

GAO

Report to the Ranking Minority Member,
Subcommittee on Oversight of
Government Management, Committee
on Governmental Affairs, U.S. Senate

June 1994

SPACE STATION

Impact of the Expanded Russian Role on Funding and Research





United States
General Accounting Office
Washington, D.C. 20548

National Security and
International Affairs Division

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The Honorable William S. Cohen
Ranking Minority Member, Subcommittee on
Oversight of Government Management,
Committee on Governmental Affairs,
United States Senate

Dear Senator Cohen:

In response to your request, we are examining the impact of Russian participation in the National Aeronautics and Space Administration's (NASA) space station program. You asked that we provide an interim report at this time on whether expanded Russian participation will (1) reduce space station funding requirements by \$2 billion, as estimated by NASA and (2) improve the station's capabilities for conducting research. We are continuing our analysis and will issue a final report to you later this year.

Background

In March 1993, the President directed NASA to redesign Space Station Freedom. The President also directed NASA to consider using Russian space assets and consider bringing Russia into the international space station partnership that already included Europe, Japan, and Canada. In a June 10, 1993, report to the President, the Advisory Committee on the Redesign of the Space Station recommended that NASA pursue opportunities for cooperation with Russia as a means to enhance the capability of the station, reduce cost, provide alternative access to the station, and increase research opportunities. The Advisory Committee also recommended that the space station be launched to an orbit that could make it accessible to Russian launches. Russia was already planning for a follow-on space station to its existing Mir space station.

The space station configuration developed by NASA during the summer redesign process was called Alpha and included hardware to be purchased from Russia. The major Russian components included the FGB energy block spacecraft (also referred to as a space tug) for propulsion, guidance, navigation, and control; Soyuz capsules for assured crew return vehicles or "lifeboats"; and systems for docking the shuttle to the station. The first piece of hardware was scheduled to be launched in September 1998, with completion of assembly in September 2003. In September 1993, NASA estimated that, under a \$2.1 billion annual funding cap imposed by the

Administration, the Alpha design would require \$19.4 billion in funding for fiscal years 1994 through 2003.¹

On September 2, 1993, the United States and Russia agreed to pursue cooperation in human space flight, eventually leading to increased Russian participation in the international space station program as a full partner. By November 1, 1993, NASA and the Russian Space Agency formally agreed on a plan to bring Russia into the space station program. The new configuration was renamed the International Space Station Alpha (ISSA). Under ISSA, major Russian contributions would be a service module for crew habitation, three research modules, a docking module, solar arrays, and propellant resupply. The United States and Russia planned to jointly provide the FGB energy block, the Soyuz capsules, and an airlock for space walks. The details of Russia's contributions and share of joint developments, as well as U.S. payments to Russia for services and hardware, are still being negotiated. Negotiations are scheduled to be completed by the end of this year.

NASA stated that, compared to the Alpha program, the ISSA program with expanded Russian involvement

