United States Government Accountability Office
Washington, DC 20548

July 17, 2006

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

Subject: *NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge*

The National Aeronautics and Space Administration (NASA) plans to spend nearly $230 billion over the next two decades implementing the Vision for Space Exploration. In January 2006, NASA publicly released its Exploration Systems Architecture Study (ESAS), which is an effort to identify the best architecture and strategy to implement the President's 2004 *Vision for Space Exploration (Vision)*.[1] The cost estimate for implementing the ESAS through fiscal year 2011 exceeds $31 billion. The estimate through fiscal year 2018 is over $122 billion, and the estimate through fiscal year 2025 is nearly $230 billion.[2] These estimates include the architecture, robotic precursor missions, supporting technologies, and funding needed to service the International Space Station (ISS).[3] NASA plans to implement this architecture through a "go as you can afford to pay" approach, wherein lower-priority efforts would be deferred, descoped, or discontinued to allow NASA to stay within its available budget profile. This approach assumes NASA's budget will increase moderately to keep pace with inflation. Given the long-term fiscal imbalances that will challenge the entire federal government now and in the future, it would be prudent for NASA to establish a program that reduces the risk that significant additional funding, beyond moderate increases for inflation, will be required to execute the program.[4] Government leaders will have to make difficult

[1] The ESAS architecture supports the development of a new Crew Exploration Vehicle (CEV), Crew Launch Vehicle (CLV), a Cargo Launch Vehicle (CaLV), and other supporting systems. The architecture also calls for various Research and Technology (R&T) and Robotic Lunar Exploration Program (RLEP) projects.
[2] All cost estimates related to the *Vision* are reported as inflated ("real year") dollars.
[3] NASA's cost estimate through 2011—$31.2 billion—included the costs of the R&T and RLEP projects needed to support the architecture. Its estimate for the first lunar landing—$104 billion—did not include $18 billion in funding for R&T and RLEP projects. To ensure consistency, the estimates for 2018 and 2025 are presented with R&T and RLEP funding included.
[4] GAO, *21st Century Challenges: Reexamining the Base of the Federal Government*, GAO-05-325SP (Washington, D.C.: Feb. 2005); *21st Century: Addressing Long-Term Fiscal Challenges Must Include a Reexamination of Mandatory Spending*, GAO-06-456T (Washington, D.C.: Feb. 15, 2006); and

decisions to resolve such challenges, and the debate over the potential cost and the federal government's role in implementing the *Vision* are emblematic of the challenges the nation will need to resolve in the years ahead.

Because of the significance of this investment, competing demands on the federal discretionary budget, and the importance of the success of NASA's exploration program to the future of U.S. human spaceflight, you requested that we assess (1) the extent to which NASA has identified the architecture and costs necessary to implement the *Vision*, (2) whether NASA's exploration architecture cost estimates fit within the agency's projected available budgets, and (3) the risks associated with NASA's acquisition strategy for the CEV project.

We presented our preliminary findings to your staff in May 2006. Because of your committee's interest in how NASA is implementing the *Vision for Space Exploration*, we are enclosing the full briefing that supported that May presentation with this report (see encl. II), along with a summary of our findings and conclusions. We are recommending that the NASA Administrator modify the current CEV acquisition strategy to ensure that the agency does not commit itself, and in turn the federal government, to a long-term contractual obligation prior to establishing a sound business case at the project's preliminary design review. In written comments, NASA nonconcurred with our recommendation and stated that it has the appropriate level of knowledge to proceed with its current acquisition strategy. As a result of its nonconcurrence, we are including as a matter for congressional consideration that the Congress should consider restricting NASA's appropriations and obligations for the CEV project to only the amount of funding necessary to successfully complete the project's preliminary design review.

Background

The *Vision* includes plans to explore the moon, Mars, and beyond.[5] The first step in implementing the *Vision* is to retire the space shuttle after completing assembly of the ISS by the end of the decade. NASA currently plans to retire the space shuttle in 2010, creating a potential gap in U.S. human spaceflight of up to 4 years before development of the CEV and the CLV is complete. Congress has voiced concern over the United States not having continuous access to space, and NASA has made it a priority to minimize the gap by accelerating the CEV project to have it in service as close to 2010 as possible. NASA's Exploration Systems Mission Directorate's (ESMD) Constellation program is responsible for the development of both the CEV and the CLV. NASA awarded concept development contracts for the CEV project to both Lockheed Martin and Northrop Grumman in July 2005 and plans to award a contract for design, development, production and sustainment in September 2006. That contract could extend through 2019. For the CLV, NASA plans to award a sole-source

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Highlights of a GAO Forum: The Long-Term Fiscal Challenge, GAO-05-282SP (Washington, D.C.: Feb. 1, 2005).

[5] The *Vision* includes a return to the moon that is intended ultimately to enable future exploration of Mars and other destinations. To accomplish this, NASA initially plans to (1) complete its work on the International Space Station by 2010, fulfilling its commitment to 15 international partner countries; (2) begin developing a new manned exploration vehicle to replace the space shuttle; and (3) return to the moon no later than 2020 in preparation for future, more ambitious missions.

contract for the first stage of the CLV to ATK-Thiokol, the manufacturer of the Shuttle's Reusable Solid Rocket Motor, in October 2006. Also, the agency plans to award Pratt & Whitney Rocketdyne, the developer of the Space Shuttle Main Engine (SSME) and J-2 engines, a sole-source contract for development of the J-2X engine in November 2006. These contractors are currently planning their respective efforts under interim contract arrangements. NASA has started in-house preliminary design work on the CLV upper stage structures and avionics and plans to begin awarding competitive contracts for production of these items in May 2007.

Despite many successes in the exploration of space, such as landing the Pathfinder and Exploration Rovers on Mars, the loss of life, unsuccessful missions, and unforeseen cost overruns have recently increased the level of concern over the benefits of such exploration, particularly with regard to human spaceflight activities. NASA has had difficulty bringing a number of projects to completion, including several efforts to build a second generation of reusable human spaceflight vehicle to replace the space shuttle. NASA has attempted several expensive endeavors such as the National Aero-Space Plane, the X-33 and X-34, and the Space Launch Initiative, among others. While these endeavors have helped to advance scientific and technical knowledge, none have completed their objective of fielding a new reusable space vehicle. We estimate that these unsuccessful development efforts have cost approximately $4.8 billion since the 1980s. The high cost of these unsuccessful efforts and the potential costs of implementing the *Vision* make it important that NASA achieve success in its new exploration program.

Our past work has shown that developing a sound business case, based on matching requirements to available and reasonably expected resources before committing to a new product development effort, reduces risk and increases the likelihood of successful outcomes.[6] At the heart of a business case is a knowledge-based approach to product development that is a best practice among leading commercial firms and successful government system developers. For a program to increase its chances of delivering a successful product, high levels of knowledge should be demonstrated before managers make significant program commitments. In essence, knowledge supplants risk over time. This building of knowledge can be described as three levels that should be attained over the course of the program:

(1) At program start, the customer's needs should match the developer's available resources in terms of availability of mature technologies, time, human capital, and funding.
(2) Midway through development, the product's design should be stable and demonstrate that it is capable of meeting performance requirements.

[6] Examples of our best practices reports include GAO, *Best Practices: Using a Knowledge-Based Approach to Improve Weapon Acquisition*, GAO-04-386SP (Washington, DC.: Jan. 2004); *Space Acquisitions: Committing Prematurely to the Transformational Satellite Program Elevates Risks for Poor Cost, Schedule, and Performance Outcomes*, GAO-04-71R (Washington, D.C.: Dec. 4, 2003); Best *Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: Jul. 15, 2002); and *Best Practices: Better Matching of Needs and Resources Will Lead to Better Weapon System Outcomes*, GAO-01-288 (Washington, DC.: Mar. 8, 2001).

(3) By the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets, and have demonstrated its reliability.

