United States General Accounting Office 143776

GAO

Testimony

For Release
on Delivery
Expected at
9:30 a.m. EST
Wednesday,
May 1, 1991

Questions Remain on the Costs, Uses, and Risks of the Redesigned Space Station

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Before the
Subcommittee on Government Activites
and Transportation
House Committee on Government Operations

GAO/T-NSIAD-91-26

GAO Form 160 (12/87)

Madam Chair and Members of the Subcommittee:

I appreciate the opportunity to testify before the Subcommittee today on the National Aeronautics and Space Administration's (NASA) space station program. My testimony will provide an overview of the space station--one of the most ambitious, costly, and controversial space projects the nation has ever undertaken. I will discuss the station's history, the concerns that led to the 1990 congressional directive to redesign the station, and the recommendations made by the Advisory Committee on the Future of the U.S. Space Program (commonly referred to as the Augustine Committee). In addition, on the basis of preliminary data gathered to date and interviews with leading space scientists, I will address the following critical questions about NASA's redesigned station:

-- Have all station-related costs been identified and fully disclosed?
-- Are station program reserves adequate, and is the station affordable?
-- Is the station justified on the basis of its tangible benefits to scientific research?
-- What technical challenges need to be considered before proceeding with the station?

RESULTS IN BRIEF

In response to congressional direction, NASA recently redesigned the space station. This smaller station will be largely assembled and tested on the ground and then placed in orbit in segments. Crew-tended capability is planned by 1997, and permanent occupancy is scheduled to begin in 1999. NASA estimates the cost of the station to the permanent occupancy phase to be $30 billion.

We believe the $30 billion estimate is an inappropriate figure to use for two reasons. First, it does not include program costs that should be attributable to the space station before permanent occupancy. Second, it does not take into consideration the costs necessary to bring the station to its full capability and to maintain, supply, and operate it beyond 1999. When these costs are added together, what we actually have is at least a $118 billion program--about $40 billion to achieve permanent occupancy and about $78 billion to keep the station operational between 2000 and 2027.

We are also concerned that NASA is not maintaining financial reserves commensurate with program risk. NASA has never before assembled a space structure as large as the space station and cannot fully anticipate the difficulties and costs. Also, the largest cost growth in the program may occur during hardware development, which has not yet begun.

Regarding the affordability of the space station program, NASA is subject to the provisions of the Omnibus Budget Reconciliation Act. Under provisions of this act, NASA competes with other domestic agencies for funding. Thus, increases in NASA's real funding may require funding reductions in other federal programs.

What will the nation receive in return for this investment? Although in 1984 NASA justified building the station based on eight potential uses, only one remains in the current design. That one remaining use is a research laboratory for microgravity and life science, two scientific endeavors that many scientists believe are incompatible and are not best conducted on the same station. The original justification included uses such as a permanent observatory and a manufacturing facility. The reduction of eight uses to one has serious implications for the scientific benefits to be derived from the development and operation of the station.

Technical challenges also remain. Of these, the reliability of the shuttle as the sole means of launching and servicing the station is one of the most difficult to accommodate. Other challenges, such as the risks posed by orbital debris and the lack of an emergency crew rescue vehicle, also must be addressed before the station can be permanently occupied.

Although the administration has always contended that one of the reasons for building the space station is to achieve U.S. preeminence in space exploration, just recently they stated it is the most important reason and that tangible scientific benefits are not the primary reason. While no one can quantify all the benefits associated with the station, the increased costs coupled with the diminished capabilities, raise questions about the relative value of the station. Given the remaining technical challenges, risks may also be higher than expected. With these factors in mind, we believe it is important for this subcommittee and other committees of the Congress to continually examine the space station program from the standpoint of schedule, risk, cost, merit, and affordability. The next significant program milestone will be the critical design review scheduled for early 1993.

