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SPACE TRANSPORTATION

Progress of the X-33 Reusable Launch Vehicle Program

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Mr. Chairman and Members of the Subcommittee:

We are pleased to be here today to discuss the status of the National Aeronautics and Space Administration's (NASA) X-33 Reusable Launch Vehicle Program. The purpose of this program, co-sponsored under a cooperative agreement between NASA and the Lockheed Martin Corporation, is to develop and demonstrate advanced technologies and techniques needed for future reusable launch vehicles. These vehicles are in essence spacecraft or rockets whose components—either all or in part—are utilized on subsequent flights. If the X-33 Program is successful, Lockheed Martin may build a small fleet of operational vehicles called VentureStars. One way for NASA to reduce future launch costs may be to phase out the space shuttle fleet and purchase launch services from commercial sources. Our testimony summarizes our recent report on the X-33 Program[1] and discusses (1) whether the X-33 Program is meeting its original cost, schedule, and performance objectives; (2) how NASA conducts oversight under the cooperative agreement; and (3) issues NASA may face if it decides to use Lockheed Martin's VentureStar to service the International Space Station. At your request, we are also commenting on the progress of the X-33 Program in meeting the intent of the National Space Transportation Policy, the directive that establishes national policy, guidelines, and implementing actions for the conduct of national space transportation programs that will sustain and revitalize U.S. space transportation capabilities.

Summary

Because of problems in developing technologies for the X-33, the program will not meet some of its original cost, schedule, and performance objectives. Costs have increased, the test vehicle's first flight was delayed by 16 months, and some performance objectives–such as a speed reduction from Mach 15 to Mach 13.8–were reduced. When the cooperative agreement was established in July 1996, Lockheed Martin and industry partners' contributions totaled $211.6 million; NASA's contribution was fixed at $912.4 million. We estimate that between July 1996 and March 1999, contractors' total contributions increased by $75 million, to $286.6 million in response to problems encountered during development. Estimated government costs for NASA civil service personnel working on the program also increased, from $95.2 million to $113.1 million. These costs for NASA

[1] *Space Transportation: Status of the X-33 Reusable Launch Vehicle Program* (GAO/NSIAD-99-176, Aug. 11, 1999).

personnel are not included in the agency's agreement contribution; they are paid out of another budget account.

Because the agreement permits NASA employees to work side by side with Lockheed Martin employees to perform various technical tasks, NASA's oversight of the program is based on real-time and detailed insights from its personnel. With information from its employees, NASA's X-33 program office monitors and verifies the program's progress and pays the contractor when it meets milestones.

Several issues will need to be addressed before NASA can decide whether to use VentureStar reusable launch vehicles to support the International Space Station. First, the results of the X-33 Program must provide sufficient information for NASA to determine that risks have been adequately reduced and that continuation of activities leading to the agency's use of VentureStar is warranted. Second, even though VentureStar reusable launch vehicles are intended to be commercially owned and operated, government financial incentives may be needed to initiate such a venture. Third, the amount NASA would have to pay in additional development and production costs to enable VentureStar to carry people would need to be determined. Fourth, the need for and effect of additional flights would need to be considered. Because VentureStar would not carry as much cargo as the space shuttle, more frequent dockings are likely. This could reduce the amount of stable time available for some science operations.

The design and management of the X-33 Program agreement reflect the intent of the National Space Transportation Policy. However, the extent that the program will achieve a cost reduction envisioned by that policy is unclear at this time. In our August 1999 report, we recommended that NASA establish performance targets and a clear linkage between the X-33 Program and the agency's objective of reducing the cost of access to space. NASA concurred with our recommendation and stated that it would develop performance targets for the X-33 Program that (1) establish a clear path leading from the X-33 flight-test vehicle to an operational reusable launch vehicle and (2) show progress toward meeting the agency's objective of significantly reducing launch costs.