Our work has shown that programs that have not attained the level of knowledge needed to support a sound business case have been plagued by cost overruns, schedule delays, decreased capability, and overall poor performance. With regard to NASA, we have reported that in some cases the agency's failure to define requirements adequately and develop realistic cost estimates—two key elements of a business case—resulted in projects costing more, taking longer, and achieving less than originally planned.

Summary

Although NASA is continuing to refine its exploration architecture cost estimates, the agency cannot at this time provide a firm estimate of what it will take to implement the architecture. The absence of firm cost estimates is mainly due to the fact that the program is in the early stages of its life cycle. According to NASA cost-estimating guidance, early life cycle phase estimates are generally based upon parametric models, which use data from projects with similar attributes to predict cost because there are usually many unknowns and actual cost or performance data are not available. NASA preliminarily identified the resources needed to implement the architecture as outlined in the architecture study primarily through the use of such models. NASA conducted a cost risk analysis of its preliminary estimates through fiscal year 2011. On the basis of this analysis and through the addition of programmatic reserves (20 percent on all development and 10 percent on all production costs), NASA is 65 percent confident that the actual cost of the program will either meet or be less than its estimate of $31.2 billion through fiscal year 2011. For the cost estimates for beyond 2011, when most of the cost risk for implementing the architecture will be realized, NASA has not applied a confidence level distinction. Since NASA released its preliminary estimates, the agency has continued to make architecture changes. For example, following the issuance of the architecture study, NASA conducted several analysis cycles during which various aspects of the architecture have evolved, such as the diameter of the CEV, the engine used to support the upper stage of the CLV, and the size of the Reusable Solid Rocket Booster on the CLV. While these changes, and others, are appropriate for this phase of the program, when concepts are still being developed, they leave the agency in the position of being unable to firmly identify program requirements and needed resources, which can also be expected at this phase of the program. According to NASA officials, once they receive more detailed contractor inputs, the agency will be able to produce higher-fidelity estimates of program cost. NASA plans to commit to a firm cost estimate at the preliminary design review (PDR) in 2008, when the program's requirements, design, and schedule will all be baselined.

NASA will be challenged to implement the architecture recommended in the study within its projected budget. Whether using the architecture study estimates of funds available or NASA's Fiscal Year 2007 Budget Submission for ESMD that was based on the architecture study cost estimates, there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources. NASA

maintains that the architecture could be implemented within the projected available budgets through fiscal year 2011 when funding is considered cumulatively. In addition, NASA preliminarily projects multibillion-dollar shortfalls for ESMD in all fiscal years from 2014 to 2020, with an overall deficit through 2025 of over $18 billion. In the short term, NASA is attempting to address this problem within the Constellation program by redirecting funds to that program from other ESMD activities to provide a significant surplus for fiscal years 2006 and 2007 to cover projected shortfalls beginning in fiscal year 2009. In addition, the Constellation program has requested more funds than required for its projects in several early years to cover shortfalls in later years. For example, the Exploration Communication and Navigation Systems project within the Constellation program plans to roll over $56.2 million from the fiscal year 2007 budget to make up for budget shortfalls in fiscal years 2008, 2009, and 2010. NASA officials stated the identified budget phasing problem could worsen given that changes made to the exploration architecture following issuance of the study will likely add to the near-term development costs, where the funding is already constrained. In addition, NASA's estimates beyond 2010 are based upon a surplus of well over $1 billion in fiscal year 2011 due to the retirement of the space shuttle fleet in 2010. However, NASA officials said the costs for retiring the space shuttle and transitioning to the new program are not fully understood, and thus the expected surplus could be less than anticipated.

NASA's current acquisition strategy for the CEV places the project at risk of significant cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. NASA plans to award a contract for the design, development, production, and sustainment of the CEV in September 2006—before it has developed key elements of a sound business case, including well-defined requirements, a preliminary design, mature technology, and firm cost estimates. The period of performance for the contract scheduled for award in September 2006 will extend through at least 2014, with the possibility of extending through 2019. This contract will comprise all design, development, and test and evaluation activities, including production of ground and flight test articles and at least four operational CEVs. Although NASA is committing to a long-term contract, it will not have the elements of a sound business case in place until the project level PDR in fiscal year 2008. Awarding a contract for design, development, production, and sustainment of the project as NASA has planned places the CEV project at increased risk of cost growth, schedule delays, and performance shortfalls. At PDR, NASA will likely (a) have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project, (b) be in a better position to commit the government to a long-term effort, and (c) have more certainty in advising Congress on required resources.

Implementing the *Vision* over the coming decades will require hundreds of billions of dollars and a sustained commitment from multiple Administrations and Congresses over the length of the program. The realistic identification of the resources needed to achieve the agency's short-term goals would provide support for such a sustained commitment over the long term. With a range of federal commitments binding the fiscal future of the United States, competition for resources within the federal government will only increase over the next several decades. Consequently, it is incumbent upon NASA to ensure that it is wisely investing its existing resources. As NASA begins to implement the *Vision* with several key acquisition decisions planned to occur this fall, it will be essential that the agency ensure that the investment decisions it is making are sound and are based upon high levels of knowledge. NASA should make the prudent decision now to ensure that it has attained the appropriate level of knowledge to support a sound business case before it commits to the project. However, under the current acquisition strategy for CEV, key knowledge—including well-defined requirements, a preliminary design, mature technology, and firm cost estimates—will not be known until over a year after the expected contract award date. Nevertheless, NASA plans to commit the government to a long-term contract. This approach increases the risk that the project will encounter significant cost overruns, schedule delays, and decreased capability. Given the nation's fiscal challenges and those that exist within NASA, the availability of significant additional resources to address such issues, should they occur, is unlikely. With the impending decisions pertaining to the CEV, NASA has the opportunity to establish a firm foundation for the entire Constellation program by ensuring that the appropriate level of knowledge is available before proceeding with its acquisition strategy and committing the government to a long-term design, development, and production effort.

Recommendation for Executive Action

Because of the importance of the CEV project to NASA's overall implementation of the *Vision*, NASA should focus on ensuring that its acquisition approach for the CEV project does not place the government at risk by committing to a long-term design and development effort without the knowledge needed to make wise investment decisions. We therefore recommend that the NASA Administrator modify the current CEV acquisition strategy to ensure that the agency does not commit itself, and in turn the federal government, to a long-term contractual obligation prior to demonstrating, through the establishment of a sound business case at the project's preliminary design review, that the project is affordable and executable.

Matter for Congressional Consideration

Based on its response to our report, it appears that NASA plans to proceed with its acquisition strategy for the CEV and award a long-term contract for the project, although it continues to lack sufficient knowledge and a sound business case for doing so. Congress is currently being asked to approve NASA's fiscal year 2007 funding request and will be asked to approve fiscal year 2008 and perhaps the fiscal year 2009 funding requests for the CEV project before NASA has demonstrated such knowledge and has provided evidence, based on that knowledge, that the project will be executable within existing and expected resources. In light of the fact that NASA plans to award the contract for the CEV in September 2006, Congress should consider restricting annual appropriations and limiting NASA's obligations for the CEV project to only the amount of funding necessary to support activities needed to successfully complete the project's preliminary design review.

Agency Comments and Our Evaluation

In written comments on a draft of this report (see encl. I), NASA nonconcurred with our recommendation that it modify the current CEV acquisition strategy to ensure that the agency does not commit itself, and in turn the federal government, to a long-term contractual commitment prior to establishing a sound business case at the project's preliminary design review. NASA stated that it has the appropriate level of knowledge to proceed with its acquisition plan to "down select" to a single Crew Exploration Vehicle prime contractor in September 2006. NASA added that it is maximizing competition by soliciting from industry a development, production, and management approach with an emphasis on life cycle cost. In the area of technology maturity, NASA stated that it has a plan and process in place to address the Thermal Protection and Landing subsystems technology risks through in-house development work and collaboration with the prime contractor. NASA also noted that during its design, development, and test and evaluation effort, the agency will be using an end-item award fee, which would make all award fees subject to a final evaluation to determine how well the product met requirements, including cost and schedule.

