U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE AND AERONAUTICS

HEARING CHARTER

Cost Management Issues in NASA's Acquisitions and Programs

Thursday, March 5, 2009
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

I. Purpose

The House Committee on Science and Technology's Subcommittee on Space and Aeronautics will convene a hearing to review the status of the National Aeronautics and Space Administration's (NASA) efforts to improve the cost management of its acquisitions and programs. The hearing will focus on (1) the results of the Government Accountability Office's (GAO) just-completed assessments of selected large-scale NASA projects and its designation of NASA acquisition management as a "high-risk" area, (2) the causes of cost growth and schedule delays in NASA acquisitions and (3) the agency's progress in addressing them.

II. Witnesses

Christopher Scolese
Acting Administrator
National Aeronautics and Space Administration

Cristina T. Chaplain
Director
Acquisition and Sourcing Management
U.S. Government Accountability Office

Gary P. Pulliam
Vice President
Civil and Commercial Operations
The Aerospace Corporation

III. Overview

When programs cost more to build and take longer than planned, NASA is able to accomplish less with the resources it is allocated. Confronted with specific instances of cost growth and schedule delay, the agency is forced to either seek additional funds or make difficult trade-offs among its portfolio of projects such as shortening missions or removing instruments. An important factor in mitigating cost growth and schedule delay is accurate information with which to make decisions and cost projections. For more than a decade, GAO has identified NASA's 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. GAO has said that in the absence of such information, NASA would be challenged to manage its programs and control program costs. GAO has also underlined the importance of sound cost management in other reports. For example, in reporting on NASA's initial efforts to implement President Bush's 2004 Vision for Space Exploration, GAO said that in the past, NASA has had difficulty meeting cost, schedule, and performance objectives for some of its projects because it failed to adequately define project requirements and quantify resources.

It is important to note that while essential to ensuring timely, effective and efficient acquisition of goods and services, integrating sound cost management in program management is not enough. For example, there must be transparency and clarity in the decision about whether design and development is appropriately performed internally or acquired from external sources. In addition, an emerging issue requiring NASA's focused attention is the impact of the growing number of bid protests lodged by vendors not selected in response to several of its procurements, such as those for new space suits (since resolved) and Commercial Resupply Services for the International Space Station. Awaiting the outcome of such bid protests can have adverse impacts on the agency's planned schedules and program budgets. Potential means of minimizing the impact of protests range from ensuring proposal evaluations are defensible to guarding against any appearances of conflict of interest in evaluation panelists and advisory review group members chosen. Finally, successful acquisition outcomes require a skilled and motivated acquisition work force. The NASA Project Management Study completed in 1981 concluded that

"Good people are the key to good project management. Sound project planning, management practices, and source evaluation approaches are all important. However, they cannot substitute for having high quality, and highly-motivated people responsible for project management; both inside and outside of government."

As GAO has indicated, NASA's need to effectively manage its programs will gain even more importance as the agency seeks to manage its wide-ranging portfolio in an increasingly constrained fiscal environment. While today's hearing will

focus specifically on cost management, the Committee on Science and Technology will continue to monitor and review a range of issues that impact NASA's ability to acquire needed goods and services in a timely, cost effective and efficient manner.

IV. Potential Hearing Issues

The following are some of the potential issues that might be raised at the hearing:

- *What are the main causes of cost growth and schedule delays in NASA programs and projects? Is there a consensus on what causes cost growth and schedule delay? Are there any similarities with those experienced by the Department of Defense and other federal agencies in their acquisition of space systems?*
- *What has NASA done to mitigate cost growth and schedule delay? Can other federal agencies benefit from NASA's corrective actions?*
- *In light of continued instances of cost growth and schedule delay in key programs such as Mars Science Lander and Glory, how effective have NASA latest efforts been?*
- *What more needs to be done to mitigate cost growth and schedule delay in NASA programs?*
- *Why is NASA acquisition management still characterized by GAO as a high-risk area after 18 years?*
- *What has NASA done in response to GAO's characterization that NASA's acquisition management is a high risk area?*
- *What must NASA do to warrant removal from GAO's high-risk list?*

V. Background

To effectively use public funds in carrying out its activities, the federal government is expected to employ sound management practices and processes, including the measurement of program performance. The Congress, Executive Branch officials, and the public want to know whether federal programs are achieving stated goals and what their costs are.

The Importance of Developing Reliable Cost Estimates

As stated in GAO's "Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs" [GAO-09-3SP], cost estimates are necessary for government programs for many reasons: supporting decisions about whether to fund one program over another, developing annual budget requests, and evaluating resource requirements at key decision points. Moreover, as stated in GAO's guide, having a realistic estimate of projected costs makes for effective resource allocation, and increases the probability of a program's success.

