U.S. GOVERNMENT SUPPORT OF THE U.S. COMMERCIAL AIRCRAFT INDUSTRY

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EXECUTIVE SUMMARY

The United States government provides massive, systematic support to the U.S. commercial aircraft industry pursuant to a long-standing U.S. policy of striving to maintain U.S. superiority in all areas of aeronautics technology. The total amount of this support cannot be quantified precisely because it is indirect and because there is a striking lack of transparency concerning many of its basic features. Nonetheless, one can reasonably estimate that U.S. government support to the U.S. commercial aircraft industry during the past fifteen years was in the range of $18 billion to $22.05 billion.[1] If current dollar rather than historical dollar figures are used for the quantification of the benefits of Department of Defense and National Aeronautics and Space Administration (NASA) research and development, the estimated range of total benefits is $33.48 billion to $41.49 billion.

The U.S. government supports the U.S. commercial aircraft industry through three principal means: (1) U.S. Department of Defense research and development (R&D); (2) NASA R&D; and (3) the U.S. tax system.

1. U.S. Department of Defense R&D

The strategic importance of aeronautics has led the U.S. Department of Defense to devote enormous resources to military aeronautics R&D in the post-World War II period. Given that the major companies in the U.S. commercial aircraft industry are deeply involved in military aeronautics development and production and that military and commercial aeronautics technology often overlap, these companies derive very substantial crossover commercial benefits from their participation in military R&D. For example, examination of each of the "quantum leaps" achieved in commercial aeronautics technology -- the Boeing 707, the wide-body jets and now the development of a supersonic civil transport plane -- reveals that substantial U.S. government involvement in the period prior to each breakthrough provided support essential to achieving the commercial innovation.

In the past fifteen years, the U.S. Department of Defense has spent approximately $50 billion on aeronautics R&D grants, with at least $6.34 billion of those funds going to the two principal U.S. producers of large commercial aircraft, Boeing and McDonnell Douglas, for aircraft-related R&D. Further, based on analyses of the applicability of military aeronautics technology to commercial uses, we estimate that the $50 billion of military aeronautics R&D constituted a benefit of between $5.9 billion and

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[1] These figures and all following dollar figures are based on actual, not constant, dollars, with the exception of several figures expressed for illustrative purposes in current dollars and explicitly described as such.

$9.7 billion to the commercial aircraft industry, taken as a whole. Expressed in current dollars, taking account of opportunity costs and compound interest accumulation, the commercial benefits of DoD R&D were between $12.42 billion and $20.18 billion.[2]

Although the Department of Defense attempts to recoup some of the commercial benefits private companies derive from participating in military R&D, between 1976 and 1990 the Department of Defense recouped only about $170 million from private companies engaged in aeronautics R&D, a tiny percentage of the total benefits these companies actually received.

In addition to the direct Defense Department R&D grants to private companies, the U.S. government also reimburses private companies for R&D projects they undertake on their own that may have military relevance. The commercial utility of such independent research and development efforts (IR&D) is even higher than in government-initiated R&D, because the companies choose the research areas themselves, and they are very conscious of the value they receive from dual use technologies. Since 1976, U.S. companies have received approximately $5 billion of reimbursements from the government for aeronautics IR&D, constituting a probable benefit to the commercial aircraft industry of between $1 billion and $1.25 billion.

2. NASA R&D

NASA R&D provides a second major form of U.S. government support for the U.S. commercial aircraft industry. One of NASA's principal goals is to promote U.S. technological superiority in aeronautics. To that end, NASA sponsors large amounts of civil aeronautics R&D, as well as some military aeronautics R&D. In the past fifteen years, NASA devoted $8.9 billion to civil and military aeronautics R&D. This R&D has consisted of large-scale projects, such as the Aircraft Energy Efficient Program and work developing the supercritical wing, as well as numerous smaller-scale projects aimed at encouraging specific technological developments in aeronautics.

Given that one of NASA's primary objectives is to support technological developments in U.S. commercial aeronautics and that NASA's military and civilian R&D goals are closely interrelated, it can be reasonably estimated that 90 percent of NASA's R&D expenditures constitute a benefit to the U.S. commercial aircraft industry. Thus, the $8.9 billion of NASA R&D in the past fifteen years translates into a benefit of $8 billion to the U.S. commercial aircraft industry. Expressed in current dollars, the commercial benefit of NASA R&D in the past fifteen years is $16.96 billion.

3. U.S. Tax System

The U.S. tax system also benefits the U.S. commercial aircraft industry. The "completed contract method" for determining when contract

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[2] See note 10, infra, for an explanation of the methodology of this actualization calculation.

income is subject to tax has allowed U.S. aircraft manufacturers to reduce taxes by deferring substantial amounts of income. Use of domestic international sales corporations (DISCs) and foreign sales corporations (FSCs) also has permitted substantial deferrals. From 1976 to 1990, these various deferrals and exemptions provided benefits of approximately $1.7 billion to Boeing and $1.4 billion to McDonnell Douglas.

Taken together, the three major quantifiable areas of support to the U.S. commercial aircraft industry provided an estimated $18 billion to $22.05 billion of benefits from 1976 to 1990, or $33.48 billion to $41.49 billion if current dollar figures are used to quantify the benefits of Department of Defense and NASA R&D. The total benefits to the industry from U.S. government support likely exceeded these amounts, however, because the U.S. government provides several other important forms of support that are exceedingly difficult to quantify. U.S. aircraft manufacturers' use of government test facilities at reduced rates and the special purchase in 1982 of McDonnell Douglas KC-10s by the U.S. government are just two examples of such other forms of support.

In sum, although a lack of transparency in the multifaceted interactions between the U.S. government and the U.S. commercial aircraft industry makes any exact quantification of overall industry benefits impossible, it is clear that U.S. government support of the U.S. commercial aircraft industry has been a pervasive element of U.S. government policy over the last two decades. Objective observers agree that U.S. government support has played a critical role in assuring the key technological advances made by the U.S. industry and thus, in assuring the competitive position the U.S. commercial aircraft industry enjoys today in markets throughout the world.

I. RESEARCH AND DEVELOPMENT: DEPARTMENT OF DEFENSE

A. Direct Department of Defense (DoD) Funding of Research and Development

The desire to maintain preeminence in military aeronautics is at the core of the U.S. government's overall commitment to U.S. aeronautics. A consistently high level of investment in aeronautics research and development (R&D) has been a key element of the U.S. military's aeronautics strategy since World War II. In the past fifteen years, military spending on aeronautics R&D has grown steadily from $1.9 billion in 1976 to approximately $5 billion in 1990, for a fifteen-year (1976-1990) total of approximately $50 billion (see Exhibit 1).

This $50 billion of government funds has benefited companies involved in every area of aeronautics technology. Given that most, if not all, of the companies involved in the manufacture of large commercial aircraft and their major subcomponents are also involved in military aeronautics, significant quantities of this military R&D funding has flowed to companies in the U.S. commercial aircraft industry. According to information drawn from official compilations of U.S. government R&D contracts, for example, Boeing received at least $5.8 billion of DoD R&D contracts between 1979 and 1990 and McDonnell Douglas received at least $6.6 billion.[3] Of these amounts, $1.79 billion of the DoD funds Boeing received were for aircraft-related R&D and $4.55 billion of the DoD funds McDonnell Douglas received were for aircraft-related R&D.[4]

Participation in the vast pool of military aeronautics R&D brings significant benefits to the U.S. commercial aircraft industry. The most important benefits are the technology transfers that occur from the military to the commercial domain. Such technology transfers are of three principal types:

° Plane-to-plane transfers: A number of new commercial aircraft have been substantially derived from particular military aircraft, with the U.S. government investment in the military aircraft underwriting a substantial part of the cost of developing the new commercial aircraft. For example, the

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[3] This information was obtained from the Federal Procurement Data Center. 1979 is the first year for which the Federal Procurement Data Center has such information available.

[4] The information on DoD R&D contracts to Boeing and McDonnell Douglas that was obtained from the Federal Procurement Data Center was organized by product service codes. The figures for aircraft-related R&D cited in the text were arrived at by adding up all the contracts whose product service codes included the term "R&D Aircraft." Examples of product service codes that were assumed not to be substantially aircraft-related are "R&D Missile and Space Systems" and "R&D Space Science."

Boeing 707, the Boeing 747, the McDonnell Douglas DC-10 and the High Speed Civil Transport currently under development borrowed or will likely borrow significantly from predecessor military planes -- the KC-135, the C-5A (for both the 747 and the DC-10) and the National Aerospace Plane respectively. These plane-to-plane transfers are discussed in greater detail below.

° Major component transfers: The transfer of military aeronautics technology to the commercial domain also occurs with respect to major aircraft components. Major components developed for military use are sometimes incorporated directly into commercial aircraft. An obvious example of this kind of transfer is jet engines, which are the single most costly component of large commercial aircraft. Most of the engines used today by U.S. large commercial aircraft were originally designed for military aircraft and developed under military contracts.

° Minor component transfers: Smaller-scale transfers of military technology to the commercial domain occur in the hundreds and even thousands of aeronautics R&D projects that private companies carry out for the military. These occur with respect to all areas of aircraft technology, including aerodynamics, navigation systems, materials, and avionics. These technology transfers are more difficult to identify and quantify because of their smaller size, but they are very significant nonetheless.

The various transfers of military aeronautics technology to the civilian domain are not mere happenstance. It is the specific policy of the Department of Defense to encourage and facilitate such transfers. This policy, known as the "dual-use policy," aims simultaneously at broadening the utility of military R&D expenditures and helping to ensure U.S. technological superiority in commercial as well as military aeronautics.

> "DoD is a firm and enthusiastic supporter of domestic technology transfers. . . . We have a science and technology program which is aimed at providing options for future military systems. There are important spin-off economic benefits to civilian technology from these dual-use technologies."[5]
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> "We are finding that technology transfer of the dual use technology is going so wonderfully into

[5] Dr. George P. Millburn, Deputy Director of Research and Engineering, Office of the Secretary of Defense, International Technology Transfer: Who Is Minding The Store?, Hearing before the Subcomm. on International Scientific Cooperation of the House Comm. on Science, Space, and Technology, 101st Cong., 1st Sess., July 19, 1989, at 69.

> the commercial sector that frankly, I don't have any idea for improving it."[6]

Given the vast quantity and complexity of DoD aeronautics R&D, it is impossible to calculate with precision the amount of such R&D that has commercial applicability. Nonetheless, given the substantive analysis concerning the significant commonalities between large commercial aircraft and military aircraft (as detailed in the four case studies below) some estimates can be made. It can be conservatively estimated that between 25 percent and 50 percent of the aircraft-related DoD R&D work carried out by the two primary U.S. manufacturers of commercial aircraft, Boeing and McDonnell Douglas, has commercial applicability.[7] With respect to R&D grants to Boeing and McDonnell Douglas that do not fall in the "R&D Aircraft" category,[8] and DoD aeronautics R&D grants to companies other than Boeing and McDonnell Douglas, a lower rate of commercial applicability exists, probably in the range of 10 percent to 15 percent.[9]

This means that the $1.79 billion of aircraft-related DoD R&D grants that Boeing received from 1979 to 1990 probably had a value to Boeing's commercial operations of between $449 million and $898 million and that the

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[6] Dr. Craig I. Fields, Director, Defense Advanced Research Projects Agency, Hearings on National Defense Authorization Act for Fiscal Year 1991 before the House Comm. on Armed Services, 101st Cong., 2d Sess., March 1, 7, 8, 15 and April 4, 1990, at 52-53.

[7] The 25 percent to 50 percent range for aircraft-related DoD R&D work is based on the analyses of the Boeing 707, Boeing 747, McDonnell Douglas DC-10, and the High Speed Civil Transport (see Section I.F below) which show substantial commonalities between these airplanes, or planned airplanes, and military aircraft. These case studies are not intended as an exhaustive analysis of military-civilian commonalities but rather as illustrations of the enduring existence of such commonalities across several generations of U.S. aircraft.

[8] As discussed in note 4, the contracts to Boeing and McDonnell Douglas that were not within the "R&D Aircraft" product codes covered a range of aeronautics-related domains, some of which probably have some relation to commercial aircraft technology -- such as "R&D Electronics and Communications" and "R&D Physical Science."

[9] This estimate of 10 percent to 15 percent was arrived at through consultations with technical experts in the aeronautics field as well as analysis of the commonalities between specific military and commercial aircraft, as discussed in Section I.F. Also, we have been advised of a 1976 study of aeronautics R&D which concludes that 15 percent of military aeronautics R&D is commercially applicable: Osborne, Jr. & P. Bartley, "Survey of Civil Application of Military Aviation Technology" (Department of Defense and Aerospace Industries Association of America, 1976). We have not, however, been able to obtain a copy of the study.

$4.55 billion of aircraft-related DoD R&D grants that went to McDonnell Douglas in the same period probably had a value to McDonnell Douglas of between $1.14 billion and $2.28 billion. For illustrative purposes, these benefit figures can also be expressed in current dollars, through a basic opportunity cost/compound interest calculation.[10] Under such a calculation, the benefit to Boeing was between $879 million and $1.76 billion and the benefit to McDonnell Douglas was between $2.23 billion and $4.45 billion.

For the other $43.6 billion of DoD aeronautics R&D (the R&D grants to Boeing and McDonnell Douglas that did not fall in the category of "R&D Aircraft" and the R&D grants that went to other companies), the commercial value was probably between $4.36 billion and $6.54 billion.[11] Expressed in current dollars, this range of benefits would be $9.31 billion to $13.97 billion. Thus, the total commercial value to the U.S. industry of the $50 billion of military aeronautics R&D was probably between $5.9 billion and $9.7 billion (or if expressed in current dollars, between $12.42 billion and $20.18 billion).

Technology transfers are not the only means by which the U.S. commercial aircraft industry benefits from military R&D. The extensive participation of private companies in highly sophisticated military R&D projects helps train technical personnel in those companies. Military R&D work also pays for basic equipment, such as highly specialized tools, that may later be used for civilian aeronautics work. Infrastructural items such as laboratories and test facilities also may be used in both military and civilian work. And even if a military R&D project does not lead to a specific technological advance, it may have commercial utility to the company

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10 For the purposes of this opportunity cost/compound interest calculation we assume that the benefits were distributed over the relevant years in proportions roughly similar to the overall distribution of DoD aeronautics R&D. For interest rates, we have used U.S. 30-year Treasury Bond rates and have compounded the interest annually up to 1991. This calculation should be considered a rough estimate made for illustrative purposes only.

11 In sum, of the $50 billion of DoD R&D, $6.34 billion went to Boeing and McDonnell Douglas for "R&D Aircraft" work, $6.04 billion went to Boeing and McDonnell Douglas for R&D work outside the "R&D Aircraft" category, and $37.6 billion went to other companies in the aeronautics industry. These figures may not be exactly correct for two reasons. First, the Federal Procurement Data Center information about contracts to Boeing and McDonnell Douglas starts at 1979 whereas the overall $50 billion figure for all DoD aeronautics R&D starts at 1976. Thus, DoD contracts to Boeing and McDonnell Douglas from 1976 to 1978 are not segregated out of the $37.6 billion figure. Second, it is not certain that all of the $12.4 billion of DoD R&D contracts to Boeing and McDonnell Douglas reported by the Federal Procurement Data Center are included in the figures we drew from Aerospace Facts and Figures 90-91 for total DoD aeronautics R&D. In any event, these two possible imprecisions point toward possible underestimating rather than overestimating and thus the figures in the text are, if anything, on the low side.

that carried it out by informing the company of research "dead-ends" that should be avoided. Finally, in some instances, the military division of an aircraft manufacturer may produce parts for civilian aircraft produced by that same manufacturer.[12] These various benefits are difficult to identify in particular cases and unlikely to be quantifiable, but they are nonetheless a significant by-product of the extensive military R&D work performed by the aeronautics industry.

B. Independent Research and Development/Bid and Proposal Costs

In addition to direct grants for military research and development, DoD provides additional support for R&D work by private companies through two other mechanisms. First, DoD will reimburse costs incurred by companies undertaking independent research and development (IR&D). IR&D differs from standard R&D in that IR&D projects are undertaken on the independent initiative of the companies, whereas standard R&D is undertaken in response to specific requests by DoD. Second, DoD systematically reimburses companies for certain costs incurred in the development of bids and proposals (B&P) for military contracts. These costs frequently include research and development costs associated with formulating a bid or proposal.

The process for determining and allocating the funding for IR&D and B&P includes four stages:

° The contractor develops its IR&D program for the upcoming year and participates in bids and proposals.

° DoD technical personnel evaluate IR&D projects to determine if they have military relevance. This requirement is met "when the contractor can demonstrate that the effort under a proposed contract or grant would have a potential relationship to a military function or operation."[13]

° DoD and the contractor negotiate advance agreements to determine the ceiling of IR&D and B&P costs that will be reimbursable by DoD in the upcoming year. In establishing these ceilings, DoD takes into account the degree to which the various proposed projects are relevant to a military use.[14]

° The costs actually recoverable from DoD are computed by dividing the contractor's projected sales to DoD by the contractor's total

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[12] There is some evidence that this occurs at Boeing.

[13] DoD FAR § 231.205.18; Armed Forces--Military Procurement Act of 1971, Pub. L. No. 91-441, §§ 203-204.

[14] DoD FAR § 242.1006; Armed Forces--Military Procurement Act of 1971, Pub. L. No. 91-441, § 203.

sales and multiplying that number by the lesser of the total IR&D/B&P costs incurred and the negotiated ceiling.[15]

Because IR&D and B&P costs are reimbursed through confidential provisions in individual defense contracts, establishing the precise quantity of benefits received by individual companies and industries is difficult, if not impossible. However, at least one commentator has argued that the methodology used to negotiate IR&D ceilings provides a 40 percent subsidy of company IR&D costs.[16] In addition, reasonable estimates of the benefits received by the aeronautics industry may be made through reference to aggregate data.

According to aggregate figures, between 1976 and 1985, the costs incurred by private companies involved in military R&D for IR&D and B&P grew from approximately $2 billion to $7 billion per year for a total of over $42 billion.[17] DoD reimbursed over $18 billion of those costs or approximately 43 percent of the costs incurred.[18] In 1989 and 1990 alone, private companies incurred over $14 billion in IR&D and B&P costs. DoD reimbursed approximately $7 billion, or half of the costs incurred.[19] Thus, we estimate that between 1976 and 1990, private companies have recovered approximately $35 billion in IR&D and B&P costs.[20]

In the 1980s, DoD aeronautics R&D constituted, on average, approximately 15 percent of total DoD R&D.[21] Thus, we believe it is

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15 Lichtenberg, US Government Subsidies to Private Military R&D Investment: The Defense Department's Independent R&D Policy, National Bureau of Economic Research, Reprint No. 1415, at 150-51 (1990); Alexander, Hill & Bodilly, The Defense Department's Support of Industry's Independent Research and Development (IR&D): Analysis and Evaluation at 13-14 (RAND 1989).

16 Lichtenberg, supra note 15, at 157.

17 RAND Study, supra note 15, at Appendix A.

18 Id.

19 Defense Contract Audit Agency, Independent Research and Development and Bid and Proposal Costs Incurred by Major Defense Contractors in the Years 1989 and 1990.

20 The $35 billion figure is the sum of the following: 1976-1985 reimbursement of $18 billion; 1989-1990 reimbursement of $7 billion; and 1986-1988 reimbursement of $10 billion (this latter figure is an estimate based on the figures for the preceding and subsequent years).

21 This percentage was calculated by dividing the annual budget authority for DoD aeronautics R&D by the annual DoD outlay for all R&D for each year of the 1980s and averaging those percentage figures. All of these data were obtained from Aerospace Facts and Figures 90-91 at 110, 111 (1990).

reasonable to assume that the aeronautics industry, on average, has received approximately 15 percent of the DoD IR&D and B&P outlays.[22] Based on this assumption, aeronautics contractors have probably received over $5 billion as reimbursement for IR&D and B&P costs since 1976.[23]

As discussed above, given the structure of the IR&D/B&P process, DoD must ensure that its support in these areas is given to projects with military relevance. However, DoD does not have to fund projects that have exclusively military applications. In fact, since contractors develop their IR&D programs on their own initiative, they may consider a variety of factors, including potential commercial applications, in selecting IR&D projects. Thus, it is likely that projects funded through DoD's IR&D and B&P reimbursements have a somewhat higher level of commercial applicability than direct R&D grants.

There is at least some direct evidence of this phenomenon. For example, IR&D carried out by the Boeing Commercial Airplane Company was instrumental in developing windshear detection systems and riblets -- drag reducing grooves molded into thin plastic film and applied to external surfaces of an airplane to reduce fuel expenditure.[24] Similarly, IR&D enabled Boeing to achieve a number of significant technological advances which contributed to the development of the 747, including: innovations relating to power spectral density; gust design procedures; runway roughness measures for dynamic taxi loads; fatigue and fracture and materials applications.[25]

Overall, we estimate that between 20 percent and 25 percent of IR&D and B&P work in the military aeronautics field has commercial

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22 This 15 percent estimate is consistent with the fact that 20 to 25 percent of all IR&D goes to the aerospace sector, which includes aeronautics and space applications. <u>See</u> Report of the National Critical Technologies Panel at 97 (1991).

23 This number is calculated by multiplying $35 billion, the estimate of total DoD reimbursed costs for IR&D and B&P between 1976 and 1990, by 15 percent, the estimate of the historic fraction of R&D outlays received by aeronautics contractors.

24 "National Benefits of IR&D," Aerospace Industries Association of America, Dec. 18, 1987, at 9.

25 <u>Research and Development Contributions to Aviation Progress</u> (RADCAP) 546 (1972). The RADCAP report is a joint Department of Defense, NASA and Department of Transportation study of U.S. aeronautical progress since 1925, reviewing the contributions of military aeronautical research and development programs to civil aviation.

applicability.[26] Therefore, the approximately $5 billion of IR&D and B&P cost reimbursements that aeronautics contractors have received in the past fifteen years entailed a benefit of between $1 billion and $1.25 billion to the commercial aircraft industry.

In sum, it is clear that U.S. government support for aeronautics research and development, through both R&D contracts as well as IR&D and B&P reimbursements, is extremely significant to the U.S. commercial aircraft industry. A 1982 study of aeronautical research and technology policy by the U.S. Office of Science and Technology Policy (a part of the Executive Office of the President of the United States) found that:

> "U.S. government investments have supported most aeronautical R&T on which the industry has depended. For example, major aeronautical firms, such as Boeing, spend less than 1.0 to 1.5 percent of their privately funded R&D budget on aeronautical R&T development activities, which is defined as research ending 2 to 3 years before start of system development."[27]

C. MANTECH

In addition to providing support to contractors to develop various technologies through R&D, IR&D and B&P, DoD's Manufacturing Technology Program (MANTECH) provides support to contractors to encourage the use of new technologies in manufacturing processes. The broad goals of MANTECH include improving the productivity and responsiveness of the U.S. industrial base by bridging the gap between R&D results and full-scale production and assuring that more effective industrial innovation is stimulated by reducing the cost and risk of applying new and improved manufacturing technology.[28]

Between 1976 and 1990, funding for MANTECH totalled close to $2 billion.[29] These funds were dedicated to all the branches of the military

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26 This estimate was arrived at through consultations with technical experts in the aeronautics field and analysis of the role that IR&D has played in the development of specific aircraft, such as detailed in the case studies in Section I.F. below.

27 Office of Science and Technology Policy, Executive Office of the President, Aeronautical Research and Technology Policy, Vol. 1: Summary Report, Nov. 1982, at 26.

28 Department of Defense Instruction No. 4200.15 (May 24, 1985); Statement of Principles for Department of Defense Manufacturing Technology Program (March 14, 1980).

29 See Lehn, An Overview of the Department of Defense Manufacturing

[Footnote continued on next page]

and to a full array of defense-related manufacturing technologies. It is not clear from the available data what proportion of the funds were dedicated to aeronautics manufacturing technologies. However, based on the fact that in the 1980s DoD aeronautics R&D constituted on average approximately 15 percent of total DoD R&D, it is reasonable to assume that the aeronautics industry has received approximately 15 percent of the DoD MANTECH funding.[30] Based on this assumption, approximately $300 million in MANTECH funding has been dedicated to facilitating the implementation of new aeronautics manufacturing technologies since 1976.

The MANTECH program guidelines specify that support should be provided only when there is a well-defined DoD requirement for the technology.[31] However, the manufacturing advances facilitated by the MANTECH program have also led to commercial benefits.[32] For example, a survey of 75 completed Air Force MANTECH projects costing $33 million found that the MANTECH project results were expected to reduce production costs by a total of $933 million -- a $534 million savings on the production of military items and a $399 million savings on commercial production.[33]

Thus, it is clear that the aeronautics industry has received significant commercial benefits from the MANTECH program. However, because detailed data on specific MANTECH projects and expenditures are not publicly available, and because of the difficulty in allocating benefits between the military and commercial spheres, it is not possible to establish the precise magnitude of the commercial benefits bestowed by MANTECH.

