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Report to the Committee on Science, House of Representatives

May 2004

NASA

Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management

GAO-04-642

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Highlights

Highlights of GAO-04-642, a report to the Committee on Science, House of Representatives

May 2004

NASA

Lack of Disciplined Cost-Estimating Processes Hinders Effective Program Management

Why GAO Did This Study

For more than a decade, GAO has identified the National Aeronautics and Space Administration's (NASA) contract management as a high-risk area—in part because of NASA's inability to collect, maintain, and report the full cost of its programs and projects. Lacking this information, NASA has been challenged to manage its programs and control program costs. The scientific and technical expectations inherent in NASA's mission create even greater challenges—especially if meeting those expectations requires NASA to reallocate funding from existing programs to support proposed new efforts.

Because cost growth has been a persistent problem in a number of NASA programs, GAO was asked to examine NASA's cost estimating for selected programs, assess NASA's cost-estimating processes and methodologies, and describe any barriers to improving NASA's cost-estimating processes. To conduct GAO's work, GAO analyzed a total of 27 NASA programs—10 of which GAO reviewed in detail.

What GAO Recommends

GAO is recommending that NASA take a number of actions to better ensure that the agency's planned and recently implemented initiatives to improve its cost-estimating practices will result in sound cost estimates and thereby enable NASA to control its programs better.

www.gao.gov/cgi-bin/getrpt?GAO-04-642.

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

Considerable change in NASA's program cost estimates—both increases and decreases—indicates that NASA lacks a clear understanding of how much its programs will cost and how long they will take to achieve their objectives. For example, the development cost estimates for more than half of the 27 programs that GAO reviewed have increased and for some programs this increase was significant—as much as 94 percent. Cost estimates changed for each of 10 programs that GAO reviewed in detail. For 8 of the 10 programs, the estimates increased. Although NASA cited specific reasons for the changes, such as technical problems and funding shortages, the variability in the cost estimates indicates that the programs lacked the sufficient knowledge needed to establish priorities, quantify risks, and make informed investment decisions, and thus predict costs.

Most notably, NASA's basic cost-estimating processes—an important tool for managing programs—lack the discipline needed to ensure that program estimates are reasonable. Specifically, GAO found that none of the 10 NASA programs that GAO reviewed in detail met all of GAO's cost-estimating criteria, which are based on criteria developed by Carnegie Mellon University's Software Engineering Institute. Moreover, none of the 10 programs fully met certain key criteria—including clearly defining the program's life cycle to establish program commitment and manage program costs, as required by NASA. In addition, only three programs provided a breakdown of the work to be performed. Without this knowledge, the programs' estimated costs 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. Finally, only two programs have a process in place for measuring cost and performance to identify risks.

NASA has limited ability to collect the program cost and schedule data needed to meet basic cost-estimating criteria. For example, as GAO has previously reported, NASA does not have a system to capture reliable financial and performance data—key to using effectively the cost-estimating tools that NASA officials state that programs employ. Further, without adequate financial and nonfinancial data, programs cannot easily track an acquisition's progress and assess whether the program can meet its cost and schedule goals before it incurs significant cost and schedule overruns. NASA identified other barriers, including limited cost-estimating staff. According to NASA officials, several initiatives are under way to remove such obstacles and improve the agency's cost-estimating practices.

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Abbreviations

AHMS Phase 1	Advanced Health Management System Phase I
ATP	Alternate Turbopump Program
CAIV	cost as an independent variable
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CARD	cost analysis requirements description
CAU	Cockpit Avionics Upgrade
CLCS	Checkout and Launch Control System
CPR	cost performance report
CRV	Crew Return Vehicle
DOD	Department of Defense
EOS	Earth Observing System
EVM	earned value management
FCF	Fluids and Combustion Facility
GP-B	Gravity Probe B
IFMP	Integrated Financial Management Program
INTEGRAL	International Gamma-Ray Astrophysics Laboratory
IPAO	Independent Program Assessment Office
MERs	Mars Exploration Rovers
MESSENGER	Mercury Surface, Space Environment, Geochemistry, and Ranging
NASA	National Aeronautics and Space Administration
NMP-EO-1	New Millennium Program Earth Observing-1
OMB	Office of Management and Budget
PMA	President's Management Agenda
SEER	System Evaluation and Estimation of Resources
SEI	Software Engineering Institute
SIRTF	Space Infrared Telescope Facility
SOFIA	Stratospheric Observatory for Infrared Astronomy
STEREO	Solar Terrestrial Relations Observatory
TDRS	Tracking and Data Relay Satellite Replenishment
TIMED	Thermosphere, Ionosphere, Mesosphere Energetics, and Dynamics
WBS	work breakdown structure

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Accountability * Integrity * Reliability

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

May 28, 2004

The Honorable Sherwood L. Boehlert
Chairman
The Honorable Bart Gordon
Ranking Minority Member
Committee on Science
House of Representatives

The lack of reliable financial and performance information has posed significant challenges to the National Aeronautics and Space Administration's (NASA) ability to manage its largest and most costly programs effectively. For nearly 15 years, NASA contract management has been on GAO's high-risk list—due in part to NASA's inability to collect, maintain, and report the full cost of its programs and projects.[1] Without such information, NASA has consistently developed unrealistic cost and schedule estimates, which, at least in part, are reflected in the cost growth and schedule increases in many of its programs.

The demanding scientific and technical expectations inherent in NASA's mission create even greater challenges for the agency to control program costs—especially if meeting those expectations requires NASA to reallocate funding from existing programs to support new efforts. Because cost growth has been a persistent problem on a number of NASA programs, you asked us to (1) identify initial cost estimates in selected NASA programs and any changes in those cost estimates, (2) assess NASA's cost-estimating processes and methodologies, and (3) describe any barriers that make it difficult for NASA to improve its cost-estimating processes.

Our review focused on 27 of 68 NASA programs in the development phase as of April 2003 or that completed development in fiscal year 2001 or 2002. To assess NASA's cost-estimating processes and methodologies, we conducted a more in-depth review of 10 of the 27 programs, which generally had the highest development cost estimate within five of NASA's

[1] U.S. General Accounting Office, *Major Management Challenges and Program Risks: National Aeronautics and Space Administration*, GAO-03-114 (Washington, D.C.: Jan. 2003).

seven Enterprises.[2] Our work was conducted between February 2003 and March 2004 in accordance with generally accepted government auditing standards. For a complete description of our scope and methodology, see appendix I.

Results in Brief

Many of the NASA programs that we reviewed cost more and took longer than was proposed at the time of congressional approval.[3] Several factors continue to put NASA projects at risk of increased cost and schedule delays. Most notably, NASA lacks the basic cost-estimating processes needed to establish priorities, quantify risks, and make informed investment decisions for its programs. Further, NASA has limited ability to collect, analyze, and use program cost and schedule data to identify and mitigate impediments to program success.

Current baseline development cost estimates for the 27 programs we reviewed varied considerably from the programs' initial baseline estimates.[4] More than half of the programs' development cost estimates increased, and for some programs, this increase was significant—as much as 94 percent. In addition, the baseline development estimates for each of 10 programs that we reviewed in detail were rebaselined—some as many as four times. For 7 of the 10 programs, the new baseline development estimate was an increase over the previous baseline estimate. Although NASA cited specific reasons for the cost growth and the recalculated baselines, such as technical problems and funding shortages, the variability in the cost estimates and the rebaselinings indicate that the programs lacked sufficient knowledge needed to make informed acquisition decisions.

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[2] NASA's Enterprises, listed in the background section of this report, function as primary business areas for implementing NASA's mission. Each Enterprise has its own strategic goals, objectives, and implementation strategies.

[3] According to NASA, congressional approval occurs when the Congress appropriates design and development funds for the program.

[4] NASA defines baseline as the technical performance and content, technology application, schedule milestones, and budget (including contingency and allowance for program adjustment) that are documented in the approved program and project plans. Current baseline development cost estimates are as of April 2003.

Although an important tool for managing programs, NASA's cost-estimating processes lack the discipline needed to ensure that program estimates are reasonable. Specifically, we found that none of the 10 NASA programs that we reviewed in detail met all of the criteria that we selected to assess NASA's cost-estimating processes. Moreover, none of the 10 programs met certain key criteria—such as clearly defining the program's life cycle. NASA procedures and guidelines require programs and projects to be managed on the basis of life-cycle cost—which the agency clearly defines—and that such cost be developed to establish the program's commitment.[5] In addition, only three programs provided a complete breakdown of the work to be performed. Without knowing the full life cycle and the work to be performed, the programs' estimated costs could be understated and thereby subject to underfunding and cost overruns, thus putting programs at risk of being reduced in scope or requiring additional funding to meet their objectives. Finally, only two programs had a process in place for measuring cost and performance to identify these potential risks and take action to avoid them.

NASA faces a number of barriers in meeting the cost-estimating criteria that we used to assess the 10 programs. For example, although NASA officials noted that programs are using cost-estimating tools, NASA generally lacks the data needed to employ these tools effectively. For more than a decade, we have reported that, despite repeated efforts, NASA has failed to develop a system to capture reliable financial and performance information. Most recently, we reported that the agency's current effort to implement a modern integrated financial management system will not, as it is being implemented, routinely provide program managers and other key stakeholders and decision makers—including the Congress—with the financial information needed to measure program performance and ensure

[5] NASA defines life-cycle cost as the total of the direct, indirect, recurring, nonrecurring, and other related expenses incurred, or estimated to be incurred, in the design, development, verification, production, operation, maintenance, support, and retirement of a system over its planned life.

accountability.[6] According to NASA officials, nonfinancial data, such as data on technology readiness levels, have also been difficult for the NASA cost-estimating community to obtain. Without adequate financial and nonfinancial data, programs cannot easily track an acquisition's progress and assess whether the program can meet its cost and schedule goals before the program incurs significant cost and schedule overruns. NASA identified other barriers, including limited cost-estimating staff. According to NASA officials, there are several initiatives under way to remove such obstacles and improve the agency's cost-estimating practices.

We are recommending that NASA take a number of actions to better ensure that the agency's initiatives result in sound cost-estimating practices and are integrated into the project approval process. Specifically, we are recommending that NASA develop an integrated plan that includes specific actions that ensure that guidance is established on rebaselining and that programs have a well-defined process in place to measure cost and performance and identify potential risks. We are also recommending that NASA establish a framework for developing life-cycle cost estimates.

In its comments on a draft of this report, NASA stated that it concurred with our recommendations. NASA believes that it has already made progress toward achieving many of the improvements intended by the recommendations by developing new guidance, implementing management controls, and instituting additional levels of project oversight. These reforms to NASA's project development and implementation processes are, in our view, positive steps in addressing some of the problems discussed in our report. However, planned improvements must be integrated and enforced on an agency wide basis; our recommendations are in line with that thrust. NASA's detailed comments are included as appendix V.

[6] U.S. General Accounting Office, *Business Modernization: NASA's Challenges in Managing Its Integrated Financial Management Program*, GAO-04-255 (Washington, D.C.: Nov. 21, 2003); *Business Modernization: Disciplined Processes Needed to Better Manage NASA's Integrated Financial Management Program*, GAO-04-118 (Washington, D.C.: Nov. 21, 2003); *Business Modernization: NASA's Integrated Financial Management Program Does Not Fully Address Agency's External Reporting Issues*, GAO-04-151 (Washington, D.C.: Nov. 21, 2003); and *Information Technology: Architecture Needed to Guide NASA's Financial Management Modernization*, GAO-04-43 (Washington, D.C.: Nov. 21, 2003).

Background

NASA's programs encompass a broad range of complex and technical activities—from investigating the composition and resources of Mars to providing satellite and aircraft observations of Earth for scientific and weather forecasting. NASA currently funds more than 100 programs and projects in various phases of execution in 7 strategic Enterprises: Space Science, Earth Science, Biological and Physical Research, Aeronautics, Space Flight, Education, and Exploration Systems. Two NASA offices have key responsibilities in ensuring the effective execution of these programs: the Office of the Chief Financial Officer, which is responsible for providing oversight and financial management of agency resources and establishing related policy guidance, and the Office of Chief Engineer, which is responsible for ensuring development efforts and mission operations are planned and conducted using sound engineering practices.

More than two-thirds of NASA's work force is made up of contractors and grantees, and 90 percent—or roughly $13 billion—of NASA's annual budget is spent on work performed by its contractors. Since 1990, we have identified NASA's contract management as a high-risk area. This assessment has been based in part on our repeated finding that NASA does not have good cost-estimating processes or the financial information needed to develop good cost estimates for its programs, making it difficult for NASA to oversee its contracts and control costs. For example, in July 2002, we reported that an independent task force convened to assess the management of the International Space Station concluded that the program's fiscal year 2002 through fiscal 2006 budget was not credible because of weaknesses in its cost-estimating processes.[7] The task force pointed out that these problems occurred because NASA had not instituted or had ignored many of the program's control and contract oversight procedures—such as preparing a full life-cycle cost estimate—that should have alerted the agency to the growing cost problem and the need for mitigating actions. According to the cost analysis team that supported the task force, NASA's focus on staying within annual budgets instead of managing total program costs was perhaps the single greatest factor in the program's cost growth.

NASA's unreliable cost estimates have significant implications for potential future endeavors, such as those outlined by the President in January of this

[7] U.S. General Accounting Office, *Space Station: Actions Under Way to Manage Cost, but Significant Challenges Remain*, GAO-02-735 (Washington, D.C.: July 17, 2002).

year. Specifically, the President called for a shift in NASA's long-term focus, envisioning that NASA will retire the shuttle program as soon as assembly of the International Space Station is completed, planned for the end of the decade; develop a new crew exploration vehicle as well as launch human missions to the moon between 2015 and 2020, and build a permanent lunar base as a stepping stone for more ambitious missions. To achieve these goals, the President proposed spending $12 billion over the next 5 years—about $1 billion of which would come from an increase in NASA's budget, currently $15.4 billion—with the remaining $11 billion being reallocated from existing NASA programs.

Developing reliable cost estimates has been difficult for agencies across the federal government. The need for reliable cost estimates is at the heart of two of the five-governmentwide initiatives in the 2002 President's Management Agenda (PMA); the two are "improved financial performance" and "budget and performance integration."[8] These initiatives are aimed at ensuring that federal financial systems produce accurate and timely information to support operating, budget, and policy decisions and that budgets are performance-based. As part of these initiatives, the President calls for changes to the budget process to better measure the real cost and performance of programs. According to the PMA, accomplishing all of the crosscutting initiatives will matter little without the integration of agency budgets with performance.

Development Cost Estimates Frequently Changed

As of April 2003, the baseline development cost estimates for the programs we reviewed varied considerably from the programs' initial baseline estimates. More than half of the programs' development cost estimates increased, and for some programs, this increase was significant. The baseline development cost estimates for each of the 10 programs we reviewed in detail were rebaselined—that is, recalculated to reflect new costs, time frames, or resources associated with program changes in program objectives, deliverables, or scope and plans. Although NASA provided specific reasons for the increased cost estimates and rebaselinings—such as delays in the development or delivery of key system components and funding shortages—it does not have guidance for determining when rebaselinings are justified. Such criteria are important to instilling discipline in the cost-estimating process.

[8] The other three initiatives are strategic human capital management, competitive sourcing, and expanded electronic government.

Most of the 27 programs we reviewed experienced a change in their development costs estimates. While 8 of the 27 programs experienced slight decreases in their development cost estimates, 17 experienced cost growth—as much as almost 94 percent. The remaining two programs had no change. Ten of the 17 programs' cost growth was greater than 25 percent. Table 1 shows the development cost estimate changes from the initial baseline to the baseline as of April 2003 and the life-cycle cost estimate for each of the 27 programs. The 10 programs that we reviewed in detail are shaded and italicized. (See app. II for assessments of the 10 programs and app. III for descriptions of the remaining 17 programs.)

