and successfully transferred the technology smoothly by utilizing the industry partnerships that were developed throughout the research.[5-35]

- 1995—NASA licenses the "ice zapper" (Electro-Expulsive Separation System), developed in 1988 from research at Ames, to Ice Management Systems, Inc. for development and marketing. The Lancair Aircraft Company has agreed to help to develop this for use on their aircraft. This has very high potential for increasing safety of very high-level flights as well as winter flying.[5-36]

- 1995—The General Electric GE90 turbofan engine makes its first flight aboard a British Airways Boeing 777. One of the most powerful air-breathing engines ever flown, it was initially certified for 84,700 pounds of thrust and is now rated for 92,000 pounds. This engine is designed to power all models of the 777 in development and other subsonic commercial widebodies planned in the next 20 years. This engine has a 10% better fuel consumption ratio than other large turbofans, lower noise levels, and emissions of 35 to 60% less. This engine benefited from two different research programs. The Quiet Clean Short-haul Experimental Engine program, and the Energy Efficient Engine program, both conducted at NASA Lewis in the 1970s.[5-37]

- 1996—Templeman Industries Aerospace Systems, Inc. developed a composite environmental air duct that offers a weight reduction of 50% in comparison to existing metallic ducting. Turned to NASA Marshall Space Flight Center to conduct a structural evaluation since it lacked the facilities and contacts to do conduct the evaluation itself. The ducting is now in production and in use by aircraft offering weight savings and thereby, increased fuel efficiency.[5-38]

- 1998—The Center-TRACON Automation System (CTAS) is installed at Dallas/Ft. Worth International and is in daily use. CTAS is software designed to optimize flight operations by being integrated into the existing radar systems. CTAS is saving an average of two minutes per flight, which lowers the costs of operation and fuel usage.[5-39]

- 2001—Ice thickness gauge researched and developed at NASA Langley. Awaits partnership with a company to commercialize the technology. Inexpensive, small and simple to produce, these sensors can be adapted to detect ice accumulation on wing surfaces and can warn of potential danger earlier so that de-icing can begin earlier. Benefits include increased safety and increased fuel efficiency due to the reduction in drag.[5-40]

These are just a few of the success stories of NASA R&D and the spillovers of that research and technology into the air transportation sector of the economy. The catalogue of successes is too great to list here, and even the failures have contributed information to the industry that may be developed for a new application at a later date.

5.5 Measures of Productivity in Air Transportation Sector

The air transportation sector, as well as the aeronautics industry as a whole, is a very large and diverse industry. The priorities that each of these actors has for research and technology are varied and driven by competition, especially since deregulation. To determine the total benefits derived from NASA R&D would require that the amount of benefit of each of the interests involved be quantified. Add to this the difficulty in identifying the path that the research and technology advances take:

> "Selecting metrics of potential benefits from a specific technology is complicated by the fact that the path technology takes from NASA R&D to product implementation is sometimes difficult to trace and to quantify the contribution made by NASA's investment. Usually many people and organizations outside NASA or NASA sponsorship have contributed to the technology by the time it is implemented. Also the final product may contain multiple new technologies that collectively produce the measurable benefit."[5-41]

In the air transportation industry, we used industry measurements to show increases in efficiency, productivity, and technological advance. These measures are not direct measures of the benefits of NASA R&D to the industry; however, the research and technology that NASA produced in its history were certainly adapted into the aerospace industry. We believe it is reasonable to assume that some of the improvements that are shown in the industry measures can be tied to NASA R&D.

5.5.1 Proxy Measures for Productivity and Technological Advance in the Sector

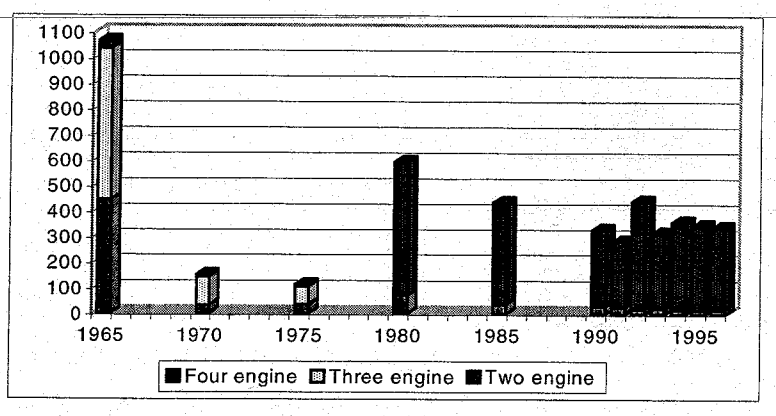
The air transportation industry produces a great deal of information. Several of the measures that we will use will be proxies for productivity and technological advances. The amount that any one NASA program contributed to any of these numbers is not addressed here. We are offering the assumption that NASA technology and research was disseminated into the aerospace industry, and that the air transportation sector of the U.S. economy has benefited from the technological transfers and spillover effects. We believe that this

assumption is reasonable because technological improvements are implemented by the industry through new purchases of aircraft, engines, and systems, as well as through the normal retrofitting and maintenance cycles. We offer these numbers as a measure of the increase of productivity of the sector and technological advances in the sector. The raw data from which these charts were produced are included in Appendix D.[5.42]

5.5.1.1 Propulsion

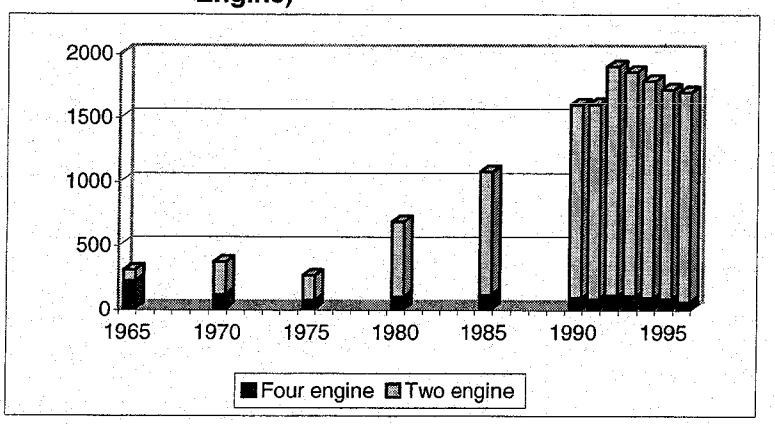
NASA programs since 1958 have focused on propulsion a great deal. The Jet Propulsion Laboratory and the NASA Lewis Research Center (now NASA Glenn) both have extensive facilities for research in this area. Several factor costs in the air transportation field are affected by propulsion. Two leading indicators of the improvement in productivity in this area are the types of engines used on an aircraft, and the number of engines used on an aircraft.

Figure 5. 11 Total Piston Aircraft



There are three engine types: piston, turboprop, and turbojet engines. Each of these types, respectively, is greater in the amount of propulsion available for thrust. Figures 5.11 through 5.13 show the relationship of these three types of engines. In Figure 5.11, productivity gains in propulsion can be shown by the decreasing reliance on piston aircraft, which totaled over 1000 of the aircraft fleets of air carriers in 1965. By 1975, the amount of piston aircraft in the fleets had shrunk to just under 100. With the introduction of a new generation of piston aircraft in the mid- to

Figure 5. 12 Total Turboprop Aircraft (More than One Engine)



late 1970s, piston engines showed a marked increase; however, the vast majority of the aircraft that used these engines now only required two engines.

Figure 5.12 shows the great increase of turboprop engines being used by the air carrier fleets. From 1965 to 1975, the amount of aircraft using this type of engine remained relatively stable around 300 aircraft. The amount of turboprop aircraft increased six fold from 1975 to 1993, from nearly 300 to nearly 1800. During this period as well, the number of aircraft using four engines slightly declined.

