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November 2004

SPACE SHUTTLE

Costs for Hubble Servicing Mission and Implementation of Safety Recommendations Not Yet Definitive

GAO-05-34

November 2004

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Highlights

Highlights of GAO-05-34, a report to the Subcommittee on VA/HUD-Independent Agencies, Committee on Appropriations, U.S. Senate

SPACE SHUTTLE

Costs for Hubble Servicing Mission and Implementation of Safety Recommendations Not Yet Definitive

Why GAO Did This Study

Hubble's continued operation has been dependent on manned servicing missions using the National Aeronautics and Space Administration's (NASA) shuttle fleet. The fleet was grounded in early 2003 following the loss of the Space Shuttle Columbia, as NASA focused its efforts on responding to recommendations made by the Columbia Accident Investigation Board (CAIB). In January 2004, NASA announced its decision to cancel the final planned Hubble servicing mission, primarily because of safety concerns. Without some type of servicing mission, NASA anticipates that Hubble will cease to support scientific investigations by the end of the decade.

NASA's decision not to service the Hubble prompted debate about potential alternatives to prolong Hubble's mission and the respective costs of these alternatives. This report addresses the basis of NASA's cost estimates to (1) service Hubble using the shuttle and (2) implement recommendations made by the CAIB. GAO is continuing its work on the Subcommittee's request that GAO examine the potential cost of a robotic servicing mission to the Hubble Telescope.

What GAO Recommends

GAO is not making recommendations in this report.

www.gao.gov/cgi-bin/getrpt?GAO-05-34.

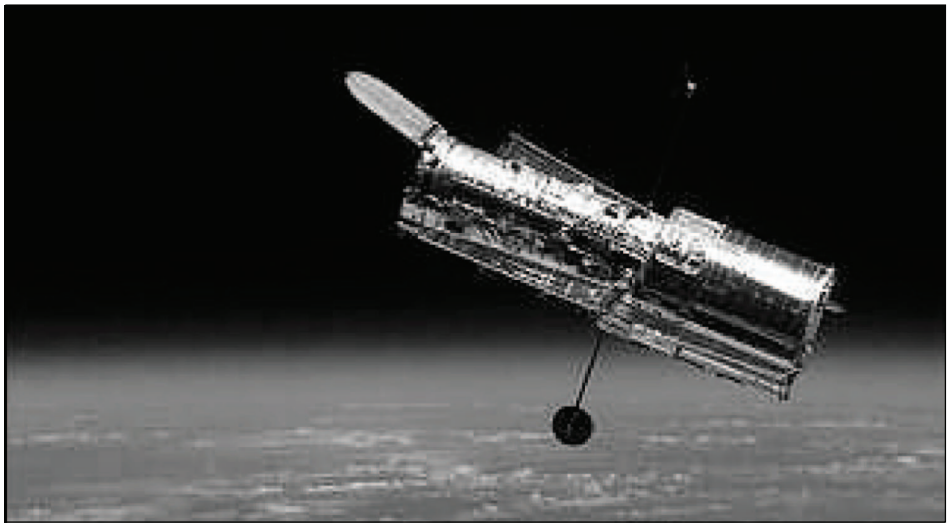
To view the full product, including the scope and methodology, click on the link above. For more information, contact Allen Li at (202) 512-4841 or lia@gao.gov.

What GAO Found

Although a shuttle servicing mission is one of the options for servicing the Hubble Space Telescope, to date, NASA does not have a definitive estimate of the potential cost. At our request, NASA prepared an estimate of the funding needed for a shuttle servicing mission to the Hubble. NASA estimates the cost at between $1.7 billion to $2.4 billion. However, documentary support for portions of the estimate is insufficient. For example, NASA officials told us that the Hubble project's sustaining engineering costs run $9 to 10 million per month, but they were unable to produce a calculation or documents to support the estimate because they do not track these costs by servicing mission. Additionally, the agency has acknowledged that many uncertainties, such as the lack of a design solution for autonomous inspection and repair of the shuttle, could change the estimate.

At the same time, NASA has yet to develop a definitive cost estimate for implementing all of the CAIB's recommendations but has developed a budget estimate for safely returning the shuttle to flight—a subset of activities recommended by the CAIB as needed to return the shuttle to full operations. NASA currently estimates return to flight costs will exceed $2 billion, but that estimate will likely be refined as the agency continues to define technical concepts. NASA provided support for portions of the estimate, but we found the support to be insufficient—either because key documents were missing or the estimates lacked sufficient detail. Further, NASA cautions that return to flight costs will remain uncertain until the first return to flight shuttle mission, which is scheduled to go to the International Space Station in spring 2005.

Hubble Space Telescope



Source: NASA.

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Abbreviations

CAIB	Columbia Accident Investigation Board
NASA	National Aeronautics and Space Administration
PRCB	Program Requirements Control Board
UCA	undefinitized contract actions

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United States Government Accountability Office
Washington, DC 20548

November 19, 2004

The Honorable Christopher S. Bond
Chairman
The Honorable Barbara A. Mikulski
Ranking Member
Subcommittee on VA/HUD-
Independent Agencies
Committee on Appropriations
United States Senate

For more than a decade, the National Aeronautics and Space Administration's (NASA) Hubble Space Telescope has provided unique images of the universe and has given scientists critical data needed to help understand a number of space mysteries. Hubble's continued operation has been dependent on NASA's space shuttle fleet, which carried crewmembers to the telescope to perform periodic maintenance and upgrades. The grounding of the shuttle fleet following the tragic loss of Space Shuttle Columbia in February 2003 put these missions to Hubble on hold, and in January 2004, NASA announced its decision to cancel the fifth and final planned Hubble servicing mission. With no future servicing missions, NASA anticipates that Hubble will cease to support scientific investigations by the end of the decade.