Table 1: Initial and Current Baseline Development Cost Estimates and Life-Cycle Cost Estimates for 27 NASA Programs

Then-year dollars in millions

	Baseline development cost estimate			
Program, by Enterprise	**Initial**	**Current (as of April 2003)[a]**	**Percent change**	**Life-cycle cost estimate (as of April 2003)[a]**
Space Science				
Space Infrared Telescope Facility (SIRTF)[b]	*$472.0*	*$610.5*	*29.3*	*$1,170.6*
2003 Mars Exploration Rovers (MERs)	*657.2*	*767.0*	*16.7*	*806.3*
Gravity Probe B (GP-B)	*529.6*	*709.3*	*33.9*	*734.9*
Strastospheric Observatory for Infrared Astronomy (SOFIA)	234.8	373.0	58.9	604.5
Solar Terrestrial Relations Observatory (STEREO)	404.7	302.1	(25.4)	423.0
Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER)	325	235.1	(27.7)	337.7
Herschel	103.7	72.7	(29.9)	277.6
Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)	176.8	176.2	(0)	253.5
Solar-B	99.3	80.4	(19.0)	146.4
Rosetta	28.4	40.1	41.2	106.0
International Gamma-Ray Astrophysics Laboratory (INTEGRAL)	8.2	11.9	45.1	51.2
Earth Science				
Terra	1,309.1	1,393.2	6.4	1,451.7
Aqua	*1,005.5*	*952.4*	*(5.3)*	*1,050.6*
Aura	*762.5*	*764.6*	*0.3*	*788.5*
Landsat-7	*445.8*	*508.8*	*14.1*	*508.8*

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Then-year dollars in millions

Program, by Enterprise	Baseline development cost estimate: Initial	Current (as of April 2003)[a]	Percent change	Life-cycle cost estimate (as of April 2003)[a]
New Millennium Program Earth Observing-1 (NMP-EO-1)	$111.7	$176.4	57.9	$192.5
SeaWinds	130.2	148.8	14.3	160.1
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)	98.0	133.9	36.6	150.9
Jason-1	77.5	87.8	13.3	127.8
Biological and Physical Research				
Fluids and Combustion Facility (FCF)	*118.9*	*114.1*	*(4.0)*	*132.0*
Aeronautics				
Hyper-X (X-43A)	*167.0*	*227.0*	*35.9*	[c]
Space Flight				
Alternate Turbopump Program (ATP)	1,056.0	764.0	(27.7)	982.0
Cockpit Avionics Upgrade (CAU)	*442.0*	*454.0*	*2.7*	*514.0*
Advanced Health Management System Phase I (AHMS Phase 1)	55.0	55.0	(0)	55.0
Tracking and Data Relay Satellite Replenishment (TDRS)	937.0	518.1	(44.7)	[d]
X-38 Crew Return Vehicle (CRV)	792.0	1,025.0	29.4	[e]
Checkout and Launch Control System (CLCS)	*206.0*	*399.0*	*93.7*	[f]

Source: NASA.

Note: The draft *NASA Cost Estimating Handbook 2002* defines then-year dollars as dollars that are escalated into the time period of performance of a contract. It further states that then-year dollars are sometimes referred to as escalated costs, inflated costs, or real-year dollars. NASA normally uses the term—real-year dollars.

[a]Includes launch vehicle cost where applicable.

[b]SIRTF was renamed the Spitzer Space Telescope in December 2003.

[c]Because Hyper-X is classified as a test program, there is no life-cycle cost estimate.

[d]A life-cycle cost estimate was not developed for the Tracking and Data Relay Satellite Replenishment program because it is currently in pre-phase A (conceptual definition). According to a NASA official, a life-cycle cost estimate will be determined before it enters phase C/D (design, development, test, and evaluation).

[e]A life-cycle cost estimate was not developed for the X-38 Crew Return Vehicle program because the program was cancelled in 2003, and the program's contracts remained undefinitized at termination—that is, the final price or estimated cost and fee were not negotiated and mutually agreed to by NASA and the contractor.

[f]A life-cycle cost estimate was not developed for the CLCS program because it was canceled due to excessive cost growth.

The development cost estimates for each of the 10 programs that we reviewed in detail have been rebaselined—for some programs, as many as four times—and for 7 of the 10 programs, the cost estimate increased each time it was rebaselined (see fig. 1).

Figure 1: History of Rebaselinings of 10 Programs' Development Cost Estimates

Then-year dollars in millions

Program	Baseline in millions	FY 2000 by quarter (1 2 3 4)	FY 2001 by quarter (1 2 3 4)	FY 2002 by quarter (1 2 3 4)	FY 2003 by quarter (1 2 3 4)
SIRTF[a]	$472			July $534	Jan $638; Apr $669; Aug $712
MERs	$657		Oct $697	Mar $729	Apr $767
GP-B	$530	May $615	Apr $631	May $667	Feb $709
Aqua	$1,006[b]				
Aura	$763[b]				
Landsat-7	$446[c]				
FCF	$119				Apr $114
Hyper-X	$167		Jan $183	Jan $217; Sept $227	
CAU	$442			Oct $454	
CLCS	$206	Nov $399[d]			

Source: NASA.

[a]SIRTF was renamed the Spitzer Space Telescope in December 2003.

[b]The baseline development estimates for the Aura and Aqua projects were rebaselined once as a result of a restructuring of the overall Earth Observing System (EOS) program in 1995 to address affordability issues. Before EOS' restructuring, the baseline was $524 million for Aura and $1.2 billion for Aqua. However, according to NASA officials, both the Congress and NASA recognize the revised baseline estimates as the initial baseline estimates.

[c]Landsat-7's initial baseline development estimate was established by the Department of Defense (DOD), which originally had responsibility for managing the program. A 1994 Presidential Directive later reassigned the program to a joint NASA, National Oceanic and Atmospheric Administration, and U.S. Geological Survey program, with NASA having responsibility for the development and launch of the satellite and development of the ground system. Landsat-7 also became a part of the EOS program. In 1995, NASA established a revised initial baseline development estimate for Landsat-7, which according to NASA officials is recognized by the Congress and NASA as the initial baseline development estimate. DOD's initial baseline estimate was not available.

[d]CLCS was rebaselined twice, but the second rebaselined estimate for CLCS was not established because NASA terminated the program due to the program's excessive cost growth.

For the 10 programs we reviewed in detail, NASA cited specific reasons for changes in the baseline development cost estimates and the recalculated baselines—many of which were related to technical problems and subsequent delays in the development or delivery of key system components, and insufficient funding and reserves, as illustrated in the following examples:

- Technical problems in the MERs program required a significant redesign of components and the development of a new landing system. Two of MERs' three rebaselinings were also the result of inadequate reserves. According to NASA officials, without the rebaselinings, the development cost "to go"[9] would have drained the program's reserves.

- The increase in CLCS's development cost estimate and rebaselining was the result of poorly defined requirements and design, software integration problems, and fundamental changes in the project's management structure and contractors' approach to the work. The project, which experienced an almost 94 percent increase in its baseline development cost estimate, was ultimately terminated.

- The GP-B program—which was rebaselined four times—experienced significant schedule slippages due to repeated technical problems, including failures in the probe's heat exchanger, the need for additional testing, payload electronics delays, and thermal vacuum test failures.

[9] According to a NASA project manager, "to go" means from this point forward to completion of the project, given the current status of the project and the resources available to complete it.

- Schedule slippages in the SIRTF program—which contributed to increases in the program's baseline development cost estimate and four rebaselinings of the estimate—were caused by delays in the delivery of components, flight software, and the mission operation system as well as launch delays that resulted from a handling accident involving a global positioning system payload and concerns of delamination on the launch vehicle's solid rocket motors.

- Changes in development cost estimates for the CAU program were primarily the result of the program's expanded scope, which occurred in October 2002, to produce modification kits that would allow the CAU upgrade to be installed into the orbiters.

- The Hyper-X program experienced three rebaselinings, and according to the project manager, the program will be rebaselined again in the near future. The rebaselinings were due to schedule slippages resulting from the need to fund an investigation of the problems experienced in the first Mach 7 flight vehicle—which was destroyed in flight—and related corrective actions to the second Mach 7 flight.[10]

Revised contract requirements, funding changes, or the realization that program goals are not achievable may require a formal rebaselining. However, NASA has not defined or provided guidance or restrictions on rebaselining to ensure that programs consistently and appropriately apply rebaselinings and do not adjust their baseline cost estimates whenever the estimates become unmanageable. Further, NASA lacks a process for systematically identifying and assessing programs that are not achieving their cost, schedule, and performance goals. Such a process has been employed by the Department of Defense (DOD), which also relies heavily on contractors to deliver complex, cutting-edge technologies to meet its mission. Specifically, DOD must report to the Congress programs that incur a cost growth of 15 percent or more in the program baseline. Moreover, DOD must justify the continuation of acquisition programs that incur a cost growth of 25 percent or more in the program baseline by certifying that specific criteria have been met—including that the new cost estimates are reasonable.[11] Under such a process, 5 of the 10 programs that we reviewed

[10] The second Hyper-X flight vehicle flew successfully at Mach 7 speed in March 2004 (see app. II).

[11] 10 U.S.C. 2433.

in detail would have been required to report to the Congress, and 4 of the 5 programs would have had to certify that their new cost estimates were reasonable.

Poor Estimating Processes and Methodologies Contributed to Wide Variations in Baseline Cost Estimates

NASA has yet to implement a well-defined process for estimating the cost of its programs—a weakness we and NASA's Inspector General have repeatedly reported.[12] Recognizing the need for such a process, NASA developed a cost-estimating handbook in 2002—the first such guidance provided to its cost-estimating community and program and project managers.[13] Despite this effort, the programs we reviewed failed to follow key cost-estimating processes, including developing and documenting full life-cycle cost estimates, summarizing estimates according to the current breakdown of work to be performed, conducting an uncertainty analysis, performing an independent review of contractors' cost estimates, and later using earned value management (EVM) to assess progress.[14]

[12] See, for example, GAO-04-118; GAO-04-255; GAO-03-114; U.S. General Accounting Office, *Space Station: Actions Under Way to Manage Cost, but Significant Challenges Remain*, GAO-02-735 (Washington, D.C.: July 17, 2002); *NASA Program Costs: Space Missions Require Substantially More Funding Than Initially Estimated*, GAO/NSIAD-93-97 (Washington, D.C.: Dec. 31, 1992); and NASA Office of Inspector General, *Final Management Letter on Failures in Cost Estimating and Risk Management Weaknesses in Prior Space Launch Initiative Assignment Numbers A-01-049-01and A-01-049-02*, IG-03-023 (Washington, D.C.: Sept. 29, 2003).

[13] The cost-estimating handbook is in draft form, but NASA made it available for official use by its cost-estimating community and program managers. NASA expected to complete the handbook by May 2004.

[14] EVM compares the actual work performed at certain stages of a job to its actual costs—rather than comparing budgeted and actual costs, the traditional management approach to assessing progress. By measuring the value of work that has been completed at certain stages in a job, EVM can alert program managers, contractors, and administrators of potential cost overruns and schedule delays before they occur and of problems that need correcting before they worsen. For a more detailed discussion of EVM, see appendix IV.

Reflecting Office of Management and Budget (OMB) guidance and best practices of government and industry leaders, NASA requires that full life-cycle cost estimates be prepared using full cost accounting,[15] that estimates be summarized according to the current breakdown of work to be performed, and that major changes be tracked to the life-cycle cost. In its draft cost-estimating handbook, NASA lists a number steps that are integral to preparing a reliable life-cycle cost estimate, including preparing or obtaining a cost analysis requirements description (CARD),[16] developing ground rules and assumptions, and developing cost range and risk assessments.

Carnegie Mellon University's Software Engineering Institute (SEI)[17] echoes the need for reliable cost-estimating processes in managing software implementations—identifying tasks to be estimated, mapping the estimates to the breakdown of work to be performed, and identifying and explaining assumptions are among SEI's requisites for producing reliable cost estimates. To evaluate the cost-estimating processes of the 10 NASA programs that we reviewed in detail, we selected 14 criteria based on SEI checklists (see table 2).[18] Many of these criteria are included in NASA's cost-estimating guidance.

[15] The full cost of a project is the sum of all direct costs, service costs, and general administrative costs. Full cost accounting ties all NASA agency costs (including civil service personnel costs) to major projects.

[16] A CARD provides a system technical description and programmatic information to create a common baseline used by the project team to develop estimates.

[17] SEI is a government-funded research organization that is widely considered an authority on software implementation.

[18] SEI developed checklists to help evaluate software costs and schedule. However, SEI states that these checklists are equally applicable to hardware and systems engineering projects.

Table 2: Summary of Criteria Used to Assess 10 NASA Programs Reviewed

Criterion	Purpose/Significance
The objectives of the estimate are stated in writing.	The objectives of the program must be clearly stated in a concise document for the cost estimator to use to develop the cost estimate. NASA guidance states that NASA programs and projects are to be defined as activities that have defined objectives along with goals and requirements.
The life cycle to which the estimate applies is clearly defined.	The life cycle must be clearly defined to ensure that the full cost of the program—that is, all direct and indirect costs for planning, procurement, operations and maintenance, and disposal—are captured. The draft NASA cost-estimating handbook states that a life-cycle cost estimate provides "an exhaustive accounting of all resources necessary to develop, deploy or field, operate, maintain, and dispose of a system over its lifetime." The handbook defines life cycle as the program's or project's "total life, beginning with mission feasibility and extending through operation and disposal or conclusion of the system or program."
The task has been appropriately sized.	This criteria asks if the appropriate metric was used in the development of the estimate, such as the size of a software product with expected amount of reuse.
The estimated cost and schedule are consistent with demonstrated accomplishments on other projects.	In other words, estimates have been validated by relating them back to demonstrated performance on completed projects.
A written summary of parameter values and their rationales accompany the estimate.	This criterion refers to the underlying cost-estimating methodology. If a parametric equation was used to generate the estimate, then the parameters that feed the equation must be provided along with an explanation of why they were chosen.
Assumptions have been identified and explained.	The draft NASA draft cost-estimating handbook states that assumptions are a critical step in any estimate and should be clearly prominent in all documentation for the estimate. Accurate assumptions can prevent inaccurate or misleading estimates.
A structured process such as a template or format has been used to ensure that key factors have not been overlooked.	This criterion refers to whether or not the program has established a work breakdown structure (WBS)—that is a structure that organizes, defines, and graphically displays the individual work units to be performed. NASA policy guidance calls for breaking down work into smaller units to facilitate cost- estimating and project and contract management as well as to help ensure that all relevant costs are captured. The guidance requires that a preliminary WBS be developed during the formulation phase, and that a final WBS be generated following contractor selection or approval to implement. The guidance further requires that programs describe the overall WBS structure and the content of each individual element of the WBS.
Uncertainties in parameter values have been identified and quantified.	Again this criterion refers to the underlying cost-estimating methodology. For all major cost drivers, an uncertainty analysis should be performed to assess the risk associated with the cost estimate.
If a dictated schedule has been imposed, an estimate of the normal schedule has been compared to the additional expenditures required to meet the dictated schedule.[a]	This criterion asks whether a dictated schedule was imposed on the program, that is, whether the program was forced to accelerate the schedule in order to meet requirements. If this occurred, then the impacts to the cost estimate need to be calculated and provided.
If more than one cost model or estimating approach has been used, any differences in results have been analyzed and explained.	This criterion checks to ensure that the primary methodology or cost model results are consistent with any secondary methodology (for example, cross checks) performed.

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Criterion	Purpose/Significance
Estimators independent of the performing organization concurred with the reasonableness of the parameter values and estimating methodology.	NASA policy guidance states, "when a project under a program has an estimated NASA life-cycle cost greater than $150 million, an independent life-cycle cost analysis is required during formulation in conjunction with initiating the preliminary design."
Estimates are current.	Estimates should be updated whenever changes to requirements affect cost or schedule. NASA policy guidance requires that the life-cycle cost estimate be updated prior to each budget submission.
The results of the estimate have been integrated with project planning and tracking.	NASA policy guidance requires that a life-cycle cost be developed to establish a program/project commitment, assessed at major reviews, and updated for each budget submission and should use currently available full cost initiative guidance.
Earned value reporting has been used to manage the program.	NASA policy guidance requires program and project managers to "ensure that EVM provisions and requirements are included in requests for proposals and contracts and ensure that an effective surveillance program is in place to provide assurance that EVM data are valid and that the contractor's integrated management system remains in compliance with the EVM criteria." The guidance further requires each program and project to periodically generate estimates at completion, perform cost and schedule variance analyses based upon pre-established thresholds, and prepare corrective action plans where necessary.

Sources: NASA and SEI.

[a]Does not apply to all programs.

Despite NASA requirements and OMB and SEI guidance, few of the 10 programs that we reviewed in detail met even a third of these criteria; only one met half. Further, none of the programs fully met certain key criteria. For example, none provided a complete life cycle with definitions or a complete description of the methodology used to generate the complete cost estimate, such as data sources and uncertainties. According to the draft NASA cost-estimating handbook, a reliable life-cycle cost estimate is critical to making realistic decisions about developing or producing a system and to determining the appropriate scope or size of a program. NASA guidance also calls for breaking down the work to be performed into smaller units to facilitate cost estimating and program and contract management and to help ensure relevant costs are not omitted. However, only 3 of the 10 programs provided a complete breakdown of the work to be performed. Table 3 shows for each program the applicable criteria that were met, partially met, or not met.[19] (See app. II for a program by program assessment.)

[19] If a program provided substantiating evidence for a criterion, we determined that the program "fully met" the criterion. If partial evidence was provided for a criterion, we determined the program "partially met" the criterion. If no evidence was found, then we determined that the criterion was "not met."