Background

The X-33 will be a half-scale model of Lockheed Martin's planned single-stage-to-orbit VentureStar, an operational vehicle that does not drop tanks and boosters along its flight path like today's launch vehicles. Lockheed Martin's and NASA's roles and responsibilities on the X-33 Program,

including joint funding arrangements, were set forth in a cooperative agreement established in July 1996.

NASA's decision on whether and how to upgrade its shuttle fleet will depend, in part, on the results of the X-33 Program. The X-33 Program is a key part of NASA's strategy to reduce launch costs from $10,000 per pound on the space shuttle to $1,000 per pound using reusable launch vehicles. If the X-33 Program is successful and Lockheed Martin decides to build VentureStar, the company plans to begin launching cargo-only flights starting in 2005 and passenger flights starting in 2007. Lockheed Martin estimates that it would cost $7.2 billion to build and begin operating two vehicles. NASA would be one of Lockheed Martin's potential customers for the cargo-only flights and, at this time, is the only anticipated customer for passenger flights. The passenger flights would carry crewmembers to and from the International Space Station.

Technical Problems Have Resulted in Increased Cost, Schedule Delays, and Reduced Performance Objectives

The X-33 Program has experienced technical difficulties developing advanced technologies for three key components of VentureStar: the fuel tanks, engines, and the heat shield. For example, the first major technical problem arose during fabrication of one of the fuel tanks used on the X-33. Sections of the tanks are made by bonding together layers of composite materials. Difficulties were encountered in bonding two lobes onto a y-shaped joint in the left-hand tank. The affected sections were removed, and two new sections were fabricated and are being installed on the tank. The right-hand fuel tank did not experience such fabrication difficulties and is undergoing qualification tests at NASA's Marshall Space Flight Center. As discussed in our August 1999 report, other technical problems were experienced while fabricating one of the exhaust ramps for the rocket engines and during fabrication of metallic panels used for thermal protection.

Resolving the technical problems increased both industry and government costs. As of March 1999, Lockheed Martin estimated that industry's contributions to complete the X-33 cooperative agreement had increased by $75 million, from $211.6 million to $286.6 million. The company has not yet formally revised the industry team's estimated contribution, but expects to do so within the near future. In addition, estimated government costs for NASA civil service personnel working on the program not included in NASA's X-33 program budget also increased, from $95.2 million to $113.1 million. These personnel costs are for salaries, benefits, and support services for the government personnel working on the program at

various NASA centers; such costs will be paid out of another NASA budget account.

In addition, the government will bear part of industries cost increases because Lockheed Martin and its partners are allowed to recover independent research and development expenses by including them as overhead in other government contracts. Potential government reimbursement of industry's independent research and development costs, which is subject to an audit or review, is estimated at $161.2 million as of March 1999. As a result, after factoring in both this potential reimbursement and NASA personnel costs not included in the program budget, we believe a more accurate representation of the estimated government's share of the X-33 Program is about $1.29 billion, while industry's estimated share is $125.4 million.

Technical difficulties have also caused test flight delays. The problems encountered during fabrication of the engines and one of the fuel tanks led to a 16-month delay of the first test flight of the X-33 vehicle, from March 1999 to July 2000. However, the program's December 2000 completion date remains unchanged. Lockheed Martin has maintained the original X-33 Program completion date by reducing VentureStar design and development work that the company had planned to accomplish. Although problems in fabricating the heat shield panels delayed delivery of the panels, this did not affect the first flight schedule because the schedule had already been delayed by the engine and fuel tank problems.

Technical problems and schedule constraints led Lockheed Martin and NASA to change two X-33 Program objectives and flight-test milestones. For example, the test flight speed objective was reduced from Mach[2] 15 to Mach 13.8. According to Lockheed Martin and NASA X-33 program managers, the flight-test speed was reduced because the detailed design phase of the program determined that the vehicle's projected weight would exceed design requirements and prevent it from reaching Mach 15. After reviewing the vehicle's design and technical objectives for the flight tests, a panel of experts convened by NASA concluded that the flight-test technical objectives could be achieved at a lower speed. According to Lockheed Martin and NASA program officials, weight reduction measures have

[2]Mach numbers represent speed measured as units of the speed of sound, which is 741 miles per hour at sea level. For example, Mach 2 equals 1,482 miles per hour.

already been incorporated into the preliminary design of the VentureStar to meet the vehicle weight requirements.

