THE 1988 BUDGET AND THE FUTURE OF THE NASA PROGRAM

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NOTE

All years referred to in this report are fiscal years unless otherwise indicated.

PREFACE

In examining the NASA budget for 1988 the Congress will make important decisions about the future of the civil space program in the face of competing spending priorities. In response to a request by the Senate Committee on Commerce, Science, and Transportation, this staff working paper analyzes the major issues in the NASA fiscal year 1988 budget, with particular emphasis on the productivity of the space program and the overall cost of space activity after the space shuttle Challenger accident.

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SUMMARY

Expectations for civil space activities exceed the budget allotted to the current program of the National Aeronautics and Space Administration (NASA). In considering the NASA budget for fiscal year 1988, the Congress will have to decide how much of the present NASA program can be afforded as it competes with other important spending priorities and as it starts to recover from the Challenger accident and its consequences.

The most immediate consequence has been to increase the cost of all space activity at the very time that NASA was turning to its next major program and budget commitment, a permanently manned space station to be deployed in the mid-1990s. No less significant, but less direct, is a reexamination of major aspects of the currently planned program, including the role of the manned space shuttle versus unmanned rockets, the usefulness of the present space station in relation to large increases in its estimated costs, the role and cost of large space science projects, and their effect on the viability of small, less costly space science projects. In order to continue NASA's agenda at its preaccident level, this analysis estimates that the cost of program additions in space transportation, space science, and the space station would increase the NASA budget by $14.0 billion above the Congressional Budget Office (CBO) baseline for fiscal years 1988 through 1992. [1]

BACKGROUND

Because the Challenger accident had such profound effects on the entire NASA program and budget, this analysis includes a brief background to highlight the particular problems that the Congress--and NASA itself--face as they plan for the 1988 budget and the year beyond.

1. The CBO baseline assumes no real growth in the NASA budget for 1988 through 1992, after subtracting $2.1 billion from the 1987 appropriation to account for the one-time appropriation to replace Challenger. The $14.5 billion estimate assumes that the program additions are not partially offset by reductions elsewhere in the NASA budget.

The NASA Program Before Challenger

The year 1986 was to have been one of significant accomplishments for NASA. In early January, popular press articles, previewing the planned course of space activities for that year, hailed 1986 as "the year of space science." Several long-term, very costly (and in some cases long-delayed) missions were to be launched, including the Galileo probe to Jupiter, the Ulysses probe to measure solar radiation, and the highly sophisticated Hubble Space Telescope. As important for other parts of the NASA research and development program were flights carrying numerous small satellites, scientific instruments, and round trip experiments.

At the same time, the shuttle system was to have realized its promise by completing a second year of operating at a significant flight rate, at or above the nine flights of 1985, and by carrying not only NASA payloads but also those of the Department of Defense (DoD), private firms, and foreign governments. The space station, described by NASA as the "next logical step," was to continue in its design phase, with actual development expenditures beginning in 1987.

These program developments were reflected in the NASA budget. Development expenditures were to end for the major research and development missions that were to have been launched. The shuttle system was to require less new federal investment and would realize budgetary savings through improved operating efficiency. Moreover, net inflows to NASA were anticipated because receipts for transportation services provided to the DoD were expected to exceed the cost of the services provided. These savings and revenue gains, along with the Administration's proposal for 1 percent annual real growth in the NASA budget, were to create a budget wedge permitting the space station to be funded.

The Challenger Accident

The Challenger accident has at best postponed this vision of U.S. activities in space and made it more expensive. At worst, a new, more modest set of objectives will characterize the post-Challenger space program.

The NASA program and budget continue to be affected by the accident. The shuttle program--the major activity in the space flight, control, and data communications function of the NASA budget--will be grounded for a minimum of two years. The goal of increasing the shuttle flight rate to 24 per year has been replaced by the goals of producing a new

orbiter and returning the shuttle system to safe flight. Budget increases were granted in 1986 and 1987 relative to the preaccident baseline of $2.6 billion--$531 million in 1986 to cope with the immediate consequences of the accident, and $2.1 billion in 1987 to replace Challenger.

Research and development programs and budgets have been particularly affected. Launch delays have caused a backup of payloads, and some of these need new development funds to meet tighter safety standards. The overall research and development budget legislated for 1987 was close to the Administration's request, but the program it would fund was radically different. Numerous missions that were to have flown in the late 1980s are being rescheduled into the mid-1990s. Those parts of the over $3 billion annual research and development program which is dependent on space flight are essentially on hold.

PROGRAM ADDITIONS FOR 1988 THROUGH 1992

The many choices confronting the Congress in the 1988 NASA budget generally fit the same pattern--the Congress can either lower the objectives of the program or significantly increase NASA funding above the CBO baseline. Real baseline budget authority for fiscal year 1988 through 1992 is $8.4 billion, derived from NASA's 1987 real funding level of $10.5 billion less the one-time $2.1 billion appropriation for an orbiter to replace Challenger, and then adjusted for inflation in the outyears. Program and funding additions in three areas are arguably necessary for NASA to achieve the goals of the preaccident program. Table S-1 presents a range of cost estimates above the CBO baseline in each of three areas: space transportation, space science, and the space station.

Space Transportation

In space transportation, the current program and budget restricts NASA's launch options to the shuttle system. Providing expendable launch vehicles (ELVs), particularly for NASA science payloads, is an alternative. The rationale supporting this option emphasizes the backlog of NASA payloads even if the shuttle recovery program were implemented as planned. Moreover, given the substantial probability of delays in the launch schedule for 1988 through 1992, the prospect of additional delays and costs in the space science program adds weight to the argument for NASA use of ELVs.

The most significant argument against the addition of rockets is its cost. The low option program included in Table S-1 would cost $700 million

above the baseline over the five-year period and provides for nine payloads during that time. The low option does not relieve pressure on the shuttle system after 1992, but does not preclude additional orders later. The high option would cost $2.3 billion over five years, but would provide for 26 payloads, including seven for the space station, between 1989 and 1995.

Space Science

While launching the backlog of payloads is the foremost issue in space science, a second problem in this area--evident before the accident--concerns the mix of large and small projects. The accident has dramatized the risks of a space science program that is dominated by large projects. Moreover, the range of problems confronted by scientists in the fields interested in space for itself, or in using the attributes of space, is best addressed by a broader number of experiments.

The large-scale projects that rely on the shuttle have been well-supported. The Hubble Space Telescope, an orbiting observatory to be launched

TABLE S-1. BUDGET AUTHORITY INCREASES ABOVE CBO BASELINE NECESSARY TO REACH PREACCIDENT GOALS
(By fiscal year, in millions of dollars of budget authority)

Space Activity	1988	1989	1990	1991	1992	1988-1992 Total
Space Transportation a/						
Low option	85	160	220	230	0	695
High option	555	335	420	495	555	2,360
Space Science	100	104	109	112	117	542
Space Station b/						
Middle option	330	1,380	1,510	1,690	1,600	6,500
High option	330	1,840	2,510	2,950	3,460	11,050

SOURCE: Congressional Budget Office.

a. Range is based on different levels of service.

b. Range is based on current budget submission and approximations of new NASA cost estimates.

and serviced by the shuttle, is a billion dollar investment that may require support costs of $200 million annually. If a decision is made to go forward with the space station, projects related to it are also likely to be supported. Intermediate and small-scale projects that cost from several million dollars to $500 million and that are directed toward a limited set of scientific objectives could be lost in the ensuing budget squeeze. To address this concern and to include room for these efforts over the next five years, several intermediate-size projects--the Topex ocean observation satellite and two smaller physics payloads--provide the basis for an illustrative increase above baseline for science spending of $100 million in 1987 dollars.

Space Station

The space station is the major NASA program and budget issue that the Congress will decide upon this year. Support for the NASA station design and program this year strongly implies support for the multiyear commitment of perhaps as much as $30 billion between 1988 and 2000.

Before the accident, the case for the NASA station emphasized benefits in scientific and commercial areas, particularly in materials and life sciences, and in robotic and automation spin-offs for U.S. manufacturing. In addition, the station is viewed by supporters as a logical step in the manned space program toward a permanent base on the moon and a manned voyage to Mars. The accident has added force to this case by creating a perception that the U.S. leadership in space is being lost to the Soviet Union and competitors in Europe and Japan.

The accident has also added to the case against the NASA station by calling attention to the uncertainty of its benefits and its final cost. The lost shuttle flights, particularly in materials and life sciences, have decreased uncertainty about the usefulness of the station. The capacity of the shuttle fleet to support the station construction phase is very unclear. Construction of the station could fill two-thirds of the shuttle manifest for several years, forcing the deferral of crucial security and science payloads.

Table S-2 presents three alternative funding profiles for the space station: the CBO baseline, the level of spending included in NASA's 1988 budget plan, and a high option based on the publicly reported new NASA cost estimate for the station (roughly $14.6 billion, in 1984 dollars, as opposed to earlier estimates of $8 billion, also in 1984 dollars). The CBO baseline, at best, would provide a modest intermittently tended space station. The

middle option plan, based on the five-year spending profile for the space station in the Administration's fiscal year 1988 request, could fund the station planned by NASA, but later than the mid-1990s completion date currently contemplated, or it could support a more modest but undefined space station in the mid-1990s. The high option is the best current estimate of the levels of spending that would be required to meet the goal included in the preaccident program--construction of the current design by the mid-1990s. Even this high option does not include transportation, operations, additional scientific equipment, and a "lifeboat" spacecraft that would allow the station crew to return to earth in the event of an emergency.