Table 3: Summary of Extent 10 NASA Programs Met Assessment Criteria

Criteria for cost estimating	Space science: GP-B	Space science: MERs	Space science: SIRTF	Earth science: Landsat-7	Earth science: Aqua	Earth science: Aura	Biological and physical research: FCF	Aeronautics: Hyper-X	Space flight: CLCS	Space flight: CAU
Objectives stated in writing	NM	P	P	NM	P	M	P	NM	P	M
Life cycle clearly defined	P	P	P	P	P	P	P	P	P	P
Tasks appropriately sized	NM	NM	P	P	NM	P	P	NM	P	M
Estimates based on demonstrated programs	NM	P	P	P	NM	P	P	NM	P	P
Parameter values and rationale documented	NM	NM	P	NM	NM	NM	P	NM	P	P
Assumptions identified and explained	P	P	P	NM	P	P	P	NM	M	M
Structured format captures all costs	P	M	P	P	P	P	M	P	P	M
Uncertainties identified and quantified	NM	NM	P	P	NM	NM	NM	NM	NM	P
Accelerated schedules show cost impacts	P	P	N/A	P	P	N/A	N/A	N/A	P	N/A
More than one estimating approach used	NM	NM	P	NM	NM	NM	P	NM	P	P
Independent and program estimates concur	P	M	P	P	P	P	P	P	M	M
Estimates reflect changes over time	P	M	P	P	P	M	P	P	P	M

Key: M = Met, P = Partially met, NM = Not met

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Criteria for cost estimating	Space science			Earth science			Biological and physical research	Aeronautics	Space flight	
	GP-B	MERs	SIRTF	Landsat-7	Aqua	Aura	FCF	Hyper-X	CLCS	CAU
Estimates used for program tracking	M	M	M	P	P	P	M	M	P	M
Earned value reporting used	P	P	P	P	P	P	M	P	P	M

Sources: NASA (data), SEI (criteria), GAO (analysis).

Key: M = Met, P = Partially met, NM = Not met

Failing to meet these criteria puts programs at certain risk. For example, underestimating a program's full life-cycle costs creates the risk that a program could be underfunded and subject to major cost overruns, which would ultimately result in the program being reduced in scope or additional funding being requested and appropriated to ensure the program meets its objectives. Conversely, overestimating life-cycle costs creates the risk that a program will be deemed unaffordable and would, therefore, go unfunded. Without a complete WBS, NASA programs cannot ensure that the life-cycle cost estimates have captured all relevant costs, which again can result in underfunding and cost overruns. Further, inconsistent WBS estimates across programs can create problems of double counting or, worse, underestimating costs when using historical program costs as a basis for projecting future costs on similar programs.

Despite the uncertainty inherent in estimating the cost of emerging technologies, all of the 10 programs we reviewed also failed to conduct an uncertainty analysis to assess risks associated with the cost estimates. Instead, the programs expressed their cost estimates as point values—which implies certainty—not as ranges or numbers with confidence levels.[20] Performing an uncertainty analysis, such as a Monte

[20] For example, a cost estimate of $1 million could be presented either as a range of $900,000 to $1.1 million or as $1 million with a confidence interval of 90 percent, indicating that there is a 10-percent chance that the cost will exceed the estimate.

Carlo simulation,[21] quantifies the amount of cost risk within a program. Only by quantifying the cost risk can management make informed decisions about risk mitigation strategies. Quantifying cost risks also provides a benchmark against which future progress can be measured. Without this knowledge, NASA may have little specific basis to determine adequate financial reserves, schedule margins, and technical performance margins to provide managers the flexibility needed to address programmatic, technical, cost, and schedule risks, as required by NASA policy.

Seven of the 10 programs also failed to have an independent review of contractors' cost estimates—as required by NASA. Instead, programs established their budgets based on contractor proposals—particularly problematic since many contractors could bid low in order to win the contract. To ensure contractor costs are realistic, NASA procedures and guidelines specifically require programs to ensure that independent reviews are conducted and that these reviews address project life-cycle costs, risk management plans, as well as technical issues. Without such reviews, NASA decision makers lacked the benchmarks needed to assess the reasonableness of the contractors' proposed costs, limiting NASA's ability to make sound investment decisions and accurately assess contractor performance.

Finally, only two programs used EVM—an approach used by DOD and leading companies to provide meaningful assessments of a program's progress by comparing the value of work performed to its costs, rather than the traditional management approach of comparing budgeted and actual costs, which can provide a distorted view of a program's progress. (For a detailed discussion of EVM, see app. IV.) By using the value of completed work as a basis for estimating the cost and time needed to complete the program, EVM can alert program managers to potential problems early in the program. NASA requires that EVM be used on all significant contracts—that is, research and development contracts with a total anticipated final value of $70 million or more, and production

[21] A Monte Carlo simulation randomly generates values for uncertain variables over and over to simulate a model. Without the aid of simulation, a model will only reveal a single outcome, generally the most likely or average scenario, but after hundreds or thousands of trials, one can view the statistics of the results and the certainty of any outcome.

contracts with a total anticipated final value of $300 million or more—which includes all of the 10 programs we reviewed in detail.[22] Although the program managers for all 10 programs stated that EVM was used in their projects, only two programs provided cost performance reports, indicating a true EVM process was in place. The remaining eight programs relied on NASA Form 533, which captures planned and actual obligations and expenditures—not the value of the work performed.[23] Without a true EVM process, programs cannot readily determine if a program is at risk of cost and schedule overruns until it is too late to make programmatic changes to avoid these risks.

NASA Has Begun to Address Certain Barriers to Effective Cost Estimating

There are several impediments that NASA needs to overcome to implement effective cost-estimating practices. These include the lack of reliable financial data and other performance information; lack of trained EVM staff, data analysis tools, and incentive for supporting and implementing EVM; and ineffective use of cost analysts. NASA has initiated several measures to begin addressing some of these impediments.

Utility of Cost-Estimating Tools Depends on the Reliability of NASA's Financial and Performance Data

According to NASA officials, state-of-the-art cost-estimating tools have been funded and implemented. For example, NASA officials told us that commercial-off-the-shelf models have been used to estimate hardware and software acquisition costs and quantify the level of uncertainty surrounding cost estimates. However, these cost-estimating tools are only as good as the data they rely on to develop the estimates. For more than a decade, we have reported that NASA has failed to develop a system to capture reliable financial and performance information, posing significant challenges to NASA's ability to estimate and control program costs. Over the past year alone, we issued numerous reports on NASA's Integrated Financial Management Program (IFMP)—the agency's third and most recent effort to implement a modern, integrated financial management system. Specifically, we found that IFMP—which is under the responsibility of the Program Executive Officer for IFMP—will not, as it is being implemented, routinely

[22] See *Earned Value Management*, NASA Policy Directive 9501.3A (Aug. 3, 2002) and *Earned Value Management Implementation on NASA Contracts*, NASA Procedural Requirements 9501.3 (Nov. 24, 2002).

[23] Form 533 captures financial information that is used as basis for the financial management and budget activities within projects and NASA-wide.

provide program managers and other key stakeholders and decision makers—including the Congress—with the financial related information needed to measure program performance and ensure accountability. For example, the core financial module (considered the backbone of the system) does not appropriately capture property, plant, and equipment, as well as material in its general ledger at the transaction level—which is needed to provide independent control over these assets. In addition, NASA implemented the system before it had the capability to capture the full costs of its programs and projects. According to headquarters officials, collecting nonfinancial data crucial to cost estimating—such as technology readiness levels, parts counts, and team and management experience and skill ratings—has also been difficult.

Use of EVM Has Been Undermined by a Lack of Trained Staff, Data Analysis Tools, and Incentive

According to headquarters officials, agencywide EVM implementation efforts began in 1996 and are recognized by NASA management as a key tool in monitoring and measuring cost trends in higher risk project elements—a tool that serves as an early warning of the need for cost-risk mitigation actions to maintain control of program costs. These officials stated that EVM has been applied to the International Space Station Program[24] and with varying levels of emphasis to other programs and projects at different NASA centers.[25] While all of the program managers for the 10 programs that we reviewed in detail stated that they used EVM, only 2 of the programs used a true EVM process.

NASA headquarters officials identified several challenges that have affected the agency's ability to implement EVM effectively, including a lack of staff and data analysis tools. According to officials, resource constraints have prevented the agency from staffing many project offices with appropriate personnel to fulfill all project functions. In addition, there has been little or no priority to include a trained EVM analyst, even if one were available. Headquarters officials also noted that EVM has been hampered by the lack of a practical automated software data analysis tool. Without such a tool, analyzing the contractors' EVM cost performance reports, which contain significant amounts of data, became a cumbersome undertaking that often resulted in incomplete and untimely analyses,

[24] The International Space Station Program was not a part of our review.

[25] NASA has nine centers located around the country and owns the Jet Propulsion Laboratory, which is operated by the California Institute of Technology.

providing little usefulness to inform management decisions. A lack of incentive to support EVM has further undermined its use. Some project managers whom we spoke with are skeptical about the benefits of EVM and argue that it has failed to help them manage or control program costs. According to NASA headquarters officials, during proposal and contract negotiation phases, contractors have also suggested not using EVM as a way to reduce contract costs. While EVM was included in most contracts for the 10 programs we reviewed in detail—as required by NASA policy—it was used only in two programs as a cost-estimating tool. In general, EVM has been viewed by NASA as a financial reporting tool. Consequently, there is little incentive to use EVM because the data needed to report financial activity is captured elsewhere, such as in Form 533.

Ineffective Use and Placement of Cost Analysts across the Agency's Cost Activities also Hinders NASA's Efforts to Improve Its Cost-Estimating Practices

NASA's efforts to improve its cost-estimating processes have also been undermined by ineffective use of its limited number of cost-estimating analysts. For example, headquarters officials state that as projects entered the formulation phase, they have typically relied on program control and budget specialists—not cost analysts—to provide the financial services to manage projects. Yet budget specialists are generally responsible for obligating and expending funding—not for conducting cost analyses that underlie the budget or ensuring budgets are based on reasonable cost estimates—and, therefore, tend to assume that the budget is realistic. While NASA officials state that its cost-estimating staff is too limited to be involved in day-to-day project execution activities, they agreed that the cost analysts could be more effectively used throughout the life cycle—particularly when projects are rebaselined and independent cost estimates of project changes must be performed.

In some cases, cost analysts are not appropriately located in the organization, which may compromise controls NASA has in place to ensure reasonable cost estimates. For example, some cost analysts at NASA's centers are located with senior systems engineers in systems management organizations, while others are not. According to NASA officials, housing the cost analysts with senior systems engineers has two key benefits. First, the systems engineers generally conduct systems analyses to help ensure that a program's requirements are properly established and that the design and validity meet the requirements. Such analyses can greatly inform the development of reasonable cost estimates. Second, the systems engineering offices afford some measures of independence for cost estimating, which, according to NASA cost- estimating guidance and procedures, is important to the overall project management process.

However, NASA officials stated that several of its centers' cost analysts are in the advocacy chain of command—not housed with senior systems engineers. For example, one center's 15 cost analysts work in the center's Office of the Chief Financial Officer—which is responsible for directing the development and execution of the center's budget—not in the systems management organization, which is independent from the rest of the center. As a result, the costs analysts' estimates may not be adequately informed by the systems engineers and may lack the objectivity required to ensure that the criteria for independence have been met.

Efforts Under Way to Remove Some Barriers and Improve Cost Estimating

NASA has several initiatives under way to improve the agency's cost-estimating processes. First, NASA has established a Cost Analysis Division in the Office of the Comptroller to strategically manage analyses related to directing and funding research, improving cost-estimating processes and practices, and providing cost-estimating tools and training throughout the agency. The division also provides, along with the Independent Program Assessment Office (IPAO), the last independent cost estimate of projects before the information is released externally. These efforts are being coordinated through a steering committee composed of the managers of the cost analysis organizations from each of the centers and IPAO's deputy director.

NASA is revising the cost sections in its governing procedures and guidelines and is finalizing its cost-estimating handbook to reflect these changes.[26] These documents will require the routine use of probabilistic cost risk analysis, a CARD document, cost as an independent variable (CAIV), and EVM. The CARD supports the project life-cycle cost estimate and a congressionally required independent cost estimate. Agency officials note that while there has been some use of CARD in the agency, its first concentrated and successful use was in the 2001 to 2002 independent cost estimate for the International Space Station program. According to headquarters officials, NASA's revised guidance and finalized cost-estimating handbook will provide direction and guidance for fully implementing the use of CARDs for major development projects. Although

[26] According to NASA officials, revisions of NASA's current governing program and project guidance—*NASA Procedures and Guidelines 7120.5B, NASA Program and Project Management Processes and Requirements* (Nov. 21, 2002)—is expected to be completed by August 2004, and the draft cost-estimating handbook was expected to be finalized by May 2004.

NASA calls for CAIV to be used routinely and notes that CAIV demonstrates a commitment to evolutionary acquisition, it has yet to provide guidance on its implementation. NASA headquarters officials stated that guidance relating to improvements in the collection of cost data is also being reflected in its revised governing procedures and guidelines.

With respect to EVM, NASA headquarters officials described several efforts under way to ensure agencywide implementation of true EVM. For example, NASA recently revised its EVM policy directives to shift ownership of EVM responsibilities from NASA's Chief Financial Officer to NASA's Chief Engineer, to emphasize that EVM is to be considered a project management tool rather than a financial management tool. NASA officials also noted that the agency is working to inform managers of the performance management capabilities available to them through EVM and to emphasize the importance of providing adequate resources and management support to ensure successful EVM implementation. Agencywide goals for EVM implementation include promoting the effective use of EVM and providing needed training and education for program and project staff. These efforts and proposed initiatives should help resolve EVM utilization problems.

Finally, NASA officials told us that the agency is planning to hire additional cost analysts to alleviate understaffing at all of its center cost analysis offices. The agency envisions a total staff of about 100 cost analysts along with additional support contractors. NASA officials also stated that it is necessary to ensure centers address the problem of having cost analysts located in the advocacy chain of command, which could affect five NASA centers.

Because NASA's initiatives have only recently been implemented or are still in the drafting or planning stage, we cannot determine to what degree these efforts will enable NASA to provide reasonable and defensible cost estimates of its programs and projects.

Conclusions

There are numerous scientific and technical challenges inherent in the successful implementation of many NASA programs. Nevertheless, the need to choose among competing alternatives within limited budget resources makes it essential that the agency and the Congress clearly understand the costs and uncertainties of programs proposed for authorization and funding. Yet, NASA does not have the disciplined cost-estimating process needed to make informed acquisition decisions, nor does the agency have processes and tools for capturing, monitoring, and managing program costs and schedules within an implementation plan on a timely basis. This makes it difficult for senior NASA officials, program and project managers, and other key stakeholders to measure performance and initiate mitigation measures when needed. Taken together, the lack of disciplined and established cost-estimating processes and tools can cause program officials to restructure projects to available resources rather than develop realistic cost estimates and implementation plans for projects. As a result, programs may have to be modified to accommodate emerging technical, cost, and schedule realities. Ultimately, programs cost more, fail to meet their schedules, or deliver less than originally envisioned. To help minimize project costs increases and implementation delays identified in this report, NASA needs to instill disciplined cost-estimating processes into its project development and approval activities and to ensure such processes are integrated with its implementation of an integrated financial management system. Without a process that prevents programs from proceeding before they have sufficiently demonstrated that key cost-estimating criteria have been met, NASA programs will continue to be at risk of cost and schedule overruns.

Recommendations for Executive Action

Improvements to NASA's cost-estimating processes will partly depend on the agency's ability to address recommendations that we made in November 2003 to help ensure NASA effectively implements a modern, integrated financial management system.[27] Notwithstanding the need to address those recommendations, to better position NASA to ensure its recent initiatives result in sound cost-estimating practices agencywide, we are making three recommendations with minimum suggested courses of action. First, we are recommending that the NASA Administrator direct the Program Executive Officer for IFMP, the Chief Financial Officer, and

[27] GAO-04-118, GAO-04-151, and GAO-04-43.

the Chief Engineer to develop an integrated plan for improving cost estimating that, at a minimum, includes specific actions for ensuring that

- guidance is established on rebaselining and that rebaselining is consistently applied to provide accountability among programs,
- true earned value management is used as an organizational management tool to bring cost to the forefront in NASA's management decision-making process,
- acquisition and earned value management policies and procedures are enforced, and
- staff and support for cost-estimating and earned value analyses are effectively used.

In addition, we recommend that the NASA Administrator direct the Chief Financial Officer to establish a standard framework for developing life-cycle cost estimates. At a minimum the framework should require each program or project to

- base its cost estimates on a full life cycle for the program—including all direct and indirect costs for operations and maintenance and disposal as well as planning and procurement—and on a work breakdown structure that encompass both in-house and contractor efforts,
- prepare a cost analysis requirements description,
- prepare an independent government estimate at each milestone of the program, and
- conduct a cost risk assessment that identifies the level of uncertainty inherent in the estimate.

