Advanced Technology Competition and the Industrialized Allies. In addition, the panel was informed of other current activities dealing with government support of aeronautics, including the White House Office of Science and Technology Policy's review of U.S. aeronautics research and technology policy and the hearings of congressional authorization and appropriations committees.

The panel considered the NASA Aeronautics Research and Technology Program, addressing specifically the 13 Systems Technology projects originally proposed for continuation in FY 1983 and subsequently proposed for termination and the originally proposed six new initiatives that were subsequently excluded. These programs and their budgetary alternatives are shown in Table 2.

In considering the individual programs, the panel has been charged with addressing the following questions.

1. Is it necessary for the government to bridge the gap between the aeronautics Research and Technology Base and early application with regard to safety, national defense, efficient transport, and the national economy?

2. What is the outlook for success and what are the time horizons of those projects excluded from the proposed FY 1983 budget? Would

industry undertake these projects (now or later) if government does not do them--and on what basis?

3. If neither government nor industry undertakes the projects noted in question 2, what will be the impact with regard to safety, national defense, efficient transport, and the national economy?

4. What should be the priorities within NASA's Aeronautics Research and Technology Program?

The panel notes that within the R&T Base NASA proposes to redistribute the activities encompassed in the categories of General Aviation/Commuter and Transport to appropriate discipline-related categories, as the latter already include research applicable to these areas.

In considering its charge, the panel adopted the following procedure.

o Describe, for each individual project or initiative, its objectives and status derived from NASA documentation and give the panel's findings.

o Combine in a summary table the assessments for excluded projects, including the panel's rating of priorities as requested in question 4.

o Discuss question 1 and other concerns of a general nature separately (see Chapter 5, "Bridging the Gap").

Judgments regarding the criticality of individual programs were influenced by the degree of completion of the program, the likelihood of success of the present activity, and in severely cut programs whether continuing work could appropriately be considered for inclusion in the R&T Base. Other fundamental criteria for assessing criticality are discussed in Chapter 3, "Considerations Affecting the Review."

With respect to question . of the charge, the panel noted the detailed assessment of the NASA aeronautics program provided in the seven-volume workshop report of the Aeronautics and Space Engineering Board and limited its own prioritization to ratings of high, medium, and low. In many cases where the panel recommends that elements of a program be included as an essential part of the R&T Base, no priority rating has been assessed. Programs with continued funding, limited to the low- and high-speed systems technology areas, are not considered in the detailed technical discussions.

Two additional topics discussed by the panel, the role of NASA system studies and possible joint industry R&D programs, appear as Appendixes G and H.

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Considerations Affecting the Review

The request from the congressional committees asked that the review evaluate, among other things, "the national criticality of these programs." Determining the national criticality of NASA programs in the broadest sense encompasses issues of economics, politics, and national security. In each of these areas, there are widely divergent views on theories, doctrines, and policies extant not only among the experts but in the body politic at large. The time and effort available for an in-depth examination of these issues by the panel were extremely limited by the brief period allowed for this review and precluded any attempt at extensive analysis of major issues in a fundamental way.

The panel therefore undertook to address the question of national criticality in as narrow a context as could reasonably meet the main purposes of this review. To this end, the members recognized the relatively immediate nature of the NASA program decisions involved and assumed that disruption of a major and relatively healthy national industry through abrupt changes in the ground rules by the government without time for the planning and implementation of alternative courses of action to compensate for these changes would not be in the national interest. Accordingly, national criticality was judged in terms of the need to ensure that R&D program decisions made now do not foreclose the timely availability of future options to meet national requirements and the need to avoid possible major negative effects on the important contributions of NASA and the aerospace industry to the national economy, the national defense, and the national transportation system.

U.S. AERONAUTICAL R&D AND THE AEROSPACE INDUSTRY

Aeronautical R&D and the aerospace industry in the United States are characterized by a history of undisputed success in aeronautical research and industrial technology under the existing division of labor among NASA, the Department of Defense, universities, and industry. Industry has carried the major burden of R&D for civil transports such as the Boeing 757, engines such as the P&W JT9D, and general aviation such as the Lear Fan 2100, and this amounts to a substantial ongoing investment. At present, the United States' share of commercial jet aircraft in airline service worldwide is about 90 percent. Aerospace exports in 1981 stood at $18 billion ($14 billion civil) and accounted for about 10 percent of all U.S. exports of nonagricultural commodities. U.S. military aircraft are in high demand throughout the non-Communist world and exports are limited by government policy more than by demand. These military aircraft have shown substantial margins of superiority in the limited combat engagements that have occurred. While many factors other than the direct contributions of R&D are involved in these successes in civil and military aircraft development, production, and sales, R&D and its effective transition to industrial applications have played an essential part in achieving the present U.S. prominence in the world marketplace for aircraft.

THE WORLD SCENE IN GOVERNMENT SUPPORT OF AEROSPACE PROGRAMS

For reasons of importance to national defense and prestige, and because of potential benefits to transportation, industrial development, and the economy, most of the highly developed nations have, since the World War I era, supported national R&D establishments in aeronautical technology.[1]

More recently, the involvement of foreign governments in supporting the aerospace industry has greatly increased, going well beyond direct support of R&D. In England and France, the major elements of the industry have been nationalized. In Germany and the Netherlands, there is substantial government ownership and subsidy of the principal companies. Moreover, in the civil transport sector there is a sort of international cartel developing in Airbus Industries, with its A-300, A-310, and proposed A-320, which preempts purely national developments with political and to some extent economic pressure applied to keep other countries from undercutting the cartel. The trend toward cartelism is thus to some degree counter to technological nationalism, which is also developing throughout the world, not only in aerospace industries but in other high-technology industries, such as microcircuits, microprocessors, and computers. Government subsidies in civil transport development (and some other

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[1]Examples (in their current incarnations) are the Royal Aircraft Establishment (RAE) in England, Office National d'Etudes et de Recherches Aerospatiales (ONERA) in France, Deutsche Forshungs und Versuchsanstalt fur Luft und Raumfahrt (DFVLR) in Germany, Nationaal Lucht und Ruimtevaartlaboratorium (NLR) in the Netherlands, Flygtekniska Forsoksanstalten (FFA) in Sweden, and NASA in the United States.

high-technology products) go far beyond early stages of R&D, extending to the nonrecurring costs of the manufacturing, inventory costs, and marketing costs and including low-interest loans to buyers.

Furthermore, since many foreign airlines are themselves nationalized or have other significant government financial involvement, their choices of aircraft are subject to political pressures, tie-in sales of desired military equipment, and trade preferences and concessions made by governments. All of this is a far cry from a free market in civil aircraft sales.

RATIONALE FOR GOVERNMENT SUPPORT OF AERONAUTICAL R&D

As long as no general political decision has been made in this country to attempt to compete in similar terms with the growing tide of foreign state capitalism, technological nationalism, and creeping cartelism in the aerospace and other high-technology industries, the panel is in substantial agreement with the principle (expressed in the Office of Management and Budget's Special Analysis K) that "technology development and demonstration projects with relatively near-term commercial applications will be curtailed as an inappropriate federal subsidy." However, the interpretation of this principle in application to specific programs poses many difficult questions.

Commercial Versus Military

In the earlier stages of R&D, the problem in the aerospace industry of defining what is "commercial" is difficult. Traditionally, the military forces of the United States have derived substantial benefit from commercial transport development, ranging from outright adoption of versions of civil models (e.g., DC-3/C-47, DC-4/C-54, Lockheed Electra/P-3, and DC-10/KC-10) to the development of specialized military transports based on state-of-the-art civil transport aircraft and engine technology (e.g., C-130 and C-141). Implicit in this military dependence on commercial transport developments and technology has been the underlying expectation that U.S. civil air transport represented a highly advanced level of attainment at any given time, so that little additional benefit could accrue to the military from undertaking more advanced transport developments on its own.

Actually, the exchange of technology between military and civil aviation in any country and worldwide is a complex interactive process. The situation is best described as the symbiotic nourishment of a common pool of technology that serves both military and civil needs, with each field of application not only drawing on the pool but also constantly replenishing it through R&D to support the broad and specific objectives of improving the performance, economy, reliability, and maintainability of aircraft and engines for civil transports and military combat aircraft. This interaction is nowhere stronger than in the engine field.

The military development of the high-bypass TF-39 fan engine for the C-5 is an interesting case. In the early 1960s, it was clear that for the new very heavy logistics transport needed by the military, a major advance in vehicle effectiveness could be achieved by using the high-bypass fan engine, which was just then passing the threshold of technical feasibility. Although the commercial advantages were also obvious at that time, no development of such an engine for commercial purposes was yet in prospect, so the military impetus pushed the development through (competitively, including General Electric and Pratt & Whitney in a technology and demonstrator engine phase). The losing airframe and engine competitors, Boeing and Pratt & Whitney, launched the commercial 747 wide-body jet transport program. Other wide-body transport programs such as the DC-10, L-1011, and Airbus followed, most of which used engines derived from the military demonstrator engines. (Rolls Royce, in a fierce effort to remain competitive for transport engines, developed the RB-211 later, which was used in the L-1011; but it found much less widespread application than did the GECF6 and the P&W JT9D.)

The helicopter field is another one where the line between military and civil technology is hard to draw, and there is virtually no new field of this technology currently under investigation which does not have both military and civil applications. The tilt-wing aircraft currently under investigation at NASA is an example. There is no way to judge at this time in what sphere the best and earliest applications may be found.

Turbopropeller engine applications may well be viewed as limited to civil transport, but it is equally likely that a tactical intratheater transport (a C-130 replacement) or a long-range naval patrol aircraft (a P-3 replacement) may be the most attractive use of that technology. Similarly, the use of composite primary structures on large aircraft may be seen as having its greatest likely payoff in civil transport, but its use for long-range and long-endurance military aircraft for the missions already mentioned, for new missions, such as the continuous patrol aircraft basing mode (which, although now abandoned for the MX, is still under consideration in other missions), or for strategic command and control is a likely possibility.

In judging the priority and desirable timing of NASA programs, the panel gave attention to both military and civil applications. When particular programs seemed likely to serve military and civil ends and to fall with the existing divisions of responsibility and effort between the Department of Defense and NASA, the panel considered them appropriate NASA programs.

Near Term Versus Long Term

It is often difficult to predict in what time frame a new development may occur. In fact, the emphasis given to a new technology in R&D, including the demonstration and confidence-building phases, may be a primary determinant of when the new technology is ready for application. Thus, the Department of Defense R&D program in high-strength composite structures (based on boron fibers but subsequently expanded to include carbon and other fibers) began in 1963. Aggressive pursuit of this program in a joint government-industry program resulted in the use of a boron fiber composite horizontal tail surface in an operational aircraft, the F-14, in less than 10 years. A constantly expanding domain of application has followed since then. Without an aggressive R&D program, the time to first application might well have been twice as long.

NASA's recent discovery of the value of winglets for drag reduction has found almost immediate possibilities for application in military aircraft, civil transport, and general aviation aircraft. Yet there is little doubt that it was appropriate for NASA to have worked on it. The supercritical wing is yet another recent NASA technology advancement that found relatively quick acceptance and application to a wide range of aircraft.

The real issue in these developments that warranted support in the NASA program was the degree of innovation involved, the broad applicability possible, and the extent of development, demonstration, verification of concept, and validation in an operational environment required before the next concept, component, or device could be incorporated with acceptable technical and economic risk in the production of civil or military aircraft. These characteristics were generally given heavy weight in the panel's determination regarding the appropriateness of specific NASA programs, especially those designated as "systems technology."

A further consideration in regard to technological developments of broad application is that, unlike NASA, industry is highly competitive and has proprietary interests; hence, the diffusion of its technology is considerably slower than that produced under NASA auspices.

