United States Government Accountability Office

GAO

Report to the Chairman, Committee on Science and Technology, House of Representatives

November 2010

NASA

Medium Launch Transition Strategy Leverages Ongoing Investments but Is Not Without Risk

GAO-11-107

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Highlights

Highlights of GAO-11-107, a report to the Chairman, Committee on Science and Technology, House of Representatives

Why GAO Did This Study

The National Aeronautics and Space Administration (NASA) has long relied on the Delta II medium class launch vehicle to launch science missions. Delta II, however, is no longer in production, and no other vehicle in the relative cost and performance range is currently certified for NASA use. Thus, NASA faces a potential gap in the availability of medium class launch vehicles that could cause design challenges, delays, or funding issues.

GAO was asked to assess (1) NASA's and the Delta II contractor's, steps to ensure resources (budget, workforce, and facilities) are available to support safe Delta II operations through the last planned NASA flight in 2011; (2) NASA's plans and contingencies for ensuring a smooth transition from current small and medium class launch vehicles to other launch vehicles for future science missions; (3) the risks associated with NASA's planned approach to fill the medium launch capability gap; and (4) technical and programmatic implications to science missions if NASA commits to new launch vehicles before they are certified and proven. GAO identified and assessed transition plans and mitigation activities and interviewed responsible NASA and government officials.

What GAO Recommends

GAO recommends that NASA perform a detailed cost estimate based on knowledge gained during launch vehicle certification and adequately budget for potential additional costs. NASA concurred.

View GAO-11-107 or key components. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

NASA's Launch Services Program (LSP) is taking steps to address risks and ensure the success of the last planned Delta II launched missions through a combination of specific government approvals and targeted government insight into contractor activities and designs. For example, LSP uses government systems engineers with technical expertise to review or repeat the contractors' engineering analyses. This is a key factor in high launch success rates. From 1990 through 2009, LSP has achieved a 98 percent launch success rate. LSP is conducting additional reviews of launch vehicle processing to mitigate risk associated with the remaining Delta II flights. LSP has also identified several specific areas of concern with the remaining Delta II flights—including contractor workforce expertise, postproduction subcontractor support, spare parts, and launch pads—and is taking steps where possible to mitigate risks and ensure the success of the remaining missions.

NASA plans to leverage ongoing investments to acquire a new medium launch capability for science missions in the relative cost and performance range of the Delta II. The agency expects to eventually certify the vehicles being developed for space station resupply for use by NASA science missions. NASA has been in coordination with agency and contractor officials responsible for these efforts. Further, the agency revised its policy to allow for faster certification of new providers. Due to an active small class launch vehicle market and NASA's relative low need for vehicles in this class, the agency has no plans to develop additional small class launch vehicles. Rather, the agency will acquire these services through the NASA Launch Services II Contract.

NASA's plan has inherent risks that need to be mitigated. NASA has not developed detailed estimates of the time and money required to resolve technical issues likely to arise during the launch vehicle certification process. As these costs are currently unknown, according to Science Mission Directorate officials, NASA has not yet budgeted for them. Further, both space station resupply vehicles have experienced delays and more delays are likely as launch vehicle development is an inherently risky endeavor. Neither potential provider currently has the facilities needed to launch the majority of NASA earth science missions requiring a medium capability.

NASA medium class science missions that are approaching their preliminary design review face uncertainties related to committing to as yet uncertified and unproven launch vehicles. Launch vehicle decisions for these missions will be made before new vehicles are certified. Because changing the launch vehicle of a science mission after its preliminary design review is likely to lead to significant cost growth and schedule delays, NASA's intention is to select a launch vehicle and accept the impacts that any delays in the certification process could have to the cost and schedule of the science mission. NASA officials also indicated that future science missions might be asked to accommodate multiple launch vehicle possibilities if the availability of future vehicles is delayed.

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United States Government Accountability Office
Washington, DC 20548

November 22, 2010

The Honorable Bart Gordon
Chairman
Committee on Science and Technology
U.S. House of Representatives

Dear Mr. Chairman:

The National Aeronautics and Space Administration (NASA) relies on the U.S. commercial market to provide launch services for its space and Earth science missions. Over the past decade, NASA has launched 60 percent of its science missions on the Delta II medium class launch vehicle.[1] The United States Air Force, which had previously shared Delta II infrastructure costs with NASA, concluded its use of United Launch Alliance's Delta II launch vehicle in August 2009 with the launch of the last in a series of eight modernized global positioning satellites.[2] NASA now bears the Delta II infrastructure costs and plans to continue to use the Delta II as a launch vehicle for three remaining science missions—Aquarius, Gravity Recovery and Interior Laboratory, and National Polar-orbiting Operational Satellite System Preparatory Project—the last of which is currently scheduled to be launched in October 2011. NASA officials indicate that these costs are currently over $45 million a year and could increase to over $60 million per year, should the launches be delayed beyond 2012. Further, NASA contends that continuing to use the Delta II beyond the last projected launch in 2011 would be a significant expense beyond NASA's budget.

NASA projects that about 40 percent of science missions through 2020 could be launched on medium class launch vehicles depending on budget and launch vehicle availability. In addition, no U.S. company is actively developing a new medium class launch vehicle with all the capabilities required for science missions. NASA science spacecraft often carry sensitive instruments that require unique interfaces and special processing and handling. Although NASA has a continuing need for medium class

[1] NASA typically uses small, medium, and intermediate class launch vehicles for science missions. These classifications are explained in greater detail in fig. 2.

[2] United Launch Alliance builds and sells the Delta II, and other launch vehicles, to the government and private industry.

launch vehicles for science missions, the agency maintains that its need is insufficient to sustain the Delta II program at prices traditionally paid. Therefore, NASA faces a potential gap in the availability of medium class launch vehicles for science missions as the Delta II goes out of operation. Until this gap is closed, NASA science missions may face design challenges or delays due to uncertainties with the missions' launch vehicle.

Based on your request, we assessed (1) NASA's and United Launch Alliance's steps to ensure resources (budget, workforce, and facilities) are available to support safe Delta II operations through the last planned NASA flight; (2) NASA's plans and contingencies for ensuring a smooth transition from current small and medium class launch vehicles to other launch vehicles for future science missions; (3) the risks associated with NASA's planned approach to fill the medium launch capability gap; and (4) technical and programmatic implications to science missions if NASA commits to new launch vehicles before they are certified and proven.

To conduct our work, we interviewed NASA and United Launch Alliance officials and obtained, reviewed, and discussed their launch vehicle transition plans. We compared NASA's transition strategy to NASA and national space policies. We reviewed United Launch Alliance's process for certifying its processing and manufacturing workforce through the last NASA Delta II flight. We interviewed officials from Orbital Sciences Corporation (Orbital) and Space Exploration Technologies (SpaceX) to discuss their plans and schedules for certifying their launch vehicles that are currently being designed to support the International Space Station's Commercial Resupply Services contract for future medium class science missions. We also obtained and reviewed launch manifests, market projections, cost estimates, workforce estimates, and launch infrastructure maintenance needs from agency and contractor officials. We examined implications of committing to new launch vehicles before they are certified and proven through discussions with NASA's Launch Services Program (LSP) and Science Mission Directorate officials, including various science mission project managers, and through review of NASA's systems engineering policy. For our full scope and methodology, see appendix I.

We conducted this performance audit from March 2010 to November 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Delta II has historically been NASA's preferred medium class launch vehicle for its science missions, launching 36, or nearly 60 percent, of the agency's science missions since October 1998. Known as the workhorse of the launch industry, the Delta II comprises a group of expendable rockets that can be configured as two or three-stage vehicles and with three, four, or nine strap-on solid rocket motors depending on mission needs. The largest configuration is referred to as Delta II Heavy.

Figure 1: Delta II Launch

Source: NASA Kennedy Space Center (NASA-KSC).