NASA Relies on Insight Gained by Working With Lockheed Martin

According to NASA program officials, the X-33 cooperative agreement establishes a partnership business relationship between NASA and Lockheed Martin, and changes to the agreement must be made bilaterally. The agreement assigns to Lockheed Martin responsibility for managing and implementing the X-33 Program but also permits substantial involvement of NASA personnel in performing various program technical tasks at NASA centers, under the direction of Lockheed Martin. However, NASA program managers ensure milestones are met before payments are made to Lockheed Martin.

The cooperative agreement enables NASA to obtain information about the program as it happens. In traditional research and development contracts, such information is gained mostly after the fact; NASA sends personnel to contractor facilities to perform an extensive review of whether the contractor performed its assigned tasks in accordance with contract specifications. In contrast, under the X-33 cooperative agreement, technical personnel work side by side with personnel from Lockheed Martin and other industry partners. This ongoing involvement in the work enables NASA to obtain real-time and detailed insight into program activities. For example, NASA became aware of a significant problem with a fuel tank component only 1-day after the problem occurred.

Oversight is also performed by entities independent of the X-33 Program. For example, NASA's Advisory Council performs periodic reviews of the X-33 Program. Members of the Council are volunteers appointed by NASA; the Council reports to the NASA Administrator. At a recent meeting, Council members discussed concerns about (1) whether there was a clear growth path leading from the X-33 flight-test vehicle to an operational single-stage-to-orbit vehicle and (2) NASA's lack of funding to pursue the shuttle/space station programs and single-stage-to-orbit development at the same time.

Issues Facing NASA if VentureStar Is Used to Support the International Space Station

Before NASA decides to use VentureStar to support the space station, it will need to evaluate (1) whether adequate progress has been made in resolving the technical problems in developing an operational reusable launch vehicle; (2) what government financial incentives, such as loan guarantees, may be needed to assist in developing an operational fleet of VentureStars; (3) what NASA's costs would be to build either two crew return modules or to modify VentureStar vehicles to carry crewmembers to and from the space station; and (4) what effect a larger number of VentureStar dockings would have on the operation of the space station and its science experiments because of VentureStar's lower cargo capacity.

Establishing confidence that the X-33 Program results support reusable launch vehicle development will be important. In 1995, the Office of Science and Technology Policy, the Office of Management and Budget, and NASA jointly established criteria to be used in deciding whether the government should proceed beyond the X-33 Program to support development of an operational single-stage-to-orbit VentureStar. The specific technical criteria for proceeding beyond the X-33 Program include requirements that NASA and the industry team use a flight-test vehicle to demonstrate technologies that are scalable to potential single-stage-to-orbit reusable launch vehicle configurations–a vehicle whose components are launched and returned as a single unit.

Another issue NASA will face is determining the future financial incentives the federal government may need to provide before Lockheed Martin can begin building VentureStar. Government incentives could be needed to enable Lockheed Martin to secure affordable private sector financing of the estimated $7.2-billion cost of building two reusable launch vehicles and begin flight operations. Borrowing costs for the VentureStar might be relatively high because investors would require a high rate of return due to the technical risks inherent in building a new space-launch vehicle. Government incentives could take several forms, including loan guarantees or NASA-funded technology development efforts.