PROGRAM DEFINITIONS AND "PACKAGING"

The fields of applied engineering science relevant to aeronautics may involve theoretical and experimental work ranging across the entire R&D spectrum, from the fundamentals of physics and chemistry to design and testing of full-scale structures and vehicles. One of the great strengths of NASA (and its predecessor, the National Advisory Committee for Aeronautics or NACA) in aeronautics has been that, short of developing specific vehicles for manufacture and operational use, there has been no limitation on where in the spectrum of R&D it might conduct its research. Its staff and facilities have been engaged in efforts to support ongoing military and civil developments as well as in programs to seek longer-range advancements in the performance, economy, and utility of a broad range of air vehicles.

The characterization of the various stages of aeronautical R&D as fundamental or basic and applied research, development, or technology is to a considerable extent arbitrary. Technology itself covers a range from theoretical analyses and small-scale laboratory experiments to complete system designs and manufacturing processes. All large organizations, and especially the government, have a tendency to use certain terminologies for purposes of budgeting and controlling programs, terminologies that by historical evolution the organization has accepted but that do not have any transcendental or universal significance in the R&D process.

Moreover, if some particular sphere of application is favored at a given time, projects having multiple applications will tend to be described as having primarily the favored application. For example, during the 1970s, and particularly after fuel price rises and shortages precipitated the energy crisis and affected civil transport economics severely, this phenomenon caused NASA's justifications for programs to gravitate toward transport aviation and fuel efficiency. Yet efforts to reduce drag, structural weight, and engine-specific fuel consumption have been the main thrusts of aeronautical R&D since the dawn of aviation and remain the essential factors in increasing operating efficiency.

Thus, the contents of individual programs must be examined <u>ab initio</u> to remove purely semantic factors from program assessments.

NATIONAL ECONOMIC AND BUDGETARY CONSIDERATIONS

As already noted, there are many widely divergent views held both by experts and others within the government, in its executive and legislative branches, and by the public concerning economic theories and policies that should be applied in determining appropriate government activities in support of civil applications. The panel did not attempt to arrive at a consensus on these major national economic issues but dealt with the economic aspects of specific NASA programs on a more pragmatic basis, which is described above and in Chapter 5, "Bridging the Gap." However, in the panel's judgments on the economic value of NASA programs, it did attempt to take into account the following general economic and budgetary considerations. (A specific discussion of the impact of NASA aeronautics programs on the national economy is given at the conclusion of Chapter 4.)

In economic terms, research often constitutes a public good and, as such, clearly merits a claim on public resources. However, such a claim is not valid for all forms of research or for unrestricted resources. Those who request or recommend that resources be committed to a specific area of research have an obligation to analyze and to limit rigorously their requirements.

Trends in the budget over time, however, allow a case to be made that expenditures in discretionary areas have fallen as a percentage of the budget over the last 20 years and will fall further over the next several years. Such a shift of composition inevitably squeezes expenditures such as research, where returns occur over time and cannot be stated with precision. There is a danger that research expenditures will inexorably be driven from the budget as incremental comparisons are made with expenditures that seem more compelling at the time. The comparison of research versus human resource expenditures constitutes an extremely difficult dilemma.

Research, development, and commercialization expenditures represent a continuum. At some imprecise point in the continuum, public expenditures represent basic, fundamental, or generic research and as such are highly appropriate. At other points, expenditures are clearly more appropriately and efficiently undertaken by the private sector. There is a gray area between these points where the appropriateness of public expenditures varies with the opportunity, the state of the economy, and international competitiveness.

National competitiveness is necessarily an important consideration. In an imperfect world economy, nations do and will support major industries through research in order to keep or develop jobs or exports. The United States must remain aware of these trends and be prepared to cope with them.

But in the final analysis ours is a mixed economy. Competition for public resources is extremely sharp, and we must depend on private sector research. Corporations cannot depend on the public sector to carry their research burden and must be prepared to take research risks and develop new investment mechanisms. Accelerated cost recovery, safe harbor leasing, and research and development partnerships are all recent policy developments that should increase the rate of return to capital investment and, therefore, provide a stimulus for private sector research. However, the net effects of these recent changes in economic factors cannot yet be definitively evaluated.

4

Programs Excluded from the NASA FY 1983 Budget

An examination of the specific programs and initiatives that have been reduced or deleted in the FY 1983 budget appears on the following pages. The three major funding levels that have been proposed for each program appear in Table 2. The panel has considered collectively the three programs dealing with composite materials; otherwise the order follows that of the budget explanation in Table 2. Statements regarding program objectives and status are derived from NASA documents and briefings and from elaboration sought by individual panel members from appropriate NASA representatives. They do not reflect the panel's views, which are contained solely in the findings.

The category labeled by NASA as Systems Studies has not been considered as an individual project. The panel believes that such paper studies are essential to NASA, to the Department of Defense, and to industry for the purpose of identifying potential new areas of aeronautics research and technology, but that funding for them is more properly included within the relevant disciplines or technology areas. (See Appendix G for a further discussion of Systems Studies.)

For some projects, the distinction of their label between Systems Technology studies and Research and Technology Base studies is not clear-cut. NASA proposes to undertake within the R&T Base some work associated with a few of the excluded projects, and the panel itself has considered certain other projects as equally appropriate to the R&T Base.

R&T BASE

Facility Productivity Improvement Program
(Aerodynamics--New Initiative)

Because of government regulations, improvement and updating of data acquisition and processing systems cannot be supported under Construction of Facilities funding. Over the years, the rehabilitation and modernization of existing facilities and the supporting data acquisition and processing systems have been inadequately funded. This initiative was an attempt to reverse this trend with $6 million in the first year directed toward providing equipment and systems to improve the productivity of two nationally important unique wind tunnel facilities, namely the Transonic Dynamic Tunnel and the Icing Research Tunnel.

Program Description and Status

Objectives To increase the overall annual throughput 70 percent by shortening experiment set-up, installation, and removal time, by automating facility and experimental systems, and by increasing real-time data processing and reduction. In the first year, a real-time data acquisition system was planned for the Transonic Dynamics Tunnel at the Langley Research Center. Also in the first year, the Icing Research Tunnel at Lewis Research Center would receive an improved water spray system, electrical power supplies, a force balance system, temperature and exhaust control systems, and rehabilitation of the steam system.

To Date Initiative denied.

Findings

These major aeronautical facilities are important national resources. In recent years, nonscheduled equipment maintenance time has increased and operating hours and occupancy hours have necessarily declined, while backlogs are building to the point where waits of 20-30 months are typical. The safety implications of aircraft icing research cannot be overemphasized. The panel regards this as the type of expenditures that cannot be deferred indefinitely. There is virtually no technical risk associated with these facility improvements.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	SUCCESS
Y			X	H				H	GOOD

COMPOSITE MATERIALS AND STRUCTURES

Description of Advanced Composites

Composites are engineering materials that result from combining two materials in such a way that new or better properties are obtained from the combination. Reinforced concrete structures and fiberglass boats are two successful current uses of composite materials. Advanced composites for aerospace applications typically consist of carefully oriented continuous fibers of carbon/graphite embedded in a polymeric resin such as epoxy. Kevlar and boron are other typical fibers, and polyimides provide another type of resin. Advanced composites offer a variety of benefits to aerospace structures, the most notable being the possibility of a weight savings of 30 percent or more. Other benefits include a freedom from corrosion, a fatigue life vastly better than that of metals, and the possibility of tailoring properties to meet specific load requirements by preselecting the directions in which the reinforcing fibers are oriented. Advanced composites are being used increasingly for lightly loaded aerospace structures, and research is under way to provide the technology needed to make large primary structures capable of handling heavy loads.

Information regarding the three NASA programs on composite materials and structures follows.

Advanced Composites Research
(R&T Base--New Initiative)

Program Description and Status

Objectives The proposed Advanced Composites Research Program addresses the development of (1) second-generation composites involving new, tougher resin matrix materials, improved mechanical properties, and increased environmental suitability; (2) high-temperature resins, including curing mechanisms, improved room and high temperature mechanical properties, and high-temperature oxidation resistance; and (3) high-temperature composites, including fiber reinforcement of superalloys (metals).

To Date Initiative denied.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECHNICAL
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	SUCCESS
Y		X		H	M	H	H	H	GOOD

Combined findings appear at the end of the description of the three composites programs.

Composite Primary Aircraft Structures (CPAS)
(Transport)

Program Description and Status

Objectives To develop composites technology for secondary and medium primary transport aircraft structures and to provide a data base that will permit safe and effective use of lightweight composites in advanced transport aircraft.

To Date With $88 million expended and 1983 scheduled to be the last year of this portion of the Aircraft Energy Efficiency (ACEE) program, stiffness-critical composite structure is now considered to be state-of-the-art and new aircraft are incorporating this technology; B-757, B-767, and Lear Fan 2100 are in the certification process. Secondary structure components have been certified and are in flight service. Composite medium/primary structure components are now completing ground test and certification programs. Success can be measured by the weight saved in various aircraft components: the L 1011 vertical fin had 28 percent weight saved (ground test in progress); the B-737 horizontal stabilizer had 22 percent weight saved (awaiting FAA certification).

Impact of Cancellation While technologies developed under this program are already in use and demand is increasing as airlines gain experience with composites, the program is not yet completed and the technology base for the use of composites has not been completed.

NECES- SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH- NICAL
					Nat.	Eff.	Nat.		
Yes/No	Now	Later	Never	Safety	Def.	Tport.	Econ.	PRIORITY	SUCCESS
Y	**	X		H	M	H	H	H	GOOD

Combined findings appear at the end of the descriptions of the three composites programs.

**There has been some application in new aircraft.

Transport Aircraft Composite Structures (TACS)
(Transport--New Initiative)

Program Description and Status

This program was planned to follow the Composite Primary Aircraft Structures (CPAS) Program to use the composite technology developed for secondary structures and medium primary structures as a base on which to develop the technology for very large, heavily loaded structures such as transport aircraft wings.

Objectives (1) To provide an independent data base for composite primary structures technology for design verification and certification. (2) To develop design, analyses, and test procedures to evaluate composite primary structure designs and verify benefits, integrity, and durability. (3) To develop technology for large-dimensioned, highly loaded composite structure. Multiple designs were planned, focused on major technology issues such as fuel containment, electrical conductivity, lightning strikes, environmental effects (rain, hail, ice, ultraviolet radiation), and interior accessibility, and independent evaluations were planned of design and test methodologies in large-scale structural systems tests.

To Date Initiative denied.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	SUCCESS
Y		X		H	M	H	H	H	GOOD

Combined Findings Regarding Composite Materials and Structures

The panel regards research on advanced aircraft composite structures to be of the highest priority among all of the unfunded programs.

The ACEE Composite Primary Aircraft Structures Program has been highly successful thus far by contributing significantly to an accelerated acceptance of composites in many aircraft structural applications. The scheduled wind-up of this program in 1983 will complete the original plan, making available information still needed for airline and FAA acceptance and certification of composite structures for both secondary and primary structural applications.

The panel supports both of the proposed new initiatives in aircraft composite structures, which are designed to supply research in different but related areas: (1) primary composite structures design approaches, alternatives, and a technology data base; (2)

research and understanding of the critical technologies for second-generation composite structures having lighter weight, more ruggedness, and higher temperature capabilities.

From a safety standpoint, the panel regards NASA's work in composites as essential to provide an independent data base for FAA certification requirements. In addition, these projects are viewed as having high potential impact on efficient transport and the national economy and moderate impact on national defense. The outlook for technical success of these projects is good. Although some composite structures are being used in some new aircraft, it is unlikely that industry would undertake projects such as CPAS and TACS in the near future, and the time element is important.

R&T BASE

High-Performance Military R&T
(Aeronautics--New Initiative)

Program Description and Status

Objective This program represents an enhancement of other high-performance activities and is aimed at aerodynamic integration for advanced missions such as supersonic cruise and maneuver, stealth, and Short Takeoff and Landing (STOL). The five parts of the program are (1) analyses to include estimates of aerodynamic performance and stability/control and correlations with wind tunnel results; (2) computations to apply existing aerodynamic codes and, if required, develop new codes for advanced unconventional configurations; (3) ground-based piloted simulations to assess handling qualities, including effects of integrated flight/propulsion controls; (4) use of ground facilities such as altitude chambers at Lewis Research Center for tests of new inlet/nozzle concepts and high temperature materials, and (5) wind tunnel tests to emphasize supersonic cruise, transonic maneuvering, and low-speed stability and control.