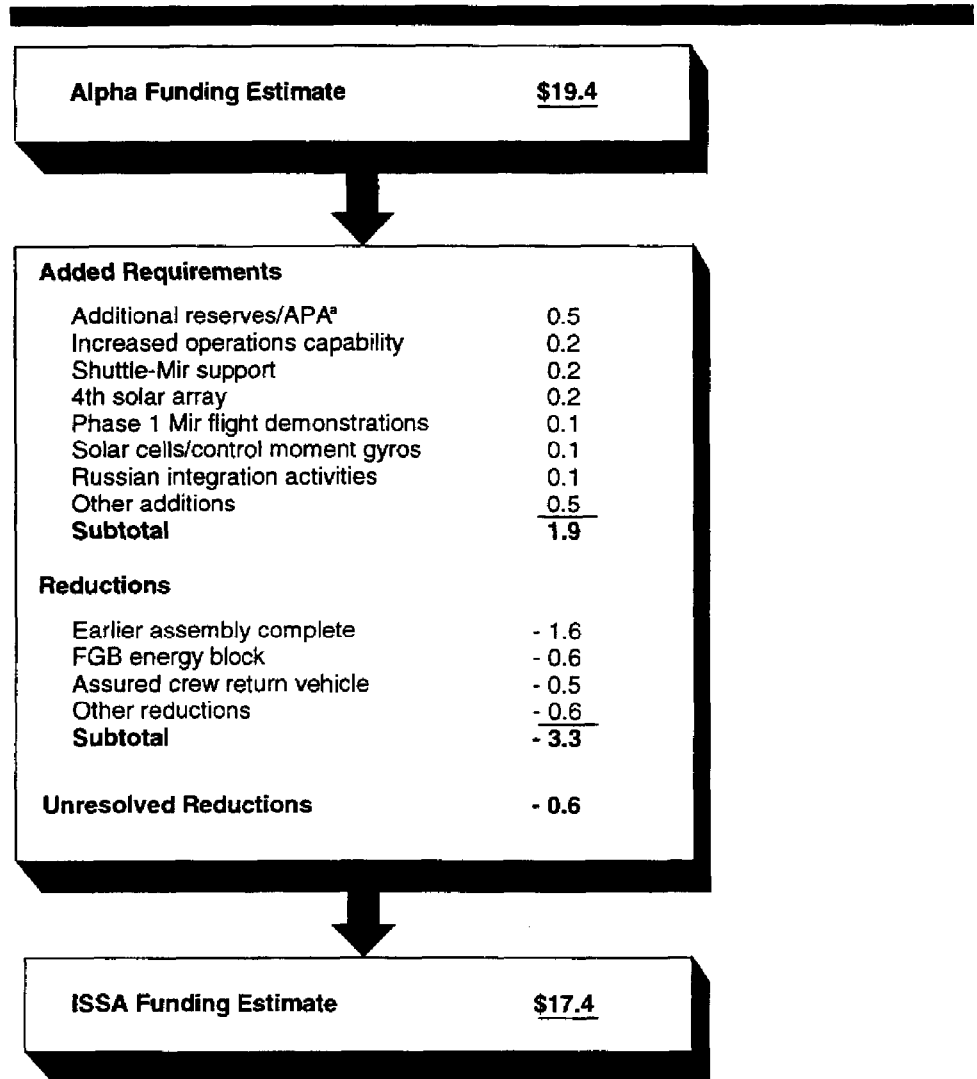
- reduces funding requirements by \$2 billion through the completion of space station assembly;
- increases total crew size from four to six;
- accelerates the launch of the first U.S. element to December 1997 and completion of assembly to June 2002;
- enables earlier research opportunities, beginning with the existing Mir space station;
- increases resources such as crew time, electrical power, and pressurized volume available to support research;
- enables dual access to the station for human space flight and logistics; and
- reduces some U.S. hardware requirements and enhances system robustness.

Estimated Funding Reduction

According to NASA officials, Russian participation would reduce U.S. funding requirements from \$19.4 billion for Alpha to \$17.4 billion for ISSA through the completion of station assembly. Figure 1 traces the \$2 billion change.

¹NASA estimated that funding for fiscal year 1993 and prior years totaled about \$10.3 billion, excluding civil service costs.

Figure 1: Change From Alpha to ISSA Estimate (Dollars in Billions)



^a"APA" (Allowance for Program Adjustment) is included to help offset major changes in scope, capability, or technical content and schedule.

Source of data: NASA.

Under Added Requirements, the Additional reserves/APA increase mostly reflects funding NASA anticipates will be needed to purchase Russian FGB energy block space tugs. The entries for Shuttle-Mir support, Phase 1 Mir flight demonstrations, and part of the Solar cells/control moment gyros

entry are related to the 10 shuttle flights to the Russian Mir space station during Phase 1. Increased operations capability, 4th solar array, Russian integration activities, and the rest of the Solar cells/control moment gyros entry include additional funding for Russian involvement in the ISSA program. According to a space station program official, the other additions line mostly includes funding for additional requirements not specifically related to increased Russian participation.

Almost half of the \$3.3 billion in specific reductions is from accelerating the assembly complete date from September 2003 to June 2002, thus removing 15 months of operations and utilization funding that was required for the Alpha program. Reductions for deleting the FGB energy block and assured crew return vehicle funding reflect agreements that NASA is negotiating with the Russian Space Agency to jointly provide these items. In the case of the assured crew return vehicle, NASA believes Russia will provide its Soyuz spacecraft with NASA paying for certain modifications. NASA still intends to purchase the FGB energy block from Russia, but the amount and terms of the contract are still being negotiated. Therefore, NASA now carries funding in its reserve line to cover FGB energy block requirements. According to a space station program official, most of the other reductions include requirements that were eliminated as a result of Russian participation. For example, NASA is negotiating with the Russians to supply propellant for the station.