BACKGROUND

In January 1984, NASA initiated a program to build a multiple-purpose space station that would be permanently occupied within a decade. The space station, named Freedom, will absorb a significant portion of the NASA budget during its development and 30-year operating life. Some elements will also be provided by European countries, Japan, and Canada. The space station will be transported in pieces and assembled in earth orbit by the space shuttle[1] and its crews.

Early History

Since 1960, NASA has studied the possibilities and technologies for a space station, including a space shuttle transportation system. However, due to budget constraints, NASA obtained approval to develop only the shuttle during the 1970s. The shuttle became operational in 1983.

The most important reason for initiating the space station program in 1984 was to take advantage of the shuttle's expected routine access to space. The space station was also expected to accommodate the private sector and international interest stimulated by the space shuttle and the first Spacelab[2] flight in 1983.

Original Justification

Both President Reagan's and President Bush's national space policy called for U.S. leadership in space and for space exploration to obtain economic and scientific benefits. NASA viewed the space station as responsive to this policy and as the next logical step toward such future projects as piloted missions to the moon or other planets. According to NASA, the long-duration experiments necessary for human exploration of the solar system could be done only on the space station. Also, the station was expected to

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[1] The space shuttle is a piloted vehicle capable of lifting 52,000 pounds of crew and cargo into a low-earth orbit--a standard orbit 110 nautical miles high at 28.5 degrees inclination from the equator.

[2] Spacelab, a reusable laboratory procured from the European Space Agency, is flown and deployed from the cargo bay of the space shuttle. Spacelab is still used for material and other scientific experiments.

permit major advances in (1) life science research, which studies the effect of lengthy exposure to space on humans, animals, and plants, and (2) microgravity research, which studies the effect of gravity on materials and proteins.

More specifically, NASA initially justified the space station based on eight functional uses: (1) a research laboratory, (2) a manufacturing facility, (3) a permanent observatory, (4) a transportation node, (5) a servicing facility, (6) an assembly facility, (7) a storage depot, and (8) a staging base for more ambitious future missions.

Original Design of the Station

After several years of analyzing user requirements and adding international elements, NASA selected a space station configuration to be assembled by 1994 at an estimated development cost of about $12.2 billion.[3] The design consisted of a central complex with a U.S. living quarters module and three laboratories (one each provided by the United States, the European Space Agency, and Japan) as well as a Canadian remote manipulator arm.[4] Also included were four automated satellites (two U.S. and two European). NASA expected that the international additions would stabilize the program because other countries tend to make commitments that exceed the U.S. budgetary cycle of one year.

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[3]The $12.2 billion is equivalent to $8.3 billion in 1984 dollars. The cost estimates in this testimony have not been deflated or discounted. They are the sums of estimated annual outlays expressed in then-year dollars.

[4]The robotic Canadian arm is similar to the space shuttle arm and is intended to be used for space station assembly and maintenance, transportation on the station, and deployment and retrieval of payloads.

Early Concerns

Faced with severe fiscal constraints, the Appropriations and Authorizations Committees expressed several concerns about the affordability of the space station. First, the Committees were concerned that budget limitations and the expensive human habitation features might preclude the addition of the U.S. laboratory. Without the laboratory, the United States could become primarily a transporter and housekeeper for international crews, who would become the primary beneficiaries of the largely U.S.-financed space station. Second, the Committees were concerned that attempts to fully fund the station could hurt NASA's science programs. Due to space shuttle cost overruns and schedule delays, these programs were already being affected.

In addressing these concerns, the Committees used two approaches. To protect NASA's science programs, they limited the station's share of NASA's budget to 25 percent for development and 10 percent for operations and expected NASA to allocate a minimum of 20 percent for science programs. Also, the Committees attempted to reduce the impact of potential budget limitations by requiring that the U.S. laboratory be one of the first elements assembled in space. The laboratory could then be used by U.S. crews during shuttle visits and the space station could later be expanded for permanent occupancy as funding permitted. The Committees believed that this "crew-tended" assembly approach might stimulate more vigorous automation and robotic efforts and reduce costs.