NASA said that its decision to cancel the servicing mission was based largely on concerns about shuttle safety—specifically, the need to implement recommendations made by the Columbia Accident Investigation Board (CAIB) for safely returning the space shuttle to flight.[1] NASA also recognized that a Hubble servicing mission would necessitate further changes both to shuttle hardware and operational procedures. However, NASA's decision has prompted considerable debate. Congressional members, scientists, and space policy experts have called for an examination of alternatives to prolong Hubble's mission, such as the possibility of servicing Hubble robotically. The CAIB Chairman suggested that only a study of the benefits and risks of a shuttle servicing mission to extend Hubble's life could determine whether it is worth the risks.

[1] The CAIB was created by NASA to investigate the February 1, 2003, loss of the space shuttle Columbia.

This report addresses the basis for NASA's cost estimates to (1) service the Hubble Telescope by using the shuttle and (2) implement the CAIB's recommendations, including those recommendations directly related to safely returning the shuttle to flight. We are continuing our work on your request that we examine the potential cost of a robotic servicing mission to the Hubble Telescope.

To assess the basis for NASA's Hubble servicing mission cost estimate, we examined NASA's rationale for its decision to cancel the final planned shuttle servicing mission, analyzed available funding estimates, and requested analytical and documentary support for selected high-dollar items to identify the sufficiency of support. In reviewing the basis for NASA's cost estimate for implementing the CAIB's recommendations, we analyzed available funding estimates and requested analytical and documentary support for selected high dollar portions of the estimate to determine the sufficiency of such support. We performed our review from March through September 2004 in accordance with generally accepted government auditing standards. For a complete description of our scope and methodology, see appendix I.

Results in Brief

Definitive cost estimates to facilitate decisions regarding options for servicing the Hubble are critical. However, NASA has not yet developed such an estimate for one of the options—a shuttle servicing mission. At our request, NASA prepared an estimate of the funding needed for a shuttle servicing mission to Hubble. However, NASA could not provide documented support for key portions of the estimate, stating that there are many uncertainties that could change the estimate, such as the lack of a design solution for two safety-related requirements—autonomous inspection and repair and crew rescue mission capabilities.

Similarly, NASA does not have a definitive cost estimate for implementing all of the CAIB recommendations. The agency has been focusing primarily on those recommendations it considers necessary to return the shuttle fleet to flight. NASA's current estimate for implementing those recommendations is more than $2 billion. NASA provided us with documentary support for portions of the estimate, but we found some of the support to be insufficient. In NASA's view, the estimate for returning the shuttle fleet to flight will remain uncertain until the first shuttle mission to the International Space Station.

In written comments, which are reprinted in appendix II, NASA stated that the agency believes that both the estimate and the methodology used in

calculating the costs of reinstating the servicing mission are sound and accurate given the level of definition of the mission at this point in time. However, the agency agreed that some portions of the servicing mission activities lacked the design maturity required to estimate the costs according to NASA accepted and established procedures.

Background

Since it was launched in 1990, the Hubble Space Telescope has sent back images of space that have made a significant contribution to our understanding of the universe. The telescope uses pointing precision, powerful optics, and state-of-the-art instruments to explore the visible, ultraviolet, and near-infrared regions of the electromagnetic spectrum. To keep it at the forefront of astronomical research and extend its operational life, Hubble's instruments have been upgraded through a series of shuttle servicing missions. The fifth and final planned servicing mission was intended to install new science instruments, replace the telescope's insulation, and replace the batteries and gyroscopes. According to NASA, the lifetime of the observatory on orbit is ultimately limited by battery life, which may extend into the 2007-2008 time frame, but scientific operations are limited by the gyroscopes that stabilize the telescope—whose lifetimes are more difficult to predict. NASA forecasts that the Hubble will likely have fewer than three operating gyroscopes by mid-2006, and fewer than two by mid-2007.

In response to congressional concerns about NASA's decision to cancel the servicing mission, NASA requested that the National Research Council[2] conduct an independent assessment of options for extending the life of the Hubble Space Telescope. In May 2004, the Council established a committee to assess the viability of a shuttle servicing mission, evaluate robotic and ground operations to extend the life of the telescope as a valuable scientific tool, assess telescope component failures and their impact, and provide an overall risk-benefit assessment of servicing options. In an interim report issued in July 2004, the committee urged NASA to commit to a Hubble servicing mission that accomplishes the

[2] The National Research Council is part of the National Academies, which also comprise the National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. They are private, nonprofit institutions that provide science, technology, and health policy advice under a congressional charter. The Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of further knowledge and advising the federal government.

objectives of the canceled servicing mission and to take no actions that would preclude using a space shuttle to carry out this mission. According to a NASA official, the agency is not actively pursuing the shuttle servicing option but is not precluding it.