To Date Initiative denied.

Findings

The panel regards this program as one where NASA has an important role to play in basic research and technology. NASA should be at the "cutting edge" in designing experimental methodology and analyses. While industry may have the capability and some of the facilities to undertake a portion of this work, their efforts can be more productively applied to configurations and systems design. In the panel's view, the sum of such individual efforts would not equal the effectiveness and possible payoff from NASA's undertaking and coordinating these activities. These technologies are seen as critical to national security, and hence are considered of high priority. The outlook for technical success is good.

NECES-SARY Yes/No	WOULD INDUSTRY UNDERTAKE Now	Later	Never	POTENTIAL IMPACT Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	OUTLOOK FOR TECH-NICAL SUCCESS
Y					H			H	GOOD

MATERIALS AND STRUCTURES

Integrated Program for Aerospace Vehicle Design (IPAD)

Program Description and Status

Original Objective To improve engineering productivity by developing technology and computer software for management of integrated design and manufacturing data (project-level engineering and manufacturing information).

Original Results Expected (1) IPAD data management to be established on CDC and IBM host computers. (2) Data base requirements to support Air Force Integrated Computer Aided Manufacturing (ICAM) effort.

Revised Scope Data management software technology will be limited to single host computers and there will be no networking capability.

Impact of Cancellation Program funding was reduced in FY 1982 and deleted as a specific line item in FY 1983. Development of technology and software for multiformat company-wide data base management will be limited to a single host computer system without geometry capability; data management of the Air Force ICAM program cannot be supported; computer networking capability will not be developed, nor will key elements of this technology be transmitted to industry.

Findings

The panel recognizes NASA's contributions in computer-aided design and manufacturing areas but finds that industry is rapidly assuming this activity. Even now, industry is working to include procurement and fiscal and quality assurance in addition to engineering and manufacturing design. While the goals of the program can be considered high in national importance with a good outlook for success, the panel finds that at this stage some level of effort in the R&T Base, but not necessarily that proposed by NASA, would be appropriate.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	
(*)[1]	X								GOOD

Aeroelasticity of Turbine Engines

Program Description and Status

Objective To develop verified analysis methods for prediction of flutter onset for various turbine engine operational regions and techniques to predict and minimize aeroelastic vibration effects in turbine engines.

To Date The fundamental data for rotor vibration modes using rotor spin rig tests have been acquired and analytical predictions have been verified. The capability to predict onset of flutter for various engine operational regions (subsonic, transonic, supersonic) has been verified. The concept of mistuning rotor blades to control forced vibration response levels has been analytically demonstrated.

Impact of Cancellation Program funds were reduced in FY 1982 and deleted as a specific line item in FY 1983. Although this work will be supported in the R&T Base at a minimum level, contracts and grants supporting analytical requirements for forced response analysis will be limited. Development of coupled aerodynamic-structural engine dynamic analysis capability, not yet available in industry, will be extended through the late 1980's. Concept studies for minimizing engine vibration response levels will be reduced in scope.

[1]An asterisk denotes that some level of effort within the R&T Base is appropriate. In most of these cases, priorities are not assigned.

Findings

The long history of engine structural failures demonstrates that safety is coupled with engine reliability, with vibrations, flutter, and distortion affecting that reliability. Industry believes that it has sufficient tools to avoid major problems with compressors and fans; analysis is checked by model tests and then in development component and engine tests at sea level and altitude. Although there are some surprises, they are worked out during development and early production at moderate cost to industry. The panel concurs that a modest effort in the NASA R&T Base is appropriate, preferably concentrated on new areas and problems.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL
					Nat.	Eff.	Nat.		
Yes/No	Now	Later	Never	Safety	Def.	Tport.	Econ.	PRIORITY	SUCCESS
(*)									

PROPULSION

Helicopter Transmission Systems

Program Description and Status

Objectives This program was designed to reduce the weight, size, cost, maintenance, and noise of helicopter transmission systems with technology transfer and information exchange achieved through out-of-house participation. Advanced mechanical components and lubrications technology were to be validated, and new generic computational analysis methods were to be developed.

To Date This transmission work is a joint effort with the U.S. Army Research and Technology Laboratory located at the NASA Lewis Research Center and is primarily directed toward Army requirements. A portion of the program involves contract fabrication of an advanced 500 hp transmission by Bell Helicopters, from which data will be shared. Another part of the program uses the NASA/Lewis UH-60 assets. This 3000 hp transmission facility provides a data base for lubricants, vibration, noise, efficiency, and stress for new systems and for modifications to current ones. The program calls for testing of single and twin input, split torque, and hybrid transmissions. At this time, NASA has participated in the program in the amount of approximately $7 million.

Impact of Cancellation Program funds were reduced in FY 1982 and deleted as a specific line item in FY 1983. Withdrawal of NASA will stretch out the program or require an increase in Army funding. It will delay develop t of new transmission designs that reflect major advances in weight and compactness for future helicopters. However, it is anticipated that the program will be supported in part with R&T Base funds.

Findings

While the main thrust of this program has been toward military use, an application to civil aircraft is anticipated. A NASA withdrawal would mean the removal of trained, experienced research engineers from the program, with a corresponding decrease in chances for success. The potential impact of this program with respect to the criteria established is moderate. The outlook for technical success is good. It is unlikely that industry would undertake such a project in the near future.

NECES-SARY Yes/No	WOULD INDUSTRY UNDERTAKE Now	Later	Never	POTENTIAL IMPACT Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	OUTLOOK FOR TECH-NICAL SUCCESS
Y		X		M	M	L	M	M	GOOD

Critical Aircraft Resources
(includes completion of Broad Property Fuels)

Program Description and Status

Objectives To provide focused technology aimed at relieving the United States of supply instabilities and cost escalations associated with aviation turbine fuels and strategic materials.

To Date Completion of Broad Property Fuels Phase I included tests of production and advanced combustor concepts operating with broadened-property fuels; initial comparisons with jet A indicate a significant increase in liner temperatures for production combustors when using broadened-property fuels; advanced double annular combustor concepts demonstrated sensitivity to reduced fuel hydrogen content.

Impact of Cancellation It will eliminate engine system evaluation and full-scale verification tests of new fuel-flexible combustor concepts, with the remaining work being scaled down to include only component rig tests. Also eliminated are major augmentations in the area of Alternative Fuels and Strategic Materials, the goals of which were to establish a detailed understanding of fuel property variations on advanced generic engine/aircraft fuel system technology and to achieve a 30 percent reduction in the use of strategic elements in turbine hot section components.

Findings

U.S. dependence on nondomestic sources for fuel and strategic materials makes this a timely field. However, the fuel definitions and timing are unclear. A modest effort in the R&T Base is appropriate, but the work on developing new combustor concepts with full-scale engine tests may be premature. Complementary work being sponsored by the Department of Defense to broaden JP 4 and JP 5 fuel specifications and explore the use of shale oil is noted. As economies in production and distribution systems compel use of a broader range of fuels, implications for air safety will need to be thoroughly researched. The panel finds that research on fuels is an appropriate area for government leadership in establishing goals and sponsoring R&D since there is little incentive to industry except in areas of possible cost reduction.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	
(*)			X						

Small Engine Component Technology
(New Initiative)

Program Description and Status

Objectives To provide advanced component technology for low-thrust engines intended for potential application to future rotor craft, commuter and general aviation, and cruise missile propulsion systems (300-4,000 shaft horsepower [shp]). This program would seek to develop a fundamental understanding and analytical data base for steady and unsteady flows, combustion, and heat transfer; to simplify designs, thereby reducing costs; and to improve thermal efficiency for a 20 percent reduction in specific fuel consumption. It includes detailed component flow mapping, development and verification of computational methods, and evaluation of specific advanced component technologies and concepts. Milestones planned for this program are in FY 1985, component analytical design techniques to be established using both computational and experimental methods; in FY 1987, completion of design verification testing of advanced technology engine components; and in FY 1988, verified analytical codes available for industry.

To Date Initiative denied.

Findings

Several substantially different engines are in the category of small engines: 300-600 shp general aviation prop power, 500-800 lb thrust military cruise missiles, and 850-4,000 shp civil and military helicopter/turboprop propulsion.

There is a need for improved small general aviation engines in the under-500 shp category. Of special interest are engines with an intermittent combustion cycle that burn kerosene instead of gasoline. This NASA program does not appear to address the latter category, but the panel was informed that NASA is conducting appropriate and important work in the R&T Base.

There are several 850-5,000 shp military and commercial engine developments under way or planned in the United States and overseas--e.g., Pratt & Whitney's PT7/PW100 series, General Electric's T700/CT7, and the U.S. Army's planned 5000 demonstrator. The market is very large, consisting of several thousand units per year for turboshafts, turboprops, and turbofan spinoffs. Large reductions in fuel consumption--up to 20-30 percent in some power ranges--are possible. The engine technology is essentially identical for military and commercial aircraft, but it differs from that for large engines in that the compressors are usually axi- or dual-centrifugal and there is more emphasis on first cost.

Development of small engines now lags behind that of large engines, and inadequate advanced research has been done in this area in recent years. Thus, the panel recognizes a need for aggressive advanced component work in the R&T Base complementing the Department of Defense's activities and aimed at a new generation of engines for the 1990's. The outlook for technical success is good. The potential impact with respect to the criteria established is moderate. Industry is not likely to undertake such activity in the near future.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	SUCCESS
(*)		X		L	M	M	M	M	GOOD

ADVANCED PROPULSION SYSTEMS

Energy Efficient Engine (E^3)

Program Description and Status

Original Objective To provide the technology base for a new generation of fuel-efficient turbofan engines with lower fuel consumption and reduced operating costs relative to current high-bypass-ratio engines.

To Date Contracts for component technology development and evaluation in an integrated engine system were awarded to General Electric and Pratt & Whitney in 1977. Approximately 75 percent of the program expenditures have been made, but success remains to be confirmed by testing of the complete engine. Program goals have been exceeded with a 90 percent efficiency fan rig test; rig tests of a 10-stage 23:1-pressure-ratio high compressor achieved goal levels of efficiency and surge margin; two-zone, segmented-liner combustors achieved emission goals (except for nitrous oxide) and met or exeeded goals for exit profile and pattern factor; 1-2 percent turbine efficiency gains relative to current turbines were achieved; and 80-85 percent mixing effectiveness in exhaust gas mixer scale model tests have been demonstrated. Component technology development has been completed, and hardware is being readied for integrated core engine system evaluation under FY 1982 funding.

Impact of Cancellation Immediate: General Electric will eliminate second integrated core and low spool test; Pratt & Whitney will eliminate all engine systems tests, including evaluation and validation of low spool components, active clearance control system, full-scale mixer performance, component interactions, systems dynamics and transient operation, component performance in real environment, and impact of secondary flows and losses. Industry teams will be disbanded, and a large government investment in test bed engines will be lost for follow-on research programs. Future: Years will be lost before industry can pick up or obtain military funding for components of the program since major companies have hundreds of millions of dollars committed to near-term turbofan developments.

Findings

The E^3 program is a classic systems technology engine demonstration program of the type that NASA, the Department of Defense, and the U.S. engine industry have used over the last 30 years to advance the state-of-the-art and establish the data base required for industry to make commitments for engineering development of jet engines. These are not prototype or production engines, although some features may be included in near-term engines. This has been a large program, funded at $20-$25 million per year for each of the two contractors, and a successful one to date, even though the core and complete systems tests still lie ahead. NASA has worked well with the engine and aircraft industry to establish requirements with high payoff for the long term and has done a good job in managing this complex program. The state-of-the-art of each engine component is being advanced, and a major step forward in the overall cycle pressure ratio is being achieved.