The CEV acquisition strategy is not knowledge-based in that it calls for maturing technologies, designing systems, and preparing for initial production concurrently—an approach that our work has shown carries the increased risk of cost and schedule overruns and decreased technical capability. Therefore, we disagree with NASA's statement that it has the appropriate level of knowledge to proceed with its current acquisition strategy and award a long-term contract for the project prior to obtaining sufficient knowledge. Specifically:

- In its response, NASA suggests that there would be no benefit in retaining two prime contractors for the CEV project through the preliminary design review and that the best return on its investment would be gained by down-selecting to one contractor and awarding the contract in September 2006. Contrary to NASA's response, addressing our recommendation would not preclude the agency from down-selecting to one contractor. The thrust of our recommendation is that NASA should lessen the government's obligation to the project at such an early stage when realistic cost estimates have yet to be established and requirements are not fully defined, and therefore limit the scope of the contract to activities needed to successfully complete the preliminary design review. At that point the project should have in place a sound business case for proceeding and hence be in a better position to justify continued investment. Implementation of the recommendation could be accomplished through various means, including by retaining two contractors through the preliminary design review and awarding a contract at that time or by down-selecting as planned in September 2006 and limiting the scope of the contract as described above.

- NASA's suggestion that it is maximizing competition by soliciting from industry its development, production, and management approach and that it will receive firm competitive prices from industry for completion of development and demonstration of two vehicles has little basis. First, while the current structure will allow for competition in the short term, the benefits of such competition will be short-lived. Without well-defined requirements, mature technologies, an approved preliminary design, and realistic cost estimates, NASA has insufficient information to ensure that it is obtaining firm competitive prices for the work conducted for the entirety of Schedule A—especially for activities beyond the project's preliminary design review.

Because NASA continues to refine the project's requirements, as demonstrated by the numerous changes to the exploration architecture as discussed in our report, it cannot provide a firm estimate of project cost. Without such information, it will likely be difficult for NASA to establish realistic "not-to-exceed" prices for Schedule B activities. Under the current strategy, NASA will not have high-fidelity, engineering-based estimates of life cycle costs for the CEV until the preliminary design review. As outlined in this report, projects with cost estimates based on early, evolving designs and top-level requirements are at increased risk of cost growth relative to estimates based on mature designs and detailed requirements—which could be achieved at the preliminary design review. According to NASA, it plans to obtain this and further knowledge about program cost, schedule, and risk elements following the contract award and in conjunction with the contractor. In the absence of such information, it is not clear how NASA can substantiate its statement that it has the knowledge necessary to commit to activities beyond the project's preliminary design review. Further, it cannot provide Congress with assurance of the appropriateness of requested funding for the project.

- NASA stated that its current acquisition strategy for the CEV minimizes the government's obligation during development by dividing the CEV contract into three separate schedules. All three schedules, however, will be awarded in September 2006 as part of one contract. Although NASA plans to include language in the negotiated CEV contract to state that the minimum quantity under Schedule B will not be applicable until that schedule's period of performance begins in 2009—a step that would lessen the government's obligation during production—it will continue to be responsible for all Schedule A activities at the time of contract award. These activities include all design, development, and test and evaluation activities, as well as the production of two operational vehicles. Contractually obligating the government to even these Schedule A activities, before it has established a sound business case to support such a commitment, is not in line with our knowledge-based approach and is ultimately not in the best interest of the government.

- NASA's investment in identifying and maturing the Thermal Protection and Landing Subsystems is a step in the right direction to ensure that these technologies are mature and available when needed. NASA has no guarantee, however, that these critical technologies will be mature by the time of the project's preliminary design review—the point at which our work has shown that technologies should be mature in order to decrease the risk of cost and schedule growth. NASA's proposed commitment to the project for activities beyond the preliminary design review before retiring these technology risks increases the likelihood that the project will experience schedule delays and cost overruns.

- NASA maintains that program risks have been marginalized and that the agency will utilize incentives, including end-item award fees, to ensure contractor performance. NASA suggests that the incentives it plans to use in the form of end-item award fees will be a powerful tool for meeting cost schedule, technical, and quality goals. The use of these tools, however, does not compensate for proceeding with a risky acquisition, nor do they lessen NASA's responsibility to implement an executable program from the start. For them to function as intended, NASA needs to address the more fundamental issues related to its acquisition strategy, including its lack of a sound business case for the CEV project.

- Finally, the use of cost-reimbursable contracting, while appropriate for early development and design efforts, places most of the cost risk for the project on the government. Given the nature of this effort, it is likely that the project will change significantly as it moves forward. Therefore, any scope changes or schedule slips could translate into additional contract cost for NASA. Such cost impacts could be minimized if NASA limited its contractual obligation to those activities needed to achieve a successful preliminary design review, as we recommended. In addition, limiting the scope of the CEV contract would allow both NASA and Congress to assess the project's progress at the preliminary design review and to decide if continued investment in the project is prudent and in the best interest of the government.

It is important to note that Congress will continue to be asked to make funding commitments in advance of CEV project events that would demonstrate that the project has the knowledge necessary to support a sound business case. Specifically, NASA's funding request for fiscal years 2007 and 2008 are scheduled to be approved before the CEV holds its preliminary design review. Since the preliminary design review is currently scheduled for March 2008, this may also be the case for fiscal year 2009. Congress should safeguard against a situation in which contractual and budget decisions could hinder its ability to tie further investments in the CEV project to demonstrated progress at the preliminary design review. As such, we have included a matter for congressional consideration.

We also received technical comments from NASA, which have been addressed in the report, as appropriate.

Scope and Methodology

To assess the extent to which NASA has identified the architecture and costs necessary to implement the *Vision* and whether NASA's exploration architecture cost estimates fit within the agency's projected available budgets, we reviewed and analyzed NASA's Exploration Systems Architecture Study, fiscal year 2007 budget request, ground rules and assumptions provided from the Constellation program to project level management estimators to perform the bottom up review, guidance for use in preparing the fiscal year 2008 budget request, NASA cost-estimating guidance in the NASA *Cost Estimating Handbook*, and congressional hearings and testimonies pertaining to NASA and the *Vision*. We also conducted interviews with NASA headquarters officials from the Cost Analysis Division, the Exploration Systems Mission Directorate, and Constellation program officials, Constellation program and CEV project officials at Johnson Space Center; CLV project officials at Marshall Space Flight Center; and cost analysts from the Kennedy Space Center. During these interviews, we discussed the methodologies used in preparing the ESAS and subsequent cost estimates, architecture changes after the ESAS and the trades being considered, budgeting issues, and procurement strategies and activities.

To assess the risks associated with NASA's acquisition strategy for the CEV project, we reviewed and analyzed CEV project documentation, including draft project plans, draft requirements documents, technology development plans, documentation included in the contract request for proposals, and past NASA human spaceflight acquisition programs. We compared NASA's plans for the CEV with criteria contained in GAO best practices work on systems acquisition. We also conducted interviews with NASA headquarters officials from the Exploration Systems Mission Directorate and Constellation Systems officials, Constellation program and CEV project officials at Johnson Space Center, and CLV project officials at Marshall Space Flight Center.

We conducted our work from January 2006 to May 2006 in accordance with generally accepted government auditing standards.

As agreed with your offices, unless you announce its contents earlier, we will not distribute this report further until 10 days from its date. At that time, we will send copies of the report to NASA's Administrator and interested congressional committees. We will also make copies available to others upon request. In addition, the report will be available at no charge on GAO's Web site at http://www.gao.gov.

Should you or your staff have any questions on matters discussed in this report, please contact me at (202) 512-4841 or lia@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Principal contributors to this report were James L. Morrison, Assistant Director; Rick Cederholm; Shelby S. Oakley; Guisseli Reyes; Sylvia Schatz; and John S. Warren, Jr.