D. Patents and Exclusive Licensing

The U.S. government also provides support for the commercial aircraft industry through another mechanism: the grant of proprietary rights to technological advances developed under government-sponsored R&D contracts.

[Footnote continued from previous page]
Technology Program at 3 (Office of the Assistant Secretary of Defense Production and Logistics, August 29, 1990); GAO, Report to the House Committee on Banking, Finance and Urban Affairs, Subcommittee on Economic Stabilization, Department of Defense Manufacturing Technology Program--Management Is Improving But Benefits Hard to Measure at 2 (November 30, 1984).

30 The intent of the MANTECH program is to facilitate the introduction of R&D advances into manufacturing processes. Thus, we believe there may be a rough equivalence of the proportion of aeronautics-related expenditures in DoD R&D and MANTECH.

31 Department of Defense Instruction No. 4200.15 (May 24, 1985).

32 GAO Report, supra note 29, at 8-9; Lehn, supra note 29, at 3.

33 GAO Report, supra note 29, at 8.

These technological advances can be divided into two general types -- patentable inventions and technical data.

1. Patents

By statute and executive order, a unified U.S. government policy exists to promote the commercialization of federally funded research.[34] Under that policy, all contractors may retain title to any inventions made in whole or in part with federal funds and to any patents covering such inventions.[35] In exchange, the U.S. government retains a royalty-free right to use the patented invention for government purposes.

In certain instances, title will pass from the contractor to the federal government. This will occur, for example:

(1) If the contractor elects not to retain title to a subject invention;

(2) If the contractor fails within certain specified times to disclose the invention to the government or to elect to retain title to the invention;

(3) In those countries in which the contractor fails to file patent applications within a specified time;[36] and

(4) In any country in which the contractor decides not to continue pursuing a patent on a subject invention.

Generally, the contractor would retain a nonexclusive royalty-free license throughout the world in each subject invention to which the government obtains title.[37]

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34 See 35 U.S.C. §§ 200 et seq. (1984); Presidential Memorandum on Government Patent Policy to the Heads of Executive Departments and Agencies, February 18, 1983; Exec. Order No. 12,591, 52 Fed. Reg. 13,414 (1987).

35 The question of allocation of rights between the government and the contractor is premised upon the existence of a "subject invention," which is defined in the Federal Acquisition Regulation (FAR) clause 52.227-12 as "any invention of the Contractor conceived or first actually reduced to practice in the performance of work under [the government] . . . contract."

36 There are certain exceptions to this rule.

37 If the contractor fails to disclose the subject invention to the government within certain specified times, however, the contractor generally relinquishes its right to the nonexclusive, royalty-free license. FAR clause 52.227-12(e).

The U.S. regulations also contain a concept called "march-in rights." For any invention to which a contractor has acquired title, the government may require the contractor, for reasons and under procedures prescribed by statute, to grant a license to a responsible applicant on reasonable terms in any field of use that the contractor has inadequately developed.

2. Technical Data

Where the government provides total funding for a project, it generally acquires unlimited rights in the technical data pertaining to the items or processes developed under the project. The government also has unlimited rights to release or disclose the data to persons outside the government, which would permit the use of the technical data by those persons for commercial purposes.

However, to encourage the commercial exploitation of technologies developed under a government contract, the government may agree to use the technical data subject to government purpose license rights (GPLR). GPLR give the government a royalty-free right to use, duplicate, and disclose data for government purposes only and to permit others to do so for government purposes only for a stated period of time. During the period when GPLR are in effect, the contractor has an exclusive right to use the technical data for commercial purposes. After the time period has elapsed, the GPLR will expire, and the government will be entitled to unlimited rights in the data.[38]

When an item or process is developed partly with government funds and partly at private expense, the respective rights of the contractor and the government "shall be agreed upon as early in the acquisition process as practicable (preferably during contract negotiations)." 10 U.S.C. § 2320(a)(2)(E).

E. Recoupment

Some parties may argue that aeronautics companies pay back to the DoD as recoupment payments a significant proportion of whatever commercial benefits they receive from participation in military R&D projects. If this assertion were true, it would greatly reduce the importance of the support received by the industry from the DoD described in the preceding sections. This section analyzes the issue of recoupment, reviewing first the basic legal provisions concerning recoupment payments to the DoD, and then examining the actual practice.

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[38] GPLR is used by DoD, not by civilian agencies.

1. Recoupment Law

a. Scope

It is the stated policy of DoD to recover the cost of developing products and technology by assessing a recoupment charge whenever a contractor sells a defense-related item or its equivalent either commercially or through a foreign military sale. These charges are intended to recoup the nonrecurring costs in DoD R&D contracts.[39] We focus on recoupment arising in the context of commercial sales, since recoupment relating to the sale of military items to foreign governments is outside the scope of this memorandum.

DoD's recoupment program is described and implemented through the Defense Department Supplement to the Federal Acquisition Regulation (DFARS), DoD Directive 2140.2 issued in 1985, and, effective May 1989, through a revised recoupment clause and related regulations. The new clause, DFARS § 252.27-1-7001, "Recovery of Nonrecurring Costs on Commercial Sales of Defense Products and Technology and of Royalty Fees for Use of DoD Technical Data," is a mandatory clause for all RDT&E contracts and subcontracts of $1 million or more. See DFARS § 271.004.

DoD's recoupment provisions apply differently to various products and technology categories. Products are divided into Major Defense Equipment (MDE) and non-MDE. MDE is any item identified as "significant combat equipment" on the United States Munitions List having nonrecurring RDT&E costs of more than $50 million or a total production cost exceeding $200 million. This category also includes commercial derivatives of MDE. Non-MDE is any item of equipment not qualifying as MDE, including major and non-major components of MDE, non-MDE end-items and components, and modification kits for such end-items.

Technology is broken down into the following three categories: (1) technical data packages to be used for the manufacture or production of any MDE or non-MDE; (2) computer software; and (3) other technology transfers, including transfers of industrial or manufacturing processes.

b. Amount To Be Reimbursed

Recoupment charges for MDE are assessed on a pro rata basis (total nonrecurring costs divided by total estimated number of units to be produced over the life of the project). In cases where a commercial item being sold has less than 90 percent commonality with the MDE item, the government usually will adjust the charge based on the degree of commonality.

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39 Nonrecurring costs are "[t]he costs funded by a Research, Development, Test and Evaluation (RDT&E) appropriation to develop or improve the product or technology under consideration either through contract DoD or in-house effort." Defense Department Supplement to the Federal Acquisition Regulation (DFARS) § 252.271-7001.

Recoupment charges also are assessed on major components of MDE items on a pro rata basis.[40]

With respect to non-MDE end-items and components, the government does not assess recoupment charges until $2 million of government RDT&E funding has been or is expected to be incurred for any particular item or component. Once this threshold is reached, the government assesses a surcharge of 5 percent of the price of the item.

For technology, recoupment charges are assessed differently for each of the three technology categories. Transfers of Technical Data Packages used in manufacturing are treated as follows:

- For Technical Data Packages (TDP) transferred to foreign entities to be used to manufacture non-MDE items for non-U.S. government use, a royalty fee of 5 percent is applied for each item manufactured for use within that country, and an 8 percent royalty fee is applied on items manufactured for third party use by or on behalf of foreign governments or international organizations.
- TDPs transferred to U.S. contractors for the manufacture of non-MDE items are subject to a royalty fee of 5 percent on those items manufactured for export, and a royalty fee of 3 percent on items manufactured for U.S. consumption.[41]
- TDPs transferred for use in manufacturing an MDE item for non-U.S. government use are not subject to a royalty fee, but the approved MDE recoupment charge will be assessed for each item manufactured using the TDP.

With respect to computer software, a pro rata recoupment charge is assessed for sales of software whenever the U.S. government funds, or is expected to fund, $2 million or more to develop the software.

For all other technology transfers, including transfers of TDPs for purposes other than manufacturing, and all transfers of industrial or manufacturing processes, the recoupment charges assessed are to equal the fair market value of the technology.[42]

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40 No charge is made on sales of non-major MDE components, however, because the recoupment charges are recovered on the related MDE item sales.

41 These fees appear to be somewhat higher than those that NASA may impose in similar circumstances. See Section II.D infra.

42 For transfers to any U.S. domestic organization, this charge shall be the lower of either: (a) a proportionate share of the DoD investment cost identified to the development of the technical data and technology involved; or (b) a fair market price for the technical data and technology involved,

[Footnote continued on next page]

Finally, waivers or reductions in the recoupment charges described above may be approved for a particular commercial sale. See DFARS § 271.005. Approval is based upon

> (i) the same criteria used to grant waivers under FMS, that is to say, whether a particular sale would significantly advance U.S. government interests in the standardization of NATO or certain other military forces, or
>
> (ii) if the domestic sale is in the best interest of the United States to satisfy a demonstrable right of the manufacturer or the purchaser, or
>
> (iii) to obtain advantage to the U.S. Government.

In sum, although the regulations on DoD recoupment have a fairly comprehensive reach, there are nonetheless clear gaps in this coverage, and DoD has considerable discretion in deciding when to assess recoupment charges. There is no mandatory recoupment clause for contracts of less than $1 million.[43] Recoupment charges are not assessed on non-Major Defense Equipment end-items and components where less than $2 million of DoD funding has been or is expected to be incurred for any particular item or component. Finally, recoupment can be waived altogether.

2. Actual Practice Regarding Recoupment

As noted above, the regulations outline a recoupment program of considerable breadth. Under the regulations, DoD is entitled to recover R&D costs through levies on commercial sales of major defense products, components, and items derived from major defense products. However, as noted above, there are a number of formal exceptions to the recoupment policy that reduce its coverage. In addition, on a practical level, the complexities

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[Footnote continued from previous page]
based on an engineering analysis of demand or the potential monetary return on investment.

43 Of the $5.8 billion of DoD R&D grants to Boeing in the 1979-1980 period, approximately $580 million were through contracts of less than $1 million. Of the $6.6 billion of DoD R&D grants to McDonnell Douglas in the same period, approximately $1.2 billion were through contracts of less than $1 million. Thus, $1.78 billion of the DoD R&D grants to Boeing and McDonnell Douglas from 1979 to 1990 were through contracts that may not have had recoupment clauses at all.

associated with assessing recoupment charges in various contexts undoubtedly limit the effective reach of the program even further.

For example, when a contractor sells a product in the commercial market that is derived from its defense work, it is very difficult to assess the amount of government support attributable to that product. First, determining the degree to which a product is a derivative of another product is necessarily complex and to some extent subjective. Further, the full range of benefits to a contractor's commercial operations could be invisible to an auditor. For example, commercial operations could benefit from the identification of technological dead-ends, and the testing and training in the use of certain tools, technical processes and facilities.

Given the relative complexity of calculating the recoupment due on commercial sales of military-related products, we would expect that the majority of the recoupment received by DoD is related to foreign military sales. This conclusion is bolstered by the fact that the majority of the literature on DoD recoupment focuses on foreign military sales and by the fact that the specific instances of recoupment are primarily in the foreign military sales sphere rather than in the commercial domain. Furthermore, it is our understanding that approximately 75 percent of all DoD recoupment results from foreign military sales.[44]

There is scanty publicly available data quantifying the actual recoupment payments made by private companies to DoD. Recoupment charges are apparently recorded in a DoD budget line item that includes a number of other categories of DoD receipts. Thus, it is not even possible to establish the total amount of recoupment charges collected by DoD.

It is possible, however, to make an estimate. We have learned that between approximately 1983 and 1988, total recoupment to DoD averaged approximately $300 million per year, that recoupment has not increased substantially since 1988 and that recoupment levels were, if anything, lower in the years prior to 1983.[45]

Given that aeronautics R&D has averaged approximately 15 percent of total DoD R&D in the 1980s,[46] it is probably reasonable to assume that approximately 15 percent of all recoupment to DoD is aeronautics-related. If

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44 Information from DoD.

45 Id. Figures in this range were recently stated publicly by a major U.S. defense contractor: Don Cassidy, Vice President for Contracts at Hughes Aircraft, said that DoD recoups between $150 million and $300 million per year. "Industry Pressure Forces DoD to Review Recoupment Policy," Defense News, April 22, 1991.

46 See supra note 21.

so, this means that approximately $45 million per year of aeronautics-related recoupment is paid by the industry to DoD.

Thus, assuming that approximately 75 percent of recoupment payments are related to foreign military sales and 25 percent to commercial sales, the amount of aeronautics-related recoupment resulting from commercial activity is on the order of $11.25 million per year. In the 1976-1990 period, therefore, we can estimate that the U.S. commercial aircraft industry made a total of approximately $170 million in recoupment payments to DoD. Although this is only a very rough estimate, it is a clear indication that the amount of recoupment paid by the U.S. commercial aircraft industry is much less than the benefits that the industry has derived from the tens of billions of dollars of DoD R&D funds for aeronautics in the 1976-1990 period.

F. Plane-to-Plane Transfers

The above sections analyzed the general phenomenon of DoD-sponsored aeronautics R&D and the benefits it provides to the U.S. commercial aircraft industry. This section examines four specific cases of military R&D benefits to the commercial industry -- the four major instances where a major commercial airplane was developed or is likely to be developed from a military airplane: the Boeing 707 (from the KC-135), the Boeing 747 (from the C-5A), the McDonnell Douglas DC-10 (from the C-5A) and the High Speed Civil Transport (from the National Aerospace Plane). Each of these cases concerns the actual or prospective introduction of a large commercial air transport plane representing a significant technological advance over existing planes. In each case, substantial U.S. military R&D made or will make the new commercial planes possible. Taken together, these cases constitute strong evidence for the proposition that no new generation of large U.S. commercial aircraft has been or will be developed without substantial government support.

1. Boeing 707

The Boeing 707, developed and launched in the 1950s, was the first major commercial airliner produced by Boeing. The 707 was an extremely successful plane that dominated commercial aircraft markets in the 1960s, and was responsible for Boeing's ascendancy over Douglas Aircraft Corporation as the primary U.S. manufacturer of commercial aircraft.

a. Benefits from the KC-135

The Boeing 707 "is an excellent example of a 'quantum jump' made possible by military technology and, also, of the mutually beneficial exchange between commercial and military aircraft."[47] In designing, testing and producing the 707, Boeing benefited from its military aeronautics contracts, and in particular, from its role in the KC-135 Air Force tanker and the B-47 and B-52 programs. According to the RADCAP Report, "[i]n the

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[47] RADCAP, supra note 25, at 536.

development of the Boeing 707, the transfer of technology from the military version to the commercial version was more than 90%."[48]

The benefits to the 707 from the KC-135 program were the most significant. Production of the 707 followed the KC-135 by about a year, and the planes were so similar that the 707 was always regarded as the commercial equivalent of the KC-135, even though the 707 was slightly larger and heavier.[49]

The development of the 707 was made much easier as a result of the testing and operational experience Boeing had first obtained through the KC-135. Both in development and in production, the 707 benefited so much from the concurrent KC-135 program that one analyst has concluded, "without the huge KC-135A program there would almost certainly have been no commercial Model 707, as its unit cost would have been too high, especially without the benefits of using some KC-135 jigs and tooling."[50]

The development of the 707 was also aided by the KC-135 program at the testing stage. Since the first 707 was not produced until 100 KC-135s had already been produced, the 707 benefited from the extensive test programs and flight experience on the nearly identical KC-135.[51] The KC-135 provided valuable data for the 707 in areas such as transonic flutter prevention and fuselage pressure testing.[52] In addition, because the Dash 80 (a prototype jet transport developed by Boeing in the early 1950s) was used as a test vehicle for the KC-135 program, the Air Force agreed to assume all flight test costs and, in addition, to pay Boeing a 6 percent fee for these tests. Since the Dash 80 was also the prototype for the 707, much of the necessary testing for the 707 development was not just free but actually generated positive cash flow for Boeing.[53]

The side-by-side production of the 707 with the KC-135 also provided substantial benefits to the 707. The 707 was assembled in a government-owned plant at Renton, Washington.[54] A portion of the production process for the two planes at that plant was identical, since 22 percent of the parts were

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48 Id. at 528.

49 The Boeing Company: Products & Programs at 13-14 (undated).

50 M.J. Hardy, Boeing 66 (1982).

51 RADCAP, at 537.

52 Id. at 533.

53 Harbridge House Inc., United States Subsidization of the Commercial Aircraft Industry II-12, II-22 (1978) (hereinafter "Harbridge House 1978 Study").

54 Id. at II-22.

exact equivalents in both aircraft.[55] In addition, for nonrecurring engineering and production costs common to both the 707 and the KC-135 programs, the government agreed that 80 percent of such costs would be charged to the KC-135 and only 20 percent to the 707.[56]

b. Benefits From the B-47 and B-52

In addition to benefits from the KC-135 program, the 707 benefited from Boeing's participation in the B-47 and B-52 long-range bomber programs. For example, the high aspect ratio, 35° swept wing design of the B-47 gave Boeing extensive aerodynamic and design data needed to develop the 707. B-47 flight experience and data provided Boeing with crucial information on wings with pylon suspended engine nacelles, on the effects of structural flexibility on aileron effectiveness and handling qualities, and on aeroelasticity. Based on this information, Boeing developed new design methods for the 707. The operational experience of the B-47 also contributed to the 707 design in the areas of structural response, load distribution, transfer functions, and fatigue testing.[57]

Similarly, Boeing's wind tunnel tests on the B-52 wing yielded valuable data on engine nacelle placement and pylon design which supplemented earlier B-47 nacelle tests. The B-52 wind tunnel tests also led to a 707 wing design that was thicker near the root, improving structural efficiency and reducing weight. The 707's use of spoilers for roll control and of inboard ailerons also came from the B-52.[58]

One indication of the extent of the benefits to the 707 from the B-47 and B-52 programs is that the 707 prototype required only 1,357 hours of wind tunnel testing, while the B-47 required 7,600 hours and the B-52 required 7,800 hours of wind tunnel time.[59]

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55 Boeing Commercial Aircraft Co., International Competition in the Production and Marketing of Commercial Aircraft 3 (1982). It should be noted that Boeing agreed to reimburse the government $110,000 per unit for the first 100 707s produced on KC-135 tooling, and $60,000 for each of the next 100 707s thus produced. Harbridge House 1978 Study, at II-22. It is difficult to assess whether such compensation is at all commensurate with the benefits received by Boeing.

56 Harbridge House 1978 Study, at II-22.

57 RADCAP, at 532-33.

58 Id. at 533, 535.

59 Harbridge House 1978 Study, at II-11.

c. Benefits from Engine Programs

The 707 also benefited enormously from military engine programs of the 1950s. The Pratt & Whitney JT-3C engine, which was used for the 707, was a commercial derivative of the Pratt & Whitney J-57, developed, tested and proven through the B-52 and KC-135 programs.[60]

The U.S. military had spent approximately $400 million on the development of the J-57 engine by 1956, and had put the engine through more than 3 million engine flight hours and 68,000 hours of engine development testing.[61] By the time the JT-3 was introduced, therefore, the military engine program had generated experience which was readily applied to the commercial engine program. For example, the military engine program developed new manufacturing technologies to solve problems involving high temperature alloys and hydrogen embrittlement, which were subsequently used for the commercial engine. Throughout both the military and commercial programs, the JT-57 and the JT-3 maintained a high degree of commonality.[62]

d. Other Benefits

Finally, a number of the benefits to the 707 from military programs came through commercial versions of equipment developed by vendors for military purposes that were used by Boeing in the 707. These included the 707 autopilot, a Bendix design derived directly from prior military experience, as well as electronic systems such as the Distance Measuring Equipment, air traffic control equipment, altimeter and antenna systems, Omega and Loran navigation systems, and the Instrument Landing System.[63]

e. Quantifying the Benefits of Military Provisions to the 707

Definitive quantification of the benefits to the 707 from military programs is probably not possible. However, according to one commentator, "[t]he 707 . . . cost Boeing only $16 million, because the military B-47, B-52, and KC-135 bore the entire brunt of development -- about $2 billion."[64]

It should also be noted that benefits to the 707 from military programs were passed along to later Boeing aircraft. For example, significant features of the 707 fuselage, which was a widened version of the

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60 RADCAP, at 532, 535.

61 Id. at 535.

62 Id. at 533-34.

63 Id. at 534-36.

64 American Institute of Aeronautics and Astronautics, The Supersonic Transport: A Factual Basis for Decision at 61.

KC-135 fuselage, were incorporated in the fuselages of the Boeing 727, 737 and 757.

2. Boeing 747

The development of the Boeing 747 is a more complex and less direct case of U.S. government support for the U.S. commercial aircraft industry. Unlike Boeing's previous success -- the 707 -- the 747 was not simply the civilian version of a military jet. Rather, the development of the 747 benefited from a variety of indirect government supports, including funding for the research and development of an overall design for a wide-body jet pursuant to a request for bids to develop a large jet for the U.S. military; funding for certain Boeing independent research programs; funding for research and development of key technologies and components, such as engines, pursuant to military programs; and access to government facilities during the flight testing phase of the project.

a. Benefits from the C-5A

The principal government program contributing to the initial development stages of the 747 was the Department of Defense competition in the early 1960s for development of a large new military transport plane, the C-5A. In 1964, DoD contracted with Boeing, Lockheed and Douglas for each of the manufacturers to develop a proposal and bid for the C-5A during a nine-month "Program Definition Phase." Although ultimately Boeing was not granted the C-5A contract, it received at least $7.5 million to research and develop its C-5A proposal.[65]

The research and development of the 747's structural and aerodynamic configuration and design benefited from Boeing's government-funded work for the C-5A proposal. Boeing conducted extensive wind tunnel testing and analysis of structural and aerodynamic design during its proposal work for the C-5A. Quantifying the extent to which Boeing's work under the C-5A program contributed to the eventual structural and aerodynamic design technology of the 747 is difficult. However, the RADCAP study states that "the extensive analyses and wind tunnel testing on the C-5A proposal aircraft undoubtedly contributed significant preliminary design information for the 747."[66] Although the final configuration of the 747 was quite different from Boeing's C-5A proposal, the testing of Boeing's C-5A proposal generated valuable data regarding the structural and aerodynamic design of wide-body jet transports generally.

Moreover, Boeing's work on the C-5A proposal enabled Boeing to develop an organization and expertise to confront the challenges posed in the development of a viable design for a wide-body jet. Thus, for example, the

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65 Harbridge House 1978 Study, at B2. Lockheed received an equal amount to research and develop its proposal. Id.

66 RADCAP, at 544.

100 engineers who conceived the design for the 747 had all been members of the team assembled to generate the C-5A proposal.[67]

b. IR&D Programs

Through independent research and development programs, supported in some measure by the U.S. Government, Boeing achieved a number of significant technological advances which contributed to the development of the 747.[68] These included innovations relating to power spectral density, gust design procedures, runway roughness measures for dynamic taxi load, fatigue and fracture and materials applications.[69]

c. Engines

Boeing also enjoyed important indirect benefits from the C-5A and other military programs directed at developing new propulsion technologies, which in turn facilitated the development of the 747. Under those military programs, the U.S. Government supported the development of the high bypass turbofan engine technology which was a critical prerequisite to the feasibility of the 747.

In the early 1960s, the Department of Defense (partially in conjunction with the FAA and NASA) provided extensive funding to the manufacturers of aircraft engines through various programs for the development of high bypass ratio turbofan engines. Pratt & Whitney (through its parent company United Aircraft), for example, received approximately $11.6 million in 1964-65 to research and develop engines to propel the C-5A, and General Electric was awarded approximately $13.4 million for its engine work in the initial C-5A competition.[70]

In the period before 1970, when the first 747 went into commercial service, the government (DoD, NASA and FAA) accounted for over 67 percent of the total R&D expenditures for turbofan engines in the United States.[71] The 747 engine, the Pratt & Whitney JT-9D, was a redesigned and improved version

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67 J. Newhouse, The Sporty Game 113 (1982).

68 Although we are unable to quantify the independent research and development grants received by Boeing, historically DoD has reimbursed between 40 percent and 50 percent of IR&D costs. See Section I.B.

69 RADCAP, at 546.

70 Harbridge House 1978 Study, at B2.

71 Booz, Allen Applied Research, Inc., A Historical Study of the Benefits Derived from Application of Technical Advances to Civil Aviation at A9 (1971) (prepared for the Joint DOT-NASA Civil Aviation R&D Policy Study).

of the Pratt & Whitney engine developed -- though not selected -- for the C-5A competition.