The only active government system technology program for large subsonic engines is the NASA E^3. The Department of Defense is not developing work on high-bypass turbofans or large turboprop gas generators and looks to NASA for support in this area. Engine technology for commercial subsonic transports and large military subsonic transports, tankers, and long-endurance aircraft is identical. Moreover, the technology for high-bypass turbofans and for large turboprop gas generators is very similar.

The panel regards such programs as E^3 for subsonic engines and the Department of Defense's Advanced Technology Engine Gas Generator Program for supersonic engines as essential to provide the technology necessary for continued U.S. leadership in military and commercial engines. Thus, this activity is viewed as having high potential impact on national defense, efficient transport, and the national economy and is considered to be of high priority. The outlook for technical success is good. Industry is not likely to undertake such activity in the near future.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT				PRIORITY	OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.		
Y		X			H	H	H	H	GOOD

Advanced Turboprop Program (ATP) and ATP, Phase III

The proposed acceleration of ATP was denied as a new initiative, and the ongoing program is proposed for termination.

Program Description and Status

Objectives To develop and evaluate the technology for efficient, reliable, and acceptable operation of advanced turboprop-powered aircraft at cruise speeds ranging from Mach 0.7 to 0.8 with attendant reduced fuel consumption, emphasizing flutter and structural dynamic characteristics of advanced propellers and systems integration for reduction of installation drag and cabin noise.

To Date Under the ACEE Program, using subscale model testing, (1) an uninstalled propeller efficiency of 80 percent at Mach 0.8 has been attained, (2) predictions of propeller near-field noise and fuselage wall noise attenuation have been verified, and (3) preliminary indications have shown that installation drag can be small. The design approach for large-scale blades (8-10 ft in diameter) has been selected.

Impact of Cancellation/Reduction No data base from large-scale experiments now exists for structural and aerodynamic characteristics of advanced propellers. Furthermore, no timely large-scale tests will be undertaken.

Descoped or delayed: Design, fabrication, and testing of large-scale blades; experimental and analytical understanding of propfan aeroelastic behavior; structure-borne noise evaluation, and attenuation research; installation aerodynamics data base with optimal nacelle/wing configuration.

Eliminated or deferred indefinitely: Large-scale ground and flight acoustic experiments; engine system component tests (gearbox, pitch change, control, inlet); large-scale system integration flight research at Mach 0.8 at 30,000 ft.

Findings

This program will be of critical importance in the late 1980's and the 1990's. High-speed propeller work requires large-scale experimental tests to validate noise, drag, aeroelastic and overall installed performance in a credible way. It is unlikely that advanced high-speed propeller propulsion will be chosen for short-haul commercial and cargo systems or military systems without successful experimental flight testing to pave the way. The question is whether propellers can power aircraft in the Mach 0.7-0.8 range at 30-35,000 ft and prove more cost effective in some types of large military or commercial aircraft than turbofans. A 15 percent reduction in fuel appears to be possible, but some panel members were skeptical about this and emphasized the need for data from large-scale tests and for realistic assessments of total installed performance. Although this is a controversial and high-risk program, it could have a profound effect on long-endurance systems, land-based antisubmarine warfare missions, and intratheater transport as well as the 100-150 passenger transport and commuter markets.

Regarding the substance of the program, the panel questions the need to meet the goals of Mach 0.8 should the 0.7-0.75 Mach range prove more efficient. Inclusion of experimental work for viable alternative advanced propellers, such as a counter-rotating prop, is also recommended in the R&T Base. Early flight test of a large 8-9 ft advanced propeller, and system studies to establish potential advantages versus advanced turbofans, are indicated as well.

Very little work has been done on propellers, either small or large, for many years. As the industry moves toward higher speeds with larger, more complex propellers, data are needed to produce and certify new types of propellers and gear boxes.

Considered as a high priority program, ATP is viewed as important to development of efficient transport and holds high promise for developing new economic markets. Its military implications make ATP of at least moderate importance to national defense. While the outlook for technical success can be viewed as fair to good, the overall risk associated with this project is such that it is unlikely that industry would undertake it in the near future. Phase III, the new initiative, represents a highly desirable acceleration of the flight research part of the total program, and some level of effort in this phase is viewed as having the same degree of importance as the ongoing ATP activity.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	
Y		X to	X		M	H	H	H	FAIR/GOOD

LOW SPEED
(Aerodynamics and Configurations)

Powered-Lift Technology
(Quiet Short-Haul Research Aircraft (QSRA) Program)

Program Description and Status

Objective To generate and verify through flight research a technology data base for the design of quiet, efficient, economical, and environmentally acceptable short-haul aircraft for future civil and military applications.

To Date The guest pilot evaluation program has been completed along with successful shipboard evaluation on the USS *Kittyhawk*.

Impact of Cancellation Portions of the program are being continued at reduced scope and pace under the High-Speed Systems Technology activity. Criteria on flying qualities and landing field for use by the FAA will be delayed, as well as further data to support Navy Short Take-off and Landing (STOL) efforts.

Findings

The QSRA Program is essentially at an end. In studying this program in 1979, the Aeronautics and Space Engineering Board concluded that it "may have marginal application because of cost and complexity." NASA has conducted technology demonstrations of STOL for many years, and further work along these lines is unlikely to affect industry's reluctance to develop STOL for commercial application at this time. STOL will likely be developed first for military applications. It is unlikely that industry would undertake such a project in the near future. A modest continuing effort in the R&T Base or in High-Speed Systems Technology is indicated.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	
(*)		X							

Tilt Rotor Research Aircraft

Program Description and Status

Objective To demonstrate and document tilt rotor technology for military and civil applications and to document the operating flight envelope, handling qualities, and terminal area characteristics.

To Date Successful demonstration of flight envelope to 318 knots and verification of aeroelastic stability have been achieved, and the initial data base is established.

Impact of Cancellation The following opportunities are eliminated: completion of flight envelope documentation, support of Joint Services V/STOL (JVX) development program, completion of mission suitability testing, and flight test of advanced rotor and flight controls.

Findings

Two tilt rotor vehicles were built by Bell for this program. Bell has received a modification to the contract that allows them to use one craft for an extensive two-year flight test program to be carried out at their expense. Data from this testing will become available to NASA. NASA's advanced rotor development program still contains funding to build and test a new composite-blade rotor for the remaining vehicle.

This is the latter part of a big program, and the FY 1983 cuts are in the lowest-priority part of the rotorcraft research and system technology programs. With the increased activities by Bell and Boeing Vertol, and the interest of the military in the tilt rotor, NASA's investment in this technology demonstration has already proven to be a success.

NECES-SARY Yes/No	WOULD INDUSTRY UNDERTAKE Now	Later	Never	POTENTIAL IMPACT Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	OUTLOOK FOR TECH-NICAL SUCCESS
N	X								GOOD

TRANSPORT
(Aerodynamics and Configurations)

Laminar Flow Control (LFC)

Program Description and Status

Objectives To develop and demonstrate a practical, reliable, maintainable boundary-layer control system for significant drag reduction of future transport aircraft, with the intent of demonstrating laminar flow control technology for industry design of LFC systems for advanced transport aircraft.

To Date The basic concept of LFC has been demonstrated, and progress has been made in unique LFC airfoil design. The present effort, with primary emphasis on development of the technology base for practical operating systems, has not proceeded to the point of resolution of its applicability.

Impact of Cancellation Because of the long-term nature of the LFC research, there will be no immediate impact of cancellation. However, resolution of the practicability of the potentially large benefits of LFC in future aircraft design must be postponed indefinitely.

Findings

Unless NASA develops a reasonably practical control system, it is unlikely there will be any application of LFC by industry. It is a high-risk project with high payoff, if successful. Of all elements in the program, this appears to offer the least likelihood of practical operational success. Supporting this project rather than alternative efficiency improvement programs does not seem advisable at this time. Safety may be compromised, rather than enhanced, due to the uncertainty of uniform spanwise functioning of an LFC system. National defense benefits are questionable, and long-term performance and maintenance questions make a positive effect on the national economy doubtful. But, in view of the potentially high returns, very modest research efforts in the R&T Base level, as proposed by NASA, seem worthwhile.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT				PRIORITY	OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.		
N*			X					L	POOR

Energy Efficient Transport (EET)

Program Description and Status

Objectives To develop and demonstrate advanced aerodynamics and active controls technology for application to derivative and new transport aircraft. Completion of the proof-of-concept flight evaluation of active controls systems and advanced technology airfoils was anticipated.

To Date The aerodynamics data base for high-aspect-ratio supercritical wings, high lift devices, controls, and propulsion integration has been developed along with techniques for structural design and fault-tolerant computer design. Flight evaluations of maneuver load control and relaxed static stability active control concepts are completed. Winglets tailored for the KC-135 and DC-10-10 have been evaluated. Design evaluation of the integrated application of active controls on a new transport design is completed, and a flight data base on aerodynamic and inertial loading for B-747 engine nacelles has been obtained. F-111 flight tests have shown that increased laminar flow can be achieved for large transport aircraft.

Impact of Cancellation Although most of the originally planned EET program has been completed (only $1.1 million was unfunded), the program wrap-up would contribute significantly in documentation of recent work and planning that could help industry and permit an improved future R&T Base program--e.g., Lockheed's active pitch control system development for the L-1011 airplane, all-electric airplane technology development studies for reduced aircraft weight, Douglas' high-aspect-ratio supercritical wing development refinement, and Boeing's work to develop natural or hybrid laminar flow concepts for future transport aircraft.

Findings

This program wrap-up is of only moderate risk and has a high probability of success. The completion of this planned program is cost effective because of the probable contributions to improved aerodynamic and structural efficiencies of future long-range aircraft. This program is viewed as a high-priority one with high potential impact on efficient transport and the national economy.

NECES-SARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECH-NICAL
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	SUCCESS
Y		X			M	H	H	H	GOOD

Terminal Configured Vehicle (TCV)

Program Description and Status

Objectives To define functional requirements and performance criteria for flight systems and displays of the future with which pilots can safely and effectively operate in the evolving National Airspace System; to make flight more efficient with respect to fuel, airspace, and time; to increase traffic flow capacity (and reduce delays); to improve operational capability in adverse weather; and to reduce noise impact on the ground.

To Date The systems demonstrated to reduce pilot workload, improve maneuvering accuracy, and enhance safety include the first application of all-digital systems in transport aircraft to display navigational and flight controls in TCV 737; the first aircraft flights using coupled curved approach paths and automatic landings with microwave landings system (MLS) data for flare guidance; electronic cockpit displays brought from laboratory to industry acceptance; area navigation and guidance systems with many features not previously used on civil aircraft; development of autoland flare law concepts with great reduction in touchdown dispersion of high-speed runway turnoff guidance systems; and minimum fuel flight profiles.

Impact of Cancellation NASA expertise and facilities will not be applied to a number of activities identified by the FAA in which NASA's help would be important in implementing the FAA's 20-year plan for updating and modernizing the National Airspace System. New airborne systems technology now in the laboratory development stage may not have attained credibility in time for the next generation of transport aircraft. Potential new aircraft benefits in safety and fuel conservation could be jeopardized unless the Air Traffic Control System is developed in a timely manner.

Findings

The TCV has provided and can continue to provide important advances in aircraft and terminal safety. The primary advantage of continuing this program would be coordination with the FAA in overhauling the air traffic system to deal with expected problems in terminal-area traffic flow and safety. Integration of the human operator with advanced displays is essential for ensuring safety as terminal-area congestion increases. Simulation cannot accomplish the total task, and the TCV has become an invaluable facility in which to verify simulation results in a real world environment.

Results have clearly been applied in the latest U.S. transport cockpits. While it is unrealistic to expect industry to continue this project, it might be reasonable to expect a limited support of cockpit human factors technology. In such a case, however, the broad availability of the results of the work would be brought into question.

Were the TCV being newly established, members of the panel would choose a smaller, more economical aircraft. However, since the B-737 has been made available, it seems sensible to use these existing systems in the near term. NASA's plans to preserve the TCV with R&T Base support appear reasonable to the panel.