Further, we recommend that the NASA Administrator develop procedures that would prohibit proposed projects from proceeding through the review and approval process when they do not address the elements of the recommended cost-estimating practices.

Agency Comments and Our Evaluation

In written comments on a draft of this report, NASA's Deputy Administrator stated that the agency concurs with the recommendations, adding that the recommendations validate and reinforce the importance of activities underway at NASA to improve cost estimating and program management.

Notwithstanding agreement with our recommendations, the Deputy Administrator believes NASA has made substantive changes and achieved significant improvements in its cost-estimating processes. For example, NASA's comments on a draft of this report cite a 1992 GAO report (GAO/NSIAD-93-97) that found a median 77 percent increase in NASA program costs. According to the Deputy Administrator, this contrasts with a 13 percent cost growth in this present study. While there may be improvements in the percent of cost growth of some projects, such declines in cost growth are often achieved by rescoping and rebaselining projects to remain within available resources, as was demonstrated in a number of projects discussed in this report. We do not believe other examples cited by the Deputy Administrator, namely termination of the Checkout and Launch Control System and cost control measures imposed on the International Space Station, demonstrate that NASA has made substantive changes and achieved significant improvements in its cost-estimating processes. Rather, we believe these examples demonstrate what happens when projects are undertaken without a full understanding of the potential costs and management challenges inherent in many of the programs NASA proposes and then implemented without adequate financial management systems in place.

With regard to our recommendation to develop guidelines for rebaselining and ensure effective use of earned value management, the Deputy Administrator cited the development of revised direction on program and project management and a refocus on risk and cost-risk analysis. NASA also now requires the establishment of cost thresholds that, if exceeded, will require a rebaselining review. Further, because much of NASA's work is performed through grants and contracts, NASA's revised procedures will emphasize how risk and technical complexity affect contractor performance. New earned value management and acquisition policies and procedures will be implemented through program management councils that will review and approve programs and projects regularly through each step of their development. Also, a new Cost Analysis Division has been established, and cost-estimating staff has been added to it and NASA's Independent Program Assessment Office. NASA also noted the importance of training needed to match the new requirements.

NASA's Deputy Administrator also concurred with our recommendation to establish a standard framework for developing life-cycle cost estimates. According to the Deputy Administrator, NASA's new processes and procedural requirements document will define the full life-cycle cost to include development, operations, maintenance, disposal, and all NASA in-house direct and indirect costs to eliminate ambiguity and ensure consistency. NASA's revised cost-estimating handbook will provide further guidance for life-cycle cost estimates. Also, project managers will be responsible for developing and maintaining a cost analysis requirements document similar to a tool DOD uses that will include the equivalent of a project and technical description; key performance parameters, including documentation of actual work breakdown structure cost elements; and initial and annual updates of the life-cycle cost estimates. NASA guidance will also require periodic independent cost estimates on major programs and approval by the respective program management council to enter into implementation after an independent estimate has been completed.

Lastly, NASA's Deputy Administrator concurred with our recommendation to prohibit proposed projects from proceeding through the review and approval process when they do not address the elements of the recommended cost-estimating practices. Accordingly, NASA's forthcoming procedural requirements will define the authority of the program management councils that will, according to NASA, enforce the requirements, including the required information, documentation, and management methods needed for proceeding through the review and approval process. The Deputy Administrator also noted the availability of recent management information system improvements that enhance visibility over project and program performance. In his general comments, the Deputy Administrator also stated that NASA had recently taken steps to address issues raised in the draft report and suggested a report title that would better reflect that progress.

We agree that NASA has initiated number of reforms to its project development and implementation processes that, if properly implemented, would be positive steps to addressing many of the problems noted in this report. However, we also note that some of these problems have been long-standing in the projects discussed in this report and in a number of other projects we and NASA's Office of Inspector General have reviewed. Furthermore, planned improvements in the past have fallen short of agencywide implementation. For example, poor or inadequate cost estimates and management oversight have been central to the problems that plagued several programs, including those intended to develop new space transportation and the International Space Station programs. A reliable financial management structure is central to the success of many measures noted by the Deputy Administrator in his reply. We recently reported and testified on the impediments that exist in achieving such a capability. Finally, we note that contract management has been a long-standing problem at NASA. In 1990, we identified NASA's contract management function as an area at high risk. During that time, there was little emphasis on end results, product performance, and cost control. NASA found itself procuring expensive hardware that did not work properly. This report shows that these types of problems still exist. Regarding the Deputy Administrator's suggestion that we revise the title of our report to reflect recent progress that NASA has made towards addressing issues that we raise, we believe NASA's improvements have been properly reflected in our report's title. We considered the concerns expressed in the Deputy Administrator's comments, and consistent with our stated position that NASA's improvements are positive steps but that its problems still persist, we revised the title accordingly.

Finally, until NASA's integrated financial management system, which is central to providing effective management and oversight, is fully implemented, performance assessments relying on cost data may be incomplete and full costing will be only partially achieved. And until these problems are resolved and the measures the Deputy Administrator noted in commenting on a draft of this report are fully implemented and integrated into the way the agency does business, NASA's contract management function will continue to be an area of concern.

As agreed with your office, 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.

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

Allen Li
Director
Acquisition and Sourcing Management

Scope and Methodology

To determine cost estimates in selected NASA programs and any changes in those estimates, we asked NASA to provide a list of programs that were currently in the development phase, and programs that had completed development or were launched in fiscal year 2001or 2002. We also asked NASA to provide the initial baseline development cost estimate and current cost estimate for the development phase and life of the program, and the reasons for changes to initial development cost estimates. NASA identified 68 programs that were currently in development or had completed development in fiscal years 2001 and 2002. These included planetary missions and Earth observatory, aeronautical technology, and space flight systems. From that universe, we selected at least one program (10 in total) from 5 of NASA's 7 Enterprises. This involved 6 of 9 NASA centers (and the Jet Propulsion Laboratory) with lead responsibility for one or more of these programs. Our selection was generally based on programs with the highest current development cost estimates within an Enterprise. We compared the initial development cost estimates NASA provided to the current development cost estimates for the programs. The initial development estimates generally reflect the projected costs at the time a new program was first approved by the Congress. The current development and life-cycle cost estimates reflect the latest estimates provided by NASA as of April 2003. We also interviewed program officials to obtain additional information related to NASA's revisions to initially established baseline development cost estimates, including the rationale for changes to the cost estimates.

We also analyzed the initial and current development cost estimates for 17 additional NASA programs, later added to the scope of our review, to ascertain the level of cost growth or decline as those programs progressed through the development phase.

To assess NASA's cost-estimating processes and methodologies, we used cost-estimating criteria developed by Carnegie Mellon University's Software Engineering Institute (SEI) designed to assess the reliability of project cost and schedule estimates. SEI is a government-funded research organization that is widely considered an authority on software implementation. SEI developed checklists with these criteria to help evaluate software costs and schedule; however, SEI states that these checklists are equally applicable to hardware and systems engineering projects. We first analyzed NASA's cost-estimating procedures and guidelines to determine if they incorporated key components of good cost-estimating practices advocated by SEI and other experts.

Based on that analysis, we selected 14 criteria from two SEI reports[1] to use in assessing NASA's cost-estimating practices for the 10 programs we selected to review in detail. Our selection of the 14 criteria from the SEI reports was based, in part, on their commonality with NASA cost-estimating procedures and guidelines. Finally, using the cost-estimating documentation provided by NASA for the 10 programs, we determined the extent to which the programs met the 14 criteria. If a program provided substantiating evidence for a criterion, we determined that the program "fully met" the criterion. If partial evidence was provided for a criterion, we determined the program "partially met" the criterion. If no evidence was found, then we determined that the criterion was "not met." Table 2 describes each of the 14 criteria and the significance of each criterion.

To identify any barriers that make it difficult to improve any weaknesses in NASA's cost-estimating processes, we reviewed our recent work on NASA's efforts to implement a modern integrated financial management system. We also provided questions to NASA headquarters that asked for information regarding NASA's ability to use its cost estimates as a management tool for its programs. We also provided questions related to the SEI criteria, and NASA's responses to these questions provided further insight into the agency's cost-estimating management process at the organizational level. In addition, we interviewed officials in NASA headquarters' Office of the Chief Financial Officer and Office of the Chief Engineer, and the center project managers for the 10 programs and other appropriate personnel to obtain further perspective on this issue.

To accomplish our work, we visited NASA headquarters, Washington, D.C., and Goddard Space Flight Center, Maryland. We also contacted officials at Marshall Space Flight Center, Alabama; Jet Propulsion Laboratory, California; Kennedy Space Center, Florida; Glenn Research Center, Ohio; Johnson Space Center, Texas; and Langley Research Center, Virginia.

We conducted our work from February 2003 to March 2004 in accordance with generally accepted government auditing standards.

[1] Software Engineering Institute, *A Manager's Checklist for Validating Software Cost and Schedule Estimates*, CMU/SEI-95-SR-004 (Pittsburgh, Penn.: Jan. 1995) and Software Engineering Institute, C*hecklists and Criteria for Evaluating the Cost and Schedule Estimating Capabilities of Software Organizations*, CMU/SEI-95-SR-005 (Pittsburgh, Penn.: 1995).

Assessments of 10 Programs Reviewed in Detail

This appendix provides a program by program assessment of the 10 NASA programs we reviewed in detail. Each assessment provides

- a brief description of the program's mission;
- the status of the program—that is, whether it is in development, operational, or terminated;
- the year the program was initiated;[1]
- the fiscal year in which the Congress approved the program—that is, when full-scale design and development funds were appropriated;
- a comparison of the initial and current (as of April 2003) baseline development estimates; and
- an assessment of the program's cost-estimating processes, methodologies, and practices to determine the extent they met the 14 cost-estimating criteria that we used to measure program performance. (Table 4 shows for each criterion the number of programs that met, partially met, or did not meet the criterion.)

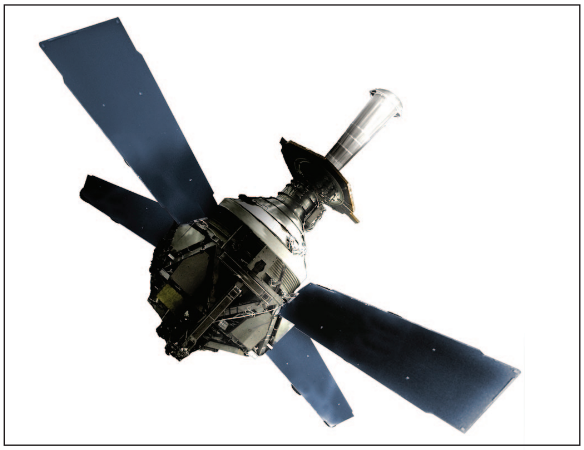
[1] We use the date the program was initiated to refer to the beginning of the formulation subprocess—the phase of a NASA program that establishes an affordable project concept and plan to meet mission objectives or technology goals.

Table 4: Summary of the Number of Programs That Met, Partially Met, or Did Not Meet Criterion

Criterion	Number of programs that met criterion		
	Met	Partially met	Not met
The objectives of the estimate are stated in writing.	2	5	3
The life cycle to which the estimate applies is clearly defined.	0	10	0
The task has been appropriately sized.	1	5	4
The estimated cost and schedule are consistent with demonstrated accomplishments on other projects.	0	7	3
A written summary of parameter values and their rationales accompany the estimate.	0	4	6
Assumptions have been identified and explained.	2	6	2
A structured process such as a template or format has been used to ensure that key factors have not been overlooked.	3	7	0
Uncertainties in parameter values have been identified and quantified.	0	3	7
If a dictated schedule has been imposed, an estimate of the normal schedule has been compared to the additional expenditures required to meet the dictated schedule.	[a]	[a]	[a]
If more than one cost model or estimating approach has been used, any differences in results have been analyzed and explained.	0	4	6
Estimators independent of the performing organization concurred with the reasonableness of the parameter values and estimating methodology.	3	7	0
Estimates are current.	3	7	0
The results of the estimate have been integrated with project planning and tracking.	6	4	0
Earned value reporting has been used to manage the program.	2	8	0

Source: NASA (data), SEI (criteria), GAO (analysis).

[a]This criterion did not apply to 5 of the 10 programs we reviewed. For those 5 programs to which the criterion did apply, none provided evidence comparing the dictated schedule to the normal schedule.



Source: Katherine Stephenson/Stanford University/Lockheed Martin/NASA.

SPACE SCIENCE

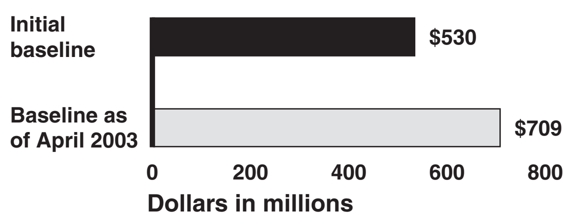
Gravity Probe B

The mission of the Gravity Probe B (GP-B) space vehicle—launched in April 2004—is to test Einstein's theory of relativity, which states that space and time are very slightly distorted by the presence of massive objects, such as Earth. Over approximately 16 months, GP-B will measure very precisely, the expected tiny changes in the direction of the spin of four gyroscopes contained in GP-B as it orbits at a 400-mile altitude directly over the poles. The gyroscopes, free from disturbance, will provide an almost perfect space-time reference system.

Program Facts

- *Status:* **Development**
- *Program initiation:* **Fiscal year 1993**
- *Program approved by Congress:* **Fiscal year 1996**
- *Comparison of initial and current baseline development estimates:* **$179.7 million or 33.9 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Estimates used as baselines for program tracking	• Estimate life cycle clearly defined • Assumptions identified and explained • Structured format used to ensure all costs are captured • Dictated schedules show cost impacts of acceleration • Independent estimates concur with program estimates • Estimates reflect changes over time • Earned value reporting used to manage program	• Estimate objectives stated in writing • Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used

Sources: NASA (data), SEI (criteria), GAO (analysis).

The GP-B program failed to provide evidence of a documented complete cost estimate, including the lack of a written objective or description of the program to be estimated. While the program assessed risk, there was no evidence of how it determined the impact the risk elements had on the cost estimates. Our other key findings related to the GP-B program are summarized as follows:

- The GP-B program failed to provide evidence of a documented complete cost estimate, including the lack of a written objective or description of the program to be estimated. While the program assessed risk, there was no evidence of how it determined the impact the risk elements had on the cost estimates. Our other key findings related to the GP-B program are summarized as follows:

- Although a partial list of assumptions was included in the GP-B cost-estimating documentation, it was not clear to us whether those assumptions pertained to the entire life- cycle cost estimate.

- A high-level cost breakdown was provided; however, descriptions for key program elements-including formulation, implementation, operations, launch vehicle, and tracking and data-were not included. A NASA official stated that a more detailed work breakdown structure existed, but this breakdown was not provided.

- The delays in the launch date-originally scheduled for 2000 and pushed out to 2003 (the actual launch was in April 2004)-causing cost overruns were documented. However, there was no explanation of how the schedule delays impacted the cost estimate.

- The GP-B program submitted independent reviews annually between 1997 and 2001 and for 2003. The 1998 independent review stated that program cost was a challenge for the program. To control costs, the 2001 independent review recommended that the program office (a) constrain the workforce, (b) replan the schedule, (c) have an independent team look again at the remaining costs, and (d) develop a contingency plan. However, none of these reviews provided details on the cost-estimating methodology.

- NASA submitted the history of programmatic changes from June 1994 to June 2004, but the associated increases in program costs were not included.

- GP-B gathers earned value type data using NASA Form 533. However, the form did not report full-earned value management data. According to a NASA official, a modified milestone-based earned value management system was used because the prime contractor resisted the implementation of a full-earned value management system.

Source: NASA.

SPACE SCIENCE

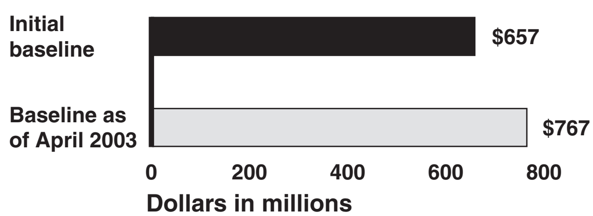
Mars Exploration Rovers

Launched in the summer of 2003, NASA's twin roving exploration robots—Spirit and Opportunity—landed on opposite sides of Mars in January 2004 in search of answers about the history of water on the red planet. Over the course of their 90-day mission, the rovers were expected to perform on-site geological investigations, searching for and characterizing a wide range of rocks and soils. The robotic geologists were equipped with mast-mounted cameras that provide 360-degree, stereoscopic, humanlike views of the terrain; robotic arms capable of human-like elbow and wrist movements; and a mechanical "fist" with a microscopic camera and rock hammer.