The unresolved reductions represented a challenge for NASA to find additional program funding reductions totaling \$0.6 billion. This was necessary to keep the ISSA program within the estimated funding available of \$17.4 billion.

Results in Brief

Funding estimates for the space station program with expanded Russian involvement are still evolving and the overall effect of Russian participation will not be known for several months. Based on information available at this time, we can report the following:

- NASA's estimated \$2 billion savings in the space station program from expanded Russian participation would be largely offset by an estimated \$1.4 billion in increased funding requirements accounted for in other parts of NASA's budget. These increased funding requirements are related to a contract with the Russian Space Agency for space station related hardware and services and to the effects of increased Russian

participation on the space shuttle's ability to support space station assembly.

- Some of NASA's \$2 billion savings may not be attributable to Russian participation. NASA's savings figure is a net amount that also includes reductions and additions that are not related to Russian participation. For example, the \$0.6 billion decrease that NASA refers to as unresolved reductions is unrelated to Russian participation. However, the net savings amount also includes at least \$0.5 billion in added funding requirements that are unrelated to expanded Russian participation.

When all space station related elements are considered, current estimates would indicate that much of the savings NASA attributes to expanded Russian participation will not be achieved. Furthermore, if only part of NASA's estimated \$2 billion savings is attributable to Russian participation, it is possible that expanded Russian involvement could result in little or no net savings. We will update our analysis of additional funding requirements based on subsequent estimates and discuss all the additions and reductions to the program and their relationship to increased Russian participation in our final report to you.

Russian participation in the space station would substantially increase overall station research resources. The first phase of Russian participation will allow for near-term research opportunities on Russia's existing Mir space station, and the accelerated assembly schedule will provide earlier research capability on the International Space Station Alpha. However, the degree to which the U.S. research community will benefit from these increased capabilities has yet to be determined. The allocation of the research resources still has to be negotiated among all the space station partners, and certain committees that advise NASA on space station research have yet to fully assess the impact of increased Russian participation.

Significant Funding Requirements Were Excluded From NASA's Net Savings Estimate

NASA's net savings estimate did not include about \$1.4 billion in estimated increases in funding requirements resulting from expanded Russian participation in the space station: (1) \$400 million for a contract between NASA and the Russian Space Agency, (2) \$73 million to outfit a second orbiter for up to 10 flights to Mir, (3) \$185 million for some performance enhancements needed in the shuttle to support assembly at a higher inclination orbit, (4) \$746 million for 2 additional shuttle flights needed to support the current assembly schedule, and (5) \$10-20 million for increasing the probability of launching the shuttle within a smaller launch

window. Space station officials disagreed with us that these amounts should be included in evaluating the impact of Russian participation on space station funding requirements.

Contract With Russian Space Agency

An estimated \$400 million contract with the Russian Space Agency covering fiscal years 1994-97 was signed in December 1993. The exact details of the contract are still being negotiated, and it is scheduled to be finalized about the end of this month. Russian participation in the space station program was to occur in three phases. All three phases were considered a single package, whose main goal was to create an effective scientific research complex earlier and at less cost. The contract was intended to compensate the Russian Space Agency for the first two phases. NASA anticipated the \$400 million would be divided between Phases I and II as follows:

- Phase I activities, estimated at \$305 million, involve up to 10 shuttle flights to the Mir space station and up to 24 months of astronaut crew time on Mir between 1995 and 1997. The shuttle flights and astronaut time are intended to help develop techniques for assembly and operation of ISSA in such areas as command and control, flight operations, logistics support and resupply, extra-vehicular activity, rendezvous, proximity operations, and docking. The contract would also pay the Russians to support U.S. science activities on Mir that are included as part of space station funding for early flight research for station utilization.
- Phase II activities, estimated at \$95 million, would combine U.S. and Russian hardware to create the crew-tended capability of ISSA. The contract could also pay for modification of some Russian hardware, such as the FGB energy block and the Soyuz assured crew return vehicle. Phase III would build on Phase II and complete the international space station with additional U.S., Russian, European, Japanese, and Canadian elements.

NASA officials disagreed that funding for this contract should be included in calculating the net savings to the space station from Russian participation.