NECESSARY	WOULD INDUSTRY UNDERTAKE			POTENTIAL IMPACT					OUTLOOK FOR TECHNICAL SUCCESS
Yes/No	Now	Later	Never	Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	PRIORITY	
(*)			X	H		M	L	L	GOOD

SUMMARY COMMENTS

A summary matrix of the panel's assessment of projects excluded from the NASA FY 1983 budget request to Congress is given in Table 3.

Those excluded Systems Technology projects and new initiatives to which the panel assigned a high priority, given by major technology area in aeronautics and with the NASA budget estimates of Table 2, are:

- o In the area of Structures and Materials
  - Composite Primary Aircraft Structures (CPAS) $ 2 million
  - Transport Aircraft Composite Structures (TACS) 4
  - Advanced Composite Materials R&T 4*
- o In the area of Propulsion
  - Energy Efficient Engine (E^3) 17
  - Advanced Turboprop Program (ATP) 9.8
  - Advanced Turboprop Program Phase III 31

TABLE 3 Summary of Findings

Excluded Programs	Necessary Yes / No	Would Industry Undertake: Now	Later	Never	Potential Impact: Safety	Nat. Def.	Eff. Tport.	Nat. Econ.	Priority	Outlook for Technical Success
Facility Productivity Improvement	Y			X	H				H	Good
Advanced Composite Materials R&T	Y		X		H	M	H	H	H	Good
Composite Primary A/C Structures (CPAS)	Y	(**)	X		H	M	H	H	H	Good
Transport A/C Composite Structures	Y		X		H	M	H	H	H	Good
High Performance Military R&T	Y					H			H	Good
Integrated Program for Aerospace Vehicle Design (IPAD)	(*)	X								Good
Aeroelasticity of Turbine Engines (ATE)	(*)									
Helicopter Transmissions	Y		X		M	M	L	M	M	Good
Broad Property Fuels/Critical Resources	(*)			X						
Systems Studies	Y*									
Small Engine Components	(*)		X		L	M	M	M	M	Good
Energy Efficient Engine (E^3)	Y		X			H	H	H	H	Good
Advanced Turboprop Systems (ATP)	Y		X to	X		M	H	H	H	Fair/Good
Advanced Turboprop, Phase III	Y		X to	X		M	H	H	H	Fair/Good
Powered Lift Technology	(*)		X							
Tilt Rotor Research	N	X								Good
Laminar Flow Control (LFC)	N*			X					L	Poor
Energy Efficient Transport (EET)	Y		X			M	H	H	H	Good
Terminal Configured Vehicle (TCV)	(*)			X	H		M	L	L	Good

*Some elements appropriate to R&T Base.
**Some applications in new aircraft.

o In the area of Aerodynamics

Energy Efficient Transport (EET)	1.1
High Performance Military R&T	4*
Productivity Improvement	6*

With respect to the Advanced Turboprop Program, some effort in preparing for the flight test phase--Phase III--is viewed as a highly desirable complement to the ongoing ground test program, in which aerodynamic, structural, and acoustic characteristics will be defined.

Thus, based on the NASA budget estimates, those programs assigned a high priority total somewhere between $48 million and $79 million, depending on the level of support allocated to ATP Phase III. Three of these programs, totaling $14 million, fall within the R&T Base.

The panel believes the implementation of these high-priority activities would result in a focused and balanced program, enabling advances in all three major divisions of aeronautical technology--structures, propulsion, and aerodynamics.

A further increase in the R&T Base of between $10 million and $20 million would appear to be a modest amount to account for the inclusion of some level of effort for the eight Systems Technology projects deemed appropriate for funding within this category.

NASA PROGRAM IMPACTS ON SAFETY, NATIONAL DEFENSE, EFFICIENT TRANSPORT, AND THE NATIONAL ECONOMY

A general discussion of considerations of safety, national defense, efficient transport, and the national economy is given in the following sections. It supplements specific discussions of these considerations, where appropriate, given in the assessments of individual projects.

Safety

In general, virtually all of the programs under consideration have some future safety implications with respect to the need to maintain or improve the present high levels of safety being achieved in aeronautical operations. These implications arise from the unique role of the government, which both develops aeronautical technologies and certificates the integrity of aeronautical products to the public. When NASA serves either as the developer of new or advanced technologies or as the clearinghouse for aeronautical data, others, such as manufacturers, universities, and government agencies, can then contribute to the broad range of evaluations needed both to determine the reliability and structural integrity of an advance and to consider its potential for increased efficiencies. Equally important for civil use, the FAA then has broad resources to draw upon in determining

*R&T Base.

whether or within what limitations to certificate a product. A recent example has been in the rapidly growing application of high-strength fiber composite structures to all types of aircraft. The continuation of NASA projects in this technology is essential to maintaining the high standards of safety in air transportation that the public expects.

Conversely, when a single manufacturer makes an advance within a proprietary system, it must risk its reputation and future success on the validity of its own findings, with no public evaluations or additional checks. Similarly, the FAA must then accept or reject the manufacturer's proposals on the basis of the same limited information.

Thus, all R&D with probable civil applications has important and sometimes subtle implications for safety. Use of technology by public carriers requires the highest standards of safety and careful establishment of priorities.

National Defense

Historically, the interaction developed between NASA and the Department of Defense has resulted in significant benefits to military programs. While the defense establishment by virtue of its mission concentrates on military-oriented programs, it makes use of technical advice from NASA. On the other hand, there are areas of broad aeronautical application in which NASA has a leading role and to which the Department of Defense has been able to contribute. A case in point is NASA's clear lead in computational aerodynamics. Other activities such as R&D facilities development and operation as well as flight test techniques development are carried out in parallel on a mutually supporting basis. Such complementary activities are of definite benefit and importance to both organizations.

In the view of the panel, almost every Systems Technology program of NASA is of significant, though not necessarily unique or overriding, military interest. With regard to specific Systems Technology programs, those on advanced composite materials and structures, energy efficient engines, and advanced turboprop systems are without doubt of great value toward advanced military systems of the future--1990 and beyond. Even though the defense establishment has significant programs for advanced composite structures, the area is so broad and so critical that the combined efforts of NASA and the military are viewed as necessary to achieve early transition of such important technology into effective and efficient systems for the future.

In the case of the Energy Efficient Engine and the Advanced Turboprop programs, the military establishment depends entirely on NASA's work as there are no comparable activities within the Defense Department. For large, long-endurance military aircraft of the future, the defense establishment relies on NASA Systems Technology programs.

Efficient Transport

U.S.-built airplanes have dominated the world's airways since World War II. They have been more productive, efficient, and reliable than almost any other competing airplanes. American manufacturers have maintained sales leadership with reasonable prices for superior products, despite frequently more advantageous terms of acquisition for airplanes built by foreign competitors.

The technical superiority of U.S. transport airplanes derives from many factors, among which are the ability and ingenuity of the airframe and engine designers, excellent postdelivery support of products by the manufacturers, close cooperation between builders and prospective users, the overall profitability of the business, and basic research by NASA and its predecessor, the National Advisory Committee on Aeronautics.

Air transportation has become a national enterprise, just like rail transportation or mass transportation for cities. Air transport has become almost the only means of overseas travel, and the major means of travel for distances of more than 300 miles on the continent. Airlift capability has become an important and integral part of military strategy.

Much of the leadership by U.S. manufacturers can be traced to early adoption of their products by U.S. airlines. These airplanes have enabled the U.S. operators to establish positions of competitive leadership and have forced foreign airlines to acquire the same type vehicles. To date, most aircraft manufacturers in the foreign countries with major airlines have not been able to produce a competitive product--with the notable exception of the multinational Airbus A-300. Thus, for many decades, advances in the efficiency, comfort, convenience, and safety of the long-distance transportation system have depended on technical progress in the U.S. aircraft industry.

Since 1973, airline fuel efficiency, as measured in passenger seat miles per gallon, has increased 40 percent. Much of this economy has resulted from retirement of older, less efficient airplanes, use of airplanes with more seats, conservation, engine improvements, and some aerodynamic improvements. More aerodynamic and propulsion improvements and weight reductions through greater use of composites will appear in new airplanes.

If American transport airplanes are to continue to serve American transportation needs and are to retain a position of technical leadership and superiority, they must continue to be more productive, more efficient, and competitive in all respects and must meet the requirements of the marketplace.

NASA programs such as the Aircraft Energy Efficiency (ACEE) Program, which includes research in aerodynamics, propulsion, composites, etc., are of prime importance to these ends. In fact, some of the products of the ACEE program have already been incorporated into airplanes and engines currently in operation.

NASA's research contributions have also assisted the FAA in developing the microwave landing system, which has been adopted as an international standard. Such an application was not foreseen when the Terminally Configured Vehicle Progam was initiated. It should continue to be of help in the development of the National Airspace System. Many contributions to operating safety have come from NASA research, and much of this research is of a broad and integrated nature and cannot normally be expected to come from industry.

National Economy

Although as indicated in Chapter 3, "Considerations Affecting the Review," and in Chapter 5, "Bridging the Gap," many factors affect the selection of civil sector R&D for government support, there is little doubt that most of the NASA programs reviewed have a potentially large future impact on the national economy. This judgment can be made without regard to the particular mechanisms that might be used to fund them, although in many cases, because of dual military and civil applicability, long-range high-risk payoff possibilities, and industry-wide applicability over a wide range of aircraft types, direct government support seems most appropriate and efficient.

The programs already discussed under "Efficient Transport," namely the Aircraft Energy Efficiency (ACEE) Program, which includes work in aerodynamics, propulsion, and composites, and the Advanced Turboprop program, typify NASA's efforts in support of maintaining the technological lead and international competitiveness of U.S. transport aircraft, which programs subsidized by foreign governments are currently challenging. The potential in these programs for improved economic efficiency of U.S. transport aircraft will in itself contribute to the national economy. An essential element of all of these potential economic benefits is improved engine fuel consumption, as exemplified by the Energy Efficient Engine Program. Large U.S. jet engines currently dominate the world air transport market to an even greater degree than in the past, since foreign aircraft such as the Airbus use them. Maintaining this significant export potential also benefits the economy.

Similar considerations apply to the general aviation area in both aircraft and engines. Although the scale of general aviation R&D generally involves smaller funding for individual projects and although much of it tends to be done in the R&T Base rather than as Systems Technology, it is important to maintain a healthy level of work in this area.

5

Bridging the Gap

The panel concurs with the OMB statement that government R&D support should be focused "on fundamental research in all basic aeronautical disciplines, the maintenance of specialized facilities for research and testing, and technology development and demonstration activities critical to the nation's needs . . . [while] technology development and demonstration projects with relatively near-term commercial applications will be curtailed as an inappropriate federal subsidy."[1]

However, the interpretation of this principle in responding to the question of whether it is necessary for the government to bridge the gap between research and early application of new technologies poses many questions. In preceding chapters, the panel has attempted to evaluate, using several criteria, whether certain technologies are critical to national needs. A remaining question is how far on the continuum of aeronautics research and development NASA appropriately should go and at what point industry or the Department of Defense should be expected to assume validation and development responsibilities for new technologies. The degree of technological and financial risk involved and whether the expected technical and financial payoff will occur in the long-term or the near-term are key elements in making this determination in addition to national criticality.

The gray area, which is under consideration in this review, is mainly in the Systems Technology area in projects characterized by NASA as proof of concept or technology demonstration.[2] Demonstration projects often have the appearance of prototype development because the article being demonstrated must be capable of

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[1]Office of Management and Budget is Special Analysis K.

[2]NASA has defined the steps of the research and development continuum as being (1) discipline research to understand basic physical phenomena and generate concepts, (2) systems research to understand the interaction between components, (3) proof-of-concept activities to establish feasibility, (4) technology validation to establish confidence, and (5) product development. NASA never engages in the latter activity and rarely in the technology validation stage.

being tested in approximately the true operating environment. The purposes of the demonstration are to establish the extent to which design analyses and engineering laboratory tests are valid as bases for projection of performance under operating conditions and to identify any unforeseen factors that must be imposed on future designs to reflect the requirements of the operating environment. The demonstration article may not be (and often is not) sized as a manufacturable and marketable product. Sometimes the demonstration is based on testing new components as operating elements of existing operational systems.