Although a crew-tended facility might lower initial costs, NASA disagreed with this approach because total costs for complete assembly would increase and because the types of experiments that could be done were the same as those being done on Spacelab. Therefore, NASA continued to pursue permanent occupancy.

Subsequent to a number of major design changes, NASA increased the estimated development cost of the station in 1991 to $18.5 billion. However, when costs for ground facilities, personnel, shuttle flights, and operations were included, the estimated cost totaled $38.3 billion.

Space Station Redirection

In providing fiscal year 1991 funding, the Appropriations Committees reiterated earlier concerns and directed NASA to redesign the station in a series of self-sufficient phases and to stay within a maximum annual funding limitation of $2.6 billion. The first phase would give the shuttle crews the use of the station for scientific experiments. This phase could be continued if Congress did not provide enough funds for permanent occupancy. The Committees also recommended that NASA (1) reduce the number of annual shuttle flights needed for assembly and operation from eight to a more realistic number and (2) emphasize microgravity research.

Similarly, in a December 1990 report, the Augustine Committee recommended that NASA reduce the station's cost, size, and assembly complexity. The report also agreed with the Appropriations Committees that the station should primarily be a research facility. However, the Augustine Committee recommended that NASA emphasize life, rather than microgravity, science.

The Redesigned Space Station

According to NASA, the recently redesigned space station, which our international partners have approved, will accommodate most of the programmatic concerns expressed by the Appropriations and Augustine Committees. The new, smaller station will be largely assembled and tested on the ground and then placed in orbit in segments so that operational capabilities will be available sooner and at less risk. Crew-tended capability for a microgravity laboratory is scheduled to be achieved by mid-1997, and permanent occupancy for a crew of four instead of eight is scheduled to begin in late 1999. NASA believes that this phased approach will require fewer annual shuttle flights (six or seven) and will reduce the need for extravehicular activity (spacewalks) for assembly and maintenance. However, the new space station will not have the capabilities or the capacities that were previously planned. Finally, the new station will essentially be a research facility for microgravity and life sciences.

SOME SPACE STATION COSTS NOT IDENTIFIED OR FULLY DISCLOSED

NASA estimated that the U.S. portion of the redesigned space station will cost about $23.4 billion by the beginning of the crew-tended phase in 1997 and $30 billion by the time permanent occupancy is scheduled to begin in 1999. However, this estimate is preliminary and is subject to change as station contracts are renegotiated and other cost elements are further defined. Of the $30 billion total, about $6.6 billion will have been appropriated by the end of this fiscal year. NASA estimates that it will cost about $54 billion to keep the station operational after permanent occupancy.

We believe the $30 billion estimate is an inappropriate figure to use for two reasons. First, it does not include some program costs that should be attributable to the space station before permanent occupancy in 1999, and second, it does not take into consideration the costs necessary to bring the station to its full capability and to maintain, supply, and operate it beyond 1999. When these costs are added together, we estimate the total program cost to be at least $118 billion--about $40 billion necessary to attain permanent occupancy in 1999 and about $78 billion to keep the station operational between the years 2000 and 2027.

Costs Prior to Permanent Occupancy

NASA's $30 billion estimate is understated by at least $10 billion because it does not include the following number of significant cost elements:

-- The cost of developing, producing, and operating a crew rescue vehicle. Development and production costs for such a vehicle, which NASA considers a prerequisite to permanent occupancy, range from an estimated $1.6 billion to $3 billion, depending on the design selected. Operating costs are estimated at about $20 million per year.

-- The cost of developing and installing a centrifuge. A centrifuge simulates different levels of gravity and is necessary for life science experiments. NASA estimates this cost at about $800 million.

-- The cost of conducting science projects on the station. Although NASA has not yet estimated this cost, NASA officials believe that, based on current experience with the Spacelab program, the annual cost of conducting science projects will be about $200 million. For fiscal years 1997 through 1999 this cost would be about $600 million.

-- The fixed cost of the 20 shuttle flights required to assemble and use the station during fiscal years 1997-99. We believe NASA should include certain costs they now treat as fixed, at least for these years, because most of the available shuttle flights would be dedicated to assembly and scientific use of the station. The fixed costs are estimated to be at least $7.5 billion.