The Commercial Space Act of 1998, U.S. Space Transportation Policy, and National Space Policy of the U.S. require NASA, to the maximum practical

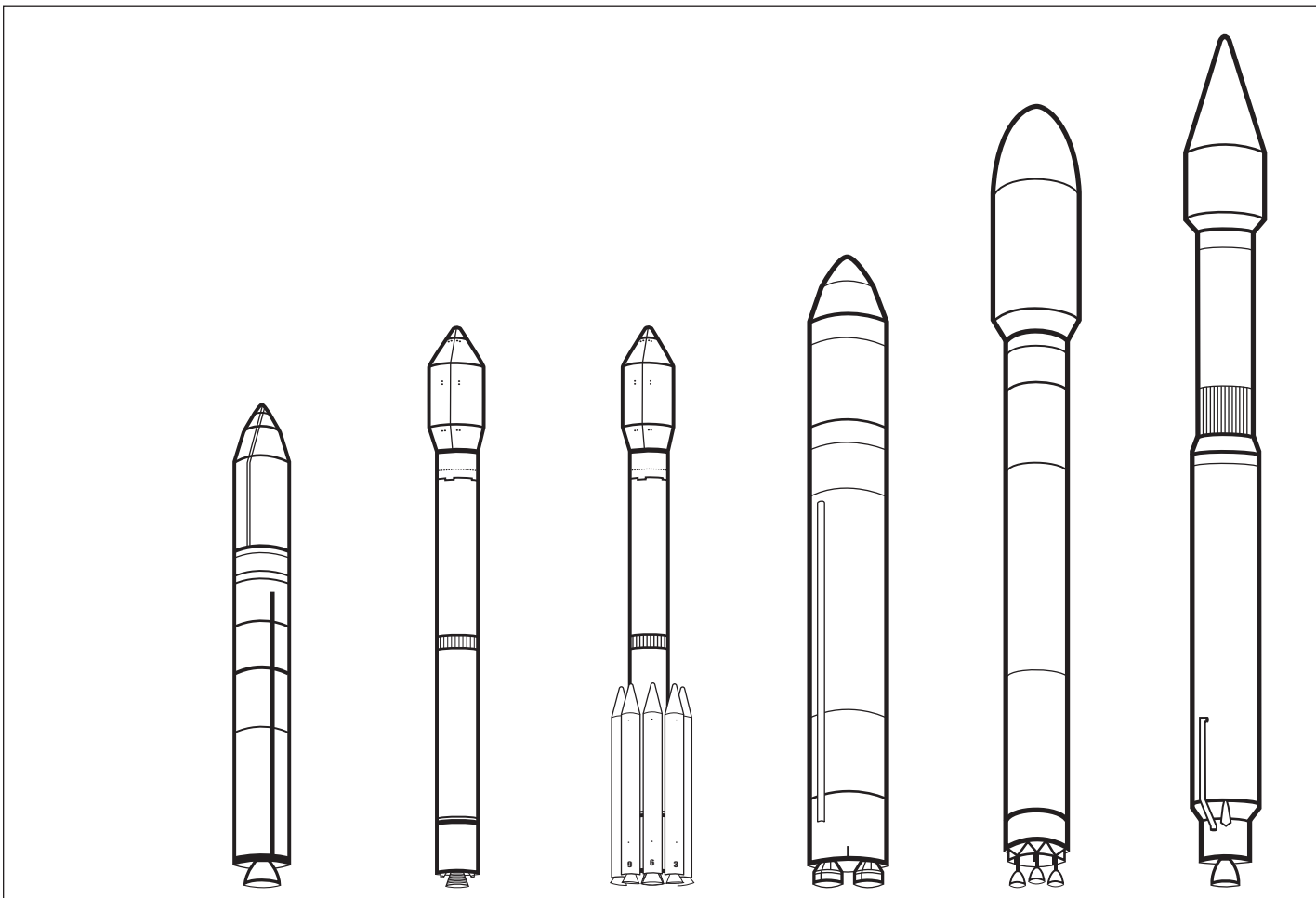
extent, to acquire launch vehicles from the U.S. commercial sector.[3] NASA uses the NASA launch services contract to acquire small, medium, and intermediate launch vehicles for NASA's science, exploration, and operational missions. The launch services contract is a multiple award indefinite delivery indefinite quantity (IDIQ) task order contract.[4] The original launch services contract competition in 2000 resulted in the award of firm-fixed price IDIQ launch services contracts with not-to-exceed prices[5] to Boeing Launch Services Incorporated (Boeing) and Lockheed Martin Commercial Launch Services Incorporated (Lockheed), which later merged to form United Launch Alliance, for the Delta and Atlas vehicles. In 2005, NASA awarded Orbital an IDIQ launch services contract for the small class launch vehicles Taurus, Taurus XL, and Pegasus XL, and in 2008 NASA awarded SpaceX an IDIQ launch services contract for the small class Falcon 1 and medium class Falcon 9 vehicles. Pursuant to the "on-ramp" clause in the launch services contract, the original solicitation remains open during the life of the contract to allow launch services providers—including contractors who have already been awarded an IDIQ launch services contract as well as other contractors—to introduce launch vehicles or technologies that were not available at the time of the award of the initial contract. See figure 2 for launch vehicles discussed in detail in this report.

[3] Commercial Space Act of 1998, Pub. L. No. 105-303, § 201(a); *U.S. Space Transportation Policy Fact Sheet*, paragraph IV.(1)(a) (Jan. 6, 2005); and *National Space Policy of the U.S.*, page 10 (June 28, 2010).

[4] An IDIQ contract requires the government to order and the contractor to furnish at least a stated minimum quantity of supplies or services during a fixed period. The government orders supplies or services under an IDIQ contract by issuing delivery orders or task orders, as appropriate. Federal Acquisition Regulation (FAR) § 16.504.

[5] Launch services provided under the contract include the basic launch vehicle, mission-specific implementation, and all necessary processing and handling, both standard to all launches and specific to individual launches.

Figure 2: Launch Vehicles and Capability



Name	Minotaur IV	Delta II	Delta II Heavy	Taurus II	Falcon 9	Atlas V
Model	N/A	7325	7925H	N/A	Block I	401
Contractor	Orbital	United Launch Alliance	United Launch Alliance	Orbital	SpaceX	United Launch Alliance
Class	Small	Medium	Medium	Medium	Medium	Intermediate
Maximum payload to escape Earth orbit	N/A	750 kg	1400 kg	1075 kg	1975 kg	3035 kg

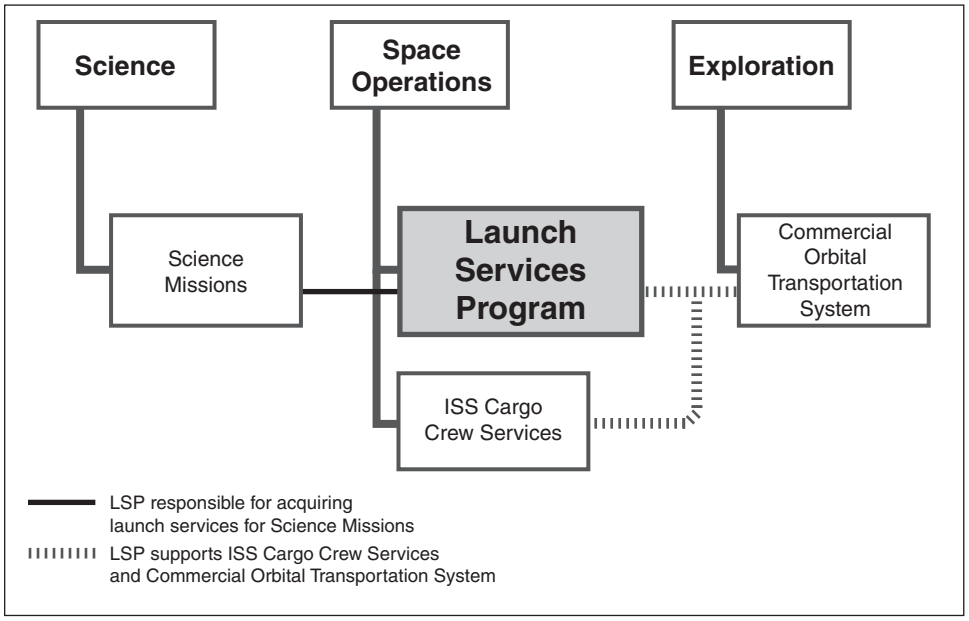
Source: NASA.