Figure 5. 13 Total Turbojet Aircraft (1965-1998)

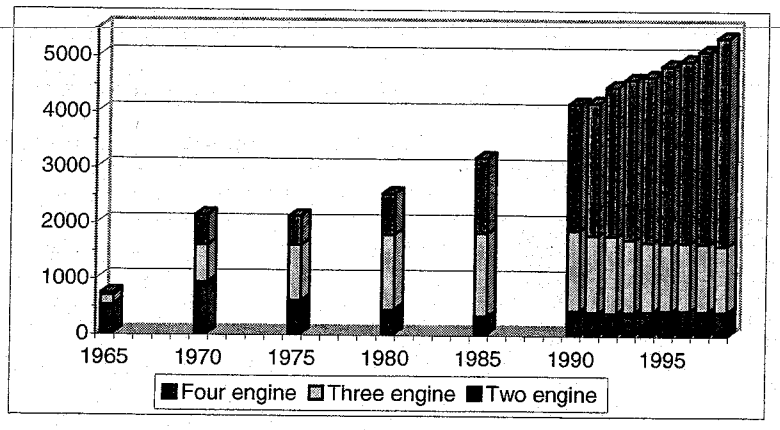


Figure 5.13 shows the dramatic rise in the use of the new turbojet technology from 1965 to 1998. Approximately 700 aircraft used this technology in 1965; today, well over five thousand use it. Initially, the number of aircraft using four of these engines increased more quickly, but since 1970, the number has declined. From 1970 to 1980, the number of aircraft using three of these engines increased the most quickly; however, since 1980, two engine aircraft have captured the largest share.

The next three charts show the distribution of two-, three-, and four-engine aircraft in each of the three engine categories. These figures show that the greater the gains in propulsion, the less need there are for three- and four-engine aircraft. In this way we can measure the gains in productivity from the adoption of these new technologies. Figures 5.14 through 5.16 show the shrinking number engines required on aircraft for all engine types.

Figure 5. 14 Number of Engines on Piston Aircraft

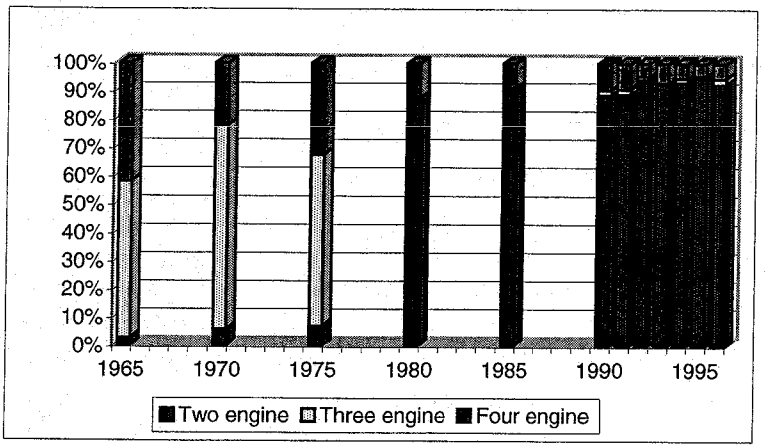


Figure 5. 15 Number of Engines on Turboprop Aircraft

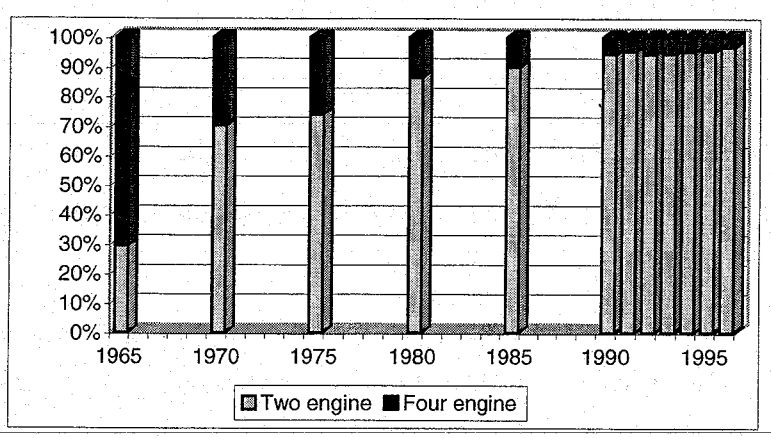
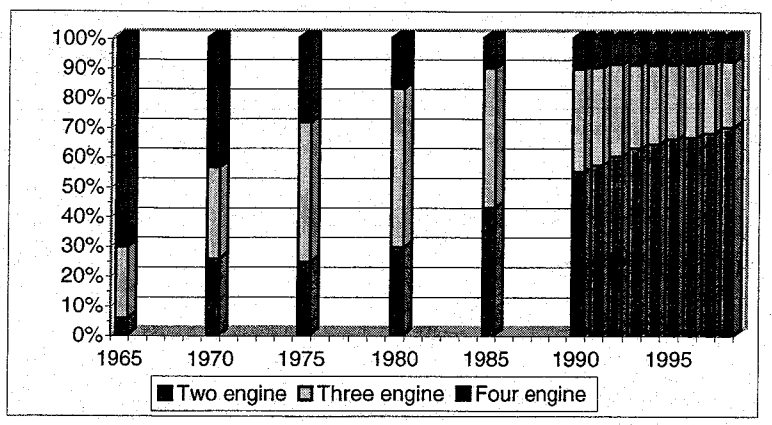


Figure 5. 16 Number of Engines on Turbojet Aircraft



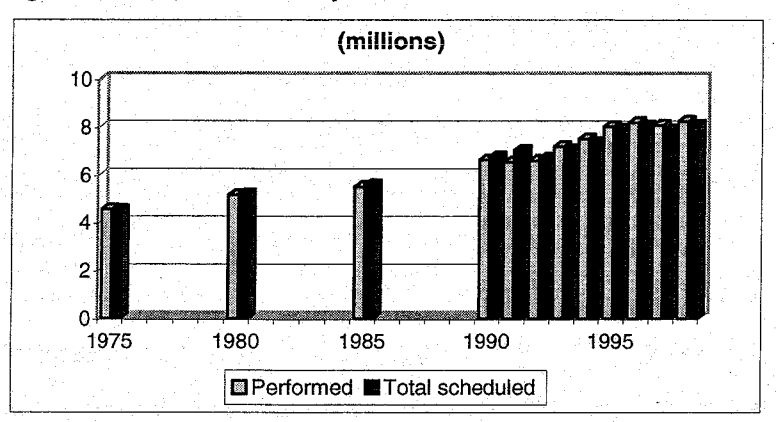
These figures show that the number of four-engine aircraft have captured a decreasing percentage of the total air carrier fleets. In 1965, 40% of the piston engine aircraft used four engines; and a full 70% of the turboprop and turbojet engine aircraft used four engines. By the 1990s, less than 10% of all types of aircraft used four engines. Instead, over 90% of piston and turboprop engine aircraft use two engines now; and 70% of the turbojet engine aircraft use two engines with another 20% using only three engines.

5.5.1.2 System Efficiency

NASA research also has played a part in improving the efficiency of air transport. Several research projects focused on decreasing the interval between landings, development of multi-vector approaches, and ground transportation systems. Positive productivity gains from this research are likely to be contained in the following data.

Figure 5.17 shows the need for increased capacity has become a concern in the

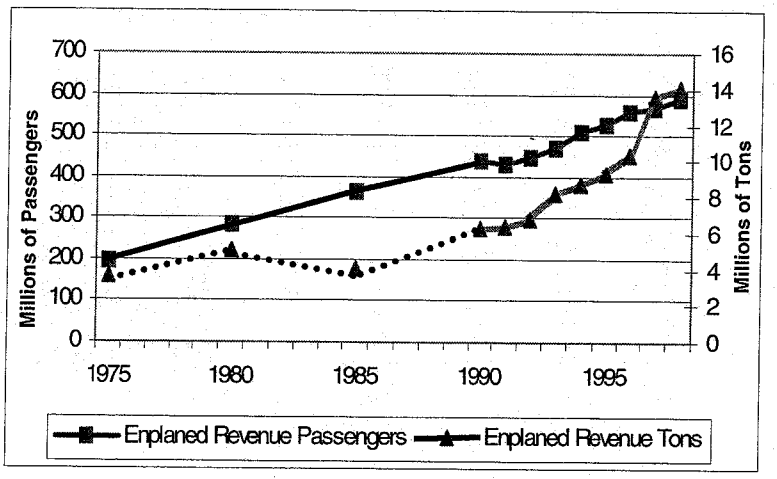
Figure 5. 17 Aircraft Departures



industry. In the last 25 years, aircraft departures have doubled, from just over 4 million in 1975, to over 8 million in 1999. In the 1970s, concern that the U.S. was approaching capacity prompted the federal government to begin research to alleviate the potential problem. In a joint venture, the FAA and NASA Langley began several research projects to address the problem. The capacity of the U.S. to handle a greater amount of air travel is a direct result of that research.