NASA is currently evaluating the feasibility of performing robotic servicing of the Hubble Telescope. To facilitate the evaluation, the agency has formulated a robotic mission concept, which includes a vehicle comprised of a robotic servicing module and another module that can be used to eventually de-orbit the telescope. The potential task list of activities for robotic servicing includes replacing the gyroscopes and batteries, installing new science instruments, and de-orbiting the observatory at the end of its life. According to a NASA official, contracts to facilitate the robotic mission were recently awarded for work to begin on October 1, 2004.

The CAIB concluded that the Columbia accident was caused by both physical and organizational failures. The Board's 15 return to flight recommendations necessary to implement before the shuttle fleet can return to flight primarily address the physical causes of the accident and include eliminating external tank debris shedding and developing a capability to inspect and make emergency repairs to the orbiter's thermal protection system. NASA publishes periodic updates to its plan for returning the shuttle to flight to demonstrate the agency's progress in implementing the CAIB recommendations. The most recent update is dated August 27, 2004. This update identifies the first shuttle flight as occurring in spring 2005.

NASA's Cost Estimate for a Hubble Servicing Mission Using the Shuttle Is Not Definitive

NASA does not currently have a definitive cost estimate for servicing the Hubble Telescope using the shuttle. The agency focused on safety concerns related to a servicing mission by the space shuttle in deciding not to proceed, and did not develop a cost estimate. At our request NASA prepared an estimate of the funding needed for a Hubble servicing mission by the space shuttle. NASA could not provide documented support for its estimate. The agency recognizes that there are many uncertainties that could change the estimate. NASA has now begun to explore the costs and benefits of various servicing alternatives, including robotic servicing, which should enable NASA to make a more informed decision regarding Hubble's future.

At our request NASA began development of an estimate of the funding needed for a shuttle servicing mission to the Hubble. The estimate provided captures additional funds over and above NASA's fiscal year 2005 budget request that would be required to reinsert the mission in the shuttle flight manifest for launch in March 2007. The estimate does not include funding already expended to support the canceled servicing mission and develop the science instruments. NASA has determined that the additional funds needed to perform a shuttle servicing mission for Hubble would be in the range of $1.7 billion to $2.4 billion. According to NASA, this estimate is based on what it might cost, but it does not take into account the technical, safety, and schedule risks that could increase the cost and/or undermine the viability of the mission. For example, NASA cites uncertainties related to two safety-related requirements: inspection and repair and crew rescue mission capabilities that would be autonomous of the International Space Station and for which NASA currently has not formulated a design solution.[3] In addition, NASA cautions that it did not examine whether design solutions could be accomplished in time to service Hubble before it ceases operations. Table 1 shows NASA's budget estimate phased by fiscal year (FY) for shuttle servicing of the Hubble Space Telescope, including ranges for some of the estimates.

[3] Although the autonomous inspection and repair capability of the shuttle's thermal protection system is a CAIB requirement for all shuttle missions, the currently planned method depends on International Space Station assets, such as the International Space Station's robotic arm to stabilize a spacewalk crew making repairs to the shuttle. A Hubble mission would not have this asset available; therefore, NASA would have to develop an alternate method for stabilizing a crewmember making repairs. The second requirement—NASA's requirement for a crew rescue shuttle—would apply to all shuttle flights, but according to NASA, the agency would need to dedicate two shuttles to a Hubble servicing mission because of the shorter amount of time to react to an emergency because the crew would not have the benefit of the International Space Station as a safe haven. The agency contends that the second (rescue) shuttle for the Hubble servicing mission would need to be on the adjacent launch pad in countdown mode at the same time the first shuttle is launched. The rescue shuttle capability would require the development of a second generation boom to be used to transfer the crew from the stricken orbiter and an enhanced camera to process imagery in time to support a go-no go rescue mission decision. In addition, a crew return kit would be needed to provide seats on the rescue shuttle for the rescued crew, and a special crew would have to be trained for the rescue mission.

Table 1: Budget Estimate for Shuttle Servicing of Hubble

Real year dollars in millions[a]

	Fiscal year							
Description	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Budget to Complete**	**Total[a]**
Sustaining engineering for Hubble project		$115	$141	$105	$26	$30	$40	**$457**
Delay de-orbit mission until 2012				(69)	(136)	79	166	**40**
Extend Hubble operations to 2012							117	**117**
Shuttle services unique to servicing mission and extravehicular activity[b]			18	15				**33**
Payload processing		7	7	13	10	7		**43**
Autonomous inspection and repair capability	$116-134	74-86	52-60	18-21				**260-300**
Autonomous rescue mission capability	85-98	116-134	61-71	31-36				**293-338**
Rescue mission unique requirements and ground operations			1	22				**22**
International Space Station Program impact (3-month delay)			(5)	(15)	(13)	(4)	50	**13**
Delay shuttle phase-out 3 months				9-0	17-72	26-249	350-757	**401-1,078**
Total[a]	**$200-231**	**$312-341**	**$275-293**	**$128-127**	**$(95)-(41)**	**$137-361**	**$723-1,130**	**$1,679-2,441**

Source: NASA.

Note: Estimates are in full cost. The concept of full cost ties all agency costs (including civil service personnel costs) to major activities. This includes costs that are directly related to a specific project, such as contractor-supplied hardware, and indirect costs such as administrative costs, rents, utilities, and travel costs that cannot be directly identified with a specific project but which can be allocated based on direct labor hours, square footage, or other methods.