Note: Atlas V 401 is the smallest Atlas V available.

When NASA needs to acquire launch services for science missions, NASA's LSP, which is responsible for acquiring launch vehicles for NASA's Science Mission Directorate, issues a request for launch service proposals. All contractors who have been awarded a launch services contract at the time NASA issues the request for launch service proposals are contractually obligated to submit a proposal, unless the contracting officer waives the requirement. NASA considers each proposal according to specified criteria and awards the task order to the contractor who provides the best value in launch services that meet NASA's requirements. The ordering period under the NASA Launch Services I contract began in 2000 and expired in summer 2010. On September 16, 2010, NASA announced the award of the NASA Launch Services II contract which, like the NASA Launch Services I contract, is a multiple award IDIQ contract. NASA selected four companies for awards: Lockheed, Orbital, SpaceX, and United Launch Alliance, and each contract has an ordering period through 2020. Orbital did not respond to the contract solicitation for its Taurus II vehicle. According to Orbital officials, it plans to take advantage of the on-ramp clause of the NASA Launch Services contract in summer 2011. According to LSP officials, competition between the launch service providers is intended to lead the providers to sell NASA launch services at prices less than the negotiated not-to-exceed prices. This competition is limited in the medium and intermediate classes, however, because of the small number of providers who have been awarded a contract. For example, United Launch Alliance is currently the only provider of intermediate class launch vehicles for Earth orbit escape missions and Space X is currently the only provider of a medium class launch vehicle on the Launch Services II contract.

While NASA's LSP is responsible for acquiring launch services for science missions, several NASA offices are involved in the development of the new commercial launch vehicles that NASA plans to use to replace the Delta II. NASA's LSP is part of NASA's Space Operations Mission Directorate but also supports, and has formal relationships with, the International Space Station Cargo Crew Services program within the Space Operations Mission Directorate and the Commercial Orbital Transportation Services program within NASA's Exploration Systems Mission Directorate. See figure 3.

Figure 3: LSP Relationships with Key NASA Offices Involved in Developing New Commercial Launch Vehicles



Source: GAO analysis of NASA data.

NASA Commercial Orbital Transportation Services (COTS) program: The COTS program, which began in 2006, is intended to facilitate the development and demonstration of end-to-end transportation systems, including the development of launch and space vehicles, ground and mission operations, and berthing with the International Space Station. Under this program, NASA provides funding to SpaceX and Orbital through funded Space Act Agreements to help offset International Space Station-related developmental costs of the Falcon 9 and Taurus II, respectively. [6] Both the SpaceX vehicle, Falcon 9, and the Orbital vehicle, Taurus II, are medium class launch vehicles similar in capability to the Delta II.[7] SpaceX plans three demonstration flights under the COTS

[6] Funded Space Act Agreements are agreements under which appropriated funds are transferred to a domestic agreement partner to accomplish a NASA mission. Funded agreements may be used only when NASA's objective cannot be accomplished through the use of a procurement contract, grant, or cooperative agreement.

[7] Falcon 9 can launch intermediate class payloads to low earth orbit.

agreement, while Orbital plans one such flight. Under these agreements NASA provides progress payments, offsetting a portion of the developer's costs, when the partners meet established milestones.

NASA's Cargo Crew Services program: The program is responsible for acquiring commercial cargo resupply services for the International Space Station through the Commercial Resupply Services (CRS) contract with SpaceX and Orbital for flights beginning in calendar year 2011. NASA has ordered 12 resupply missions to the International Space Station from SpaceX, and 8 from Orbital. SpaceX and Orbital will use their respective launch vehicles, Falcon 9 and Taurus II, to provide these services.

NASA Is Taking Steps to Address Risk and Ensure Success of Remaining Delta II Missions

NASA's LSP is taking steps to address risk and ensure the success of the last planned Delta II launched missions. LSP's risk mitigation strategy uses established oversight mechanisms to address areas of concern and to assure the success of all remaining Delta II launched missions. LSP has issued task orders to United Launch Alliance for the final three Delta II missions through the Launch Services I contract. LSP exercises oversight of United Launch Alliance through a combination of specific government approvals and targeted government insight into contractor activities and designs.[8] Specific areas requiring government approval include spacecraft-to-launch vehicle interface control documents, mission-unique hardware and software design, top-level test plans, and requirements and success criteria for integrated vehicle systems. The government also has insight into baseline vehicle design, analyses, models and configuration management, critical flight hardware pedigree and postflight anomaly, and compliance evaluations.

An important element in LSP's oversight approach is the use of engineering review boards to independently review and validate the competency and adequacy of the contractor's technical efforts.[9] According

[8] Government approval entails providing the launch service contractor formally documented authority to proceed and/or formal acceptance of requirements, plans, tests, or success criteria in specified areas. Government insight means acquiring knowledge and understanding of contractors' actions by the monitoring of selected metrics and/or milestones through insight, documentation review, meeting attendance, and other means.

[9] Engineering review boards are multidisciplinary, systems-engineering based reviews of requirements and designs.

to LSP officials, having government systems engineers with the technical expertise to review or repeat the contractors' engineering analyses is a key factor in high launch success rates. From 1990 through 2009, NASA has achieved about a 98 percent launch success rate—compared to about a 69 percent success rate for U.S. commercial launches without significant U.S. government involvement.[10] Likewise, United Launch Alliance officials indicate that their company has never had a mission failure, successfully launching 37 missions in a 36-month period from December 2006 through December 2009.[11]

LSP is taking some additional actions to mitigate risk associated with the remaining Delta II flights. Due to the current low flight rate of the vehicle, LSP is conducting targeted field site closeout photo reviews during vehicle processing for each remaining NASA Delta II mission. According to agency officials, a closeout photo review includes photographing system components as assembly and processing steps are completed, and reviewing photographs to ensure assembly and processing steps were conducted as required. NASA conducts similar closeout photo reviews on the Pegasus and Taurus launch vehicle missions for the same reason—low flight rates.

LSP has also identified several specific areas of concern with the remaining Delta II flights—including contractor workforce expertise, postproduction subcontractor support, spare parts, and launch pads—that must be mitigated where possible to ensure the success of the remaining missions.

> *Workforce Expertise:* United Launch Alliance is taking steps to mitigate the risk that workforce expertise may be lost. For example, it actively tracks the certifications necessary for assembly, integration, ground operations, processing, and launch of the Delta II. United Launch Alliance also tracks the current certifications of the Delta II workforce and provides training necessary to retain the required certifications. To retain critical skills, United Launch Alliance uses essentially the same workforce for the Delta II and Delta IV, a vehicle that shares significant

[10] LSP has had 64 successful launches and 1 launch failure since the organization was formed in 1998.

[11] Both Lockheed and Boeing had failures in their respective Atlas and Delta programs before the United Launch Alliance merger.

commonality. LSP officials indicated that the LSP workforce would remain essentially unchanged through the last missions as LSP is responsible not only for Delta II but for all NASA science mission launches.

Postproduction Subcontractor Support: LSP is funding an approximately $8 million per year, postproduction support relationship, managed by United Launch Alliance, with key Delta II subcontractors. According to agency officials, this will ensure that subcontractors with knowledge and expertise needed to manufacture or repair subcomponents are available if needed. United Launch Alliance has contracted with Alliant Techsystems, Incorporated for solid rocket motors, Pratt & Whitney Rocketdyne for the first stage engine, and Aerojet for the second stage engine through fiscal year 2011.