Such substantial funding of engine development costs undoubtedly provided significant benefits to wide-body jets generally and the 747 in particular. Given the fact that an aircraft's propulsion system constitutes a large proportion of the overall component costs, and given the importance of engine technology to the feasibility of wide-body jets, large-scale government subsidization of engine development costs likely had a substantial impact on the overall development costs of the 747.

d. Other Components

In addition to the benefits described above, a number of other components in the 747 benefited from military programs:

° Flight Control and Avionics: Perhaps as much as 50 percent of the flight control equipment used in the 747 was derived from military sources; most of the technology transfer in this area came through other systems produced by Boeing for the military.[72] In addition, the 747's avionics systems came primarily from subcontractors who used militarily-derived methods and techniques for a broad range of navigation and communications instruments.[73]

° Landing Gear: Boeing developed the 16-wheel high-flotation main landing gear, used in the 747, during its research for the C-5A proposal.[74]

° Titanium Forgings: Boeing utilized a number of innovative materials in the 747 in order to reduce its weight, including fiberglass panels and titanium structures. Wyman-Gorman, a Boeing subcontractor, was able to produce the large titanium forgings for the 747 with the use of special military tooling.[75]

e. Flight Testing

During the extensive flight testing of the 747, which cost a total of $67.7 million, Boeing used government flight-test facilities in addition to its own airfields. Specifically, Boeing used military facilities at Edwards Air Force Base, Roswell Air Force Base and Moses Lake as well as Boeing's own facilities at Boeing Field and Paine Field.[76]

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72 RADCAP, at 546.

73 Id. at 547.

74 Harbridge House 1978 Study, at II-3.

75 RADCAP, at 548.

76 Id. At this point, it is unclear whether or how Boeing was charged for the use of the military facilities.

3. DC-10

In developing the DC-10, McDonnell Douglas benefited substantially from previous research, technical development and testing done pursuant to military programs and government-funded research. One prominent illustration of this phenomenon is the fact that the engine used on the DC-10 was, in large measure, derived from an engine developed pursuant to a military program. Military programs and government-funded research also supported the development of the DC-10 in a variety of other, if less prominent, ways.

a. Propulsion

The DC-10 benefited substantially from the close relationship between the CF6 engine used for the DC-10 and the TF-39 developed for military use. The government invested $212 million to develop the TF-39 engine.[77] Except for the fan system, the CF6 engine employed basically the same technology as the TF-39.[78] Moreover, the high bypass fan used in the CF6 engine was based on developments made in NASA and military programs, and the installation technology for the high bypass fan engines was developed pursuant to government-funded research.[79]

Furthermore, the development and testing of the CF6 was substantially facilitated by the related TF-39 program. For example, prior to the first DC-10 commercial flight in 1971, 27,000 of the 30,500 hours of engine development testing had been completed in the TF-39 configuration. In addition, the development of the CF6 was facilitated by the 128,000 engine flight hours accumulated by the C-5A aircraft.

b. Technical Advances Incorporated

The DC-10 was also the beneficiary of numerous technical developments which had their roots in military programs, including, *inter alia*: (1) advances in the design of the airfoil section of the wing derived, in part, through work done by McDonnell Douglas in developing its C-5A proposal; (2) advances in nacelle and pylon drag design derived, in part, through work done by McDonnell Douglas in developing its C-5A proposal; (3) the development of double-slotted wing flaps which was facilitated by McDonnell Douglas' military programs, particularly those relating to fighter aircraft; (4) advances in nacelle strakes which were first investigated pursuant to a military program; and (5) advances in the design of the flight control system which were based on principles of redundancy developed pursuant to military

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77 *Id*. at 553.

78 *Id*. at 551.

79 *Id*. at 551.

programs dating back to the late 1950's.[80] Moreover, potential deficiencies in the aerodynamic design were avoided due to McDonnell Douglas' past military and commercial aircraft programs.[81]

c. Hardware Transfers

Direct transfer of hardware from military aircraft to the DC-10 was not common. However, strong common evolutionary sources can be identified in many areas. Government-conceived or sponsored hardware concepts that were applied to the design of the structure of the DC-10 include: (1) titanium slat and flap tracks; (2) floor structure; (3) forming of large skin structures; (4) local overaging technique for T6 to T73; (5) cold drawn and aged titanium springs; (6) brazed stainless steel hydraulic tubing; (7) brazed chemically pure titanium tubing with Ti-6Al-4V fittings; (8) thin wall aluminum (356) castings; (9) isothermal no-draft Ti-6-6-2 forgings; (10) welded and brazed acoustical panels from Inconel 718 and 316L; and (11) investment castings from Inconel 718.[82] In the area of flight control, the autopilot for the DC-10 was a derivative of the autopilot developed for the C-133, the C-141 redundant yaw damper experience provided background for the DC-10, and previous work done on a military hydraulics actuation system was applied to the DC-10. According to one estimate, approximately 30 percent of the DC-10 flight control technology was derived from military sources.[83] A smaller, but significant percentage of the avionics equipment configuration and navigation systems in the DC-10 were directly derived from military programs. Further, the electronics systems techniques were, in large part, derived from military programs as were the antenna techniques.[84]

d. Government-Sponsored Research

The results of government-sponsored research and development in the areas of non-stationary aerodynamics; low level turbulence measurement, definition and analysis; fracture toughness; parametric fatigue analysis; structural analysis programming and manufacturing technology were directly transferred to the DC-10 design team.[85] Similarly, McDonnell Douglas' independent research and development, funded by the government through

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80 Id. at 549-51.

81 Id. at 550.

82 Id. at 552-53.

83 Id. at 553.

84 Id. at 554.

85 Id. at 551.

military programs, made major contributions to McDonnell Douglas' data bank and was an important part of the technology needed to design the DC-10.[86]

4. Supersonic and Hypersonic Transports

The fourth example of U.S. government investment in "quantum leap" aircraft technology that will result in the plane-to-plane transfer of technology from the military to the civilian side is the current work being done on supersonic and hypersonic transports. The two primary programs in this area are the National Aerospace Plane (NASP) and the High Speed Civil Transport (HSCT). The NASP is to be a space and military aircraft that would travel at an altitude of approximately 150,000 feet at speeds of Mach 5 to Mach 15. The HSCT is to be a long-range high speed civil transport that would fly at 60,000 feet at speeds of Mach 2 to Mach 5. The basic outline of these two programs is set out below, followed by a brief analysis of the commercial significance of the NASP and the potential interrelation of the two programs.

a. National Aerospace Plane

In January 1986, DoD (through DARPA, the Air Force and the Navy), NASA and the Strategic Defense Initiative Organization initiated a $700 million program to design the NASP, a vehicle that could take off horizontally from an aircraft runway, fly directly into low earth orbit at 25 times faster than the speed of sound and demonstrate single-stage-to-orbit (SSTO) operations.[87] In April 1986, DARPA awarded $7 million in contracts to a number of U.S. aircraft manufacturers, including Boeing and McDonnell Douglas, in a competition for the conceptual design of the NASP.[88]

The NASP is now in its Phase II contract stage which will last until January 1993, at which time a decision will be made on whether or not to build a pair of X-30 research vehicles to validate the computational fluid dynamics, materials, structures and propulsion development aspects of the program. On February 1, 1991, the Air Force--NASA joint program office awarded McDonnell Douglas, General Dynamics, Rockwell Corp.'s North American Aircraft, Pratt & Whitney, and Rockwell's Rocketdyne, joined in a single team, a $502 million contract to continue airframe and propulsion development on the NASP up to the planned 1993 deadline.[89]

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86 Id. at 552.

87 Statement by John J. Welsh, Jr., Assistant Secretary of the Air Force for Acquisition, Hearing before the Subcomm. on Research and Development of the Comm. on Armed Services and the Subcomm. on Technology and Competitiveness of the House Comm. on Science Space, and Technology, March 12, 1991, quoted in Defense News, March 18, 1991, at 3.

88 "Aircraft Design," Aerospace America, December 1988, at 70.

89 Defense News, March 18, 1991, at 3.

As shown in the chart below, total funding for NASP through fiscal year 1991 was $1.8 billion, with the total cost for the technology development phase of the NASP program estimated at $3.3 billion.[90]

NASP Funding (millions)[91]

	DoD	NASA	Total
FY 1988	$338	$148	$486
FY 1989	569	237	806
FY 1990	195	59	254
FY 1991	163	95	258
FY 1992[92]	[233]	[72]	[305]
Total	1498	611	2109

b. High Speed Civil Transport

The technological development of HSCT can be traced back to the Supersonic Cruise Transport (SST) program started in the early 1960s, the Supersonic Cruise Research (SCR) program which lasted from 1973 until 1981, and more recently, the NASP program.[93] In addition, various R&D programs initially undertaken for military purposes are now being transferred to HSCT applications. For example, test programs on military applications of vortex flap technology were expanded to include vortex flap research applicable to wing designs for the HSCT.[94]

Efforts aimed specifically at the development of HSCT began in 1986, when NASA let two 3-phase study contracts to Boeing Aircraft and McDonnell Douglas to examine the state of readiness of HSCT technology, alternative

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90 Space Flight, April 1991, at 135.

91 NASP Fiscal Year 1991 Budget Request, at 15; Joint Hearing of the Committee on Science, Space and Technology, and the Subcommittee on Research and Development of the Committee on the Armed Services House of Representatives, August 2, 1989 at 66; "NASP Industry Consortium is Hailed as Model for Future High-Tech Projects," Space News, March 18, 1991, at 4.

92 1992 figures are budget requests.

93 Study of High Speed Civil Transport, NASA, at 17 (1989).

94 Aviation Week & Space Technology, June 18, 1991, at 84.

design concepts, environmental issues, and economic and market issues.[95] Then, in 1989, NASA developed a proposed HSCT research and technology (R&T) program to assess the technology needed for the aircraft industry to reach a decision on whether to proceed with development and production of an HSCT.[96] Although the R&T program is aimed at developing technologies for an HSCT, NASA hopes that at the conclusion of the program, the technology will be validated to the point where the U.S. aerospace industry will move forward and develop a commercial HSCT. To help ensure this, the program is to be a joint industry-government activity.[97]

The HSCT R&T program estimates that HSCT development will require combined NASA and industry contributions amounting to $1.5 to $2.0 billion over ten to twelve years.[98] NASA's 1990 budget included $25 million to initiate efforts related to the development of an environmentally and economically sound high speed commercial transport.

In 1991, NASA efforts aimed at providing a foundation for development of a new HSCT were accelerated. NASA earlier had planned to initiate a six-year, $1-billion Phase 2 high-speed program in fiscal year 1993. Progress was so rapid in Phase 1, however, that a Phase 2 element involving propulsion system materials is being initiated a year early in fiscal year 1992 with a request for $16.5 million.[99]

c. Carryover Benefits from NASP to HSCT

Although the NASP and the HSCT ultimately are intended to be quite different planes, the technical requirements and capabilities of the high speed flight which each will specialize in are similar, and therefore much of the technology development on the NASP and HSCT has been parallel, complementary, and performed by the same contractors. NASP and HSCT technology areas under development include propulsion systems and fuels; aerodynamics; materials and structures; flight and engine control systems; and displays and navigational systems.[100]

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95 Study of High Speed Civil Transport, at 7.

96 Id. at 57.

97 Id.

98 Id. Although there was no specific HSCT program prior to 1989, NASA spent approximately $10 million to $15 million in FY '88 on related technologies. Study of High Speed Civil Transport, at 12.

99 Aviation Week & Space Technology, March 18, 1991, at 149.

100 Commercial High Speed Aircraft Opportunities and Issues 23 (1989); T.J. Gregory & H. Wright, National Aerospace Plane Status and Plans at 149-56 (May 1989); Jane's - All the World's Aircraft, 1989-1990, at 471.

Numerous reports and official statements demonstrate the potential interrelationship between the two vehicles and their development. For example, one report states:

> "Although not directed toward a supersonic civilian aircraft, the NASP program bears some relation to the current interest in HSCT. . . . While there is little relationship between the NASP and an HSCT in the Mach 2-4 range, some of the technologies developed for the NASP may be applicable. The potential applicability would be significantly greater for an HSCT in the Mach 5 range . . . particularly with materials and engine technologies. In addition, the NASP program has contributed to the renewed interest in an HSCT and has helped maintain active research into high speed flight. . . ."[101]

The link between the military and civilian application of high speed flight is further demonstrated by a statement in National Aeronautical R&D Goals, a 1985 report prepared by the Executive Office of the President, Office of Science and Technology Policy which states:

> Gaining sustained supersonic cruise capability is of very high priority for future military aircraft survivability. . . . However, this military capability is also aligned with highly constructive civil opportunities that could benefit the U.S. in important non-military areas as well.

In general, there is a strong belief that through the NASP program, a competitive base for future hypersonic programs is being established.[102] NASP could yield "technologies that would not only add to an overall defense technology base but help to maintain U.S. leadership in technologies critical to the aerospace industry, show important benefits to a wide spectrum of high tech industries and provide revolutionary methods of transportation: civilian, military and space-oriented."[103]

NASP work on composites is a primary example of an area of development expected to have numerous commercial spinoffs. The National Materials and Structures Augmentation Program (NMASAP) consortium, which includes all five NASP contractors, was established to develop these materials cooperatively and accelerate their development. Each NASP contractor has a contract with

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101 Commercial High Speed Aircraft Opportunities and Issues, at 3.

102 See Statement of J. Welsh, supra note 87.

103 Space Flight, April 1991, at 134.

the government to lead the development of a particular material, with such contracts to date totaling nearly $150 million. As stated in Congressional testimony on the National Critical Materials Council, "[t]he NMASAP achievements have laid the ground work for materials spin-offs which may be applicable to the medical, automotive, and commercial aircraft industries."[104]

II. RESEARCH AND DEVELOPMENT: NASA

A. NASA Overview

1. Introduction

As described in Aeronautics and Space Report of the President -- 1989-1990 Activities, "[t]he National Aeronautics and Space Administration (NASA), established in 1958, is responsible for planning, conducting, and managing civilian research and development activities in aeronautics and space." As such, one of NASA's principal missions is to help preserve U.S. leadership in aeronautics.

> "Since the early days of aviation, the technology developed by NASA and its predecessor -- the National Advisory Committee on Aeronautics -- has been a major factor in the preeminence of this Nation in atmospheric flight -- both in military aircraft and in civil transports. Today, the aircraft industry is the leading contributor to our balance of trade, providing a positive contribution and a favorable balance of $16.8 billion last year. Eighty-six out of every hundred civil transports in the world today were built in the United States. More than a million Americans earn their living in aeronautics. Clearly, our Nation is the world leader in aeronautics. We need to keep it that way."[105]

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[104] Testimony by Robert H. Gulcher, Rockwell International and Ned D. Newman, McDonnell Douglas, on the NASP Materials and Augmentation Program, Hearing on the National Critical Materials Council before the Subcomm. on Transportation, Aviation and Materials of the House Comm. on Science, Space and Technology, June 26, 1990, at 66-67.

[105] Dr. James C. Fletcher, Administrator, National Aeronautics and Space Administration, 1990 NASA Authorization, Hearings before the Subcomm. on Space Science and Applications of the House Comm. on Science, Space, and Technology, 101st Cong. 1st Sess., February 2, 28, March 1, 7, 9, 21, 23, April 4, 5, 6, 11, 18, 1989, Vol. II, at 17.

> "Since the establishment of NACA in 1915, through the formation of NASA in 1958, and into the 1990s, our aeronautics program has represented an important technological resource within the United States, broadly contributing to both civil and military aviation. These 75 years have forged a strong partnership with industry and academia which has been the foundation for major aviation advancements and which still serves today as the model for cooperation in other fields."[106]

* * *

> "The ongoing NASA aeronautics research and technology program is vigorous and productive. We conduct pioneering research in emerging technologies, selectively conduct the highest payoff systems technology programs, and produce technologies that industry can incorporate into future products. The results of our research are major factors in our country's aeronautical leadership. We have provided much of the technology base that has enabled the United States to be the world leader in aviation."[107]

In order to fulfill its mission and responsibilities, NASA is the primary government provider of civilian R&D funds for the aeronautics industry. NASA is best known for its large-scale R&D efforts such as the Aircraft Energy Efficient Program (ACEE), the noise reduction program, and the supersonic/hypersonic transport program. However, NASA has also sponsored and been involved in many smaller-scale, shorter-term R&D projects targeted at providing practical solutions to problems and issues in the aeronautics field such as aircraft icing sensors, windshear prediction and various air safety spinoffs. Many of the technological advances produced by NASA research have been incorporated by U.S. manufacturers of large commercial aircraft into their products, resulting in large cost-savings to those manufacturers. Furthermore, the U.S. companies that perform this R&D

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[106] Arnold D. Aldrich, Associate Administrator, National Aeronautics and Space Administration, Aeronautics, Exploration and Technology, <u>1991 NASA Authorization Hearing before the Subcomm. on Transportation, Aviation and Materials of the House Comm. on Science, Space, and Technology</u>, 101st Cong., 2d Sess., March 20, 1990, No. 112, Vol. I, at 7, 19.

[107] Dr. William F. Ballhaus, Jr., Director, Ames Research Center, National Aeronautics and Space Administration, <u>1990 NASA Authorization Hearing before the Subcomm. on Transportation, Aviation and Materials of the House Committee on Science, Space, and Technology</u>, 101st Cong., 1st Sess., April 26, 1989, No. 17, Vol. I, at 8-9.

work benefit greatly from the training it provides to company personnel and from the associated advances in in-house research, design and production capabilities.

In addition to civilian aeronautics R&D, NASA, usually in conjunction with the Department of Defense, also funds military R&D projects in the aeronautics field. The National Aerospace Plane program is a prime example of this type of research. NASA's military R&D contributes to U.S. technological superiority in military aircraft. It also provides significant crossover benefits to the U.S. commercial aircraft industry. Due to the fact that NASA is deeply involved in civilian aeronautics R&D, its military R&D activities are closely related to civilian aeronautics and have a high level of crossover benefits. The 1982 study of aeronautical research and technology by the White House Office of Science and Technology Policy concluded, for example, that "90 percent or more of the current NASA R&T development efforts have applicability to both civil and military aeronautical products."[108]

In general NASA civilian and military R&D have played a major role in the development of the U.S. commercial aircraft industry:

> "During the postwar period, the commercial aircraft industry has benefited from substantial direct (NASA and NACA) and indirect (military research and IR&D) federal financial support for research. The size of the federal R&D investment, as well as the existence of a dedicated civilian technology development program, renders the aircraft industry unique among U.S. manufacturing industries. Both NACA and NASA were centers for generic research and reduced the costs to industry of R&D through operation and construction of testing and research installations. Moreover, both civilian and military research programs encouraged the wide diffusion of technological knowledge within the aircraft industry, supporting the development of a readily accessible industry knowledge base. In this way, the federal programs operated in a fashion that closely resembles the cooperative R&D programs in the Japanese economy."[109]

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[108] See <u>supra</u> note 27, Vol. II at VII-14.

[109] D. Mowery & N. Rosenberg, <u>Technology and the Pursuit of Economic Growth</u> 188 (1989).

2. NASA's Organizational Structure

A diagram of NASA's organizational structure is contained in Exhibit 2. As the diagram indicates, there are four offices responsible for overseeing and undertaking the majority of R&D projects within NASA: 1) Aeronautics Exploration & Technology; 2) Space Science & Applications; 3) Space Flight; 4) Space Operations. As the name implies, the Office of Aeronautics Exploration & Technology undertakes the majority of activities related to the commercial aircraft industry. This office is responsible for the planning, advocacy, direction, execution, and evaluation of projects and research activities concerned with aeronautics research and technology.[110]

The offices of Space Science & Applications, Space Flight and Space Operations are all involved in different aspects of space activities including programs directed toward understanding the space environment, developing space transportation capabilities, and providing spacecraft operations and control and communication centers.

3. NASA Aeronautics Budget

NASA's budget is organized into five major sections: (1) Research and Development; (2) Space Flight, Control & Data Communications; (3) Construction of Facilities; (4) Research and Program Management; and (5) Inspector General.[111]

All or almost all of NASA's aeronautics programs (civilian and military) fall under the section of the Research and Development budget called Aeronautical Research & Technology which is administered by the Office of Aeronautics, Exploration and Technology. The Aeronautical Research and Technology budget is divided into two primary areas: (a) research and technology base and (b) systems technology programs.[112] Research and technology base funding covers broad research areas such as fluid and thermal physics research and technology, propulsion and power research and technology, and materials and structures research and technology. Systems technology programs cover funding for specific technology programs such as rotor craft systems technology, high-performance aircraft systems technology, advanced propulsion systems technology, and high speed research.[113]

The NASA aeronautics budget has grown fairly consistently from $324.9 million in 1976 to $931.8 million in 1990. It totalled $8.9 billion from 1976 to 1990. Yearly figures for the total NASA budget and the NASA

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110 Aeronautics and Space Report of the President, 1989-1990 Activities, at 10.

111 NASA Budget Estimates, Fiscal Year 1991, Vol. I.

112 *Id*. at RD 12-1.

113 *Id*. at RD 12-5, 12-26.

aeronautics budget from 1976 to 1990 are set out in Exhibit 3. According to information drawn from official compilations of NASA R&D contracts, Boeing received at least $311 million of NASA R&D contracts between 1979 and 1990 and McDonnell Douglas received at least $1.68 billion of NASA R&D contracts in the same period.[114]

Given that one of NASA's primary objectives is to assist U.S. commercial aeronautics and that, as discussed above, NASA's military and civilian R&D programs are closely interrelated and almost all are highly applicable to commercial aeronautics products, it can be reasonably estimated that 90 percent of NASA's aeronautics R&D expenditures constitute a benefit to the U.S. commercial aircraft industry. Thus, the $8.9 billion of NASA R&D in the past fifteen years translates into a benefit to the U.S. commercial aircraft industry of $8 billion. Expressed in current dollar terms using an opportunity cost/compound interest formula, the benefit of NASA R&D is $16.96 billion.[115]

4. Dissemination of NASA R&D Results

An important issue with respect to NASA R&D is that of the distribution and availability to commercial manufacturers of NASA's research and development work. Some parties might argue that all civilian R&D results are freely available to the public and therefore provide no special benefit to U.S. manufacturers vis-a-vis foreign manufacturers. Such a claim, however, would not appear to be true.

First, NASA regulations specifically provide that U.S. companies may be given "early access" of two years or more to documents that "contain the results of NASA research and development which has significant potential for domestic benefit, either for commercial or Government use."[116]

One example where research results were withheld has been publicly documented. In the late 1960s, NASA did some fundamental research on supercritical wing technology which came to have important, widespread commercial applications in the 1970s and 1980s. NASA did not make the results of its research equally available to all parties.

> "The results of this first work on the integral or unslotted airfoil were given limited

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114 This information was obtained from the Federal Procurement Data Center.

115 This calculation is based upon 30-year U.S. Treasury Bond interest rates for each of the years from 1976 to 1990. The calculation assumes annual compounding up to 1991. As with the current dollar calculations concerning benefits from DoD R&D, this calculation should be considered a rough estimate for illustrative purposes only.

116 NASA Scientific and Technical Information Handbook: Documentation, Approval, and Dissemination, ¶ 203.1(c) (Feb. 6, 1987).

> distribution in 1967 in a confidential Langley working paper. NASA recognized the importance of the discovery and applied for patents on the supercritical wing in Canada, France, Great Britain, Australia, Israel, Italy, Sweden, Holland, Germany, and Japan. In order that American-made aircraft could take advantage of the discovery, no public announcement of the supercritical wing was made until NASA's news release on February 7, 1969."[117]

Moreover, even if the final, published results of particular research are freely available, the private company or companies which participated in the R&D project would inevitably have an advantage over companies that learned about the research secondhand and at a later date, i.e., when it was finally published. The R&D contractors would have personnel trained in the areas relating to the R&D, as well as a much better and earlier understanding of its importance and possible commercial applications. The fact that NASA R&D contracts go almost exclusively to U.S. companies points to a clear benefit for the U.S. industry relative to its foreign competitors.[118]

B. Major NASA Programs

As noted in the overview of NASA's aeronautics R&D activities above, NASA has carried out a number of large-scale R&D efforts. Such efforts are multi-year programs consisting of a series of research projects unified by a central programmatic objective. This section presents an overview of one major program, the Aircraft Energy Efficient Program, in order to illuminate the direct commercial relevance of these NASA programs. In addition, this section briefly describes three other major NASA civilian aeronautics R&D programs: the noise reduction program, the supercritical wing program, and the high-lift system program.

1. Aircraft Energy Efficient Program[119]

NASA's Aircraft Energy Efficient (ACEE) program was initiated in 1976 with the objective of increasing the fuel efficiency of large commercial aircraft. The ACEE program consisted of six separate R&D projects. These projects and their commercial benefits are summarized below. To emphasize the significance of the ACEE program, it should be noted here that according

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117 Midwest Research Institute, Economic Impact and Technological Progress of NASA Research and Development Expenditures, Vol. III at III-14 - III-15 (1988).

