Statement of
Mr. Gary P. Pulliam
Vice President, Civil and Commercial Operations
The Aerospace Corporation

before the

Subcommittee on Space and Aeronautics
Committee on Science and Technology
U.S. House of Representatives
Honorable Gabrielle Giffords, Chairwoman

March 5, 2009

Madam Chairwoman and Members of the Subcommittee:

I am pleased to present The Aerospace Corporation's findings, assessments, and recommendations on cost and schedule management issues in NASA's programs.

The Aerospace Corporation

The Aerospace Corporation is a private, nonprofit corporation, headquartered in El Segundo, California. Aerospace was created in 1960 at the recommendation of Congress and the Secretary of the Air Force to provide research, development, and advisory services to the United States government in the planning and acquisition of space, launch, and ground systems and their related technologies. We provide a stable, objective, expert source of engineering analysis and advice to the government, free from organizational conflict of interest. We are focused on the government's best interests, with no profit motive or predilection for any particular design or technical solution.

Aerospace does not compete with industry for government contracts, and we do not manufacture products. The government relies on Aerospace for objective development of pre-competitive system specifications and impartial evaluation of competing concepts and engineering hardware developments to ensure that government procurements can meet the user's needs in a cost-and-performance-effective manner.

Aerospace employs about 4,000 people of whom 2,700 are scientists and engineers with expertise in all aspects of space systems engineering and technology. As its primary activity, Aerospace operates a Federally Funded Research and Development Center sponsored by the Under Secretary of the Air Force and managed by the Space and Missile Systems Center in El Segundo, California. Our principal tasks are systems planning, systems engineering, integration, flight readiness verification, operations support, and anomaly resolution for National Security Space (NSS) systems. Through our comprehensive knowledge of space systems and our sponsor's needs, our breadth of staff expertise, and our long term, stable relationship with the

government, we are able to integrate technical lessons learned across all NSS space programs and develop system-of-systems architectures that integrate the functions of many separate space and ground systems.

The Aerospace Corporation also undertakes projects for civil agencies, including the National Aeronautics and Space Administration (NASA). Such projects contribute to the common good of the nation while broadening the knowledge base of the corporation. Aerospace's support to NASA includes work on solutions to the foam and ice debris damage that resulted in the loss of the Space Shuttle Columbia, analysis of alternatives to robotically servicing the Hubble Space Telescope, and contributions to the Mars Exploration Rovers program. Our support to NASA includes its headquarters and virtually all directorates as well as almost every NASA Center. NASA and the NSS clients emphasize different areas when they task Aerospace. NASA requests far less support but proportionately more programmatic and budgeting support while the NSS clients place primary emphasis on technical support. While Aerospace certainly does not have full and complete insight into all NASA programs and projects, nor do we support all NASA programs, we have a unique relationship with NASA and have unique insights which we are privileged to share with the committee.

The subcommittee asked us to focus our testimony on: 1) Identifying the main causes of cost growth and schedule delays in NASA programs and projects found during the course of The Aerospace Corporation's body of work at NASA; 2) Assessing the effectiveness of NASA's efforts in mitigating them; and 3) Identifying, in the context of The Aerospace Corporation's work at other federal agencies, any similarities in cost growth and schedule delays experienced at NASA.

Identifying the main causes of cost growth and schedule delays in NASA programs and projects found during the course of The Aerospace Corporation's body of work at NASA

Aerospace has enjoyed a relationship with NASA for many years. We have studied NASA project cost and schedule for the Administrator, Associate Administrator, the Office of Program Analysis and Evaluation, Headquarters Mission Directorates, and many NASA Centers. Our work with NASA reveals that cost growth and schedule delays result from a variety of complex reasons.

In recent years, NASA has commissioned several studies to determine the primary contributing factors to cost and schedule growth. These studies, as well as others in the field, identified several common themes: significant optimism in initial designs, changes in scope associated with the evolution of the design over time, the inherent technical difficulty of developing world class technologies, and the effect of external influences on the project such as funding instability. Although the conclusions stated above are primarily drawn from the analysis of a subset of NASA's science missions, we believe that the observations are applicable to a broader array of NASA projects.