Spare Parts: United Launch Alliance has implemented a process, which has previously been used on the last flights of other vehicles, to ensure key spare parts are available to support the final Delta II missions. This process identifies irreplaceable or critical hardware the unavailability, loss, or damage of which cannot be remedied without serious impact to program cost, schedule, or technical performance. United Launch Alliance has identified 28 such items for Delta II and will mitigate the risk of spare parts availability by either purchasing additional spares beyond planned needs or implementing quality assurance activities to minimize risk. In addition, LSP personnel have been assigned to assess and monitor Delta II launch vehicle spare parts during the retirement of the Delta II. United Launch Alliance also indicated the five currently unsold Delta II vehicles in the heavy configuration could be cannibalized for parts, if needed, for the remaining NASA Delta II missions.

Launch Pads: NASA has assumed responsibility for the operation and maintenance of the Delta II launch pads—Space Launch Complexes 17A and 17B at Cape Canaveral Air Force Station and Space Launch Complex 2 at Vandenberg Air Force Base—from the Air Force. NASA will perform continuing periodic maintenance through the final planned NASA Delta II flights from Space Launch Complex 17B in September 2011 and Space Launch Complex 2 in June and October 2011. The cost of ongoing operation and maintenance is included in the launch services contracts between LSP and United Launch Alliance. In some instances, however,

efforts beyond continuing maintenance are necessary. For instance, NASA is recertifying the fuel storage and water deluge systems at Space Launch Complex 17B.[12] See figure 4.

Figure 4: RP-1 Fuel Tank at Space Launch Complex 17B

Source: GAO.

Note: RP-1 fuel container at SLC 17B with insulation removed from welds so they can be inspected as part of recertifying fuel storage.

NASA officials estimate this effort will cost about $500,000 beyond normal operation and maintenance costs. NASA has also placed Space Launch Complex 17A in a "safe and secure" mode so that it can be cannibalized for spare parts to support remaining launches, if needed. Space Launch Complex 2 at Vandenberg Air Force Base has been undergoing more extensive renovations over the past few years to reduce risk, including the replacement of hydraulic systems and repairs to the lightning protection and water deluge systems. The renovation projects at Space Launch Complex 2 cost approximately $18 million and were funded by LSP.

[12] Water deluge systems flood the launch pad during launch to dampen vibrations and reduce fire risks.

NASA Plans to Leverage Falcon 9 and Taurus II Investments to Fill Medium Class Capability Gap While Its Approach for Small Class Vehicles Remains Unchanged

NASA plans to leverage ongoing investments in the COTS and CRS vehicles—Falcon 9 and Taurus II—to acquire a new medium launch capability for science missions in the relative cost and performance range of the Delta II.[13] LSP has been coordinating with NASA and contractor officials responsible for these efforts. Further, NASA revised its policy directive on launch vehicle certification[14] to allow the providers to certify their vehicles more quickly than would have been possible under the previous policy. Due to an active small class launch vehicle market and NASA's relative low need for vehicles in this class, the agency has no immediate plans to develop additional small class launch vehicles. Rather, the agency will acquire small class launch services using the NASA Launch Services II contract.

NASA Plans to Leverage Falcon 9 and Taurus II Investments to Fill Medium Class Capability Gap

NASA's plan to transition from Delta II to other medium class launch providers is to eventually certify the vehicles being developed for space station resupply for use by NASA science missions. This plan originated from a series of studies beginning in 2006 which examined launch market conditions and assessed whether the agency should continue to fly Delta II beyond the then-current Delta II manifest. These studies found that NASA should phase out Delta II, begin working with alternative launch providers to acquire a new medium class launch vehicle, and use vehicles—such as Atlas V or Delta IV—as an interim solution until alternative launch providers are ready. These studies culminated in an August 2009 report to Congress which laid out NASA's plans for transitioning to future small and medium class launch vehicles and discussed contingencies, each of which could involve additional time or funding, should the preferred solution not come to fruition as planned.[15] For example, NASA could:

- Continue indefinitely to launch medium class science missions on the Atlas V, which is capable of launching payloads with more size and mass than Falcon 9 or Taurus II but is about twice as expensive.

[13] The price for standard launch services on a Falcon 9 is roughly equivalent to the price paid in the past for Delta II standard launch services.

[14] NASA's approach to determining a launch vehicle's risk is through a launch vehicle certification process, which is laid out in NASA Policy Directive 8610.7D, *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions* (Jan. 31, 2008).

[15] *NASA: Strategy for Small and Medium-Class Launch Services pursuant to Section 621 of the NASA Authorization Act of 2008* (P.L. 110-422) (Aug. 2009).

- Launch multiple missions simultaneously on larger launch vehicles, which is a viable option in some instances, but according to NASA is difficult to coordinate due to specific factors such as orbit, destination, and development and launch schedule.

- Use the five remaining Delta II heavy configuration vehicles. Considering the additional infrastructure and postproduction support costs that Delta II would require, however, its costs could exceed that of the Atlas V and further it cannot easily be used for most earth science missions because of launch facility constraints.

- Use foreign launch vehicles or decommissioned excess Department of Defense (DOD) intercontinental ballistic missiles, such as Minotaur, as space transportation vehicles. The use of such vehicles, however, is governed by law and policy and would require time to be approved.

NASA believes that its preferred approach would leverage ongoing NASA investments in Falcon 9 and Taurus II made by the COTS and CRS programs and allow it to negotiate discounted prices for increased quantities of a common launch vehicle.

NASA's Launch Services Program Involvement in COTS and CRS Is Intended to Smooth Transition

LSP's involvement in the COTS and CRS efforts is intended, in part, to smooth NASA's transition to future medium class launch vehicles for science missions by giving LSP detailed, firsthand technical knowledge of the candidate vehicles. NASA's LSP has been in coordination with Orbital, SpaceX, and NASA's COTS and CRS programs for several years. For example, in addition to the funded Space Act Agreements under the COTS program, LSP entered into a nonreimbursable Space Act Agreement[16] with Orbital for technical insight into the development and design of the Taurus II in 2008. According to LSP officials, this partnership is expected to result in the agency gaining a better understanding of the launch vehicle, which will assist LSP when they begin the certification process for science missions and will allow Orbital access to NASA expertise for review of launch vehicle development documentation and independent assessments

[16] A nonreimbursable Space Act Agreement involves NASA and one or more partners in a mutually beneficial activity that furthers NASA's mission, where each party bears the cost of its participation and there is no exchange of funds between the parties. Under such arrangements, NASA can offer personnel, support services, equipment, expertise, information, or facilities. These agreements can be used for collaborative efforts that build on each partner's areas of expertise and for which the end results are of interest to both parties.

of various Taurus II systems and performance. This relationship has already provided benefits. For example, through this relationship, LSP persuaded Orbital to include additional engine testing into the Taurus II test strategy that will ultimately contribute to the certification effort for science missions. LSP does not have such an agreement in place with SpaceX; however, LSP may gain insight into SpaceX's design for Falcon 9 that should provide similar benefits because SpaceX was awarded a NASA Launch Services contract in 2008 and 2010. SpaceX was awarded a Launch Services I and II contract, but NASA has not awarded SpaceX any task orders under those contracts. If NASA had awarded SpaceX a task order, its technical insight to Falcon 9 would be greater.

In 2007, LSP entered into a Memorandum of Understanding with the Commercial Crew and Cargo Program Office which manages the COTS demonstration missions. Although LSP is not responsible for mission success, under this agreement it serves in a consulting role. For example, LSP is a member of the COTS advisory team and provides technical guidance, mentoring, and lessons learned relating to launch system development. LSP also attends technical meetings, such as preliminary design reviews, as requested.