Modification of Second Orbiter

In order to fly 10 shuttle flights to the Mir space station during Phase I, a second orbiter will have to be outfitted with a docking mechanism and other hardware at an estimated cost of about \$73 million. One orbiter has already been fitted for the docking mechanism as part of an October 1992 agreement between the United States and Russia for one shuttle-Mir

docking to exchange an astronaut and cosmonaut. This agreement pre-dates the current Russian involvement, and the modification of this orbiter was approved prior to the increased Russian role. According to NASA officials, the 10 shuttle flights to Mir are important risk reduction activities for building ISSA. The time required to prepare an orbiter for its next flight limits it to flying about two missions a year. As a result, flying 10 missions to Mir over a 3-year period requires that a second orbiter be modified to allow it to dock to Mir. NASA officials stated that funding would be required for modifying a second orbiter for the 10 shuttle flights to Mir, but disagreed that this estimated funding should be included in evaluating space station funding.

Shuttle Performance Enhancements

Increased Russian participation under ISSA will impact the shuttle's ability to support space station assembly. To take advantage of Russia's launch capabilities, the space station's orbital inclination will be increased from the 28.8 degrees planned under Alpha to 51.6 degrees.² This increase will reduce the shuttle's payload capacity by about one-third, or 13,000 pounds.

NASA's plan to regain the 13,000 pounds of lift capacity lost because of the change in orbital inclination requires several modifications to the shuttle system. The most critical of these is a new external fuel tank, called the super lightweight tank. This tank is made with a lighter aluminum-lithium alloy so that the tank's weight is reduced and the shuttle's lift capability is increased by about 8,000 pounds. In addition, the plan calls for development of a lighter booster, motor nozzle extension, lighter seats, and a number of other weight-reducing modifications to the orbiter vehicle.

The preliminary estimated total funding required for all the enhancements needed is \$535 million, of which about \$350 million is for the super lightweight fuel tank. Since this tank was planned under the Alpha program, only the remaining \$185 million relates to increased Russian participation. NASA expects to have a better estimate by the end of this month. A shuttle program official said that these other enhancements are being undertaken in order to support assembly of the station at the higher inclination. NASA believes that funding for shuttle modifications should be accounted for in the shuttle budget, and not the station budget.

²The angle of an object's orbit relative to the equatorial plane of the Earth is referred to as orbital inclination.

In developing the super lightweight tank, NASA is experiencing problems that it characterizes as normal for this type of project. Lightweight tank project officials believe that they understand the problems and that they can resolve them without delaying the station assembly schedule. However, the solutions to the development problems could increase tank development costs, reduce the amount of lift gain provided by the new tank, or both.

Additional Shuttle Flights

Because the shuttle would have less lift capacity under the ISSA program, ISSA will require two more shuttle flights for assembly than Alpha. Even if NASA successfully implements its strategy to regain 13,000 pounds of lift capacity, the shuttle's lift capacity to the ISSA orbit will still be less than that to the Alpha orbit because the lightweight tank was also planned for the Alpha program. The currently planned ISSA assembly sequence calls for 21 assembly flights, while the Alpha design called for 19. The two additional shuttle flights add \$746 million to the station's funding requirements, based on NASA's estimated average cost of \$373 million per shuttle flight in fiscal year 1999.³

Space station officials disagreed that the additional flights should be valued at an average cost of \$373 million each. In past space station cost estimates, NASA has valued shuttle flights at a marginal cost for fuel and other expendable items of about \$40 million per flight. In prior reports, we have stated that the average cost per shuttle flight should be allocated to the space station program during the period when the shuttle system will be predominately used for the station's launch, assembly, and use.⁴ The two additional flights for ISSA would occur during that period.

The number of space station related shuttle flights required during the assembly period could change due to such things as changes in station configuration or assembly sequence, or the use of other launch vehicles. For example, under the Alpha and ISSA programs, the European Space Agency has proposed to launch its laboratory module on an expendable launch vehicle. We are continuing to review the number of shuttle flights

³In the past, we have included the cost of all the shuttle flights that support the station program in estimating the total funding requirements for the space station assembly. In this instance, however, since we are reviewing the impact of increased Russian participation, we considered only the difference in the number of shuttle flights between the ISSA and Alpha designs.

⁴Space Transportation: The Content and Uses of Shuttle Cost Estimates (GAO/NSIAD-93-115, Jan. 28, 1993); Space Station: Program Instability and Cost Growth Continue Pending Redesign (GAO/NSIAD-93-187, May 18, 1993).

required during assembly and will evaluate whether any changes are related to Russian participation.