GAO's guide defines a cost estimate as the summation of individual cost elements, using established methods and valid data to estimate the future costs of a program, based on what is known today. The management of a cost estimate involves continually updating the estimate with actual data as they become available, revising the estimate to reflect program changes, and analyzing differences between estimated and actual costs.

The guide further states that the ability to generate reliable cost estimates is a critical function. Without this ability, agencies are at risk of experiencing cost overruns, missed deadlines, and performance shortfalls—all recurring problems that GAO's program assessments have revealed. Furthermore, cost increases often mean that the government cannot fund as many activities as planned or deliver them when promised.

Cost Growth and Schedule Delays In NASA Programs

The need to mitigate cost growth and schedule delay in NASA programs is not a new concern. As early as 1981, it was identified by the NASA Project Management Study. In an article featured in NASA's ASK project management publication, Dr. C. Howard Robins, former deputy associate administrator for Space, said that the study, colloquially referred to as the "Hearth Study," would "*come to be viewed within NASA as a landmark*". Both the House Committee on Science and Technology and House Committee on Appropriations requested the study due to congressional concerns about cost and schedule performance problems. The House Science and Technology Committee letter dated September 19, 1980 to NASA stated:

"A number of large projects, for example Galileo, LANDSAT-D, space telescope, and ISPM, are experiencing cost and schedule problems."
"The Committee encourages NASA to take the necessary steps to minimize the cost and schedule impact of the problems associated with these ongoing programs. Further, the Committee has authorized new starts in the space and applications area and is anxious that sound project management principles be applied from the beginning of these new programs."

The 1981 study was the first multi-project study of program/project management by NASA and also the first study of the topic by an agency-wide NASA team. Langley Research Center Director Donald P. Hearth led a team that studied thirteen robotic projects, including projects such as Viking and Voyager, undertaken over a twenty-two-year period.

The study found significant problems, including inadequate project definition and over-optimism during advocacy. Several recommendations were made, such as requiring a formal definition review prior to the NASA decision to include the project in its budget request. A more detailed list of conclusions and summary

recommendations made in the Hearth Study are included in Appendix A. More importantly, the study said that its conclusions and recommendations should be viewed with the following comments in mind:

"*During recent years, several projects have experienced major cost increases without apparent forewarning. This has damaged NASA's credibility and reputation for successful project management. Actions by NASA management are, therefore, necessary; particularly, in light of NASA's external environment and the pressures on government budgets.*

The Study Team verified, from its examination of a group of representative projects that the cost performance of a project is closely related to the application of sound project management principles and/or the use of available management tools. Therefore, the Study Team's Conclusions and Recommendations are not intended to suggest the superposition of either an additional hierarchy of management, or the addition of new management tools within the current NASA system. Rather they stress the need for continuing application of the basic principles of sound project management by NASA, refinement of existing management tools, and the continuing verification, by NASA's top management, that the principles are being followed and available tools are being used."

In ensuing years, NASA cost growth and schedule issues were conducted in its robotic and human space flight mission areas, including the International Space Station. More recently, the issues of cost growth and schedule delays in NASA programs have been addressed in legislation and analyzed in studies by GAO, the National Research Council (NRC), and NASA itself.

NASA Authorization Act of 2005

Cost growth and schedule delay were addressed in the NASA Authorization Act of 2005 (P.L. 109-155). Provisions were enacted to help NASA and Congress spot potential cost growth and schedule problems early in the development phase of a major program. Rather than discouraging risk taking, these provisions were intended to encourage NASA managers to identify risks as early as possible, when they are more readily managed and solutions are more easily implemented.

- Under the 2005 Act, a Baseline Report is required whenever a major program completes required reviews and is approved to proceed to implementation. NASA's policy defines a project life-cycle in two phases—the formulation and implementation phases. During the formulation phase, projects develop and define requirements and lead up to a preliminary design review. Projects also complete development of mission-critical or enabling technology with associated demonstrations. The implementation phase begins after project confirmation.

After completing the Baseline Report, the Act requires NASA to report periodically on a major program through an Annual Report, which is provided as part of the annual agency budget submittal to the Congress, until the program enters operation. The provision defines a major program as an activity with a life-cycle cost estimate greater than $100 million. Having established the baseline, the 2005 legislation sets thresholds that, if exceeded, require agency action. Notification to Congress and an internal evaluation are required in the event that any major program exceeds its originally estimated development cost by more than 15 percent or exceeds its originally planned schedule by more than six months. The Act also requires Congress to evaluate whether to continue the major program in the event that it exceeds its originally estimated development cost by more than 30 percent or $1 billion.

- The NASA Authorization Act of 2000 was amended to better reflect current mission cost categories by increasing the cost threshold that could trigger an independent cost analysis from $150,000,000 to $250,000,000 and by requiring the Administrator, rather than the chief financial officer, to conduct the independent cost analysis.