LSP also has a Memorandum of Agreement in place with the International Space Station program to support the CRS missions. Under the terms of this agreement, LSP will perform nonrecurring and limited recurring technical assessments and make recommendations for specific launch vehicle hardware, software, and analyses. While LSP is not responsible for mission success, it will perform launch vehicle mission and fleet risk assessments, focusing on systems that have been historical causes of mission failure. The assessments that LSP will conduct include

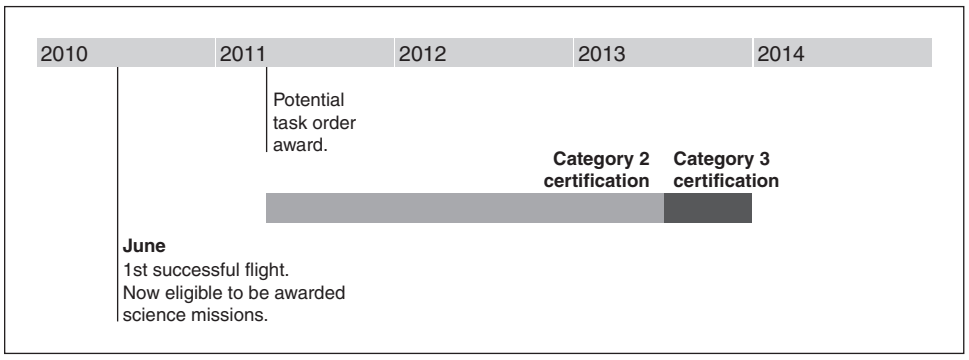
- a postflight data review for each flight;
- a mission-unique design review for the first flight of each launch vehicle configuration;
- a "test like you fly" hardware qualification assessment for launch vehicle propulsion, flight controls, and separation systems; and
- an assessment of the launch vehicles' guidance, navigation, and control design and an assessment of flight software and recurring software development practices.

Some of these assessments, such as the "test like you fly" hardware qualification assessment, could be applicable to the eventual certification process for science missions and LSP technical oversight of new launch providers, as long as the same launch vehicle configuration is used. This

could shorten the length of time required to certify the vehicles for science missions.

The formal certification process for each launch vehicle will commence after LSP awards a task order to the contractor for a science mission. Under the Launch Services II contract, a vehicle cannot be considered for a launch service task order for a science mission until it has had a successful first flight. Falcon 9 had a successful first flight in June 2010, but has not been awarded a science mission. The Taurus II's first flight will be no sooner than September 2011. According to NASA, on average it takes about 3 years once a task order is awarded to complete certification. Therefore, if Falcon 9 is awarded one of the first science missions under the Launch Services II contract, assuming only limited technical challenges and only minor changes are needed for certification, NASA could certify Falcon 9 to category 2 by mid 2013 and to category 3 by late 2013 or early 2014.[17] According to NASA, if resources are available, LSP may proactively begin the formal certification process for Falcon 9 or Taurus II prior to award of a task order for a science mission under the Launch Services II contract. See figure 5 for a time line for certifying Falcon 9 based on a potential task order award in early 2011.

Figure 5: Certification Time Line for Falcon 9 Based on Potential Launch Services Task Order Award



Source: GAO analysis of NASA data.

[17]A category 3 launch vehicle is a low-risk vehicle certified to launch missions of all risk classifications A, B, C, and D missions. A category 2 launch vehicle is a medium-risk vehicle certified to launch risk classification B, C, and D missions. See table 1 for more details.

NASA's Revision of Certification Requirements Allows Faster Certification of Launch Vehicles

NASA revised its launch policy to enable more certification opportunities for emerging launch vehicle providers, and according to LSP officials, these changes could also speed up the certification process. LSP officials indicate that the former policy could have required 10 or more years to certify a new vehicle to category 3, the highest level of vehicle certification, and given the imminent retirement of the Delta II, NASA considered this gap too large.[18] NASA eventually plans to certify the Falcon 9 and Taurus II vehicles to category 3. However, NASA may initially certify the vehicles to category 2, the next highest certification depending on the payload risk classification of the initial mission or missions to use the new vehicle. The Science Mission Directorate assigns payload risk classifications, A through D, with A being least tolerant to risk. See table 1. The risk posture then becomes a requirement in securing a launch vehicle through the Launch Services contract.

Table 1: Criteria for NASA Science Payload Risk Classification for Certified Launch Vehicles

Characterization	Class A	Class B	Class C	Class D
Required Launch Vehicle Category	Category 3	Category 3, Sometimes Category 2	Category 3 or 2	Category 3, 2, or 1
Priority (Criticality to Agency Acceptable Risk Level Strategic Plan)	High priority, very low (minimized) risk	High priority, low risk	Medium priority, medium risk	Low priority, high risk
National significance	Very high	High	Medium	Low to medium
Complexity	Very high to high	High to medium	Medium to low	Medium to low
Mission Lifetime (Primary Baseline Mission)	Long, > 5years	Medium, 2-5 years	Short	Short, < 2 years
Cost	High	High to medium	Medium to low	Low

Source: NASA.

Under the revised policy,[19] there are three alternative approaches to certification to category 3, as shown in table 2.

[18] NASA Policy Directive 8610.7C, *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions* (Apr. 5, 2005) required 14 consecutive successful flights of a new launch vehicle for certification to category 3.

[19] NASA Policy Directive 8610.7D, *Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions* (Jan. 31, 2008).

Table 2: Summary of Category 2 and 3 Certification Alternatives

Category 2 certification alternatives		Category 3 certification alternatives		
Alternative 1	**Alternative 2**	**Alternative 1**	**Alternative 2**	**Alternative 3**
1 successful flight of a common launch vehicle configuration, instrumented to provide design verification and flight performance data Postflight operations/anomaly resolution process NASA flight margin verification	3 successful flights (minimum 2 consecutive) of a common launch vehicle configuration, instrumented to provide design verification and flight performance data Postflight operations/anomaly resolution process NASA flight margin verification	14 consecutive successful flights (95 percent demonstrated reliability at 50 percent confidence) of a common launch vehicle configuration, instrumented to provide design verification and flight performance data Postflight operations/ anomaly resolution process NASA flight margin verification	6 successful flights (minimum 3 consecutive) of a common launch vehicle configuration instrumented to provide design verification and flight performance data Postflight operations/ anomaly resolution process NASA flight margin verification	3 successful flights (minimum 2 consecutive) of a common launch vehicle configuration instrumented to provide design verification and flight performance data Postflight operations/ anomaly resolution process NASA flight margin verification
Additional NASA analyses and review	Additional NASA analyses and review NASA independent validation and verification		Additional NASA analyses and review NASA independent validation and verification	Additional NASA analyses and review including a full root cause or "fishbone" analysis. NASA independent validation and verification Hardware qualification

Source: NASA data.

When a category 3 certification is required of one of the new vehicles, NASA plans to use the certification alternative that requires 3 successful flights (2 of which must be consecutive) of the same vehicle configuration, a flight margin verification, and a full vehicle root cause analysis, among

other analyses, to certify the vehicles.[20] If the first NASA mission using one of the new vehicles only requires a category 2 certified vehicle, then NASA will use one of the category 2 alternatives as appropriate. Currently, Orbital has 8 Taurus II CRS missions under contract with NASA, and SpaceX has 12 Falcon 9 CRS missions under contract with NASA, as well as commercial contracts. These flights, if successful, may be applied to NASA's certification requirements, as long as at least 3 successful flights are based upon the same vehicle configuration. Changes to a vehicle's configuration—the distinct combination of core propulsive stages and hardware—will reset the number of required successful flights.

NASA Plans to Rely on Existing Small Class Launch Vehicles Providers

NASA's near-term plan for small class launch vehicles is to rely on small class providers through the NASA Launch Services II contract because the number of small class launch vehicles currently available is sufficient to meet NASA's needs. The small class launch services market currently has five U.S. launch vehicles—SpaceX's Falcon 1; Orbital's Taurus and Pegasus; Lockheed's Athena; and DOD's Minotaur—although Minotaur is not readily available to NASA.[21] NASA's strategy is to seek competition without encouraging oversupply, which will allow the market to stabilize over the next several years. According to agency officials, the fostering of a small class of launch vehicles is important because new launch service providers have tended to start with smaller vehicles before moving on to develop larger ones. However, NASA forecasts only about one science mission in the small class per year. Because DOD has typically used Minotaur launch vehicles in the small class, NASA asserts that its needs, along with the needs of the commercial market, can only provide enough business to support about one to two providers in the small class.