118 British Aerospace, for example, has received only one R&D contract from NASA in the past twenty years. This pattern appears to be similar for the other major European manufacturers.

119 Appendix B describes the ACEE program in more detail.

to NASA experts, "[t]he ACEE programme was the genesis of the Boeing 757 and 767 aeroplanes."[120]

a. Energy Efficient Engine Project

The Energy Efficient Engine (E^3) Project, which was funded from 1975 to 1983, was an outgrowth of NASA's work in the early 1970s on a fuel-efficient engine. The goal of the E^3 project was to reduce fuel usage and direct operating costs while meeting future FAA regulations and EPA exhaust emission standards for turbofan jet engines (specifically General Electric's CF6-50C and Pratt & Whitney's JT9D-7A).[121]

Under the E^3 project, contracts were awarded to General Electric and Pratt & Whitney. While original component test results focused on the GE CF6, the E^3 program resulted in numerous design and performance improvements on the PW2000 for the narrow-body Boeing 757, and the PW4000 series for wide-body aircraft such as the DC-10 and 747. NASA expended approximately $200 million on the program over its nine-year life.[122]

b. Advanced Turboprop Project

The objective of the Advanced Turboprop (ATP) project was to achieve a 15 to 20 percent fuel saving over existing turbofan aircraft by developing technology for a fuel efficient short-to-medium range, 100-150 passenger advanced turboprop aircraft traveling at cruise speeds up to Mach .80 and altitudes of up to 35,000.[123] Boeing, McDonnell Douglas, Lockheed, Pratt & Whitney and General Electric all participated in ATP. The technology was successfully validated in three flight tests conducted on Boeing and McDonnell Douglas aircraft. The commercial applications of this program, however, never reached series production because high noise levels and lower oil prices decreased the economic value of implementing this technology.[124]

After 1987, propulsion work initiated during the ATP project was refocused on Ultra High Bypass (UHB) engine technology aimed at reducing fuel consumption by an additional 25 to 30 percent beyond that of the latest

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120 R. Petersen & B. Holmes, "U.S. Aeronautical Research for the 1990s," World Aerospace Technology 91 at 52 (London 1991).

121 Fuel Economy, at 29; Comptroller General, Report to Congress, "A Look at NASA's Aircraft Energy Efficient Program," at 39 (GAO, July 28, 1980) (hereinafter "Comptroller's Report"); see also Aeronautics and Space Report of the President, 1981 Activities, at 26.

122 Comptroller's Report at 42-43.

123 Fuel Economy in Aviation, NASA, at 43 (1985) (hereinafter "Fuel Economy").

124 Aeronautics Research and Technology, NASA (1988).

generation turbofan-powered aircraft.[125] Although UHB programs were funded at approximately $12 million per fiscal year from 1988 through 1991, UHB also did not reach series production for the same reasons described above.[126] NASA, however, has continued its interest in reducing the noise level of UHB engines, and plans to make further requests for FY 1993 funding.[127]

Total costs of the ATP project through 1987 -- when initial objectives were completed -- totalled $140 million.[128] In addition, UHB program funding through 1991 was $48 million.[129]

c. Engine Component Improvement Project

The Engine Component Improvement (ECI) project was directed at improving performance and reducing fuel consumption of various existing commercial aircraft engines, in particular Pratt & Whitney's JT8D and JT9D and GE's CF6.[130]

NASA expended approximately $40 million on the ECI program from 1974 to 1979.[131] Contracts awarded to Pratt & Whitney under the ECI project resulted in several system and design improvements to existing JT8D and JT9D engines as well as new engine configurations, such as the PW2037.[132] Among the aircraft that have benefited from this technology are the DC-9, DC-10 and Boeing 727, 737, and 747.[133]

As a result of the commercial success of the JT8D engine, Pratt & Whitney repaid the U.S. government approximately $19.2 million of the initial $26.3 million government investment through cost-recovery provisions contained in the initial contract.[134] Although Pratt & Whitney is expected to repay the remaining $7.1 million during the early 1990s, the company at a

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125 Information from NASA; "UHB Technology Validation - The Final Step," AIAA-88-2807 (July 1988).

126 Information from NASA.

127 Id.

128 Id.

129 Id.

130 Fuel Economy, at 9-10.

131 Comptroller's Report, at 37; information from NASA.

132 NASA ECI Programs: Benefits to Pratt & Whitney Engines (1982).

133 Fuel Economy, at 15.

134 Aviation Daily, March 7, 1989.

minimum received the equivalent of an interest free loan of $26.3 million over approximately 15 years.[135]

d. Composite Primary Aircraft Structures Project

The Composite Primary Aircraft Structures (CPAS) project was an outgrowth of research conducted by NASA in the early 1970s. The goal of the CPAS project was to facilitate the use of composite components to reduce the weight of aircraft by 25 percent and to increase fuel efficiency by 10 to 15 percent.[136] To implement the project, NASA contracted with Boeing, McDonnell Douglas and Lockheed to develop and test components and wing sections.[137]

Components developed during the CPAS program have been used in the DC-10, L-1011, and B-727, 757, and 767 airplanes.[138] In addition, advances made in composite research during the CPAS project are now being used in projects such as the NASP and High Speed Civil Transport. The estimated annual cost to the government of R&D for the CPAS project has varied between $110 million and $217 million.[139]

e. Energy Efficient Transport Program

The Energy Efficient Transport (EET) project focused on the technological development of aerodynamics and active controls and included investigation of airfoils, winglets, airframes, engines, high-lift devices for a supercritical wing, laminar flow, surface coatings and active controls.[140] Boeing, McDonnell Douglas, Lockheed and Pratt & Whitney all participated in development and testing under the EET project.

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135 Information from NASA.

136 Fuel Economy, at 59-60.

137 Id. at 62-71.

138 Id; Statement of R. Schauffle, V.P. Engineering, McDonnell Douglas, 1986 NASA Senate Budget Authorization Hearings, at 551. Other components for some or all of the aircraft, such as the electronic flight systems, may have been developed under other government programs, such as the Federal Aviation Administration's Electronic Flight Instrument System program.

139 Comptroller's Report, at 57-58.

140 Fuel Economy, at 77-91.

The DC-10, the B-757 and 767, and the L-1011-500 all incorporated technology from this project.[141] The R&D cost estimate for the EET project was $85.7 million.[142]

f. Laminar Flow Control Project

The Laminar Flow Control (LFC) project was intended to increase fuel efficiency by 20 to 40 percent by developing a suction system to reduce surface-airstream friction.[143] Under this project, NASA contracted with Boeing, McDonnell Douglas and Lockheed to enhance laminar flow control.[144] At the conclusion of this project, laminar flow research was continued under the Research and Technology Base Program, with an emphasis on applications for fuel efficient subsonic and high speed transport.[145]

The R&D cost estimate for the LFC project was $227 million.[146] Additional funding has been requested for a "Wing Route Experiment," based on the LFC program which is aimed at increasing fuel efficiency for 600 to 1,000 passenger subsonic transports. This $300 million line item, however, has yet to be approved.[147]

2. Aircraft Noise Reduction Program[148]

There were two series of NASA programs between 1965 and 1979 that examined the problem of aircraft noise. A panel convened in 1965 to assess the growing problem of noise around airports concluded that an initiative for reducing aircraft noise could only come from the federal government. Under an executive office mandate, NASA established a separate R&D project for aircraft noise. NASA was unable to assemble sufficient internal staff for

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141 Fuel Economy, at 77-91. Also, in cooperation with NASA, McDonnell Douglas developed winglets for the MD-11. These winglets, which reduce drag and increase overall performance, are in use on the MD-11.

142 Comptroller's Report, at 49.

143 Id.

144 Fuel Economy, at 101.

145 "Research in Natural Laminar Flow and Laminar Flow Control," NASA Conference Publication 2487 Pt. 1, at 2, 28 (1987); information from NASA.

146 Comptroller's Report, at 53.

147 Information from NASA.

148 Information on NASA's Aircraft Noise Reduction program has been drawn from J. Langford, Federal Investment in Aeronautical Research & Development: Analyzing the NASA Experience (MIT Doctoral Dissertation, June 1987).

this project, however, and turned to large-scale contracting with industry. Three major programs eventually emerged:

- Acoustic Nacelle Program -- headed by NASA's Langley Research Center and aimed at determining the feasibility of nacelle retrofits for existing airliners;

- Quiet Engine Program -- headed by NASA's Lewis Research Center to develop a demonstrator engine optimized for low noise; and

- Steep Approach Program -- conducted jointly by NASA's Langley, Dryden and Ames Research Centers to develop techniques and equipment for rapid descents into airports, with the goal of minimizing noise exposure on the ground.

Ensuing debate over noise reduction during the 1970s led NASA to initiate a new series of programs which, like the first wave of programs, was intended both to provide data and options for regulatory decisions and to advance the technology of noise reduction. These programs included:

- REFAN -- NASA's largest noise reduction program, undertaken to determine feasibility of reducing noise levels by retrofitting existing aircraft with REFAN engines and new acoustically treated nacelles;

- QCSEE (Quiet Clean STOL Experimental Engines) -- under which NASA built and tested two research engines designed for low-noise operation on short takeoff and landing aircraft; and

- QCGAT (Quiet Clean General Aviation Turbine) -- undertaken in an effort to extend noise- and pollution-reduction technology to smaller engines than those engines used in previous efforts.

Federal R&D expenditures to remedy the aircraft noise problem eventually totaled more than $500 million, with almost 85 percent spent through the aeronautics programs of NASA.[149] Each of these six noise reduction programs had an impact on the commercial aircraft industry. In particular, the sound-absorbing material (SAM) developed by the Acoustic Nacelle Program was promptly incorporated into the B-747, DC-10, and L-1011. It was fitted into new production versions of the B-727, B-737, and DC-9 beginning in 1972, and this alone allowed these aircraft to meet certain federal acquisition regulations. The private sector has continued to refine

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149 Federal Interagency Aviation Noise Panel, Federal Research, Technology, and Demonstration Programs in Aviation Noise, Office of Noise Abatement & Control, U.S. Environmental Protection Agency (EPA 440/9-78-307), March 1978.

the effectiveness of SAM. New generations of material are used extensively in new Stage 3 aircraft such as the B-757, B-767 and MD-80.[150]

3. Supercritical Wing Program[151]

From 1964 through 1975, NASA conducted research, wind tunnel tests, and flight validation programs regarding supercritical wing design, a significant technological advance in wing design that has permitted substantial increases in the speed and efficiency of large commercial aircraft. From 1964 on, NASA and the U.S. industry worked closely together to refine this concept into an efficient transportation technology. As noted above in the section on dissemination of NASA research, NASA recognized the importance of the supercritical wing discovery and helped the U.S. industry take advantage of it by delaying public announcement of it. In addition, "[t]he extensive experimental results obtained after 1967 on refinements and applications of the NASA supercritical airfoils remained classified until 1983."[152]

4. High-Lift System Program[153]

Early test flights of NASA's supercritical wing for commercial transport aircraft demonstrated the necessity of developing high-lift systems for these newer airfoils to improve aircraft lift at low speed. In response, in the early 1970s NASA initiated a research program to explore high-lift devices and promote development of superior multi-element airfoil systems for transport aircraft. This program resulted in significant improvements in theory, design techniques and test methods.

One approach to high-lift or multi-element airfoil analysis was developed by Lockheed under the sponsorship of the NASA Langley Research Center.[154] Boeing, under NASA contract, made a substantial "modification and

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[150] Vaughn Bloomenthal of Boeing said in 1973 that, "much of the original acoustic technology was developed in the NASA . . . program starting in 1967. That work has been invaluable in arriving at today's acoustic configurations." House Hearings, Aircraft Noise Abatement, December 1973, at 142.

[151] *See generally* Midwest Research Institute, Economic Impact and Technological Progress of NASA Research and Development Expenditures (1988) (hereinafter "Midwest Research Institute Study").

[152] *Id.* at III-15.

[153] Information on NASA's High-Lift System program has been drawn from the Midwest Research Institute Study.

[154] W.A. Stevens, S.H. Goradia, & J.A. Braden, "Mathematical Model for Two-Dimensional Multi-Component Airfoils in Viscous Flows," NASA TM-89125, July 1987.

clarification of the NASA-Lockheed multielement airfoil computer program" in 1977 and 1978. This program marked the beginning of an eight-year refinement of high-lift systems of Boeing's aircraft.[155] Both Boeing and McDonnell Douglas engineers were enthusiastic about the data provided by Langley's low turbulence pressure tunnel: "a real jewel -- a unique national resource."[156] The 12-foot tunnel at Ames was also relied on extensively until it was derated and scheduled for extended repairs. McDonnell Douglas engineers who worked most extensively with Ames in the mid and late 1980s indicated that lack of availability of the 12-foot tunnel significantly hampered or delayed the development of the advanced high-lift systems.[157]

Benefits derived from industry and NASA advances in high-lift design, including the ability to develop advanced high-lift sections and proceed to wind-tunnel testing, virtually assured that the aerodynamic characteristics will be close to those desired. Thus, both the time and cost to create and certify new high-lift systems have been reduced.

C. Analysis of Specific Contracts

In order to analyze the commercial benefits from NASA R&D at a more specific level, we examined a number of NASA R&D contracts obtained through earlier Freedom of Information Act requests. Three such contracts, all part of NASA's JT8D engine program, are described below.

NASA's JT8D program, which was carried out in the 1970s as part of the noise reduction program described above, was a two-phase program aimed at redesigning the JT8D engine to make it quieter. Phase I of the program involved defining and designing the engine modifications, initiating the procurement of experimental hardware and preparing for engine testing. Phase II involved testing the modified engine (known as the refan JT8D engine) and producing retrofit kits for the engine.

The first of the three contracts under consideration here was one between NASA and the United Aircraft Corporation (Pratt & Whitney Aircraft Division), dated June 29, 1973. The total amount obligated under the contract was $15 million. Under the contract, Pratt & Whitney was responsible for completing the engine refan modifications design, producing and testing refan engines and providing retrofit kits for refan engines. This contract, and the JT8D program generally, were of great commercial significance to Pratt & Whitney, since they led to a major improvement in the JT8D engine and ensured its continuing use in major commercial aircraft.

The second contract was between NASA and the McDonnell Douglas Corporation, also dated June 29, 1973. The contract, for $7.8 million, was

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155 Midwest Research Institute Study, at III-32.

156 Id. at III-35.

157 Id.

part of Phase II of the JT8D refan project. McDonnell Douglas was responsible for identifying the modifications required to install the modified JT8D engine on the DC-9; designing and fabricating flightworthy nacelles and aircraft modifications; providing engineering support and hardware for engine ground tests at Pratt & Whitney; and performing demonstration flights of the modified DC-9 equipped with JT8D refan engines.

The contract and the JT8D refan program generally had commercial significance for McDonnell Douglas. The JT8D refan program permitted McDonnell Douglas to keep its DC-9 program alive. The DC-9 program had been suffering due to weight problems encountered with rear-mounted engines. The only practical solution was to carry out a weight modification to the JT8D engine to permit its use on the DC-9.

The third contract was between NASA and Boeing, dated July 11, 1973. The total obligated amount under the contract was $4.5 million. The contract was also part of Phase II of the JT8D refan program. Under the contract, Boeing was to test the installation of JT8D refan engines on the 727. Specifically, Boeing was responsible for the following tasks: identifying the modifications to the 727 necessary to install the modified engines; designing the nacelles; providing hardware for engine ground tests; performing demonstration ground tests of the refanned 727 engine; and developing retrofit kit costs for the 727.

This contract was commercially significant to Boeing because Boeing faced a choice between trying to upgrade the 727 with the refan JT8D engine or re-engining the 737 with the CFM-56 high bypass engine. The work under this contract -- testing the JT8D on the 727 -- underwrote the costs for Boeing of assessing the 727 option. Boeing ultimately decided to concentrate on re-engining the 737.

Each of these contracts represents an important example of how NASA R&D directly and intentionally benefits the U.S. commercial aircraft industry. Taken together, the contracts demonstrate how one major R&D project can provide benefits to a range of U.S. companies simultaneously, even when those companies may be in competition with each other. The contracts also demonstrate the immediate competitive value of participating directly in the R&D activities, rather than having to await publication of the results of the efforts several years later.

D. NASA Recoupment

1. NASA Recoupment Policy in Theory

When a project undertaken by a private company for NASA involves the development of a product or technology having an estimated development cost of over $10 million, NASA retains the option of including a recoupment provision in the relevant contract.[158] The inclusion of a recoupment provision is not required, however, absent a specific congressional mandate.[159]

NASA considers a variety of factors in determining whether recoupment is appropriate, including the expected impact of recoupment on NASA's objective of preserving the role of the U.S. as the leader in aeronautical and space technology; the nature of the activity; whether there is a viable and effective mechanism for obtaining recoupment; and the extent to which NASA, through its funding, has developed a practical application of the specific technological capability involved.[160]

The relevant program office is charged with estimating the Government's investment and recommending the recoupment fee to be charged in the setting of individual contracts. The guidelines provide that recoupment pricing shall be equitable and nondiscriminatory and suggest that where a product is sold or leased, consideration should be given to a recoupment policy based on the _pro rata_ share of the Government's nonrecurring costs.[161] The recoupment price is periodically reviewed and may be reduced or eliminated based on, _inter alia_, existing market conditions; the negative impact of recoupment on the availability of NASA developed technological capability; or the interests of the United States.[162]

2. _NASA Recoupment in Practice_

The NASA recoupment provisions in the three contracts described in the preceding section of this report follow a standard format. The provisions mandate that if a contractor sells or leases a product developed under a NASA contract or a product entirely or substantially derived from technology developed under a NASA contract, the Government is entitled to a maximum of 3 to 4 percent of the receipts from that sale or lease, as reimbursement for the cost of development paid by the Government. In addition, the provisions require the contractor to pay to the Government a maximum of 5 to 10 percent of all sums received from third parties for the right to sell, lease, or manufacture the complex and potentially subjective task.

A variety of factors are to be considered in establishing the actual recoupment charge, including the extent to which the contractor's own funds

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158 _See_ "Recoupment Policy for the Use of NASA Technology," NASA Management Instruction No. 5109.13A at 7(a)(2) (June 15, 1978).

159 _Id_. at 7(b)(2).

160 _Id_. at 7(b)(3).

161 _Id_. at 7(c).

162 _Id_. at 8(b).

were utilized in the design of the product; the extent to which contractor-developed technology was utilized in the design of the product; the competitive environment; and the ability of the contractor to sell the product. Direct reimbursement is reduced by the amounts paid through third party licenses. Total reimbursement also is capped at the level of funding provided by the Government. Further, some of the contracts provide that if full reimbursement is not made within a certain time period, generally about 10 years, the balance will be waived. Finally, reimbursement can be waived altogether.

To the best of our knowledge, there are no published data indicating the aggregate recoupment charges actually levied on private contractors. However, one of the most pronounced features of the program is the broad discretion retained by NASA with regard to the entire process, starting with decisions about the inclusion of recoupment provisions in contracts in the first instance, through retention of the power to waive contractually required recoupment fees.

Further, collection of recoupment charges outside the context of direct sales of the product developed under the contract, even if called for theoretically, could prove difficult. Determining whether a product is "entirely or substantially" derived from a product or technology developed for NASA would necessarily be a complex and potentially subjective task.

Further, a contractor's commercial program could benefit substantially from the contractor's participation in a NASA project, regardless of whether the project led to any direct commercial spin-offs which might be subject to recoupment. For example, the commercial program could benefit from the identification of technological dead-ends, the on-the-job training given to the contractor's employees, and the testing and training in the use of certain tools, technical processes and facilities. Moreover, even if NASA did receive full recoupment through levies on sales of commercial spin-offs, given the cap on recoupment, the private contractors would still have enjoyed the equivalent of a multi-year interest free loan equal to the original NASA funding for the period prior to full repayment.[163]

III. TAX PROGRAMS[164]

In addition to the very significant benefits that the U.S. commercial aircraft industry receives from participation in government-sponsored R&D projects, the industry also receives major benefits from the U.S. tax system. These benefits have included the completed contract method for long-term contracts, domestic international sales corporations, foreign sales corporations and investment tax credits. Based on publicly-available data, one can estimate that since 1976, the completed contract method, domestic

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163 Of course, NASA's waiver of recoupment of any portion of the funds would constitute a grant in the year of the waiver.

164 *See* Appendix C for a more detailed account of this topic.

international sales corporations and foreign sales corporations have provided special benefits of approximately $1.7 billion to Boeing and $1.4 billion to McDonnell Douglas. See Exhibit 4.

A. Completed Contract Method for Long-Term Contracts

From 1976 through 1989, the aerospace industry accounted for long-term contracts under the completed contract method (CCM) of accounting. Under CCM, the gross contract price is included in income, and costs associated with the contract are deducted, in the year the work required by the contract is completed and accepted. This provides a tax deferral of income, and the associated income tax, until the contract is fully completed. The stated rationale for CCM is that contracts extending over a long period of time may be subject to significant risks and thus the amount of profit realized by the taxpayer, if any, cannot be ascertained with any certainty until the contract is completed. Tax policy analysts, however, have viewed the CCM rules as little more than a tax break tailored specifically for large contractors like Boeing and McDonnell Douglas.[165]

Congress also recognized that the CCM rules provided an unwarranted deferral of income for long-term contracts.[166] The Joint Committee on Taxation (Joint Committee) prepared the Study of 1983 Effective Tax Rates on Selected Large U.S. Corporations which showed that several large corporations had significant levels of deferred taxes and low effective tax rates as a result of the CCM rules.[167]

Boeing has reported deferred taxes attributable to "completed contract method and related inventory costs" of $1.645 billion over the period 1976 through 1990. These tax deferrals, because of the time value of money, effectively saved Boeing approximately $619.55 million of interest over the same period. See Exhibit 4.

McDonnell Douglas' Annual Reports to shareholders show deferred income taxes from uncompleted contracts of $1.281 billion over the period 1976 through 1990. These tax deferrals, because of the time value of money, effectively saved McDonnell Douglas approximately $899.26 million of interest over the same period. See Exhibit 4.

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165 See Citizens for Tax Justice, Third Annual List of America's Corporate Taxpayers and Corporate Freeloaders, July 1986 (noting that "for one set of particularly successful corporate tax avoiders, defense contractors, something called the 'completed contract method' is pivotal" to "legal" tax avoidance.)

166 See Staff of Joint Committee on Taxation, 100th Cong., 1st Sess., General Explanation of the Tax Reform Act of 1986 (1987).

167 Id. at 527.

Because the CCM rules were limited by the Tax Reform Act of 1986 and subsequently eliminated in 1989, large aerospace contractors like Boeing and McDonnell Douglas are now paying back those deferred taxes. Boeing has paid $316 million in 1987, $677 million in 1988, $213 million in 1989, and $111 million in 1990. McDonnell Douglas paid $261 million in 1988, $268 million in 1989, and $207 million in 1990.

This so-called payback, however, leaves these companies well ahead of the game for two reasons. First, the interest saved on the deferred tax payments will never be paid back and thus is a permanent benefit. Second, corporate tax rates were reduced sharply, from a 46 percent maximum corporate rate to the current rate of 34 percent, by the 1986 Tax Act. Thus, taxes were deferred under the CCM rules during years in which the statutory rate was 46 percent, but were then paid back during years in which the statutory rate was reduced to 34 percent. This benefit can be roughly estimated as having been $429 million for Boeing and $334 million for McDonnell Douglas.[168]

B. Domestic International Sales Corporations and Foreign Sales Corporations

Congress provided significant tax incentives for exports when it created the domestic international sales corporation (DISC). Under the original DISC provisions, profits of a DISC were taxed to the shareholders only when distributed or deemed distributed to its shareholders. A DISC was deemed to have distributed 50 percent of its export profits and 100 percent of its nonexport profits annually. Federal tax could be deferred indefinitely on the remaining 50 percent of the DISC's export profits. The DISC provisions also provided special intercompany pricing rules which allowed a substantial portion of the U.S. profit on sales from the U.S. parent corporation to the DISC to be attributed to the DISC.

Controversy erupted between the United States and other signatories of the General Agreement on Tariffs and Trade (GATT), including members of the European Community, concerning the DISC. The United States eventually agreed to propose legislation that would address the GATT concerns with respect to the indefinite deferral of taxes on DISC income.