NASA Authorization Act of 2008

Concerns regarding the increasing number of Earth science missions that were exceeding the 15 percent threshold established in the NASA Authorization Act of 2005 prompted a requirement in the NASA Authorization Act of 2008 for an independent review of the situation. Specifically, the Act directs the NASA Administrator to arrange for an independent external assessment to identify the primary causes of cost growth in large, medium, and small space and Earth science spacecraft mission classes. The external assessment is to also identify recommendations and provide a report within 15 months of the enactment of the Act. The National Research Council has been tasked by NASA to perform this review.

In addition, the Glory program was reauthorized in the NASA Authorization Act of 2008, responding to the requirement in the 2005 NASA Authorization Act that Congress evaluate whether to continue a major program in the event that it exceeds its originally estimated development cost by more than 30 percent.

GAO Reports

GAO has issued a number of reports dealing with cost and schedule problems in NASA's programs and with NASA's acquisition process:

- In its report of May 2004 on what it described as NASA's lack of disciplined cost-estimating processes [GAO-04-642], GAO stated that the considerable

flux it found in NASA's program cost estimates—both increases and decreases—was an indication that NASA lacked a clear understanding of how much its programs will cost and how long they will take to achieve their objectives. GAO found that the development cost estimates for more than half of the 27 programs it reviewed had increased, and that for some programs, this increase was significant—as much as 94 percent. GAO also reported that NASA's basic cost-estimating processes—an important tool for managing programs—lacked the discipline needed to ensure that program estimates were reasonable. GAO recommended 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. NASA concurred with GAO's recommendations.

- In March 2005, GAO reported [GAO-06-634] that the James Webb Space Telescope (JWST) program increased its life-cycle cost estimate from $3.5 billion to $4.5 billion and extended its schedule by almost 2 years. More than a third of the cost increase was caused by requirement additions and other changes. An increase in the program's contingency funding ["reserves"] accounted for the remainder—about 12 percent—of the growth. About half of the cost growth was due to schedule slippage. A delay by the Administration in approving the use of a European Space Agency-supplied Ariane 5 launch vehicle resulted in a 1-year delay; an additional 10-month slip was caused by NASA's budget profile limitations in fiscal years 2006 and 2007.

  GAO reported that although the JWST program revised its acquisition strategy to conform to NASA's acquisition policies, the program still faced considerable challenges because it has not fully implemented a "knowledge-based" approach to its acquisition. For example, GAO noted that when program officials initiated work and before the JWST program revised its acquisition strategy, these officials had intended to have NASA commit to program start with immature technologies and without a preliminary design. Despite the program's change in acquisition strategy to address GAO's concerns, GAO concluded that the revised plan still might not permit the maturity of key technologies to be adequately tested prior to program start. Consequently, GAO recommended that the NASA Administrator direct the JWST program to (1) fully apply a knowledge-based acquisition approach to ensure that adequate knowledge is attained at key decision points and (2) continue to adhere to NASA acquisition policy and go forward only after demonstrating that it is meeting incremental knowledge markers and has sufficient funds to execute the program. NASA concurred with GAO's recommendations.

- Following a review requested by this Committee's then-Ranking Member, Rep. Bart Gordon, GAO reported in December 2005 [GAO-06-218] that while NASA's revised policy for developing flight systems and ground support projects incorporated some of the best practices used by successful

developers, it lacked certain key criteria and major decision reviews that support a knowledge-based acquisition framework. For example, NASA's policy requires projects to conduct a major decision review before moving from formulation to implementation and that prior to moving from formulation to implementation, projects must validate requirements and develop realistic cost and schedule estimates. However, as GAO found, NASA's policies did not require projects to demonstrate technologies at high levels of maturity before program start. By not establishing a minimum threshold for technology maturity, GAO said that NASA increased the risk that design changes would be required later in development, when such changes are typically more costly to make. GAO made several recommendations to help ensure NASA uses a knowledge-based acquisition approach in making informed investment decisions. NASA concurred with GAO's recommendations.

In releasing GAO's report, Rep. Gordon said:

"As NASA embarks on an initiative to return American astronauts to the Moon - an endeavor estimated to cost more than $100 billion over the next 13 years - we need to have confidence that the agency will be good stewards of taxpayer dollars." He added *"In its report out today, the GAO offers some common-sense recommendations aimed at reducing the chances that NASA's projects will suffer cost growth and schedule delays. I hope NASA will take the GAO's guidance seriously."*

- This week, GAO released its report [GAO-09-306] assessing the status of 18 large-scale projects at NASA. GAO's independent assessment was conducted in response to the explanatory statement of the House Committee on Appropriations accompanying the Consolidated Appropriations Act of 2008; the Committee on Science and Technology was a co-requester of the assessment. Ms. Cristina Chaplain, a witness at this hearing, directed GAO's work and will highlight the report's findings to the Subcommittee. GAO compared projects against best practice criteria for system development including attainment of knowledge on technologies and design. The office found that 10 out of 13 projects that had entered the implementation phase of the project life-cycle experienced significant cost and/or schedule growth. For those projects, GAO found that development costs increased by an average of 13 percent from baseline cost estimates that were established just 2 or 3 years ago; average launch delay was 11 months.