Optimism in Initial Design

NASA, as part of its charter, conducts unprecedented exploration and science. These missions continually push the envelope of the capabilities required by its human spaceflight and scientific instruments and spacecraft. The novelty and value of these science instruments are indisputable, as evidenced by the recent discovery by the Fermi Gamma Ray Space Telescope of the highest-energy gamma-ray burst ever recorded. At the same time, there is significant competitive pressure, both within NASA and among its contractors, to initiate a mission at the lowest possible cost. As noted by former NASA Administrator James Webb, it is not unusual for teams to "put their best foot forward" when proposing a new mission. In a recent study of the cost and schedule growth of 40 NASA science missions, only 5 of the 40 missions investigated resulted in no cost and schedule growth while over a quarter experienced cost growth greater than 40% above and beyond the project's internal cost reserves. In some cases, the content or complexity

of the technical baseline is underappreciated. In other cases, the initial estimate of technical resources such as mass or power is inadequate or reliance on heritage systems is overstated. The initial inadequate technical baseline and/or poorly defined requirements lead to an artificially low initial cost estimate resulting in significant cost growth beyond the project's internal cost reserves. Furthermore, optimism may be introduced into the cost estimating process from empirical cost models that do not incorporate cancelled missions, missions currently in development that are experiencing difficulties, or missions whose actual costs have been omitted or modified based on "unusual" circumstances. Another key driver of a project's final cost is schedule risk, which is often not adequately captured, making the initial schedule incompatible with the budget, resulting in an overall plan that is not executable. In summary, the optimism in the initial design starts the cycle, which is exacerbated by limitations in the cost estimating process.

Scope Changes as the Design Evolves

The natural progression of a mission from its early conceptual design through its detailed design and implementation typically requires that resources (weight, power, performance etc.) be added to meet stressing requirements. This growth in required spacecraft resources results in an associated cost growth. The understatement of the required resources is built into how the cost of the initial technical baseline is estimated. For example, while a recent historical study of robotic science missions observed that mass grew over 40% on average from initial design inception to flight design, large mass growth factors are typically not applied in determining a cost estimate. Often, the complexity of the development effort, underestimated at the outset, is more fully understood as the development progresses. While the accuracy of project estimates improves over time, cost growth, over and above reserves, still occurs deep into the project life cycle. In short, the concept that is proposed is often not what is built. The initial cost estimate is likewise not representative of the final, as-built configuration due to required changes as the understanding of the design evolves. In essence, cost estimators are trying to estimate a moving target as projects progress toward their final design form.

Inherent Difficulty of Developing World Class Technologies

NASA is continually pushing the technological envelope to reach its science objectives. The difficulty of landing a piece of hardware the size of a small car on the surface of another planet is only one example of the challenges that NASA faces on a regular basis. Each NASA development is unique, technically challenging and inherently difficult. To confront these challenges, technology is essential. The lack of mature critical technologies at project start contributes to the cost and schedule growth. A generally accepted risk avoidance practice is to fund focused technology development prior to system development. NASA, however, has reduced technology development funding in many areas due to budget constraints. Technology immaturity in science missions is often most apparent in instrument development, as opposed to spacecraft. Instrument development difficulties often lead to schedule delays in which a "marching army" cost is incurred awaiting instrument delivery. Additional investment to mature instruments, prior to the start of full project development, could potentially lead to reduced cost and schedule growth for science missions.

External Influences

External influences can have a major effect on cost and schedule performance. From the program or project manager's perspective, whether change comes from Congress or from inside NASA, the effects are the same. Examples of external influences outside a project's control include budget modifications, funding instability, changes in requirements or priorities, and launch vehicle delays. The project manager depends on access to unallocated budget, or reserves, to

address problems. When Headquarters or Congress reassigns budget or change priorities, it is often at the cost of increased execution risks that fall outside of a given project's ability to accommodate within reserves. Within a portfolio, cost growth in one project may result in reducing funding to other projects making them all less executable. The resulting domino effect impacts all missions that follow as missions that have not started are postponed or missions early in their development are stretched to fit annual budget constraints.