Costs Subsequent to Permanent Occupancy

NASA estimates the station's operating costs to be at least $54 billion after permanent occupancy. This figure is understated by a minimum of $24 billion because it does not include the following:

-- Investment costs after occupancy to bring the station up to 75 kilowatts of power and to accommodate an eight-person permanent crew. NASA believes this additional investment, which will cost about $2.5 billion, is necessary to meet international commitments.

-- Shuttle flight costs to support the station during its permanent occupancy. Based on a NASA estimate of a minimum of four annual shuttle flights to support the station, this cost will be at least $8.6 billion.

-- The salaries of the program's civil service staff. According to NASA estimates, about $250 million a year is needed for civil service staff to conduct a full range of technical, managerial, and administrative requirements. This adds about $6.8 billion for the period 2000 through 2027.

-- The cost to conduct scientific research on the station. This cost is at least $5.4 billion, assuming the annual cost is equal to the annual cost of conducting science experiments prior to permanent occupancy.

MANAGEMENT OF PROGRAM RESERVES AND AFFORDABILITY ISSUES

Besides the potential cost increases, we are concerned about the program's (1) financial reserves and (2) overall affordability. Regarding the financial reserves, NASA normally allocates about

30 to 35 percent of the total program cost for high-risk, advanced technology projects such as the space station to allow for unanticipated technical problems and cost growth. Although this was originally done, the reserves were routinely reduced to accommodate congressional reductions to annual program budget proposals. Further, NASA sometimes uses its program reserves to pay for otherwise unfunded program needs. For example, NASA plans to use its reserves for such items as housing for the centrifuge and defining the design of the crew rescue vehicle. Since NASA does not protect its financial reserves, they are usually depleted during the budget year and are not available for their intended purpose. This year's reserves, for example, were depleted within the first 6 months of the fiscal year.

NASA officials stated they are now providing 10 percent reserves for the operating year and up to 15 percent for the outyears. However, we believe that, even if properly maintained, these margins are not commensurate with program risks because NASA has never before assembled a space structure as large as the space station and cannot fully anticipate the difficulties and costs. Also, the largest cost growth in the program may occur during hardware development, which has not yet begun.

Regarding the affordability of the space station program, NASA is subject to the provisions of the Omnibus Budget Reconciliation Act, which established ceilings for all discretionary spending for 1991-95 and for domestic discretionary spending for 1991-93. Under provisions of this act, NASA competes with other domestic agencies for funding. Thus, increases in NASA's real funding may require funding reductions in other federal programs. The President's fiscal year 1992 budget request proposes a $1.8 billion increase in NASA's budget. Several House committees have already indicated NASA's 1992 request is unaffordable and will be reduced. For example, the House Budget Committee called for the proposed NASA budget to be cut by $1.2 billion. What effect implementation of these cuts would have on the space station program is uncertain, but increasing claims by the program on the NASA budget could affect the agency's other programs.

INTENDED USES OF THE SPACE STATION

Although NASA originally justified the space station based on eight potential uses, only one now remains--as a research laboratory to conduct microgravity and life science experiments. According to NASA, crew-tended operations will focus on microgravity research, as specified by the Appropriations Committees. After the space station is permanently occupied, life science research will have priority, as suggested by the Augustine Committee, but microgravity research will continue.

Questions have been raised in the scientific community about the wisdom of having human habitats and research facilities for microgravity and life science on the same spacecraft. The debate has focused on the incompatibility of crew members, who will cause vibrational disturbances, with microgravity experiments. Some experts are also concerned that the redesigned space station may not meet the research requirements of either microgravity science or life science and question whether the station is even necessary for such research. On the basis of our interviews with NASA researchers and scientific advisors in these fields, we believe that a space station is required to prepare humans for long-duration space missions to other planets.