  As an illustration, the development cost of the Mars Science Laboratory (MSL) increased in the past year by over $200 million—more than a 26% increase and now stands at over $1.2 billion. GAO anticipates that the MSL's development cost will be even greater due to the launch being delayed from October 2009 to 2011, a 25-month delay. Initially scheduled for September 2009, the next window of opportunity for a Mars launch occurs in the October/November 2011 timeframe. NASA notified the Committee of that

delay in December 2008, with the agency stating that a 2009 launch would be too risky because of technical uncertainties. Regarding the challenges faced by MSL, GAO reported that the program relied on several heritage technologies that had to be re-designed, re-engineered, or replaced. For example, the heat shield made of a light-weight material had flown on previous missions and was considered nearly ready. But a setback in testing forced NASA to select a new and less mature technology. Also, the initial decision to use dry lubricated lightweight titanium gears for rover actuators had to be revisited when NASA found, during fabrication, that the gears would not meet its durability needs. As a result, the project has had to revert to heavier stainless steel gears with a wet lubricant used by prior projects. To keep the lubricant from freezing in Martian temperatures, the project also had to add heaters. GAO said this increased the mass of the MSL's rover.

The underestimation of complexity resulting from the planned use of new or heritage technology is not unique to the MSL mission. GAO said that many of the projects reviewed indicated that they had experienced challenges in developing new technologies or retrofitting older technologies as well as in managing their contractors. From a general standpoint, NASA projects faced difficulty understanding the risks and challenges they were up against when they started their efforts. Challenges GAO identified included technology maturity, design stability, complexity of heritage technology, contractor performance, and performance by a development partner such as an international space agency. GAO did not make recommendations in this report as it acknowledged that NASA was undertaking an array of initiatives aimed at improving program management, cost estimating, and contractor oversight. However, GAO said that NASA would benefit from a more disciplined approach to its acquisitions and called for continued attention to NASA's efforts to enable the agency to maximize the effectiveness of its acquisition investments.

NRC's Review of NASA's Beyond Einstein Program

NRC released a report in September 2007 entitled "NASA's Beyond Einstein Program: An Architecture for Implementation". Prompted by Congress and the Office of Science and Technology Policy, NASA and the Department of Energy asked the committee to assess the five proposed mission concepts for achieving the goals of the Beyond Einstein space-based physics research initiative, and recommend one for first development and launch.

As part of its charge, the committee was tasked with determining the realism of preliminary technology and management plans, and cost estimates of the candidate Beyond Einstein mission set. Five mission areas—Joint Dark Energy Mission, Black Hole Finder Probe, Inflation Probe, and Einstein Great Observatories—comprised 11 mission candidates. Criteria used by the

committee included plans for the maturing of critical mission technology, technical performance margins, schedule margins, risk-mitigation plans, and the proposal's estimated costs versus independent probable cost estimates prepared by the committee.

The committee worked with an experienced outside contractor to develop independent cost estimates and a probable cost range for each candidate mission. The probable cost ranges were also compared with those of previous missions of similar scope and complexity. In all cases, the committee found higher costs and longer schedules than those estimated by the mission teams. The committee observed that this is typical of the differences between the estimates developed by mission teams and by independent cost estimators at this early stage of a program. Given the long history of missions comparable to the Beyond Einstein mission candidates, the committee said that it believed that the most realistic cost range for each of these missions is significantly more than the current estimates provided by the research teams.

In discussing its assessment of mission readiness, the committee stressed the importance of technology readiness as a key consideration in the decision to proceed to mission development. The committee said that ideally, mission development should not commence until all new technologies necessary for mission success have reached a certain level of technology readiness. Experience has shown, the committee added, "*that NASA and other missions pay the price when a mission enters development prematurely*".

NASA Self-Examinations

NASA research on incidents of cost and schedule growth and their causes is conducted by a number of organizations and individuals. Typically, according to NASA, this research is intended to assist the organization in evaluating performance trends; evaluate the effectiveness of their own organizational processes, tools and methods; and develop proposals for changes to their organization, processes, methods, and tools. NASA's Office of Program Analysis and Evaluation (PA&E) performs studies on an on-going basis and the topic of cost growth is frequently discussed at NASA Project Management Workshops and Cost Community Events such as a Cost Symposium. Because there is no clearinghouse for all cost estimating research being undertaken within NASA, the full extent of the agency's research in cost growth and schedule delay cannot be fully characterized. Nonetheless, the following four examples are illustrative of self examinations the agency has undertaken in recent years.