The amount of people and freight moved by the air-transportation sector of the economy can be seen in Figure 5.18. The amount of passengers enplaned in 1975 was approximately 200 million. By 1998, nearly 600 million passengers traveled by air. The amount of freight also has been increasing over the last 25 years, from nearly 150 million tons in 1975 to over 600 tons in 1998. The increase in the amount of people and freight carried resulted from several technological improvements, many of which have benefited from NASA research. This increase in capacity comes from not only system-enhancing technologies, and an increase in the efficiency of the system, but also from improvements in high-thrust engine technologies and lighter aerospace materials that allow for larger aircraft to meet this growing demand.

Figure 5. 18 Amount of Cargo and Passengers (1975-1999)



5.5.1.3 Navigation and Avionic Improvements

The next proxy measurement shows the improvements to the aircraft systems developed with the help of NASA research. By developing new systems which allow for better navigation and control of the aircraft, the improvements in this sector have allowed air carriers to become more productive by shrinking the number of employees needed to operate and maintain their fleets. Although not a perfect measure since this accounts for more than just flight crews and maintenance, the trend is discernable in Figure 5.19. The amount of employees per aircraft in 1980 was 125. In 1999, the amount of employees was 117.

This trend is much more pronounced, however, when one looks at the major and national carriers. Figure 5.20 shows that the major carriers with the largest fleets reduced their employees per aircraft from nearly 155 in 1980 to almost 138 in 1999, a reduction of 11%. The national carriers also reduced their employees per aircraft by nearly 26% during the same period, from nearly 70 in 1980 to 52 in 1999 (see Figure 5.21). The reason this trend is not shown as clearly in the graph in Figure 5.20 can be seen in the information in Figure 5.22. Smaller regional air carriers have been increasing their number of employees per plane. This may be due to a greater focus on customer service in these smaller airlines or perhaps by the fact that some smaller airlines tend to purchase older aircraft. During this time period, their employees per aircraft have increased from nearly 18 in 1980 to 45 in 1999.

Figure 5. 19 Employees per Aircraft (All Carriers)

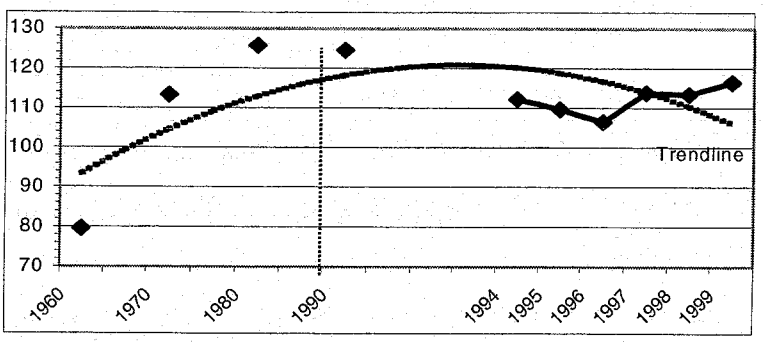


Figure 5. 20 Employees per Aircraft--Majors

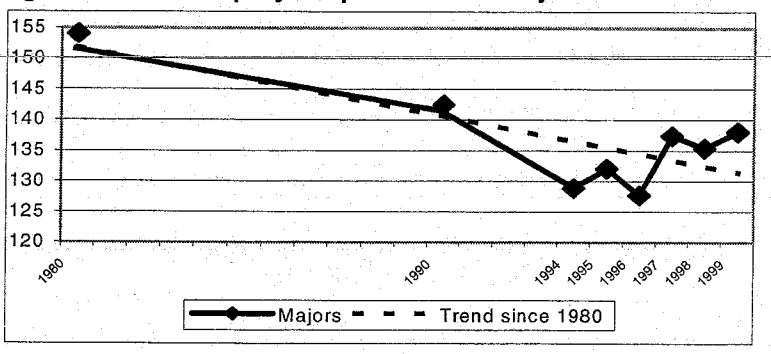


Figure 5. 21 Employees per Aircraft--Nationals

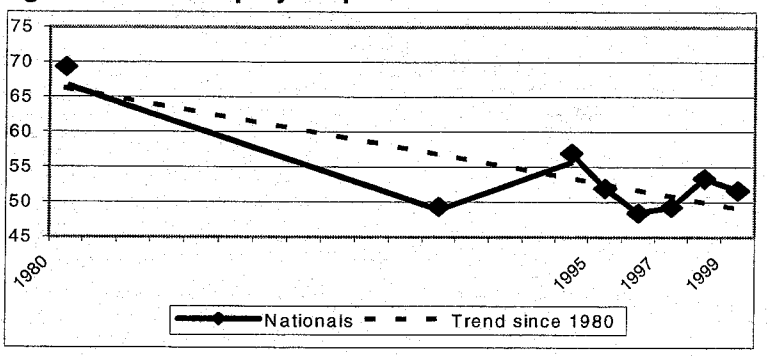
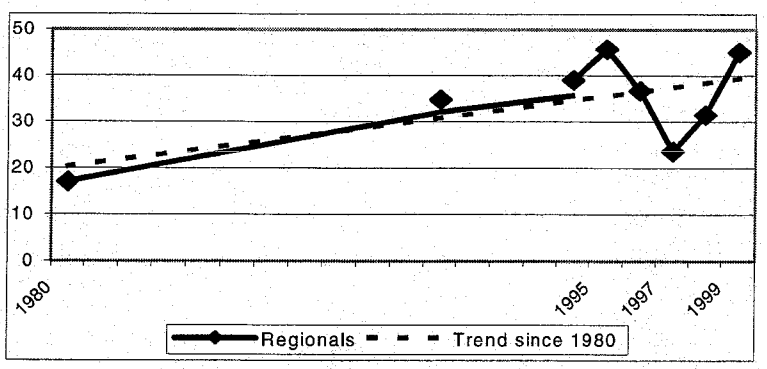


Figure 5. 22 Employees per Aircraft--Regionals



5.5.1.4 Safety Improvements

Several improvements have been made to aeronautical systems that have directly benefited the air transportation sector of the economy. NASA has worked on instrumentation, air traffic control systems, weather prediction systems (including windshear prediction), and navigation systems. Determining the return on investment and economic gains for these research areas is problematic; several proxy measures can be used to show that aviation has improved during NASA involvement in these types of safety-related research programs.

When one looks at the statistics for the number of fatal accidents since NASA's formation, there seems to be no major improvement in the reduction of accidents, nor in the amount of casualties per year (see Figure 5.23). These figures, however, do not take into account the great increase in the number of aircraft and passengers over the past 40 years. When these factors are taken into account, the results are dramatically different. Figures 5.24 and 5.25 show the marked improvement in safety as aeronautical research and development began to address