A central conclusion of this analysis is that the expectations of the preaccident program cannot be realized without substantial spending increases above the CBO baseline. Full funding of the additions to the NASA program considered in this analysis would raise NASA spending to $9.9 billion in 1988, $1.0 billion above the baseline, and to $62.5 billion over the 1988-1992 period, $14.0 billion above the $48.5 billion baseline. Moreover, this analysis excludes some of the aspirations of the preaccident NASA program and more recent suggestions that the NASA budget include development of a new, unmanned, heavy lift vehicle. Still the increases over the baseline are indicative of the support necessary to permit NASA to reach the goals of the preaccident program. The Congress must determine, therefore, which aspects of the NASA program deserve sizable increases above baseline and which should be deferred or reexamined in the light of competing spending priorities.

TABLE S-2. SPACE STATION FUNDING PROFILES, FISCAL YEARS 1988-1992
(In millions of dollars of budget authority)

Profits	1988	1989	1990	1991	1992	1988-1992 Total
CBO Baseline	440	460	490	520	540	2,450
Middle Option	770	1,840	2,000	2,200	2,140	8,950
High Option	770	2,300	3,000	3,500	4,000	13,500

SOURCE: CBO baseline real 1987 spending adjusted for inflation through 1992; Middle Option, 1988 Administration request and outyear projections; and High Option, recent NASA estimate as reported in *Science*, February 27, 1987, p. 965.

CHAPTER I

INTRODUCTION

The Challenger accident of January 1986 has substantially disrupted the program and budget of the National Aeronautics and Space Administration (NASA). This report examines the extent of this disruption and the choices confronting the Congress in considering the NASA program and budget for fiscal year 1988. Particular emphasis is placed on space transportation in recognition of its central role in the NASA program.

THE SHUTTLE SYSTEM'S ROLE IN THE NASA PROGRAM

The linchpin of the current NASA program is the space transportation system (sometimes called the shuttle system). Space science and technology programs currently depend on the shuttle system to launch satellites in orbit around the earth, or probes to the planets, or to carry instruments and round-trip experiments. As a purely logistical matter, the minimum of two years' grounding of the shuttle system has left NASA with very limited access to space until the shuttle returns to flight. NASA's program and budget do not include procurements of expendable launch vehicles (ELVs)--traditional rockets--to supplement the shuttle when it returns to operation in 1988.

Three airplane-like, manned spacecrafts, referred to as orbiters or shuttles, are the most visible part of the system. A fourth orbiter to replace the Challenger is on order, although funds may not be expended until August. During a shuttle flight, an orbiter is launched into space by two solid fuel rockets (called solid rocket boosters), to which the orbiter is attached, and by three liquid fuel engines that are contained in the spacecraft fuselage, but draw fuel from a large fuel tank (called the external tank) attached to the underbelly of the orbiter between the two solid fuel rockets.

Each orbiter can carry a variety of cargoes to and from space--satellites, instruments, or a laboratory unit called spacelab that expands the volume of space in which people can work. Shuttle-borne satellites that require orbits higher than 160 to 200 nautical miles are typically attached to rockets and carried in the shuttle cargo bay; after the shuttle reaches its

orbit, the satellites are then launched by their rockets to their final earth orbits or beyond to the planets. These "upperstage" rockets come in a variety of sizes designed to service different payloads.

The shuttle system includes a great deal more than the visible hardware and activity of a typical flight. Incorporated in the system are launch and landing facilities, manufacturing plants for major components (such as the booster rockets and fuel tanks), and a large institutional and management structure. These operations are spread over the major NASA centers, most prominently the Kennedy Space Center in Florida, the Marshall Space Flight Center in Alabama, and the Johnson Manned Space Flight Center in Texas. Both NASA and private contractor personnel are involved.

NASA's high expectations for the shuttle system have consistently been unfulfilled. From the 1970s on, the expected number of flights per year has decreased as actual performance has never reached projected goals.[1] By 1986, however, the system seemed ready to deliver its promised capability, and a variety of national security, commercial, and space science missions were to be launched.

On January 28, 1986, the orbiter Challenger was destroyed and its crew of seven killed, when a seal on the right solid rocket booster malfunctioned. The Rodgers Commission, an investigatory commission chartered by the President, described the ensuing conflagration as "... an explosive burn of hydrogen and oxygen propellants that destroyed the external tank and exposed the orbiter to severe aerodynamic loads that caused complete structural breakup."[2] Also lost was a Tracking and Relay Data Satellite (TRDS) that Challenger was to have deployed. As a consequence, the solid rocket booster seam, or joint, is being redesigned and many aspects of the whole system reexamined. The system is projected to return to flight in February 1988, at the earliest.

The effects of the Challenger accident on the NASA program will not be limited to 1986 or even to this decade. In strictly physical terms, space science payloads that were to have been launched in the 1980s will not be

1. For a discussion of the history of the shuttle system, see Congressional Budget Office, *Pricing Options for the Space Shuttle* (March 1985), and *Setting Space Transportation Policy for the 1990s* (October 1986.)

2. *Report of the Presidential Commission on the Space Shuttle Challenger Accident*, The White House, June 6, 1986, p. 19.

launched until the 1990s. Moreover, questions have been raised about the physical capability of the shuttle system to support NASA's next major project, a permanently manned space station. As important as these physical issues are, the accident has also set into motion a number of concerns about the NASA program and its budget.

THE NASA BUDGET AND TRENDS IN PROGRAM FUNDING

The real growth of the NASA budget over the last five years has been 3 percent annually, if the extraordinary appropriation of $2.1 billion to replace the Challenger is excluded from the fiscal year 1987 funding. If the orbiter is included, the rate increases to 9 percent. The NASA budget is divided into four parts: research and development; space flight, control, and data communications; research and program management; and construction of facilities. 3/ Research and program management and construction of facilities have consistently represented 20 percent of NASA spending. The more visible space flight and research and development programs account for the remaining 80 percent. This analysis is limited to these two major areas.

The space flight, control, and data communications area received the largest budget increases following the Challenger accident, as it is the program directly responsible for space transportation. A 1986 supplemental appropriation and the 1987 special appropriation to fund fully the replacement of the Challenger totaled $2.6 billion in funding unanticipated by the NASA 1987 budget estimate.

Before the Challenger accident, the research and development share of the NASA budget was growing at the expense of the space flight share. In 1983, space flight accounted for 53 percent of the NASA budget while research and development accounted for 28 percent. By 1986, the space flight share had shrunk to 47 percent while the research and development share had increased to 34 percent. Until the Challenger accident, these trends were expected to continue; the NASA budget estimate for 1986 submitted with the fiscal year 1987 budget request projected a 37 percent share

3. NASA funding is drawn entirely from two budget functions, function 250, general science, space and technology, that accounted for 92 percent of NASA funding on average from fiscal years 1983 through 1987 and function 400, transportation, funding the NASA aeronautical research program, on average 8 percent of NASA funding from 1983 through 1987.

for research and development and only a 44 percent share for space flight. But a $531 million supplemental appropriation in June 1986 and subsequent reprogramming of research and development funds to the space flight account in the wake of the accident dampened the swing towards research and development.

The decline in the space flight share through 1986 reflected the completion of the shuttle fleet. NASA planned to continue this shift in funding as operational efficiencies in the shuttle system occurred and customer service revenues grew. Before the accident, these inflows were expected to add $320 million in 1986 and $704 million in 1987 to the funding used to operate the shuttle system. If the 1987 funding to replace Challenger were excluded, real spending in the space flight account would decline by 2 percent annually from 1983 through 1987. But space flight budget requirements have increased, and in 1987 again accounted for 55 percent of NASA funding as a result of the accident, the subsequent reexamination of the entire shuttle system, and the loss of revenues from the Department of Defense (DoD) and commercial clients as shuttle flights were cancelled.

The preaccident trend in the NASA budget was consistent with the direction of its program. The shuttle investment was to begin to pay dividends and would claim fewer budget resources. This would allow growth in NASA spending for its research and development mission from small-scale experiments; to the billion dollar orbiting observatory, the Hubble Space Telescope; and finally to the development and construction of the space station. But if the research and development agenda remains unchanged, and the space flight portion of the budget now must grow to assure the availability of space transportation, then questions arise as to whether the preaccident program can be accomplished without significantly higher growth in NASA spending than anticipated before the accident.

CHAPTER II

THE CHALLENGER ACCIDENT: RESULTANT PROGRAM AND BUDGET CHANGES

The Challenger accident affected NASA programs and budgets well beyond the immediate need to identify and resolve the problems revealed by the shuttle explosion. Virtually all NASA programs were reoriented by the accident and resulting halt in shuttle flights. This chapter identifies these effects and, in doing so, establishes a budgetary and programmatic starting point for considering the options before the Congress as it examines the NASA budget for fiscal year 1988.