Engine demonstration projects, for example, pose particular difficulties for many critical observers of aeronautical R&D programs, because a demonstration engine looks like a complete prototype engine and operates like one. Yet the demonstration engine is only intended to determine the interactive performance of separately developed components (fans, compressors, combustors, turbines). The demonstration engine is usually not flight weight in all components, nor does it have a flight-type fuel control system, starting provisions, power takeoffs, compressed air bleeds, and other appurtenances necessary for a flight engine. Moreover, the demonstration engine does not meet flight safety and reliability standards; it is simply a bench test device. That the demonstration engine is not really intended to be a prototype of an operational, marketable engine is perhaps best illustrated by the fact that it may be in a considerably different size class from the most obvious specific applications (e.g., the military-sponsored General Electric demonstration engine that led to the TF-39 eventually installed in the C-5A was sized at less than half the thrust level of the operational engine). Thus, an engine demonstration project is clearly distinguishable from a full-scale engine engineering development program.

Such demonstration projects are intended to build confidence in an innovative design concept, structural arrangement, components, device, or material in order to permit not only the potential manufacturer but also the user (military services, airlines, etc.) and the certifying agency (FAA) to appraise the merits and anticipate the problems of the innovation properly.

Clearly, if an innovation primarily for commercial use is specific in nature and proprietary to one manufacturer, the burden of demonstration must be assumed by that manufacturer. But where a new technology is intrinsically likely to be industry-wide, may have many applications in many forms, has potential military and civil applications, is costly to demonstrate, and has important implications for safety and other regulatory concerns, then government funding may be the most appropriate way to carry out the demonstration project. The degree to which the stated criteria apply to any particular area of innovation is inevitably a matter of judgment, but such technological advances as the use of high-strength composite structures in aircraft clearly have properly been undertaken with government support of demonstration projects. The rate of progress in this area will continue to depend on the degree to which R&D is aggressively pursued, although the initial hurdles requiring demonstration have undoubtedly been overcome for the level of technology now being introduced in a number of new civil and military aircraft--e.g., the Boeing 757/767 flight control surfaces and the "Harrier" AV-8B Marine V/STOL fighter main wing structure. However, new matrix materials, fibers, and structural arrangements and their relationship to design, fabrication, inspection, and operating and maintenance problems will continue to be the subjects for R&D, and if sufficiently large technological advances with high potential performance and economic advantage seem to be in prospect at some future time, a new round of demonstration projects would be in order.

The financial dimensions of introducing major innovations in large transport aircraft may be perceived by considering that the cost of launching such a program may be several billion dollars and the sums required may well exceed the net worth of an aircraft manufacturer ("you bet your company" is one description of this situation). Furthermore, concern over "risk taking in recent years has led to the need for a greater degree of confiden[illegible] a new technology before financial interests are willing to back industry in the development of a new product. Demonstration/proof-of-concept projects help to determine when, in what areas of application, and with what technical confidence aircraft manufacturers may be ready and willing to adopt advanced technologies prior to proceeding with these large financial undertakings. In addition, they help both government and industry to identify areas of R&D where additional work may be necessary to reduce technical risks before product development.

There is general agreement that the lead time for maturation of a given technology should be a factor in determini[illegible] whether NASA should appropriately be involved. Yet, as noted earlier, it is often difficult to predict in what time frame a new development may occur. As indicated in Chapter 3 in the section "Near Term Versus Long Term," aggressive pursuit of fiber composite technology in a joint government-industry program resulted in the use of a boron fiber composite horizontal tail surface on the F-14 aircraft in less than 10 years, and the recent NASA discovery of the winglet for drag reduction has found almost immediate possibilities for application in military and civil aircraft.

The panel agrees that near-term commercial applications are the responsibility of industry, but longer-term high-risk development and demonstration, reflecting new, advanced concepts, are viewed as essential to the nation's needs, are unlikely to be supported by industry, and should be an issue for federal government concern. These activities do not necessarily fill an identifiable need at the present time, but seek to maintain a viable economic and defense posture 10 or 20 years hence.

6

Related Program Concerns

In the course of the panel's discussions, several issues arose, in addition to the specific charges to the panel, regarding which the members of the panel wish to record their concern.

LACK OF NEW INITIATIVES IN THE AERONAUTICS BUDGET

The panel views with great concern the deferral of NASA's new initiatives in aeronautics for the past two years. New initiatives tend to be revolutionary rather than evolutionary. Accordingly, most industrial or commercial organizations cannot or will not risk something that may fail completely or take 10 to 15 years to culminate in a profitable product. This is where government laboratories have a unique role to play. One of the most important functions for any government laboratory is to study these new areas--at the basic research level, at the applied research and exploratory development level, and if necessary at the demonstration level.

Such areas as advanced composites research, new vehicle and engine efficiency concepts, and advanced numerical techniques, which may significantly affect the development and overall quality of new aerospace systems, warrant vigorous pursuit if the United States is to maintain a competitive posture in the coming decades. Because the impact of such initiatives is negligible in the near term, it is easy to continue to defer these activities. In the panel's view, the decline and deferral of long-term R&D may result in severe setbacks in the U.S. defense and economic posture near the turn of the century.

ADEQUACY AND BALANCE OF THE R&T BASE PROGRAM

A secondary and inadvertent effect of terminating Systems Technology programs may be to redistribute research in the R&T Base away from basic and long-range research.

When a Systems Technology program is terminated, some element of it should often appropriately be transferred to the R&T Base; for example, a typical $10 million program might contain within it as much as $1 or $2 million of fundamental work to support the specific program. The panel observed that NASA has proposed to reprogram approximately $11 million to the R&T Base to carry on fundamental work and continue other parts of eliminated programs at reduced levels. In the panel's review of the individual Systems Technology programs, several programs appeared to be essentially groupings of individual projects that properly belonged in the R&T Base. The panel has recommended that these programs continue at some level in the R&T Base as well.

It is not clear, however, whether current and planned growth of the R&T Base is adequate to absorb these transfers from the canceled programs, or whether such shifts will curtail or eliminate important existing research programs in the R&T Base. This assumes that NASA management will appropriately rebalance the R&T Base when funding levels are determined.

In addition, the pressure on the NASA laboratories, under the long-term trend of budget reductions in aeronautics programs combined with the proposed sharp FY 1983 reductions, could result in NASA's preserving in-house capabilities at the expense of programs conducted out of house. Admittedly, if such pressures continue NASA will be faced with losing its own cadre of experts, if not the absolute capability of the organization. But budget reductions immediately affect the health of university research, existing teams of experts within the aeronautics industry, and the unique and successful relationship that has existed among NASA, the universities, and industry. Once abandoned, these arrangements will be difficult to rebuild, if not irretrievably lost.

Figure 2 demonstrates this trend over a 10-year period. It shows that in constant dollars support for research projects with industry has declined by a factor of three and that university contracts have fallen somewhat over the past four years. In this regard, it is noted that there have been some cancellations of approved multiyear basic research programs at universities and projections that some current long-term programs will not be continued in out years. This has occurred during a period when the universities have been under financial strain from the cancellation of other government support and from difficulties in raising funds. These reductions can adversely affect the support of basic and applied engineering research at universities and in industry and preclude the important contributions these institutions can make. A reduction in the support for engineering research at universities also weakens educational opportunities for future engineers. The panel concludes from the available data that, unless university, industry, and other contracts are continued at a viable level, basic research will receive less support in the proposed "expanded" R&T Base than in previous budgets.

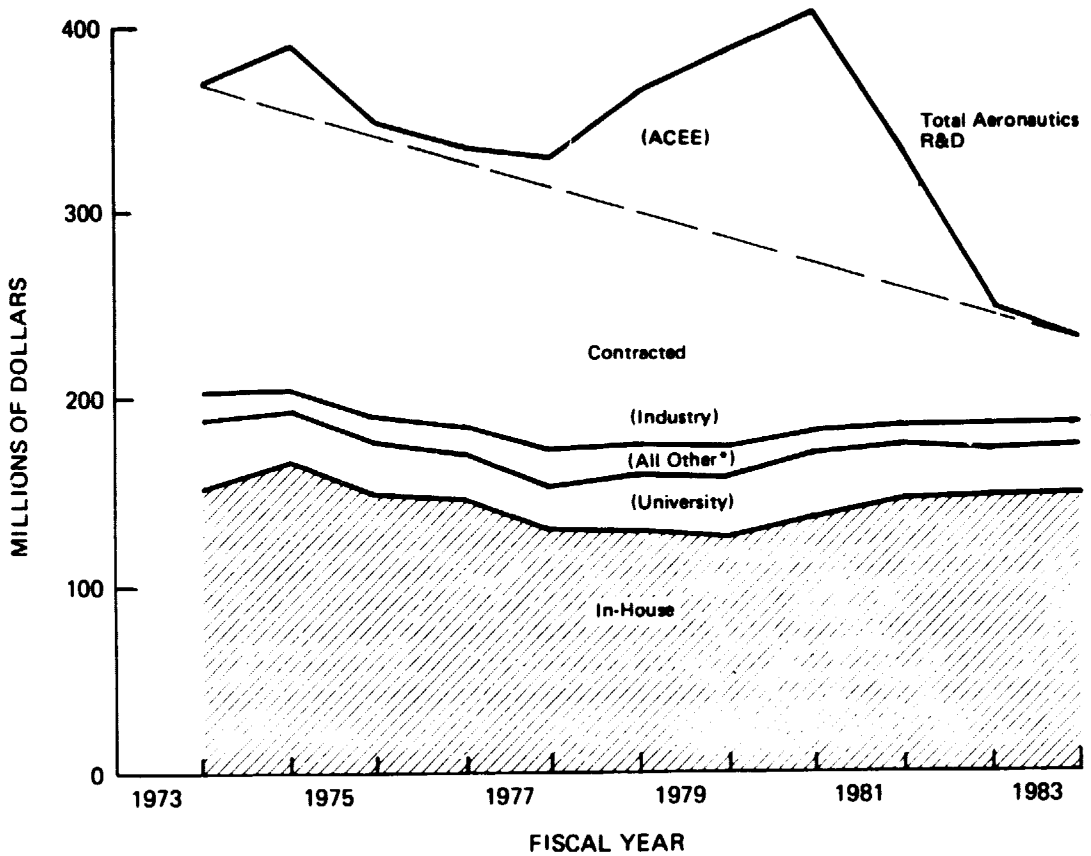

FIGURE 2 Aeronautics R&D contrac..d and performed in house (in FY 1983 dollars). Figure courtesy of NASA.
*All other includes nonprofit organizations, FFRDC's, other agencies, and foreign organizations.

Brief Biographies of Panel Members

ALEXANDER H. FLAX, Chairman, is President of the Institute for Defense Analyses. He received a B.Aero.E. from New York University in 1940 and a Ph.D. in Physics from the University of Buffalo in 1957. He was an engineer in the aircraft industry from 1940 to 1946 and then was with the Cornell Aeronautical Laboratory, eventually as Vice President-Technical Director. Dr. Flax served as Chief Scientist of the Air Force and as Assistant Secretary of the Air Force for R&D. His experience and interests have been in air and space vehicle engineering and in systems and policy analysis.

SEYMOUR M. BOGDONOFF is Chairman of the Department of Mechanical and Aerospace Engineering at Princeton University. He received a B.S. in Aeronautical Engineering from Rensselaer Polytechnic Institute in 1942 and an M.S.E. in Aeronautical Engineering from Princeton University in 1948. From 1942 to 1946 he was with the National Advisory Committee on Aeronautics (NACA) at Langley Field, where he was Assistant Section Head of the Fluid and Gas Dynamics Analysis Section. Since 1946 he has been Head of the Gas Dynamics Laboratory at Princeton, specializing in high-speed fluid mechanics, particularly shock waves and turbulent boundary layers.