Allen Li
Director
Acquisition and Sourcing Management

Enclosures

Comments from the National Aeronautics and Space Administration

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

July 6, 2006

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

Dear Mr. Li:

NASA has reviewed the Government Accountability Office (GAO) draft report entitled "NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge (GAO Code 120515, Report Number GAO-06-817R)." Thank you for the opportunity to provide comments on the recommendation in the report.

NASA embraces GAO's recognition that a "knowledge-based" approach reduces risks and increases the likelihood of successful outcomes. As the primary steward for achieving the Vision for Space Exploration, NASA fully recognizes the importance of investing its resources wisely and maintaining stakeholder confidence in its performance. NASA has the appropriate level of knowledge to proceed with its knowledge- and performance-based acquisition plan to "down-select" a single Crew Exploration Vehicle (CEV) prime contractor in September 2006. The Agency's acquisition strategy and plans capitalize on the benefits of competition, focus on performance, and address the inherent risk of complex development projects. Accordingly, NASA nonconcurs with GAO's recommendation that the NASA Administrator modify the current CEV acquisition strategy.

NASA is maximizing competition by soliciting from industry their development, production, and management approach with an emphasis on Life Cycle Cost (LCC) for the CEV. While in this competitive environment, NASA will receive firm competitive prices from industry to complete development of the CEV and demonstrate one pressurized crew vehicle and one pressurized unmanned vehicle. Under this competition, NASA will also establish not-to-exceed prices for production of required CEVs to support the current flight manifest through 2019. The foundation of the CEV acquisition strategy is focused on gaining commitment from industry for a design solution and controlling LCC through competition and incentives.

NASA has diligently invested the time and resources in the formulation phase of the CEV project in order to develop the knowledge necessary to commit to a long-term design and development effort. In May 2005, the Exploration Systems Architecture Study (ESAS) was initiated with one of its tasks being to provide a complete assessment of the top-level CEV requirements. As a result of the ESAS, the architecture and the top-level requirements for the CEV were chosen. With the level of knowledge gained through the Agency's investment in the ESAS and with its acquisition strategy, NASA perceives no benefit in retaining two prime contractors through Preliminary Design Review (PDR) at an estimated cost of $1 billion each. Instead, NASA has determined that a better return on its investment would be gained by competitively issuing two Phase 1 CEV prime contracts for conceptual design and trade studies against the ESAS architecture for an estimated cost of $46 million each and including the CEV requirements as part of the CEV Phase 2 contract competition. Additionally, NASA established an intra-agency CEV Smart Buyer team which performed trade studies and design analyses that were used by the CEV Project Office to understand and verify the appropriateness of the requirements incorporated into the CEV Phase 2 solicitation and evaluation of proposals. With knowledge gained from ESAS, the Smart Buyer team, and the CEV Phase 1 contracts, NASA is now in a sound position to "down-select" a single prime contractor, thereby base-lining an industry approach and commitment to meet the desired outcomes of the CEV project.

NASA's business approach is consistent with GAO's knowledge-based recommendation and recognition that knowledge replaces risk over time. The CEV acquisition strategy contains separate contract schedules and design reviews which are equivalent to GAO's defined Knowledge Points. NASA's acquisition strategy minimizes the Government's obligation during development by dividing the CEV contract into three different schedules:

- Schedule A for Design Development, Test, and Evaluation (DDT&E).
- Schedule B for production beyond Schedule A.
- Schedule C for sustaining activities during production and operation.

Schedule A is authorized at contract award and continues through the first flight demonstration of each design variant of the CEV. Schedule A executes the formulation phase of the project such that NASA can utilize the contractor's knowledge to develop a set of validated requirements, including component specifications and mature technologies by the project's PDR. The current CEV strategy will allow NASA and the contractor to attain further appreciation and knowledge about the project and its required resources to provide firm cost, schedule, and risk elements. At this point, the Non-Advocacy Review (NAR) is typically scheduled immediately following the baseline of the project's preliminary design.

Authorization of Schedule B is planned post PDR, NAR, and the Critical Design Review (CDR) and is currently limited to a minimum production quantity of two units. Authorization of Schedule C is planned at approximately the same time as Schedule B. The CEV strategy does not commit the Agency to any production until the NAR milestone is met. Additionally, utilizing Delivery Orders (Indefinite Delivery Indefinite Quantity) for Schedules B and C provides NASA with the ability to order only the units and the sustaining engineering necessary, with appropriate incentives, when the requirements and costs are better understood by NASA and industry. NASA will not commit to Schedule B or C activities until it is time to implement that portion of the contract. To mitigate concerns about the minimum production quantity of two units under the production contract (Schedule B), language will be included in the final negotiated CEV contract that will make explicit that the minimum quantity will not be applicable until the period of performance of Schedule B begins. First production orders are planned to be placed in the fall of 2009, nine months after the baseline of the CEV's critical design or CDR (Knowledge Point 3).

NASA has a plan and process in place to address technology risks through in-house development work and collaboration with the prime contractor. For example, NASA has identified two areas where the additional technology maturation is needed: the Thermal Protection Subsystem and the Landing Subsystem. NASA has in-house advanced development plans (ADP) to develop these technologies with Prime Contractor participation through PDR. While the Prime Contractor will participate with the ADP, it will not assume development responsibility until after PDR.

Incentives are a critical element in the business case for the CEV project. During DDT&E, NASA will use an end-item award fee. This makes all award fees subject to final determination only after the product has been demonstrated to meet requirements, including cost and schedule. This is a powerful tool for the NASA project manager and provides incentive to all elements of the project: cost (including life cycle costs), schedule, technical, and most importantly, quality. There will be inherent motivation toward schedule performance by means of concluding each project milestone with an award fee determination. Since no provisional payments will be made, industry will not receive interim payments until the completion of an established project milestone. A slip in schedule will be reflected both in a delay in receipt of the interim payment and in the NASA evaluation that will eventually follow.

In summary, NASA is confident that its acquisition strategy and plans for selecting a CEV Prime Contractor are based on sound business case, will establish a firm foundation for the Constellation Program, and are in the Government's best interest.

Sincerely,

Shana Dale
Deputy Administrator

GAO Accountability * Integrity * Reliability

Briefing

Briefing for Congressional Staff May 2006

NASA: Long-Term Commitment to and Investment in Space Exploration Program Requires More Knowledge

Why GAO Did This Study

In January 2006, the National Aeronautics and Space Administration (NASA) publicly released its Exploration Systems Architecture Study (ESAS), which aimed to identify the best architecture and strategy to implement the President's 2004 *Vision for Space Exploration (Vision)*. The ESAS architecture supports development of a new Crew Exploration Vehicle (CEV), Crew Launch Vehicle (CLV), Cargo Launch Vehicle (CaLV), and other supporting systems, which are part of NASA's Exploration Systems Mission Directorate's (ESMD) Constellation program. The architecture also calls for various Research and Technology (R&T) and Robotic Lunar Exploration Program (RLEP) projects.

The cost estimate for implementing the ESAS through fiscal year 2011 exceeds $31 billion. The estimate through fiscal year 2018 is $122 billion and the estimate through fiscal year 2025 is nearly $230 billion. These estimates include the architecture, robotic precursor missions, supporting technologies, and funding needed to service the International Space Station (ISS).

Because of the significance of this investment, competing demands on the federal discretionary budget, and the importance of the success of NASA's exploration program to the future of U.S. human spaceflight, we assessed (1) the extent to which NASA has identified the architecture and costs necessary to implement the *Vision*, (2) whether NASA's exploration architecture cost estimates fit within the agency's projected budgets, and (3) the risks associated with NASA's acquisition strategy for the CEV.