Legislation was adopted by Congress as part of the Deficit Reduction Act of 1984 (1984 Tax Act). All DISCs were deemed to have terminated on December 31, 1984, and any accumulated tax-deferred income at December 31, 1984, was treated as previously taxed income. As a result, income originally

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168 These estimates are based on the assumption that prior to 1986, Boeing and McDonnell Douglas were paying taxes (on income not deferred under CCM) at the maximum statutory rate of 46 percent and that since the enactment of the 1986 Tax Act, they have been paying at the new lowered maximum rate of 34 percent. _See_ Appendix C, note 26.

considered to be tax-deferred under the DISC provisions was permanently exempted from taxation.

Congress created the Foreign Sales Corporation (FSC) as part of the 1984 Tax Act in large part to replace the DISC provisions. It was apparent, however, that the new FSC provisions raised some of the same tax subsidy concerns as the DISC provisions. The FSC provisions actually exempt a portion of the FSC's export income from tax. Thus, the FSC differs from the DISC, which only allowed the deferral of income.

The DISC and FSC provisions have benefited those companies engaged in significant exporting, including aerospace companies. The amount of tax liability forgiven on accumulated DISC income by the 1984 Tax Act was estimated at between $10 billion and $14 billion for all industries, with Boeing and McDonnell Douglas among the principal beneficiaries because of their large accumulated deferrals.

Boeing's 1984 Annual Report stated that its deferred tax liability on DISC income amounted to $397 million. McDonnell Douglas' 1983 Annual Report disclosed that its accumulated deferred DISC income was $323.2 million. McDonnell Douglas' 1984 Annual Report does not disclose the total DISC forgiveness from which the company benefited although the total forgiveness can be estimated as having been approximately $148 million.[169]

As for the FSC, Boeing's Annual Reports and SEC filings disclose that the company has derived benefits from the FSC provisions of $35 million in 1985, $49 million in 1986, $22 million in 1987, $35 million in 1988, $44 million in 1989, and $97 million in 1990, for a total benefit of $282 million.

McDonnell Douglas disclosed in its 1986 Annual Report that it had "export tax-exempt income" of $18.9 million in 1985 and $9.3 million in 1986. In subsequent years, its Annual Reports showed "export tax-exempt income" of $9 million for 1987, $9 million for 1988, $26 million for 1989, and $8 million for 1990, for a total of $80.2 million for the period 1985 through 1990.[170]

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[169] This estimate was arrived at by multiplying the $323.2 million of deferred DISC income by the maximum statutory marginal tax rate of 46 percent.

[170] We have assumed that "export tax-exempt income" refers to the FSC tax benefit in such years, since from Annual Reports for years before 1984 it is clear that the term "export tax-exempt income" referred to DISC tax-exempt income. Compare 1983 McDonnell Douglas Annual Report, at 24 with 1985 McDonnell Douglas Annual Report, at 30.

IV. OTHER PROGRAMS AND ACTIVITIES

The three forms of support analyzed above -- DoD R&D, NASA R&D, and tax programs -- provide the bulk of readily identifiable U.S. government support for the U.S. commercial aircraft industry. Nonetheless, a variety of other programs and activities also provide benefits to this industry. In this section, we examine the benefits involved in the use of government test facilities by U.S. aeronautics companies and the 1982 U.S. government purchase of McDonnell Douglas KC-10s. We also note the fact that financial flows between the military and commercial sides of Boeing and McDonnell Douglas may constitute a form of benefit to commercial activities. Finally, one area not covered in this report relates to the aeronautics R&D projects carried out by the U.S. Federal Aviation Administration, which may in some cases be beneficial to the U.S. commercial aircraft industry.

A. Use of Government Facilities

A further form of government support to the commercial aircraft industry involves government test facilities used in aeronautics R&D. According to the National Critical Technologies Panel,

> "Aeronautical test facilities, such as wind tunnels, engine test cells, and supercomputers are required to conceive and validate aspects of aircraft design, construction, and operation. A state-of-the-art aeronautical testing infrastructure is therefore required for the United States to design, build, and operate advanced aircraft."[171]

The most important government-owned facilities utilized by the aircraft industry are operated by NASA and the Air Force. In addition, the Navy, Army, and Departments of Energy, Commerce, and Transportation, also maintain federal facilities.[172] As of 1985, the replacement value of NASA and DoD facilities alone was estimated to be $10 billion.[173]

In some circumstances, U.S. aircraft manufacturers are allowed to use government facilities at low or no cost. This section briefly examines industry use of NASA and Air Force facilities. A more detailed analysis is presented in Appendix D.

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171 Report of the National Critical Technologies Panel at 96 (1991).

172 U.S. Department of Commerce, Federal Laboratory and Technology Resources (1990).

173 The Competitive Status of the U.S. Civil Aviation Manufacturing Industry 117 (1985).

1. NASA Facilities

NASA's aeronautical research facilities have been described by NASA as "unique national assets."[174] Indeed, the Chairman of the House Subcommittee on Transportation, Aviation and Materials has credited those facilities with "provid[ing] the foundation for America's traditionally strongest industry, building airplanes."[175] As of 1982, NASA maintained 42 major aeronautical research facilities among its centers, valued at approximately $4 billion.[176] As of 1985, fourteen of those facilities had no equal worldwide in size and/or speed in meeting user requirements.[177]

NASA's Aeronautics Research and Testing (R&T) programs are primarily conducted at three research centers: Ames Research Center located in both Moffett Field and Edwards, California; the Lewis Research Center in Cleveland, Ohio; and the Langley Research Center in Hampton, Virginia. Each center is used in four different ways: (i) NASA-only testing; (ii) projects conducted jointly by NASA and industry; (iii) projects conducted by NASA and another government agency, usually DoD; and (iv) industry-only projects.

Of these four types of usage, the joint NASA-industry projects most clearly appear to involve government-sponsored benefits to the industry.[178] In such projects, NASA typically pays both the variable and fixed costs associated with the project. As NASA's contribution is funded through its budget, it normally provides at its expense the testing facilities, engineering capability, and power/electricity to support the project. The industry partner pays only for the hardware or technology model to be tested. There is no exchange of funds between NASA and the industry partner in these cooperative programs, regardless of whether their objectives are commercial or military applications. The data generated by these joint projects may be published by NASA, but NASA is sometimes willing to delay data release for some period of time, normally up to one year.

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174 NASA Aeronautics (1991).

175 Cong. Rec. 2194 (May 13, 1982) (Statement of Rep. Glickman).

176 J. Langford, Federal Investment in Aeronautical Research & Development: Analyzing the NASA Experience at 28-29 (MIT Doctoral Dissertation, June 1987).

177 Aeronautical Facilities Catalog, Volume 1, NASA, January 1985.

178 According to NASA, in industry-only projects the user companies bear all direct and indirect costs of the project. See Appendix D.

NASA's major aeronautics R&T centers are described below.

a. Ames Research Center

The Ames Research Center has facilities valued at approximately $3 billion and includes a facility in Moffett, California (Ames-Moffett) and the Dryden Flight Research Center (Ames-Dryden).[179] In addition to maintaining the world's largest network of wind tunnels, valued at $1 billion, the Ames Research Center has a number of unique testing and technology capabilities. All of these facilities and capabilities are available to and utilized by the aircraft industry for both military and commercial applications. Nearly every important aircraft developed in recent years has been tested in the wind tunnels at Ames.

As with other NASA facilities, private companies are charged a fee for tests they conduct at the Ames facilities that are not performed in conjunction with a government agency. Fees for standard tests conducted by private companies at Ames' facilities are roughly between $3,000 and $4,000 per hour.[180] For example, at the end of 1990, Boeing tested its 767-X model in Ames' facilities at a price of $750,000 for four weeks of testing. In addition, on three other occasions, Boeing has tested its proposed new aircraft models in Ames' wind tunnels.[181]

b. Lewis Research Center

The primary focus of the Lewis Research Center's facilities and capabilities is on aeronautical and space propulsion. These facilities are particularly relevant to the development of U.S. civil and military aircraft.

Several collaborative government and industry projects have been undertaken which have directly benefited the commercial aircraft sector. An example of such a project is the 1987 joint effort of Lewis and a NASA/industry team working on advanced turboprop propulsion as part of the fuel saving effort of the Aircraft Energy Efficient Program (ACEE).[182] Flight tests and wind tunnel testing of scale models helped Boeing and McDonnell Douglas design the turboprop for future aircraft in the 100-150 passenger class.[183]

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179 Aviation Week and Space Technology, June 24, 1991, at 45.

180 Information from NASA.

181 Aviation Week & Space Technology, October 8, 1990.

182 Aerospace America, October 1988, at 14-15.

183 Id.

c. Langley Research Center

The Langley Research Center specializes primarily in aerodynamics, fluid dynamics, computer science, and structures and materials research. A number of Langley facilities are used for both civil and military applications.

Langley has been involved in several government-industry projects aimed at developing commercial technology for the aircraft industry. For example, in 1990, a joint government-industry program which included the Air Force's Wright Research and Development Center, NASA-Langley, and Boeing's Commercial Airplane Group, modified and tested a wing-suction device designed to produce laminar air flow over a wing to reduce airplane drag by 10 percent or more.[184]

2. Air Force Facilities

Information about U.S. military aeronautics facilities, and their use by private industry, is difficult to obtain. The U.S. Air Force maintains numerous aeronautics test facilities, including the Wright Research Laboratory, Air Force Flight Test Center, Design and Analysis Branch, Flight Dynamics Laboratory, Propulsion Wind Tunnel Facility, and Von Karman Gas Dynamics Facility. These facilities, in particular Wright Research Laboratory and the Air Force Flight Test Center, conduct research and testing in conjunction with industry.[185]

Private companies generally use these facilities only for DoD-sponsored projects. In such situations, the facility may be provided to the contractor at no charge, as part of the government's contribution to the project. To the extent that DoD-sponsored R&D projects involve commercially relevant work for private companies, these companies are deriving a benefit from the free use of the military test facilities.

B. Special Purchase of KC-10s

1. Description of Events

The KC-10 is the military version of the DC-10; in fact, the two planes have 88 percent of their parts in common and are manufactured on the same production line.[186] Beginning in 1981, McDonnell Douglas began warning that it would have to close its KC-10/DC-10 production line, absent an

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184 Aviation Daily, August 24, 1990, at 360.

185 Federal Laboratory and Technology Resources, U.S. Department of Commerce (1990).

186 "Air Force Will Upgrade Aerial Refueling Capabilities," Aviation Week and Space Technology, August 11, 1980, at 56.

additional KC-10 order by the U.S. government.[187] McDonnell Douglas ultimately succeeded in encouraging the U.S. government to purchase additional KC-10s. An order for 44 KC-10s was made at the end of 1982, with deliveries extending through 1987, and the DC-10 production line thereby remained open.[188]

The ability to keep the DC-10 production line open as a result of the 1982 KC-10 order (and a follow-up order for KC-10s in 1985) kept McDonnell Douglas in the market for large, commercial aircraft long enough to develop the MD-11, a derivative of the DC-10.[189] Indeed, McDonnell Douglas itself questioned whether it would have been able to build a derivative of the DC-10 if it had had to shut down the DC-10 production line.[190] More importantly, absent the ability to build the MD-11 and to thereby answer the competition provided by Boeing and Airbus, McDonnell Douglas would have had to leave the market.[191]

The special utility of keeping the DC-10 production line open derived from the high degree of commonality between the DC-10 and MD-11. This commonality between the two aircraft is easily illustrated: the fuselage for the MD-11 is simply a stretched version of the DC-10, and the MD-11 uses a DC-10 wing, albeit with a modified profile aft of the rear spar.[192]

The specific benefits to McDonnell Douglas in keeping the DC-10 line open for development and production of the MD-11 included the savings from not having to close and reopen the line and the savings from preserving its learning curve advantage -- it was able to use the same production team that had worked on the DC-10 to produce the MD-11. In terms of the learning curve, McDonnell Douglas has stated that when it produced the first MD-11 it was as if that first plane was the 447th plane to come off the production

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187 O'Lone, "New Order Dip Threatens Airframe Makers' Future," Aviation Week & Space Technology, May 3, 1982, at 16; Reuters Wire Service, October 7, 1981; Reuters Wire Service, September 13, 1982; Lindsey, "Lockheed to Halt Output of Tristar," New York Times, December 8, 1981, at 1.

188 "Military Order Safeguards DC-10's Future," Financial Times, December 24, 1982, at 22.

189 Id.

190 "McDonnell Must Decide Soon on Fate of DC-10 Production," Wall Street Journal, January 9, 1985, at 10.

191 "How Long, How Thin, How Many?", Flight International, June 13, 1987, at 95.

192 Id.

line.[193] According to McDonnell Douglas Vice President Worsham, McDonnell Douglas' development costs for the MD-11 were only $700 million, compared to $3.5 billion for the A330/340, the airplane Worsham has described as the "head to head competitor" of the MD-11.[194] Worsham estimates the learning experiences from the DC-10 that were applied to the MD-11 resulted in a 75 percent savings in the development and production costs of the MD-11.[195]

2. Calculation of Benefit

McDonnell Douglas' learning curve advantage would have been reduced markedly and its development and production costs for the MD-11 would have been substantially higher if it had not received the U.S. government's KC-10 order in 1982 and, as a result, had closed its DC-10/KC-10 production line. Airbus has calculated that, based on various assumptions -- including the degree of commonality between the DC-10 and MD-11; McDonnell Douglas' estimate of the number of MD-11s that will be sold over the life of the program; the cost savings in not having to close and reopen the DC-10/KC-10 production line; and the production costs for the MD-11 -- the 1982 KC-10 order saved McDonnell Douglas roughly $800 million in connection with the development and production of the MD-11.

C. Military-Civilian Cross-Subsidization

A possible form of government-sponsored benefit to the U.S. commercial aircraft industry that lies outside the scope of this report is that stemming from the military activities of the companies that manufacture large commercial aircraft. The argument has been made that profits and revenues from military activities underwrite the commercial activities of the major U.S. aircraft manufacturers. For example, Nathan Rosenberg, a noted U.S. commentator on the industry has said:

> "High profits and federal research support in the development and sale of military aircraft have comprised an important government subsidy to the development and manufacture of new commercial designs.[196]

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193 1991 National Defense Authorization Act Hearings, March 1, 7, 8, 15 and April 4, 1990, at 346-47.

194 Hearing before the Subcomm. on Commerce, Consumer Protection and Competitiveness of the House Comm. on Energy and Commerce, 100th Cong., 1st Sess., June 23, 1987, at 69-70.

195 Id. at 58.

196 R. Nelson, Government and Technical Progress: A Cross-Industry Analysis 148 (1982).

Similarly, the 1982 report on aeronautics research by the U.S. Office of Science and Technology Policy stated:

> "In summary, military procurement can effectively subsidize commercial ventures, just as any large customer purchase can affect the viability of a firm. Such carry-over effects can influence the competition in the commercial market, and can have distributional consequences in the commercial sector that are independent of public policy."[197]

The industry itself openly acknowledges the point. As Boeing's Chairman, Frank Shrontz, recently stated:

> "[A] defense-commercial mix provides long-term stability and a testing ground for new technologies lacking immediate commercial application. Financially, there have been times when the defense side carried the commercial business.[198]

In general, the close relationship that major U.S. defense contractors, such as McDonnell Douglas and Boeing, have with the U.S. government may open the door to special financial support from the government. In early 1991, for example, McDonnell Douglas, faced with serious cash flow problems, quietly asked the Department of Defense for a $1 billion advance on major defense contracts.[199] Although it appears that McDonnell Douglas ultimately withdrew its request, the Department of Defense did consider the request seriously and undertook specific planning for a financial assistance effort.[200] Facts about the incident are still emerging and whether or not government assistance was actually given, the incident underlines the special relationship that exists between major U.S. defense contractors and the U.S. government as well as the possible financial benefits that relationship may bring to private companies.

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197 Office of Science and Technology Policy, Executive Office of the President, Aeronautical Research and Technology Policy, Volume II: Final Report, Nov. 1982, at V-26.

198 Wall Street Journal, July 30, 1991, at 1.

199 Wall Street Journal, July 24, 1991, at 4.

200 Id.

V. TRANSPARENCY

A significant feature of almost all the forms of support given by the U.S. government to the U.S. commercial aircraft industry is a very low level of transparency. That is to say, although it is possible to identify the major forms of support and make some estimates of their overall magnitude, obtaining detailed information is difficult or impossible in many cases. As a result, precise quantification of the benefits to the U.S. industry usually is not possible. Some of the major areas in which transparency is most noticeably lacking are the following:

° DoD R&D: Most information about military R&D work in aeronautics is classified, greatly limiting the available information on that subject. Without highly specific information about military R&D projects, it is difficult to assess the amount or degree of commercial utility in any particular project. We were able to obtain basic information about R&D contracts between DoD and Boeing and McDonnell Douglas, including such information as the date, contract amount, contracting agency, and product service code involved in each contract. It is not practically possible, however, to get detailed information about the technical content of those contracts. The Freedom of Information Act (FOIA) theoretically can be used to obtain copies of certain DoD R&D contracts, but it is a very limited tool -- past experience has shown that many of the requests for contracts are denied and even those contracts that are released may have been redacted to eliminate critical details. In addition, the government's response to FOIA requests is very slow.

° IR&D: IR&D outlays are related to military R&D projects, and thus information on IR&D also has proved to be difficult to obtain. Although it was possible to develop an estimate of the overall amount of IR&D outlays for aeronautics R&D projects, it was not possible to obtain specific figures for the aeronautics-related IR&D figures for IR&D outlays to particular companies or any listing of specific IR&D projects.

° MANTECH: It was not possible to obtain figures for the amount of MANTECH funds that have gone to specific companies or to obtain descriptions of specific MANTECH programs.

° DoD Recoupment: There is very little publicly available information about DoD recoupment practices. There are no published figures on the precise amount of recoupment that DoD receives from private companies. We obtained estimates of such amounts through informal means; although we believe the figures to be accurate, they are not authoritative, given that they are not official. It is not possible to find out how much a particular company has paid in recoupment charges to DoD or to determine whether a company paid recoupment on any particular R&D contract.

° NASA R&D: Information about NASA R&D is somewhat more available than data concerning DoD R&D, given the civilian nature of much of NASA's activities. Nonetheless, there are still areas of NASA's aeronautics work where it is very difficult to find useful information. Information on NASA recoupment practices, for example, is as scarce or even more scarce as information on DoD recoupment. We were not even able to obtain an informal estimate of total recoupment paid to NASA. NASA's practices concerning the public dissemination of R&D findings present another difficult problem. It is not possible to determine systematically in what instances NASA has delayed dissemination of research findings for the sake of U.S. industry, although it is known that such delays have occurred.

° Government Facilities: Our research indicates that the use of government R&D facilities by private companies is often governed by informal personal relationships rather than regulatory procedures, particularly with respect to usage fees. Such informal relationships are not subject to public scrutiny and render substantive information-gathering on the subject impossible.

In sum, problems with the transparency of U.S. government programs are numerous and significant. The low level of transparency is not a coincidental feature of the programs under study. Rather, it is an inevitable feature of the intimate relationship between the U.S. government and the U.S. commercial aircraft industry. The government and the industry have been operating in a close, cooperative fashion for so long that they have developed many kinds of ties that are rarely, if ever, held up to public scrutiny.

SUPERSONIC AND HYPERSONIC TRANSPORTS

A. Introduction

When President Reagan highlighted the National Aerospace Plane (NASP) in his 1986 State of the Union message and made reference to use of the vehicle as the "Orient Express," U.S. attention turned to the opportunities and potential of this high speed form of flight. Since that time, numerous U.S. governmental agencies as well as sectors of U.S. industry have begun to study the technology, economic considerations and applications of high speed flight, as well as to develop the materials, components, structures, fuel, etc., needed to make high speed flight a reality.

While both the NASP and the "Orient Express," or as it is known more generically, High Speed Civil Transport (HSCT), contemplate high speed flight, the programs differ in the speed and elevation at which the proposed vehicles will travel. The NASP is expected to travel out of the atmosphere at approximately 150,000 feet and at speeds of Mach 5 to Mach 15, while HSCT would fly within the atmosphere at 60,000 feet and at speeds of Mach 2 to Mach 5.[1]

Because of these technical differences, the potential uses for the two vehicles likewise differ. The NASP is seen more as a space and military aircraft while HSCT is a long-range, high-speed civil aircraft. Nonetheless, because the requirements and capabilities of high speed flight are similar, the planned technology developed for these two vehicles (although different) is parallel and complementary. NASP areas under development include propulsion systems and fuels; aerodynamics; materials and structures; flight and engine control systems; and displays and navigational systems. All of these efforts run parallel to those of HSCT, with much of the work performed by the same contractors. For example, use of a computational technique known as computational fluid dynamics was developed for the NASP, but it also will be applied to the HSCT.[2] In addition, NASA has indicated that NASP work in materials and computer analysis methods is applicable to HSCT.[3]

Numerous reports and official statements demonstrate the potential interrelationship between the two vehicles and their development. For example, one report states,

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[1] Jane's - All the World's Aircraft, 1989-1990 at 471; Commercial High Speed Aircraft Opportunities and Issues, Senate Committee on Commerce, Science and Transportation 2 (1989).

[2] Commercial High Speed Aircraft Opportunities and Issues, at 23; T.J. Gregory & H. Wright, National Aerospace Plane Status and Plans, May 1989, at 149-56; Jane's - All the World's Aircraft, 1989-1990, at 471.

[3] Commercial High Speed Aircraft Opportunities and Issues, at 58.

> "Although not directed toward a supersonic civilian aircraft, the NASP program bears some relation to the current interest in HSCT. . . . While there is little relationship between the NASP and an HSCT in the Mach 2-4 range, some of the technologies developed for the NASP may be applicable. The potential applicability would be significantly greater for an HSCT in the Mach 5 range . . . particularly with materials and engine technologies. In addition, the NASP program has contributed to the renewed interest in an HSCT and has helped maintain active research into high speed flight."[4]

The links between the military and civilian application of high speed flight are further demonstrated by a statement in National Aeronautical R&D Goals, a 1985 report prepared by the Executive Office of the President, Office of Science and Technology Policy which states,

> "Gaining sustained supersonic cruise capability is of very high priority for future military aircraft survivability. . . . However, this military capability is also aligned with highly constructive civil opportunities that could benefit the U.S. in important non-military areas as well."

The following sections describe the NASP and HSCT programs in greater detail.

B. National Aerospace Plane

1. Description of Program

NASP's origins can be traced to a 1984 Defense Advanced Projects Research Agency (DARPA) investigation into hypersonic air breathing propulsion. The first manifestation of a serious U.S. government interest in designing a hypersonic vehicle came in January 1986, when the government initiated a $700 million program to design the National Aerospace Plane. The NASP was envisioned as a vehicle that could take off horizontally from an aircraft runway, fly directly into low earth orbit at 25 times faster than the speed of sound and demonstrate single-stage-to-orbit (SSTO) operations. This would be made possible by developing certain key technologies, including air breathing propulsion, advanced materials and structures, actively-cooled

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4 Id. at 3.

structures and computational fluid dynamics.[5] The program was originally undertaken jointly by the DoD (through DARPA, the Air Force and the Navy), NASA and the Strategic Defense Initiative Organization. In April 1986, DARPA awarded $7 million in contracts to a number of U.S. aircraft manufacturers, including Boeing and McDonnell Douglas, in a competition for the conceptual design of the NASP. In 1988, the management of the NASP shifted from DARPA to the Air Force.[6]

The NASP is now in its Phase II contract stage, extended 30 months into January 1993, when a decision will be made on whether or not to build a pair of X-30 research vehicles to validate the computational fluid dynamics, materials, structures and propulsion development aspects of the program.

As part of Phase II, on February 1, 1991, the Air Force-NASA joint program office awarded five U.S. companies, joined in a single team, a $502 million contract to continue airframe and propulsion development on the NASP up to the planned 1993 deadline. The five companies are General Dynamics, McDonnell Douglas, Pratt & Whitney, and Rockwell International's Rocketdyne and North American Aircraft Divisions.[7] Each of these contractors has a lead role in different technological aspects of the program:

- McDonnell Douglas has lead responsibilities in the areas of fuselage development, vehicle thermal controls and aerodynamic stability and control;

- General Dynamics is to lead the integration of airframe subassemblies and integration of the vehicle's airframe and engines;

- Rockwell Corp.'s North American Aircraft is to lead efforts in developing the X-30's vehicle management system and vehicle subsystems;

- Pratt & Whitney has lead responsibility in engine flow path integration and controls; and

- Rockwell's Rocketdyne will lead engine systems integration and propulsion structures and materials efforts.[8]

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5 Statement by John J. Welsh, Jr., Assistant Secretary of the Air Force for Acquisition, Hearings before the Subcomm. on Research and Development of the Comm. on Armed Services and the Subcomm. on Technology and Competitiveness of the House Comm. on Science, Space, and Technology, March 12, 1991, quoted in Defense News, March 18, 1991, at 3.

6 "Aircraft Design," Aerospace America, December 1988, at 70.