In February 1986, NASA presented the Congress with its budget plan for fiscal year 1987 in *Budget Estimates, Fiscal Year 1987.*[1] This document and the projections, estimates, and policies underlying it provide the most complete picture of the civil space program anticipated before the Challenger accident. The pervasive effects of the Challenger disaster on the NASA program and budget are revealed by a comparison of these preaccident estimates of funding in 1986 (after correcting for the reductions required in 1986 by the Balanced Budget Act) and in 1987 with the postaccident 1986 actual numbers and 1987 estimates found in the subsequent plan, *Budget Estimates, Fiscal Year 1988.*[2]

As indicated in Chapter I, the accident affected both the overall NASA budget and the distribution of budget authority between the two major parts of the NASA program: space flight--the portion of the program responsible for the shuttle system--and research and development (R&D)--the part of the program responsible for developing new space hardware and space science and applications programs. The widespread effects of the accident within each of these programs is the concern of this chapter.

While the Challenger accident was the dominant force reshaping the NASA program and budget plans for fiscal years 1986 and 1987, other influences altered spending plans in these years. The 1986 budget estimates

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1. National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I (February 1986).

2. National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1988*, vol. I (February 1987).

used as a point of comparison in this analysis are corrected to reflect reductions in 1986 spending authority required by the Balanced Budget and Emergency Deficit Control Act of 1985 (the Balanced Budget Act). Although the 1987 postaccident estimates for particular programs also reflect the effects of forces other than the accident, no single force affects all parts of the program in 1987, as the Balanced Budget Act did in 1986. In the review of particular programs that follows, the larger changes unrelated to the accident are noted.

SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS

The space flight, control, and data communications program has undergone a complete change in its goals and activities and has received large increases in its budget authority as a result of the accident. The preaccident goals of providing routine access to space and continuing to develop the system flight rate toward 24 shuttle launches annually have been supplanted by the new objectives of returning the system to safe flight and replacing the Challenger. The increased funding granted to the space flight, control, and data communications account is shown in Table 1.

Maintaining and operating the shuttle system accounted for over 75 percent of the $3.6 billion in funding granted this area during 1985, the last year unaffected by the accident. The balance ($796 million in 1985) was spent to provide tracking, telemetry, control, and data acquisition in support of the shuttle system and other space flight activities.

Responsiblity for the shuttle is divided between the shuttle production and operational capability program and the space transportation operations program. The effects of the accident are most prominent in these program areas. Table 1 compares the preaccident budget estimates for these areas with comparable budget estimates submitted in support of the postaccident NASA budget request. Postaccident 1986 funding was higher in these major space flight accounts than that estimated before the accident. The production and capability portion increased by $477 million, or 53.7 percent, but was offset partially by a $45 million decline in operations funding. Budget authority for the orbiter procurement in 1987 drives the production and capability estimate four times higher than foreseen before the accident, $3.1 billion compared with $745 million. Operations cost estimates for 1987 registered a $322 million, or 21 percent, increase after the accident, which was more than offset by a net revenue decline of $883 million relative to preaccident expectations.

Shuttle Production and Operational Capability

The major objective of this program is to ensure the flight capability of the shuttle fleet. The postaccident program goals are to restore the shuttle system to safe operations and to procure a new orbiter to replace Challenger. This program also includes funding for the redesign of the solid rocket booster joint, identified as the cause of the Challenger accident.

TABLE 1. BUDGET FOR SPACE FLIGHT, CONTROL, AND DATA COMMUNICATIONS, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Program Components	1986	1987
Total, Space Flight, Control and Data Communications Account		
Preaccident	3,241	3,069
Postaccident	3,666	5,815
Percent Change	13.1	89.5
Space Transportation Programs		
Shuttle Production and Operational Capability, with Replacement Orbiter		
Preaccident	888	745
Postaccident	1,365	3,105
Percent Change	53.7	316.6
Space Transportation Operations		
Preaccident	1,685	1,525
Postaccident	1,640	1,847
Percent Change	-2.7	21.1
Space and Ground Networks, Communication, and Data Systems		
Preaccident	668	799
Postaccident	660	863
Percent Change	-1.2	8.0

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

The preaccident program goal was to attain a system flight rate of 24 launches per year. NASA now maintains a goal of 16 to 20 shuttle flights per year, but safety concerns may constrain it. Consequently, planning exercises within NASA have adopted a broad range of future flight rates. For example, the NASA mixed-fleet analysis subjects its findings to sensitivity analysis, employing a range of flight rates from 12 per year to 16 per year. [3]

The specific costs in the shuttle production and operational capability program associated with the accident are shown in Table 2. NASA has divided these costs into two groups, "anomaly resolution/corrective actions" and "response to the Rogers Commission." The former accounts for almost $800 million in total, $600 million of which will have been spent in 1986 and 1987, the largest part to redesign and test the solid rocket booster identified as the cause of the accident. Only $170 million of the $580 million earmarked to respond to the Rogers Commission Report was included in the 1986 and 1987 programs. These funds and those NASA deems necessary to request in the future are spread over a number of items including modifications to the orbiters ($130 million in total) and implementation of a crew escape system ($150 million in total).

Space Transportation Operations

NASA expects shuttle flights to resume in February 1988. But spending for these flights occurs in earlier years, since flying the shuttle requires activity and budget support in the two years before an actual shuttle launch. A major change in this program caused by the accident is the loss of revenues to NASA for providing shuttle services to the DoD and to foreign and commercial customers. The preaccident projections of these inflows for 1986 and 1987 and current expectations are shown in Table 3. Since NASA was not able to meet these commitments and now bars commercial satellite launches from the shuttle if these payloads can be launched by an ELV, NASA will refund $179 million to one federal and several commercial customers during fiscal year 1987. For both 1986 and 1987, postaccident revenues will be less than expected before the accident--by $42 million in 1986 and $883 million in 1987, the sum of lost anticipated inflows of $704 million and refunds of $179 million. In amending the 1987 budget, the Congress

3. National Aeronautics and Space Administration, Office of Space Flight, *Report of the NASA Mixed-Fleet Study Team* (January 1987).

provided NASA with funds to compensate for DoD payments that would have been made during that year. In the future, DoD will receive nine shuttle flights in recognition of advanced payments in years before 1986 for launch services postponed by the accident.

TABLE 2. CHALLENGER ACCIDENT COSTS INCURRED IN THE SHUTTLE PRODUCTION AND OPERATIONAL CABABILITY DEVELOPMENT PROGRAM
(In millions of dollars of budget authority)

	Fiscal Years 1986/1987	Balance to Completion	Total
Anomaly (Problem) Resolution and Corrective Action	605	193	798
Actions in Response to the Rogers Commission	170	410	580
Total	775	603	1,378

SOURCE: National Aeronautics and Space Administration.

TABLE 3. SHUTTLE OPERATIONS REIMBURSEMENTS, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority)

Time Period	1986	1987
Preaccident	320	704
Postaccident	278	-179

SOURCE: National Aeronautics and Space Administration.

Space and Ground Network, Communications, and Data Systems

The loss of a Tracking and Data Relay Satellite (TDRS) in the accident will require replacing the lost satellite and delaying a planned transition from the current ground tracking network to the space-based TDRS system. Launch delays for these satellites, shown in Table 4, will necessitate maintenance of the ground network not only in 1986 and 1987 but at least into 1988 when the TDRS may become fully operational. Table 1 compares pre- and postaccident budget authority for 1986 and 1987 for the space and ground network, communications, and data systems program.

Replacement of the TDRS satellite will require over $35 million of unanticipated spending in 1986 and 1987. The Administration has requested $76 million in 1988, with a balance to completion of $135 million beyond 1988. Ground network stations in six locations that were to have been closed in mid-1986 will remain in operation until at least late 1988 at a cost of $43 million.

RESEARCH AND DEVELOPMENT

Three of the six major components of the NASA research and development program, accounting for over 70 percent of R&D spending in 1986, were

TABLE 4. LAUNCH DELAYS FOR THE TRACKING AND DATA RELAY SATELLITE (TDRS)

Satellite	Preaccident Launch Date	Current Launch Date
TDRS-D	7/22/86	9/22/88
TDRS-C	2/16/87	2/18/88
TDRS-E (Replaces TRDS-B lost in accident)	n.a.	2nd Quarter 1991

SOURCE: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986.

Note: n.a. = not applicable.

affected significantly by the flight cancellation caused by the accident. These flight-dependent programs are space transportation capability development, space science and applications, and commercial scientific projects. Table 5 shows total R&D budget authority before and after the accident. Despite major changes in program activity, funding changed relatively little. 4/

TABLE 5. BUDGET FOR RESEARCH AND DEVELOPMENT, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
Preaccident	2,618	3,003
Postaccident	2,619	3,128
Percent Change	0.0	4.2

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

The effect of shuttle flight delays on the R&D program has been pervasive. (Table A-1 in the appendix provides a complete list.) The average launch delay for all science activity, including several foreign and joint payloads, is over 40 months for those payloads that have been rescheduled. Some delays were likely to have occurred even without the accident because of the optimistic preaccident view of the shuttle flight rate presented in the November 1985 manifest, but for the most part the average delay is caused by the accident.