Assessing the effectiveness of NASA's efforts in mitigating them (cost and schedule delays)

NASA initiated several measures to mitigate cost and schedule growth since the middle of this decade. Some of these measures are strategic in nature, such as budgeting at the 70% confidence level, and some are more tactical, such as the collection of historical data to provide a sound basis for new cost and schedule methodology development. Schedule estimation, which is a relatively new capability within the industry, is an area in which NASA is investing to improve the state of the practice commensurate with the more mature cost analysis methodologies. Affordability analysis, which allows examination of portfolio interactions, longer-range planning/analysis, and evaluation of cost risk and reserve policies, is another capability in which NASA has invested. Several introspective studies were commissioned to more fully understand the reasons for cost and schedule growth and provide recommendations on how to limit growth. The majority of these studies received peer review and have been published in the public domain. The progress in each of these areas is commendable.

The collection of cost, schedule, and technical data is vital to developing representative cost and schedule models that are based in historical fact. NASA has embarked on an initiative to collect data, the Cost Analysis Data Requirement (CADRe) initiative. Aerospace is a contributor to this effort. Prior to the CADRe initiative, NASA's historical cost and schedule data collection from the early 1990s had been scarce and was based primarily upon the ability of individual organizations or programs to gather their own cost data. The CADRe initiative has institutionalized collection of data at specific milestones for a large set of missions across a large number of organizations. This data is invaluable in understanding and analyzing the cost and schedule growth of NASA projects and identifying contributing factors and causal relationships.

In spite of these efforts, significant uncertainty remains in the cost estimating process. To offset this uncertainty, NASA has moved to estimating cost in a probabilistic fashion where a range of cost is estimated with associated confidence levels. NASA has also instituted a new requirement for budgeting projects at a higher level of confidence than previously experienced with a goal of giving projects a 70% chance of successfully meeting their budget. The validity of this approach, however, depends on the stability and soundness of the baseline. Every project has a budget estimate set by many inputs. Significant changes in these underlying assumptions and technical baseline will reduce the program's budget confidence. Furthermore, substantial differences of opinion remain within the cost-estimating community on how to develop and interpret probabilistic estimates.

For effective NASA cost and schedule performance execution, the project must manage to a valid baseline estimate. One area of concern for the NASA project managers is the relevance and utility of independent cost estimates they do not own. Different methodologies are used by the project and independent estimate such that there is not a common understanding of the basis of estimate for each. Projects typically use bottoms up estimates that do not necessarily incorporate all of the risks. The disconnect between independent cost estimates and project estimates is exacerbated by the fact that unanticipated risks often manifest themselves late in development cycle during integration and test, when it is often too late to make adjustments. Greater transparency into the basis of estimate for each approach is important and needs to be communicated in ways that both the cost estimating community and project managers

understand and recognize. One effort underway to strengthen the connection between an independent cost estimate and the project estimate is to include the effects of risk and risk mitigation to promote the project's ownership of the estimate. Incorporating the project's assessment of risks into the cost estimating process earlier and more often can put greater validity into the project's baseline cost estimate and provide a more robust reserve posture and promote the project's ownership of the estimate. NASA is using aspects of this philosophy on some of its projects. Continued expansion of its use should reduce unexpected cost and schedule growth in the future.

The results of these measures have not yet had time to reach fruition as missions developed under the new initiatives have not yet been fully deployed. New methodologies such as schedule analysis tools and strategic mission portfolio models take time to influence project and program design in order to develop more robust project and program plans. Although it is too early to make an assessment, the studies that NASA has conducted and the initiatives that NASA has begun should move the agency toward a more positive outcome and improve the ability to predict and control cost and schedule in its future.

Identifying, in the context of The Aerospace Corporation's work at other federal agencies, any similarities in cost growth and schedule delays experienced by NASA

NASA is not alone in facing challenges in cost and schedule growth. The causes outlined above including optimism, growth, technology, and external influences, are not unique to NASA. The military procurement system has been analyzed for decades. Dozens of major commissions, panels, and academic studies have echoed these same issues, and we generally concur with the findings. The Aerospace Corporation's current and previous Presidents supported the May 2003 Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs. That group reported:

> *The space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the acquisition process. These estimates lead to unrealistic budgets and unexecutable programs.*

The Task Force went on to note the need for new technology and the impact of technology risk on cost and schedule risk.