Summary

Although NASA is continuing to refine its exploration architecture cost estimates, the agency cannot at this time provide a firm estimate of what it will take to implement the architecture. The absence of firm cost estimates is mainly due to the fact that the program is in its early stages. NASA preliminarily identified the resources needed to implement the architecture as outlined in the ESAS. However, since that time, NASA has continued to make architecture changes. For example, following the issuance of the ESAS, NASA undertook several analysis cycles in which various aspects of the architecture have evolved, such as the diameter of the CEV, the engine used to support the upper stage of the CLV, and the size of the Reusable Solid Rocket Booster on the CLV. These changes, and others, are appropriate for this phase of the program, when concepts are being developed, but leave NASA in the position of being unable to firmly identify program requirements and needed resources. NASA plans to commit to a firm cost estimate at the preliminary design review (PDR) in 2008, when the programs' requirements, design, and schedule will all be baselined.

NASA will be challenged to implement the ESAS architecture with its projected budget. Whether using the ESAS estimates of funds available or NASA's fiscal year 2007 budget submission that was based upon the ESAS estimates, there are years when NASA does not have sufficient funding to implement the architecture. Some yearly shortfalls exceed $1 billion, while in other years the funding available exceeds needed resources. NASA maintains that the architecture could be implemented within its projected available budgets through fiscal year 2011 when funding is considered cumulatively. In the short term, NASA has redirected funds to the Constellation program from other ESMD activities to provide a significant surplus for fiscal years 2006 and 2007 to cover projected shortfalls for the program beginning in fiscal year 2009. The identified budget phasing problem in ESAS could worsen, given that changes to the architecture following the ESAS will likely add to the near term development costs, where funding is already constrained. In addition, NASA anticipates a significant surplus in fiscal year 2011 because of the retirement of the space shuttle fleet in 2010. However, the transition costs are not fully understood.

NASA's acquisition strategy for the CEV places the project at risk of cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. NASA plans to award a contract for design, development, production, and sustainment of the CEV in September 2006—before it has developed well-defined requirements, a preliminary design, mature technology, and firm cost estimates. This information is not expected until the project-level PDR in fiscal year 2008. At that point, NASA will likely (a) have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project, (b) be in a better position to commit the government to a long-term effort, and (c) have more certainty in advising Congress on required resources.

Briefing Structure

Background

Implementing the Vision

NASA plans to bring the President's *Vision* to reality over the next several decades by

- conducting exploration activities in low-Earth orbit; for example, flying the space shuttle to complete assembly of the ISS;
- exploring beyond low-Earth orbit; for example, establishing sustained exploration of the moon and Mars;
- developing transportation that supports exploration; for example, building crew exploration vehicles; and
- pursuing opportunities for international and commercial participation.

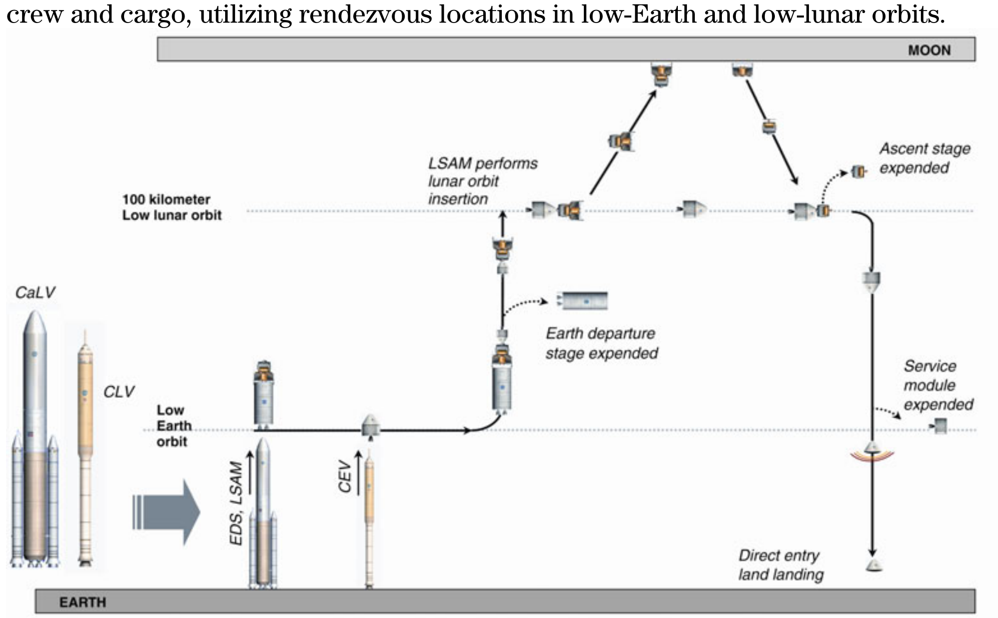
Exploration Contracts

NASA awarded concept development contracts to both Lockheed Martin and Northrop Grumman for the CEV project in July 2005. NASA plans to down-select to one contractor and award a contract for development, production, and sustainment of the CEV in September 2006. That contract could extend through 2019.

NASA plans to award a sole-source contract for the first stage of the CLV to ATK-Thiokol, the manufacturer of the Shuttle's Reusable Solid Rocket Motor, in October 2006. Also, the agency plans to award Pratt & Whitney Rocketdyne, the developer of the Space Shuttle Main Engine (SSME) and J-2 engines, a sole-source contract for development of the J-2X engine in November 2006. These contractors are currently planning their respective efforts under interim contract arrangements. NASA has started in-house preliminary design work on the CLV upper stage structures and avionics and plans to begin awarding competitive contracts for production of these items in May 2007.

Original Exploration Systems Architecture Study Overview

The ESAS outlined the recommended architecture and strategy for implementation of the *Vision*. The primary vehicles and elements of the architecture include the CEV, the CLV, the CaLV that includes the Earth Departure Stage (EDS), and the Lunar Surface Access Module (LSAM). The diagram below outlines a launch mission for crew and cargo, utilizing rendezvous locations in low-Earth and low-lunar orbits.



Source: NASA.

The original ESAS architecture is described below. Changes made to the architecture since the release of ESAS are described in later sections.

CEV: The CEV is a reusable, Apollo-derived cone-shaped capsule launched atop the CLV. The CEV consists of a Command Module (CM), a Service Module (SM), and a Launch Abort System (LAS). The CEV is sized at 5.5 meter diameters for lunar polar missions carrying a crew of four, and is also reconfigurable to accommodate up to six crew members for missions to ISS. The vehicle uses a Low Impact Docking System (LIDS) for ISS and lunar missions. The vehicle is reusable for up to 10 missions and will land on land with a water landing as a backup. The SM utilizes a pressure-fed liquid oxygen (LOX)/methane propulsion system.

CLV: The CLV consists of a shuttle-derived four-segment Reusable Solid Rocket Booster (RSRB) first stage and a newly designed upper stage with one modified, and now expendable, SSME. It will launch 25 metric tons to low-Earth orbit and serve as the long-term crew launch capability for the United States.

CaLV: The CaLV will use a heritage shuttle external tank-derived LOX/liquid hydrogen core stage propelled by five redesigned SSMEs. Attached to this core stage are two newly developed five-segment RSRBs, allowing over 100 metric tons to be launched to low-Earth orbit. The upper stage, which also serves as the EDS, uses an external tank-derived LOX/liquid hydrogen system and will employ two Saturn-derived J-2 engines.

LSAM: The LSAM is an expendable two-stage module launched atop the CaLV. The descent stage will utilize a LOX/liquid hydrogen propulsion system while the ascent stage will use a pressure-fed LOX-methane propulsion system. A crew cabin will be located on the ascent stage and will have an airlock to allow docking with the CEV. The LSAM will be able to land at any location on the lunar surface and will house a four-member crew for up to 7 days.

Cost Estimating

Cost-Estimating Process

NASA's *Cost Estimating Handbook* outlines cost-estimating processes in relation to acquisition life cycle phases.