Lockheed Martin plans to build VentureStars that initially carry only cargo and begin flights in 2005. Lockheed Martin is designing the VentureStar primarily to meet the needs of commercial customers who want to launch satellites. However, because much of Lockheed Martin's VentureStar projected revenues will come from servicing the International Space Station, the company is exploring design modifications that would enable the vehicles to carry four or five crewmembers. According to NASA's X-33

program manager, if the agency chooses to use VentureStar to service the International Space Station, NASA would need to obtain either two crew modules, at an estimated cost of $900 million to $1.2 billion, to be carried in the VentureStar cargo bay or two crew transfer/return vehicles being developed for the International Space Station.[3]

NASA will need to determine the effect of VentureStar on space station operations if it chooses to use that vehicle to assume the space shuttle's mission. For example, the agency's projections show that more VentureStar flights would be needed because the space shuttle can carry heavier payloads. Additional flights would result in more docking and undocking operations, potentially disrupting scientific activities aboard the space station. The space station requires replenishment of supplies for science experiments as well as propulsion fuel, spare parts, food, water, and air. Periodic replacement of station crewmembers is also required. NASA currently plans to use an average of five shuttle flights per year to resupply the station and to have some of its international partners use an average of eight flights per year to supply the station on other launch vehicles. Additional resupply flights would likely be required to provide the people and materials needed to solve technical problems that may arise aboard the space station. Each space shuttle can carry 34,200 pounds of cargo, including up to seven people, to the space station. However, in servicing the International Space Station, a VentureStar vehicle would be able to carry 25,800 pounds of cargo or three to four people and a small amount of cargo. Also, NASA plans to use shuttle crewmembers on the resupply flights to perform maintenance of the station. According to NASA X-33 program officials, a VentureStar vehicle would have to make two to three flights to provide as much cargo, as many people, or as much maintenance support to the space station as a single shuttle flight. The actual number of flights would depend on the mix of cargo, people, and maintenance operations required for a particular mission.

[3] The emergency return vehicle for the International Space Station crew is being considered as an alternative that would be attached to the exterior of the VentureStar.

Progress Toward Meeting National Space Transportation Policy Goals

The design and management agreement of the X-33 Program reflect the goals and guidelines of the National Space Transportation Policy. Issued in August 1994, this policy establishes national policy, guidelines, and implementing actions for the conduct of national space transportation programs that will sustain and revitalize U.S. space transportation capabilities. Assuring reliable and affordable access to space through U.S. space transportation capabilities is identified as a fundamental goal. In support of that goal, the policy states that the U.S. government will promote the reduction in the cost of current space transportation systems. Relevant to the X-33 Program, the policy's guidelines state that (1) NASA will be the lead agency for technology development and demonstration of next generation reusable space transportation systems, (2) the objective of NASA's technology development and demonstration effort is to support government and private sector decisions by the end of the decade on development of an operational next-generation reusable launch system, and (3) it is envisioned that the private sector could have a significant role in managing the development and operation of a new reusable space transportation system.

The X-33 partnership established between NASA and Lockheed Martin, Lockheed Martin's proposed VentureStar, and NASA's intent to acquire commercially provided launch services are indications that NASA is meeting the intent of the policy. However, the extent the X-33 Program will enable NASA to achieve cost reductions is unclear at this time and depends on the success NASA and Lockheed Martin achieve in resolving several challenges. These challenges range, in the short term, from implementing a successful test flight program that demonstrates needed technologies to, in the long term, moving ahead with a reusable launch vehicle such as the VentureStar that can meet both commercial and government needs in a timely and cost-effective manner. In this regard, adopting annual measurable objectives and performance targets that establish a clear path leading from the X-33 test flight vehicle to an operational reusable launch vehicle, as we recommended in our August 1999 report, will help ensure the program continues in that direction. NASA concurred with our recommendation.

Mr. Chairman, this concludes our statement. We will be happy to answer any questions you or Members of the Subcommittee may have.

Contact and Acknowledgement

For future contacts regarding this testimony, please contact Allen Li at (202) 512-4841. Individuals making key contributions to this testimony included Jerry Herley, Jeffery Webster, and Lorene Sarne.

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