In programs that depend on space flight, funds spent in previous years--to plan missions, integrate payloads and launch vehicles, and to plan for the analysis of flight data--were to a greater or lesser extent lost

4. The change in the 1987 figures includes the addition of $80 million to the research and development activities in the communications portion of the space applications program to support the Advanced Communications Technology Satellite (ACTS), a spending addition and program change unrelated to the accident.

because of the accident. Flight delays will require all of these tasks to be reworked. In some cases, delays will permit new sensors to be attached to spacecrafts, increasing the productivity of these missions. The mere act of storing payloads and maintaining project teams absorbed funds that might have otherwise been used to operate and maintain payloads in orbit or to analyze flight data. Both large, very visible programs, such as the Hubble Space Telescope, and small, less costly ones have suffered from these delays in scheduling.

Space Transportation Capability Development

This program is a mixture of space transportation research and development, procurement of already developed hardware, and operation of already developed systems. The accident has delayed missions requiring upperstages (additional rockets used to boost payloads from the low earth orbit of the shuttle to higher orbits or to other planets). It has also disrupted upperstage procurements. In addition, increased safety concerns following the accident led to the cancellation of the Centaur upperstage program, necessitating alternative procurement for the three planetary missions scheduled to use the Centaur. Numerous spacelab missions, also a prominent part of the space transportation capability development program, were postponed, on average by 50 months.

Overall budget authority for space transportation capability development changed as a result of the accident, decreasing by 2 percent for 1986 and increasing by 6 percent for 1987, as shown in Table 6. The lower part of the table shows changes in pre- and postaccident budget authority for the major components of the space transportation capability development program. More spending will occur for upperstage procurement, as a consequence of the Centaur cancellation, and less spending will occur for other flight-related areas, including spacelab and payload operations and equipment development.

Space Science and Applications

Space science and applications is arguably the heart of the civil space program. The expansion of knowledge for knowledge's sake and the direct and indirect application of space science and technology for the public welfare and private economic gain are key products of all civil space spending. Space science and applications can be viewed as the ends to which the nation's large investments in space flight and proposed investment in a space station are the means.

TABLE 6. BUDGETS FOR TOTAL SPACE TRANSPORTATION CAPABILITY DEVELOPMENT PROGRAM AND FOR MAJOR COMPONENTS, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
Total Program		
Preaccident	411	466
Postaccident	404	496
Percent Change	-1.7	6.4
Major Components		
Spacelab		
Preaccident	90	90
Postaccident	78	74
Percent Change	-13.3	-17.8
Upperstages		
Preaccident	113	85
Postaccident	122	161
Percent Change	8.0	89.4
Payload Operations and Support Equipment		
Preaccident	59	73
Postaccident	55	45
Percent Change	-6.8	-38.4
Orbital Maneuvering Vehicle		
Preaccident	5	70
Postaccident	5	45
Percent Change	0.0	-35.7

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

The current space science and applications program is divided into eight areas: physics and astronomy, life science, planetary exploration, solid earth observations, environmental observations, materials processing in space, communications, and information systems. Solid earth observation, communications, and information systems have been relatively unaffected by the accident. In the other five areas, the grounding of the shuttle system meant no access to space. Moreover, even before the accident, delays in realizing the promised potential of the shuttle had already decreased science output from that anticipated in the early 1980s.

Table 7 presents the overall budget authority for space science and applications before and after the accident. The small changes in budget authority, less than 1 percent in 1986 and a 6 percent increase in 1987, belie the substantial changes in program activity, which are described in the following sections.

Physics and Astronomy. The flight delays shown in Table 8 will cause substantial setbacks in the physics and astronomy program. Budget authority for 1986 decreased by less than 2 percent, while 1987 funding increased by more than 2 percent after the accident, as shown in Table 9.

The *Hubble Space Telescope* (HST) is the centerpiece of the physics and astronomy program, accounting for 12 percent of the space science

TABLE 7. BUDGET FOR SPACE SCIENCE AND APPLICATIONS, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
	Total Program	
Preaccident	1,473	1,464
Postaccident	1,477	1,553
Percent Change	0.3	6.1

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

budget in 1987. The HST will be the first of four orbiting observatories spanning the electromagnetic spectrum. Because, unlike previous major observatory spacecraft, the HST is designed to be serviced in space and periodically refurbished in orbit, it depends entirely on the shuttle.

The telescope was to have been launched in October 1986, but has been delayed for a minimum of two years. Table 9 shows the budget authority for the HST for 1986 and 1987. The most significant increase resulting from the Challenger accident occurs in the development account for which current estimates for 1987 show an increase of more than $70 million over

TABLE 8. PHYSICS AND ASTRONOMY PAYLOAD LAUNCH DELAYS[a]

Payload	Preaccident Launch Date	Current Launch Date	Delay (In months)
Astro-1	3/6/86	1/19/89	34
Hubble Space Telescope	10/86	11/17/88	25
Environmental Observation Mission	10/27/86	Unscheduled	--
Astro-2	1/12/87	Unscheduled	--
Shuttle High Energy Astro Physics Laboratory	1/12/87	4th Quarter 1993	82
Spartan-2	1/27/87	2nd Quarter 1991	52
Space Life Sciences Laboratory 1	3/16/87	12/7/89	33
Spartan-3	8/4/87	2nd Quarter 1992	57
Astro-3	8/18/87	Unscheduled	--
Rosat	9/28/87	1st Quarter 1994	77
Spartan 205	11/9/87	Unscheduled	--
Gamma Ray Observatory	6/8/88	1/18/90	19
Spartan-211	6/14/88	Unscheduled	--
Cosmic Background Explorer	7/15/88	Unscheduled	--

SOURCE: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986.

a. Astronomy and physics payloads were also to have flown on some of the 10 materials science labs listed on the November 1985 manifest.

TABLE 9. BUDGET FOR TOTAL PHYSICS AND ASTRONOMY PROGRAM AND FOR MAJOR COMPONENTS, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
Total Program		
Preaccident	580	539
Postaccident	569	553
Percent Change	-1.9	2.6
Major Components		
Hubble Space Telescope		
Development		
Preaccident	126	28
Postaccident	126	101
Percent Change	0.0	260.7
Operations and Maintenance		
Preaccident	88	138
Postaccident	84	92
Percent Change	-4.5	-33.3
Total		
Preaccident	216	166
Postaccident	210	193
Percent Change	-2.8	16.8
Spacelab/Space Station Payload Development and Mission Management		
Preaccident	98	115
Postaccident	89	90
Percent Change	-9.2	-21.7
Suborbital Programs		
Preaccident	60	64
Postaccident	60	75
Percent Change	0.0	17.2

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

the preaccident estimate of $28 million. Increased spending on the HST is required to meet more stringent shuttle safety requirements, to store and maintain the spacecraft, to maintain the project team, and to refine the spacecraft before launch.

The refinements made during the two years of unanticipated downtime will improve the HST. Moreover, expenses incurred to maintain the highly specialized technical teams over the unexpected two-year hiatus are less than those necessary to shut down operations today and reconstitute these teams in the future. Yet, these are side considerations relative to the central fact that the benefits of two years of operations have been lost and the productivity of the entire civil space program has been diminished.

The *Gamma Ray Observeratory* (GRO) is the second of the orbiting observatories and, like the HST, is designed to be serviced in space. The budget authority allocated to GRO for 1986 and 1987 did not noticeably change as a result of the accident. The GRO is scheduled to be launched in January 1990, 18 months later than planned before the accident. But delays in any of the 15 flights preceding the scheduled GRO launch would further delay the observatory.

Spacelab payload development and mission management has experienced significant reductions in budget authority and program delays as a result of the accident. The spacelab includes two major sections: a manned laboratory section, carried in the forward half of the shuttle cargo bay, and several pallets, carried in the rear half of the cargo bay, to which instruments can be attached. These instruments constitute the major physics and astronomy use of spacelab. The postaccident rescheduling of numerous spacelab missions allowed decreases in 1986 and 1987 budget authority of 9 percent and 22 percent, respectively. Comparative budget authority figures are presented in Table 9.

The *Explorer Program* relies on small, relatively low-cost satellites to achieve limited physics and astronomy research objectives. The program fits with larger, more costly projects by developing the science and technology base necessary to decide upon and design larger projects. The accident has created substantial launch delays in the Explorer program. Moreover, over 40 Explorer proposals are on hold, waiting for the existing backlog to be cleared. Pre- and postaccident budget estimates have remained largely unchanged by the accident.

The *Suborbital Program* has received increased attention and budget authority as a consequence of the accident. This program conducts

experiments that can use small rockets, balloons, or aircraft rather than those requiring large rockets or the shuttle. Postaccident estimates of budget authority, shown in Table 9 were unchanged for 1986 and 17 percent higher for 1987 than comparable preaccident estimates.

Life Sciences

The primary concern of the life sciences program is understanding the effects of space on living organisms. Each shuttle flight contributes to this knowledge, as do specific large- and small-scale experiments, particularly those using the spacelab. Although overall budget authority reflects little change, 1987 budget authority for flight experiments has decreased in favor of research and analysis, as Table 10 shows.