Figure 5. 23 Fatal Worldwide Multi-Engined Airliner Accidents per Month

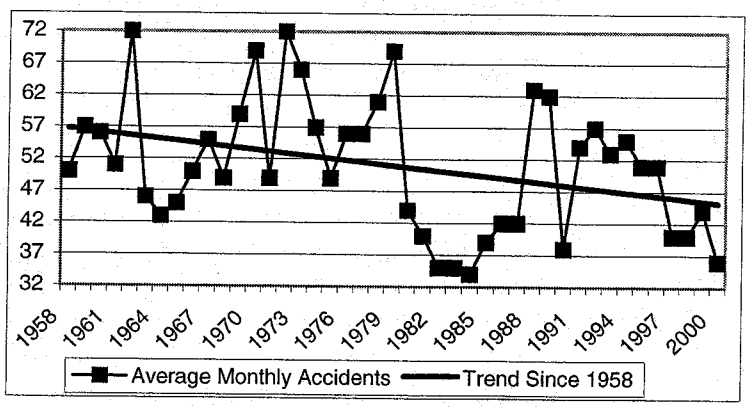


Figure 5. 24 Fatal Accidents per Million Aircraft Miles, Jet Age

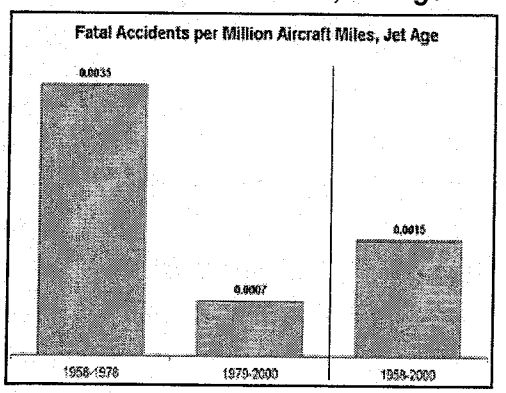


Figure 5. 25 Fatal Accidents Per Million Miles

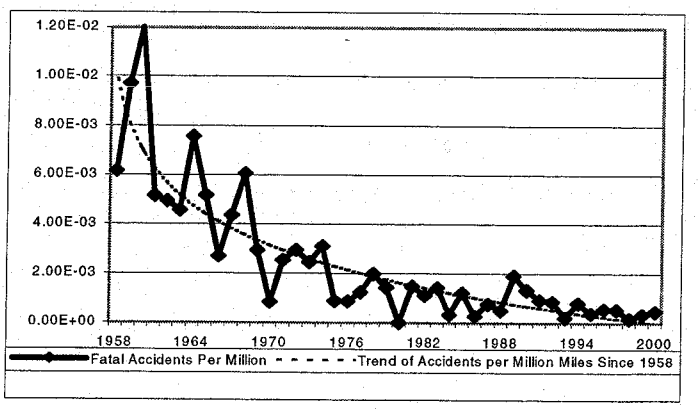
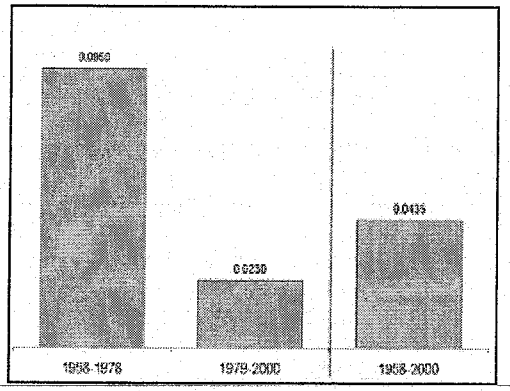


Figure 5. 26 Fatal Accidents Per Million Aircraft Departures, Jet Age



safety concerns. In the 20-year period from 1958-1978, there were an average of 0.0035 fatalities per million aircraft miles. This figure was reduced by 80 percent to an average of 0.0007 fatalities per million aircraft miles.

There has also been an improvement also in the average number of fatalities per million aircraft departures. Figure 5.26 shows the decline of accidents from the first 20 years of the jet age, which averaged 0.095 per million departures, to the last 20 years, which averaged 0.023 per million departures. This reduction of nearly 76 percent reflects improvements in aviation safety, some of which was contributed to by NASA. Figure 5.27 tracks the decline of accidents over the last 40 years. A definite downward trend can be seen throughout this period.

Figure 5. 27 Fatal Accidents per Million Aircraft Departures, Jet Age

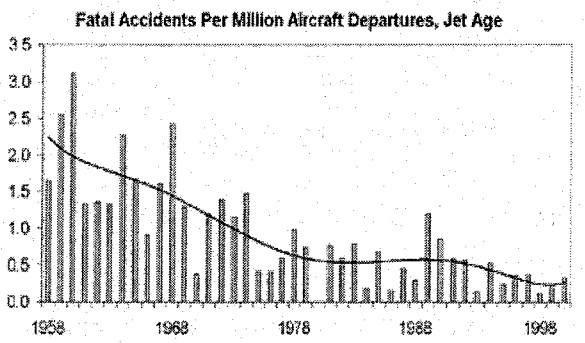
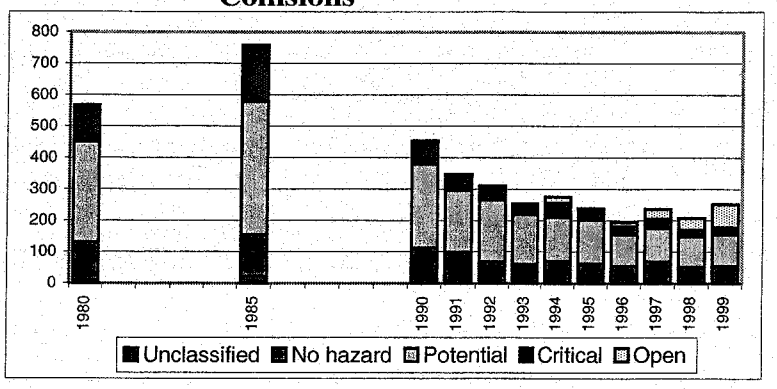


Figure 5.28 shows the improvement in navigation and air traffic control by showing the decrease in the number of near midair collisions. The significant decrease in the amount of these reports may show the increase in the ability of air traffic controllers and pilots to navigate the ever more crowded skies. The research and development of safety-related systems and devices funded through NASA programs have been instrumental in these safety improvements. Continued research into the cause of

Figure 5. 28[5-43] Number of Pilot-Reported Near Midair Collisions



accidents and their prevention by NASA is likely to help to continue this trend.

5.5.1.5 Fuel Efficiency

Another way to show increases in productivity for the air transportation sector is to analyze improvements in fuel efficiency. Improvements in engine efficiency, aeronautical construction, drag-reducing materials, and lighter component parts contribute to increases in fuel efficiency. NASA has been engaged in research in all of these aspects, and the proxy of fuel efficiency can demonstrate productivity increases in the air transportation sector. Figure 5.29 shows that fuel is a very large input cost for the air transportation sector. In 2000, the sector used 20.3 billion gallons of fuel at a cost of over $16.3 billion. The ability to save fuel in using more efficient aircraft and engines has a great effect on the productivity of the sector because of multiplier effects.

Figure 5. 29 Amount and Cost of Fuel in Air Transportation Sector

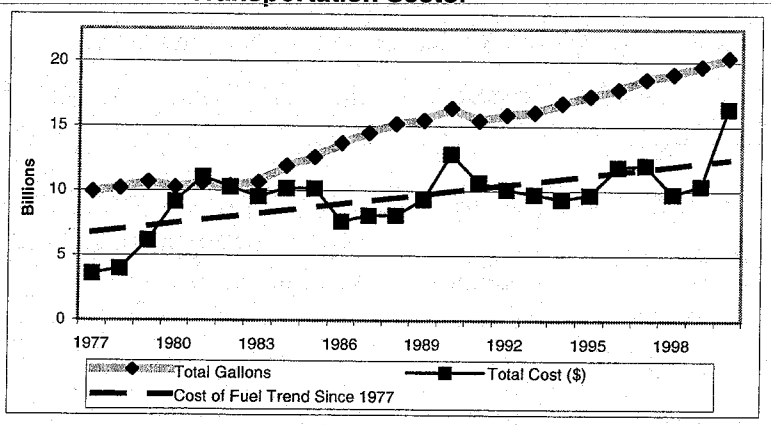
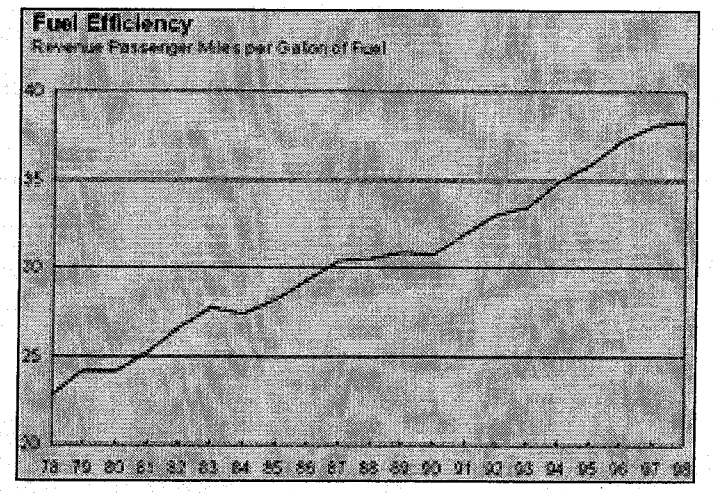


Figure 5.30 shows the dramatic rise in fuel efficiency since 1978. In the 20-year period shown, the amount of passenger miles per gallon of fuel has risen nearly 65 percent. NASA programs designed to address fuel efficiency were begun during the oil crises of the 1970s. The improvements in fuel efficiency shown by the chart are an indicator of the better technology developed and implemented during that time.