Program Facts

- *Status:* **Operations**
- *Program initiation:* **Fiscal year 2000**
- *Program approved by Congress:* **Fiscal year 2001**
- *Comparison of initial and current baseline development estimates:* **$109.8 million or 16.7 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Structured format used to ensure all costs are captured • Independent estimates concur with program estimates • Estimates are kept current by reflecting changes over time • Estimates used as baselines for program tracking	• Estimate objectives stated in writing • Estimate life cycle clearly defined • Estimated costs based on demonstrated programs • Assumptions identified and explained • Dictated schedules show cost impact of acceleration • Earned value reporting used to manage program	• Tasks appropriately sized • Written documentation of parameter values and rationale • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used

Sources: NASA (data), SEI (criteria), GAO (analysis).

The MERs program failed to provide evidence of a documented complete cost estimate. However, the main reason for the more than $100 million cost growth was the imposed schedule requirements. As NASA stated, there was a "less than optimal utilization of project funds…driven by the significant loss of leverage associated with design heritage from the Pathfinder mission and the extremely tight schedule which did not have any resiliency to accommodate the design changes and flight hardware delays." Our other key findings related to the MERs program are summarized as follows:

- While the MERs cost-estimating supporting documentation provided to us collectively described the program's objectives, no one document clearly and concisely described the overall objectives-key to developing a reliable life-cycle cost estimate.

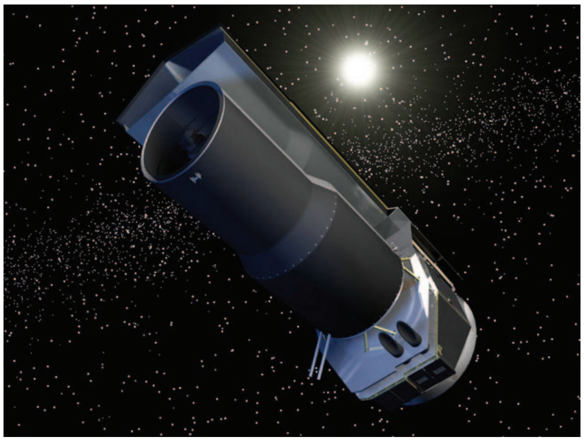
- A high-level breakout of the life-cycle phases of the estimate was provided, but descriptions of the phases were not included in the documentation.

- NASA stated that the program relied on design heritage from the Pathfinder program. This assumption ultimately led to cost and schedule overruns and rebaselinings.

- Some high-level assumptions about the cost estimate were provided. A reference to "cost guidelines" was made, but those guidelines were not provided. One document showed the cost estimate assumptions for the flight system component of the program.

- MERs was initially given a 3-year development schedule to meet the May to June 2003 launch window-determined by the relative positions of the Earth and Mars. To meet this date within the initial budget, NASA planned to leverage existing technology. However, the program soon discovered this would not be possible. With the launch date set, the program embarked on multiple concurrent development efforts to meet the schedule, leading to cost overruns.

- A NASA official stated that the MERs program did not have an integrated earned value management system. Instead, the program used NASA form 533, which does not track earned value data since there is no measure of the progress of work performed.



Source: NASA.

SPACE SCIENCE

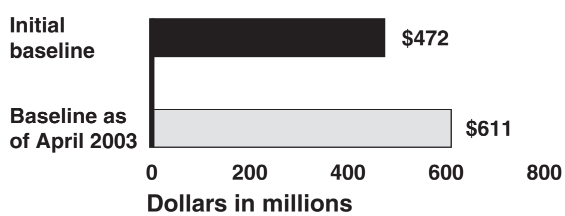
Space Infrared Telescope Facility

The Space Infrared Telescope Facility (now called Spitzer), launched in August 2003, is the fourth and final mission in NASA's Great Observatories Program—a program designed to see the universe in different kinds of light. During its planned 2½-year mission, SIRTF aims to detect infrared heat, which is mostly blocked by the Earth's atmosphere. Infrared light penetrates gas and dust clouds, allowing scientists to peer into hidden regions of space, revealing star formations, centers of galaxies, and newly forming planetary systems. Infrared light also provides information about cooler objects, such as dim stars, extrasolar planets, and giant molecular clouds.

Program Facts

- *Status:* **Operations**
- *Program initiation:* **Fiscal year 1984**
- *Program approved by Congress:* **Fiscal year 1998**
- *Comparison of initial and current baseline development estimates:* **$139 million or 29.3 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Estimates used as baselines for program tracking	• Estimate objectives stated in writing • Estimate life cycle clearly defined • Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Assumptions identified and explained • Structured format used to ensure all costs are captured • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used • Independent estimates concur with program estimates • Estimates reflect changes over time • Earned value reporting used to manage program	

Sources: NASA (data), SEI (criteria), GAO (analysis).

The SIRTF program failed to provide supporting documentation-such as sources of data, estimating approach by work breakdown structure element, and any uncertainties that may accompany the cost elements—to the evidence provided on various cost elements and high level explanations of the methodology used to estimate them. Further, the life-cycle cost estimate was underestimated because it did not account for various operations and maintenance costs once SIRTF was launched—despite the prelaunch cost growth SIRTF experienced due to technical problems such as weight growth, thermal design issues, telescope heritage problems, and aperture door risks. Our other key findings related to the SIRTF program are summarized as follows:

- NASA provided elements of a cost estimate in 1997 non-advocate briefing slides, but the objectives of the estimates were not concisely or clearly stated. And while the SIRTF program plan described the overall program objectives, it did not include the level of detail needed to generate an estimate.

- The SIRTF 1996 life-cycle cost estimate did not include key life-cycle costs, such as field support, science, mission operations, flight operations, and storage. To identify all costs associated with SIRTF's life cycle, estimates needed to include all costs that support SIRTF's planned 2½-year mission.

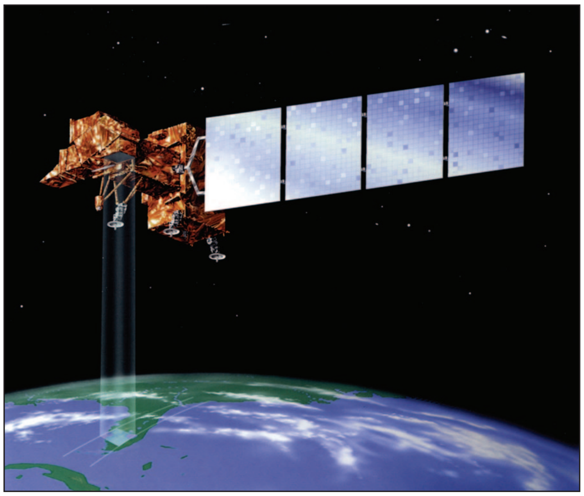
- NASA submitted an example of the parametric model inputs, but provided no parameters for software. In addition, the 1996 non-advocate review showed a high-level estimation and validation approach, but did not include detailed documentation of the sources of data, an estimating approach by work breakdown structure element, or any uncertainties that might accompany the cost elements. Finally, the 1997 nonadvocate review showed detailed estimates for SIRTF subelements, but no supportive documentation.

- The 1996 and 1997 nonadvocate reviews showed that cost probability simulations were conducted for certain SIRTF elements, but we found no evidence that this type of analysis was done for the whole estimate.

- The 1996 nonadvocate review showed that the cost basis had been validated by independent cost modeling and industry estimates. In the Fall of 2001, independent reviewers recommended adding 3 to 6 months and $32 million to $55 million to the development program. In October 2002, independent reviews suggested that an additional $73 million to $130 million would be required for operations activities.

- The development estimate changed four times over the history of the program. The primary reason for the increases was delays in the schedule. These changes were tracked in the program plan and task plan.

- Despite the evidence of monthly tracking, we do not view this as indicative of earned value analysis since there was no measure of the progress of work performed. Furthermore, there was no description of the variances' drivers. NASA stated that earned value was applied to the SIRTF program using a rudimentary Excel-based system, but submitted no reports from this system.



Source: NASA.

EARTH SCIENCE

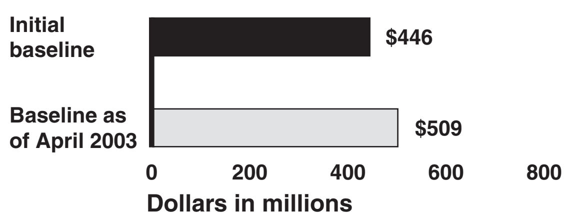
Landsat-7

Launched in April 1999, Landsat-7 is the latest in a series of earth observation satellites. Since 1972, Landsat satellites have collected continuous data on the earth's continental surfaces for land surface monitoring and global change research. Landsat-7's combination of synoptic coverage, high spatial resolution, spectral range, and radiometric calibration is unparalleled and provides digital data in greater quantities, more quickly, and at lower cost than at any previous time in Landsat's history.

Program Facts

- *Status:* **Operations**
- *Program initiation:* **Fiscal year 1992**
- *Program approved by Congress:* **Fiscal year 1995**
- *Comparison of initial and current baseline development estimates:* **$63 million or 14.1 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
	• Estimate life cycle clearly defined • Tasks appropriately sized • Estimated costs based on demonstrated programs • Structured format used to ensure all costs are captured • Parameter value uncertainties identified and quantified • Dictated schedules show cost impacts of acceleration • Independent estimates concur with program estimates • Estimates reflect changes over time • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Estimate objectives stated in writing • Written documentation of parameter values and rationale • Assumptions identified and explained • More than one cost model or estimating approach used

Sources: NASA (data), SEI (criteria), GAO (analysis).

The Landsat-7 program lacked documentation of a complete life-cycle cost estimate. Our other key findings related to the Landsat-7 program are summarized as follows:

- None of the Landsat-7 cost-estimating supporting documentation provided to us described the cost estimate for the complete life cycle (1994-2005). While we found a high-level work breakdown of costs through 2004, it is unclear if those costs included all life-cycle costs. For example, in April 2003, NASA provided us a cost estimate of $509 million for its portion of the life-cycle cost for Landsat-7. However, in a major review in 1996, a total life-cycle cost of $848 million was presented. Although the funding breakout showed the U.S. Geological Survey, National Oceanic and Atmospheric Administration, and DOD as having funding responsibility for about $400 million of the $848 million, it is unclear what the true life-cycle cost of Landsat-7 is from the documentation presented.

- Landsat-7's program plan is highly dependent on heritage from Landsat-6 for management, budget, and schedule. We find this approach questionable because Landsat 6's failures were never fully understood and NASA's last significant involvement was on Landsat-5, launched in 1984. Further, internal NASA reviewers warned in 1998 that heritage without original staff was not heritage and that 20-year old designs could not be reproduced.

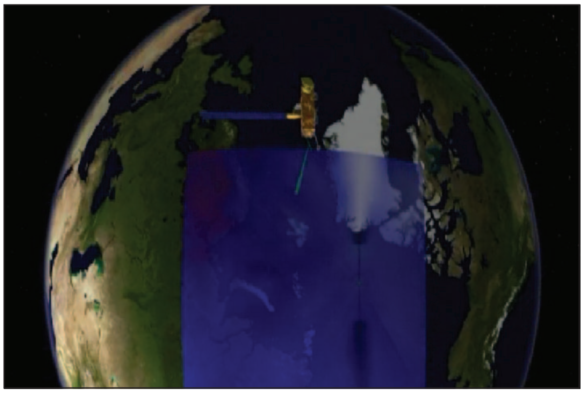
- Although Landsat-7's launch date was accelerated to May 1998—to accommodate closing of the contractor's facility at Valley Forge—no corresponding impact to the cost estimate was provided. Ultimately, a series of design and production problems, uncovered during system level testing, delayed launch and increased cost by more than $50 million.

- Two independent reviews—in March 1996 and in April 1997—found that ground system development commitments had not been met and program contingency funds were critically low. The 1997 review characterized the integration and testing schedule as optimistic and the May 1998 launch date as unrealistic. Despite these reviews, it is unclear whether the assessments concurred with the program cost estimate since we found no summary of such a comparison in the data.

- NASA submitted a time-phased estimate that compared 1997 and 1998 cost estimates and provided high-level reasons for the changes and a summary of contingency cost changes from 1995 to 1998. However, we found no documentation of the entire life-cycle cost estimate for the initial program, nor the changes that occurred over time.

- A financial status report for October 1998 to April 1999 compared planned and actual costs as well as obligations and expenditures and provided a top-level explanation of cost variances using the work breakdown structure cited in the document. While the documentation also provided causes for launch delays, we found no evidence of data that detailed the corresponding cost impact.

- According to NASA documentation, a project action was initiated in March 1995 to develop a performance measurement system. Cost and schedule variances were reported for August 1996, but due to a lack of detail, we were unable to determine whether this was truly earned value data.



Source: NASA.

EARTH SCIENCE

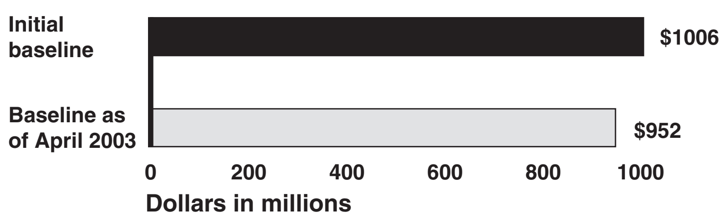
Aqua

Aqua, part of the Earth Observing System (EOS), is expected to provide a 6-year chronology of Earth and its processes. Launched in May 2002, the Aqua satellite collects information on evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea and land ice, and snow cover. Aqua also measures radiative energy fluxes; aerosols; land vegetation cover; dissolved organic matter and phytoplankton in the oceans; and air, land, and water temperatures. Measurements taken by on-board instruments will allow scientists to assess long-term climate change, identify its human and natural causes, and advance the development of models for long-term forecasting.

Program Facts

- *Status:* **Operations**
- *Program initiation:* **Fiscal year 1991**
- *Program approved by Congress:* **Fiscal year 1991**
- *Comparison of initial and current baseline development estimates:* **$53.1 million or 5.3 percent decrease**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
	• Estimate objectives stated in writing • Estimate life cycle clearly defined • Assumptions identified and explained • Structured format used to ensure all costs are captured • Dictated schedules show cost impacts of acceleration • Independent estimates concur with program estimates • Estimates reflect changes over time • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used

Sources: NASA (data), SEI (criteria), GAO (analysis).

The Aqua program lacked evidence of a well-documented life-cycle cost estimate. Delays in Aqua's launch, originally scheduled for December 2000, increased the program's cost to over $49 million, contributing to cost overruns. Our other key findings related to the Aqua program are summarized as follows:

- The President's budget submission for fiscal year 2003 indicated that the $49 million increase in the program baseline included costs for project support; imaging, sound, and sensor instruments; launch vehicle; and contingency. However, we found no evidence of operations, support, and other potential costs. Further, the President's fiscal year 2002 budget assumed project support and operations costs only for launch plus 120 days, although the program's life cycle is planned for continuance beyond 120 days. Aqua was built to gather data for six years and for full life-cycle cost estimating; the estimate should represent the lifetime of operations expected for Aqua.

- We found under the assumptions for the President's 2002 Budget Request that the costs represented project support through launch plus 120 days. Furthermore, we found that the budget estimate did not include costs for mission operations beyond the initial 120 days.

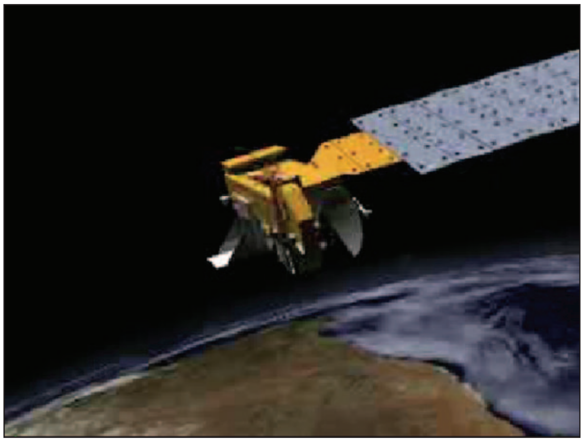
- A high-level work breakdown structure was provided, but it did not include all costs for the life cycle.

- The effect of a slip in the launch readiness date, which caused a significant delay, on the cost estimate was not provided.

- While NASA provided evidence of independent reviews of the program, the most recent one provided was in 2000, and the reviewers concluded that there would be significant budget shortfalls in fiscal years 2001 and 2002.

- Although evidence of changes to life-cycle costs estimates was provided, we found no evidence showing that the entire life-cycle cost estimate was kept current given that the estimate did not include costs for operations and support.

- We found evidence that the budget estimates were analyzed and presented to management in a June 11, 2002, monthly status review; however, this analysis was not indicative of a true earned value management approach.



Source: NASA.