[a]In some cases, totals do not add because of rounding.

[b]Extravehicular activity is a space walk.

While we did not independently verify each component of NASA's estimate, we requested that NASA provide the analytical basis and documentary support for selected portions of the estimate, primarily those with large dollar values. NASA could not provide the requested information. For example, NASA officials told us that the Hubble project's sustaining engineering costs run $9 to10 million per month, but they were unable to produce a calculation or documents to support the estimate because they do not track these costs by servicing mission. We also requested the basis of estimate for the costs to delay shuttle phase-out and for tools development for vehicle inspection and repair without the International Space Station (a component of extravehicular activity above). In response, NASA provided the assumptions upon which the estimates were based and stated that the estimates were based on information provided by Johnson Space Center and Kennedy Space Center subject matter experts. NASA also added that rigorous cost estimating techniques could not be applied to the tools development estimate because a rescue mission currently is only a concept. No analytical or documentary support was provided. In estimating the cost for the autonomous inspection and repair and rescue mission capabilities, NASA used a 30 to 50 percent uncertainty factor because of the very high uncertainty in the cost of developing and conducting a mission that is not adequately defined—i.e., NASA's estimate of $425 million plus 50 percent equals the $638 million upper range shown in the table above for these two items added together. As with the other estimates for which we requested analytical and documentary support, NASA was not able to provide it because the agency could not do a risk analysis without a design solution, according to a NASA official. The lack of documented support for portions of NASA's estimate increases the risk of variation to the estimate. Further, NASA recognizes that there are many uncertainties that could change the current estimate.

The 2004 NASA Cost Estimating Handbook states that cost analysts should document the results of cost estimates during the entire cost estimating process and that the documentation should provide sufficient information on how the estimate was developed so that independent cost analysts could reproduce the estimate. According to the handbook, the value of the documentation and analysis is in providing an understanding of the cost elements so that decision-makers can make informed decisions.

Recently, we also reported that dependable cost estimates are essential for establishing priorities and making informed investment decisions in the face of limited budgets.[4] Without this knowledge, a program's estimated cost could be understated and thereby subject to underfunding and cost overruns, putting programs at risk of being reduced in scope or requiring additional funding to meet their objectives.

Since we began our review, attention has focused on alternatives to a shuttle mission, such as robotic servicing of Hubble. NASA has formed a team to evaluate Hubble servicing alternatives, including cost information. This analysis should enable NASA to make a more informed decision about Hubble's future and facilitate NASA's evaluation of the feasibility of robotic servicing options.

Estimate for Implementing CAIB Recommendations Is Not Fully Developed

Currently, NASA has developed budget estimates for implementing the CAIB recommendations required to return the space shuttle to flight but not for all of the CAIB recommendations. NASA provided us with documentary support for portions of the return to flight estimate, but we found it to be insufficient. According to NASA, the agency's cost for returning the shuttle to flight, which is slightly over $2 billion, will remain uncertain until the completion of the first shuttle missions to the International Space Station in fiscal year 2005.

NASA's return to flight activities involve enhancing the shuttle's external tank, thermal protection system, solid rocket boosters, and imagery system to address the physical cause of the Columbia accident—a piece of insulating foam that separated from the external tank and struck a reinforced carbon-carbon panel on the leading edge of the orbiter's left wing. To address this cause, NASA is working to eliminate all external tank debris shedding. Efforts are also in place to improve the orbiter's thermal protection system, which includes heat resistant tiles, blankets, and reinforced carbon-carbon panels on the leading edge of the wing and nose cap of the shuttle, to increase the orbiter's ability to sustain minor debris damage. NASA is also redesigning the method for catching bolts that break apart when the external tank and solid rocket boosters separate as well as providing the capability to obtain and downlink images after the separation. NASA and the United States Air Force are working to improve

[4] GAO, *NASA: Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management*, GAO-04-642 (Washington, D.C.: May 28, 2004).

the use of ground cameras for viewing launch activities. Table 2 shows NASA's budget estimates for return-to-flight activities.

Table 2: Return to Flight Budget Estimates as of July 2004

Real year dollars in millions[a]

	Fiscal year				
Activity	**2003**	**2004**	**2005**	**2006–2009[a]**	**Total[b]**
Orbiter reinforced carbon-carbon inspections	$2	$38	$7		
On-orbit thermal protection system inspection and extravehicular activity tile repair	20	68	130		
Orbiter workforce	0	5	37		
Orbiter thermal protection system hardening	0	28	34		
Orbiter certification/verification	0	47	26		
Orbiter other	0	15	16		
External tank items (camera, bipod ramp, etc.)	11	114	94		
Solid rocket booster items (bolt catcher, camera, etc.)	1	8	26		
Ground camera ascent imagery upgrade	8	40	58		
Kennedy Space Center ground operations workforce	0	32	36		
Other (system integration, hardware processing and operations systems verification, and space shuttle main engine technical assessment)	0	67	177		
Stafford-Covey team		3	1		
Total[b]	**$42**	**$465**	**$643**	**$1,067**	**$2,217**

Source: NASA.

Note: According to NASA, not all elements of full cost have been distributed to return to flight activities.

[a]Fiscal years 2006-2009 are NASA preliminary estimates, and a cost breakout by activity is not available.

[b]In some cases, totals do not add because of rounding.