TABLE 10. BUDGET FOR LIFE SCIENCES PROGRAM, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Major Components	1986	1987
Life Sciences Flight Experiments		
Preaccident	32	37
Postaccident	32	30
Percent Change	0.0	-18.9
Research and Analysis		
Preaccident	34	38
Postaccident	34	48
Percent Change	0.0	26.3
Total		
Preaccident	66	75
Postaccident	66	72
Percent Change	0.0	-4.0

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

A major focus of the life sciences program is the *Space Life Sciences Laboratory*, originally scheduled to fly in March 1987 but subsequently rescheduled to December 1989. The life sciences program is also providing experiments for the *International Materials Laboratory* mission, delayed from May 1987 to April 1990. Smaller-scale experiments will begin when the shuttle returns to service.

Planetary Exploration

Three major NASA planetary probes--the Galileo to Jupiter, the Magellan to Venus, and the Mars Observer--and a fourth international venture, the Ulysses solar observation spacecraft, have been substantially delayed by the accident. Table 11 shows the effect of the accident on the launch dates of these missions. Actual arrival times at final destination will be pushed back further in some cases because of changes in mission plans and, in the case of Galileo and Ulysses, the accident-related cancellation of the shuttle Centaur upperstage program.

Table 12 presents overall budget authority estimates for planetary exploration before and after the accident. Budget authority increased by 4.4 percent for 1986 and 11 percent for 1987. Major changes are evident for

TABLE 11. PLANETARY MISSION LAUNCH DELAYS

Mission	Preaccident Launch Date	Current Launch Date	Delay (In months)
Ulysses	5/15/86	10/5/90	53
Galileo	5/20/86	11/1/89	41
Magellan (Venus Radar Mapper)	4/6/88	4/25/89	13
Mars Observer	8/90	4th Quarter 1992	27

SOURCE: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986.

1987 in the components of Galileo and Ulysses presented in Table 12, as development funds are expanded to store spacecraft, replan missions, and integrate new upperstages. Before the accident, development accounts were to be closed for the Galileo and Ulysses missions. Current estimates provide $81 million in development funds for the two missions, $71 million for Galileo and $10 million for Ulysses. Projected costs for the Magellan Venus mission are higher than before the accident for both 1986 and 1987, as Table 12 shows, and its launch date has been delayed. In addition, it will be necessary to procure new hardware, since NASA originally planned to use some Galileo spare parts for Magellan.

TABLE 12. BUDGET FOR PLANETARY EXPLORATION PROGRAM, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
	Total Program	
Preaccident	339	323
Postaccident	354	358
Percent Change	4.4	10.8
	Major Components	
Galileo		
Development		
Preaccident	54	0
Postaccident	64	71
Percent Change	18.5	0.0
Operations		
Preaccident	11	48
Postaccident	0	0
Percent Change	-100.0	-100.0
Total		
Preaccident	65	48
Postaccident	64	71
Percent Change	-1.5	47.9

(Continued)

Environmental Observation

The environmental observation program uses the perspective offered by earth orbit to study the magnetosphere, the atmosphere, the oceans, and the interaction of these systems with human activity. The accident will cause flight delays in this program, leading to a decrease in budget authority for 1987, as Table 13 shows. The *Upper Atmospheric Research Satellite* (UARS) is the major mission in the program and bears most of the weight of the overall program cut in both 1986 and 1987, (see Table 13). Slowing this effort is justified by the unavailability of launch services until the early 1990s.

TABLE 12. (Continued)

Time Period	1986	1987
	Major Components	
Ulysses		
Development		
Preaccident	6	0
Postaccident	9	10
Percent Change	50.0	0.0
Operations		
Preaccident	2	5
Postaccident	0	0
Percent Change	-100.0	-100.0
Total		
Preaccident	8	5
Postaccident	9	10
Percent Change	11.4	100
Magellan/Venus		
Preaccident	107	67
Postaccident	120	93
Percent Change	12.5	38.8

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

Materials Processing in Space

While this program accounts for only 1 percent of NASA's total R&D spending, it represents the area that many observers see as the most significant commercial application of space technology since the communications satellites. Moreover, materials science experiments and, ultimately, processing of semiconductor materials, ceramics, and pharmaceuticals for commercial sales are among the most potentially significant uses of the proposed space station. The accident has not affected budget authority in this area, but a series of 10 materials science laboratory flights will be substantially delayed, as Table 14 shows.

TABLE 13. BUDGET FOR ENVIRONMENTAL OBSERVATIONS PROGRAM, FISCAL YEARS 1986 AND 1987
(In millions of dollars of budget authority and percent changes)

Time Period	1986	1987
Total Program		
Preaccident	272	368
Postaccident	272	321
Percent Change	0.0	-12.8
Upper Atmosphere Research Satellite Mission		
Preaccident	114	152
Postaccident	114	114
Percent Change	0.0	-25.0

SOURCE: National Aeronautics and Space Administration, *Budget Estimates, Fiscal Year 1987*, vol. I and *Budget Estimates, Fiscal Year 1988*, vol. I.

TABLE 14. PAYLOAD AND MISSION DELAYS IN MATERIALS PROCESSING IN SPACE

Mission or Payload	Preaccident Launch Date	Current Launch Date	Delay (In months)
Long Duration Exposure Facility (retrieval)	9/27/86	11/15/90	50
Materials Science Laboratory 3	11/6/86	6/21/89	31
Materials Science Laboratory 5	3/24/87	7/26/90	40
Evaluation of Oxygen Interaction with Materials	4/14/87	2nd Quarter 1991	49
Materials Science Laboratory 4 (Materials Equipment Assembly)	4/14/87	9/21/89	29
International Materials Laboratory 1	5/27/87	4/20/90	35
Long Duration Exposure Facility 2	6/9/87	Unscheduled	--
Materials Science Laboratory 7	7/15/87	2nd Quarter 1992	58
Materials Science Laboratory 6 (Materials Equipment Assembly)	8/4/87	2/14/91	42
Materials Science Laboratory 8	11/9/87	3rd Quarter 1993	69
Materials Science Laboratory 9	3/24/88	2nd Quarter 1994	75
Eureca	3/24/88	4/4/91	37
Materials Science Laboratory 10	6/14/88	Unscheduled	--

SOURCE: National Aeronautics and Space Administration, Space Transportation System, Space Shuttle Payload Flight Assignments, November 1985 and October 1986.

CHAPTER III

OPTIONS

The NASA's conception of the civil space program has not changed as a result of the Challenger accident. In space transportation, the shuttle remains NASA's sole access to space. Progress in space science increasingly will be sought in a small number of large and long-term missions. As its next major NASA development project, NASA plans to build a permanently manned space station by the mid-1990s. A manned voyage to Mars is contemplated.

Achieving these program goals will necessitate increasing funding above the levels anticipated before the accident. The routine access to space promised by the shuttle system remains a program goal rather than an achievement. Space science payloads are in storage rather than orbit. Anticipated funding for the space station has been preempted by the demands of recovering from the substantial shock inflicted by the accident and subsequent two-year loss of access to space. While the accident is not the direct cause of all increased funding requirements, particularly those for the space station, it is a major factor underlying the overall NASA budget.

This chapter reviews program alternatives and spending additions in three major areas: space transportation, space science, and the space station. In space transportation, a "mixed-fleet" alternative is considered which would add expendable launch vehicles (ELVs) to the current "shuttle-only" NASA program and budget. In space science, the status of the program is examined, with particular attention directed to the mix of projects. Finally, the rationale for the space station is examined in the context of the Challenger accident, and its funding is reviewed in light of the tighter NASA budget following the accident.

THE CBO BASELINE FOR NASA

The CBO baseline estimates future funding levels for programs based on the current funding level adjusted for projected inflation. The NASA baseline for fiscal year 1988 represents a special circumstance. Because $2.1 billion in 1987 funding was an extraordinary one-time appropriation to replace

Challenger, the level of $8.4 billion is used as a starting point for the purpose of creating the 1988 baseline rather than the full 1987 NASA budget of $10.5 billion. Table 15 shows the CBO baseline for 1988 through 1992, broken down into the four major accounts: research and development; space flight, control, and data communications; research and program management; and construction of facilities.

The baseline presumes no specific program, but is only a projected level of funds that can be used to fund any number of choices. By raising the price of major program items, the Challenger accident has greatly diminished the program NASA can purchase with its budget. The cost of space transportation has increased as the shuttle system flight rate has been scaled back, as revenues from governmental and commercial customers have fallen below expectations, and as safety concerns have increased launch

TABLE 15. CBO BASELINE FOR NASA, FISCAL YEARS 1987 THROUGH 1992
(In millions of dollars of budget authority)

Major Account	1987	1988	1989	1990	1991	1992
Space Flight, Control, and Data Communications	5,815.0	3,871.6	4,049.4	4,241.1	4,444.0	4,650.6
(Less Orbiter)	(3,715.0)					
Research and Development	3,127.7	3,272.0	3,446.6	3,642.2	3,843.9	4,040.6
Research and Program Management	1,425.0	1,551.7	1,580.5	1,612.6	1,633.2	1,653.9
Construction of Facilities	166.3	172.6	179.2	185.6	192.5	199.7
Total	10,534.0	8,867.9	9,255.7	9,681.6	10,113.7	10,544.8
(Less Orbiter)	(8,434.0)					

SOURCE: Congressional Budget Office.

costs in general.[1] In addition, the unanticipated launch delays and attendent costs to the research and development (R&D) program have diminished the program that can be purchased with current R&D funding. Thus, while the NASA baseline has not changed, the amount of services that it can buy has declined substantially. In this sense, maintaining the level of the baseline means significantly decreasing the NASA program.