- In February 2004, NASA completed an analysis comparing initial and final budget estimates of development costs for 45 recent projects and computed percent budget growth as a surrogate for cost growth. The analysis found that an average cost growth of 36% and a median growth of 26%; 35 of 45 projects exceeded the initial budget estimate. The relative change from the

total of the 45 initial budgets to the total of the 45 final budgets indicated a total growth of 28%. In comparing historical budget growth trends in the Department of Defense (DOD) and NASA as well as describing the cost-estimating process changes made by DOD, NASA analysts suggested that NASA cost-estimating processes were in need of reform. But the analysts also listed a number of changes already in progress that would have beneficial impact, such as the then near-release of an update of NPR 7120.5 codifying the requirement for an Independent Program Assessment Office project review prior to the two key project milestones and requirements for a Cost Analysis Requirements Description (CARD) and a full continuum of sound cost- and program management practices; updating of NASA's Cost Estimating Handbook; and development of training tools for program managers. But the analysts also indicated that still needed was a method for capturing project cost, technical, and schedule data recorded in a standardized format and collected at a reasonable frequency.

- At a NASA Cost Symposium in July 2007, analysts from the Aerospace Corporation and NASA conducted a presentation entitled "Using Historical NASA Cost and Schedule Growth to set Future Program and Project Reserve Guidelines". Analysts discussed their investigation of the cost and schedule growth history for 40 science missions—the "mission set". By looking at historical schedule and cost growth, analysts sought to determine whether the past could be used to establish guidelines for the levels of reserves needed for future missions.

  Reserves are unallocated funds that are provided to counter risks to costs and schedule that are unanticipated; they reduce the probability that actual costs will overrun estimates. In essence, they act as contingency funds to address circumstances or outcomes that were not conceived of by an observer at a given point in time--what is commonly known in project planning as "*unknown* unknowns*"*. In contrast, "known unknowns*"* refers to circumstances or outcomes that are known to be possible, but for which it is unknown whether or not those outcomes or circumstances will be realized.

  Examination of the historical data set by the analysts from Aerospace and the Science Mission Directorate (SMD) showed that the majority of projects had experienced cost and schedule growth and that this cost and schedule growth was substantial. The average cost and schedule growth for the mission set was 27% and 22%, respectively. Analysts said the data highlighted that the primary internal reason for cost and schedule growth was instrument development issues, and the fundamental external reason for the growth was launch vehicle delay.

  Analysis of project reserves was challenging to the analysts. This is because reserve levels are not explicitly identified in NASA budget documents. Using NASA backup budget documents and other sources, analysts were able to

identify reserve values for eighteen of the forty missions were obtained. The cost reserve levels held by each mission varied from 10 to 30% while the average reserve was on the order of 18%. Additionally, although specific schedule reserve could not be identified from the budget, a general industry rule of thumb that was prevalent when these missions were developed was that a mission should carry one-month of schedule reserve for each year of development. This equates to an 8.3% schedule reserve for the project.

Suggestions provided by analysts from Aerospace and SMD included doing the following:

- Requiring better technical and programmatic definitions at the beginning of a project
- Independently assessing design and cost/schedule assumptions
- Performing earlier instrument development to reduce risk
- Holding instrument CDR prior to spacecraft and mission PDR
- Considering increased cost and schedule reserves for projects, some to be held outside the project

“Best Practices” for the control of cost and schedule in a project were also identified, including:

- Proper mission scoping
- Robust initial cost and schedule estimate
- Monthly estimates to complete
- Importance of managing to schedule
- Effective Use of Earned Value Management (EVM). Both the IMAGE and Stardust missions used EVM. EVM is a technique that compares 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 cost and time needed to complete the program, earned value can alert program managers to potential problems early in the program. As was stated for the IMAGE mission: “*The Earned Value system worked well as an early indicator of cost problems ahead*”

Analysts also stated that the real problem is that there is no incentive for any project manager to underrun cost estimates. They said that in today's culture, an underrun is considered evidence that the project manager did not do enough testing or analysis or should have added another instrument or made the resolution better. A secondary problem identified by the analysts was that project managers do not have the authority to control costs, such as not being able to remove excess personnel without Center Director approval. Until more control is given to the project manager and incentives are put into place to return funding, analysts concluded that cost growth will still occur.