7 Defense News, March 18, 1991, at 3.

8 Aviation Week & Space Technology, October 29, 1990, at 39.

2. Benefits

Although the primary function of the NASP as now contemplated focuses on single-stage-to-orbit operation with primary emphasis on the military applications of this capability, there also has been considerable discussion of the industrial and commercial benefits of this program. While the benefits and applications of the NASP are still under study and are not yet fully understood, there is a strong belief that through the NASP program a competitive base for future commercial hypersonic programs is being established.[9] NASP could yield "technologies that would not only add to an overall defense technology base but help to maintain U.S. leadership in technologies critical to the aerospace industry, show important benefits to a wide spectrum of high tech industries and provide revolutionary methods of transportation: civilian, military and space-oriented."[10]

One of the primary spinoff technologies frequently discussed in reference to the NASP is NASP-derived vehicles, or NDV, whose function would be to launch payloads into space in a cost effective manner.[11] Other areas where the technologies to be demonstrated in the NASP program could be applied to civilian transports include military aircraft; air, space, and fleet defense interceptors; space interdiction; and sustained hypersonic flight within the atmosphere.[12]

Work on composites is one of the primary areas of NASP development that is expected to have numerous commercial spinoffs. Early in the NASP program, government officials and industry experts recognized the importance of advanced materials to the program.[13] A consortium was therefore established to develop these materials cooperatively and accelerate their development. The National Materials and Structures Augmentation Program (NMASAP) consortium involves all five NASP contractors with the primary objective of accelerating the development of selected materials for the NASP research vehicle, the X-30, in a much shorter time than the typical 15 years

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9 See Statement of J. Welsh, supra note 5.

10 Id.

11 Space Flight, April 1991, at 134.

12 "NASP Keeps Moving," Space Markets, February 1989, at 84; see also NASP Materials and Structures Augmentation Program Overview, AIAA, October 1990, at 5.

13 Testimony by Robert H. Gulcher, Rockwell International and Ned D. Newman, McDonnell Douglas, on the NASP Materials and Augmentation Program, Hearing on the National Critical Materials Council before the Subcomm. on Transportation, Aviation and Materials of the House Comm. on Science, Space and Technology, June 26, 1990.

generally necessary to qualify materials for use in manned aerospace vehicles.[14]

As a participant in the NMASAP, each NASP contractor has a contract with the government to lead the development of a particular material. General Dynamics is developing refractory composites; McDonnell Douglas, titanium metal matrix composites; Pratt & Whitney, high specific creep strength materials; North American Aircraft, titanium aluminized materials; and Rocketdyne, high-conductivity composites.

The five contracts total nearly $150 million and involve subcontractors from across the nation. This was a significant increase over the $17 million level of funding initially established in the NASP program for material development.[15] As stated in Congressional testimony on the National Critical Materials Council, "the NMASAP team has already made the program a success by accomplishing many industry firsts as well as providing benefits and spin-offs in other areas. The NMASAP achievements have laid the ground work for material spin-offs which may be applicable to the medical, automotive, and commercial aircraft industries."[16]

3. NASP Funding

As shown on the following table, although there have been annual fluctuations in funding for NASP, total funding through FY 1991 was $1.8 billion.

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14 Id.

15 Id.

16 Id. at 66-67.

NASP FUNDING (millions)[17]

	DoD	NASA	Total
1988	$338	$148	$486
1989	569	237	806
1990	195	59	254
1991	163	95	258
1992[18]	[233]	[72]	[305]
Total	1498	611	2109

The NASP's proposed $305 million budget for 1992 has been divided according to its different technologies. A total of $105 million is allocated for air breathing engines; $65 million for materials structures; $55 million for airframe research; $45 million for test facilities; and $35 million for fuel subsystems.[19] According to John Welsh, Assistant Secretary of the Air Force for Acquisition, "the $2 billion invested by the U.S. government and U.S. companies in NASP research is four times what the rest of the world has spent on developing hypersonic planes."[20] $3.3 billion is the estimated total cost for the NASP technology development program.[21]

C. High Speed Civil Transport

1. Description of Program

High-Speed Civil Transport (HSCT) is a supersonic commercial aircraft which would fly at speeds two to five times faster than the speed of sound, over a range of about 10,000 km and carry about 300 passengers.[22] The HSCT

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17 NASP Fiscal Year 1991 Budget Request, at 15; "NASP Industry Consortium is Hailed as Model for Future High-Tech Projects," Space News, March 18, 1991, at 4.

18 The 1992 figures are budget requests.

19 Defense News, March 18, 1991, at 4.

20 Id. at 3.

21 Space Flight, April 1991, at 135.

22 Commercial High Speed Aircraft Opportunities and Issues, supra note 1, at 7.

would reduce the costs of air transportation services and travel time for both passengers and freight over long routes.[23]

The development of HSCT technology can be traced back to U.S. interest in and development of supersonic transport starting shortly after World War II. Programs such as the Supersonic Cruise Transport (SST), which started in the early 1960s, and the Supersonic Cruise Research (SCR) program, which lasted from 1973 until 1981, were instrumental in developing technology associated with civilian supersonic aircraft.[24] "The development of the HSCT benefited from previous and ongoing related work. This includes the supersonic transport work of the 1960s; the advanced supersonic work activity of the 1970s including follow-on research by NASA, the Concorde, and the National Aerospace Plane."[25]

In addition, various R&D programs initially undertaken for military purposes are now being transferred to HSCT applications. For example, test programs on military applications of vortex flap technology were expanded to include vortex flap research applicable to wing designs for the HSCT.[26]

In 1986, motivated by former President Reagan's speech on the "Orient Express," NASA let two 3-phase study contracts to Boeing Aircraft and McDonnell Douglas to examine the state of readiness of HSCT technology, alternative design concepts, environmental issues, and economic and market issues.[27]

In 1989, at the request of Congress, NASA developed a proposed HSCT research and technology (R&T) program to validate the technology needed for the aircraft industry to reach a decision on whether to proceed with development and production of an HSCT. The program focuses on the four areas of technology for the HSCT -- propulsion, aerodynamics, structures and materials, and systems -- with the objective of increasing operating efficiency for an HSCT well above that which could be achieved with current technology.[28]

Although the R&T program is aimed at developing technologies for an HSCT, NASA does not intend to build an aircraft prototype or even prototypes of major components. Rather, NASA hopes that at the end of the research and technology program, the technology will be validated to the point where the

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23 Id. at 4.

24 Id. at 12.

25 Study of High Speed Civil Transport, NASA 1989, at 17.

26 Aviation Week & Space Technology, June 18, 1990, at 84.

27 Study of High Speed Civil Transport, at 7.

28 Id. at 57.

U.S. aerospace industry will move forward and develop a commercial HSCT. According to NASA, its program should significantly lower the risks associated with development of an HSCT fleet through the research and validation of the technologies needed to meet environmental and economic requirements in the first decade of the 21st century.[29] To help ensure its success, the program is to be a joint industry-government activity along the lines of previous efforts under the leadership of NASA and its predecessor NACA.[30]

2. HSCT Funding

In 1989, with the initiation of the HSCT R&T program, estimates of combined NASA and industry contributions amounting to $1.5 to $2.0 billion over ten to twelve years were projected for this program.[31] NASA's 1990 budget included $25 million to initiate technology efforts related to the development of an environmentally and economically sound high speed commercial transport. In 1990, a NASA study contract was awarded to General Electric and Pratt & Whitney to look at the possibility of developing a Mach 1.5 to Mach 3.5 engine.[32]

In 1991, NASA efforts aimed at providing a foundation for development of a new HSCT were accelerated. NASA earlier had planned to initiate a six-year, $1-billion Phase 2 high-speed program in fiscal year 1993. Progress was so rapid in Phase 1, however, that at least one Phase 2 element involving propulsion system materials is being initiated in fiscal year 1992 with requested funding of $16.5 million.[33]

Although government funding for the research portion of the HSCT program appears to be forthcoming, there is considerable discussion of how a prototype and an actual HSCT fleet will be financed. Both government and industry representatives appear to acknowledge openly that government assistance will be needed to produce a commercial HSCT fleet, as development costs are expected to exceed levels economically feasible for manufacturers.[34] Some industry analysts estimate the cost of a prototype

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29 Id. at 7.

30 Id. at 57.

31 Id. Although there was no specific HSCT program prior to 1989, NASA spent approximately $10 to $15 million in FY '88 on related technologies. Id. at 12.

32 Aerospace Daily, October 10, 1990, at 43.

33 Aviation Week & Space Technology, March 18, 1991, at 149.

34 Commercial High Speed Aircraft Opportunities and Issues.

HSCT vehicle to be between $5 and $10 billion, although the cost situation is highly uncertain.[35]

While there is consensus in the industry that government assistance of some kind will be needed, there is little agreement about the form that assistance should take. Industry representatives feel the proper role for NASA is to undertake the research and validate the technology to resolve the high technological risks. However, the industry feels that it should take the lead in developing the program from that point on, even if additional federal support is needed.[36]

Others propose that the government should also buy the first several aircraft to be produced. This would provide a guaranteed market that could give manufacturers enough assurance of recovering their investment to permit them to proceed with commercial development after technology validation and demonstration. A difficulty with this approach, however, is the uncertainty about how many planes would have to be bought in order to provide a sufficient incentive.

As an alternative approach, some analysts have suggested tax credits, guaranteed loans and other financial assistance to help the industry proceed with commercial development of an HSCT. The likelihood that development costs will be very high, however, means that such incentives may not be sufficient in and of themselves to convince the industry to move ahead. However, reports indicate that in conjunction with guaranteed purchases or an international consortium, such financial incentives might be helpful.[37]

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35 Id.

36 Id.

37 Id. at 61.

AIRCRAFT ENERGY EFFICIENT PROGRAM (ACEE)

NASA's ACEE program was initiated in 1976 with the objective of increasing the fuel efficiency of aircraft through research and development (R&D) under six projects: (i) Advanced Turboprop; (ii) Energy Efficient Engine; (iii) Engine Component Improvement; (iv) Composite Primary Aircraft Structures; (v) Energy Efficient Transport; and (vi) Laminar Flow Control. Management of this program was undertaken by NASA's Lewis Research Center in Cleveland, Ohio and at NASA's Langley Research Center in Hampton, Virginia. As the ACEE program was specifically directed at reducing commercial air transport fuel consumption, this program provided direct benefits to the commercial aviation industry. Indeed, NASA estimated that the ACEE program provided industry with over a five-year jump up its technology learning curve concerning fuel efficiency.[1]

While most of the projects associated with the original ACEE program were concluded in the early to mid-80s, the commercial applications of many of these programs and their successors can be widely seen today. According to NASA experts, for example, "[t]he ACEE programme was the genesis of the Boeing 757 and 767 aeroplanes."[2] Outlined below is a description of the original six ACEE projects and the status of these projects today, together with a brief listing of follow-up NASA studies in this area.

A. Energy Efficient Engine (E3) Project

1. Historical Background

The E^3 project was an outgrowth of NASA's work in the early 1970s on a fuel-efficient engine. The goal of the E^3 project was to guide technology efforts for turbofan jet engines (specifically General Electric's CF6-50C and Pratt & Whitney's JT9D-7A) to: (i) reduce fuel usage by at least 12 percent and the performance deterioration rate by at least 50 percent; (ii) reduce direct operating costs by at least five percent; and (iii) meet future FAA regulations and EPA exhaust emission standards.[3]

Under the E^3 project, contracts were awarded to General Electric and Pratt & Whitney to: (i) design a Flight Propulsion System; (ii) design, build and test components; and (iii) integrate the components into engine systems for experimental purposes.

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1 Fuel Economy in Aviation, NASA, at 30 (1983) (hereinafter "Fuel Economy").

2 R. Petersen & B. Holmes, "U.S. Aeronautical Research for the 1990s," World Aerospace Technology 91, at 52 (London 1991).

3 Fuel Economy in Aviation, at 29; Comptroller General, Report to Congress, "A Look at NASA's Aircraft Energy Efficient Program," (GAO, July 28, 1980) at 39 (hereinafter "Comptroller's Report"); see also Aeronautics and Space Report of the President, 1981 Activities, at 26.

2. Current Status

The results of the E^3 program yielded a 12 percent reduction in specific fuel consumption, a 5 percent reduction in direct operating costs, and a 50 percent reduction in the specific fuel consumption deterioration rate. While original component test results focused on the General Electric CF6, the E^3 program resulted in numerous design and performance improvements for other engines as well. These included the PW-2000 for the narrow-body Boeing 757 and the PW-4000 series for wide-body aircraft such as the DC-10 and 747.

3. Costs and Funding

Fiscal year 1983 was the final year of funding for the E^3 project. Approximately $200 million were expended on the E^3 program over approximately nine years.[4]

B. Advanced Turboprop (ATP) Project

1. Historical Background

The objective of the ATP project was to develop technology for the efficient, reliable, and acceptable operation of a short-to-medium range, 100-150 passenger advanced turboprop aircraft at cruise speeds up to Mach .80 and altitudes up to 35,000. The goal was to achieve a 15 to 20 percent fuel savings over current turbofan aircraft while maintaining the cabin noise and vibration levels of those aircraft.[5]

Boeing, McDonnell Douglas, Lockheed, Pratt & Whitney and General Electric (GE) all participated in the ATP project. The program reached fruition in 1987 with successful validation of technology readiness in three series of flight tests: (i) GE/Boeing flight tests of the GE gearless unducted fan (UDF) on a Boeing B-727 aircraft; (ii) the NASA/Lockheed Propfan Test Assessment of a single rotation advanced turboprop on a Gulf Stream II aircraft; and (iii) the GE/McDonnell Douglas flight tests of the UDF on an MD-80 aircraft. These flight tests verified the readiness of ATP technology for commercial engine development. The commercial applications of this program, however, never reached series production because high noise levels and lower oil prices decreased the economic value of implementing this technology.[6]

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4 Comptroller's Report, at 42-43.

5 Fuel Economy, at 43.

6 NASA Aeronautics Research and Technology 1988, NASA (1988).

2. Current Status

According to an official involved in NASA's Engine Propulsion Program, propulsion work undertaken after 1987 as part of the ATP project has been refocused on Ultra High Bypass (UHB) engine technology.[7] UHB technology aims to reduce fuel consumption by an additional 25 to 30 percent beyond that of the latest generation turbofan-powered aircraft, providing up to a 50 percent improvement relative to the majority of aircraft that comprise the 100 to 150 passenger fleet.[8]

A UHB demonstrator flight test program undertaken by McDonnell Douglas in 1987 led the company to consider development of the MD-91 and MD-92, two commercial aircraft vehicles derived from the MD-80 series. However, according to industry sources, the MD-90 series utilizing UHB did not reach production because high noise levels and decreasing fuel prices eliminated the economic necessity and value of production. UHB programs were funded at approximately $12 million per fiscal year (FY) from 1988 through 1991.[9] Although FY '92 budget requests for this program were denied, NASA plans to make requests for FY '93 funding. NASA's goal is to reduce UHB noise levels so that if fuel prices increase, UHB engines will be in a position to enter production quickly.[10]

3. Costs and Funding

Total costs of the ATP project through 1987 -- when initial objectives were completed -- totalled $140 million.[11] The UHB program funding through 1991 was $48 million. Given that a large portion of UHB research concerns propulsion technologies potentially suitable for the High Speed Civil Transport (HSCT), future generations of UHB technology will be incorporated into HSCT research and have been programmed into the FY '92 NASA budget as such.[12]

C. Engine Component Improvement (ECI) Project

1. Historical Background

The ECI project was directed at improving the performance of various existing commercial aircraft engines and thereby reducing their fuel

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7 Information from NASA.

8 "UHB Technology Validation - The Final Step," AIAA-88-2807 (July 1988).

9 Information from NASA.

10 Id.

11 Id.

12 Id.

consumption. Contracts under the ECI project were awarded to Pratt & Whitney and GE, who in turn subcontracted with McDonnell Douglas, Boeing and three major airlines. The ECI project focused on three major air transport engines -- Pratt & Whitney's JT8D and JT9D, and GE's CF6.[13]

The ECI program advanced the state-of-the-art of thermal barrier coatings and ceramic seal systems; demonstrated the practicality of an advanced turbine clearance control system and an advanced fan design in the JT9D engine; and demonstrated the advantages of modern cooling, sealing and aerodynamic designs in the high pressure turbine and compressor of the JT8D engine.[14] These improvements were incorporated into existing JT8D and JT9D engines as well as into technology advances transferred to new engine configurations, including the PW2037 and the NASA-sponsored Energy Efficient Engine.[15] According to W.O. Gaffin, the ECI Program Manager at Pratt & Whitney, "[t]he ECI program resulted in significant improvements in current JT8D and JT9D engine models, and has made significant contributions toward improvements in advanced commercial engine models under development at PWA."[16] Among the aircraft that have benefited from this technology are the DC-9, DC-10 and Boeing 727, 737, and 747.[17]

2. Current Status

Improvements to jet aircraft engines resulting from the ECI program can currently be seen in savings of 2 to 4 billion gallons of fuel -- worth between $1.5 billion and $3 billion -- for aircraft entering service in the United States through 1990.[18]

3. Costs and Funding

Approximately $40 million were expended on the ECI program from 1974-1979, with 45 percent of the budget allocated to engine diagnostics and 55 percent to performance improvement.[19]

As a result of the commercial success of the JT8D engine, Pratt & Whitney has repaid the government approximately $19.2 million of the initial

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[13] Fuel Economy, at 9-10.

[14] NASA ECI Programs: Benefits to Pratt & Whitney Engines (1982).

[15] Id.

[16] Id.; see also Aviation Daily, March 7, 1989.

[17] Fuel Economy, at 15.

[18] Aviation Daily, March 7, 1989.

[19] Comptroller's Report, at 37; information from NASA.

$26.3 million ECI program contract.[20] The ECI program contract included provisions designed to recoup the government's investment if Pratt & Whitney made commercial sales as a result of the NASA program.[21] Repayments are based on sales receipts and licenses and technical agreements that permit others to sell, lease or manufacture parts for the two engines. Pratt & Whitney is expected to repay the remaining $7.1 million during the early 1990s.[22] In effect, Pratt & Whitney was provided an interest free loan on $26.3 million over approximately 15 years.[23]

D. Composite Primary Aircraft Structures (CPAS) Project

1. Historical Background

The CPAS project was an outgrowth of research conducted by NASA in the early 1970s. The goal of the CPAS project was to facilitate the use of composite components to reduce the weight of aircraft by 25 percent and to increase fuel efficiency by 10 to 15 percent.[24] The project sought not only to develop composite components but also to test them on transport aircraft.[25]

To implement the project, NASA contracted with Boeing, McDonnell Douglas and Lockheed to develop and test components in three stages: (i) representative secondary structures; (ii) medium-sized primary structures; and (iii) wing sections.[26]

According to NASA, the CPAS project pushed commercial aircraft companies 5-10 years ahead in composite research and utilization.[27] CPAS components have been used in a number of aircraft parts including: (i) the DC-10 rudder; (ii) the DC-10 and L-1011 vertical fin; (iii) the B-727 elevators; (iv) the B-737 horizontal tail; and (v) the L-1011 ailerons.[28] In addition, as stated by a Boeing official in a Senate Authorization Hearing

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20 Aviation Daily, March 7, 1989.

21 Id.

22 Id.

23 Information from NASA.

24 Fuel Economy, at 59-60.

25 Id. at 60.

26 Id. at 62-71.

27 Id. at 62-71.

28 Id.

for the 1986 NASA budget, this research was instrumental in the decision by Boeing to expand the use of composites in the 757/767 airplanes.[29]

2. Current Status

Although work on the CPAS project was completed in the mid-'80s, advances made in composite research during the CPAS project are now being used in projects such as the NASP and High Speed Civil Transport. These efforts should benefit the aircraft industry through reduced costs of composite R&D as well as shorter lead times on development efforts relating to composites.

3. Costs and Funding

The estimated annual cost to the government of R&D for the CPAS project has varied between $110 million and $217 million.[30]

E. Energy Efficient Transport (EET) Program

1. Historical Background

The EET project focused on the technological development of 'aerodynamics and active controls to form a data base for manufacturers that would assist them in building energy-efficient aircraft."[31] This focus on aerodynamics in the EET project included investigation of airfoils, winglets, airframes, engines, high-lift devices for a supercritical wing, laminar flow, surface coatings and active controls.[32] Boeing, McDonnell Douglas, Lockheed and Pratt & Whitney all participated in development and testing under the EET project.

2. Current Status

Examples of aircraft which have incorporated technology from this project are the DC-10 (winglets); the B-757 and 767 (high-lift devices); and the L-1011-500 (active controls).[33]

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29 Statement of R. Schauffle, V.P. Engineering, McDonnell Douglas, 1986 NASA Senate Budget Authorization Hearings, at 551.

30 Comptroller's Report, at 57-58.

31 Fuel Economy, at 77.

32 Id. at 77-91.

33 Fuel Economy, at 77-91.

3. Costs and Funding

The R&D cost estimate for the EET project was $85.7 million.[34]

F. Laminar Flow Control (LFC) Project

1. Historical Background

The LFC project was intended to "develop and demonstrate by 1985 a practical, reliable and maintainable suction system for reducing surface-airstream friction, thereby increasing fuel efficiency by 20 to 40 percent."[35]

Under this project, NASA contracted with Boeing, McDonnell Douglas and Lockheed to design potential configurations, structural concepts and suction systems to enhance laminar flow control.[36] NASA believed that LFC technology would be of greatest use on long-range flights (2,500 to 5,000 nautical miles). Although Boeing apparently suspended its LFC activities in 1978, McDonnell Douglas and Lockheed continued their participation in the project until its conclusion in the mid-1980s.

2. Current Status

At the conclusion of the LFC project, laminar flow control research was continued under NASA's Research and Technology Base Program with an emphasis on applications for fuel efficient subsonic and high speed transport.[37] Examples of several NASA tests undertaken in the area of laminar flow include a test undertaken in 1985 at NASA's Langley Research Center on the C-140 Jet Star to evaluate the laminar flow systems on typical commercial flight routes and to study the effects of weather on the system's operation and condition.[38] NASA had also flight tested a "contoured glove" installed on the wing of a Boeing 757.[39]

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34 Comptroller's Report, at 49.

35 Id.

36 Fuel Economy, at 101.

37 "Research in Natural Laminar Flow and Laminar Flow Control," NASA Conference Publication 2487 Pt. 1, at 2, 28 (1987); information from NASA.

38 Aviation Week & Space Technology, April 15, 1985, at 58.

39 NASA 1986 Annual Report, at 24-25.

3. Costs and Funding

The R&D cost estimate for the LFC project, which concluded in the mid-80s, was $227 million.[40] However, according to the NASA Technical Project Manager, a recent proposal for a "Wing Route Experiment," based on the laminar flow control program, and aimed at increasing fuel efficiency for 600 to 1,000 passenger subsonic transports, was submitted for budget authorization. This $300 million line item has yet to be approved.

40 Comptroller's Report, at 53.

TAX PROGRAMS

The U.S. system of taxation has provided significant benefits to the aerospace industry through various tax deferrals and exemptions. Based on publicly-available data, one can estimate that since 1976, these benefits have amounted to approximately $1.7 billion to Boeing and $1.4 billion to McDonnell Douglas. See Exhibit 4.

A. Completed Contract Method for Long-Term Contracts

1. Description of the Rules

The tax laws of the United States have permitted taxpayers to account for income received from certain long-term contracts under the completed contract method ("CCM") of accounting since at least 1918.[1] The stated rationale for CCM is that contracts extending over a long period of time may be subject to significant risks and thus the amount of profit realized by the taxpayer, if any, cannot be ascertained with any certainty until the contract is completed. However, tax policy analysts have viewed the CCM rules as a tax subsidy program for large companies like Boeing and McDonnell Douglas.[2]

CCM provides that the gross contract price is included in income, and costs associated with the contract are deducted, in the year the contract is completed and accepted. CCM accounting differentiates between "contract-related" costs, which are capitalized and deducted when the contract is completed and income is recognized, and "period" costs, which are deducted in the tax year in which they are paid or accrued and are not allocable to a long-term contract. Regulations adopted in 1976 provided very detailed rules for the allocation of costs between contract costs and period costs.

Repeal of the CCM rules was proposed by the Reagan Administration in 1982. The Tax Equity and Fiscal Responsibility Act of 1982 did not repeal the CCM rules, but did modify the cost allocation rules, requiring more extensive capitalization of costs.

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1 Treas. Reg. § 33, art. 121 (Revenue Act of 1916, as amended by Revenue Act of 1917). A "long-term contract" is generally defined as a building, installation, construction or manufacturing contract that is not completed by the end of the taxable year in which such contract is commenced. Treas. Reg. § 1.451-3(b)(1)(i).