EARTH SCIENCE

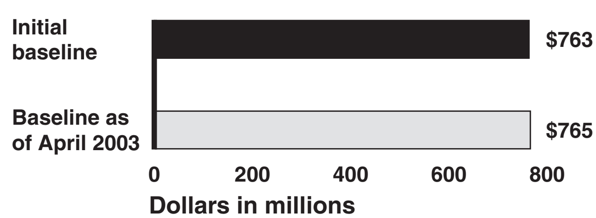
Aura

Scheduled for launch in June 2004, the Aura satellite is the third in a series of major Earth-observing satellites to study environment and climate change. The first and second missions, Terra and Aqua, were designed to study the land, oceans, and the Earth's radiation budget. Aura's mission is to study, for at least a 5-year period, the Earth's ozone, air quality, and climate, focusing exclusively on the composition, chemistry, and dynamics of the Earth's upper and lower atmospheres.

Program Facts

- *Status:* **Development**
- *Program initiation:* **Fiscal year 1991**
- *Program approved by Congress:* **Fiscal year 1994**
- *Comparison of initial and current baseline development estimates:* **$2.1 million or 0.3 percent increase**

Development Baselines



Source: GAO.

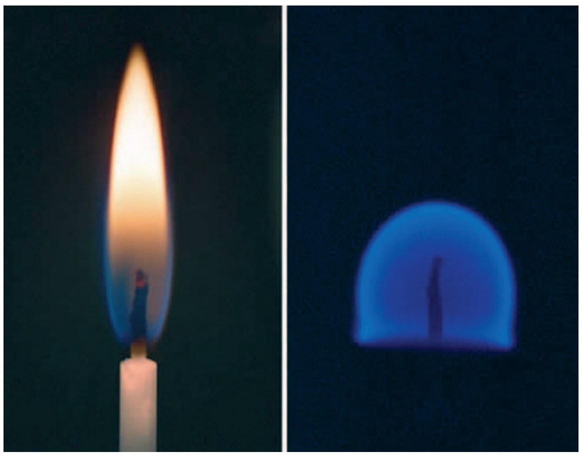
Cost-Estimating Criteria

Met	Partially met	Not met
• Estimate objectives stated in writing • Estimates reflect changes over time	• Estimate life cycle clearly defined • Tasks appropriately sized • Estimated costs based on demonstrated programs • Assumptions identified and explained • Structured format used to ensure all costs are captured • Independent estimators concur with program estimates • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Written documentation of parameter values and rationale • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used

Sources: NASA (data), SEI (criteria), GAO (analysis).

The Aura program lacked evidence of a life-cycle cost estimate with a methodology, a complete work breakdown structure, or other supporting documentation. Without such evidence, we were unable to determine if all associated program costs were included and if the cost estimate were reliable. Our other key findings related to the Aura program are summarized as follows:

- A 2002 budget document included funding for Aura development plus 90 days of support after launch, but it did not include costs for launch vehicle contingencies or funding for operations.
- Evidence of mass and wattage allocations for Aura power did not clearly show how these data were used and whether they were used to derive a cost estimate based on a cost/pound or cost/watt cost-estimating relationship.
- Expected efficiencies gained through the Aqua program's experience were not clearly documented. Aqua's experience was expected to reduce Aura's cost, schedule, and technical risks because the majority of Aura's structural drawings and spacecraft database are common with Aqua's; similar launch site and vehicle activities are also expected to provide additional efficiencies.
- Four independent reviews of cost estimates for Aura were conducted—in July 1998, October 1998, October 1999, and October 2000; however, we found no evidence of a cost-estimating methodology or reviewer concurrence with the estimates.
- While we also found some evidence that the program was using program baselines for program tracking—such as a financial status report that showed monthly trends for cumulative cost as well as obligation plans versus actual costs and obligations—the evidence was not convincing enough to demonstrate that baselines were consistently used for program tracking.
- Although NASA documented use of earned value management data for the Aura program in the third quarter of 1998, 1999, and 2000, officials stated that the program had not used such data during the past year and a half. While a March 2003 cost performance report provided earned value management data for one of Aura's four ozone instruments, evidence that the Aura program as a whole was using earned value management data on a monthly basis was not provided in the Aura documentation.



Source: NASA.

A flame in gravity (left) and in microgravity (right).

BIOLOGICAL AND PHYSICAL RESEARCH

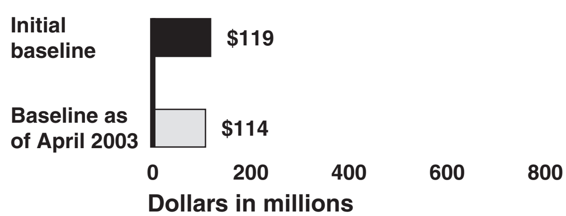
Fluids and Combustion Facility

The Fluids and Combustion Facility (FCF) is designed to be a permanent modular facility for conducting microgravity experiments on the International Space Station. Through these experiments, scientists hope to enhance their understanding of gravity's role in a wide range of physical processes, including materials science, power, propulsion, combustion, fluid physics, and plasma physics. FCF is to be composed of two racks that share mutually necessary hardware. The fluids integration rack will be used to perform investigations for microscopic imaging to particle tracking. The combustion integration rack will be used to study the process of combustion in a near weightless environment with the aim of improving fire safety and increasing fuel efficiency.

Program Facts

- *Status:* **Development**
- *Program initiation:* **Fiscal year 1987**
- *Program approved by Congress:* **Fiscal year 2001**
- *Comparison of initial and current baseline development estimates:* **$4.8 million or 4 percent decrease**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Structured format used to ensure all costs are captured • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Estimate objectives stated in writing • Estimate life cycle clearly defined • Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Assumptions identified and explained • More than one cost model or estimating approach used • Independent estimates concur with program estimates • Estimates reflect changes over time	• Parameter value uncertainties identified and quantified

Sources: NASA (data), SEI (criteria), GAO (analysis).

The FCF program lacked evidence to determine the consistency and efficiency of the program's estimating. Further, the life-cycle cost estimates did not provide a clear description of costs included, and the life cycle began in 1999—12 years after the program was initiated. Our other key findings related to the FCF program are summarized as follows:

- The February 2001 FCF independent cost estimate—an estimate-to-complete in real year dollars—clearly defined the objectives of the estimate and the ground rules and assumptions of what was and what was not contained in the estimate. Further, it took into account previous development status. However, because detailed initial and life-cycle cost estimates were not provided, we could not determine if the objectives of the initial estimates were clearly defined.
- Although the 2001 FCF independent cost estimate clearly defined the life cycle that the estimate applied to, it did not cover the program from its initiation in 1987. Instead, development costs were considered sunk costs in another NASA area. In addition, an estimate of operations support did not include an analysis or boundaries to back up the estimate. Finally, the current total life- cycle cost for the FCF program was not evident in the documents provided.
- All cost estimates for software that were provided and reviewed have been appropriately sized; however, there were no initial estimates available for FCF software to review or compare against the preliminary design review. Further, the independent cost estimate did not map to the preliminary design review to allow comparisons.
- The government estimate for FCF's prime development contract was broken down by work breakdown structure element and provided a basis of estimates for each element that showed the formula of how the cost was derived. However, supporting documentation did not show how the hours or cost of materials were estimated or explain the parameters that might have been used in the estimates.
- While an independent cost assessment was provided with a complete cost estimate stating assumptions and cost and schedule risks, no conclusions were provided. The independent assessors did not provide opinions on the reasonableness of the parameter values and estimating methodology. NASA provided a list of formal assessments the FCF program had completed, but the underlying documentation was not provided. Therefore, it was not clear to us whether or not the performing agencies of those assessments concurred with the parameter values and methodology.
- NASA provided a budget trace that showed the changes to the program estimates from the year 2000 to 2003. The budget trace provided the cost estimates from that period in the program forward. This trace explained the changes to the estimates at a top level from year to year. However, there were no details provided to show what specifically caused the changes in each of the year's estimates.

Source: NASA.

AERONAUTICS

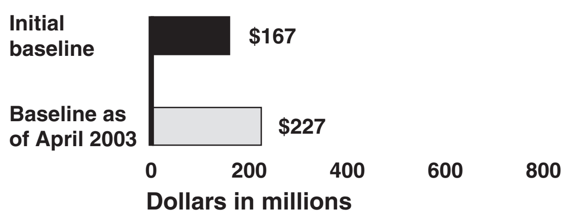
Hyper-X Program

The goal of NASA's Hyper-X program is to flight validate key propulsion and related technologies for air-breathing hypersonic aircraft. The Hyper-X (X-43A) vehicle, launched in March 2004, flew at Mach 7—greater than the cruising speed of the SR-71, the world's fastest air-breathing aircraft, which cruises slightly above Mach 3. The highest speed attained by NASA's rocket-powered X-15 was Mach 6.7, back in 1967. NASA anticipates that the technologies exposed by the Hyper-X Program will increase payload capacities and reduce costs for future air and space vehicles.

Program Facts

- *Status:* **Development**
- *Program initiation:* **Fiscal year 1996**
- *Program approved by Congress:* **Fiscal year 1998**
- *Comparison of initial and current baseline development estimates:* **$60 million or 35.9 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Estimates used as baselines for program tracking	• Estimate life cycle clearly defined • Structured format used to ensure all costs are captured • Independent estimates concur with program estimates • Estimates are kept current by reflecting changes over time • Earned value reporting used to manage program	• Estimate objectives stated in writing • Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Assumptions identified and explained • More than one cost model or estimating approach used • Parameter value uncertainties identified and quantified

Sources: NASA (data), SEI (criteria), GAO (analysis).

The Hyper-X program lacked a program plan and a detailed, activity-based work breakdown structure to manage schedule, funding, and staffing at multiple sites—which resulted in the program's consistently running over its budget and not meeting schedule requirements despite the program's high level of technical expertise needed to complete the project. Our other key findings related to the Hyper-X program are summarized as follows:

- The supporting cost-estimating documentation provided to us for the Hyper-X program included no definition of the life cycle. Information provided in those documents consisted of past costs with some projections of post-production modification and support costs. However, the costs and projections were stated at a high level and did not include an explanation of where they occurred in the life cycle.

- Although a partial cost estimate in a work breakdown structure format implied that a structure was established for the program by 1996, the structure was not explicitly provided. The contractor's financial management report for July 2002 was also provided in a work breakdown structure format, but no master structure was included in the data to decipher the extent of the effort. Further, a NASA official stated that a work breakdown structure was used for both major contracts, however, it was not used to track costs.

- A nonadvocate review and a cost validation review stated that the Hyper-X program could not meet program objectives within current program funding and that additional funding would be required. However, parameter values and estimating methodology were not discussed in the documents.

- Updated estimates for the Hyper-X program were not provided in the two aforementioned reviews. However, information in the Hyper-X program status brief indicated that NASA had to use some updated cost information to determine that cost overruns were going to occur for the particular system for which it was proposing alternatives.

- In a monthly contractor financial management report containing the variance analysis, the earned value report, and the progress report (the only monthly report provided) for the Hyper-X contract—only actual and planned costs were included; no earned value data for analysis were provided. In addition, the total value provided in this report totaled $67.8 million—well below the Hyper-X program's total cost. Furthermore, a NASA official stated that EVM was a deliverable on the contracts, but the contractor used NASA form 533, which does not provide full EVM data. Also, the data showed that there were no EVM specialists employed in the Hyper-X program office. As a result, the evidence provided was insufficient for us to determine whether the Hyper-X program was implementing earned value throughout the total program.

Source: NASA.

SPACE FLIGHT

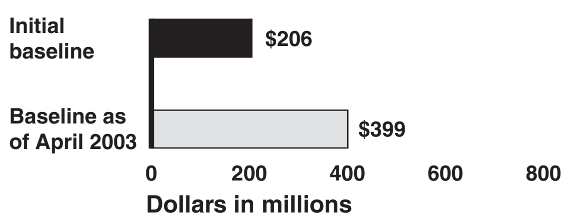
Checkout and Launch Control System

The Checkout and Launch Control System (CLCS) was intended to replace a central component in NASA's existing launch processing system for the space shuttle. The original justification for CLCS was that a substantial portion of the vendors for the command control and monitor system no longer provided support. In addition, out-of-date software and systems were expected to increase costs. CLCS promised to reduce staff, paperwork, and operations and maintenance costs by 50 percent. The program was canceled in September 2002 due to cost overruns, which according to NASA, were caused by factors such as software development delays based on poorly defined requirements and design, integration problems, and a lack of experienced development staff.

Program Facts

- *Status:* **Canceled**
- *Program initiation:* **Fiscal year 1996**
- *Program approved by Congress:* **Fiscal year 1998**
- *Comparison of initial and current baseline development estimates:* **$193 million or 93.7 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Assumptions identified and explained • Independent estimators concur with program estimates	• Estimate objectives stated in writing • Estimate life cycle clearly defined • Tasks appropriately sized • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Structured format used to ensure all costs are captured • More than one cost model or estimating approach used • Dictated schedules show cost impacts of acceleration • Estimates reflect changes over time • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Parameter value uncertainties identified and quantified

Sources: NASA (data), SEI (criteria), GAO (analysis).

The CLCS program lacked complete evidence supporting the cost estimate. Our other key findings related to the CLCS program are summarized as follows:

- The description of the program objectives and overview provided in the program commitment agreement was not the description used to generate the cost estimate, and supporting documentation of the detailed cost estimated referred to in the 1997 non-advocate review briefing was not provided.
- The total life cycle and WBS were not defined in the program's life-cycle cost estimate.
- The 1997 nonadvocate review identified the analogy to be used as well as six different projects for parametric estimating. However, no details on the cost model parameters were documented.
- No evidence was provided to explain how the schedule slip—from June 2001 to June 2005—impacted the cost estimate.
- Various documents discuss various estimating approaches, but no evidence of the differences in estimating approaches being analyzed was provided.
- Detailed descriptions of changes in CLCS estimates were not provided, although NASA stated that changes were tracked and estimates were updated accordingly.
- A briefing on CLCS software stated that progress was tracked against the plan for software development, but no documentation on such tracking at a total program level was provided.
- A program management review included a graphic displaying earned value data, and a NASA official stated in an interview that EVM had been used since 2000. However, cost performance reports or other supporting documentation showing that EVM had been used were not provided.

Source: NASA.

SPACE FLIGHT

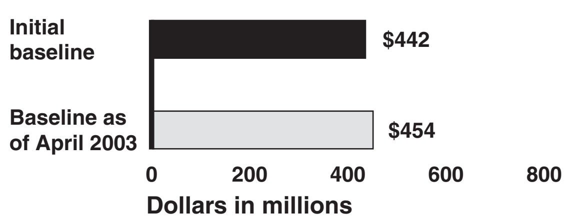
Cockpit Avionics Upgrade

The Cockpit Avionics Upgrade (CAU) project is redesigning the display formats on the liquid crystal displays of the space shuttle cockpit. The objective of the redesign is to enhance flight safety by presenting the crew with flight and vehicle critical information in a user-friendly format that enhances situational awareness. Because the new display format uses graphics and color to present complex information, crews are expected to have better and more rapid decision-making capability under off-nominal conditions than could be made with the legacy system, enhancing flight safety and the crew's ability to meet mission objectives.

Program Facts

- *Status:* **Development**
- *Program initiation:* **Fiscal year 2000**
- *Program approved by Congress:* **Fiscal year 2003**
- *Comparison of initial and current baseline development estimates:* **$12 million or 2.7 percent increase**

Development Baselines



Source: GAO.

Cost-Estimating Criteria

Met	Partially met	Not met
• Estimate objectives stated in writing • Tasks appropriately sized • Assumptions identified and explained • Structured format used to ensure all costs are captured • Independent estimators concur with program estimates • Estimates reflect changes over time • Estimates used as baselines for program tracking • Earned value reporting used to manage program	• Estimate life cycle clearly defined • Estimated costs based on demonstrated programs • Written documentation of parameter values and rationale • Parameter value uncertainties identified and quantified • More than one cost model or estimating approach used	

Sources: NASA (data), SEI (criteria), GAO (analysis).

Our assessment results for the CAU program were the highest among the ten programs we reviewed. However, we noted some weaknesses. The contractor failed to include full life-cycle costs in its life-cycle cost estimate and detailed cost information for some work breakdown structure elements to support the estimate and the analogies to historical known programs. Further, we found no evidence that the CAU program office conducted its own cost estimate prior to receiving the contractor's proposal, providing the office no objective means to assess the realism of the contractor's estimate before the nonadvocate reviews conducted in July 2001 and October 2002. Our other key findings related to the CAU program are summarized as follows:

- CAU project costs for certain life-cycle costs through 2008—such as design, development, and certification and delivery of the hardware and software; facility costs associated with the upgrade; and development of operational products associated with the upgrade, as well as reserves—were documented. However, other projects costs, such as installation costs, costs to sustain engineering, and operations and support were not. The sustaining engineering costs after 2008 were assumed to be zero because the costs would be absorbed through efficiencies provided by the CAU system. However, the assumption is unproven and could lead to higher costs after 2008. Further, although NASA requires that each estimate include specific information—including scope, definitions of terms, ground rules and assumptions, detailed description of the estimating methodology and the rationale for the approach, time-phased dollar estimates, pricing factors, and results of quantitative risk analyses—we found no evidence of this detailed information. Finally, the CAU program office said that impacts to the project due to full cost accounting have not been defined.