In the following options, programs are considered that would require funding substantially above the baseline. The alternative to appropriations above the baseline would be curtailment of activities funded under the current program and reprogramming of those funds to different activities. The $2.1 billion appropriation to replace the Challenger orbiter is the largest single reprogramming option, although delaying the space station or stopping all other new development projects are also possibilities. In appropriating full funding to replace the Challenger in 1987, the Congress restricted outlays until August 1987, thus reprogramming of the funds is possible.

A previous CBO study presented several reasons for acquiring a replacement orbiter: (1) to furnish transportation for the space station, (2) to provide insurance against the loss of another orbiter, and (3) to provide for manned space flight capability into the next century as no replacement system is currently possible before the year 2000.[2] But production of a new orbiter does not appear to be warranted by the demand for the shuttle itself through the year 2000. Moreover, if the space station can make extensive use of currently available ELVs (a prospect recently acknowledged by NASA) and a new development effort is initiated to provide an unmanned cargo carrier (perhaps funded by the Department of Defense), then the case for the orbiter is weakened. Nevertheless, a four-orbiter fleet is viewed by NASA and many outside observers as needed to achieve the goals of the preaccident program.

SPACE TRANSPORTATION

The shuttle remains NASA's only access to space in the postaccident program. Under NASA's present program and budget plan, the three existing orbiters (and a fourth on order to be delivered in the early 1990s) will be the only launch vehicles available to NASA for the indefinite future. Much of

1. Congressional Budget Office, *Setting Space Transportation Policy for the 1990s* (October 1986), p. 25.

2. Ibid., pp. 37-41.

this dependence is unavoidable in that many NASA civil space payloads can only fly on the shuttle. A significant part of the NASA backlog, however, could be flown on expendable launch vehicles. In confronting a similar situation, the directors of the military space program requested and received Congressional funding to add ELVs to the program's allotted shuttle flights. But NASA has not proposed an ELV supplement to the shuttle because it has confidence in the shuttle recovery program and because supporting a mixed fleeet into the 1990s could require as much as $500 million dollars annually in new budget authority not now included in the NASA budget plan.

Program Options and Issues

The October 1986 shuttle manifest plans for 53 orbiter flights from 1988 through 1992. Of these, the manifest has assigned 24 early flights to the Department of Defense and another 7.5 early launches to various scientific missions and commercial clients. This leaves 21.5 flights for the rest of the civil space agenda. Two-thirds of these 21.5 flights, however, will not be available until 1991 and 1992, as Table 16 shows. The 7.5 flights assigned to three planetary missions, the Hubble Space Telescope (HST), two dedicated

TABLE 16. THE OCTOBER 1986 MANIFEST FOR SHUTTLE FLIGHTS (By fiscal year)

Flight Customers	1988	1989	1990	1991	1992
Department of Defense	2.0	5.0	5.0	5.0	7.0
Major NASA and Commercial	1.0	2.0	3.0	3.0	1.5
Other NASA	1.0	2.0	2.0	7.0	6.5
Total	4.0	9.0	10.0	15.0	15.0

SOURCE: National Aeronautics and Space Administration, Space Shuttle Payload Flight Assignments (October 1986).

spacelab flights, and three Tracking and Data Relay Satellites (TDRS) reflect the priorities of these payloads in the overall NASA program. The deferral of the bulk of other space science activities until the 1990s also implies a judgment about priorities.

Against this background, NASA's Office of Space Flight initiated a mixed-fleet study to examine the possibilites of integrating ELVs into NASA's program and budget.[3] The major conclusion of the study was that, during the 1988-1995 period, even if the shuttle system met the preformance goals of the October 1986 manifest, a large volume of NASA scientific payloads would not have access to space. The study made allowance for differing shuttle flight rates in the 1990s, variability in DoD requirements, and a delay in the delivery date of the orbiter to replace Challenger.

But the study did not assess the effects of variability in the shuttle launch program in the 1988 through 1990 period. This is an issue of considerable importance because the space science program and budget depend on the shuttle's returning to flight. If shuttle launch delays during this period should leave the total number of flights substantially below the 21.5 projected for scientific use in the October 1986 manifest, the cost and productivity of the parts of the NASA space science program that remained grounded would be affected much as they were by the Challenger accident.

Through September 1990, the manifest includes flights carrying two TDRS, the HST, the Gamma Ray Observatory, two space lab flights, and two planetary missions (with a third planetary opportunity currently scheduled as the first flight of fiscal 1991). Delaying these launches would burden the space science program with additional mission planning and storage costs, as well as further postponing the scientific returns to the large investments already made in these programs. In the case of TDRS, substantial delays would require additional spending to maintain the ground tracking network, as has been the case in 1986 and 1987. Table 17 lists the major NASA payloads on the October 1986 manifest and the budgetary consequences of their delays.

The HST spacelab missions, and some other payloads cannot be launched by an ELV. But payloads that must use the shuttle would be less likely to experience delays if ELVs were used to meet other launch require-

3. National Aeronautics and Space Administration, Office of Space Flight, "Report of the Mixed Fleet Study Team," January 16, 1987.

ments. The scope of this report does not permit a review of the shuttle recovery program or of whether the program will reach the goals specified by the October 1986 manifest. Nevertheless, the probability of delay is ever present, as NASA has pointed out on many occasions.

Probable delays in the return of the shuttle system to flight and a lower-than-planned flight rate through 1990, as well as the analysis developed by NASA in its mixed-fleet study, suggest that NASA's use of ELVs is a viable alternative to the present shuttle-only policy. In developing options, the NASA study proposed a number of general alternatives and provided cost estimates for each. Table 18 lists the payloads identified by NASA that

TABLE 17. MAJOR PAYLOADS TO BE LAUNCHED IN FISCAL YEARS 1980-1990 AND POTENTIAL CONSEQUENCES OF LAUNCH DELAYS

Payload	Launch Date	Consequences
Tracking and Data Relay Satellites C and D	2/88 and 9/88	Storage costs and maintenance of ground network at approximately $50 million per year.
Hubble Space Telescope	11/88	Replanning mission, maintaining team, and storage cost of $7 million per month.
Magellan (Venus Radar Mapper)	4/89	Replanning, storage, and potential longer delay in arrival.
Galileo	11/89	Replanning and storage cost, $3 to $4 million per month, and potential longer delay in arrival.
Space Life Science Laboratory	12/89	Replanning and storage cost.
Gamma Ray Observer	1/90	Replanning and storage cost.
International Materials Laboratory	4/90	Replanning and storage cost.

SOURCE: National Aeronautics and Space Administration.

could be carried by ELVs in the 1988-1995 period if a decision were made to use unmanned rockets extensively. In that event, NASA could pursue one of two options:

- A low-range ELV option that would carry 9 payloads, and
- A high-range ELV option that would carry an additional 17 payloads for a total of 26.

TABLE 18. MISSION CANDIDATES FOR POSSIBLE NASA LAUNCHING BY ELVs, HIGH AND LOW OPTIONS

Mission	Launch Date
Low Option	
TDRS-E	1989
Mars Observer	1990
Rosat	1990
Planetary Backup	1991
EUUE	1991
TDRS-G	1992
Geotail	1992
Wind	1992
Polar	1992
High Option (low option plus)	
LGO	1993
CRAF	1993
TDRS-H	1993
Cluster	1993
CFMFE	1993
Space Station 5	1993
GD-B	1994
Space Stations 8 and 9	1994
Space Stations 12 and 13	1994
CASINI	1995
Space Stations 15, 16, 17, and 18	1995
Space Station 24	1995

SOURCE:National Aeronautics and Space Administration, Office of Space Flight, "Report of the Mixed Fleet Study Team," January 16, 1987.

Taken together, the two options bound the possibilities of ELV use by NASA from 1988 through 1995, including the use of ELVs in the construction of the space station.

NASA use of ELVs would fit well with the general evolution of U.S. space transportation policy. The DoD has concluded that more than one launch system is necessary to assure the flight of vital national security payloads. The argument is equally valid for NASA. The decision to phase out orbiter launches of commercial satellites that can be flown by ELVs opens this market to private U.S. firms. The price competitiveness of U.S. producers and their commercial market share will depend initially on the volume of U.S. government launch orders. Sustained DoD procurement will be essential to maintain a viable U.S. industry. Additional NASA procurements would also support the competitiveness of the U.S. industry. [4]

The programmatic implications of the two ELV options differ in extent rather than type. Any decision to use ELVs for NASA payloads would increase NASA's access to space. As a consequence, the probability of further delays and additional costs would be decreased. Moreover, pursuing either option would lessen any subtle pressures within NASA to meet its return-to-flight goal of February 1988 and the schedule laid out in the October 1986 manifest.