[20]Flight margin verification compares the predicted performance of a launch vehicle design to the actual performance of a launch vehicle system during flight with the intent of ensuring that demonstrated performance margins are sufficient to ensure safety and reliability. Root cause analysis is a structured evaluation method that identifies the root causes for an undesired outcome and the actions adequate to prevent recurrence. A root cause is one of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated, or modified, would have prevented the undesired outcome. Root cause analysis should continue until organizational factors have been identified, or until data are exhausted.

[21]SpaceX, Orbital, and Lockheed were awarded Launch Services II contracts in 2010. Minotaur is derived from decommissioned intercontinental ballistic missiles and its use by NASA is governed by law and policy.

NASA Plan to Acquire Future Medium Class Launch Vehicles Includes Inherent Risk

NASA has a reasonable plan for addressing the medium launch capability gap, but its approach has inherent risks that need to be mitigated. First, NASA has not developed detailed estimates of the time and money required to resolve technical issues likely to arise during the launch vehicle certification process. Second, both Taurus II and Falcon 9 have already experienced delays and history indicates more delays are likely as launch vehicle development is an inherently risky endeavor. Finally, neither potential provider currently has the proper facilities, such as a West Coast launch site, needed to launch the majority of NASA earth science missions requiring a medium capability.

NASA Lacks Detailed Estimates for Time and Money Needed to Ensure Adequate Resources Are Available

NASA has not prepared a detailed estimate of the potential costs to resolve technical issues and implement modifications and upgrades required for NASA's specific science mission needs that are likely to arise during the certification process for Falcon 9 and Taurus II. Based on the historical costs of certifying launch vehicles such as Atlas V, LSP estimates about $15 million could be required for each vehicle. LSP officials noted that if serious problems or shortfalls are discovered during the certification process, or extensive changes need to be made to the basic launch vehicle design to accommodate science mission needs, these costs could be higher. For example, if the certification process uncovers inadequacies with the contractors' qualification test program or the flight margin verifications uncover significant differences between predicted and actual system performance in flight, NASA or the contractor may be faced with significant cost increases or delays. Ancillary changes to components such as connectors and payload adapters needed to accommodate the science mission spacecraft are unlikely to increase estimated costs. According to NASA officials, relative immaturity of a vehicle and inexperience of a provider could contribute to higher costs and additional time needed for certification. Further, any additional work needed may not be achievable within the expected 3-year time frame of the certification process.

Based on anticipated labor rates, LSP estimates that the total cost to conduct the assessments necessary to certify each vehicle will be about $10 million. These costs are in addition to the approximately $15 million NASA anticipates will be required to resolve technical issues and implement required modifications and upgrades resulting from the certification assessment. According to program officials, these costs would be passed on to the customer, the Science Mission Directorate, which would determine how to budget for these costs. For example, the directorate could assign these costs to the first mission to use a new launch vehicle, or amortize the cost over the first several missions.

However, it is currently undetermined who would pay the costs for fixes needed to meet NASA's specific science mission requirements. In the case of the Atlas V, such costs were shared by NASA, DOD, and the contractor. The responsibility for these costs will have to be negotiated as needed between LSP, the Science Mission Directorate, and the contractors. As additional costs are currently unknown, according to Science Mission Directorate officials, NASA has yet to budget for them. GAO's Cost Estimating Guide, however, indicates that assumptions should be made about the costs of unknowns and that contingency funding should be reserved to cover potential costs.[22]

Schedule Delays with Taurus II and Falcon 9 Have Occurred and More Are Likely

Both SpaceX and Orbital have experienced delays in the development and testing of Falcon 9 and Taurus II, respectively. We reported in June 2009 that both companies were working under aggressive schedules and their vehicles were experiencing schedule delays—at the time, the first flight of the Falcon 9 was scheduled for June 2009 but slipped to June 2010, whereas the first flight of the Taurus II was scheduled for December 2010 and has now slipped to no earlier than September 2011.[23] Further, our past work and NASA's experience indicate that more delays are likely, given that developing launch vehicles is an inherently complex and risky endeavor.[24] For example, we reported in 2005 that the Air Force's Delta IV Heavy Lift Vehicle's first operational flight was delayed 6 months, due in part to design problems discovered in testing.[25] Likewise, according to NASA, vehicle histories from SpaceX, Orbital, and United Launch Alliance indicate that the average delay in the third successful launch of a new vehicle is 31 months from the manifested date of launch.[26] The contractors for Falcon 9 and Taurus II are not currently awarded any task orders for science missions; therefore the formal certification process for each has

[22] GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, GAO-09-3SP (Washington, D.C.: Mar. 2009).

[23] GAO, *NASA: Commercial Partners are Making Progress, but Face Aggressive Schedules to Demonstrate Critical Space Station Cargo Transport Capabilities*, GAO-09-618 (Washington, D.C.: Jun. 16, 2009).

[24] GAO, *NASA: Constellation Program Cost and Schedule Will Remain Uncertain Until a Sound Business Case Is Established*, GAO-09-844 (Washington, D.C.: Aug. 26, 2010).

[25] GAO, *Defense Acquisitions: Assessments of Selected Major Weapon Programs*, GAO-05-301 (Washington, D.C.: Mar. 31, 2005).

[26] Vehicles include all configurations of the Delta IV, two configurations of Atlas V, Falcon 1, Pegasus, and Taurus.

not begun. Consequently, the schedule and budget of any science mission that is assigned to one of these vehicles could be negatively impacted if delays occur in the certification process. While NASA expects these vehicles will eventually become a viable option for medium class science missions, it is uncertain how long the process might take.

SpaceX and Orbital Lack Facilities Necessary to Meet Requirements for Some Science Missions

Neither SpaceX nor Orbital currently has a high-inclination launch site option for its medium class vehicle, yet the majority of NASA's Earth science missions require such a site due to the high inclination required to achieve a polar orbit.[27] Launches from the East Coast of the United States are suitable only for low-inclination orbits because major population centers underlie the trajectory required for high-inclination launches. High-inclination launches are accomplished from the West Coast because the flight trajectory avoids populated areas. Orbital is conducting a site selection survey and its West Coast options include Kodiak, Alaska; Space Launch Complex 2 at Vandenberg Air Force Base, California; and Space Launch Complex 8, also at Vandenberg Air Force Base, California, which Orbital currently uses to launch the Minotaur. According to Orbital officials, the site selection decision is expected in 2011, with the site ready for operations as early as 2014. According to SpaceX officials, SpaceX plans are underway to secure a Falcon 9 launch site at Vandenberg Air Force Base for high-inclination launches. This capability is planned to be ready for operation by late 2012. However, if the launch sites are not available when needed, NASA's planned science mission manifest could be negatively impacted, as 12 of the 14 medium class science missions planned through 2020 that do not yet have assigned launch vehicles require a high-inclination launch.

[27] Inclination is the angular distance of the orbital plane from the plane of the planet's equator. An inclination of 0 degrees means the spacecraft orbits the planet at its equator and in the same direction as the planet rotates. An inclination of 90 degrees indicates a polar orbit in which the spacecraft passes over the north and south poles of the planet.

Science Missions in Development Face Uncertainties Related to Committing to Launch Vehicles before They Are Certified and Proven

NASA science missions requiring a medium class launch vehicle that are approaching their preliminary design review face uncertainties related to committing to as-yet uncertified and unproven launch vehicles. The preliminary design review marks the point at which it is demonstrated that the preliminary design meets system requirements with acceptable risk and within cost and schedule constraints, and establishes the basis for proceeding with detailed design. Shortly after the preliminary design review, a project establishes its commitment baseline which documents the project's estimated cost and schedule. From this point on, almost all changes to baselines are expected to represent successive refinements, not fundamental changes. NASA program managers indicated that the launch vehicle of a science mission should be assigned by the preliminary design review to allow the science mission design team to optimize their spacecraft based on the operational characteristics of the launch vehicle. A number of NASA science missions are approaching the preliminary design review; therefore, decisions need to be made about the launch vehicle for these missions. However, as indicated by figure 6, some decisions will have to be made before either the Falcon 9 or Taurus II is certified for science missions.