Although the Administration has always contended that one of the reasons for building the space station is to achieve U.S. preeminence in space exploration, just recently they stated it is the most important reason and that tangible scientific benefits are not the primary reason.

Conflict Between Microgravity Science and Human Habitation

Microgravity science research is conducted in a reduced gravity environment. Its purpose is to understand the role of gravity in processing materials, such as glass, ceramics, and metals, and to determine the molecular structure of proteins in living cells. Currently, NASA and commercial scientists perform microgravity experiments using the shuttle mid-deck,[5] the Spacelab, NASA's KC-135 jet aircraft, and drop towers.[6]

Two possible benefits to be derived from microgravity research are the development of less flawed crystals to improve computer technology and the growth of large protein crystals to use in understanding how diseases occur and in developing the counterattacking medicines for illnesses such as cancer. The human and economic return of these endeavors--if successful--could be enormous.

According to the Assistant to the President for Science and Technology and the Congressional Budget Office, NASA was too optimistic in science's ability to achieve these benefits in the near term while justifying the large investment required for the space station. In a February 1991 report,[7] the Congressional Budget Office stated that "the last 10 years have confirmed that processing materials in space is an expensive, high-risk activity

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[5]The shuttle mid-deck is the second of three decks in the shuttle crew compartment. It contains space for airlocks, sleep stations, and equipment lockers. The equipment lockers are used to carry microgravity experiments.

[6]Drop towers are ground-based test facilities that can subject material samples and experiment packages to 4- to 30-second periods of zero gravity conditions during free fall.

[7]Encouraging Private Investment in Space Activities (Washington, D.C.: Congressional Budget Office, Feb. 1991), p. 82.

that is not likely to produce economic returns in the near future" and that "even as a basic research activity, the results to date have been discouraging."

When the Congress decides whether microgravity science merits a large research facility, it must consider the views of the National Research Council, which in a recent report[8] stated that only 13 percent of all microgravity experiments planned by NASA and commercial scientists require longer periods of time in space than current spacecraft can provide. Another Council report[9] concluded that any microgravity research experiments conducted on the space station did not merit the investment and that "more research progress could be achieved in a shorter period of time and at a fraction of the cost through an expanded program of Spacelab missions and of free-flyer experiments."

Several microgravity experts we interviewed said that a free-flying platform is needed in addition to the station. Some preferred the free-flying platform for their experiments. For example, the Director of a NASA-sponsored Center for the Commercial Development of Space, which is principally involved in protein crystal growth experiments, said that during the crew-tended phase, the Center could best use the space station between shuttle visits because of the vibration caused by astronauts and the docking of the shuttle orbiter. He hoped that NASA would add a crew-tended, free-flyer to the space station, once it is permanently inhabited, so that he could continue his experiments. While other microgravity experts believed that the station would provide adequate capability during the crew-tended phase, most believed that the vibrations caused by

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[8]Report of the Committee on a Commercially Developed Space Facility (Washington, D.C.: National Academy Press, 1989), p. 23.

[9]Space Studies Board Position on the Proposed Redesign of Space Station Freedom (Washington, D.C.: Space Studies Board of the National Research Council, Mar. 14, 1991), p. 2.

crew members and their life support equipment would adversely affect many microgravity experiments.

Microgravity experts also expressed the following concerns about the usefulness of the redesigned space station:

-- The four-person crew may not have enough time to conduct experiments in a reasonable time period.

-- The time between shuttle flights to retrieve the experiments may be too long. For example, once the materials are returned and analyzed on the earth, it may be difficult to distinguish between the effect of several months of microgravity exposure and the effect of an experiment that is designed to be conducted over a shorter period.

-- The on-board data processing and telecommunications capabilities have been reduced. The microgravity users may not be able to properly monitor and analyze the experiments.

Finally, the Assistant to the President for Science and Technology, in a March 11, 1991, letter to Vice President Quayle, concluded that many microgravity experiments could not be conducted while astronauts were assembling or inhabiting the station and that microgravity science did not provide a significant rationale for the space station.