However, the majority of NASA's budget estimates for returning the shuttle to flight are not fully developed—including those for fiscal year 2005—as indicated by the agency's internal approval process. The Program Requirements Control Board (PRCB) is responsible for directing studies of identified problems, formulating alternative solutions, selecting the best

solution, and developing overall estimates.[5] According to NASA, actions approved with PRCB directives have mature estimates, while those with control board actions in process—that is currently under review but with no issued directives yet—are less mature. Both the content and estimates for return to flight work that have not yet been reviewed by the control board are very preliminary and subject to considerable variation. Table 3 shows the status of control board review of NASA return to flight budget estimates and the percent of the total estimate at each level of review.

Table 3: Return to Flight Budget Estimate Review Status as of July 2004

Real year dollars in millions

	Fiscal year								
Review status	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**Total[a]**	**Percent of total[a]**
Control board review complete; directive issued	$31	$319	$117	$53	$47	$49	$39	**$655**	29
Been to control board; directive not yet issued	11	146	217	117	125	134	109	**859**	39
In review process			309	162	84	79	70	**704**	32
Total Return to Flight activities[a]	**$42**	**$465**	**$643**	**$331**	**$257**	**$261**	**$218**	**$2,217**	**100**

Source: NASA.

Note: According to NASA, not all elements of full cost have been distributed to return to flight activities.

[a]In some cases, totals do not add because of rounding.

[5] The membership of the PRCB includes the Space Shuttle Program Manager, Deputy Manager, all Project and Element Managers, Safety and Mission Assurance personnel, and the Team Leader of the return to flight Planning Team.

NASA provided us with the PRCB directives and in some cases, attachments which the agency believes support the estimate.[6] However, we did not find this support to be sufficient. According to NASA's cost estimating handbook, estimates should be documented with sufficient detail to be reproducible by an independent analyst. Nevertheless, in many cases, there were no documents attached to the directive, and in cases where documents were attached to the directives, the documents generally provided high-level estimates with little detail and no documentation to show how NASA arrived at the estimate. For example, a request for $1.8 million to fund the network to support external tank camera transmissions indicated that $1.516 million of the amount would be needed for Goddard Space Flight Center to provide the necessary equipment at receiving stations, labor, subcontractor costs, and travel and that the remaining $290,000 would be needed for improvements to the receiving antennas ($104,000) and recurring costs ($62,000 per flight) for three trucks and the associated transponder time. However, the documents did not show how the requester for the $1.8 million arrived at the estimates. NASA officials told us that the reason for this was that the managers approving the directives trusted their employees to accurately calculate the estimate and maintain the support. In addition, our review of the documents indicated and NASA confirmed that quite a few of the estimates were based on undefinitized contract actions (UCA)—that is, unnegotiated contract changes. Under these actions, NASA officials can authorize work to begin before NASA and the contractor agree on a final estimated cost and fee. As we have stated in our high-risk series, relying on unnegotiated changes is risky because it increases the potential for

[6] We attempted to obtain analytical and documentary support for the return to flight estimates on two occasions. First, in May 2004, we requested support for three high-dollar items for which we were told the estimates ranged from strong to weak to a mixture. In response to this request, NASA told us that the detailed bases of estimate for the activities were being developed and that NASA would report on return to flight expenses to Congress and GAO in a few weeks. Then, several weeks later when NASA released the July 28 return to flight update, we requested support for the three largest estimates, two of which were the same items for which we requested support in May. In response, NASA provided the PRCB directives and backup documents underlying the estimates that the agency considers to be mature. After we reviewed these documents and concluded that the support was not adequate, NASA offered to select some additional examples to show that the estimates were credible.

unanticipated cost growth.[7] This, in turn, may force the agency to divert scarce budget resources intended for other important programs. As of July 31, 2004, NASA records showed 17 UCAs related to return to flight with not-to-exceed amounts totaling $147.5 million. NASA's estimate for the entire effort under these UCAs totals about $325 million, or 15 percent of NASA's current $2.2 billion return to flight estimate.

In June 2004, NASA established additional requirements for funding requests submitted to the PRCB. Under the new policy, an independent cost estimate must be developed for requests greater than $25 million, and a program-level cost evaluation must be completed for requests over $1 million. The program-level evaluation consists of a set of standard questions to document the rationale and background for cost-related questions. The responses to the questions are initially assessed by a cost analyst but are reviewed by the Space Shuttle Program Business Manager before submission to the PRCB.

NASA provided us with two examples of requests falling under the new requirements. Both of the examples had better support than those with PRCB directives, but documentary support was still not apparent. For example, the funding request for a debris radar indicated that the estimate was based on a partnering agreement with the Navy and the Navy's use of the technology. However, the program-level evaluation pointed out that no detailed cost backup was provided. The other example, which was a funding request to change the processes currently in place for the Space Shuttle Program's problem reporting and corrective action system, was very well supported in terms of analysis, as the requester prepared detailed spreadsheets calculating the funding requirements according to a breakdown of the work to be performed, cited sources for labor rates, and provided assumptions underlying the calculations. However, as pointed out in the program evaluation of the request, there was no support provided for the estimate other than the initiator's knowledge of the change. We believe that future compliance with NASA's new policy establishing additional requirements for funding requests and the inclusion

[7] GAO, *NASA: Major Management Challenges and Program Risks*, GAO-03-849T (Washington, D.C.: June 12, 2003); GAO, *High-Risk Series: An Update*, GAO-03-119 (Washington, D.C.: January 2003); GAO, *Major Management Challenges and Program Risks: National Aeronautics and Space Administration*, GAO-03-114 (Washington, D.C.: January 2003); GAO, *High-Risk Series: An Update*, GAO-01-263 (Washington, D.C.: January 2001); and GAO, *Major Management Challenges and Program Risks: National Aeronautics and Space Administration*, GAO-01-258 (Washington, D.C.: January 2001).

of documentary support could potentially result in more credible return to flight budget estimates.