- The nonadvocate review costs were based on applied parametric estimating tools using CAU development process and technical descriptions of products including PRICE-H and NAFCOM for hardware development and SEER SEM for software development. Detailed assumptions for hardware and software development were provided, but there was no detail supporting the cost estimates for a number of elements, including ground facilities and integrated logistics, to facilitate re-creation of the estimate.

- PRICE-H and NAFCOM cost models were used to estimate hardware development; however, the documentation did not address whether there were any differences in model results; therefore, it is unclear whether one model was used for the primary estimate and the other was used to validate that estimate as a crosscheck. For software, we only found evidence of the SEER-SEM model.

Summary Descriptions of the 17 Additional Programs

In addition to the 10 programs that we reviewed in detail, we analyzed the initial and current development cost estimates for 17 other NASA programs.

Space Science Enterprise

Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED)

NASA's TIMED satellite is conducting the first global study of the Earth's mesosphere, lower thermosphere, and ionosphere—segments of the Earth's atmosphere located between 40 and 110 miles above the planet. Initially, TIMED's mission was to last 2 years, beginning with its launch in December 2001, but NASA extended the satellite's orbital operations through 2006. TIMED's goal is to improve our understanding of the influences the sun and humans have on this "gateway region" as well as the effects of its atmospheric variability on satellites and spacecraft reentering the Earth's atmosphere.

International Gamma-Ray Astrophysics Laboratory (INTEGRAL)

INTEGRAL is a European Space Agency mission, with Russian and U.S. involvement. Launched in October 2002, the INTEGRAL satellite is equipped with two telescopes designed to register elusive gamma rays—some of the universe's most energetic radiation—and give insight into the most violent processes in our universe. Through INTEGRAL, scientists plan to study black holes' interaction with their surroundings, the explosion of supernovae and their role in forming chemical elements, the nature of powerful gamma-ray bursts, and transient sources that suddenly change brightness. U.S. participation consists of co-investigators providing hardware and software components to the spectrometer and imager instruments, a co-investigator for the data center, a mission scientist, and a provision for ground tracking and data collection.

Rosetta

Rosetta is a European Space Agency mission whose objectives are to study the origin of and the relationship between comets and interstellar material and to improve our knowledge of the origins of the Solar System. The Rosetta satellite was launched in March 2004 and, after a long cruise phase, is planned to rendezvous with comet Churyumov-Gerasimenko in 2014. Plans call for Rosetta to orbit the comet while taking scientific measurements and to position a probe on the comet surface to take in-situ measurements. U.S. involvement includes developing three remote-sensing instruments and a subsystem for a fourth instrument.

Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER)

Currently scheduled to launch during a 15-day period that opens July 30, 2004, the MESSENGER spacecraft is intended to collect images of Mercury. Through these images, NASA scientists hope to determine Mercury's geological history and the nature of its surface composition, core, poles, exosphere and magnetosphere, and magnetic field. This information is expected to provide scientists with a better understanding of how Earth was formed, how it evolved, and how it interacts with the sun.

Solar Terrestrial Relations Observatory (STEREO)

Through STEREO—an international collaboration involving France, Germany, the United Kingdom, and the United States—NASA plans to trace the flow of energy and matter from the sun to Earth by studying the solar origin of coronal mass ejections, their evolution in the heliosphere, and their effects on geospace. Twin STEREO observatories, scheduled to be launched in November 2005, will be used to develop a three-dimensional, time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind. Because coronal mass ejections are the prime drivers of major space weather hazards, STEREO is expected to greatly improve our understanding of the most severe disturbances of the Sun-Earth system. The observatories will also provide a continuous data stream for the purpose of real-time space weather forecasts.

Stratospheric Observatory for Infrared Astronomy (SOFIA)

The SOFIA observatory—a modified Boeing 747 aircraft with a permanently installed telescope, which NASA plans to begin flying in 2005—will be used to study different astronomical objects and phenomena, including star births and deaths; solar system formations; complex molecules in space; planets, comets, and asteroids in our solar system; nebulae and dust in galaxies; and black holes at the centers of galaxies. The telescope, provided through a partnership with the German Aerospace Center, is designed to provide routine access to nearly all of the visual, infrared, far-infrared, and submillimeter parts of the spectrum. As such, SOFIA is expected to extend the range of astrophysical observations significantly beyond that of previous infrared airborne observatories through increases in sensitivity and angular resolution. NASA plans to incorporate new or upgraded technologies over the aircraft's lifetime to allow additional scientific exploration. Because most of the instruments are to be designed and built by graduate students and post-doctoral scientists in universities throughout the United States, SOFIA will serve as a training ground for the next generation of instrument builders.

Solar-B Observatory

The Solar-B program's objectives are to investigate the interaction between the Sun's magnetic field and its corona and to understand the sources of solar variability. Solar-B is a Japanese Institute of Space and Astronautical Science mission, with significant U.S. involvement, and follows the Solar-A collaboration among Japan, the United Kingdom, and the United States. The observatory is designed to consist of a set of optical, extreme ultraviolet, and X-ray instruments, and NASA is expected to provide components for each. The Solar-B observatory is scheduled to be launched on a Japanese M-V rocket out of Kagoshima, Japan, in September 2006.

Herschel Space Observatory

The European Space Agency's Herschel Space Observatory (formerly the Far Infrared and Submillimetre Telescope, or FIRST) houses an infrared telescope that is expected to observe virtually unexplored spectrum wavelengths that cannot be observed from the ground. Scheduled for launch in February 2007, Herschel is expected to enable scientists to better understand galaxy formation, evolution in the early universe, and the nature of active galaxy power sources; star-forming regions and interstellar medium physics in the Milky Way and other galaxies; and the molecular chemistry of cometary, planetary, and satellite atmospheres in our solar system. NASA is providing components for two of the three instruments that will be flown on Herschel: the Heterodyne Instrument for Far Infrared and the Spectral and Photometric Imaging Receiver.

Earth Science Enterprise

Terra

Launched in February 2000, Terra is providing measurements that, according to NASA, are significantly contributing to the understanding of the total Earth system. Specifically, Terra is collecting 200 gigabytes of data each day on the earth's physical and radiative properties of clouds, air-land

and air-sea exchanges of energy, carbon, and water as well as measurements of trace gases and volcanology. One of the first operational uses of Terra was to provide imagery to support the U.S. Forest Service's efforts to combat forest fires in the western United States. Through Terra, fire fighters were able to identify the locations of active fires, instead of locations of smoke, providing them with the data needed to better control spreading fires. Terra data were also used by the Geography Department of Dartmouth College in New Hampshire to assist in flood hazard reduction programs.

New Millennium Program's Earth Observing-1 (EO-1)

NASA's New Millennium Program (NMP) is designed to identify, develop, and flight-validate key instrument and spacecraft technologies that can enable new or more cost-effective approaches to conducting science missions. EO-1—the first NMP mission, launched in November 2000—includes three land imaging instruments that are expected to lead to a new generation of lighter weight, higher performance, and lower cost Landsat-type Earth surface imaging instruments.

Jason-1

The mission of the Jason-1 program, a cooperative effort with the French Space Agency, is to study the global oceans. Launched in December 2001, the Jason-1 satellite was expected to monitor ocean circulation and events such as El Nino and ocean eddies and to improve global climate forecasts and predictions. The Jason-1 satellite was positioned to orbit the earth in tandem with TOPEX/Poseidon, an earlier generation satellite launched in 1992, to provide data to the National Oceanic and Atmospheric Administration.

SeaWinds

The SeaWinds satellite, launched in December 2002, is providing high-resolution, ocean surface wind data used for studies of ocean circulation, climate, and air-sea interaction to understand global climate changes and weather patterns better. By using long-term wind data in numerical weather and wave prediction models, SeaWinds is expected to improve weather forecasts near coastlines and storm warning and monitoring.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (Calipso)

The Calipso satellite, scheduled for launch in 2005, is being designed to study the effect that aerosols and clouds have on the Earth's radiation balance, which ultimately controls the temperature of the Earth. Calipso is expected to provide scientists with data to construct three-dimensional structures of the atmosphere, enabling new observationally based assessments of the radiative effects of aerosol and clouds that will greatly improve our ability to predict future climate change. NASA plans to fly Calipso in formation with Aqua and CloudSat, a satellite being designed to measure the vertical structure of clouds from space and contribute to a better understanding of the role of clouds in the Earth's climate system. The Calipso program is a cooperative effort with France.

Space Flight Enterprise

X-38 Crew Return Vehicle (CRV)

The X-38 Crew Return Vehicle was cancelled in April 2002, due to its single purpose design and the potentially high costs identified by an independent assessment. The purpose of the CRV project was to initiate work toward an independent U.S. crew return capability for the International Space Station. As envisioned, CRV was expected to serve as a back-up to the space shuttle orbiters by providing resupply to the station or change-out crew, or accommodating safe return for up to seven crew members who may be ill or injured or in the event that a catastrophic failure of the station made it unable to support life.

Alternate Turbopump Program (ATP)

ATP's primary objectives were to significantly improve the safety and operating margins of the high-pressure turbopump in the space shuttle's main engine and to eliminate the need to remove the turbopump for postflight maintenance. An alternative turbopump was successfully implemented in the shuttle launched in April 2002. According to NASA, ATP's development contract, signed in December 1986, specifically addressed shortcomings of the previous turbopumps; took advantage of the latest technologies; and applied lessons learned. The contract called for the parallel development of two high-pressure turbopumps—one that operates on oxidization and one on fuel. However, 5 years into the program, technical problems prompted NASA to end parallel development and concentrate first on developing the oxidizer turbopump, which was first flown in July 1995. Although development of the fuel turbopump resumed in 1994, extreme high temperatures, pressures, and rotor speeds resulted in significant design challenges and the design certification review was not completed until March 2001. The full implementation of the fuel turbopump into flight was completed beginning with the April 2002 shuttle flight.

Tracking and Data Relay Satellite (TDRS) Replenishment

In December 2002, the TDRS Replenishment project achieved its goal: launch three geosynchronous satellites to replace the existing aging satellite constellation, and thereby continue to provide space network tracking, data, voice, and video services to NASA scientific satellites, the Space Shuttle program, the International Space Station, and other NASA customers. According to NASA, the functional and technical performance requirements for the replacement satellites—launched in June 2000, March 2002, and December 2002—are virtually identical to those of the previous satellites.

Advanced Health Management System (AHMS) Phase 1

AHMS is expected to provide safe shutdown of the space shuttle main engine during potentially catastrophic high-pressure turbopump failures through improved monitoring of engine vibration and anomaly response capabilities. According to NASA, AHMS modifications include (1) adding a vibration redline monitor for high pressure turbopumps, (2) doubling memory capacity and employing radiation tolerant memory, (3) adding an external communication interface for a potential phase-two health management computer, and (4) eliminating existing memory retention batteries and replacing them with nonvolatile memory. While NASA stated the AHMS will be available for launch in January 2005, the shuttle fleet's return to flight date is planned for March or April 2005.

Description of Earned Value Management

Earned value management (EVM) goes beyond the two-dimensional approach of comparing budgeted costs to actuals. Instead, it attempts to compare the value of work accomplished during a given period with the work scheduled for that period. By using the value of completed work as a basis for estimating the cost and time needed to complete the program, earned value can alert program managers to potential problems early in the program.

An accurate, valid, and current performance management baseline is needed to perform useful analyses using EVM. In 1996, in response to acquisition reform initiatives, the Department of Defense (DOD) adopted 32 criteria for evaluating the quality of management systems. In general terms, the 32 criteria require contractors to (1) define the contractual scope of work using a work breakdown structure; (2) identify organizational responsibility for the work; (3) integrate internal management subsystems; (4) schedule and budget authorized work; (5) measure the progress of work based on objective indicators; (6) collect the cost of labor and materials associated with the work performed; (7) analyze any variances from planned cost and schedules; (8) forecast costs at contract completion; and (9) control changes. The criteria have become the standard for EVM and have been adopted by major U.S. government agencies, industry, and the governments of Canada and Australia. The full application of EVM system criteria is appropriate for large cost reimbursable contracts where the government bears the cost risk. For such contracts, management discipline prescribed by the criteria is essential. In addition, data from an EVM system have been proved to provide objective reports of contract status, allowing numerous indices and performance measures to be calculated. These can then be used to develop accurate estimates of anticipated costs at completion, providing early warning of impending schedule delays and cost overruns.

Table 5 lists the 32 criteria, organized into five basic categories: organization, planning and budgeting, accounting considerations, analysis and management reports, and revisions and data maintenance.

Table 5: Thirty-Two Criteria for Evaluating the Quality of Management Systems

Category	Criteria
Organization	1. Define the authorized work elements for the program. A work breakdown structure, tailored for effective internal management control, is commonly used in this process.
	2. Identify the program organizational structure, including the major subcontractors responsible for accomplishing the authorized work, and define the organizational elements in which work will be planned and controlled.
	3. Provide for the integration of the company's planning, scheduling, budgeting, work authorization, and cost accumulation processes with each other and, as appropriate, the program work breakdown structure and the program organizational structure.
	4. Identify the company organization or function responsible for controlling overhead (indirect costs).
	5. Provide for integration of the program work breakdown structure and the program organizational structure in a manner that permits cost and schedule performance measurement by elements of either or both structures as needed.
Planning and budgeting	6. Schedule the authorized work in a manner that describes the sequence of work and identifies significant task interdependencies required to meet the requirements of the program.
	7. Identify physical products, milestones, technical performance goals, or other indicators that will be used to measure progress.
	8. Establish and maintain a time-phased budget baseline, at the control account level, against which program performance can be measured. Budget for far-term efforts may be held in higher-level accounts until an appropriate time for allocation at the control account level. Initial budgets established for performance measurement will be based on either internal management goals or the external customer-negotiated target cost, including estimates for authorized but undefinitized work. On government contracts, if an over target baseline is used for performance measurement reporting purposes, prior notification must be provided to the customer.
	9. Establish budgets for authorized work with identification of significant cost elements (labor and material, for example) as needed for internal management and for control of subcontractors.
	10. To the extent it is practical to identify the authorized work in discrete work packages, establish budgets for this work in terms of dollars, hours, or other measurable units. Where the entire control account is not subdivided into work packages, identify the far term effort in larger planning packages for budget and scheduling purposes.
	11. Provide that the sum of all work package budgets plus planning package budgets within a control account equals the control account budget.
	12. Identify and control level of effort activity by time-phased budgets established for this purpose. Only that effort which is unmeasurable or for which measurement is impractical may be classified as level of effort.
	13. Establish overhead budgets for each significant organizational component of the company for expenses that will become indirect costs. Reflect in the program budgets, at the appropriate level, the amounts in overhead pools that are planned to be allocated to the program as indirect costs.
	14. Identify management reserves and undistributed budget.
	15. Provide that the program target cost goal is reconciled with the sum of all internal program budgets and management reserves.
Accounting considerations	16. Record direct costs in a manner consistent with the budgets in a formal system controlled by the general books of account.

(Continued From Previous Page)

Category	Criteria
	17. When a work breakdown structure is used, summarize direct costs from control accounts into the work breakdown structure without allocation of a single control account to two or more work breakdown structure elements.
	18. Summarize direct costs from the control accounts into the contractor's organizational elements without allocation of a single control account to two or more organizational elements.
	19. Record all indirect costs that will be allocated to the contract.
	20. Identify unit costs, equivalent units costs, or lot costs when needed.
	21. For EVM, the material accounting system will provide (1) accurate cost accumulation and assignment of costs to control accounts in a manner consistent with the budgets using recognized, acceptable, costing techniques; (2) cost performance measurement at the point in time most suitable for the category of material involved, but no earlier than the time of progress payments or actual receipt of material; and (3) full accountability of all material purchased for the program, including the residual inventory.
Analysis and management reports	22. At least on a monthly basis, generate the following information at the control account and other levels as necessary for management control using actual cost data from, or reconcilable with, the accounting system: (1) Comparison of the amount of planned budget and the amount of budget earned for work accomplished. This comparison provides the schedule variance. (2) Comparison of the amount of the budget earned and the actual (applied where appropriate) direct costs for the same work. This comparison provides the cost variance.
	23. Identify, at least monthly, the significant differences between both planned and actual schedule performance and planned and actual cost performance, and provide the reasons for the variances in the detail needed by program management.
	24. Identify budgeted and applied (or actual) indirect costs at the level and frequency needed by management for effective control, along with the reasons for any significant variances.
	25. Summarize the data elements and associated variances through the program organization and/or work breakdown structure to support management needs and any customer reporting specified in the contract.
	26. Implement managerial actions taken as the result of earned value information.
	27. Develop revised estimates of cost at completion based on performance to date, commitment values for material, and estimates of future conditions. Compare this information with the performance measurement baseline to identify variances at completion important to company management and any applicable customer reporting requirements, including statements of funding requirements.
Revisions and data maintenance	28. Incorporate authorized changes in a timely manner, recording the effects of such changes in budgets and schedules. In the directed effort prior to negotiation of a change, base such revisions on the amount estimated and budgeted to the program organizations.
	29. Reconcile current budgets to prior budgets in terms of changes to the authorized work and internal replanning in the detail needed by management for effective control.
	30. Control retroactive changes to records pertaining to work performed that would change previously reported amounts for actual costs, earned value, or budgets. Adjustments should be made only for correction of errors, routine accounting adjustments, effects of customer or management directed changes, or to improve the baseline integrity and accuracy of performance measurement data.
	31. Prevent revisions to the program budget except for authorized changes.
	32. Document changes to the performance measurement baseline.