Station Not Critical for Most Life Science Research

Life science research can be divided into two categories:

-- long-duration human life science, which concerns the effects of radiation and the microgravity environment on humans living 6 months or longer in space, and

-- basic life science, which concerns the effects of radiation and microgravity on plants and animals.

According to the scientists we interviewed, only 10 percent of all NASA life science research requires a permanently inhabited space station. However, this research in long-duration human life science is considered essential if the United States plans to send humans on long missions to places like Mars (an estimated 3-year round-trip). The research will focus on determining the effects of such travel on the astronaut's health and ways to combat the deleterious effects of weightlessness and radiation.

Currently, much of this research is being conducted on rats on the Soviet free-flyer Cosmos and suspended in earth-based laboratories; and on humans in studies on prolonged bed rest, and on the Soviet space station Mir. However, according to NASA's Director of Life Sciences, understanding the effects of weightlessness on humans will ultimately require permanent habitation of a weightless facility for at least 6 months. However, several scientists indicated that, in general, any permanently occupied space platform would satisfy their needs.

Long-duration human life science also involves the development of life-support systems for humans traveling in space for years at a time without benefit of resupply. NASA is already testing systems that recycle water and air using chemicals and plants. Although most of this testing is being conducted in earth-based laboratories, the systems will ultimately have to be tested in the space environment.

A number of experts questioned the space station's capabilities for long-duration human life science. For example, the National Research Council's Space Studies Board strongly endorsed the need for a space-based laboratory to study the physiological consequences of long-term space flight but stated that the redesigned space station does not provide the facilities required for such research. Also, the Assistant to the President for Science and Technology, in his March 1991 letter to Vice President Quayle, concluded that since the redesigned space station is justified solely to support human space exploration, the station design must include a human centrifuge. Following that letter, NASA announced that it had added a centrifuge to the station. However, this centrifuge is not large enough to gain required information on human responses to extended microgravity exposure.

The consensus among the basic life scientists we spoke with was that they would use the space station if it were available but that all of their experiments, except for the long-duration studies of people, could be performed by other means. For example, NASA has obtained significant data by flying rats and plants on the Soviet Cosmos. Also of promise, according to several scientists, is the LifeSat program, which is an American version of Cosmos. Beginning in 1996, LifeSat will expose cell cultures, worms, small plants, and microorganisms to varying amounts of radiation for up to 60 days. The data collected will be critical to human space flight because radiation greatly increases outside low-earth orbit.

TECHNICAL CHALLENGES

As the space station program progresses, NASA faces at least three important technical challenges:

-- the uncertain reliability of the space shuttle's performance,

-- the potential hazard to the space station from orbital debris, and

-- the lack of an emergency crew return vehicle.

Questionable Reliability of the Space Shuttle

Although the restructured space station relies solely on the shuttle for assembly, supply, and maintenance, many questions have been raised about the reliability of the shuttle's performance. Any shuttle launch delays will delay the space station program and increase its costs.

At this time, there are three shuttles in the fleet; the fourth shuttle, the Endeavor, is scheduled to be launched for the first time in April 1992. Currently, NASA estimates that 23 to 26 shuttle flights will be needed between 1995 and 1999 to assemble and begin scientific use of the station. NASA also projects, beginning in 1994, a maximum rate of 10 shuttle flights annually, of which up to 6 or 7 would be dedicated to the space station starting in 1997. While 10 annual flights appears more realistic than NASA's previous estimate of 24, NASA may not be able to achieve this rate.

To date, the agency has not achieved its projected flight rate. The most flights launched in any year were nine, in 1985, and according to the Challenger investigation team, that number of flights strained the system. Since the Challenger accident, the largest number of flights was six, in 1990.

Following the accident, NASA added a number of safety-enhancing maintenance and inspection requirements that substantially increased the time required to process shuttles for flight, that is, to inspect and refurbish the orbiter, external tank, and solid rocket boosters through pre-launch, launch, post-launch, landing, and retrieval activities. To achieve 10 flights a year, NASA will have to reduce its processing time from the current post-Challenger average of 183 days to an average of only 99 days. Although NASA has determined where reductions are needed, it has not specifically identified how to make them.