According to NASA, estimates for fiscal year 2005 and beyond will be refined as the Space Shuttle Program comes to closure on return to flight technical solutions and the return to flight plan is finalized. NASA expects that by late fall of 2004, a better understanding of the fiscal year 2005 financial situation will be developed. However, NASA cautions that the total cost of returning the shuttle to flight will remain uncertain until completion of the first shuttle missions to the space station, scheduled to begin in spring 2005.

Agency Comments and Our Evaluation

In written comments on a draft of this report, the NASA Deputy Administrator stated that the agency believes that both the estimate and methodology used in the calculation of costs for reinstating the Hubble Space Telescope servicing mission are sound and accurate, given the level of definition at this point in time. Notwithstanding that belief, the agency agreed that portions of the servicing mission activities lacked the design maturity required to estimate the costs according to accepted and established NASA procedures.

Specifically, NASA agrees that the Hubble Space Telescope work breakdown structure was not constructed to collect program costs. At the same time, NASA believes it is erroneous to suggest that NASA has no valid basis for the numbers provided, citing the "Servicing Mission 4 Resources Management Plan," which describes the effort required for completion of a servicing mission. According to NASA, although the program's accounting system does not capture sustaining engineering costs in GAO's preferred format, the Servicing Mission 4 Resources Management Plan details mission schedules and staffing, and applying contractor and civil service rates to that staffing level can accurately reflect the effort required to execute a servicing mission. We requested this type of analysis and documentary support, but NASA representatives did not offer such a calculation. Rather, the officials stated that the sustaining engineering costs were based on management's assessment of contractor financial data and in-house service pool charges and that these activities could not be traced back to source documentation. Without adequate supporting data, we cannot assess the accuracy and reliability of such information.

NASA acknowledged that the agency does not have a technical design from which to derive the cost for the on-orbit inspection and repair of the

shuttle independent of support from the International Space Station. In the case of the unsupported cost estimate for delaying the phase out of the space shuttle in order to complete a manned Hubble servicing mission, NASA stated that it used approved budget projections for the operating years affected by the insertion of the Hubble servicing mission and prorated the extension of the service life. According to NASA, a range was added to the estimate to account for uncertainties and retention of critical skills. The estimates were presented as a rough order of magnitude. NASA stated that it provided its assumptions to demonstrate the reasonableness of the estimates. Nevertheless, in spite of the uncertainties in the estimate, which we recognized in our report, NASA guidance states that cost estimates should be documented during the entire cost estimating process and that the documentation should provide sufficient information on how an estimate was developed to be reproducible by independent cost analysts. NASA did not provide us with this type of documentation. Without adequate supporting data, we cannot assess the accuracy and reliability of such information. We do not agree that the use of approved budget projections is a reliable cost estimating methodology, particularly given the long-term budget implications of the extension of the space shuttle's service life.

NASA believes that the examples it provided of the actions to implement several of the CAIB recommendations attest to the rigor of the process and approved procedures NASA utilized to validate the costs. According to NASA, the estimates will mature as the technical solutions mature, but the estimates were not refined at the time of our review. The agency believes the outstanding technical issues necessary to return to flight are beginning to be resolved. However, the examples that NASA provided were in support of estimates that the agency considers mature. We requested support for high dollar portions of NASA's estimate, which the agency did not provide. However, NASA selectively provided examples of what it considered to be mature estimates. We reviewed the examples but found that most of them contained insufficient documentation to assess the reliability of the estimates. In many cases, there were no documents in the approval packages to support the estimates, and in cases where there were documents, they generally provided high-level estimates with little detail and no documentation to show how NASA arrived at the estimates. We believe that because of its difficulty providing reliable cost estimates, NASA cannot provide the Congress assurance that its budget request for the shuttle program for fiscal year 2006 will be sufficient and that shortfalls would not need to be met through reductions in other NASA programs.

NASA stated that it believes the use of UCAs is both reasonable and necessary for return to flight activities. We agree that UCAs may be justified to facilitate work outside the scope of existing contracts to expedite the return to flight activities. However, the use of UCAs appears to be a growing trend and is a risky contract management practice because it increases the potential for unanticipated cost growth. In the past, we cited the agency's use of UCAs as one of the reasons we retained contract management as a high-risk designation for NASA to focus management attention on problem areas that involve substantial resources.[8]

Finally, NASA agrees that cost estimates for significant development activities should be appropriately documented. According to NASA, additional requirements for cost estimates and internal controls recently established by the program represent a step in ensuring the appropriate documentation is developed as solutions are identified. As stated in our report, we believe that future compliance with this new policy could potentially result in more credible budget estimates.