- In March 2008, NASA's SMD, assisted by the Science Applications International Corporation (SAIC) presented a summary overview entitled "SMD Cost/Schedule Performance Study" before the NASA Advisory Council's Planetary Science Subcommittee. The objective of the study was to evaluate the cost/schedule performance record of selected SMD flight projects to determine key drivers of cost/schedule performance, and implementation approaches that enhance performance of SMD missions. Project Managers and other key staff members were interviewed to collect narrative descriptions to compare with and explain the detailed historical data. Among its findings, the study showed that:

  - Cost history data for 21 of the 24 projects studied indicated cost growth. Total cost growth from the start of the design phase to Estimate-to-Complete (ETC) at Launch for all projects studied represented a combined impact of $2.0 Billion to SMD's mission portfolio.
  - Schedule history data indicated schedule slips for 19 of the 24 projects studied. The delays ranged from 5 to 42 months.
  - Interview comments by eight projects cited early planning deficiencies as a significant source of development problems (underestimates, inexperience, inadequate early technology investment, and/or design heritage that was not realized).
  - The four projects that reported using EVM as a management tool showed lower average growth in development costs compared to projects that did not use EVM.

  Regarding the key drivers that affected cost/schedule performance for SMD projects, internal factors identified were over-optimism early in the project's formulation phase, as instrument development complexity. Launch service issues and unstable or inadequate initial funding profiles were cited as the most common external factors affecting cost and schedule. Among the study's recommendations to mitigate cost growth and schedule slips was one that SMD require more rigor in the process used to generate early cost and schedule estimates and establish a minimum set of requirements for a credible basis of estimate for mission concept costing. It was also recommended that projects be encouraged to include more conservatism in base estimates early in the process and be required to carefully evaluate all key project assumptions including design heritage credits.

- At a presentation before the Goddard Space Flight Center Symposium in June 2008, a member of the Aerospace Corporation discussed perspectives on mission cost and schedule performance trends, building on his team's review of 40 NASA robotic science missions. The team's findings included the following:

  - While estimates become more accurate as a project matures, the greatest growth manifests itself late in the project during integration and test.

- Data highlighted that the primary reason for cost and schedule growth is internal project technical and development issues often associated with instruments.
- Initial project estimates may be unreliable due to design and technology immaturity and inherent optimism.
- Better technical and programmatic appraisal early in the life cycle is needed along with independent assessment of design and programmatic assumptions.

In addition, the team analyzed the relationship between cost, schedule and complexity. A complexity index was established for the projects reviewed based on performance, mass, power and technology choices. The team plotted missions' cost versus complexity index and found a near linear rising "band" where successful missions cluster. On the other hand, those missions failed that were below that clustered range. This led the team to characterize this area as the "no-fly zone".

GAO's Characterization of NASA Acquisition Management as High Risk

Since 1990, GAO has periodically reported on government operations that it identifies as "high risk." This effort has brought focus to problems impeding effective government and costing the government billions of dollars each year. GAO's high-risk status reports are provided at the start of each new Congress. Historically, high-risk areas have been so designated because of traditional vulnerabilities related to their greater susceptibility to fraud, waste, abuse, and mismanagement. As GAO's high-risk program has evolved, it has increasingly used the high-risk designation to draw attention to areas associated with broad-based transformations needed to achieve greater economy, efficiency, effectiveness, accountability, and sustainability of selected key government programs and operations. In 1990, GAO designated NASA's contract management as high risk in view of persistent cost growth and schedule slippage in the majority of its major projects. Since that time, GAO's high-risk work has focused on identifying a number of causal factors, including antiquated financial management systems, poor cost estimating, and undefinitized contracts.

In the January 2009 update of its high risk list [GAO-09-271], GAO reported that since the 2007 high-risk update, NASA had taken significant steps to improve its acquisition management with the implementation of new policies and procedures and the development of a corrective action plan to address weaknesses in areas identified as high risk by GAO. For example, NASA revised its acquisition and engineering polices to incorporate elements of a knowledge-based approach that should allow the agency to make informed decisions. According to GAO, NASA is also instituting a new approach whereby senior leadership is reviewing acquisition strategies earlier in the process and developed broad procurement tenets to guide the agency's procurement practices. Among procurement policy

reforms, GAO noted that an earned value management procurement policy has been established and a requirement that all award fee contracts undergo a cost-benefit analysis has been codified to improve the likelihood that NASA is using its resources most effectively. GAO noted NASA's broad plan for reducing acquisition risk and observed that successful implementation of both the plan and revised policies should stem cost growth and schedule slippage.

However, GAO said that because cost growth and schedule delays persist, this area—now titled "acquisition management" because of the scope of issues that need to be resolved—remains high risk. GAO added that to maximize NASA's investment dollars, implementation needs to be complemented by vigorous executive leadership to foster the expansion of a business-oriented culture and a sustained commitment to identify and take action on projects that are not achieving cost, schedule or performance goals upon which they were based when they were initiated. Ms. Cristina Chaplain, who directed GAO's effort looking at NASA, is a witness at today's hearing and will highlight her team's findings.