Figure 6: Launch Vehicle Decision Dates (or Preliminary Design Review Dates) and Planned Launch Dates for Missions Potentially Needing Medium Launch Capability Vehicles

Mission name	Launch vehicle decision needed	Planned launch date
SMAP	03/2011	11/2014
JPSS-1	TBD	2014
ICESat-2	11/2011	10/2015
Discovery 12	TBD	2016
EX-1	TBD	2016
Grace-FO	TBD	2016
EX-2	TBD	2017
DESDynI-L	2013	2017
Earliest Falcon 9 category 3 certification -		**Late 2013/Early 2014**
CLARREO-1	2014	2017
Discovery 13	TBD	2018
JPSS-2	TBD	2018
PACE	TBD	2018
ASCENDS	TBD	2019
EX-3	TBD	2019
CLARREO-2	TBD	2020
EX-4	TBD	2020
STP-5	TBD	2020
SWOT	TBD	2020

Source: GAO analysis of NASA data.

Note: EX-1, EX-2, EX-3, and EX-4 could be launched on a small or medium class vehicle depending on budget and launch vehicle availability. The launch vehicle decision is most optimally made prior to the preliminary design review, which as indicated above generally occurs 3-4 years prior to the planned launch date.

The Soil Moisture Active and Passive (SMAP), Joint Polar Satellite System (JPSS-1), and Ice, Cloud, and land Elevation Satellite (ICESat-2) missions are approaching their preliminary design reviews and are the first three missions requiring a medium capability for which a Falcon 9 could potentially be selected for launch services. Falcon 9 had a successful first flight in June 2010 and could potentially be certified as a category 3 vehicle by late 2013 or early 2014. NASA is planning for the imminent release of a request for launch service proposals for the SMAP mission and tentatively plans to issue requests for proposals for the JPSS and ICESat-2 missions in

spring 2011. If Falcon 9, the only medium class launch vehicle currently available under the Launch Services II contract, is selected for any of these missions, the mission launch date will be tied to a successful certification of the Falcon 9 launch vehicle. Because the preliminary design review establishes the basis for proceeding with detailed design, according to NASA officials, any changes to accommodate a new launch vehicle after the preliminary design review are fundamental changes and rarely, if ever, occur.[28] Therefore, NASA's intention is to select a launch vehicle and accept any delays and residual cost increases to the science mission associated with delays in the certification process. According to NASA officials, changing the planned launch vehicle of a science mission after its preliminary design review is a fundamental change to the mission design and would lead to significant cost growth and schedule delays.[29] As figure 6 illustrates, several NASA missions require a launch vehicle decision prior to the certification of Falcon 9. While NASA expects that Falcon 9 could be certified to a category 3 prior to the planned launch dates of these missions, given the relative immaturity of the launch vehicle and the likelihood of further delays, the schedule for these missions could be at risk if the Falcon 9, or any other unproven launch vehicle, is selected.

NASA officials indicated that science missions within the next few years might be asked to design to accommodate multiple launch vehicle possibilities if the availability of future vehicles is delayed or until the task order is issued for the particular mission. Science Mission Directorate officials indicated that while designing to accommodate multiple launch vehicles is possible, the practice is cumbersome, especially when continued beyond the preliminary design review. Under this type of design scenario, every decision is constrained to the worst case performance

[28] The changes required to several mission launch vehicles after the 1986 Challenger accident illustrate the impact. For example, NASA moved the Cosmic Background Explorer Mission from the Space Shuttle to a Delta I launch vehicle. Consequently, every design element of the Cosmic Background Explorer mission spacecraft had to be reconsidered, from how its solar panels would deploy to how the science instruments would be affected by the vibrations they would encounter on the new launch vehicle. Ultimately, the mission was successfully launched in November 1989, 16 months later than originally scheduled on the Space Shuttle, but only after NASA collocated engineers and scientists and worked in some instances 7 days a week in three around-the-clock shifts.

[29] In 1997, GAO reported that several Department of Defense satellite systems were transitioned to Evolved Expendable Launch Vehicles after they had been designed to launch on other vehicles. These changes resulted in approximately $117 million in additional costs to the programs. GAO, *Access to Space: Issues Associated with DOD's Evolved Expendable Launch Vehicle Program*, GAO/NSIAD-97-130 (Washington, D.C.: Jun. 24, 1997).

characteristic of the competing vehicles. Consequently, overall mission effectiveness is reduced, because benefits associated with a particular vehicle are traded away to design to the lesser set of capabilities of another vehicle. Thus, if the less constrained vehicle is chosen, that capability is left unused. Ultimately, the scientific benefit of the planned mission is reduced, because the science payload may have to be adjusted to accommodate reduced launch capability.

Conclusions

NASA is taking an appropriate approach to help ensure the success of the remaining Delta II missions by adequately addressing workforce, support, and launch infrastructure risks. Nevertheless, an affordable and reliable medium launch capability is critical to NASA meeting its scientific goals. NASA has a plan in place for obtaining this capability through Orbital and SpaceX's vehicles, but past experience with other development programs and recent history with both vehicles indicate that maturing and certifying these vehicles for use by science missions is likely to prove more difficult and costly than currently anticipated. If the companies are not successful in delivering, in a timely manner, reliable and cost-effective upgraded launch vehicles that can be used for NASA science missions, NASA will lack an affordable domestic launch capability in the medium performance vehicle class and could be forced to use more costly or time-consuming options. Further, costs associated with addressing any issues discovered during the certification process and resulting from the need to delay missions or use other alternatives will require trade-offs to be made that will likely impact the number of science missions the agency can afford.

Recommendations for Executive Action

Given the likelihood of delays and additional costs associated with developing and fielding a medium class launch vehicle fully certified for science missions and the implications to funding available to support science missions, we recommend that as LSP gains a more complete understanding of the detailed designs and actual performance of the Falcon 9 and Taurus II, the NASA Administrator require,

- NASA's Science Mission Directorate—in conjunction with NASA's Space Operations Mission Directorate—to perform a detailed cost estimate to determine the likely costs of certification and the trade-offs required to fund these costs. This estimate should at a minimum examine the need for funds to resolve technical issues with the Falcon 9 and Taurus II launch vehicles discovered through the certification process. The estimate should also examine the costs associated with delaying science missions if necessary until launch vehicles are

available or contingencies such as selecting more costly or time-consuming launch options.

Given that NASA's Science Mission Directorate could have to fund additional significant costs for certification and the use of contingencies, we recommend that the NASA Administrator require,

- that the costs identified through developing the detail cost estimate are adequately budgeted for and identified by the Science Mission Directorate.

Until such time, however, that these costs are better understood, we recommend that the NASA Administrator require,

- the Science Mission Directorate to identify and budget for additional contingency funding for the projects requiring a medium launch capability vehicle and approaching their preliminary design review prior to certification of Falcon 9 and Taurus II that could be impacted by additional costs associated with certification of these vehicles, including the need to address technical issues and shoulder delays in the certification process.

Agency Comments and Our Evaluation

In written comments on a draft of this report (see app. II), NASA concurred with our recommendations. NASA acknowledged the risks associated with its transition strategy for medium class launch vehicles and recognized the importance of developing detailed cost estimates, budgeting for known costs, and identifying and budgeting additional contingency funding for unknown costs. NASA stated that the Space Operations Mission Directorate will develop detailed estimates of the costs to certify the new vehicles as well as to resolve technical issues during certification, and the Science Mission Directorate will estimate the costs for its missions if certification is delayed. Based on these estimates, the Science Mission Directorate will appropriately budget for certification costs and potential contingencies in future budget cycles. Separately, NASA provided technical comments, which have been addressed in the report, as appropriate.