- In Pre-Phase A, there are many unknowns. At this point, the most effective cost-estimating approach is a parametric or analogous methodology, i.e., data from projects with similar attributes is used to predict the cost.
- In Phase A, conceptual designs are better defined and a better understanding of the system requirements and technical risks exists. But, parametric or analogous cost-estimating techniques are still used, because detailed data may still be unavailable.
- In Phase B, system designs are defined below the subsystem level. At this point, estimating methodologies evolve to more detailed parametric or engineering buildup estimates supported by technical experts. By the end of Phase B, specific data are available to prepare a full life cycle cost estimate.
- In Phases C and D, cost estimates are refined to include actual data. At this point, the preferred cost methodology is an engineering buildup based on the lowest level of detail available, including overhead, labor, and material costs.

Firm Cost Estimates Cannot Be Developed at This Time

NASA's cost estimates for implementing its exploration architecture are preliminary—a fact that NASA has acknowledged since the ESAS was publicly released. As part of the ESAS effort, NASA laid out the cost estimates for implementing the recommended architecture. Because the ESAS effort was an early life cycle activity, Pre-Phase A, the majority of the individual estimates were based upon parametric models, with little actual data.

The ESAS process evaluated the cost of various alternative exploration architectures based upon high-level program requirements. The recommended architecture costs totaled

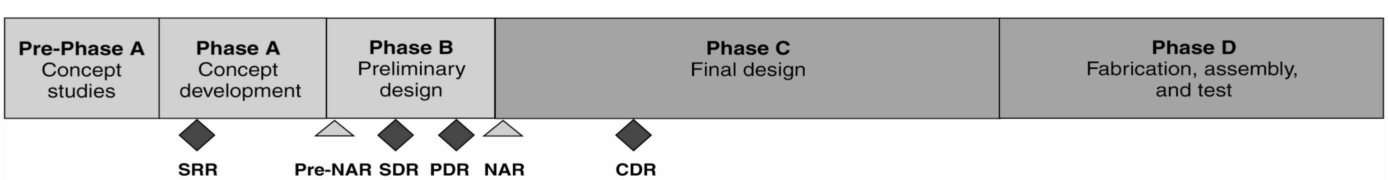
- over $31 billion dollars through fiscal year 2011,
- over $122 billion through fiscal year 2018, and
- close to $230 billion through fiscal year 2025.[1]

NASA conducted a cost risk analysis of the estimates through fiscal year 2011. This analysis provided a 65 percent confidence level for the estimate (i.e., NASA is 65 percent certain that the actual cost of the program will either meet or be less than the estimate). To obtain this level of confidence in the estimates, NASA included programmatic reserves—20 percent on all development and 10 percent on all production costs. NASA only conducted the risk analysis through the first flight date of the CEV at the time of ESAS—2011—leaving the estimates through 2018 and 2025, when most of the cost risk for implementing the architecture will be realized, with no confidence level distinction. According to NASA officials, the cost risk analysis lacked quality because of the evolving nature of the requirements for the architecture and the compressed time frames with which they had to conduct the analysis. According to NASA officials, once they receive more detailed contractor inputs, the agency will be able to produce higher-fidelity estimates of program cost. NASA has stated that it would not commit to a cost estimate for implementing the exploration architecture until the Constellation program's PDR, which will occur in late fiscal year 2008. At that time, the requirements, design, schedule, and cost will all be baselined.

NASA refined the architecture several times since ESAS. As a result of these changes, the costs associated with the architecture have also changed. As part of the fiscal year 2007 budget formulation process, NASA made two major changes to plans laid out in the ESAS. First, the requirement for use of a LOX/methane engine on the CEV service module—a high-risk development—was removed, and the approach for meeting the propulsion requirement was left to the discretion of the contractor. Second, the first flight of the CEV was delayed until no later than 2014.

[1] NASA's cost estimate through 2011—$31 billion— included the costs of the R&T and RLEP projects needed to support the architecture. Its estimate for the first lunar landing—$104 billion—did not include $18 billion in funding for R&T and RLEP projects. To ensure consistency, the estimates for 2018 and 2025 are presented with R&T and RLEP funding included. The estimates include $20 billion to service the ISS.

NASA's Life Cycle for Flight Systems and Ground Support Projects through Phase D



SRR = System Requirements Review
SDR = System Definition Review
NAR = Non-Advocate Review
Pre-NAR = Preliminary Non-Advocate Review
PDR = Preliminary Design Review
CDR = Critical Design Review

Source: NASA.

Cost Estimating

Cost Estimate Issues

Historically, NASA has shown that it lacks a clear understanding of how much its programs will cost and how long they will take to achieve their objectives. NASA's cost estimates have often been unreasonable when committing to programs because of several factors, including inadequate requirements definition; changes in program content; and inadequate processes to establish priorities, quantify risks, and make informed investment decisions. GAO has reported on these issues for several years in both its high-risk series and in specific reviews of programs where NASA failed to apply discipline to its cost estimates to ensure those estimates were reasonable. For example, in 2002, GAO reported that since 1995, estimates for completion of the ISS had increased by $13 billion and the scheduled completion date had slipped 4 years. Also, in 2004, GAO conducted a review of 27 other NASA programs and reported that the initial baseline estimates for over half of those programs were understated.

Costs for NASA programs have historically been greater, on average, than initial estimates anticipated. A 2004 Congressional Budget Office (CBO) examination of 72 NASA programs spanning the past 30 years found that costs of NASA programs have increased, on average, 45 percent from initial budget estimates.

Firm Cost Estimates Cannot Be Developed at This Time, cont'd

Subsequent to the submission of NASA's fiscal year 2007 budget, the Constellation program conducted an internal bottom-up review (BUR) of program costs. The goal of the BUR was to identify the funding it would take to "get the job done," which, according to the BUR guidance, means conducting the first flight of the CEV to the ISS by 2012 and first lunar mission by 2017. This review attempted to determine the cost impact of several major changes that were made to the architecture. These changes included a reduction in CEV diameter from 5.5 to 5 meters, use of a five-segment RSRB and a Saturn-derived J-2x engine on the upper stage of the CLV, deletion of the unpressurized cargo CEV, the addition of an ISS docking system (Androgynous Peripheral Attachment System), and the inclusion of a Ka Band for High Definition Television on the CEV. Some of these architecture changes may help lessen technology development risks in the future program due to the planned commonality between the CLV and CaLV launch systems. While the results of this review were an attempt to provide more fidelity to the Constellation program's cost estimates, given the continued lack of a firm program baseline for requirements, design, and schedule, along with a continued lack of input from contractors, it is unlikely that the program had the level of detail available to support a true estimate of total costs this early in the program life cycle.

ESMD is conducting a follow-on review to the Constellation program's BUR as NASA enters its fiscal year 2008 budget formulation cycle. As part of this latest review, NASA has continued to evaluate changes to the program architecture and schedule, such as the use of the RS-68 engine on the CaLV and the delay of the first lunar mission to either fiscal year 2019 or fiscal year 2020.

The continued evolution of the exploration architecture serves to highlight the preliminary nature of architecture itself and its associated cost estimates. Although NASA is continuing to refine its cost estimates for implementing the architecture to provide a more reliable estimate of cost, history suggests that program costs could increase significantly over estimates. In 2004, CBO reported that fulfilling the *Vision* could require the addition of billions of dollars to NASA's estimates of cost or extending the schedule for the first lunar landing by several years. Applying NASA's average cost growth figure of 45 percent to the ESAS cost estimates, assuming NASA business as usual, would result in an increase of almost $14 billion over the $31 billion it estimates it will need through 2011. With a significant increase in NASA budgets unlikely, given the current national fiscal imbalance, this level of cost growth could result in an unsustainable long-term exploration program.

Funding Shortfalls

NASA Funding Approach

The NASA Administrator recently testified that the agency is facing challenges to ensuring adequate funding for the priorities of the President and Congress within available budgetary resources. He stated that NASA has adopted a "go as you can afford to pay" approach to funding its exploration missions. This approach assumes NASA's top line budget will grow at the moderate rate identified in the President's fiscal year 2007 budget request.