Shuttle Launch Probability Improvements

The change to a higher inclination for ISSA also reduces the shuttle's window of opportunity to launch from 50 minutes to 5 minutes on a given day. NASA's preliminary estimate of the total funding needed to implement a strategy for increasing the probability of launching in the narrower window is \$10 million to \$20 million, with many improvements requiring little or no funding.

The strategy that NASA is considering includes changing some weather-related constraints established in the event the shuttle has to return to the launch site after an abort, adding a day in which the shuttle could rendezvous with the space station, and building in an additional hold early in the launch countdown to address potential problems that may arise. If all the identified improvements can be implemented, NASA estimates that the probability of launch in the 5-minute window can be raised to the same probability of launch as in a 50-minute window.

Some of NASA's \$2 Billion Savings May Not Be Related to Expanded Russian Involvement

NASA has attributed the \$2 billion reduction to Russian participation. However, this estimated net savings also includes reductions and additions, which are unrelated to Russian involvement; thus, it is possible that some of the estimated net savings are achieved from changes unrelated to Russian participation.

Some of the reductions that are not related to Russian participation would be achieved by redesigning ground facilities to make greater use of commercial products and cost-effective architectures, streamlining logistics, and minimizing sustaining engineering support. These activities, which account for savings of over \$600 million, were previously carried as unresolved reductions and were necessary in order for NASA to stay within the \$17.4 billion available funding.

Among the funding additions that are unrelated to Russian participation are docking mechanisms and an airlock for the shuttle. This hardware, plus refinements to certain estimates as the program matured, collectively account for \$400 million of the other additions entry shown in figure 1. Also unrelated to Russian participation was \$100 million of the increase shown in the reserves/APA entry.

We are continuing to review the details of the reductions and additions that comprise the \$2 billion net savings to determine which amounts are related and unrelated to Russian participation.

Research Potential Could Be Enhanced, but Specific Benefits Have Not Yet Been Fully Determined

Increased Russian participation in the space station should provide more resources critical to research productivity, earlier research opportunities, and better access to the Russian research community. However, because specific allocations of the station resources must still be negotiated, it is not yet clear to what degree the U.S. research community will benefit. In addition, committees that advise NASA on space station research have not yet had an opportunity to review the details of increased Russian involvement and assess its impact on research planned for the station.

Space Station's Overall Research Potential Is Enhanced

Crew time has long been identified as the constraining factor for research productivity on the space station. The addition of two crew members, which would be made possible by adding the Russian service module, would be an important benefit to the research community. With only four crew members on the Alpha station, crew time for experiments would have been limited to two dedicated crew members; the other two would have had to operate and maintain the space station. With a crew of six aboard ISSA, NASA believes four crew members could be dedicated to research. The additional crew members would also increase the pool of subjects for life sciences research on the effects of long-duration space flight.

Electrical power is another important resource that would increase under the ISSA design. Total annual average power on the station has increased from 69 kilowatts (kw) to 110 kw, with an increase to users from 42 kw to 73 kw. The increase in total power was achieved by adding a fourth solar array supplied by the United States, with the remainder coming from Russian solar arrays. Although power increased substantially at assembly complete, the power levels to users actually decreased during assembly. The Alpha design provided average power of about 13 kw to users during assembly. ISSA, however, only provides 8 kw or less during much of the initial research operations. NASA is studying ways to increase power to users during initial ISSA operations.

Russian participation could also provide research opportunities earlier than the Alpha program would have. First, the shuttle flights to Mir and astronaut stay-time aboard Mir during Phase I offer opportunities to

conduct long-duration experiments 4 years earlier than under the Alpha program. The Mir missions can also serve as science risk reduction activities by allowing NASA to test and evaluate experimental facilities and procedures. Second, the ISSA station is scheduled to reach initial research capability 11 months earlier and assembly complete 15 months earlier. Third, under ISSA, crew members will stay aboard the station after the shuttle departs starting in 1998 rather than 2003. While this is intended mainly for assembly purposes, NASA anticipates that the crew would also be available to conduct experiments between assembly activities.

NASA officials believe that increased Russian participation will result in better access to Russian researchers and research data. Although U.S. and Russian researchers have been sharing data for many years, space station cooperation will open the door to much wider and deeper access to the Russian research community, including areas of expertise that would be valuable to U.S. researchers such as space medicine, plant biology, and computational physics.