Figure 5. 30 Fuel Efficiency



The next two charts show the operating costs of the most common types of airframes. The Boeing 747 and the Boeing 777 are large, long-distance aircraft; the Boeing 767 and the Boeing 757 are medium, mid-range aircraft; the Airbus 320, Boeing 737 and the McDonnell Douglas 80 smaller, shorter-range aircraft.[5-44] Figure 5.31 shows the operating costs of these aircraft. The 747 (more specifically, the B747-400), which was introduced in the 1960s costs nearly $7000 per hour to run compared to the new 777, which costs under $4000 per hour. According to Air Transportation Association (ATA) statistics, older models of the 747 (B747-200/300) cost even more, with an operating cost per hour of $8600.[5-45] Figure 5.32 shows the increase of efficiency even more, measuring the cost per average seat miles (ASM) (dividing the cost by the number of seats and miles flown). The Boeing 777 has a cost of approximately 2.7 cents per ASM compared to the 747 with a cost of over 3.4 cents. This savings of over 20 percent is embodied into the next generation of technology that is represented by the new 777. Another indicator of improving technology is the difference in operating costs of the Boeing 737, which is based on older technology, and the 757 and 767, which are based in new technology. The operating cost of the 737 is 4.4 cents per ASM compared to nearly 3.6 cents for the 767 and 3.3 cents for the 757. The technological improvements represented in the 757 and 767 led to a savings of 33 percent and 18 percent respectively over the older technology represented by the 737.

Figure 5. 31 Aircraft Operating cost per Hour

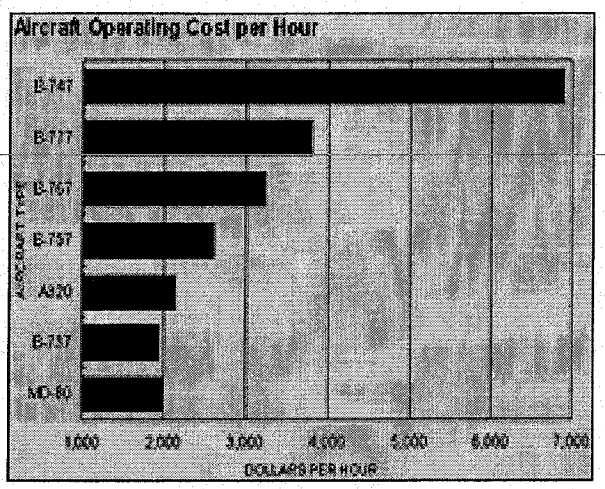


Figure 5. 32 Aircraft Operating Cost per ASM

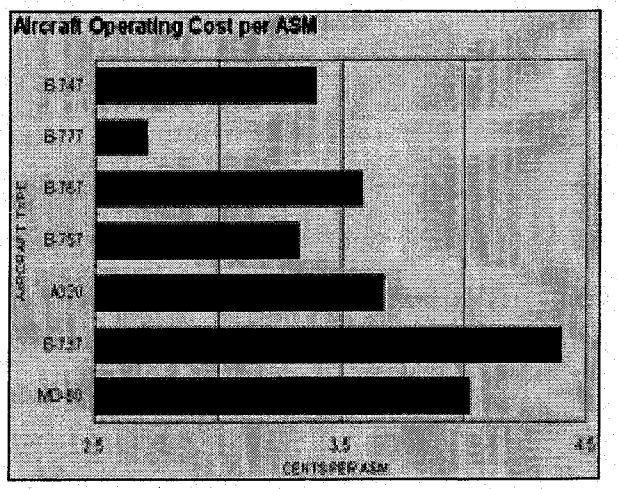
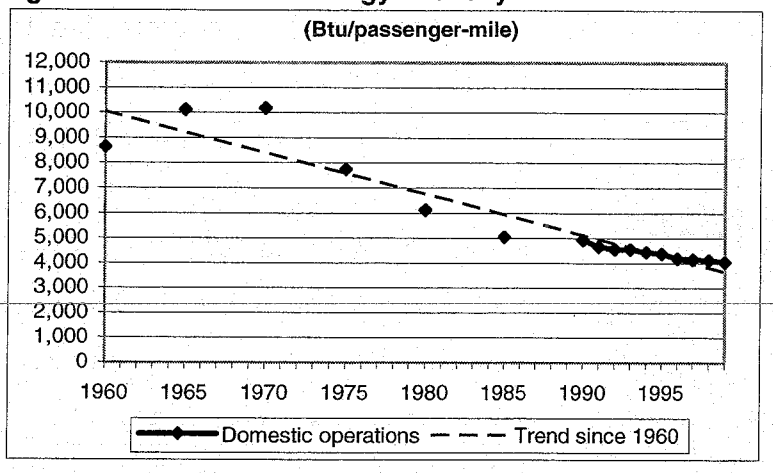


Figure 5.33 shows the overall trend in the air transport industry over the period of NASA R&D investment in the aeronautic sector. The steepest decline in the energy intensity of the industry occurred from 1970 to 1985 which corresponds to the improvements made in jet propulsion in the late 1960s and early 1970s as well as the political influence brought to bear during the energy crises of the 1970s and early 1980s. The savings that the sector has realized because of this increased efficiency is evident in these charts; however, the appropriability of these savings to increased technology supported by NASA R&D is difficult to measure.

Figure 5. 33 Aircraft Energy Intensity



5.5.2 Confounding Factors in Assessing NASA R&D Returns in Productivity

As stated before, to provide a reliable measure of the returns in productivity and technological advancement from NASA R&D investment one would have to determine all input factors, the amount of transferability of each factor, and the role NASA R&D played in the development of each factor. Once this was done, one would then have to determine the amount of investment that NASA contributed to the research and development of the input factor as compared to the amount that others invested. No simple method of determining these types of productivity returns from NASA investment exists. We have endeavored to show a connection between NASA investment in aeronautics in general and the productivity gains that have been shown in the air transportation industry. As NASA research has continued to address problems of aeronautics, several positive technological advancements have been made. Furthermore, these advances have led to increased productivity in the sector. However, NASA is not a sole actor in aeronautical R&D; neither does it act alone in its research programs. Often NASA uses industry to further develop, test and apply basic research. These factors give rise to irreconcilable concerns about measuring the returns in any reliable way.

5.5 Conclusion

Although there are several factors which cloud the ability of researchers to determine the direct benefits of NASA R&D programs and spending in the air transportation sector, it should be clear that the sector as a whole has benefited a great deal from the development of new processes, and technologies in aerodynamics. Lighter building materials and component parts; more powerful, fuel-efficient and environmentally-friendly engines; better avionics and navigation; and improved systems for takeoffs, landings and ground movement have contributed to quicker flights, larger and more quiet aircraft, more efficient use of resources, and greater safety. These benefits are a direct result of NASA aeronautical research and development. The productivity improvements in the air transportation sector reflect these improvements in technology through several measures. The exact amount that NASA R&D contributed and continues to contribute to this sector may remain a question, but the fact that NASA has contributed somewhat to the increased productivity and safety of the sector is unquestionable.

6. CONCLUSIONS

The role played by NASA in technological research and development has changed over time. One can generally describe three ages of the funding history and political environment surrounding NASA that might be termed the Lunar Age, the Technology Transfer Age, and the Marketplace Age. In the Lunar Age, which runs from the birth of NASA in 1958 to 1974, R&D activities focused almost exclusively on the space race to the moon and space applications for public projects such as weather satellites. In the Technology Transfer Age, spanning 1975 to about 1992, NASA became more focused on developing technologies with tangible benefits for the broader public and private sectors. The period we are in today, the Marketplace Age, is one in which NASA R&D has assimilated competitive business practices and now develops new technologies with the goal of maximizing returns on investment. In evaluating the economic impacts of NASA's R&D programs it will be important to view these impacts in the context presented by each of these periods in NASA's political history.

NASA R&D investments differ from conventional capital investments because in addition to short-term economic benefits that disappear when the project ends, technical progress that results from R&D investments is a major source of long-term economic growth. New technology stimulates growth by making existing production methods more efficient and by creating new products and services that not only generate new markets, industries and opportunities, but also can also increase efficiency in people's daily activities and improve the overall quality of life.

Today, funds for space vie against many other priorities (although the annual expenditures on civilian space activities have been large, they still account for well under 1% of the annual U.S. government budget). The need to evaluate, justify, and measure economic returns for the investment has taken on higher priority than in the past. However, the benefits from R&D investment in space are more difficult to measure and more unpredictable than the short-term benefits that accrue from immediate jobs and income created by direct federal spending.

Standard economic models are devised to quantify what can be measured. What should be measured is entirely different. Recent works attempting to evaluate returns to R&D investment suggest that all approaches are incomplete because they ignore or

mismeasure key economic impacts. If the view is taken that space is a national laboratory then the less direct impacts of basic research resulting from new knowledge, social networking, etc., need to be included. In other words, a measure of the value of man-made national resources should be developed. Such a value must integrate easily understood and standard economic measures with political and social values.

In another complementary view of space investment, NASA space projects also create an infrastructure that will lead to other space projects and unplanned improvements in our economic system similar to past public works projects. The economic impacts of structural changes in our society from these types of investments are not clearly separated and measured in our standard economic yardsticks of GNP and related statistics. About all that can be accurately said of space R&D investments is that economic impacts will occur and those impacts, in the long run, will be sizable.