Similarities between NASA and DOD in their Acquisition of Space Systems

GAO has reported that the costs for DOD space acquisitions over the past several decades have consistently been underestimated—sometimes by billions of dollars. For example, Space Based Infrared System High program costs were originally estimated at $4 billion, but the program is now estimated to cost over $10 billion. Estimated costs for the National Polar-orbiting Operational Satellite System program--conducted jointly by DOD, the National Oceanic and Atmospheric Administration and NASA--have grown from almost $6 billion at program start to over $11 billion.

GAO found in November 2006 [GAO-07-96] that, for the most part, cost growth in DOD space acquisitions has been caused by the tendency to start programs before knowing whether requirements can be achieved within available resources—largely because of pressures to secure funding. GAO reported that unrealistic program office cost estimates exacerbated space acquisition problems and that with budgets originally set at unrealistic amounts, DOD has had to resort to continually shifting funds to and from programs, and such shifts have had costly, reverberating effects.

GAO's analyses of six ongoing space programs shows some parallels with challenges faced by NASA. GAO found that original cost estimates were particularly unrealistic regarding the potential for savings from increased contractor program management responsibilities, the constancy and availability of the industrial base, savings that could be accrued from heritage systems, the amount of weight growth that would occur during a program, the availability of mature technology, the stability of funding, the stability of requirements, and the

achievability of planned schedules. Ms. Cristina Chaplain, who directed GAO's effort looking at DOD's space acquisitions, is a witness at today's hearing and will highlight her team's findings. In addition, Mr. Gary P. Pulliam, from the Aerospace Corporation, has been asked to comment on whether there are any similarities in cost growth and schedule delays experienced by NASA and the Department of Defense/other federal agencies in their acquisition of space systems, and whether there are any "lessons learned" that would be applicable to these organizations.

Latest Actions by NASA to Address Cost Growth and Schedule Delay in its Programs

In addition to agreeing to the recommendations made by GAO, NASA has implemented corrective actions on its own to address the issue of cost and schedule performance. For example, it has:

- Issued the 2008 NASA Cost Estimating Handbook (CEH), a reorganized and updated version of the 2004 handbook. According to NASA, the handbook provides useful information on cost estimating for the entire NASA Cost Estimating Community. It is meant to be both informative for the new cost estimator and a good reference document for the experienced cost estimator. Explanatory material accompanying the handbook indicates that based on the extensive feedback from the NASA Cost Estimating Community, the 2008 edition of the handbook has been streamlined to make references easy to find, simplified to make new initiatives easy to understand, and clarified to communicate key policy messages efficiently. The material also says that the handbook's information provides NASA-relevant perspectives and NASA-centric data useful in the NASA environment and facilitates the development of reliable, comprehensive, defensible, and well documented cost estimates.
- Instituted a policy of budgeting to the 70 percent confidence level. The policy, which is applicable to space flight and information technology programs and projects, is institutionalized in a new NASA Policy Directive (NPD 1000.5), effective January 15, 2009. Programs are to be budgeted at a confidence level of 70 percent or the level approved by an authority of the Agency-level management council. As an example, a 70 percent confidence level is the point on the joint cost and schedule probability distribution where there is a 70 percent probability that the project will be completed at, or lower than, the estimated cost and at or before the projected completion date. In the case of the Constellation program, the confidence level was set at 65% by then-Administrator Michael Griffin due to programmatic conclusions regarding the amount of technology heritage that would inform the Constellation designs.
- Emphasized educating NASA staff on the need for probabilistic cost and schedule estimating, how to do it, and providing enabling tools.
- Implemented independent assessments of projects through Standing Review Boards.

- Conducted in depth interviews with past NASA Program Managers to better understand root causes of cost growth and schedule delay. In particular, NASA recognized the need to fully understand which factors contributed the most.
- Collected ideas to improve cost and schedule estimates, such as spending more on R&D to mature technology readiness levels, developing instruments first, demanding better data to support claims at decision gates, and keeping requirements stable.
- Established, under the Office of the Chief Engineer, the Academy of Program/Project & Engineering Leadership (APPEL) which provides leadership, advice, direction, and support for the development and education of the NASA program/project management and engineering community. Among its numerous functions, the Academy facilitates the dissemination of "lessons learned" and "best practices" through knowledge sharing activities, including conferences, forums, publications, case studies, and communities of practice.