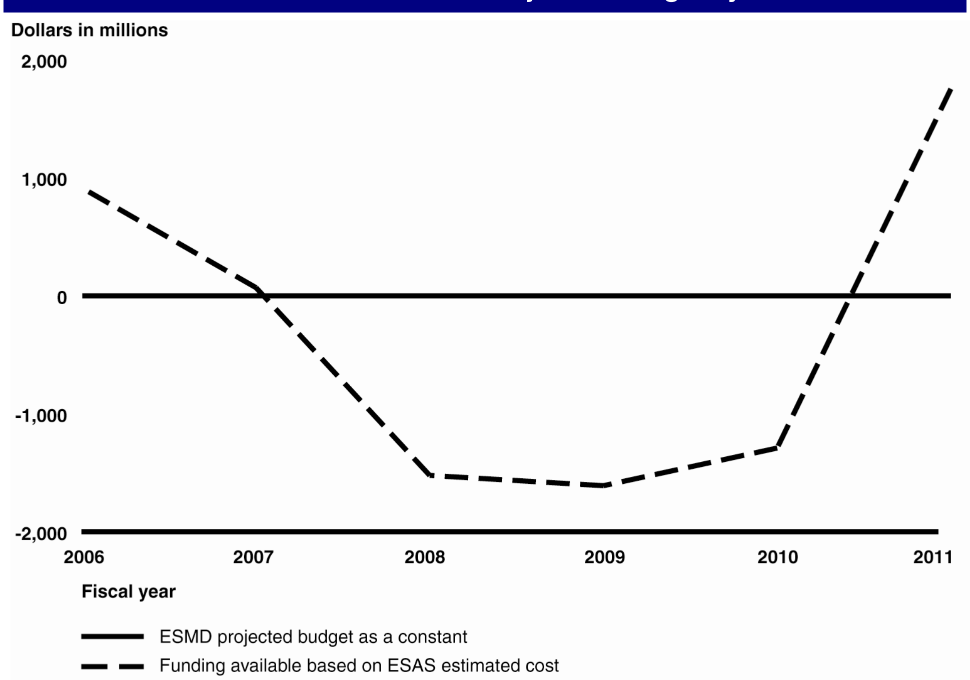
Under this approach, NASA would implement its priority missions within available resources and planned budgets through the redirection of funding for longer-term and lower-priority R&T elements within ESMD. As a result, several ESMD R&T programs and missions were discontinued, descoped, or deferred. That funding, in turn, was shifted into the Constellation Program to accelerate development of the CEV and the CLV.

Expected Budget Challenges Architecture Implementation

NASA will be challenged to implement the exploration architecture, given the agency's expected budget profile. The ESAS effort defined the recommended architecture and preliminary costs, which NASA contends would allow the program to be accomplished within available budgets through fiscal year 2011. However, phasing issues still needed to be resolved. On an annual basis, NASA cannot afford to implement the architecture, although, cumulatively, for fiscal years 2007-2011, the agency says it has the money available. Beginning with fiscal year 2014 and for the remainder of the decade, where the anticipated available budgets were adjusted for inflation, the ESAS cost projections show yearly multibillion-dollar shortfalls with an overall deficit through 2025 of over $18 billion.

The projected ESMD available budget figures used in the ESAS were developed well in advance of NASA's fiscal year 2007 President's budget submission. However, using the updated budget estimates from the fiscal year 2007 budget, the phasing issue becomes more pronounced when compared to ESAS estimated costs. As shown in the chart below, ESAS estimates could be accommodated within the ESMD available budget through fiscal year 2007. From fiscal year 2008 through fiscal year 2010, however, NASA anticipates annual budget shortfalls for implementing the architecture within ESMD to exceed $1 billion per year. This shortfall could be partially offset, at least within the Constellation program, by a carryover of approximately $1 billion in both fiscal years 2006 and 2007 as a result of funds redirected from R&T activities within ESMD to that program. In addition, NASA officials stated the Constellation program has requested more funding than required for its projects in several years to cover shortfalls in later years. For example, the Exploration Communication and Navigation Systems project within the Constellation program plans to roll over $56.2 million from the fiscal year 2007 budget to make up for budget shortfalls in fiscal years 2008, 2009, and 2010.

ESAS Estimated Cost versus ESMD Projected Budget by Fiscal Year



Source: NASA (data) and GAO (analysis).

Funding Shortfall

Gap in Human Spaceflight

The *Vision* called for retirement of the space shuttle fleet by the end of this decade and that the CEV should be available no later than 2014, creating a potential gap in human spaceflight of up to 4 years. The NASA Administrator has stated that it is a priority of the agency to close this gap and that the agency has taken steps to have the CEV in service as close to 2010 as possible.

On the basis of lessons learned from the period between the end of the Apollo Program and the first flight of the space shuttle, the Administrator outlined several reasons why the CEV should not be delayed. These reasons include the potential for

- stagnation in the aerospace industry,
- loss of critical expertise,
- withering of the industrial base,
- higher overall program costs,
- program schedule delays, and
- loss of leadership in space exploration.

Congress has also voiced its concern over the potential gap in human spaceflight. In the National Aeronautics and Space Administration Authorization Act of 2005, Congress stated it is the policy of the United States to have the capability for human access to space on a continuous basis.

Expected Budget Challenges Architecture Implementation, cont'd

NASA's approach, however, appears to be contrary the agency's stated "go as you can afford to pay" approach to implement priority missions within available resources. In addition, the surplus shown in fiscal year 2011 is dependent upon dollars becoming available from the retirement of the space shuttle fleet, even though NASA officials stated the costs associated with retiring the space shuttle and transitioning to new architecture are not fully understood and the expected surplus could be less than anticipated. The shortfall presented by the fiscal year 2007 budget would not allow NASA to accomplish the stated program objectives within available resources over the next 5 years.

In addition, changes to the architecture implementation schedule have not been consistent within the Constellation program. As previously stated, NASA moved the scheduled initial operational capability (IOC) date of the CEV to no later than 2014 during the fiscal year 2007 budget formulation process. This change, along with modifications to the architecture, allowed NASA's estimates to meet its overall budget profile, despite continued year-to-year budget phasing issues. However, because of NASA's focus on minimizing the gap between the retirement of the space shuttle and the first flight of the CEV to the ISS, the program continued to attempt to meet the earlier IOC date for the CEV through its various analysis cycles. The earlier 2012 IOC date was retained as the planning date during the bottom-up review process, the Phase II request for proposal to the contractors involved CEV development, and the recent announcement concerning its intention to purchase the J-2x engine for the CLV from Pratt & Whitney Rocketdyne.

The 2012 date for CEV IOC, in addition to changes the Constellation program made to the architecture during the BUR process, did not alleviate issues with the short-term funding profile. According to Constellation program officials, the net result of these changes will add more cost to the early years of the program, when funding is already constrained and phasing issues persist. Although the results of the BUR will not be released, indications from Constellation program officials are that the estimated costs of the program are higher than the ESAS estimated costs and available funding per NASA's budget profile.

In the meantime, NASA continues to look for ways to resolve its budget phasing issues, such as by making additional changes to the exploration architecture. As the Constellation program executes its budget formulation process for the fiscal year 2008 budget cycle, it is currently analyzing options to the current architecture in an attempt to reduce development and production costs. For example, NASA recently announced that it intends to use five RS-68 engines instead of five SSMEs for the CaLV core stage, which would also require the CaLV core stage diameter to be increased to approximately 33 feet to accommodate the additional propellant needed by the RS-68 engines.

CEV Project

Best Practices

GAO has frequently reported on the importance of developing a sound business case before committing resources to a new product development effort. The business case in its simplest form is demonstrated evidence that (1) the need for the product is valid and that it can best be met with the chosen concept, and (2) the chosen concept can be developed and produced using existing and reasonably expected resources.

GAO has undertaken a best practices body of work on how leading developers use a knowledge-based approach to develop products that reduces risks and increases the likelihood of successful outcomes. This type of approach is based on the premise of attaining knowledge about a program and the resources available before making a contractual or financial commitment. Knowledge that supports a sound business case includes well-defined requirements, a preliminary design, mature technology, and realistic cost estimates.