For example, the telecommunications industry has been altered radically as a result of satellite communications technology. Long-distance communications have become less expensive and new services are being offered. In the twenty years between 1965 and 1985, the cost of living index trebled while the unit service charge on Intelsat satellites fell 90% (Hertzfeld, 1992). Not only has the supply side of communications changed, but improved products and services have increased the demand for communication satellites. Associated with space hardware has been the development of a rapid and competitive market for complementary technologies including earth receiving stations and support services. Although it is likely that economic studies of the impacts and benefits of satellite communications have recorded some of this growth, it is unlikely that they could have accounted fully for the extent of technological diffusion and its impact. Additionally, in the presence of confounding non-economic factors, it is unclear how much of this growth can (should) be attributed to NASA R&D investment.

The benefits and impacts on the economy from investments in R&D are often not immediate. It may take years or decades for an idea to be transformed into a marketable product or service. The unpredictable ways that technology is transferred and the problems inherent in tracing the progression of ideas and experiments into consumer products whose sales contribute to the gross domestic product create many of the measurement difficulties.

A few of the issues in ROI analysis that were brought out in this report suggest a set of questions for the analyst to consider.

(1) Does the output of R&D become obsolete, thus requiring some estimation of the rate of depreciation? If so, what rate should be used?

(2) Can the economies-of-scale impacts on productivity and other non-technological factors be distinguished from NASA R&D-related productivity growth and how can these variables be segregated for quantitative analysis?

(3) How and when should hard-to-measure economic benefits (e.g., spin-offs) be included in ROI evaluations?

(4) What are the indicia of whether federal R&D funds to private industry act as a complement (social benefit) or a substitute (social cost) for private industry R&D?

(5) How important is the role of science and basic research produced by NASA on increasing commercial productivity (i.e., can the benefits from indirect impacts be determined)?

(6) How should the time structure of the effects of R&D on productivity (i.e., lags) be incorporated into ROI models and analyses?

(7) Since almost all space R&D is government supported, how should the traditional economic models, built on the operating assumption of a freely competitive market, be modified?

In answering these questions, the tradeoffs and limitations to ROI analysis become apparent. Still, society demands some type of benefit-cost analysis to guide the investment of scarce public funds. In responding, economic and political/cultural objectives should be balanced. The latter refers to our political desire to maintain technological leadership in the world and our cultural need to devote resources to exploring the unknown. Models and measures should be constructed to meet this balance and the nonquantifiable returns should be recognized. Understanding the different economic and political objectives will begin to put space R&D in perspective. Case studies show a definite relationship between R&D expenditure and productivity, but are biased toward winners. Aggregate models can only infer this relationship but can capture the externalities, which often have major economic impacts. Thus, a well structured series of case studies, using consistent methodology to allow summation of the results, plus good theoretical modeling incorporating more general

economic measures of benefits may be the best way to establish reliable and believable economic measures of the returns to space R&D.

In applying the case study approach to evaluate returns on NASA R&D investment in the areas of communication satellites and air transportation, the general welfare impacts that are hard to measure are especially important to consider. In the communication satellite industry, NASA's investment worked as an accelerator creating an environment where companies felt more comfortable taking risks in investing in new technologies. The air transportation sector has clearly had significant productivity increases that correlate with NASA's investment, but showing causality is may not be feasible.

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8. APPENDIX A: PUBLIC LAWS PERTAINING TO NASA

Bill Number, (Date) (Public Law Number)	**Contents and Type of Legislation**
	1974
H.R.11864 (9/3/74) (P.L. 93-409)	· Development of prototype solar heating systems and prototypes of combined solar heating and cooling systems for use in residential dwellings.
H.R.15572 (9/6/74) (P.L. 93-414)	· Makes appropriations for research, development, and construction of facilities for FY 1975.
	1975
H.R.4700 (6/19/75) (P.L. 94-39)	· Research and development, construction of facilities, and for research and program management. · Research and development funds to be used for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. · Enter into contracts for tracking and data relay satellite services.
	1976
H.R.8800 (9/17/76) (P.L. 94-413)	· Declares, under the National Aeronautics and Space Act, the unique competence of the National Aeronautics and Space Administration (NASA) is required to be directed toward ground propulsion systems and research and development thereon, and requires NASA to initiate such research and development.
H.R.12453 (6/4/76) (P.L. 94-307)	· Research and development, construction of facilities, and research and program management. · Expresses the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible, and that NASA should explore ways and means of distributing its research and development funds whenever feasible. · Authorizes NASA, if authorized in an appropriation Act, to enter into a contract for tracking and data relay satellite services.
	1977
H.R.4088 (7/30/77) (P.L. 95-76)	· Authorizes the appropriation of designated sums to the National Aeronautics and Space Administration for research and development programs, construction of facilities, including land acquisition, and research and program management.

· Authorizes the Administration, when so provided in appropriation Acts, to enter into and to maintain a contract for tracking and data relay satellite services.

· Authorizes the appropriation of an additional $95,000,000 in fiscal year 1977 for augmentation of the Research, Development, Test and Evaluation program and acceleration of the Orbiter production for the Space Shuttle Program.

1978

H.R.11401 (9/30/78)
(P.L. 95-401)

· Research and development programs, construction of facilities, and research and program management.

· Explore ways and means of geographically distributing its research and development funds.

· Authorizes the use of appropriations for "Research and development" for: (1) items of a capital nature (other than acquisition of land) required at locations other than NASA installations for the performance of research and development contracts; and (2) grants to nonprofit organizations whose primary purpose is the conduct of scientific research for purchase or construction of additional research facilities. Prohibits such funds to be used for construction of a facility, including collateral equipment, the cost of which exceeds $250,000.

· Amends the National Aeronautics and Space Act of 1958 to direct NASA to assist in bioengineering research, development, and demonstration programs designed to alleviate and minimize the effects of disabilities of handicapped individuals.

1979

H.R.1786 (8/8/79)
(P.L. 96-48)

· Authorizes appropriations to the National Aeronautics and Space Administration (NASA) for research and development, construction of facilities, and research and program management.

· Permits appropriations for research and development to be used: (1) for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts; and (2) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities.

· Expresses the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible, and that NASA should explore ways and means of distributing its research and development funds whenever feasible.

1980

H.R.7542 (7/8/80) (P.L. 96-304)	· Supplemental appropriation which does not specify direction of funds
H.R.7631 (12/15/80) (P.L. 96-526)	· Appropriations for research and development (earmarks funds for specified projects, facilities construction, and research and program management.
S.2240 (7/30/80) (P.L. 96-316)	· Research and development, construction of facilities, and research and program management. · Permits appropriations for research and development to be used: (1) for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts; and (2) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. · Expresses the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible, and that NASA should explore ways and means of distributing its research and development funds whenever feasible.

1981

H.R.4034 (12/23/81) (P.L. 97-101)	· Appropriations for research and development, the construction of facilities, and research and program management. · Prohibits NASA from using any funds appropriated in this Act to support the development of techniques to analyze extraterrestrial radio signals for signs of intelligent life.
S.1098 (12/21/81) (P.L. 97-96)	· Authorizes appropriations for research and development to be used for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts, and for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. · Amends the National Aeronautics and Space Act of 1958 to state that any object intended for launch, or assembled in outer space, which is temporarily present in the United States, shall not constitute infringement of any patent, as specified. · Requires NASA to review and report to the authorizing committees of Congress on alternative systems for space transportation system upper stages before appropriations for procurement of any upper stages are expended.

1982

H.R.5890 (10/15/82) (P.L. 97-324)	· Authorizes appropriations to the National Aeronautics and Space Administration (NASA) for research and development, construction of facilities, and research and program management for FY 1983.

· Permits appropriations for research and development to be used for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts, and for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities.

· Expresses the sense of Congress that consideration should be given to the geographical distribution of research funds.

· Authorizes the Secretary of Commerce to: (1) plan for the management and operation of a civil land remote sensing satellite system transferred from NASA; (2) provide for user fees; and (3) plan for the transfer of such systems to the private sector. Directs the Secretary to conduct feasibility studies for such transfer and report to Congress on them by February 1, 1983.

H.R.6956 (9/30/82)
(P.L. 97-212)

· Research and development, the construction of facilities, and research and program management.

· Prohibits NASA from using any funds to develop a fifth space shuttle orbiter without the approval of the Committees on Appropriations.