Even with the fourth shuttle, NASA should still be concerned about its ability to sustain 10 shuttle flights annually because of (1) the risk of shuttle attrition an (2) the continuing need to reduce shuttle processing time. Both the Office of Technology Assessment and the Augustine Committee believe that another shuttle will likely be lost before the station is completed. NASA agrees that the risk of shuttle attrition is significant. NASA recently added a shuttle maintenance and inspection program to its normal shuttle processing requirements. This new program will take a shuttle out of operation for long periods of time.

Risk Posed by Orbital Debris

Orbital debris--which is left in orbits around the earth from prior space missions--could pose a significant hazard to the space station. For example, a 1-centimeter aluminum sphere (almost the diameter of an aspirin tablet) traveling at 22,000 miles an hour would strike a spacecraft with roughly the force of a 400-pound safe traveling at 60 miles an hour. An estimated 3.6 million pieces of debris now circle the earth, including 140,000 pieces larger than 1 centimeter. The debris ranges in size from entire rocket bodies to paint chips.

In a prior report,[10] we noted a significant increase in the estimated amount of debris since 1984, when NASA approved a model of the debris environment. However, documents used to guide contractors in designing and developing the station had not been revised to reflect this increase. Also, while NASA was considering various protection techniques to safeguard the station and its crew

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[10] Space Program: Space Debris a Potential Threat to Space Station and Shuttle (GAO/IMTEC-90-18, Apr. 6, 1990).

from debris, it had not yet begun the risk and cost analyses needed to support future design decisions. We recommended that NASA make these analyses, in association with a valid debris model, in time to incorporate the results into the station's final design requirements.

While NASA agrees that orbital debris is a growing threat, it has not yet revised the 1984 design document to advise contractors of the seriousness of this threat. Once revised, the document will show that the amount of debris larger than 1-centimeter is expected to increase about five-fold between 1984 and 2005, from about 40,000 particles to an estimated 200,000 particles. Further, NASA has started three of four space debris risk assessments and is currently evaluating funding requirements for the fourth assessment. Determining the potential cost impacts of the orbital debris hazard depends on completion of these risk assessments. The assessments must be ready for the critical design review now scheduled for March 1993.

NASA's other decisions related to space debris have apparently postponed confrontation of the problem. First, to conserve weight, NASA will not initially install the full amount of debris shielding required to protect the station for its entire life. Second, NASA will not, at least during the station's first 5 years of operation, attempt to maneuver away from large debris objects tracked by the U.S. Space Command. These objects are predicted to come close, under NASA's definition, about 40 times a year. This decision was reportedly based on the relatively low probability--about 1 percent--of being hit by these objects. According to NASA's space debris expert, both decisions represented an acceptable risk--but only for the first 5 years of operation. He said that additional shielding and avoidance maneuvering would undoubtedly be needed as orbital debris increases.

Although space debris will likely affect the station's future design and cost, NASA cannot fully measure the impact until (1) contractors are specifically told to modify their designs to accommodate the more serious space debris environment and (2) NASA completes the appropriate hazard and risk analyses.

Lack of an Emergency
Crew Return Vehicle

During operations with a permanent crew, a spacecraft may be needed for emergency or unplanned returns from the space station due to accidents or astronaut illnesses. Given the shuttle's long processing time and unreliable launch capability, the shuttle does not provide an adequate emergency crew return capability.

NASA considers a backup vehicle to return crew in an emergency a prerequisite for the start of permanent occupancy in 1999. NASA is currently pursuing concept design studies of a crew return vehicle and plans to issue a request for proposals in fiscal year 1993 for the development of three vehicles, including a prototype. NASA officials projected that the development program would take 6 years to complete. They added that if this program was delayed, the date for permanent occupancy would slip, and as a result, costs would increase.

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This concludes my prepared statement. I would be pleased to respond to your questions.