Source: Interim Defense Acquisition Guide Book, Appendix 4.

The standard format for tracking earned value is through a cost performance report (CPR). The CPR is a monthly compilation of cost, schedule, and technical data, which displays the performance measurement baseline, any cost and schedule variances from that baseline, the amount of management reserve used to date, the portion of the contract that is authorized unpriced work, and the contractor's latest revised estimate to complete the program. As a result, the CPR can be used as an effective management tool because it provides the program manager with early warning of potential cost and schedule overruns.

Using data from the CPR, a program manager can assess trends in cost and schedule performance. This information is useful because trends tend to continue and can be difficult to reverse. Studies have shown that once programs are 15 percent complete, the performance indicators are indicative of the final outcome. For example, a CPR showing a negative trend for schedule status would indicate that the program is behind schedule. By analyzing the CPR, one could determine the cause of the schedule problem such as delayed flight tests, changes in requirements, or test problems because the CPR contains a section that describes the reasons for the negative status. A negative schedule can be a predictor of later cost problems because additional spending is often necessary to resolve problems. CPR data also provide the basis for independent assessments of a program's cost and schedule status and can be used to project final costs at completion in addition to determining when a program should be completed.

Examining a program's management reserves is another way that a program can use a CPR to determine potential issues early on. Management reserves, which are funds that may be used as needed, provide flexibility to cope with problems or unexpected events. EVM experts agree that transfers of management reserves should be tracked and reported because they are often problem indicators. An alarming situation arises if the CPR shows that the management reserves are being used at a faster pace than the program is progressing toward completion. For example, a problem would be indicated if a program has used 80 percent of its management reserves, but only completed 40 percent of its work. A program's management reserves should contain at least 10 percent of the cost to complete a program so that funds will always be available to cover future unexpected problems that are more likely to surface as the program moves into the testing and evaluation phase.

Comments from the National Aeronautics and Space Administration

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

May 24, 2004

Mr. Allen Li
Director, Acquisition and Sourcing
Management Team
United States General Accounting Office
Washington, DC 20548

Dear Mr. Li:

NASA appreciates the opportunity to comment on your draft report (General Accounting Office (GAO)-04-642) entitled "Lack of Disciplined Cost-Estimating Processes Undermines NASA's Ability to Effectively Manage Its Programs."

We concur with the recommendations of your report and your observations as they validate and reinforce the importance of activities already underway at NASA to improve cost estimating and program management. We believe that NASA, while still pursuing important improvements in many areas related to cost management, has already made substantive changes and achieved significant improvements in its cost-estimating processes. Some examples are as follows:

- <u>Reduction in Cost Growth:</u>
  In your December 1992 report, "NASA Program Costs: Space Missions Require Substantially More Funding Than Initially Estimated" (GAO/NSIAD-93-97), GAO cited a median 77 percent increase in Agency program cost growth. This contrasts with a 13 percent median cost growth in the present study – a dramatic improvement.
- <u>Project Termination:</u>
  NASA has recently terminated projects with high cost growth, such as the Checkout and Launch Control System (CLCS), the highest growth project in your report.
- <u>Space Station Reforms:</u>
  From the President's FY 2005 Budget Request, Office of Management and Budget (OMB) states, "During the 1990s, International Space Station costs were spiraling out of control, potentially threatening other NASA programs and using taxpayer resources ineffectively. Using independent reviews and implementing management reforms, Space Station managers have since gained control over the costs of this unique laboratory."

In order to ensure that the title of your report is appropriately consistent with your findings, we would suggest the title could be revised to recognize steps we have recently taken to address the issues you raise. We believe the title of the report would better reflect the current status if it were changed to "Consistent Implementation of NASA's Cost Management Processes are Necessary to Ensure Effective Program and Project Management." NASA has already identified several key processes in this area and must now be diligent in ensuring consistent implementation of those processes, whereas the title of the draft report implies that there are no processes.

The following paragraphs provide the current status and planned approach for addressing each of the recommendations made by GAO in its draft report.

Recommendation 1: GAO recommends that the NASA Administrator direct the Program Executive Officer for IFMP, Chief Financial Officer and Chief Engineer to develop an integrated plan that, at a minimum, includes specific actions for ensuring that

- **guidance is established on rebaselining and that rebaselining is consistently applied to provide accountability among programs**
- **true earned value management is used as an organizational management tool to bring cost to the forefront in NASA's management decision-making process**
- **acquisition and earned value management policies and procedures are enforced, and**
- **staff and support for cost-estimating and earned value analyses are effectively used.**

NASA concurs with this recommendation, and is making progress towards implementation, including development of revised direction for program and project management by the Office of the Chief Engineer and design and implementation under the IFM Program's Integrated Asset Management (IAM) effort of enhanced Agencywide Project Management and Earned Value analytical capabilities. This revised direction is NASA Procedural Requirement (NPR) 7120.5C, entitled "NASA Program and Project Management Processes and Requirements." As an example of our commitment to implementing these reforms, we have changed the name from "NASA Procedural Guidance" to "NASA Procedural Requirement" to make clear that these directives are requirements and are in no way optional. NPR 7120.5C will be released in August 2004 to replace NASA Procedural Guidance (NPG) 7120.5B. This management system governs the formulation, approval, implementation, and evaluation of all Agency programs and projects. An integral part of NPR 7120.5C will be NASA's new Continuous Cost-Risk Management (CCRM) process, focusing cost-estimators, earned value management (EVM) analysts, and program analysts on risk and cost-risk insight. This will improve their effectiveness at making better estimates and identifying potential problems as they emerge, thereby controlling program and project cost growth.

We acknowledge that requirements must be established and discipline must be enforced in both determining when rebaselining is necessary and in the actual implementation of rebaselining activities when they are determined to be necessary. NASA has created firm requirements that establish thresholds that, if exceeded, will require a rebaselining review by the governing Program Management Council (PMC). NASA has governing PMCs at the Center level, Enterprise level, or Agency level depending on the size and criticality of the program or project. Each is comprised of senior representatives, has the authority to impose program and project management requirements, and regularly reviews programs and projects for satisfactory performance. A rebaselining review will require strict adherence to justification procedures, to include reasons for the cost growth, value of the program to the Agency and the Nation, an updated life-cycle cost estimate (LCCE), and evidence that a team is in place that is capable of managing the project to the updated technical, schedule and cost targets. If a rebaselining is determined to be appropriate, traceability to the original baseline will be ensured.

NASA recognizes the need for improved Earned Value Management (EVM) implementation on development projects across the Agency. It also recognizes the challenges with implementing true, full-cost EVM that seamlessly integrates in-house and multiple contractor activities. Accomplishing this requires evolution of Integrated Financial Management Program (IFMP) business practices and the integration of EVM software with business management systems. NPR 7120.5C will also reinforce implementation of EVM by providing requirements for EVM. The Office of the Chief Engineer is now responsible for EVM requirements definition and compliance at NASA, and is working with all Enterprises to ensure that full criteria-compliant EVM is a part of every major project and that EVM principles are applied to smaller projects.

To ensure that the most up-to-date EVM practices are consistently implemented across NASA, the Deputy Chief Engineer Chairs the newly formed EVM Focal Point Council (FPC). The EVM FPC meets every 2 months, and includes representatives from the Enterprises and the IFMP who are experienced in EVM design, development, and implementation. NASA's training personnel are also included in the FPC to help develop EVM training modules. At present, the EVM FPC has formed seven working groups to address various improvements. The EVM FPC will also be publishing an EVM Handbook that will contain the results of each EVM FPC working group and provide the latest guidance to the NASA EVM community. The EVM FPC is overseeing the selection of software tools, prototype testing, and the rollout of a resultant set of pilot tools in FY 2005 that project managers can use to more readily and consistently implement EVM policy.

Acquisition management is another area receiving great emphasis in NPR 7120.5C. Approximately 90 percent of NASA's work is performed through grants and contracts, underscoring the importance of acquisition strategies. New rules of engagement require project plans to dedicate extensive effort to acquisition planning and strategy, with an emphasis on how risk and technical complexity affect contractor performance. The new practices also emphasize methods for incentivizing contractor performance to achieve Agency safety, reliability, and performance goals.

Enforcement of these new EVM and acquisition policies and procedures will be achieved through Program Management Councils which will review and approve programs and projects regularly, including each step of their development, based on the new requirements in NPR 7120.5C. Additionally, the Contract Management module, which is part of IFM's IAM rollout, will significantly help move the Agency off GAO's "High Risk" list in Contract Management.

Prior to the initiation of this GAO study, NASA had already taken critical steps to address staffing and support needs for cost estimating and earned value management. For example, a new Cost Analysis Division, reporting to the Comptroller, has been established at NASA Headquarters. This division is being staffed with six new high-level civil service cost estimators. In addition, senior cost analyst positions have been added to the Independent Program Assessment Office (IPAO), the Agency's lead for conducting program and project cost estimates and technical reviews at key milestones. IPAO's Deputy Director will act as lead for Independent Cost Estimates. We are also strengthening interactions between the IPAO and the Center System Management Offices (SMOs); the SMO's provide an additional source of cost estimating expertise independently of projects. These measures will enable new cost management policy and direction that will ensure effective use of NASA-wide staff, and support cost estimating and earned value analysis capability.

NASA recognizes the importance of supporting its new management requirements with training. NASA recently moved the personnel responsible for engineering and management training to the Office of the Chief Engineer. NASA's Chief Engineer controls NPR 7120.5C, and will ensure that training is well matched to the new requirements, especially the cost-risk principles of NASA's new Continuous Cost-Risk Management (CCRM) process. Implementation of CCRM has already begun on programs in the Exploration Systems Enterprise, and full implementation of NASA's CCRM is expected to take place following publication of 7120.5C. NASA has developed not only a strategy for an improved, rigorous and disciplined cost estimating and EVM capability, but a genuine enhancement to overall project management.

Recommendation 2: In addition, we recommend that the NASA Administrator direct the Chief Financial Officer to establish a standard framework for developing life-cycle cost estimates. At a minimum the framework should require each program or project to

- **base its cost estimates on a full life cycle for the program – including all direct and indirect costs for operations and maintenance and disposal as well as planning and procurement – and on a work breakdown structure that encompass both in-house and contractors efforts,**
- **prepare a cost analysis requirements document,**
- **prepare an independent government estimate at each milestone of the program, and**
- **conduct a cost risk assessment that identifies the level of uncertainty inherent in the estimate.**

NASA concurs with this recommendation. NASA agrees that there is a need for consistency in defining life-cycle costs that includes the full cost of NASA's programs.

NPR 7120.5C will clearly define the full life-cycle cost to include development, operations, maintenance, disposal and all NASA in-house direct and indirect costs, including civil service salary, materials, service pool, Center G&A, and Corporate G&A to eliminate ambiguity and ensure consistency. Life-cycle cost estimates will be done for those phases relevant to the program or project – for example, some NASA activities are technology or test programs that may not include all the life cycle phases of a spacecraft development project.

The revised Cost Estimating Handbook, based on NPR 7120.5C, will provide further guidance for life-cycle cost estimates. Both NPR 7120.5C and the revised cost estimating handbook will require rigorous development of life-cycle cost estimates, to include cost-risk assessment, for all phases of the program's life cycle.

The recommendation for the preparation of a cost analysis requirements document, similar to the Department of Defense's (DoD) cost analysis requirements description (CARD), is addressed by a similar but improved tool called the Cost Analysis Data Requirement or "CADRe." The Project Manager is responsible for developing and maintaining the CADRe, which has three basic parts: (1) a DoD CARD-equivalent project and technical description document; (2) identification and valuation of key engineering performance parameters, including updates over time, and documentation of actual Work Breakdown Structure (WBS) element costs; and (3) initial and annual updates of life-cycle cost estimates (LCCE). The LCCE is separable from the CADRe so that the CARD-equivalent portion of the CADRe can be given to an independent cost-estimating group, like the IPAO, so that it can perform an independent cost estimate (ICE) without knowledge of the project estimate.

NPR 7120.5C, complemented with guidance contained in the revised Cost Estimating Handbook, will require an ICE for major programs (identified by size and criticality) at least twice -- prior to entering Phase B (corresponding to the System Design Review) and prior to entering Phase C/D (corresponding to the Preliminary Design Review). These estimates may be done by in-house organizations, such as the IPAO, by outside experts from Federally Funded Research and Development Centers (FFRDCs) or industry, or some combination thereof.

The transition from Phase A/B to Phase C/D, or from formulation to implementation, is a critical transition and one that NASA has emphasized in its budget structure. Prior to Phase C, when projects are in formulation, there tends to be a high level of uncertainty as designs mature. NASA communicates to its stakeholders that estimates should be expected to change in this phase. Budgets for programs and projects in the formulation phase are included in the "technology and advanced concepts" category of the budget. To move into Phase C/D, projects must be approved by their governing PMC, having already gone through a Preliminary Design Review and had an Independent Cost Estimate. Once projects are approved by their PMC to enter implementation and begin Phase C/D, the funding is transferred from "technology and advanced concepts" to the "development" category, at which time NASA commits to the cost and schedule estimates with confidence. In Phase C/D, NASA relies primarily on EVM to capture cost performance and estimates-to-complete, although updates to Independent Cost Estimates may also be used as required. These updates will be enabled through continual cost estimating community involvement in implementing annual parametric estimates as required by the CADRe. NASA is implementing these requirements at the present time.

NASA has already implemented guidance and training to ensure that all Independent Cost Estimates are based on risk and expressed in terms of probability distributions. Naturally, estimates that are performed very early in the development cycle contain higher levels of uncertainty, and NASA communicates that uncertainty to stakeholders through the budget, as described above, in briefings and in updates to the NASA Operating Plans. The vast majority of systems developed by NASA are unprecedented, and variation in cost estimates is to be expected as they mature from initial risk mitigation efforts (such as early technology development) through the phases of the project life cycle. The Comptroller and IPAO are preparing and testing alternative cost estimating tools that can be used early in development cycles for crosschecks and validation against traditional cost estimating methods.

Cost uncertainty analyses are required as part of the NASA Continuous Cost-Risk Management (CCRM) process. The CCRM process not only requires identification of the uncertainty inherent in the estimate, it ties this identification to the monitoring and management of medium- and high-risk WBS elements using EVM. NASA has also recently developed a policy for cost-risk data generation and analysis, and has documented it as "the 12 Tenets of NASA Cost-Risk" in the updated cost-estimating handbook.

The requirement for a CADRe is presently being implemented on all major new development programs, and will be institutionally required with its inclusion in the upcoming NPR 7120.5C. NASA is implementing milestone ICE requirements at the present time, along with uncertainty analysis requirements on ICEs and LCCEs, to include operations, maintenance, and disposal costs.

Recommendation 3: **Further, we recommend that the NASA Administrator develop procedures such that proposed projects not be allowed to proceed through the review and approval process when they do not address the elements of the recommended cost estimating practices.**

NASA concurs with this recommendation.

The new version of NPR 7120.5 defines the authority of the governing PMCs that will enforce the program requirements for proceeding through the review and approval process. It also makes very clear to project managers the procedures that have to be followed along with information and documentation required in the project plan to successfully receive authority to proceed at key milestone gates. The document also clearly identifies management methods for ensuring that projects perform according to plan.

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NASA's recent implementation of its Executive Financial Management Information Dashboard ("Erasmus") provides the Administrator and the senior management of the Agency direct insight into individual Project and Program performance on a monthly basis. The Office of the Chief Engineer reviews Erasmus "stoplight" information regularly, and significant variances, such as cost estimating deficiencies, are identified for PMC review. Additionally, the Agency-wide Business Warehouse tool provides users across the Agency complete access to the full cost of projects or functional activities. Furthermore, the completion of populating FY05 phasing plan data in the new Budget Formulation tool will provide additional functionality to users, giving them complete access to actual versus planned cost performance.

Again, thank you for the critical insight the report provided. We assure you that we are well on our way toward implementing your recommendations.

Cordially,

Frederick D. Gregory
Deputy Administrator

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