1983

H.R.2065 (07/15/83)
(P.L. 98-52)

· Authorizes appropriations for research and development to be used for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts, and for grants to nonprofit institutions of higher education or to nonprofit organizations whose primary purpose is the conduct of scientific research for purchase or construction of additional research facilities.

· Expresses the sense of Congress that NASA should consider geographical distribution when distributing its research and development funds.

· Amends the National Aeronautics and Space Act of 1958 to prohibit the misuse of the agency's name and initials. Permits the Attorney General to initiate a civil proceeding to enjoin such misuse. Requires the transfer to NASA of three government-owned tracts of NASA used land and improvements at Ellington Air Force Base, Texas, without any transfer of funds.

· Prohibits the Secretary of Commerce from transferring the ownership or management of any civil land remote sensing space satellite system until a comprehensive plan for such a transfer is submitted to and enacted into law by Congress.

· Requires any decisions concerning the commercialization of same or all of the existing expendable launch vehicle technologies and associated facilities be presented to the appropriate congressional committees for 30 days unless each such committee transmits a written notice of no objection to the Administrator before the expiration of such period.

· Authorizes appropriations for operating such satellite system during FY 1984

H.R.3133 (7/12/83)

· Appropriations for research and development, space light, control, and data

(P.L. 98-45)

· communications the construction of facilities, and research and program management.

· Prohibits the use of NASA appropriations for leasing or constructing a contractor-funded facility when NASA would be required to amortize the contractor's investment, unless specifically authorized in an appropriation act or approved by the House and Senate Committees on Appropriations

1984

H.R.4170 (7/18/84)
(P.L. 98-369)

· Requires the Administrators of the Office of Federal Procurement Policy, GSA, and NASA, by January 31, 1985, to complete a study of alternatives and recommend to specified congressional committees a plan to increase the opportunities to achieve full and open competition in the procurement of professional, technical, and managerial services.

H.R.5154 (7/16/84)
(P.L. 98-361)

· Authorizes appropriations for research and development and space flight, control, and data communications to be used for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts, and for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research for purchase or construction of additional research facilities.

· Declares that it is the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible and that NASA should explore ways of doing so

· Directs the Administrator of NASA to continue and to enhance remote-sensing research and development programs, especially experiments in space, technology development, and cooperative projects with other public and private research entities

· Declares the intent of Congress that expenditures for the advanced turboprop program should be recouped by NASA if and when commercially successful products are developed by the aircraft industry as a direct result of such activities. Requires the Administrator to submit to Congress a plan for the payment of royalties to NASA by aircraft industry firms with respect to such products.

· Declares that the general welfare of the United States requires that NASA seek and encourage, to the maximum extent possible, the fullest commercial use of space

· Permits the Administrator of NASA to transfer to an academic institution or nonprofit organization title to all Federal scientific research or development equipment which has been loaned to it for at least two years, provided that NASA does not need such property and it is being used by the organization holding it for a purpose consistent with the use intended when the property was loaned.

· Directs the President to establish a National Commission on Space, composed of specified executive branch and congressional ex officio and advisory members, plus fifteen qualified individuals appointed by the President.

H.R.5155 (7/17/84)

· Directs the Administrator of the National Aeronautics and Space Administration

(P.L. 98-365)	(NASA) to continue and to enhance NASA's programs of remote-sensing research and development, including developing programs and technologies and cooperating with public and private entities.
H.R.5713 (7/18/84) (P.L. 98-371)	· Appropriations for research and development, space flight, control, and data communications, the construction of facilities, and research and program management. · Requires NASA to use research and development appropriations to: (1) study an option which phases in the permanently manned features of the space station as one of the reference configurations to be examined in space station systems definition studies; and (2) report the results of such study to specified congressional committees before NASA's Administrator selects the configuration for the permanently manned space station. Requires a specified amount of such appropriations to be withheld from obligation or expenditure until April 1, 1985. Prohibits the use of NASA appropriations for leasing or constructing a contractor-funded facility when NASA would be required to amortize the contractor's investment, unless specifically authorized in an appropriation Act or approved by the House and Senate Committees on Appropriations. Permits NASA to use funds appropriated for research and development and for space flight, control, and data communications to enter into a contract with the California Institute of Technology to amortize the Central Engineering Building. Permits NASA to test a flat per diem system for employee travel allowances. Directs the Administrator of NASA to establish an Advanced Technology Advisory Committee which shall prepare a report identifying space station systems which advance automation and robotic technologies. Authorizes NASA to provide NSF with Class VI Computers on a fully reimbursable basis. Authorizes NSF to sell such computers to institutions of higher education.

1985

H.R.1714 (12/5/85) (P.L. 99-170)	· Authorization for specified activities relating to: (1) research and development; (2) space flight, control and data communications; (3) construction of facilities; and (4) research and program management · Permits appropriations for research and development and for space flight, control and data communications to be used: (1) for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts; and (2) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. · Declares that it is the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible, and that NASA should explore ways of doing so. · Provides that the authorization for the space shuttle includes provision for: (1) production of a fleet of four space shuttle orbiters, including structural and component spares; and (2) production readiness for a fifth orbiter vehicle. · Directs the Administrator to initiate an immediate feasibility study to ensure flight opportunities for a diverse segment of the American public, including a physically disabled American.

· Authorizes the Administrator to set a price lower than the base price or the reduced price, or to provide no-cost flights, for any commercial or foreign user of STS who is involved in research, development, or demonstration programs with NASA.

H.R.2577 (8/15/85)
(P.L. 99-88)

· Supplemental appropriations for research and program management.

H.R.3038 (11/25/85)
(P.L. 99-160)

· Appropriations for research and development, space flight, control, and data communications, the construction of facilities, and research and program management.

· Prohibits the use of NASA appropriations for leasing or constructing a contractor-funded facility when NASA would be required to amortize the contractor's investment, unless specifically authorized in an appropriation Act or approved by the House and Senate Committees on Appropriations. Allows the Administrator of NASA to authorize such facility lease or construction if deferral until enactment of the next appropriation Act would be inconsistent with the Nation's interest in aeronautical and space activities. Requires the Administrator to consult with the congressional Committees on Appropriations before making such an authorization.

· Authorizes the Administrator of NASA to contract with the State of Mississippi for the transfer to the United States Government of the Mississippi Technology Transfer Center at the National Space Technologies Laboratories in Hancock County, Mississippi

1986

H.R.4515 (7/2/86)
(P.L. 99-349)

· Makes supplemental appropriations for FY 1987 to NASA. Direction of funds not specified.

1987

H.R.1827 (7/11/87)
(P.L. 100-71)

· Supplemental appropriations for fiscal year ending September 30, 1987.

· Prohibits funds appropriated by this or any other Act for research, development, testing, and evaluation for the National Aeronautics and Space Administration (NASA) or the Department of Defense from being expended for the Advanced Launch System/Heavy Lift Launch Vehicle (ALS), or for the design, construction, or modification of test facilities for rocket propulsion systems to be integrated into or be compatible with ALS until the House and Senate Committees on Appropriations have received a plan from the Secretary of Defense and the Administrator of NASA, and has been approved by the President, delineating the respective responsibilities of, and apportioning costs to, NASA and the Department of Defense with respect to the ALS program and the House and Senate Committees on Appropriations have established a date for the release of such funds.

· Transfers a specified amount of funds appropriated for research, development, test, and evaluation for the defense agencies to NASA as part of the ALS program. Prohibits funds appropriated by this Act from being expended for research, development, test, and evaluation intended to facilitate deployment of a ballistic missile defense system.

H.R.2782 (10/30/87)
(P.L. 100-147)

· Authorization for specified activities relating to: (1) research and development; (2) space flight, control, and data communications; (3) construction of facilities; and (4) research and program management.

· Authorizes the NASA Administrator to transfer a specified amount from any unobligated funds for prior years (with certain exceptions) for the preparation of the Mars Observer Spacecraft for launch in 1992.

· Permits appropriations for research and development and for Space Research and Technology and for Transatmospheric Research Technology programs to be used for any items of a capital nature (other than acquisition of land) which may be required at locations other than NASA installations for the performance of research and development contracts, and for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for the purchase or construction of additional research facilities. Requires the Administrator of NASA to notify specified congressional officers and committees whenever the cost of a facility exceeds a specified amount. Permits funds appropriated for research and development, for space flight, control, and data communications, or for construction of facilities to remain available without fiscal year limitation.