Other potential benefits include an increase in the volume of pressurized areas of the station, which provide a "shirt sleeve" environment for conducting experiments, as well as for storage and logistics to support research. The total pressurized volume aboard ISSA—1,202 cubic meters—would be about 50 percent greater than that on Alpha. In addition, the change to a higher inclination would also allow remote sensing of more of the Earth's surface and far more of its land mass. At this point, however, only one U.S. remote sensing payload has been identified as a candidate for the space station.

Allocation of Resources Must Still Be Negotiated

The allocation of resources such as crew time, power, and payload rack space is based on a formula agreed to by the international partners in memorandums of understanding under the intergovernmental agreement governing the space station. In allocating resources, the agreement takes into consideration research facilities and common infrastructure provided by each partner. For example, under Alpha, the United States, Europe, and Japan each were providing a laboratory module. Because the United States was contributing the infrastructure, such as the habitation module, truss structure, propulsion and guidance systems, and electrical power systems, the agreement allocated a fixed percentage of the laboratory space in the European and Japanese modules to the United States. Under ISSA, the agreement must now consider the Russian contribution in terms of both

laboratory space as well as common infrastructure, such as the service module to house the additional crew members.

NASA believes that the United States and current international partners will gain additional research resources as a result of Russian participation. However, until the intergovernmental agreement and memorandums of understanding are renegotiated, it will not be clear how much more, if any, of each resource will be allocated to the United States. For example, although total user power would increase by 31 kw under ISSA, NASA had estimated that 27 kw of that would be allocated to Russia, with the total power allocated to U.S. and other international partner users increasing by 4 kw. NASA officials expect negotiations on the agreement and the memorandums of understanding to be completed by the end of this year.

Advisory Committees Still Need to Fully Assess Impact of Russian Participation

Several committees with members from outside of NASA have been established to review NASA's plans for supporting space-based research. These groups represent some of the potential users and provide important advice to NASA on the space station's design and use from the researcher's perspective. When one of these committees, the Space Station Science and Applications Advisory Subcommittee, met in February, NASA officials were not able to provide sufficient details about increased Russian participation for the group to fully assess the impact on research utilization. The committee's subsequent report stated that the group was encouraged by the research potential added by Russian space assets, but was concerned that the specifics of the Russian partnership were not presented. The committee requested that NASA more fully present details at its next meeting. This committee, and several others, are scheduled to meet in June and July, after which they should be in a better position to assess the impact of Russian participation on planned research.

Scope and Methodology

To accomplish our objectives, we compared the Alpha program as documented in the September 1993 Program Implementation Plan to the current ISSA program. We

- interviewed NASA officials and reviewed pertinent documents from the space station program, space shuttle program, and science offices; super lightweight tank, main engine, solid rocket motor, and orbiter vehicle projects; and mission operations and flight crew operations directorates;
- attended various NASA reviews on the design of the space station, including the Systems Requirements Review and the Systems Design Review;

- attended meetings of committees advising NASA on space station design and utilization issues, including the Advisory Committee on the Redesign of the Space Station; Space Station Science and Applications Advisory Subcommittee; National Research Council (NRC) Aeronautics and Space Engineering Board, Committee on Space Station; NRC Space Studies Board, Committee on Space Biology and Medicine; NRC Space Studies Board, Committee on Microgravity Research; Space Station Advisory Committee; and Aerospace Medicine Advisory Committee; and
- analyzed and compared budget data for the Alpha and ISSA programs.

We conducted our review at NASA headquarters, Johnson Space Center, Kennedy Space Center, and Marshall Space Flight Center. The foreign policy issues related to the Russian participation were not within the scope of our work. We also did not assess the risk to the space station program should Russian participation be terminated for any reason.

We performed our work between August 1993 and June 1994 in accordance with generally accepted government auditing standards. As requested, we did not obtain agency comments on this report. However, on several occasions, we discussed our findings with NASA personnel, including officials of the space station, space shuttle, and science offices and included their comments as appropriate in this report.

Unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 10 days from its issue date. At that time, we will send copies of this report to the NASA Administrator; the Director, Office of Management and Budget; appropriate congressional committees; and other interested parties upon request.

Please contact me on (202) 512-8412 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix I.

Sincerely yours,



Donna M. Heivilin
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