Risk Management and the Challenge Of Containing Project Costs

Meeting technical and safety goals while also meeting programmatic constraints related to cost and schedule is a tremendous challenge. To that end, identifying and managing risks can be of significant help, as they are closely related to cost management efforts—initially in the planning of the project when costs are estimated and later during development when cost fluctuations invariably occur. Since mission success is the primary goal of any NASA activity, the agency has recognized that effective risk management is critical to achieving that mission success. The implementation of a thorough, disciplined risk management approach is now required of all NASA programs and projects.

Because of the pressure to contain costs, difficult decisions often need to be made when unplanned increases occur. To manage cost increases, particularly when increased funding is not provided, NASA projects have in the past altered (1) the scope of the project, including the elimination of scientific instruments, (2) management oversight by reducing the number of personnel assigned to that function, and (3) the testing sequence or reduced the testing requirements.

When performed without sufficient recognition of risks, making such alterations can lead to catastrophic results as was demonstrated by the "lessons learned" activity following the failure of the Mars Climate Orbiter probe. That spacecraft, developed under the Faster, Better, Cheaper (FBC) mantra advanced by NASA in the 1990s, was lost as it was landing on Mars in September 1999. In its report on Project Management in NASA dated March 13, 2000, the Mars Climate Orbiter Mishap Investigation Board stated that:

"Greater attention needs to be paid to risk identification and management. Risk

management should be employed throughout the life cycle of the project, much the way cost, schedule and content are managed. Risk, therefore, becomes the "fourth dimension" of project management — treated equally as important as cost and schedule."

The Board also said that it saw strong evidence that the systems engineering team and the systems processes were inadequate on the project, adding that:

"Inadequate independent verification and validation of Mars Climate Orbiter ground software (end-to-end testing to validate the small forces ground software performance and its applicability to the software interface specification did not appear to be accomplished)."

With regards to reduced oversight, the Board noted:

"To exacerbate this situation, the mission was understaffed, with virtually no Jet Propulsion Laboratory oversight of Lockheed Martin Astronautics' subsystem developments. Thus, as the mission workforce was reduced and focus shifted from spacecraft development to operations, several mission critical functions — such as navigation and software validation — received insufficient management oversight."

The lesson learned, the Board said was that:

"In the era of "Faster, Better, Cheaper," projects and line organizations need to be extremely vigilant to ensure that a ***Mission Success First*** *attitude propagates through all levels of the organization. A proper balance of contractor and project oversight by technical divisions at NASA field centers is required to ensure mission success and to develop a sense of ownership of the project by the institution*."

Appendix A

NASA PROJECT MANAGEMENT STUDY (January 1981)
(Known as the "Hearth Study")

OBJECTIVES

- To assess project management in NASA
- To identify generic reasons which aggravate cost and schedule growth
- To recommend appropriate actions by NASA

SUMMARY CONCLUSIONS

- Significant contributors to cost growth of several NASA projects
    - Technical complexity of projects
    - Inadequate definition prior to commitment
    - Effect of low contractor bids
    - Poor tracking of contractor accomplishments
- Significant contributors to good cost performance of several NASA projects
    - The function of the NASA project manager
    - Adequate definition prior to commitment
    - Proper planning and management of reserves
    - Early understanding between NASA and implementing contractor
    - Good implementation by NASA and contractor(s)
- Not significant factors in cost growth of several NASA projects
    - Inability to make cost estimates when project well defined
    - Non-utilization of classified technologies
    - Excessive influence of "users"
- Difficulty to quantify effect of high inflation has contributed to cost growth in recent years
- Use and definition of reserves not consistent within NASA
- Ground segments have experienced cost growth and are not well defined prior to implementation
- Management of some projects assigned to multiple NASA Centers without timely interface definition
- Concurrent developments increase risk substantially
- Other concerns
    - Industry's workload, interest in NASA work, etc
    - Composition of NASA workforce

SUMMARY OF RECOMMENDATIONS

- Continue to pursue technically-advanced projects. Expect cost growth in some future projects.
- Require pre-project analysis and definition phases. Sufficient definition funding in NASA budget. Formal definition reviews. Require approved project initiation agreement and project plan.
- Select contractors primarily on technical considerations, management plans, past performance, etc.
- Issue NASA Policy to have adequate visibility of contractor activity. Center Directors responsible for policy implementation. Requires strong NASA in-house capability and adequate center resources.
- Fund implementing contractor at low level to develop thorough understanding. NASA project manager reconfirms or changes initial commitment.
- Provide completion costs of major projects in terms of budget-years dollars.
- Issue NASA Policy to have adequate reserves in all major projects. Based on definition maturity, risk, technical complexity, and concurrent developments. Managed by Headquarters program manager and project manager.
- General practice, minimize NASA management interfaces. When teaming of NASA Centers is appropriate, define interfaces prior to project implementation.
- Revise and re-issue NASA management Instructions defining project management policies.