We will send copies of the report to NASA's Administrator and interested congressional committees. The report will be available at no charge on the GAO 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 at ChaplainC@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff that made key contributions to this report are listed in appendix III.

Sincerely yours,

Cristina T. Chaplain
Director, Acquisition and Sourcing Management

Appendix I: Scope and Methodology

To examine the National Space and Aeronautics Administration's (NASA) and United Launch Alliance's steps to ensure resources (budget, workforce, and facilities) are available to support safe Delta II operations through the last planned NASA flight, we interviewed NASA Launch Services Program (LSP) program officials and United Launch Alliance program officials and reviewed their launch vehicle transition plans. We obtained contract documents, launch manifests, risk information sheets, and engineering review board documentation from LSP to examine NASA's planned contracting and technical approach for managing NASA's remaining Delta II missions. We also compared NASA's transition strategy to NASA and national space policies. We reviewed United Launch Alliance's processes for certifying its work force for processing and manufacturing, launch manifests, market projections, cost estimates, workforce estimates, and launch infrastructure maintenance needs through the last planned NASA Delta II flight in October 2011. We also visited Space Launch Complex 17B at Cape Canaveral Air Force Station, Florida and visually inspected ongoing efforts to maintain Delta II launch capability through the last planned Delta II flight from this facility in 2011 and interviewed relevant NASA and contractor personnel at the launch complex regarding their maintenance efforts.

To examine NASA's plans and contingencies for ensuring a smooth transition from current small and medium class launch vehicles to other launch vehicles for future science missions, we interviewed relevant program officials and obtained and reviewed agency documents related to their transition plans. We interviewed officials within NASA's Exploration Systems Mission Directorate, Space Operations Mission Directorate, and Science Mission Directorate regarding these plans. We also discussed these plans with NASA's Office of Inspector General. We further interviewed officials from Orbital Sciences Corporation and Space Exploration Technologies to discuss their plans for certifying their launch vehicles, which are currently being designed to support the Commercial Resupply Services contract for future medium class science missions. We reviewed the launch providers' launch vehicle manifests and launch vehicle histories. We compared the agency's plans for certifying these vehicles to relevant NASA policy directives, risk mitigation strategies, U.S. law, and National Space Policy. We also examined how the agency's certification requirements have evolved to facilitate transition to future launch services providers.

To examine the risks associated with NASA's planned approach to fill the medium launch capability gap, we interviewed officials with NASA's Launch Services Program and identified and analyzed risks, and their

accompanying mitigation strategies. We interviewed NASA Science Mission Directorate and Space Operations Mission Directorate and contractor officials responsible for both the Falcon 9 and Taurus II development programs and determined where their programs are in the development process and obtained their estimates of when these vehicles might be ready to launch science missions. We also reviewed prior GAO reports and identified risks common to all spacecraft development efforts.

To examine technical and programmatic implications to science missions if NASA commits to new launch vehicles before they are certified and proven, we reviewed NASA's systems engineering policy and interviewed officials with NASA's Science Mission Directorate, NASA science mission project managers, and the Launch Services Program and discussed potential cost and schedule effects of committing to unproven launch vehicles.

We conducted this performance audit from March 2010 to November 2010 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comments from National Aeronautics and Space Administration

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

NOV 19 2010

Ms. Cristina T. Chaplain
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

NASA appreciates the opportunity to comment on your draft report entitled, "NASA Medium Launch Transition Strategy Leverages Ongoing Investments But Is Not Without Risk" (GAO-11-107). Given the current changes in the commercial launch vehicle market and the outlook for the next several years, NASA has been actively engaged in managing risks associated with launch vehicle availability and cost, including those risks related to the close out and/or start up of launch vehicle lines. NASA activities to date are consistent with those recommended by the Government Accountability Office (GAO), and the Agency concurs with the recommendations as outlined below.

As part of this engagement, the GAO evaluated the steps NASA is taking to ensure the safe fly-out of the three remaining science missions that will use the Delta II launch vehicle and NASA's plans for future launch vehicles, including the Falcon 9 and Taurus II. NASA agrees with the conclusions of this report. However, it should be noted that implementation of recommendations relative to Taurus II will be accomplished at a later date. As the draft report indicates, in September 2010, NASA announced contract awards of the NASA Launch Services (NLS) II contract to Lockheed Martin, Orbital Sciences Corp., SpaceX, and United Launch Services. Based on these contract awards, the Falcon 9 may be proposed as a launch vehicle for future NASA missions while the Taurus II must be on-ramped at a later time in accordance with the contract before it may be proposed for use. NASA also notes that the Falcon 9 has had a successful first flight while the Taurus II has not. While NASA intends to follow a similar process to certify both vehicles at the appropriate time, currently the Agency's activities in support of launch services for science missions are focused on the Falcon 9.

In the draft report, GAO makes three recommendations to address NASA's need for a detailed estimate of the costs to certify a Medium Class Launch Vehicle capability as well as adequate budget planning for these and additional contingency costs.

Recommendation 1: GAO recommends the NASA Administrator require the NASA Science Mission Directorate - in conjunction with the Space Operations Mission Directorate - to perform a detailed cost estimate to determine the likely costs of certification and the trade-offs required to fund these costs. This estimate should at a minimum examine the need for funds

to resolve technical issues with the Falcon 9 and Taurus II launch vehicles discovered through the certification process. The estimate should also examine the costs associated with delaying science missions if necessary until launch vehicles are available or contingencies such as selecting more costly or time-consuming launch options.

Response: NASA concurs with this recommendation. The NASA Space Operations Mission Directorate will provide an estimate to the Science Mission Directorate of the cost to certify the Falcon 9 launch vehicle as well as to resolve technical issues during certification. The Science Mission Directorate will estimate costs for its science missions if certification is delayed. The initial budget estimates will be completed in time for the Fiscal Year 2013 budget cycle and may be updated in subsequent ones. NASA will follow a similar process for the Taurus II launch vehicle once it becomes available under NLS II.

Recommendation 2: Given that the NASA Science Mission Directorate could have to fund additional significant costs for certification and the use of contingencies, we recommend that the NASA Administrator require that the costs identified through developing the detail cost estimate are adequately budgeted for and identified by the Science Mission Directorate.

Response: NASA concurs with this recommendation. For the Falcon 9, the Science Mission Directorate will appropriately budget for such costs for certification and use of contingencies identified through the Space Operations Mission Directorate review, effective with the Fiscal Year 2013 budget cycle. NASA will follow a similar process for the Taurus II launch vehicle once it becomes available under NLS II.

Recommendation 3: Until such time, however, that these costs are better understood, we recommend that the NASA Administrator require the Science Mission Directorate to identify and budget for additional contingency funding for the projects requiring a medium launch capability vehicle and approaching their preliminary design review prior to certification of Falcon 9 and Taurus II that could be impacted by additional costs associated with certification of these vehicles, including the need to address technical issues and shoulder delays in the certification process.

Response: NASA concurs with this recommendation. For the Falcon 9, the Science Mission Directorate will factor preliminary certification cost estimates into the Fiscal Year 2012 budget. NASA will follow a similar process for the Taurus II launch vehicle once it becomes available under NLS II.

We will continue to work to address the issues identified by the GAO. If you have any questions or require additional information, please contact Ms. Ellen Cohen, Policy Analyst in the Science Mission Directorate, at 202-358-0812.

Thank you again for the opportunity to review this draft report, and we are looking forward to your final report to Congress.

Sincerely,

Edward J. Weiler
Associate Administrator for
Science Mission Directorate

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contact

Cristina T. Chaplain (202)512-4841 or chaplainc@gao.gov

Acknowledgments

In addition to the contact named above, Shelby S. Oakley, Assistant Director; Dr. Timothy M. Persons, Chief Scientist; Morgan Delaney Ramaker; Laura Greifner; Kristine R. Hassinger; Carrie W. Rogers; Roxanna T. Sun; and John S. Warren Jr. made key contributions to this report.

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