Spending Consequences

The case against a mixed fleet is its cost. NASA estimates of the cost of the low-range and high-range options for mixed fleets are presented in Table 19. Both estimates include the costs of launch vehicles and services and the concomitant saving in the shuttle accounts. The low-range option includes no commitment beyond 1991, while the high-range alternative includes launches through 1995. One potential saving consequence is unaccounted for in the cost estimates for the mixed-fleet option. If a payload is flown on an ELV that otherwise would have been delayed by slippage in the shuttle schedule, then the storage and replanning costs for that payload are avoided.

SPACE SCIENCE

The dominant issue in the area of space science, as discussed in the previous section, is the manner in which space payloads will be launched over the

4. Congressional Budget Office, *Setting Space Transportation Policy for the 1990s* (October 1986).

TABLE 19. ANNUAL COSTS OF HIGH- AND LOW-RANGE ELV OPTIONS
(By fiscal year, in millions of dollars of budget authority)

Option	1988	1989	1990	1991	1992
Low Option	85	160	220	230	0
High Option [a]	555	335	420	495	555

SOURCE: National Aeronautics and Space Administration, Office of Space Flight, "Report of the Mixed Fleet Study Team," January 17, 1987, and supporting materials.

a. High option figures are converted from the NASA constant 1986 dollar estimates by estimated 1987 price level changes and CBO projections through 1992.

next several years. Beyond this larger issue is the balance between large and small efforts in space science. The danger is that small experiments and single-purpose satellites, often capable of being launched on ELV's, will be caught in a budget squeeze among space transportation recovery, large space science projects, and the space station. If budgetary constraints prevent the initiation of new programs while recovery from the accident is being undertaken, the consequences of the accident could be felt well into the latter half of the 1990s. The choice confronting the Congress in the 1988 program and beyond is whether or not to pursue rapidly new space science efforts, and if so, on what scale. One option would be to fund smaller, less costly scientific experiments in addition to devoting resources to large investments such as the HST.

Program Issues

A recently released report, prepared by the Space and Earth Science Advisory Committee (SESAC), culminated a two-year study of the NASA Space Science and Applications programs, and concluded that, even in the absence of the Challenger accident, serious stresses were emerging in these activities.[5] Programmatic aspirations were portrayed as exceeding the budget

5. The Space and Earth Sciences Advisory Committee of the NASA Advisory Council, "The Crisis in Space and Earth Sciences, A Time for a New Commitment" (November 1986).

for this NASA account by 25 percent to 30 percent (in 1986 dollars) from 1986 into the early 1990s, even before accounting for the accident-induced hiatus.

The advisory committee pointed out that a more widespread scientific interest in space, both within and among scientific disciplines, had increased the demand for space science activity. In some areas, past progress laid the foundation for "facilities class" missions--that is, technologically sophisticated and costly efforts (in the committee's scheme, costing $600 million to $1 billion) providing research opportunities to a large group of researchers (for example, the HST). In those areas in which the use of the space environment is relatively new (for example, materials sciences), smaller-scale, less costly efforts may make significant gains at a cost of a "few million dollars," according to the committee. Still other areas, such as monitoring the atmosphere or the ocean surface, could benefit from "moderate-sized missions," typically a single satellite, launchable by an ELV or the shuttle, designed to focus on a specific set of scientific questions, and costing $100 million to $600 million.

The SESAC report warns of the danger of a program dominated by large-scale scientific projects, both in terms of increased risk and lower scientific return to the program. A corollary of the increased sophistication of large-scale science has been higher cost and greater risk. For example, the technical, scheduling, and budgetary risks inherent in a program like the Galileo probe to Jupiter are compounded by the risk in the launch mode itself. Moreover, in the case of Galileo and several other large space science efforts, the shuttle and the associated upperstage rocket booster are themselves barely out of the research and development stage and subject to their own independent set of budgetary, scheduling, and technical uncertainties. From the vantage point of the program as a whole, the benefits of large-scale, high-risk projects may justify the risk. The accident, however, has illustrated the substantial cost if risk becomes reality.

The scientific gains of additional spending accruing to small- and intermediate-scale activities might exceed the gains of additional spending on large-scale efforts. The SESAC notes that research and analysis must be balanced with experimentation and a continuous flow of new data. Over the last decade, large experiments dependent on the shuttle experienced delays of several years, even before the accident. Such delays leave established and aspiring scientists without new observations with which to further the process of discovery. In contrast, smaller and medium-sized efforts, particularly if flown on ELVs, might be less subject to delay and able to contribute to the vitality of the whole program even if delays beset larger efforts. The

continuation of this type of effort, self-contained and independent of other development efforts, will remain important as the agenda for space science applications increasingly becomes focused on projects dependent on the space station.

Spending Consequences

Unlike the large items such as a replacement orbiter, the space station, or the HST, smaller-scale program initiatives have restricted benefits and accordingly lower payoffs. They lack the appeal of a larger effort and, it has been argued, are more likely to suffer cutbacks in the face of budget constraints. This issue will be addressed this year, as the Congress decides what level of support to grant to the Topex, an ocean observation satellite in the medium class started in fiscal year 1987, and to the Global Geospace Science program (GGS), a new project in solar and terrestrial physics requiring two satellites, Polar and Wind, at the low end of the medium class.

The more general issue through 1992 is whether or not funding will be granted to intermediate- and small-scale projects in a budget and program dominated by transportation and the space station. Taking the current budget request as typical, a single spending profile of $100 million (1987 dollars) above baseline is included as an option to ensure support for intermediate- and small-scale science efforts through 1992.

THE SPACE STATION

The space station is the major issue confronting the NASA program and budget over the next five years. The Challenger accident has directly affected this project in several ways. It has reduced the opportunities to use the shuttle as a prototype for scientific, and perhaps industrial, applications envisaged as major station activities. Uncertainties about the reliability of the shuttle's flight rate has raised the idea of using ELVs to help build the space station. This same concern prompts the idea of including a "lifeboat" on the station to permit the station crew to return to earth without the shuttle in the event of an emergency. The accident has directly affected the budget available for the space station in that the cost of the accident and lost revenue inflows and operating efficiencies in space transporation have eliminated the "wedge" of budgetary savings that were in part to pay for the station. Beyond these direct linkages, the reassessment of the NASA program in the wake of the accident has probably contributed to a more realistic estimate of station costs well above the $8 billion (in 1984 dollars) offered by NASA over the last two years.

Program Issues and Options

The major concern with the space station program has been the usefulness of the particular configuration proposed by NASA relative to its cost. 6/ Although it is beyond the scope of this study to address this large question in detail, several arguments for and against the station are reviewed.

The current space station plan includes a habitable core of several pressurized modules, a power source, and communication and observation equipment, all attached to a structure roughly one hundred yards long and half as wide. Two additional unmanned platforms are included in the station plan to provide additional capability for material experimentation and observation. The station would serve both scientific and technical needs and would be built as an international venture with European and Japanese laboratory modules and a Canadian remote manipulator arm. The current design concept foresees an evolution toward a larger structure in the future.

Advocates contend that the scientific, technical, and commercial value of the station would be substantial. The station's laboratory would permit experimentation with organic and inorganic materials in a microgravity environment with implications for the manufacture (initially on earth, but perhaps later in space) of strong, lightweight materials, drugs, and materials to produce more capable electronic components, among others. Advances would occur in understanding the human capability to live and work in space. Knowledge of the effects of prolonged weightlessness on humans would pave the way for a permanent base on the moon or for a two-year round-trip to Mars. Experience gathered in working in low earth orbit is seen as a prelude to servicing satellites and reducing the costs of such space applications as communications and satellite photography. The support for robotics and automation offered by the program is often noted as a significant spinoff for the earthbound economy in general and U.S. manufacturing in particular.

Added to this list of benefits is the prestige gain of drawing even with or perhaps eclipsing the Soviet space station program. Moreover, a successful cooperative venture of this scope could lay the foundation for future international cooperation in large space endeavors of the future.

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6. A representative view of the spectrum of opinion on this issue can be found in two studies: National Research Council, Space Applications Board Commission on Engineering and Technical Systems, *Practical Applications of a Space Station* (Washington D.C.: National Academy Press, 1984); and, Office of Technology Assessment, *Civilian Space Station and the Future in Space* (1984).

The case against the current program stresses the uncertainty of the space station's benefits relative to its costs. It has been argued that a more modest effort (or series of efforts) might prove to be a better strategy. A smaller station could later be expanded if the realistic potential of areas like materials processing required a permanently manned station. Critics point out that the station's equatorial orbit precludes it from functioning as a service point for platforms in polar orbit, the most useful orbit for most earth observation applications. Similarly, the station orbit is far removed from the 22,000 mile "high equatorial" geosynchronous orbit used by most communications satellites, requiring additional investment in a vehicle that would transfer satellites to and from the station. This added investment jeopardizes the claims of cost reduction from on-orbit, station-based satellite servicing.

While gains in technologies, such as robotics and automation, would undoubtedly occur under the current plan, similar gains could be obtained from a more modest effort as well. Moreover, if the compelling reason to undertake the current plan is improving U.S. manufacturing technology, a program of public support directed to that end might be less costly and more effective.