In its most recent critique of defense acquisition, the Government Accountability Office noted:

> *Invariably, the Department of Defense and the Congress end up continually shifting funds to and from programs – undermining well-performing programs to pay for poorly performing ones. At the program level, weapon system programs are initiated without sufficient knowledge about requirements, technology, and design maturity. Instead, managers rely on assumptions that are consistently too optimistic, exposing programs to significant and unnecessary risks and ultimately cost growth and schedule delays." (Defense Management: Actions Needed to Overcome Long-standing Challenges with Weapon Systems Acquisition and Service Contract Management. GAO-09-362T, February 11, 2009)*

While each federal agency can point to unique problems and circumstances which impact project development, the fundamental challenges of good cost and schedule estimating and performance are remarkably similar across federal agencies.

Conclusion

NASA's challenging mission includes a varied portfolio and substantial technological challenges. Many factors contribute to cost and schedule growth, but optimism in initial designs, changes in scope over time, the inherent technical difficulty of maturing technologies, and external influences are common themes we found. Many of these conditions and constraints exist for other federal agencies. NASA has initiated several measures to mitigate cost and schedule growth and these efforts should provide positive results over the next few years.

The Aerospace Corporation is pleased that the subcommittee requested we offer our views and stand ready for your questions.

Further Reading

1) Bearden, D., Boudrough R., and Wertz J., Chapter on "Cost Modeling", Reducing the Cost of Space Systems, Microcosm Press, 1998.
2) Apgar, H., Bearden D. and Wong R., Chapter on "Cost Modeling", Space Mission Analysis and Design (SMAD) 3rd edition, Microcosm Press, 1999
3) Bearden, David A., "A Complexity-based Risk Assessment of Low-Cost Planetary Missions: When is a Mission Too Fast and Too Cheap?", Fourth IAA International Conference on Low-Cost Planetary Missions, JHU/APL, Laurel, MD, 2-5 May, 2000.
4) Bearden, David A., "Small Satellite Costs", Crosslink Magazine, The Aerospace Corporation, Winter 2000-2001.
5) Bitten, R., Lao, N., Muhle, J., "Joint Government/Industry Space Programs: Lessons Learned And Recommendations", SPACE 2001 Conference, 28–30 August 2001
6) Bitten R.E., Bearden D.A., Lao N.Y. and Park, T.H., "The Effect of Schedule Constraints on the Success of Planetary Missions", Fifth IAA International Conference on Low-Cost Planetary Missions, 24 September 2003.
7) Bitten R.E., Emmons D., Min I.A., and Radcliffe T.O., "An Integrated Architecture Design/Cost/Scheduling Approach for Future Space Exploration Program Affordability," 1st Space Exploration Conference, 30 January – 1 February 2005.
8) Bearden, D.A., "Perspectives on NASA Robotic Mission Success with a Cost and Schedule-constrained Environment", Aerospace Risk Symposium, Manhattan Beach, CA, August 2005.
9) Bitten R.E., Bearden D.A., Emmons D.L., "A Quantitative Assessment of Complexity, Cost, and Schedule: Achieving A Balanced Approach For Program Success", 6th IAA International Low Cost Planetary Conference, Japan, 11-13 October 2005.
10) Bitten R.E., "Determining When A Mission Is "Outside The Box": Guidelines For A Cost-Constrained Environment", 6th IAA International Low Cost Planetary Conference, 11-13 October 2005.
11) Bitten R., Emmons D., Freaner C., "Using Historical NASA Cost and Schedule Growth to Set Future Program and Project Reserve Guidelines", IEEE Aerospace Conference, Big Sky, Montana, 3-10 March 2007.
12) Emmons D., "A Quantitative Approach to Independent Schedule Estimates of Planetary & Earth-orbiting Missions", 2008 ISPA-SCEA Joint International Conference, Netherlands, 12-14 May 2008.
13) Freaner C., Bitten R., Bearden D., and Emmons D., "An Assessment of the Inherent Optimism in Early Conceptual Designs and its Effect on Cost and Schedule Growth", 2008 SSCAG/SCAF/EACE Joint International Conference, Noordwijk, The Netherlands, 15-16 May 2008.
14) Bearden D. "Perspectives on NASA Mission Cost and Schedule Performance Trends", Presentation at GSFC Symposium, 3 June 2008.