2 See Citizens for Tax Justice, Third Annual List of America's Corporate Taxpayers and Corporate Freeloaders, July 1986 (noting that "for one set of particularly successful corporate tax avoiders, defense contractors, something called the 'completed contract method' is pivotal" to "legal" tax avoidance.)

The Tax Reform Act of 1986 ("1986 Tax Act") further reduced the revenue deferral available under the CCM rules.[3] Congress believed that the CCM accounting procedures permitted an unwarranted deferral of income for long-term contracts.[4] Thus, "Congress believed it was appropriate to limit the tax deferral obtainable through use of the completed contract method by requiring that a portion of the income from long-term contracts be reported on a percentage of completion method."[5]

The Congressional Joint Committee on Taxation ("Joint Committee") prepared the Study of 1983 Effective Tax Rates on Selected Large U.S. Corporations, which showed that several large corporations had significant levels of deferred taxes and low effective tax rates as a result of the CCM rules.[6] The Joint Committee noted that the annual reports of certain large defense contractors reflected negative tax rates resulting from net operating loss carryforwards generated through the use of the CCM rules in prior years.

The new rules provided by the 1986 Tax Act required all contractors, except for certain small construction contracts that are completed within 2 years, to use a hybrid "percentage of completion-capitalized cost method" ("PCM-CCM") to account for long-term contracts.[7] Under the PCM-CCM rules, a certain percentage of the contract items are accounted for under the percentage of completion method and the remaining costs are accounted for under the taxpayer's normal method of accounting, which could include the completed contract method. The 1986 Tax Act provided that contractors were required to account for 40 percent of the items with respect to a long-term contract under the percentage of completion method.[8] The remaining 60 percent could be accounted for under the CCM rules. These provisions are effective for contracts entered into after February 28, 1986.

The percentage of completion method is determined by comparing total contract costs incurred before the close of the taxable year with the total estimated contract costs. Gross income is recognized by the taxpayer according to the percentage of the contract completed during each taxable year, and costs incurred during the year are currently deductible. Thus, the taxpayer must include in gross income for the taxable year an amount equal to the product of (i) the gross contract price and (ii) the percentage of the

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3 P.L. 99-514, § 804 (enacting new I.R.C. § 460).

4 See Staff of Joint Committee on Taxation, 100th Cong., 1st Sess., General Explanation of the Tax Reform Act of 1986 (1987).

5 Id. at 527.

6 Id.

7 I.R.C. § 460(a)(1).

8 Id.

contract completed during the year, less any amounts included in gross income for prior years.

The Joint Committee estimated that the changes brought about in the accounting for long-term contracts by the 1986 Tax Act would raise approximately $10 billion of revenue over the five-year period from fiscal 1987 to fiscal 1991.[9] It was reported that approximately $1.5 billion of this amount would be raised from the aerospace industry.[10]

Over the following three years, Congress continued to reduce the tax deferrals available under the CCM rules. The Revenue Act of 1987 reduced the revenue deferral benefits associated with the CCM rules by requiring contractors to account for 70 percent of the items with respect to a long-term contract under the percentage of completion method.[11] Thus, only 30 percent of the items with respect to a long-term contract could be accounted for using the CCM rules. The Budget Committee of the House of Representatives explained that the current rules which allow a portion of a long-term contract to be reported under the CCM rules permit "an unwarranted deferral of income."[12]

Congress provided further limitations on the CCM rules in the Technical and Miscellaneous Revenue Act of 1988 by requiring contractors to account for 90 percent of the items with respect to a long-term contract under the percentage of completion method.[13] Congress once again recognized that the deferral provided by CCM does not provide an accurate measure of gross income over the course of a long-term contract.

> The committee believes that the rules of present law that permit a portion of a long-term contract to be reported on the completed contract or accrual method of accounting do not accurately measure the income earned under the contract for any taxable year because a portion of the income from the contract may be deferred until the contract [is] completed or the items produced under the contract are shipped or delivered. The committee believes that the percentage of completion method

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9 Id.

10 "Aerospace Industry Overview," Bear, Stearns, & Co. Report, August 29, 1986.

11 P.L. 100-203, § 10203.

12 Budget Committee Report, H.R. Rep. No. 391 (Parts 1 and 2), 100th Cong., 1st Sess. (1987).

13 P.L. 100-647, § 5041(a).

> provides a more accurate measure of income earned under a contract during any year.[14]

The CCM rules were eliminated by the Revenue Reconciliation Act of 1989 ("1989 Act") for all but a limited class of taxpayers.[15] After the 1989 Act, the only taxpayers excepted from the percentage of completion method are those taxpayers whose average gross receipts for the prior three taxable years do not exceed $10 million.[16] As a result, most long-term contracts entered into on or after July 11, 1989, must be accounted for under the percentage of completion method of accounting.[17]

2. Tax Benefits Realized

Prior to 1976, the CCM rules were restricted to construction, building and installation contracts. In 1976, the categories of eligible contracts were broadened to include long-term manufacturing. This change enabled aerospace contractors to utilize the CCM rules and, as of 1985, nearly all aerospace companies reportedly used the CCM rules to account for long-term contracts.[18]

The aerospace, shipbuilding and construction industries vigorously opposed repeal of the CCM rules in 1982. The aerospace industry argued that the proposals "could easily raise the cost of national defense more than they would produce in added tax revenues" (emphasis in the original) essentially maintaining that the tax expenditure was a more efficient subsidy than direct payments.[19] A similar argument was made in a July 28, 1986 letter to the Treasury Department by the CEOs of 10 major defense contractors, including Boeing, McDonnell Douglas and Hughes. Treasury, in a letter from Assistant Secretary J. Roger Mentz dated April 2, 1986, acknowledged the importance of the CCM rules to aerospace and certain other industries, and expressed the Administration's position that the method should be retained.

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14 Ways and Means Committee Report, H.R. Rep. No. 795, 100th Cong., 2d Sess. (1988).

15 P.L. 101-239, § 7621.

16 I.R.C. § 460(e).

17 I.R.C. § 460.

18 Statement of the Aerospace Industries Association before the Senate Finance Committee Hearings on the President's Tax Proposals, October 4, 1985.

19 Statement of John S. Nolan on behalf of the Aerospace Industries Association before the Senate Finance Committee on March 19, 1982, at 3, and before the House Ways and Means Committee on April 2, 1982, at 3 (emphasis in original).

In an informal survey of 22 aerospace defense contractors conducted by the Aerospace Industries Association in 1982, half of the companies reported that the deferred tax liability attributable to the CCM rules was equivalent to 25 percent of the shareholder equity of these companies.[20]

Boeing has reported deferred taxes attributable to "completed contract method and related inventory costs" of: $385 million in 1978; $52 million in 1981; $170 million in 1982; $138 million in 1983; $298 million in 1984; $248 million in 1985; and $354 million in 1986, for a total of $1.645 billion.[21] One can estimate that these tax deferrals, because of the time value of money, effectively saved Boeing approximately $619.55 million of interest over the period 1976 through 1990. See Exhibit 4.

McDonnell Douglas in 1980 reportedly paid no federal income tax and reported tax deferrals of $96.4 million on "earnings from uncompleted contracts."[22] In subsequent years, McDonnell Douglas' Annual Reports to shareholders show deferred income tax from uncompleted contracts of $363.9 million in 1978, $130 million in 1979, $96.4 million in 1980, $139.1 million in 1981, $117 million in 1982, $132.2 million in 1984, $95.1 million in 1985, $71.2 million in 1986, and $136 million in 1987, for a total of $1,280.9 million for the period from 1978 through 1987.[23] One can estimate that these tax deferrals, because of the time value of money, effectively saved McDonnell Douglas approximately $899.26 million of interest over the period 1976 through 1990. See Exhibit 4.

Because of changes brought about by the 1986 Tax Act and subsequent limitations in the CCM rules which resulted in the eventual elimination of the completed contract method for Boeing, McDonnell Douglas and other large aerospace contractors, these same companies have largely paid back those deferred taxes. In 1987, Boeing paid $316 million previously deferred under the CCM rules, as well as $677 million in 1988, $213 million in 1989, and $111 million in 1990.[24] In 1988, McDonnell Douglas paid $261 million

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20 Statement by John S. Nolan on behalf of the Aerospace Industries Association before the Senate Finance Committee on March 19, 1982, at 28.

21 See 1980 Boeing Annual Report at 29; 1983 Boeing Annual Report at 29; and 1986 Boeing Annual Report at 35.

22 Washington Post, March 27, 1982, at A1.

23 See 1980 McDonnell Douglas Annual Report at 34; 1983 McDonnell Douglas Annual Report at 25; 1986 McDonnell Douglas Annual Report at 30; 1989 McDonnell Douglas Annual Report at 37.

24 1989 Boeing Annual Report at 37; 1990 Boeing Annual Report at 39.

previously deferred under the CCM rules, as well as $268 million in 1989, and $207 million in 1990.[25]

This so-called payback, however, leaves these companies with a significant net tax benefit, for two reasons. First, the interest saved on the deferred tax payments will never be paid back and thus is a permanent financial benefit. The second benefit results from the reduction in corporate tax rates brought about by the 1986 Tax Act, which reduced the maximum corporate rate from 46 percent to the current rate of 34 percent. That is, taxes under the CCM rules were deferred during years in which the statutory rate was 46 percent, but were then paid back during years in which the statutory rate was reduced to 34 percent. This benefit can be roughly estimated as having been $429 million for Boeing and $334 million for McDonnell Douglas.[26]

B. Domestic International Sales Corporations and Foreign Sales Corporations

1. Domestic International Sales Corporations

Congress provided significant tax incentives for exports when it created the domestic international sales corporation ("DISC") in the Revenue Act of 1971.[27] There is little doubt that the tax deferral provided by the DISC provisions made export transactions more profitable than comparable sales made within the U.S.[28]

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[25] 1989 McDonnell Douglas Annual Report at 37; 1990 McDonnell Douglas Annual Report at 41.

[26] This estimate was arrived at using the following method and assumptions: If Boeing were paying taxes at the maximum statutory rate of 46 percent during the years it was deferring tax liability under CCM, the $1.645 billion of deferred taxes represent $3.576 billion of income upon which tax liability was deferred. If we assume that after CCM was abolished Boeing paid taxes on this income at the new lower maximum rate of 34 percent, Boeing saved 12 percent (the difference between the 46 percent and 34 percent rates) of this $3.576 billion, or $429 million. The equivalent figures for McDonnell Douglas are $2.784 billion of income upon which tax liability was deferred and a $334 million benefit (12 percent of $2.784 billion).

[27] See P.L. 92-178 (adding new sections 991 to 997 to the Internal Revenue Code ("I.R.C.")).

[28] See Rothkopf, "DISC: Qualifying under the New Export Income Laws: Advantages and Hazards," 36 J. Tax'n 130 (March 1972).

The DISC, which must be incorporated under the laws of a state or the District of Columbia, is exempt from federal tax.[29] Under the original DISC provisions, profits of a DISC were taxed to the shareholders only when distributed or deemed distributed to its shareholders. A DISC was deemed to have distributed 50 percent of its export profits and 100 percent of its nonexport profits annually. Federal tax could be deferred indefinitely on the remaining 50 percent of the DISC's export profits.

One of the significant benefits provided by the DISC was achieved through special intercompany pricing rules which allowed a substantial portion of the U.S. profit on sales from the U.S. parent corporation to the DISC to be attributed to the DISC.[30]

a. Tax Reform Act of 1976

The Tax Reform Act of 1976 retained the basic structure of the original DISC legislation. The DISC remained a non-taxpaying entity and the very favorable intercompany pricing rules remained in place. However, there was one important change in the deferral provisions which required the deferral to be computed on an incremental basis. For taxable years beginning after 1975, the 50 percent deferral of prior law was available only for "incremental export income," i.e., income attributable to export gross receipts in excess of 67 percent of average gross receipts over a four-year moving base period.[31]

The DISC provisions were a source of controversy between the United States and other signatories of the General Agreement on Tariffs and Trade ("GATT"), including members of the European Communities. The European Communities argued that the DISC was an illegal export subsidy because it essentially allowed an indefinite deferral of taxes on income earned in the United States.[32]

In 1976, a GATT Panel Report concluded that the DISC provisions had some characteristics of an export subsidy, primarily focusing on the fact that the U.S. taxpayers were not charged interest on the DISC tax deferrals.[33] The United States defended the DISC provisions and maintained that the DISC acted as an export incentive similar to provisions adopted by some of its European trading partners.

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29 I.R.C. § 991; Treas. Reg. § 1.991-1(a).

30 I.R.C. § 994(a); Treas. Reg. § 1.994-1(a).

31 P.L. 94-455, 94th Cong., 2d Sess., 90 Stat. 1520 (1976).

32 See Deficit Reduction Act of 1984, Explanation of Provisions Approved by the Committee on March 21, 1984, 98th Cong., 2d Sess., Vol. I, at 634 (Comm. Print 1984).

33 Id.

Even though not conceding that the DISC provisions violated GATT, the United States agreed to the adoption of the GATT Panel Reports on the DISC and the related tax practices of some of its European trading partners, including Belgium, France and the Netherlands. The Panel Reports were accepted, subject to a 1981 GATT Council decision which qualified the findings in the Panel Reports.[34] The 1981 GATT Council decision provided that, among other things, GATT signatories are not required to tax export income attributable to domestic economic processes; arm's-length pricing principles should be observed between exporting enterprises and commonly controlled foreign buyers; and the GATT does not prohibit measures intended to avoid the double taxation of foreign source income.[35]

Ensuing debate over the tax deferral benefits provided by the DISC provisions raised the possibility of a breakdown in the GATT dispute settlement process, resulting in the isolation of the United States over the DISC issue. The EC requested authorization from the GATT Council to take retaliatory action against the United States. To resolve these problems, the United States agreed to propose legislation that would address the concerns of other GATT members with respect to the DISC.

b. The Deficit Reduction Act of 1984

Legislation was adopted by Congress as part of the Deficit Reduction Act of 1984 ("1984 Tax Act"). All DISCs were deemed to have terminated on December 31, 1984. Any accumulated tax-deferred income of the DISC at December 31, 1984 was treated as previously taxed income and thus exempted from taxation. As a result, income that was considered to be tax-deferred income under the DISC provisions was permanently exempted from taxation.

Congress created the Foreign Sales Corporation ("FSC") to replace the DISC provisions. Congress knew, however, that the new FSC provisions might give rise to further EC protests:

> Although it was aware that the EC had again raised questions about the GATT compatibility of certain aspects of [the FSC] proposal, Congress enacted this legislation based on its own assessment, and that of the Administration, that the legislation satisfies GATT rules. In light of the considerable effort required to replace the DISC and the new burdens placed on U.S. exporters, Congress expected the Administration to defend vigorously the legislation against any GATT challenge and to inform Congress immediately

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34 Id.

35 Id.

of all GATT developments relating to the legislation.[36]

The DISC was not eliminated completely by the 1984 Tax Act. Instead, Congress created the "interest charge DISC," which continued the tax deferral to U.S. export companies on limited amounts of export income.[37] Like its predecessor, an interest charge DISC is a tax-exempt domestic corporation, with operational provisions similar to those provided under the original DISC provisions. However, the shareholders of an interest charge DISC are charged interest on the deferred income, with interest rates tied to Treasury bill rates.[38] Interest is calculated on the tax that would otherwise be due on the deferred income, as if such income actually was distributed to the DISC shareholders. In addition, the tax deferral is only available for taxable income not exceeding $10 million of qualified export receipts.[39] Taxable income attributable to qualified export receipts in excess of $10 million is deemed to be distributed and thus currently taxable to the shareholders.[40]

2. Foreign Sales Corporations

Congress created the Foreign Sales Corporation ("FSC") as part of the 1984 Tax Act in large part to replace the DISC. These provisions exempt a portion of the FSC's export income from tax by treating certain "exempt foreign trade income" as "foreign source income which is not effectively connected with the conduct of a trade or business within the United States."[41] Thus, the FSC differs from the DISC, which only allowed the deferral of income. The FSC exempts income from taxation rather than deferring payment.

A U.S. corporation is entitled to a 100 percent dividends-received deduction for distributions of earnings and profits attributable to foreign trade income, including both (i) exempt foreign trade income, and (ii) nonexempt foreign trade income which is determined under the administrative pricing rules.[42] Distributions from a FSC are deemed to be made first out of the FSC's foreign trade income. The result is that no corporate-level tax is imposed on exempt foreign trade income, and only a

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36 General Explanation of the Revenue Provisions of the Deficit Reduction Act of 1984, H.R. 4170, 98th Cong., 2d Sess. at 1042 (1984).

37 1984 Tax Act, § 802.

38 I.R.C. § 995(f).

39 I.R.C. § 995(b)(1).

40 Id.

41 I.R.C. § 921(a).

42 I.R.C. § 245(c).

single-level corporate tax (at the FSC level) is imposed on nonexempt foreign trade income. This contrasts with the DISC provisions which provided for no tax to be levied at the corporate level.

Only the "foreign trade income" of a FSC qualifies for the exemption from federal tax.[43] Foreign trade income is defined as the gross income of a FSC attributable to "foreign trading gross receipts."[44] Foreign trading gross receipts are defined as the gross receipts of a FSC from: (1) the sale, exchange, or other disposition of export property;[45] (2) the lease or rental of export property for use by the lessee outside the United States; (3) services which are related and subsidiary to those transactions described in (1) and (2); (4) engineering or architectural services for construction projects located (or proposed for location) outside the United States; and (5) certain managerial services performed for an unrelated FSC or DISC.[46]

Certain income is specifically excluded from the definition of foreign trading gross receipts if: (1) the export property or services are for ultimate use in the U.S. or for use by the U.S. government if such use is required by law or regulation; (2) such transaction is accomplished by a subsidy; or (3) such receipts are from another FSC which is a member of the same group of controlled corporations.[47] Investment income and carrying charges are also excluded from the definition of foreign trading gross receipts.[48]

A FSC will be treated as having foreign trading gross receipts only if two requirements are satisfied: (1) the management of the FSC is performed outside the United States; and (2) the "economic process" with respect to the

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43 I.R.C. § 921(a).

44 I.R.C. § 923(b).

45 "Export property," the sale of which gives rise to foreign trading gross receipts, is property manufactured, produced, grown, or extracted in the U.S. other than by a FSC, which is held primarily for sale, lease or rental by or to a FSC for direct use, consumption or disposition outside the U.S., and not more than 50 percent of the fair market value of which is attributable to imported articles. I.R.C. 927(a)(1). Export property specifically does not include: (1) Property leased or rented by a FSC for use by another member of the controlled group of corporations to which the FSC belongs; (2) Intangible property; (3) Oil or gas or any primary products thereof; (4) Products whose export is restricted to protect the economy; and (5) Products determined by the U.S. President to be in short supply. I.R.C. § 927(a)(2),(3).

46 I.R.C. § 924(a).

47 I.R.C. § 924(f)(1).

48 I.R.C. § 924(f)(2).

FSC transactions takes place outside the United States.[49] The foreign management requirement is satisfied if: (1) all meetings of the board of directors and of the shareholders take place outside the United States; (2) the FSC's principal bank account is maintained outside the United States; and (3) all dividends, legal and accounting fees, and the salaries of officers and members of the board of directors are disbursed from bank accounts outside the United States.[50]

The foreign economic process requirement has two parts, the first relating to the sales portion of the transaction, and the second relating to the direct costs incurred in connection with the transaction. With respect to the sales portion, an FSC will not be considered to earn foreign trading gross receipts from a transaction unless the FSC, or a person under contract with the FSC, participates outside the United States in either the solicitation (other than advertising), negotiation, or making of the contract relating to the transaction.[51] With respect to direct costs, an FSC will not earn foreign trading gross receipts from a transaction unless the foreign direct costs incurred by the FSC attributable to the transaction equal or exceed 50 percent of the total direct costs incurred by the FSC with respect to the transaction.[52] There is also an alternative test, under which foreign direct costs incurred by the FSC attributable to any two of five enumerated activities relating to disposition of export property equal or exceed 85 percent of the total direct costs of at least two of those five activities.[53]

The amount of foreign trading income which will be eligible for exemption from tax depends on which pricing rules are used to determine the amount of a FSC's foreign trade income. If arm's-length pricing is used, then the amount of exempt foreign trade income is generally 30 percent of foreign trade income if the FSC has a corporate shareholder.[54] If the income earned by the FSC is determined under the administrative pricing rules, then the amount of exempt foreign trade income is generally 15/23 of the foreign trade income if the FSC has a corporate shareholder, subject to certain limitations and qualifications.[55]

Some have questioned whether the tax savings are worth the administrative burdens of qualifying a corporation as a FSC, especially

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[49] I.R.C. § 924(b)(1).

[50] I.R.C. § 924(c).

[51] I.R.C. § 924(d)(1)(A).

[52] I.R.C. § 924(d)(1)(B).

[53] I.R.C. § 924(d)(2).

[54] I.R.C. §§ 923(a)(2) and 291(a)(4).

[55] I.R.C. §§ 923(a)(3) and 291(a)(4).

considering that the 1986 Tax Act reduced the highest marginal tax rates from 46 percent to 34 percent.[56] In particular, companies with "excess foreign tax credits" may no longer receive benefit from use of an FSC.

3. Benefits Derived from Use of DISCs and FSCs

The DISC and FSC provisions have benefited those companies engaged in significant exporting, including aerospace companies. The Aerospace Industries Association of America wrote a letter on January 30, 1984 to Senator Robert Dole, then chairman of the Senate Finance Committee, which stated that the industry's total exports reached $17.3 billion in 1983. The letter further observed that "the continuing ability of the U.S. aerospace industry to contribute a large trade surplus to the total U.S. balance of trade will depend on the industry's ability to effectively counter the growing competitive strength of foreign aerospace producers."

The amount of tax liability forgiven on accumulated DISC income by the 1984 Tax Act was estimated at between $10 and $14 billion for all industries. A report prepared by the staff of Senator Howard Metzenbaum estimated the U.S. tax deferral on DISC income at $13.6 billion. The report attributed more than $3 billion of this amount to ten corporations, including Boeing and McDonnell Douglas. A contemporaneous press report quoted a Senate aide as stating that "in absolute terms, Boeing and McDonnell Douglas would be among the principal beneficiaries of the forgiveness because of their large accumulated deferrals."[57]

On July 14, 1984 an editorial in the New York Times criticized the 1984 Tax Act for failing to reduce the federal deficit. Referring to the tax forgiveness of accumulated DISC income, the editorial stated that the "bill's greatest generosity is to companies with large export sales," naming Boeing and McDonnell Douglas, among others.

In its 1984 Annual Report to Shareholders, Boeing stated the extent of its deferred tax liability on DISC income as $397 million. 1984 Boeing Annual Report at 26. McDonnell Douglas' Annual Report disclosed that its accumulated deferred DISC income was $323.2 million. 1983 McDonnell Douglas Annual Report at 24. McDonnell Douglas' 1984 Annual Report does not disclose the total DISC forgiveness from which the company benefited, although the total forgiveness can be estimated as having been approximately $148 million.[58]

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56 P.L. 99-514, § 601(a).

57 Aviation Week & Space Technology, July 2, 1984, at 25.

58 This estimate was arrived at by multiplying the $323.2 million of deferred DISC income by the maximum statutory marginal tax rate of 46%.

As for the FSC, in Boeing's Annual Reports and SEC filings, Boeing disclosed that it has derived benefits from the FSC provisions of $35 million in 1985, $49 million in 1986, $22 million in 1987, $35 million in 1988, $44 million in 1989, and $97 million in 1990 for a total of $282 million.[59]

McDonnell Douglas disclosed in its 1986 Annual Report that it had "export tax-exempt income" of $18.9 million in 1985 and $9.3 million in 1986. 1986 McDonnell Douglas Annual Report at 30. In subsequent years, the Annual Reports showed export tax-exempt income of $9 million for 1987, $9 million for 1988, $26 million for 1989, and $8 million for 1990, for a total of $80.2 million for the period 1985 through 1990.[60]

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59 1986 Boeing Annual Report at 35; 1989 Boeing Annual Report at 39; 1990 Boeing Annual Report at 39.

60 We have assumed that export tax-exempt income refers to the FSC tax benefit in such years, since from earlier Annual Reports it is clear that the term export tax-exempt income for years before 1984 referred to DISC tax-exempt income. <u>Compare</u> 1983 McDonnell Douglas Annual Report at 24 <u>with</u> 1985 McDonnell Douglas Annual Report at 30.