The accident enters into this discussion in several ways. There is a pervasive feeling that the United States has fallen behind the Soviet Union in space, and has lost international prestige. Similarly, the point is frequently made that Europe and Japan will convert their national space programs into technological leadership and economic gain vis-a-vis the United States. A project as large and demanding as the current space station plan is viewed as an answer to these challenges and as a way to restore the U.S. national commitment to space and its concomitant prestige.

The accident also has added to the critics' case, however. As discussed in Chapter II, numerous materials science and life science flights were lost to the accident. Many of these flights could have revealed specific lines of inquiry to be pursued on the station or suggested design features to be added to the basic configuration. These opportunities are essentially lost, and the uncertainties associated with the station accordingly increased.

The role of expendable launch vehicles in station construction and resupply has received increased attention because of the accident. If the four-orbiter shuttle system of the early 1990s were restricted to twelve flights a year, as the National Research Council projects, space station construction and resupply could absorb two thirds of the shuttle's flights dur-

ing the two years of construction.[7] As there are other high-priority uses for shuttle flights--for example, national security missions--it might be desirable to substitute ELVs for shuttle flights when feasible. The NASA mixed-fleet study identifies seven candidate flights from 1992 through 1995.

Spending Consequences

This section examines three funding profiles for the space station, which are compared in Table 20. The first, the CBO baseline for the space station, is set at the 1987 level of $420 million, corrected for inflation through 1992. This level would fund only the design stage of the current plan or, perhaps, a much more modest man-tended station some time during the 1990s.

The second scenario, drawn from the Administration's current budget estimates for 1988 through 1992, foresees spending for the space station substantially above baseline. Station funding would exceed the baseline by roughly $1.5 billion each year of the 1989-1992 period under this plan. Recent testimony by the NASA Administrator indicates that the current space station plan would cost even more than the figures shown here.[8] Thus, the Administration's budget plan for the space station becomes a "middle option," providing for the current plan on a delayed basis or for some more modest alternative by the mid-1990s.

A third space station funding profile, labeled "high-option" is a rough "high-option" approximation of the 1988 through 1992 appropriations that would allow the current program to proceed toward deployment in the mid-1990s. This higher spending is above the baseline by almost $2.0 billion in 1989 and climbs to a $3.5 billion gap by 1992.

Even the "high-option" estimate would not capture the full cost of the proposed NASA space station if the project were defined to include transportation costs, the cost of science and technology experiments, operations cost, and a "lifeboat" to return astronauts to earth in the event of an emergency. The elements included as costs by NASA are design and development, hardware and construction, ground support, and a $3.8 billion (in 1984

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7. The National Research Council, "Post-Challenger Assessment of Space Shuttle Flight Rates and Utilization," National Academy Press (October 1986).

8. James Fletcher, Testimony before the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Technology of the United States Senate, February 3, 1987.

dollars) management reserve. This reserve has been included to account for the type of delays and cost growth that have occurred in recent NASA efforts, including the space shuttle, the Galileo, and the HST.

NASA PROGRAM AND BUDGET OPTIONS FOR 1988 THROUGH 1992

Continued progress toward the goals specified in the preaccident program would require spending above the CBO baseline. A program rationale for increased spending can be drawn in each of the three areas discussed above. This section estimates the NASA budget from 1988 through 1992 if any, or all, of the additions to the NASA program were supported by the Congress. As previously discussed, program activities could be further curtailed beyond the effects of the accident, or the funds appropriated for the replacement orbiter could be reprogrammed to fund other parts of the program.

Table 21 presents the CBO baseline and a range of estimated funding increases above the baseline necessary to implement the program additions

TABLE 20. SPACE STATION FUNDING PROFILES, FISCAL YEARS 1988-1992
(In millions of dollars of budget authority)

Profiles	1988	1989	1990	1991	1992	1988-1992 Total
CBO Baseline	440	460	490	520	540	2,450
Middle Option	770	1,840	2,000	2,200	2,140	8,950
Change from Baseline	330	1,380	1,510	1,680	1,600	6,500
High Option	770	2,300	3,000	3,500	4,000	13,500
Change from Baseline	330	1,840	2,510	2,980	3,460	11,050

SOURCE: CBO baseline: real 1987 spending adjusted for inflation through 1992; Middle Option: 1988 Administration request and outyear projections; and High Option: recent NASA estimate as reported in *Science*, February 27, 1987, p. 965.

TABLE 21. CBO BASELINE AND THE RANGE OF ESTIMATED FUNDING LEVELS ABOVE BASELINE TO SUPPORT VARIOUS PROGRAM ADDITIONS
(By fiscal year, in billions of dollars of budget authority)

Program Levels	1988	1989	1990	1991	1992	Type of Program Additions to Baseline Covered by Range
CBO Baseline	8.9	9.3	9.7	10.1	10.5	n.a.
Space Transportation						**low-option** use of ELVs--9 payloads through 1992; **high-option** use of ELVs--21 payloads through 1995
Low option	0.1	0.2	0.2	0.2	0.0	
High option	0.6	0.3	0.4	0.5	0.6	
Space Science	0.1	0.1	0.1	0.1	0.2	Start and maintain higher level of intermediate- and small-scale science projects
Space Station a/						**middle option**--delayed and/or smaller space station; **high option**--current plan implemented by the mid-1990s
Middle option	0.3 b/	1.4	1.5	1.7	1.6	
Upper option	0.3 b/	1.8	2.5	3.0	3.5	

SOURCE: Congressional Budget Office.

NOTE: n.a. = not applicable

a. Baseline includes space station funding of $430 (in 1987 dollars) from 1988 through 1992.

b. The Administration's request is the starting point for both space station profiles.

APPENDIX

TABLE A-1. MAJOR RESEARCH AND DEVELOPMENT PAYLOADS, 1986 THROUGH 1987, BEFORE AND AFTER CHALLENGER ACCIDENT

Payload	Preaccident Launch Date	Current Launch Date	Delay (In months)
Astro-1	3/6/86	1/19/89	34
Ulysses	5/15/86	10/5/90	53
Galileo	5/20/86	11/1/89	41
EOS-1	7/22/86	5/4/90	45
Hubble Space Telescope	8/18/86	11/17/88	27
Long Duration Exposure Facility (retrieval)	9/27/86	11/15/90	50
Environmental Observation Mission	10/27/86	Unscheduled	--
Materials Science Laboratory 3	11/6/86	6/21/89	31
Astro-2	1/12/87	Unscheduled	--
Shuttle High Energy Astro Physics Laboratory	1/27/87	4th Quarter 1993	82
Spartan-2	1/27/87	2nd Quarter 1991	52
EOS-2	2/16/87	3rd Quarter 1991	53
Space Life Sciences Laboratory 1	3/16/87	12/7/89	33
Space Radar Laboratory 2	3/18/87	1st Quarter 1993	71
Materials Science Laboratory 5	3/24/87	7/26/90	40
Space Shuttle Backscatter Ultra-Violet Instrument 1	4/14/87	2/14/91	46
Evaluation of Oxygen Interaction with Materials	4/14/87	2nd Quarter 1991	49
Materials Science Laboratory 4 (Materials Equipment Assembly)	4/14/87	9/21/89	29
International Materials Laboratory 1	5/27/87	4/20/90	35
Long Duration Exposure Facility	6/9/87	Unscheduled	--
Materials Science Laboratory 7	7/15/87	2nd Quarter 1992	58

(Continued)

TABLE A-1. (Continued)

Payload	Preaccident Launch Date	Current Launch Date	Delay (In months)
Space Shuttle Backscatter Ultra-Violet Instrument 1	8/4/87	3rd Quarter 1991	48
Materials Science Laboratory 6 (Materials Equipment Assembly)	8/4/87	2/14/91	42
Spartan-3	8/4/87	2nd Quarter 1992	57
Astro-3	8/18/87	Unscheduled	--
Combined Release and Radio Effects Satellite	8/18/87	3rd Quarter 1992	60
Sunlab-1	9/28/87	Unscheduled	--
Rosat	9/28/87	1st Quarter 1994	77
Materials Science Laboratory 8	11/9/87	3rd Quarter 1993	69
Spartan-205	11/9/87	Unscheduled	--
Space Shuttle Backscatter Ultra-Violet Instrument 3	11/16/87	1st Quarter 1992	51
Environmental Observation Mission 3	2/2/88	Unscheduled	--
Spacelab J	2/23/88	2nd Quarter 1991	39
Materials Science Laboratory 9	3/24/88	2nd Quarter 1994	75
Spartan-206	3/24/88	Unscheduled	--
Eureca	3/24/88	4/4/91	37
Magellan (Venur Radar Mapper)	4/6/88	4/25/89	13
Space Shuttle Backscatter Ultra-Violet Instrument 4	6/8/88	3rd Quarter 1992	50
Gamma Ray Observatory	6/8/88	1/18/90	19
Materials Science Laboratory 10	6/14/88	Unscheduled	--
Spartan-211	6/14/88	Unscheduled	--
Cosmic Background Explorer	7/15/88	Unscheduled	--
Space Life Sciences Laboratory 2	7/20/88	3rd Quarter 1992	49

SOURCE: National Aeronautics and Space Administration, *Space Transportation System, Space Shuttle Payload Flight Assignments*, November 1985 and October 1985.