Use of this approach has enabled leading organizations to deliver high-quality products on time and within budget. Conversely, GAO has also reported that major systems that have not established a sound business case have been plagued by cost overruns, schedule delays, decreased capability, and overall poor performance. NASA's track record in developing systems has not been good. GAO and others have reported that NASA has had numerous problems with its programs and projects, including underestimating program complexity and technology maturity, and inadequate review and systems engineering processes.

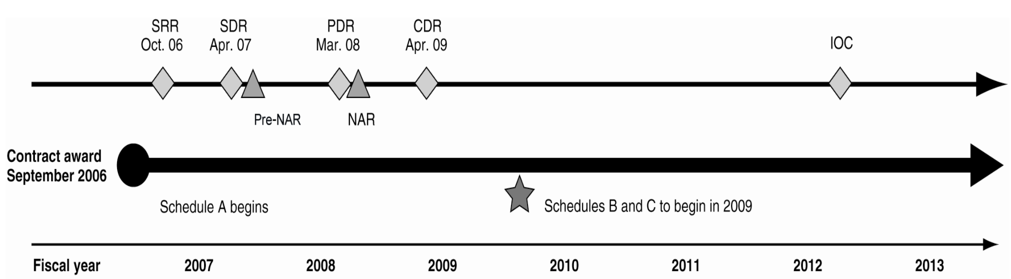
Lack of Sound Business Case Puts CEV Acquisition at Risk

NASA's acquisition strategy for the CEV places the project at risk of cost overruns, schedule delays, and performance shortfalls because it commits the government to a long-term product development effort before establishing a sound business case. In September 2006, NASA plans to award a contract for design, development, production, and sustainment of the CEV—before it has developed well-defined requirements, a preliminary design, mature technology, and firm cost estimates for the project. The CEV project might not have all the elements of a sound business case in place until the project-level PDR in March 2008. At the completion of the PDR, NASA will approve the selected prime contractor's preliminary design based on detailed, validated requirements. Further, CEV project officials indicated that the CEV project plans to retire all technology risks by the PDR. At that point, NASA will likely have the increased knowledge necessary to develop a sound business case that includes high-fidelity, engineering-based estimates of life cycle cost for the CEV project. With this business case in hand, NASA would be in a better position to commit the government to a long-term design and development effort. NASA officials disagree and have stated that it is appropriate for them to proceed with the contract award because the agency is selecting "a designer, not a design" for the CEV. In reality, by awarding a contract as planned in September 2006, NASA is not only committing to an unknown design but to production and long-term sustainment of the CEV as well.

The CEV contract scheduled for award in September 2006 will have three schedules. At the time of contract award, NASA will be responsible for fee earned and the reasonable, allowable, and allocable costs incurred by the contractor in the performance of Schedule A and the minimum quantities under Schedules B and C.

- **Schedule A** is for design, development, test and evaluation of the CEV. Deliverables under Schedule A include all test articles and two operational CEV vehicles—one human-rated variant and one pressurized cargo variant.
- **Schedule B** is for production beyond the two operational vehicles delivered under Schedule A. The CEV request for proposal states that the "guaranteed minimum" quantity for Schedule B is "two CEV," the type of which, according to NASA officials, is undetermined.
- **Schedule C** is for sustainment in support of operations and in support of Schedule B activities.

CEV Timeline



Source: NASA (data) and GAO (presentation).

Note: Contract award for all schedules is planned for September 2006. Schedule B and C performance periods are from 2009 to 2014 with an additional 5-year performance option to end in 2019.

CEV Project

Past Development Attempts

NASA has tried unsuccessfully to develop a number of vehicles to replace the shuttle over the past three decades. In the 1980s NASA initiated the National Aero-Space Plane (NASP) to build and test a manned experimental flight vehicle for demonstrating single-stage-to-orbit space launch and sustained hypersonic cruise capability. NASA canceled the program as it was experiencing cost overruns, schedule delays, and technology problems. GAO reported that from 1986 to 1993 NASA spent $398 million for the NASP program.

In the 1990s, NASA began the X-33 program to develop single-stage-to orbit technology and the X-34 to demonstrate reusable two-stage-to -orbit technologies. According to a 2006 Congressional Research Service report, NASA terminated the X-33 and X-34 in March 2001—after spending over $1.4 billion—because the cost to complete them was too high relative to the benefits. In 1999, GAO reported that technical problems and unrealistic cost estimates on the X-33 project alone led to cost overruns of $75 million and over a year's delay.

In 2004, after the announcement of the *Vision*, NASA canceled the Space Launch Initiative (SLI) program, which was to provide both launch capabilities and an emergency crew return from the ISS. NASA's Inspector General reported that NASA did not verify and validate basic requirements for its second generation space transportation, while GAO reported that key management controls could not be implemented until such requirements were defined. GAO estimates that from 2001 to 2005 NASA provided the SLI program with about $3 billion in funding.

Lack of Sound Business Case Puts CEV Acquisition at Risk, cont'd

An important step in developing a sound business case is defining requirements. The acquisition strategy for the CEV lays out a series of reviews to validate and approve CEV requirements. These reviews result in approved system-level requirements at the October 2006 System Requirements Review (SRR), and approved subsystem-level requirements at the April 2007 System Definition Review (SDR) and culminate with validated and approved component-level requirements at the March 2008 PDR. Under the current CEV strategy, NASA will select the winning contractor about 1 month before the system level requirements are approved at the SRR, over a year and a half before detailed component-level requirements are approved at the PDR.

Another aspect of a sound business case is having mature technologies before committing to product development. The CEV's acquisition strategy is predicated upon using mature technologies as the basis for system development. However, contractors will also be given discretion to include immature technologies in areas where technology advancement is critical to meeting requirements. NASA has independently identified technology risks and implemented advanced technology development projects to address risks in the areas of the thermal shielding needed for reentry and the landing systems needed for ground landings. CEV project officials also expect that each contractor's proposal will include additional technology development risks. Under the current CEV strategy, NASA is awarding a contract for product development and production of the first two variants of the CEV before it has resolved these technology development risks.

Appendix

Contributors

If you have any questions concerning this briefing, please call Allen Li at (202) 512-4841. Other key contributors to this briefing were James L. Morrison, Assistant Director; Rick Cederholm; Shelby S. Oakley; Guisseli Reyes; Sylvia Schatz; and John S. Warren, Jr.

Scope and Methodology

To assess the extent to which NASA has identified the architecture and costs necessary to implement the *Vision* and whether NASA's exploration architecture fits within the agency's projected available budgets, we reviewed and analyzed NASA's Exploration Systems Architecture Study, fiscal year 2007 budget request, ground rules and assumptions provided from the Constellation program to project-level management estimators to perform the BUR, guidance for use in preparing the fiscal year 2008 budget request, NASA cost-estimating guidance in the NASA *Cost Estimating Handbook*, and congressional hearings and testimonies pertaining to NASA and the *Vision*. We also conducted interviews with NASA headquarters officials from the Cost Analysis Division, the Exploration Systems Mission Directorate, and the Constellation Program; Constellation program and CEV project officials at Johnson Space Center; CLV project officials at Marshall Space Flight Center; and cost analysts from Kennedy Space Center. During these interviews, we discussed the methodologies used in preparing the ESAS and subsequent cost estimates, architecture changes after ESAS and the trades being considered, budgeting issues, and procurement strategies and activities.

To assess the risks associated with NASA's acquisition strategy for the CEV project, we reviewed and analyzed CEV project documentation, including draft project plans, draft requirements documents, technology development plans, documentation included in the contract request for proposals, and documentation for past NASA human space flight acquisition programs. We compared NASA's plans for the CEV with criteria contained in GAO best practices work on systems acquisition. We also conducted interviews with NASA headquarters officials from the Exploration Systems Mission Directorate, Constellation Program and CEV project officials at Johnson Space Center, and CLV project officials at Marshall Space Flight Center.

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