JOHN G. BORGER is now a private consultant after retiring in 1980 from Pan American World Airways, where he was Vice President and Chief Engineer. He joined Pan Am in 1935, shortly after receiving a B.S. in Aeronautical Engineering from the Massachusetts Institute of Technology in 1934. He has participated in the development and application of many transport airplanes, including the Boeing B-314, Stratocruiser, B-707, B-747, Douglas DC-6B, DC-7C, DC-8, Lockheed Constellation, L1011-500, Convair CV-240, Dassault Falcon 20, and others. He has also conducted design reviews of the Concorde and U.S. supersonic transport.

W. BOWMAN CUTTER III is a partner in the Washington, D.C., office of Coopers & Lybrand, where he heads their business planning group. He received a B.A. in Economics and Anthropology from Harvard University in 1964. From 1964 to 1966 he studied at Oxford University, Balliol College, as a Rhodes Scholar and received his master's degree in Anthropology and Development Economics. From 1966 to 1968 he earned a M.P.A. in Public Affairs-Public Finance from Princeton University, the Woodrow Wilson School. Immediately prior to joining Coopers & Lybrand in February 1981, Mr. Cutter was the Executive Associate Director for Budget of the Office of Management and Budget and a principal architect of the Energy Security Act that created the Synthetic Fuels Corporation. Before Mr. Cutter's appointment to the Office of Management and Budget, he held senior financial management positions at Northwest Industries, Inc., in Chicago and the Washington Post Company in Washington, D.C. Mr. Cutter continues to be an active speaker and author on the varied aspects of the budget process.

JOHN H. ENDERS is President of the Flight Safety Foundation, an independent, internationally supported, nonprofit organization that fosters safety consciousness within the aviation community. Mr. Enders is a graduate of Case Institute of Technology. He is a former NACA/NASA research engineer and test pilot and managed NASA's Aviation Safety Research programs for about 15 years. During his career he was also a pilot in the United States Air Force's Strategic Air Command and a research officer with the Air Research and Development Command. He was NASA liaison representative to the National Aeronautics and Space Council staff and was Technical Advisor to the Federal Aviation Administration (FAA) Associate Administrator for Safety. Mr. Enders was a consultant with the National Research Council's Committee on FAA Airworthiness Certification Procedures and with the Congressional Office of Technology Assessment on projects associated with Air Traffic Control.

GEORGE S. GRAFF is a retired corporate vice president of the McDonnell Douglas Corporation and retired president of the McDonnell Aircraft Company. He received a B.A. from DeSales College in 1939 and a B.S. in Aeronautical Engineering from the University of Detroit in 1942. After joining McDonnell Douglas in 1942 Mr. Graff contributed heavily to the aerodynamic and general technical development of several Air Force and Navy fighter aircraft. He managed the development of the F-3H and later the F-4 Phantom II, over 4,000 of which are now serving the Air Force, Navy, and other allied countries throughout the world. He also contributed significantly to development of a small transport, to several missile programs, and to the Mercury and Gemini space programs.

WILLIAM T. HAMILTON is Vice President and Chief Scientist for the Boeing Military Airplane Company in Seattle, Washington. He received a B.S. in Aeronautical Engineering in 1941 and an M.S. in Aeronautical Engineering in 1947 from the University of Washington. Mr. Hamilton was Chief of Aerodynamics Engineering during the development of Boeing's 707 and B-52 programs. He was involved in the preliminary design and configuration development of Boeing's Dyna-Soar, Minuteman, B-70, and F-111 efforts and was Director of Engineering for the supersonic transport program. In Boeing's Aerospace Company he made significant contributions to Boeing's Shuttle, IUS, Large Space Telescope, and YC-14 AMST efforts. As Vice President of Research and Development of Boeing's Commercial Airplane Company, he contributed significantly to development of the 757 and 767.

JAMES N. KREBS is Vice President and General Manager of the Aircraft Engine Group's Military and Small Commercial Engine Operations for the General Electric Company. He graduated from Northwestern University in 1945 with a B.S. in Mechanical Engineering. He has held many design, development, marketing, and general management assignments during his 35 years with General Electric's jet engine business. During the 1950s he was engaged in design and development of General Electric's first Mach 2 variable stator turbojet (J79) and first small lightweight supersonic turbojet (J85). In the early 1960s he directed the company's entry into business jet programs. Later he directed the product planning and advanced design of high-bypass turbofans, including the CF6 and CFM56. In more recent years he has been closely associated with the development and production of General Electric's new line of military engines--F404, F101, F101 DFE, T700--becoming Vice President of Military Engines in 1978.

WESLEY A. KUHRT is a consultant to United Technologies Corporation and recently retired as Senior Vice President-Technology. He received a S.B. and S.M. at the Massachusetts Institute of Technology in Aeronautical Engineering in 1939 and 1940. Since joining the Pratt & Whitney Division of United Technologies Corporation (formerly United Aircraft Corporation) in 1941, he has served as Director of Research for the Corporation, as President of the Sikorsky Aircraft Division, and most recently with the corporate office activities as Senior Vice President-Technology. He is known for his work on a variety of propulsion systems and for the application of advanced technology in helicopter design. Mr. Kuhrt established a plasma physics program at the UTC Research Laboratories that led to the development of MHD devices and ion propulsion systems, and established a controlled thermonuclear fusion program.

PETER R. MURRAY is a private aerospace consultant. He received a B.S. in Physics from Antioch College, Ohio, in 1938. He spent 32 years at Wright-Patterson Air Force Base, Ohio, as Technical Director for guided missile R&D and as Director of the Air Force Avionics Laboratory, developing guidance and control equipment for pilotless aircraft and missiles. He completed his combined military-civilian career with the Air Force in 1972 as Acting Director of Laboratories for the Air Force Systems Command.

THOMAS C. MUSE is a consultant in aeronautical engineering. He received a B.S. in Engineering from the University of Virginia in 1939. Subsequently, he studied aeronautical subjects at the University of California at Los Angeles and the California Institute of Technology. He attended Harvard Business School in the AMP 33 class. He was a research engineer for NACA at its Langley Laboratory during World War II and was employed by the Douglas Aircraft Company as an aircraft research and design engineer from 1945 to 1950. From 1950 until his retirement in

1973 he was employed in the Office of the Secretary of Defense as staff expert on research and development of military aircraft.

DAVID D. THOMAS is a consultant to the General Aviation Manufacturers Association on safety and airspace matters. He served in the federal government for over 30 years, starting as an air traffic controller and ending as Deputy Administrator of the Federal Aviation Administration. He is a past president of the Flight Safety Foundation and has received many honors for his work in air safety. He has been a pilot for 40 years and holds ratings in piston, turboprop, and jet aircraft.

SHEILA E. WIDNALL is a Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology. She received a B.S. in 1960, an M.S. in 1961, and a Ph.D. in 1964 in Aeronautical Engineering, all from MIT. She has been a member of the faculty at MIT since 1964 and has just completed a two-year term as Chairman of the faculty. From 1974 to 1975 she served as Director of University Research for the U.S. Department of Transportation.

JAMES J. KRAMER, Advisor, is the manager of advanced technology programs in the Washington area for the Aircraft Engine Group of the General Electric Company. He received an A.B. in 1949 and an M.A. in 1951 from Xavier University. In 1951 he joined the technical staff of NACA Lewis Laboratory, which later became the NASA Lewis Research Center, where he was involved in research on propulsion systems for aircraft and space vehicles. He joined the NASA headquarters staff in Washington, D.C., in 1971 and became the NASA Associate Administrator for Aeronautics and Space Technology in 1977. He retired from government service in 1979 and joined the General Electric Company as manager of strategic planning for the Aircraft Engine Group.

RAYMOND F. SIEWERT, Military Liaison, is Staff Specialist for Aeronautics Engineering Technology with the Office of the Secretary for Defense. He received a B.S. in Aeronautical Engineering from the University of Illinois in 1954 and a M.S. in Public Administration from George Washington University in 1975. He is an expert in the aerodynamics, stability, control, and handling qualities of all types of aircraft, including the Vertical/Short Takeoff and Landing Vehicle.

Appendixes

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Appendix A

MARCH 8 AND MARCH 18, 1982, LETTERS FROM
THE HONORABLE EDWARD P. BOLAND AND SENATOR JAKE GARN

United States Senate
COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

March 8, 1982

Mr. James M. Beggs
Administrator
National Aeronautics and
Space Administration
Washington, D.C. 20546

Dear Mr. Beggs:

In accordance with the relationship between NASA and the National Research Council (NRC) established by House Report 96-1476, we hereby request a review of NASA's plans to significantly reduce its FY 1983 aeronautical research and technology programs.

Specifically, we request that the NRC Committee on NASA Program Reviews establish a mechanism to examine the potential impact of these proposed changes. The review should identify those areas of key programs no longer included in the FY 83 budget and: (1) address the national criticality of those programs; (2) assess the risk associated with the satisfactory completion of each of the programs; and (3) determine the degree to which these programs might be assumed by the private sector.

To assist in making a decision regarding this subject in a timely fashion, a briefing on the findings of the review panel is requested by July 16, 1982.

Sincerely,

Edward P. Boland
Chairman
HUD-Independent Agencies
Subcommittee
House Appropriations

Jake Garn
Chairman
HUD-Independent Agencies
Subcommittee
Senate Appropriations

cc: Mr. Frank Press

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57-58

United States Senate

COMMITTEE ON APPROPRIATIONS
WASHINGTON, D.C. 20510

March 18, 1982

Mr. James M. Beggs
Administrator
National Aeronautics and
  Space Administration
Washington, D.C.   20546

Dear Mr. Beggs:

On the basis of staff discussion regarding clarification of the second paragraph of our March 8 letter to you, the item which reads

> "(2) assess the risk associated with satisfactory completion of each of the programs; .."

can be re-phrased as

> "(2) assess the risk (probability of success) associated with achieving the objectives of each of these programs; .."

Sincerely,

Jake Garn
Chairman
HUD-Independent Agencies
  Subcommittee

cc: Dr. Frank Press

Appendix B

COMMITTEE ON NASA SCIENTIFIC AND TECHNOLOGICAL PROGRAM REVIEWS

NORMAN HACKERMAN, President, Rice University, Houston, Texas, Chairman
WILLIAM A. ANDERS, Vice President and General Manager, General Electric Company, Dewitt, New York
RAYMOND L. BISPLINGHOFF, Director for Research and Development, Tyco Laboratories, Inc., Exeter, New Hampshire
EUGENE E. COVERT, Professor of Aeronautics, Massachusetts Institute of Technology, Cambridge, Massachusettes
ALEXANDER H. FLAX, President, Institute for Defense Analyses, Alexandria, Virginia
RICCARDO GIACCONI, Director, Space Telescope Science Institute, Johns Hopkins University, Baltimore, Maryland
JOHN W. TOWNSEND, Jr., President, Fairchild Space and Electronics Company, Germantown, Maryland
GERALD J. WASSERBURG, John D. MacArthur Professor of Geology and Geophysics, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California
HERBERT FRIEDMAN, Co-Chairman, Commission on Physical Sciences, Mathematics, and Resources, National Research Council, Washington, D.C., Ex-Officio Member
H. GUYFORD STEVER, Chairman, Commission on Engineering and Technical Systems, National Research Council, Washington, D.C., Ex-Officio Member

Appendix C

GUIDELINES FOR A REVIEW OF REDUCTIONS IN NASA'S AERONAUTICS PROGRAM

The National Academy of Sciences/National Academy of Engineering through the National Research Council contracted to furnish the National Aeronautics and Space Administration, through the NASA Chief Engineer, a review of NASA Aeronautical Technology Program Reductions in response to Congressional request. This review is the second task under a broader contractual arrangement with NASA to provide Congress with NRC evaluations of major NASA program changes. The request issued by letter dated March 8, 1982, from Senator Garn and Congressman Boland to NASA Administrator James Beggs with further explanatory note of March 18, 1982, from Senator Garn stated the charge:

> In accordance with the relationship between NASA and the National Research Council established by House Report 96-1476, we hereby request a review of NASA's plans to significantly reduce its FY 83 aeronautical research and technology programs.
>
> Specifically, we request that the NRC Committee on NASA program Reviews establish a mechanism to examine the potential impact of these proposed changes. The review should identify those areas of key programs no longer included in the FY 83 budget and: (1) address the national criticality of these programs; (2) assess the risk associated with satisfactory completion of each of the programs [i.e., assess the risk (probability of success) associated with achieving the objectives of each of these programs]; and (3) determine the degree to which these programs might be assumed by the private sector.
>
> To assist in making a decision regarding this subject in a timely fashion, a briefing on the findings of the review panel is requested by July 16, 1982.