In a broader context, reliable and supportable cost estimating processes are important tools for managing programs. Without this knowledge, a program's estimated cost could be understated and thereby subject to underfunding and cost overruns, putting programs at risk of being reduced in scope or requiring additional funding to meet their objectives. Further, without adequate financial and nonfinancial data, programs cannot easily track an acquisition's progress and assess actions to be taken before it incurs significant cost increases and schedule delays.

As agreed with your offices, unless you announce its contents earlier, we will not distribute this report further until 30 days from its date. At that time, we will send copies to the NASA Administrator and interested congressional committees. We will make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

[8] *High-Risk Series: An Update* (GAO-01-263, January 2001).

If you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or lia@gao.gov. Key contributors to this report are acknowledged in appendix III.

Allen Li
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To assess the basis for NASA's Hubble servicing mission cost estimate, we analyzed NASA's estimate of the funding needed for a shuttle servicing mission and supporting documentation, and we reviewed NASA documents explaining the rationale for the decision and identifying alternatives to shuttle servicing. We interviewed program and project officials to clarify our understanding of the available cost information and NASA's rationale for the decision. To test the sufficiency of the support for the estimates provided by NASA, we requested the analytical basis and documentary support for selected portions of the estimates, primarily those with large dollar values. In addition, we compared NASA's decision-making process with relevant Office of Management and Budget and NASA guidance on information and analyses recommended to enable decision-makers to select the best alternative.

To determine the basis for NASA's cost estimate for implementing all of the CAIB recommendations, we reviewed the CAIB report (volume 1), NASA's return to flight implementation plan and budget estimates, and agency documentation discussing the return to flight budget estimate. We interviewed program officials to obtain a better understanding of NASA's plans for returning the space shuttle to flight, the status of that effort, and the estimated cost. To test the sufficiency of the support for NASA's return to flight estimate, we requested the analytical basis and documentary support for selected high dollar portions of the estimate.

To accomplish our work, we visited NASA Headquarters, Washington, D.C.; and Goddard Space Flight Center, Maryland.

We performed our review from March through September 2004 in accordance with generally accepted government auditing standards.

Appendix II: Comments from the National Aeronautics and Space Administration

National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

November 10, 2004

Mr. Allen Li
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Mr. Li:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to comment on your draft report (Government Accountability Office (GAO) Code 120335, Report Number GAO-05-34) entitled "Costs for Hubble Servicing Mission and Implementation of Safety Recommendations Not Yet Definitive."

Costs for Reinstating a Shuttle-based Hubble Servicing Mission (SM)

NASA believes that both the estimate and the methodology used in the calculation of costs for reinstating an SM-4 mission are sound and accurate given the level of definition of the mission at this point in time. It is true, as the GAO has recognized in the report, that some portions of the identified Shuttle SM-4 reinstatement activities lacked the design maturity required to estimate the costs according to NASA accepted and established procedures. NASA believes that the cost ranges applied to these items are reasonable given that acceptable design solutions are unknown at this time. Comments on specific statements contained in the report are offered in the following paragraphs:

Page 7: "NASA could not provide . . . the analytical basis and documentary support for selected portions of the estimate." The report goes on to cite the Hubble program's $9-10 million monthly burn rate for the core engineering team, stating that NASA was "unable to produce a calculation or documents to support the estimate because they do not track these costs by servicing mission."

NASA Response: While it is true that the Hubble Space Telescope (HST) work breakdown structure was never constructed to collect program costs by individual servicing mission, it is erroneous to suggest that NASA has no valid basis for the numbers provided.

Over the course of this study, NASA granted GAO full access to all HST program accounting archives and budget estimates, including budget packages, presentation materials, contractor data, and supporting documentation. Among the materials provided to GAO was a

report entitled, "Servicing Mission 4 Resources Management Plan," dated November 2003. This document includes a detailed description of the effort required for safe completion of a servicing mission to Hubble, which NASA has done successfully four times since the observatory was launched in 1990.

Though the program's accounting system does not capture sustaining engineering costs in the format that GAO would have preferred, the effort involved with mission safety and success is well understood. The Resources Management Plan details mission schedules, historical staffing levels, skill mix, contractor and civil service FTEs—all of which have been refined as a result of experience, and lessons learned over the years. The $9-10 million per month can be derived by applying contractor and civil service rates to these FTE numbers. It is a simple computation that accurately reflects the effort required to safely execute SM-4.

In a letter to NASA Administrator Sean O'Keefe dated March 11, 2004, Senators Christopher Bond and Barbara Mikulski requested that NASA "take no action to stop, suspend or terminate any contracts or employment in connection with the final servicing mission until this study is completed and Congress has taken action on NASA's fiscal year 2005 budget." In response to this request, the Hubble program has continued to retain the core team of experts described in the Resources Management Plan—some of whom have worked on the project since launch—at the $9-10 million per month level. These are the people needed to do the job safely, and NASA stands by the estimates provided.

Page 7: "We also requested the basis of estimate for the costs to delay Shuttle phase-out and for tools development for [on-orbit] vehicle inspection and repair without the International Space Station . . . In response, NASA provided the assumptions upon which the estimates were based … No analytical or documentary support was provided."