USE OF GOVERNMENT FACILITIES

A. Historical Background

The impetus for the establishment of U.S. government aeronautic testing, research and development facilities occurred at the beginning of World War II when it became evident that a rapid expansion of the aircraft industry was required. Initially, the U.S. government offered special incentives and a variety of economic concessions to the industry, such as rapid depreciation schemes allowing companies to amortize newly constructed plants over the space of five years, as compared to the normal 20- or 30-year period. However, incentives and concessions did not sufficiently encourage the construction of much-needed large aircraft factories. These were eventually built at public expense and leased to the companies. After the war, the aircraft business decreased and the U.S. government was unable to convince companies to purchase these factories. As a result, companies such as General Dynamics and Lockheed still continue to lease factories from the government, thereby avoiding the fixed cost of owning a large facility, as well as certain state property taxes.

Today, the most important government-owned facilities utilized by the aircraft industry are operated by NASA and the Air Force and these facilities are examined below.[1] These facilities -- which include wind tunnels, propulsion laboratories and supercomputers -- provide a broad range of testing and research and development capabilities. As of 1985, the replacement value of NASA and Department of Defense facilities alone was estimated to be $10 billion.[2]

B. NASA Facilities

NASA's aeronautical research facilities -- including wind tunnels, simulators and advanced computing facilities -- have been described by NASA as "unique national assets."[3] Indeed, the Chairman of the House Subcommittee on Transportation, Aviation and Materials has credited those facilities with "provid[ing] the foundation for America's traditionally strongest industry, building airplanes."[4]

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[1] In addition, the Navy, Army, and Departments of Energy, Commerce, and Transportation, also maintain federal aeronautics facilities. Federal Laboratory and Technology Resources, U.S. Department of Commerce (1990).

[2] The Competitive Status of the U.S. Civil Aviation Manufacturing Industry 117 (1985).

[3] NASA Aeronautics, 1991.

[4] Cong. Rec. 2194 (May 13, 1982) (Statement of Rep. Glickman).

As of 1982, NASA maintained 42 major aeronautical research facilities among its centers, valued at approximately $4 billion.[5] As of 1985, fourteen of those facilities had no equal worldwide in size and/or speed in meeting user requirements.[6] Indeed, the AIAA has said that "NASA's 19 wind tunnels underpin U.S. competitiveness in civil aeronautics."[7]

NASA's wind tunnels alone are valued at several billion dollars. NASA Aeronautics, 1991. The value of these wind tunnels is further evidenced by the 1989 NASA Major Wind Tunnel Revitalization Program, to be completed in 1993 for approximately $300 million. The wind tunnel program will replace the structural shell and refurbish the test section and equipment of the Ames pressure wind tunnel; rehabilitate motors and critical equipment for the Lewis supersonic tunnel; and modernize nozzles, heaters, and controls for the hypersonic facilities complex at Langley.[8]

In addition to supporting the work of NASA, these facilities support research and development being undertaken by the aerospace industry and other Government agencies, including the Federal Aviation Administration (FAA), the Department of Defense (DoD), and the Department of Energy (DoE).[9]

NASA's aeronautics research and testing (R&T) programs are primarily conducted at three research centers: the Ames Research Center located in Moffett Field and Edwards, California; the Lewis Research Center in Cleveland, Ohio; and the Langley Research Center in Hampton, Virginia. Each center conducts research in close coordination with other government research organizations, universities and industry. In practice, the centers conduct four general types of testing:[10]

NASA only -- NASA sponsored projects.

NASA-industry -- Projects conducted jointly by NASA and industry. Although each project is negotiated on a case-by-case basis, several generalizations can be made:

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5 J. Langford, Federal Investment in Aeronautical Research & Development: Analyzing the NASA Experience, at 28-29 (MIT Doctoral Dissertation, June 1987).

6 Aeronautical Facilities Catalogue, Volume 1, NASA, January 1985.

7 Aerospace America, February 1988.

8 1991 NASA Authorization Hearings, March 20, 1990 at 27; Aviation Week & Space Technology, October 8, 1990; NASA Aeronautics, 1991.

9 NASA Aeronautics, 1991.

10 Information from NASA.

- NASA typically pays both variable and fixed costs associated with the project. NASA's contribution is funded through its budget. NASA normally provides at its expense the testing facilities, engineering capability, and power/electricity to support the project; the industry partner pays only for the hardware or model to be tested.

- There is no exchange of funds between NASA and the industry partner in these cooperative programs, regardless of whether their objectives are commercial or military applications.

NASA-government -- Projects conducted by NASA and DoD, including testing by commercial entities under DoD-sponsored projects.

Industry only -- Projects that involve the use of a NASA facility by a private company for research or testing, where the data generated by the projects are held as proprietary information by the user company. NASA officials stated that all direct and indirect costs associated with the project are borne by the user company. NASA officials also say that NASA facilities are used infrequently for this purpose, because a heavy fee is charged to the user company.

Of these four types of users of NASA test facilities, it is the second -- joint NASA-industry projects -- that readily appears to involve benefits to private industry. In such projects, private companies are essentially being allowed to use extremely valuable test facilities for free. The projects are ones which necessarily concern issues of interest to NASA, but given NASA's broad involvement in civil aviation, the project may still be of direct commercial significance to the companies.

The results of such joint projects may be published by NASA, but it is not known what percentage of commercially significant results are in fact published. In addition, NASA may sometimes agree not to release data for some period, usually not more than 12 months, after the testing has been completed.

Three of NASA's major aeronautics R&T facilities are described below.

1. Ames Research Center

a. Description of Facility

The Ames Research Center has facilities valued at approximately $3 billion and includes a facility in Moffett, California (Ames-Moffett) as well as the Dryden Flight Research Center (Ames-Dryden).[11] In addition to maintaining the world's largest network of wind tunnels, valued at

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[11] Aviation Week & Space Technology, June 24, 1991, at 45.

$1 billion, the Ames Research Center has a number of unique capabilities ranging from aerodynamic testing and flight simulation, to human factor research, to computer and supercomputer technology available through numerical aerodynamic simulation.[12] Ames-Dryden's extensive flight test research capability complements the Ames-Moffett ground test capability. Key systems technology areas at the two centers include: propulsion/airframe integration, powered lift technology, and rotorcraft aeromechanics.

All of these facilities and capabilities are available to and utilized by the aircraft industry for both military and commercial applications.[13] Nearly every important aircraft developed in recent years has been tested in the wind tunnels at Ames. The results of future research on High Speed Civil Transport (HSCT), the National Aerospace Plane (NASP), and other new commercial aircraft will be tested at Ames.[14]

Projects conducted at Ames-Dryden have led to major advances in many military and civil aircraft. For example, during the 1970s, an F-8 aircraft was modified at Ames-Dryden with an all-electric flight control system from which developed the digital fly-by-wire concept now used on both military and commercial aircraft.[15] In addition, an F-8 was also used in the 1970s to

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12 Aerospace America, October 1990; Aviation Week & Space Technology, June 24, 1991, at 45.

13 According to the Office of Science and Technology, the utilization percentage of Ames Research Center facilities by civil, military, and NASA entities is as follows:

	Percentage of Use for:		
Facility	Civil Purposes	Military Purposes	NASA Purposes
12' Pressure Tunnel	18%	32%	50%
Flight Simulator for Advanced Aircraft	10	55	35
Vertical Motion Simulator	25	15	60

J. Langford, Federal Investment in Aeronautical Research and Development: Analyzing the NASA Experience, at 29. It is not clear from this publication whether "NASA purposes" includes joint NASA-civil use of the facilities.

14 Aviation Week & Space Technology, October 8, 1990, at 71.

15 NASA Facts, NASA, January 1991, at 2.

test a new airfoil called a supercritical wing, which is now widely used on both military and commercial aircraft.[16]

Ames' state-of-the-art supercomputer complex -- known as the Numerical Aerodynamic Simulation System (NAS) -- is used in computational fluid dynamics and is considered a "national asset."[17] The NAS has been and continues to be used to pioneer new developments over a broad range of aerospace applications including structural mechanics, aeroelasticity, turbo-machinery, rotorcraft and powered lift modeling, as well as for development of the NASP. The NAS is used by the aerospace industry, universities and federal agencies. The selection criteria for use of the computer complex include national need, how timely the proposed project is, and the technical quality of the project.[18]

b. Description of Benefit

As with other NASA facilities, private companies are charged a fee for tests they conduct at the Ames facilities that are not performed in conjunction with a government agency. Fees for standard tests conducted by private companies at Ames' facilities are roughly between $3,000 and $4,000 per hour.[19] For example, at the end of 1990, Boeing tested its 767-X model in Ames' facilities at a price of $750,000 for four weeks of testing.

2. Lewis Research Center

a. Description of Facility

The primary focus of the Lewis Research Center's facilities and capabilities is propulsion, including aeropropulsion, jet propulsion, space propulsion, space power, and space science/applications. Lewis' aeropropulsion facilities are particularly relevant to the development of U.S. civil and military aircraft.[20]

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16 Id.

17 Aerospace America, October 1990.

18 Id.

19 Information from NASA.

20 NASA Aeronautics, 1991. According to the Office of Science and Technology, the utilization of Lewis facilities by civil, military and NASA entities is as follows:

	Percentage of Use for:		
Facility	Civil Purposes	Military Purposes	NASA Purposes

[Footnote continued on next page]

Several collaborative government and industry projects have been undertaken which have directly benefited the commercial aircraft sector. An example of such a project is the 1987 joint effort of NASA-Lewis and a NASA/industry team working on advanced turboprop propulsion as part of the Aircraft Energy Efficient (ACEE) Program.[21] Flight tests and wind tunnel testing of scale models helped Boeing and McDonnell Douglas design the turboprop for future aircraft in the 100-150 passenger class.[22]

b. Description of Benefit

As noted above, private industry does not pay NASA for the use of its facilities where, as with the ACEE program, the tests are performed as part of a joint NASA-industry project. The ability to use NASA facilities without charge on joint projects with the U.S. government clearly confers a benefit on the U.S. industry. When private companies use the facilities on their own, they pay a fee. Although there is not a set fee schedule for the use of Lewis' major facilities by private industry, NASA provides the following rough order of magnitude for test costs, which do not include the cost of test-specific equipment:[23]

[Footnote continued from previous page]

High Pressure/Temp Facility	0%	0%	100%
8 x 6 Trans/Supersonic Tunnel	55	0	45
Icing Research Tunnel	28	30	42

J. Langford, Federal Investment in Aeronautical Research and Development: Analyzing the NASA Experience, at 29. It is not clear from this publication whether "NASA purposes" includes joint NASA-civil use of the facilities.

21 Aerospace America, October 1988, at 14-15.

22 Id.

23 Aeropropulsion Facilities and Experiments Division, NASA Lewis Research Center (undated).

Facility	Cost (per week)
10' x 10' Wind Tunnel	$ 160,000
8' x 6' Wind Tunnel	80,000
9' x 15' Wind Tunnel	55,000
Propulsion Systems Lab (PSL)	200,000
Icing Research Tunnel	40,000

3. Langley Research Center

a. Description of Facility

The Langley Research Center specializes in fundamental aerodynamics and fluid dynamics, computer science, unsteady aerodynamics, and aeroelasticity. Aerodynamic testing to support the research in each of these areas is a major focus of the Center. In addition, the Center is a leader in structures and materials research with a primary focus on the development and validation of structural analysis methods and research in airframe metallic and composite materials. The Center also conducts fundamental research on fault tolerant electronic systems and flight control.[24] A number of Langley facilities are used for both civil and military applications.[25]

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24 NASA Aeronautics, 1991.

25 According to the Office of Science and Technology, the utilization of Langley facilities by civil, military and NASA entities is as follows:

	Percentage of Use for:		
Facility	Civil Purposes	Military Purposes	NASA Purposes
.3M Cryogenic Transonic Tunnel	40%	0%	60%
National Transonic Facility	40	40	20
Transonic Dynamic Tunnel	7	45	48
Spin Tunnel	30	13	57
8' High Temp Structure			

[Footnote continued on next page]

Langley has been involved in several government/industry projects aimed at developing commercial applications for the aircraft industry. For example, in 1990, a joint government-industry program, which included the Air Force's Wright Research and Development Center, NASA-Langley, and Boeing's Commercial Airplane Group, modified and tested a wing-suction device designed to produce laminar air flow over a wing to reduce airplane drag by 10 percent or more. This program modified 22 feet of the left wing of a Boeing 757 jetliner with a titanium leading edge skin penetrated by roughly 19 million tiny holes drilled with a laser.[26] As a result of this program, Boeing proved that it could manufacture a sufficiently smooth, permeable wing structure at a reasonable cost. Each percentage point of drag eliminated by the U.S. transport fleet represents an estimated savings in fuel costs to the U.S. airline industry of $100 million annually.[27] Such fuel savings benefit Boeing by making its aircraft more competitive in the marketplace. Moreover, because this was a joint industry-government project, Boeing presumably did not pay for the use of Langley's facilities.

b. Description of Benefits

Listed below are the charges to private companies for the use of several of Langley's facilities:[28]

[Footnote continued from previous page]

8' High Temp Structure Tunnel	0	10	90
Impact Dynamic Facility	10	20	70
Landing Loads & Traction Facility	10	45	45
Aircraft Noise Reduction Lab	30	0	70

J. Langford, Federal Investment in Aeronautical Research & Development: Analyzing the NASA Experience, at 29. It is not clear from this publication whether "NASA purposes" includes joint NASA-civil use of the facilities.

26 Aviation Daily, August 24, 1990, at 360.

27 Id.

28 Information from NASA.

Facility	Cost (per week)
14' x 22' Subsonic Windtunnel	$ 56,788
16' Transonic Windtunnel	66,240
Unitary Plan Windtunnel	53,827

C. Air Force Facilities

The U.S. Air Force maintains numerous aeronautic test facilities including the Wright Research Laboratory, Air Force Flight Test Center, Design and Analysis Branch, Flight Dynamics Laboratory, Propulsion Wind Tunnel Facility, and Von Karman Gas Dynamics Facility. These facilities, and in particular, Wright Research Laboratory and the Air Force Flight Test Center, conduct research and testing in conjunction with private industry.[29]

Private companies use these facilities normally only as part of a DoD-sponsored project. In such situations the facility may be provided to the contractor at no charge, as part of the government's contribution to the project. To the extent that DoD-sponsored R&D projects involve commercially relevant work for private companies, those companies are deriving a benefit from the free use of the military test facilities.

Two of the U.S. Air Force's test facilities are described below:

1. Wright Research Laboratory

a. Description of Facility

Wright Research Laboratory is made up of the Aerospace Structures Information and Analysis Center (ASIAC) and the Flight Dynamics Laboratory. Its functional areas include all facets of aerospace structural design and analysis, and structures and dynamics.[30] Wright Research Laboratory recently worked in conjunction with Boeing and NASA on the Boeing 757 to produce laminar air flow over the wings.

b. Description of Benefits

The Wright Research Laboratory can only be used by the U.S. aircraft industry in conjunction with a federal partner. In these projects -- which are called cooperative research and development agreements (CRDAs) -- the federal partner provides personnel, services, facilities and equipment while

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29 Federal Laboratory and Technology Resources, U.S. Department of Commerce, 1990.

30 Federal Laboratory and Technology Resources, U.S. Department of Commerce, 1990.

the industry partner contributes its resources as well as funding. Wright apparently does not provide funding for CRDAs.[31]

2. Air Force Test Flight Center

a. Description of Facility

The Air Force Test Flight Center at Edwards Air Force Base conducts and supports tests of manned and unmanned aerospace vehicles and conducts flight evaluations and recovery of research. The center is known worldwide for its unique ability to conduct aerodynamic tests on current and future aircraft that will serve the United States. Since the early 1980s, the Air Force Flight Test Center has experienced a steady increase in test and support activity. Federal funds were recently allocated to correct severe problems with the Center's infrastructure.[32]

The Air Force Flight Test Center is utilized by the aircraft industry for civil and military projects. For example, the U.S. Air Force/McDonnell Douglas C-17 transport is scheduled to begin flight testing sometime during 1991 or 1992. Indeed, a new facility was built at Edwards for aerial delivery evaluations. The C-17 Combined Test Force (CTF) expects to have five aircraft at Edwards by February 1992 and to have between 900 and 1000 people housed in upgraded facilities by June 1992. The CTF will be conducting a multiservice test program because the U.S. Army will be the C-17's biggest customer.[33] At this time, it is unclear whether the C-17 will have future commercial applications.

b. Description of Benefits

In order for the aircraft industry to utilize the Air Force Flight Test Center, a company must have a DoD sponsor. Depending on the particular project, the Air Force Flight Test Center's contribution to the project includes labor, facilities, expertise, and fuel.[34]

D. Changing Role of Government-Owned Facilities

Although many government-owned facilities were originally built at public expense and leased to aircraft companies, the role of these facilities with regard to industry has evolved into a more collaborative relationship. Through programs such as NASP, a process called "mainlining" has developed in which government laboratories and research centers accept responsibility for pieces of work related to the main development path of the program.

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31 Information from DoD.

32 Aviation Week & Space Technology, February 4, 1991.

33 Id.

34 Information from DoD.

Mainlining brings the government-run facilities into positions often played by contract research laboratories or subcontractors. This allows the program officials to consolidate the skills needed in the program. In addition, it permits a clear line of responsibility and accountability for every item developed under the effort.[35]

This new role for researchers and technicians at government facilities will further integrate the capabilities and resources of government-funded efforts with industry initiatives, thereby increasing the benefits to industry from these centers.

35 Aviation Week & Space Technology, October 29, 1990.

DEPARTMENT OF DEFENSE
AERONAUTICS RESEARCH AND DEVELOPMENT
Fiscal Years 1976-1989

Year	$ (millions)
BUDGET AUTHORITY	
1976	1,941
Tr. Qtr.	480
1977	2,256
1978	2,807
1979	2,240
1980	2,336
1981	2,653
1982	2,984
1983	3,221
1984	3,224
1985	3,422
1986	4,927
1987	4,179
1988	5,223
1989	5,063
TOTAL 1976-1989	$ 46,956
OUTLAYS*	
1982	2,657
1983	2,920
1984	2,995
1985	3,101
1986	4,373
1987	4,182
1988	4,656
1989	4,896
TOTAL 1982-1989	$ 29,780

SOURCE: Aerospace Facts and Figures 90-91 110 (1990)

* Figures for outlays are not available for years prior to 1982.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

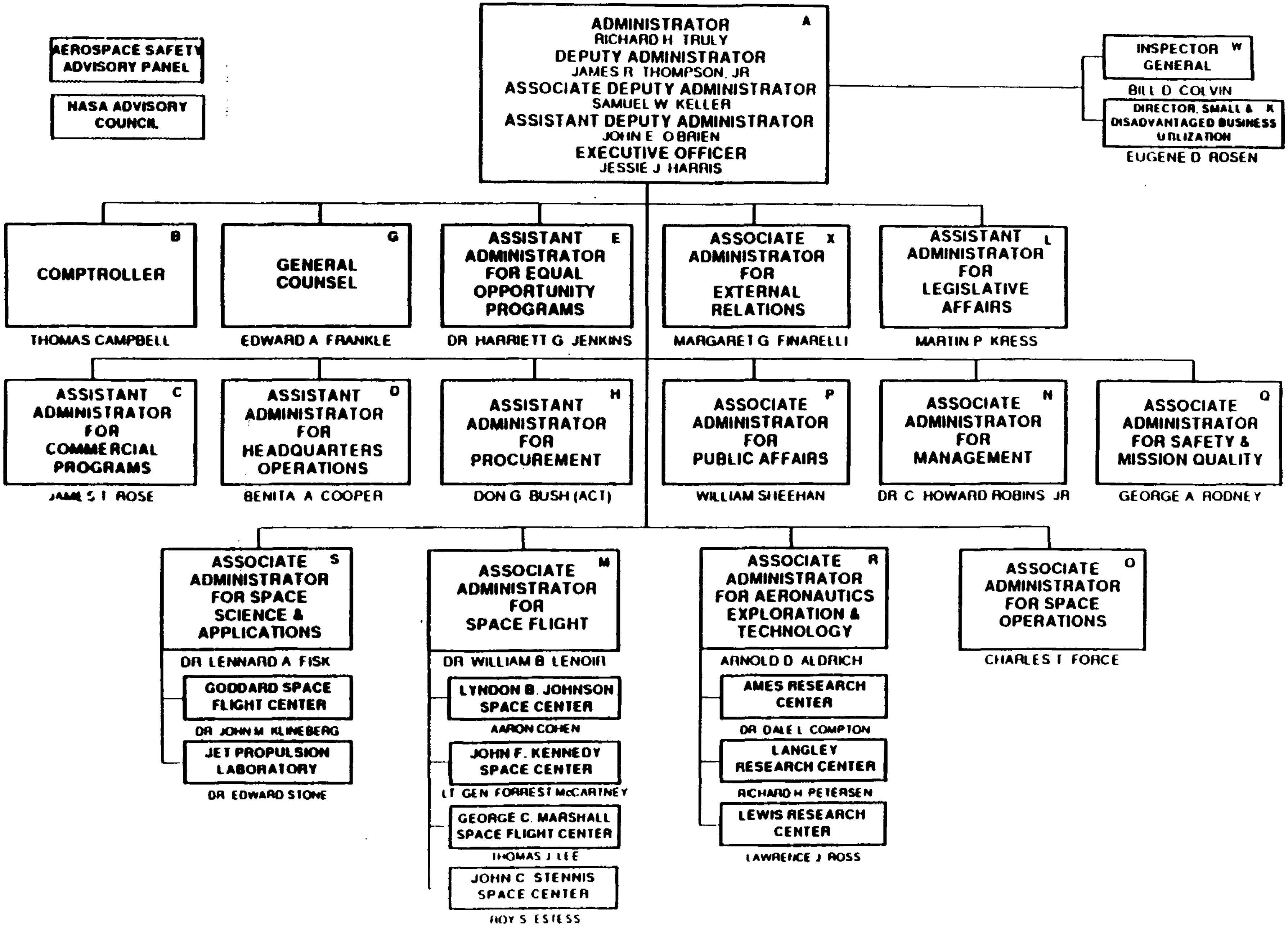

EXHIBIT 2

NASA AERONAUTICS BUDGET 1976-1990
(in millions)

Year	Total NASA Budget	Aeronautics Budget	% of Total Budget
1976	$ 3,550.3	$ 324.9	% 9.2
1977	3,817.8	377.6	9.9
1978	4,060.1	437.2	10.8
1979	4,595.5	565.1	12.3
1980	5,240.2	559.8	10.7
1981	5,518.4	526.0	9.5
1982	6,043.9	516.3	8.5
1983	6,875.3	547.4	8.0
1984	7,248.0	599.7	8.3
1985	7,572.6	647.7	8.6
1986	7,766.0	601.0	7.7
1987	10,507.0	698.0	6.6
1988	9,025.8	723.4	8.0
1989	10,969.0	871.5	7.9
1990	13,073.4	931.8	7.1
Total	105,863.3	8,927.4	8.4

Source: The Aeronautics and Space Report of the President, 1976-1990, Appendices E1 (Space Activities of the U.S. Government) and E3 (Aeronautics Budget for NASA).

Summary of Estimated Tax Benefits
(all figures are in millions)

Boeing

	FSC permanent tax deferral	DISC tax liability forgiven	CCM interest on deferred payments[1]	CCM lowered rate on deferred payments	Total Benefits By Year
1990	$97.00				$97.00
1989	44.00				44.00
1988	35.00				35.00
1987	22.00			$429.00	451.00
1986	49.00		$119.45		168.45
1985	35.00		113.91		148.91
1984		$397.00	89.11		486.11
1983			94.90		94.90
1982			91.02		91.02
1981			34.21		34.21
1980			27.97		27.97
1979			22.02		22.02
1978			26.96		26.96
1977			0.00		0.00
1976			0.00		0.00
Totals:	$282.00	$397.00	$619.55	$429.00	$1727.55

McDonnell Douglas

	FSC permanent tax deferral	DISC tax liability forgiven[2]	CCM interest on deferred payments[1]	CCM lowered rate on deferred payments	Total Benefits By Year
1990	$8.00				$8.00
1989	26.00				26.00
1988	9.00				9.00
1987	9.00		$99.67	$334.00	442.67
1986	9.30		88.79		98.09
1985	18.90		103.87		122.77
1984		$148.67	94.36		243.03
1983			129.82		129.82
1982			169.28		169.28
1981			87.53		87.53
1980			70.84		70.84
1979			29.63		29.63
1978			25.47		25.47
1977			0.00		0.00
1976			0.00		0.00
Totals	$80.20	$148.67	$899.26	$334.00	$1462.13

1 Calculated as interest earned on a one-year deferral at the following rates:

1987 8%
1986 8%
1985 10%
1984 10%
1983 16%
1982 20%
1981 12%
1980 12%
1979 6%
1978 7%

2 This figure is an estimate derived by multiplying McDonnell Douglas' $323.2 million of accumulated deferred DISC income by the maximum statutory corporate tax rate for 1984 of 46%.