· Prohibits any civil space station authorized under this title from being used to: (1) carry or place in orbit any nuclear weapon or any other weapon of mass destruction; (2) install any such weapon or any celestial body; or (3) station any such weapon in space in any other manner. Permits this civil space station to be used only for peaceful purposes.

· Requires the Administrator, for each of FY 1989 through 1996, to submit a budget request to the Congress, with budget estimates for the fiscal year involved and the two succeeding fiscal years, for the capital development of the space station. Limits the amount for Space Station development to no more than 25 percent of the total budget submission for NASA for any one fiscal year.

· Limits the amount for operation and enhancement of the Space Station to ten percent of the total budget submission for NASA for any one fiscal year.

· Expresses the sense of the Congress concerning the geographical distribution of NASA research and development funds. Directs the Administrator to report by January 15, 1988, to specified congressional committees on consideration and exploration of such distribution during FY 1987.

· Amends the National Aeronautics and Space Act of 1958 to permit the Administrator to accept gifts and donations for the construction of a space shuttle orbiter. Provides that all gifts and donations not needed for such construction be used in tribute to the crew of the space shuttle Challenger and in furtherance of the exploration of space. Directs the Administrator to select the name of the space shuttle orbiter from among suggestions from elementary and secondary school students.

· Expresses the sense of the Congress that the capital investment in space satellites and vehicles should be enhanced and protected by establishing a system of servicing, rehabilitation, and repair capabilities in orbit (satellite servicing). Directs the Administrator to study satellite servicing, taking specified factors into consideration, and report on such study to the Congress by January 15, 1988.

· Express the sense of the Congress that the solid rocket motor project of the space shuttle program would benefit from competition, and that an advanced solid rocket motor would enhance the margin of safety, reliability, and performance of the space shuttle. Directs the Administrator, by the date of the President's FY 1990 budget request to the Congress for NASA, to request proposals for acquiring an advanced solid rocket motor by competitive procurement.

1988

H.R.4399 (11/15/88) (P.L. 100-657)

· Expresses the sense of the Congress that the United States should explore ways and means of developing a dialogue with appropriate foreign governments to produce guidelines for access to launch services by satellite builders and users to assure reasonable and fair international competition in commercial space activities.

· Directs the Administrator of NASA to: (1) design a program to support research into launch systems component technologies to develop higher performance and lower costs for commercial and Government launches; and (2) report to the Congress outlining the program.

H.R.4686 (11/3/88) (P.L. 100-591)

· Authorizes the Administrator to enter into an agreement with the Administrator of the National Aeronautics and Space Administration (NASA) regarding the use of NASA facilities to study the human factor aspects of a highly automated environment upon air traffic controllers. Prescribes the contents of such research. Authorizes appropriations.

S.2209 (11/17/88) (P.L. 100-685)

· Authorizes FY 1989 appropriations to NASA for specified activities relating to: (1) research and development; (2) space flight, control, and data communications; (3) construction of facilities; and (4) research and program management, including scientific consultations.

· Directs the Administrator of the National Aeronautics and Space Administration (NASA) to submit to specified congressional committees, by March 15, 1989, a five-year capital development plan, including: (1) economic assumptions, budgetary requirements, and estimates of expenditures relating to objectives; (2) a detailed operating plan for FY 1989 and program plans for FY 1990 through 1993; and (3) estimates of total projected investments in various capital improvements necessary for plan objectives.

· Expresses the sense of the House of Representatives that the NASA budget should increase substantially, with a goal of at least 15 percent growth for each of the five years immediately following this Act's enactment.

· Authorizes FY 1990 and 1991 appropriations, as well as those for FY 1989, for research and development associated with the U.S. International Space Station.

· Permits appropriations for the first two categories listed above to be used for certain items of a capital nature (other than land acquisition) required for the performance of research and development contracts, and for grants to nonprofit educational and research organizations to augment their research facilities.

· Declares it to be the sense of the Congress that it is in the national interest to consider geographical distribution, whenever feasible, in allotting Federal research funds and that NASA should explore ways to do so.

· Amends the National Aeronautics and Space Act of 1958 to authorize certain NASA-related personnel to make warrantless arrests, under limited circumstances, in accordance with regulations prescribed by the Administrator and approved by the Attorney General.

· Makes specified funds authorized for space flight, control, and data communications available, without fiscal year limitation, in connection with the advanced solid rocket motor project of the space shuttle program, if the Administrator determines that it is in the best interest of the United States to accept a proposal offering a privately financed and non-Government-owned production facility.

· Directs the Administrator to: (1) contract with the National Academy of Sciences to review the microgravity research capability of the United States and issue a report addressing specified issues with respect to a commercially developed space facility; (2) contract with the National Academy of Public Administration to consider various features associated with Government costs that might be associated with such a facility; and (3) report to specified congressional committees, no later than May 15, 1989, on topics relating to a commercially developed space facility and microgravity facilities.

· Authorizes the NASA Administrator to lease to the State of Ohio or to an appropriate tax-exempt entity specified property at the Lewis Research Center in Cuyahoga County, Ohio, for an aerospace institute to serve as a facility for aeronautical and space research, the training and education of space and aeronautical engineers, and technology transfer activities. Permits, in addition, agreements for NASA administrative, maintenance, instructional, and other support for this institute.

· Authorizes the FAA Administrator to enter into an agreement with the NASA Administrator regarding the use of NASA facilities to study the human factor aspects of a highly automated environment upon air traffic controllers. Prescribes the contents of such research. Authorizes appropriations.

1989

H.R.2916 (11/9/89)
(P.L. 101-144)

· Appropriations for research and development, space flight, control and data communications, construction of facilities, research and program management and the Office of Inspector General.

1990

H.R.5158 (11/5/90)
(P.L. 101-507)

· Makes appropriations for FY 1991.

· Requires the NASA Administrator and the EPA Administrator to ensure that at least eight percent of Federal funding for prime and subcontracts (including those for the space station, wastewater treatment, and leaking underground storage tanks) be available to business concerns or other organizations owned or controlled by socially and economically disadvantaged individuals, including historically Black colleges and universities and minority educational institutions, and economically disadvantaged women.

· Sets forth limitations on average employment in EPA and NASA headquarters.

S.2287 (11/16/90)
(P.L. 101-611)

· Authorization for specified activities relating to: (1) research and development; (2) space flight, control, and data communications; (3) construction of facilities; (4) research and program management, including scientific consultations; and (5) the Inspector General.

· Permits appropriations for the first two numbered categories to be used for certain items of a capital nature (other than land acquisition) required for the performance of research and development contracts and for grants to nonprofit educational and research organizations to augment their research facilities.

· Amends the National Aeronautics and Space Act of 1958 to add to the functions of NASA those of: (1) seeking and encouraging the fullest commercial use of space; and (2) encouraging and providing for Federal Government use of commercially provided space services and hardware.

· Requires the Administrator to: (1) distribute research and development funds geographically in order to provide the broadest practicable participation in NASA programs; (2) award to a domestic firm a contract that, under the use of competitive procedures, would be awarded to a foreign firm, if certain conditions exist; and (3) submit to specified congressional committees certain reports relating to the Advanced Solid Rocket Motor.

· Directs the Secretary of Defense and the Administrator to jointly pursue on a high priority basis a National Aero-Space Plane program to develop and demonstrate, by 1997, a primarily air breathing single-state-to-orbit and long range hypersonic cruise research flight vehicle. Requires, as much as possible, technological information developed to be transferred to the military and to the domestic civil aviation and other private industries. Requires joint development of management plan.

1991

H.R.1988 (12/9/91)
(P.L. 102-195)

· Authorization for activities relating to: (1) research and development; (2) space flight, control, and data communications; (3) construction of facilities; (4) research and program management, including scientific consultations; and (5) the Inspector General.

· Permits appropriations for the first two numbered categories to be used for certain items of a capital nature (other than land acquisition) required for the performance of research and development contracts and for grants to nonprofit educational and research organizations to augment their research facilities.

· Amends the National Aeronautics and Space Administration Authorization Act, Fiscal Year 1991 to increase the authorization of appropriations for the Comet Rendezvous Asteroid Flyby/Cassini (CRAF/Cassini) mission. Modifies requirements regarding when certain amounts are available for the mission.

· Expresses the sense of the Congress that it is in the national interest to give consideration to the geographical distribution of Federal research funds whenever feasible.

· Prohibits, until 30 days following congressional receipt of the Administrator's full explanation, the use of funds appropriated pursuant to this Act for any program that: (1) has been eliminated by the Congress; (2) is in excess of the amount actually authorized for the particular program (except for construction of facilities); or (3) has not been presented to either of the relevant congressional committees.