NASA Response: As acknowledged on Page 4 of the report, NASA was requested to provide an estimate for the delay in Shuttle phase-out and on-orbit inspection and repair, independent of support from the Space Station, by the GAO. The report also acknowledges that NASA has no baseline technical concept for the on-orbit inspection and repair of the Shuttle, independent of the station, upon which to base a cost estimate. In the case of the Shuttle phase-out delay costs, NASA simply used approved budget projections for the operating years affected by the insertion of a Hubble mission and prorated an extension of the Shuttle's service life beyond the 2010 end point assumed in the President's FY 2005 request. A range was added to the estimate to account for uncertainties associated with continued production of Shuttle hardware and retention of critical skills. The on-orbit inspection and repair estimate was represented at the time as a "rough order of magnitude (ROM)" and is consistent with the lack of any reasonable level of technical detail. Still, NASA provided its assumptions, along with a description of one possible approach and a summary of technical uncertainties, with which the reasonableness of the ROM estimate could be determined.

Costs for Implementing Safety Recommendations

NASA is committed to full implementation of all of the recommendations of the Columbia Accident Investigation Board (CAIB). NASA's Return to Flight (RTF) efforts continue to evolve as appropriate solutions are identified. NASA employs a rigorous review process to

approve specific projects required to safely return the Shuttle to flight. The technical scope of work is defined, schedules are built, and standard cost-estimating methodologies are employed to gain approval for implementation. NASA believes that the detailed examples provided to the GAO attest to the rigor of the technical process and that NASA is applying approved procedures for validating costs. NASA provided the GAO access to detailed information on the technical, programmatic and cost elements of the RTF activities over the course of the investigation this past summer. NASA stands behind the cost estimates provided for the RTF efforts as known at that time. As the activity matures, so will the cost estimates. Comments on specific statements contained in the report are offered in the following paragraphs:

Page 11: "NASA provided us with PRCB directives and in some cases, attachments which the Agency believes support the estimate. However, we did not find this support to be sufficient. According to NASA's cost-estimating handbook, estimates should be documented with sufficient detail to be reproducible by an independent analyst."

NASA Response: In July 2004, NASA reported revised cost estimates for Shuttle return to flight (RTF) and advised Congress that the estimates will continue to evolve as RTF technical solutions matured. Indeed, multiple paths were being pursued for some of the technical solutions that greatly complicated the Agency's ability to accurately forecast costs. The Agency also stated that the final costs for RTF would not be known until after the first Shuttle missions, at which time the effectiveness of the solutions could be properly assessed. NASA also stated that the cost estimates would be refined over the summer and another update would be provided to Congress in the fall of 2004. The GAO audit began in March of 2004 and completed in September of 2004. The auditors were advised that the estimates were still being refined as multiple-path solutions were being down-selected and the Agency began to finalize its RTF plan. NASA concedes that the estimates were not refined to the level that could withstand an independent audit at the time the GAO reviewed them, and that the Shuttle program is only now beginning to close the outstanding technical issues that must be solved to return to flight safely, and that allow for cost uncertainties to be resolved.

Page 11: "In addition, our review of the documents indicated and NASA confirmed that quite a few of the estimates were based on undefinitized contract actions (UCAs) – that is, unnegotiated contract changes . . . As we have stated in our high-risk series, relying on unnegotiated changes is risky because it increases the potential for unanticipated cost growth."

NASA Response: The use of UCAs to advance RTF activity is both reasonable and necessary. As previously stated, the technical solutions to RTF recommendations put forth by the Columbia Accident and Investigation Board (CAIB) have evolved over time. NASA is breaking new ground with changes to the Shuttle's external tank, thermal protection system, debris prevention and monitoring, and on-orbit inspection and repair techniques. In some cases, multiple paths have been chosen to ensure that at least one solution would be successful in achieving a safe return to flight. To facilitate the work, much of which is outside the scope of existing contracts, UCAs have been employed to avoid the months of delay that would result if NASA were to wait until its contractors responded to a quote request with a firm, auditable proposal. To maintain control over content and costs, NASA has used UCAs only when necessary, and strict limits have been placed on the scope of work and on "not-to-exceed" costs. This approach has

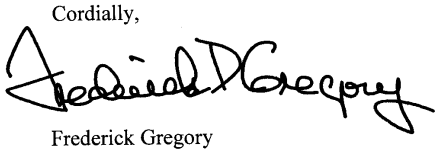
provided the Shuttle program the flexibility to pursue RTF efforts aggressively, but within reasonable and prudent controls.

Page 12: "In June 2004, NASA established additional requirements for funding requests submitted to the [Shuttle program] PRCB. Under the new policy, an independent cost estimate must be developed for requests greater than $25 million, and a program-level cost evaluation must be completed for requests over $1 million . . . NASA provided us two examples … Both examples had better support than those with PRCB directives, but documentary support was still not apparent."

NASA Response: NASA agrees that cost estimates for significant development activities should be appropriately documented. The additional requirements for independent cost estimates and internal controls established by the Shuttle program this past June, and acknowledged by the GAO audit, represent a significant step in ensuring that the appropriate level of documentation is developed as RTF technical solutions are determined, and made available for future examination.

In summary, NASA believes that the support for the cost estimates provided for both the reinstatement of a Shuttle-based Hubble Servicing Mission and the implementation of the CAIB recommendations are accurate given the maturity of the design solutions for each these activities.

Cordially,



Frederick Gregory
Deputy Administrator

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Allen Li (202) 512-4841

Acknowledgments

Staff making key contributions to this report were Jerry Herley, Erin Schoening, Karen Sloan, and Jonathan Watkins.

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