To deal with the request for carrying out reviews of NASA programs, the NRC established the Committee on NASA Program Reviews. In order to address diverse problems, the committee has been authorized to establish ad hoc review panels, of which this--the panel to review reductions in the NASA Aeronautics Program--is the second.

In carrying out this review, account should be taken of recent studies related to NASA's aeronautics program conducted by the NRC

Aeronautics and Space Engineering Board, which include "NASA's Role in Aeronautics: A Workshop" (7 volumes), "NASA's Aeronautics Research and Technology Base," and "NASA's Aeronautics Program: Systems Technology and Experimental Programs." The work of the NRC panel conducting a Review of Advanced Technology Competition and the Industrialized Allies should be taken into consideration as well.

The review panel is to consider the NASA Aeronautics Research and Technology Program as a whole to include the Research and Technology Base, the Systems Technology generic fields, their individual projects and proposed new initiatives from their level of effort in FY 81 or earlier to date. Four areas deemed to be of primary importance with regard to aeronautical systems are:

Safety
National Defense
Efficient Transport
National Economy

The panel shall address the following questions:

1) Is it necessary for the government to bridge the gap between the Aeronauti Research and Technology Base and early application with regard to the four areas noted above?

2) What is the outlook for success and what are the time horizons of those projects excluded from the proposed FY 83 budget? Would industry undertake these projects (now or later) if government does not do them and on what basis?

3) If neither government nor industry undertakes the projects noted in question 2), what will be the impact with regard to the four areas noted above?

4) What should be the priorities within NASA's Aeronautics Research and Technology Program?

It is understood that NASA will provide information and data on the following: scientific and technical objectives of their aeronautics research and technology programs, their funding levels by project from FY 81 or earlier to those proposed for FY 83, and detailed descriptions of the Aeronautics System Technology projects (as well as proposed new initiatives) to include, for those projects to be terminated, their anticipated status at the time of termination.

It is requested that the task be completed and the report be forwarded to the Committee on NASA Program Reviews by June 30, 1982.

Committee on NASA Program Reviews
Washington, D.C.
March 27, 1982

Appendix D

EXCERPTS FROM THE OFFICE OF MANAGEMENT AND BUDGET'S SPECIAL ANALYSIS K

SPECIAL ANALYSIS K

RESEARCH AND DEVELOPMENT

This analysis summarizes the funding of research and development across all departments and agencies. It consists of two parts. The first highlights the R. & D. policies and trends in the 1983 budget. The second describes in more detail the R. & D. programs of the 13 agencies whose 1983 obligations account for over 99% of total Federal funding for R. & D.

The Federal Government does not have a separate R. & D. budget. Rather, R. & D. programs are reviewed and funded primarily in the context of the missions of individual agencies and on the basis of their importance in meeting mission objectives.

PART I. HIGHLIGHTS

R. & D. activities are supported by the Federal Government in two broad categories, namely, to meet:

- Federal Government needs—where the sole or primary user of the R. & D. is the Government itself, for example, in national defense and environmental regulation.
- National needs—where the Federal Government helps to assure the strength of the Nation's economy and the welfare of its citizens through the support of R. & D. in specific areas such as agriculture, energy, and health.

The 1983 budget reflects a clearer delineation, than has been the case in the past, between the responsibilities of the Federal Government and those of the private sector with respect to R. & D. to help meet national needs.

The Federal Government has two main responsibilities with respect to R. & D. to meet national needs.

- First, it should provide a climate for technological innovation which encourages private sector R. & D. investment that best reflects the realities of the marketplace where new and improved processes and products are developed, bought, and sold. The administration is fulfilling this responsibility primarily by reducing Government spending, regulation and taxes. Thus, the administration's R. & D. policy is part of its overall economic policy.
- Second, the Government should focus its direct R. & D. support on those areas where there is substantial prospect for significant economic gain to the Nation, but where the pri-

vate sector is unlikely to invest adequately in the national interest because the benefits, in large measure, are not immediately "appropriable" by individual firms. Thus, for example, the Federal Government supports basic research across all scientific disciplines but limits its spending on technology development to technologies requiring a long period of initial development, such as fusion power, where the risk is high but the payoff to the Nation is potentially large. This strategy is reflected in the funding for R. & D. to meet national needs in the 1983 budget.....

- *National Aeronautics and Space Administration (NASA).*—Obligations for the conduct of R. & D. by NASA are estimated at $6.5 billion for 1983. $0.7 billion over 1982. Increased funding for 1983 is proposed to assure timely transition of the Space Shuttle to an operational system and to continue the highest priority research and space exploration projects, including the further development of the Space Telescope, Gamma-Ray Observatory and the Galileo Mission to Jupiter.....

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Through the programs of NASA, the Federal Government makes investments in R. & D. that yield new space technologies to improve the national security and the long-term scientific and technological strength of the Nation. They also provide new knowledge about the earth, the solar system, and the universe.

In 1983, the R. & D. request would continue flight missions launched in prior years (e.g., Voyagers to the outer planets) and further development of most major ongoing projects, including the Space Shuttle. Obligations for the conduct of R. & D. would increase by $672 million in 1983 to a total of $6.5 billion. Within this amount, basic research would amount to $682 million, an increase of $102 million over 1982. Obligations for construction of facilities in 1983 would total $116 million.....

Aeronautical Research and Technology Programs.—In 1983, support will be focused on fundamental research in all basic aeronautical disciplines, the maintenance of specialized facilities for research and testing, and technology development and demonstration activities critical to the Nation's defense needs.

Research emphasis will be placed on:
- Aerodynamics, propulsion and avionics;
- Flight controls and human-vehicle interaction; and
- Materials and structures.

Technology development and demonstration projects with relatively near term commercial applications will be curtailed as an inappropriate Federal subsidy.....

Appendix E

NASA OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY
BRIEFING PERSONNEL

DR. JACK L. KERREBROCK, Associate Administrator
DR. RAYMOND S. COLLADAY, Deputy Associate Administrator
MR. C. ROBERT NYSMITH, Assistant Associate Administrator for Management
MR. WILLIAM P. PETERSON, Director, Resources and Management Division
MR. FREDERICK P. POVINELLI, Director, Institutional and Program Support Division
DR. LEONARD A. HARRIS, Director, Aerospace Research Division
DR. CECIL C. ROSEN, III, Deputy Director, Aerospace Research Division
MR. ROGER L. WINBLADE, Manager, Subsonic Office

Appendix F

REPRESENTATIVES FROM ORGANIZATIONS
WHO MADE PRESENTATIONS TO THE PANEL

MS. VIRGINIA LOPEZ, Director, Aerospace Research Center, Aerospace Industries Association

MR. ALLEN SKAGGS, Vice President Civil Aviation, Aerospace Research Center, Aerospace Industries Association

MR. JOSEPH SNODGRASS, Director of Aviation Programs, Aerospace Research Center, Aerospace Industries Association

MR. JEFF STRUTHERS, Chief, Science and Space Programs Branch, Office of Management and Budget

DR. LOUIS MONTULLI, Study Director, Office of Science and Technology Policy

MR. JAMES E. GORMLEY, Vice President, Government Relations, General Aviation Manufacturers Association

MR. STANLEY GREEN, Vice President and General Counsel, General Aviation Manufacturers Association

MR. SIEGBERT B. PORITZKY, Director of Systems Engineering Management, Federal Aviation Administration

MR. RAYMOND SIEWERT, Director of Engineering Technology, Department of Defense, Office of the Undersecretary of Defense, Research and Engineering

Appendix G

THE ROLE OF NASA SYSTEMS STUDIES

System studies are an essential element of any engineering or applied science program. The more complex the end products to which the R&D is to be applied and the more advanced the technology involved, the more important the system studies. Modern air transports and military aircraft are both highly complex and involve much advanced technology. Aeronautical R&D, therefore, requires support by extensive system studies. Only by examining a wide range of potential applications of emerging technology can proper emphasis be placed on the various specific areas included in all phases of the R&D process. In many cases, system studies also provide guidance on the specific problems that must be addressed.

System studies of aircraft usually comprise integrated designs of potential future aircraft systems incorporating new technologies as they are projected to be available at some future time. These study designs may cover a range of technological and end-use parameters and superficially appear to be what an industry design team normally does to design an end product. However, the system study designs are generally limited in detail but of broader scope in ranges of applications and technological variables. NASA's role in sponsoring these studies is to bring in the results of their own technology base programs in establishing the scope and direction of the studies and to integrate and evaluate the results of several industry design teams in the airframe, engine, and possibly equipment areas, as appropriate to the particular potential development under study. NASA also brings in the concerns of users (e.g., airlines) and government agencies such as FAA and seeks to arrive at overall assessments as to the potential value and timing of new technologies in various applications and the R&D needed to achieve potential advances. The specific system designs analyzed in this process are generic and are not likely to represent, even approximately, specific products to be manufactured and marketed by industry at some future time.

Appendix H

JOINT INDUSTRY R&D PROGRAMS

In considering whether it would be possible for the aircraft engine industry to fund demonstration R&D programs, it should be noted that the major large engine manufacturers presently are investing \$100-\$200 million annually in engineering development of commercial engines for the near term. Demonstration engine programs for transport or military applications currently involve costs of about \$100 million, while the total cost of developing a new transport (or military) engine may come to a billion dollars. Funding for a typical demonstration engine project has run at an average of \$25 million annually over four years. Clearly, investments on the nearer-term projects involve much less risk in both the technical and commercial aspects and earlier (and hence financially more attractive) payoffs. This factor tends to mitigate against industry investments in longer-term, more uncertain, future developments.

However, there are, in principle, many ways in which industry could pool its efforts in conducting research and development programs of industry-wide interest. Recently, the integrated circuit industry and the computer industry in the United States undertook joint sponsorship of university programs and other programs as part of their efforts to counter foreign-government-subsidized programs. In the areas of electric utilities and industrial abrasives, there is a history of industry associations that conduct R&D.

The antitrust laws and regulations are often cited as obstacles to such activities. However, the legal complexities are such that it is difficult to determine in advance what is and what is not permissible. Moreover, the government's antitrust policies have changed over the years and will probably continue to evolve. In general, recent Justice Department documents indicate cooperative industry R&D is more likely to be acceptable under existing antitrust policies if it is directed toward basic or fundamental research, becoming less acceptable as the development end of the R&D spectrum is approached. As noted, however, the characterization of the various stages of the R&D process is subject to wide ranges of interpretation, and it is difficult to conjecture how specific proposals might be judged.

Aside from the legal aspects of the problem, the structure of given industries and the competitive environment both at home and abroad influence the attitudes of those industries toward cooperative R&D and determine the kinds of arrangements that are desirable and feasible. An example of a situation posing special competitive and antitrust considerations is the jet engine industry, in which there are only two U.S. producers of large jet engines for transports and military aircraft (General Electric and Pratt & Whitney). The panel did not pursue the potential for cooperative industrial research in depth but found some reservation on the part of both the aircraft and engine industry representatives with whom the matter was discussed. The general aviation manufacturers' representatives, however, seemed less inclined to rule out the possibility of cooperative R&D in some areas.

Since the establishment of workable and legally permissible mechanisms and organizations for conducting cooperative R&D would undoubtedly take several years to achieve acceptance and operational effectiveness, the panel did not consider cooperative R&D as a feasible near-term alternative to government funding for most of the programs in the FY 1983 budget.

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