SEPTEMBER 25, 2012

AUDIT REPORT

OFFICE OF AUDITS

NASA'S PLANS TO MODIFY THE ARES I MOBILE LAUNCHER IN SUPPORT OF THE SPACE LAUNCH SYSTEM

OFFICE OF INSPECTOR GENERAL

National Aeronautics and
Space Administration

REPORT NO. IG-12-022 (ASSIGNMENT NO. A-12-007-00)

Final report released by:

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Inspector General

Acronyms

GSDO	Ground Systems Development and Operations
MPCV	Multi-Purpose Crew Vehicle
OMB	Office of Management and Budget
RS&H	Reynolds, Smith, and Hill
SLS	Space Launch System

OVERVIEW

NASA'S PLANS TO MODIFY THE ARES I MOBILE LAUNCHER IN SUPPORT OF THE SPACE LAUNCH SYSTEM

The Issue

NASA's newest Mobile Launcher was designed and built at Kennedy Space Center to support assembly, testing, transportation, and launch of the Constellation Program's Ares I launch vehicle.[1] The Mobile Launcher, completed in August 2010 at a cost of $234 million, consists of a two-story base, a 355-foot-tall launch umbilical tower, and facility ground support systems that include power, communications, and water.

Figure 1. The Ares I Mobile Launcher at Kennedy Space Center on November 30, 2011. (Source: Mr. Neil Berger, Mobile Launcher Deputy Project Manager)

In February 2010 – before the Mobile Launcher could be used – the President proposed cancellation of the Constellation Program and unveiled a new direction for NASA's space program.[2] The subsequently enacted NASA Authorization Act of 2010 (the Act) directed NASA to design the Space Launch System (SLS), a new heavy-lift rocket capable of deep space exploration. The Act required NASA to design the SLS with an initial capability of lifting payloads weighing between 70 and 100 tons and a fully evolved capability of lifting 130 tons or more.[3] As a result, NASA is designing a family of SLS launch vehicles that will be heavier, larger, and more powerful than the Ares I. The Act also directed NASA to use, to the extent practicable, existing investments and infrastructure in developing and operating the SLS.

By August 2011, two NASA-sponsored trade studies concluded that the Agency could strengthen and modify the

[1] NASA established the Constellation Program in response to the National Aeronautics and Space Administration Authorization Act of 2005, Public Law 109-155, December 30, 2005, which called for development of a crew launch vehicle, heavy launch vehicle, and crew exploration vehicle to return to the Moon and serve as a stepping-stone to future exploration of Mars and other destinations.

[2] In place of Constellation, the President's budget proposed a program that focused on leveraging advanced technology, international partnerships, and commercial capabilities to set the stage for a revitalized human space flight program.

[3] As a comparison, the Satern V rockets used to launch the Apollo missions to the Moon were capable of launching 130 tons into low Earth orbit while the Space Shuttle was capable of launching 30 tons into low Earth orbit.

Mobile Launcher to support the heavier weight and additional thrust of the SLS. According to NASA, not only are the necessary modifications technically feasible, but using the Mobile Launcher to support the SLS Program is the most cost-effective approach to launching the SLS when compared to modifying one of the three existing Space Shuttle Mobile Launcher Platforms or building a new launch platform.[4] Specifically, preliminary cost estimates found that modifying the Mobile Launcher would cost $54 million, modifying the Space Shuttle Mobile Launcher Platforms would cost $93 million, and constructing a new mobile launch platform would cost $122 million.

The SLS Program is in the early stages of design during which NASA officials are identifying how the Program will accomplish its goals.[5] Technical details about the vehicle's design are still under development; therefore, the configuration of the launch vehicle will evolve as the Program progresses.

In designing the Mobile Launcher, NASA used $25 million from the American Recovery and Reinvestment Act of 2009 (Recovery Act).[6]

The Office of Inspector General initiated this audit to determine whether NASA sufficiently evaluated all possible alternatives to ensure that modifying the Mobile Launcher in support of the SLS is in the best interest of the Government. We also reviewed NASA's use of and accounting for the $25 million in Recovery Act funds.

Results

The OIG found that NASA's decision to modify the Ares I Mobile Launcher is technically feasible and the most cost-effective option for launching at least the initial versions of the SLS vehicles. However, further assessment of planned modifications to the Mobile Launcher will be needed as the SLS continues to evolve and its design solidifies. While NASA performed two trade studies that supported its decision to modify the Ares I Mobile Launcher, both studies were based on preliminary assumptions and limited information about the configuration of the SLS. Because SLS vehicles will increase in size as they evolve, these early studies may not have addressed all the challenges or costs associated with launching the larger vehicles. Additionally, the SLS, the Orion Multi-Purpose Crew Vehicle (MPCV), and the Ground Systems

[4] The three Space Shuttle Mobile Launcher Platforms were originally designed and used for the Apollo Program and were later modified for the Space Shuttle.

[5] The SLS Program is in the formulation phase as outlined by NASA Procedural Requirements 7120.5E, "NASA Space Flight Program and Project Management Requirements," August 14, 2012. Project formulation consists of developing and defining the project requirements and cost/schedule basis, and designing a plan for implementation including an acquisition strategy, contractor selection, and long-lead procurement.

[6] American Recovery and Reinvestment Act of 2009, February 17, 2009. The Act provided funds for job preservation and creation, infrastructure investment, energy efficiency and science, assistance to the unemployed, and State and local fiscal stabilization.

Development and Operations (GSDO) programs – the three components of NASA's planned deep space exploration missions – are in relatively early stages of development. Successful integration of the three elements will require an interdependent management structure (known as an Exploration Systems Integration Strategy) to ensure the programs are effectively communicating their individual and collective requirements. Lastly, we determined that NASA properly tracked and accounted for its use of Recovery Act funds in designing the Mobile Launcher.

Two Trade Studies Support Decision to Modify the Ares I Mobile Launcher. Two NASA-sponsored trade studies compared three mobile launcher options to support the SLS: modify the Ares I Mobile Launcher, modify one of the Agency's three Mobile Launcher Platforms previously used by the Space Shuttle Program, or build a new mobile launcher. Based on the studies, the Agency concluded that modifying the Ares I Mobile Launcher was the most cost-effective alternative. The two studies' cost estimates for modifying the Ares I Mobile Launcher – $54 million and $74 million – are not directly comparable due in part to differences in assumptions about the launch vehicles that would use the Mobile Launcher and whether the Mobile Launcher would include a tower to support the launch vehicles.

NASA's Decision to Modify the Mobile Launcher Was Based on Limited Information and Preliminary Assumptions. The two trade studies that NASA relied on to support its decision to modify the Mobile Launcher were based on limited information and preliminary assumptions that may not address all challenges or costs associated with launching the larger evolved version of the SLS.[7] Both studies relied on information available at the time and, because the SLS vehicle configurations are still being formulated, some technical details have changed since the studies were performed while other details have not yet been decided. The scope of the two studies also varied in that one study did not evaluate modifications that may need to be made to the tower, while the other included tower modifications that it concluded will be necessary for the Mobile Launcher to launch the SLS.

In addition to the unknown cost and schedule impact of tower modifications that may be needed to launch the fully evolved 130-ton SLS, NASA plans to use new, advanced booster technology currently under development for the 130-ton vehicle. Neither study included the possible impacts to the Mobile Launcher that such new technology might pose. As such, the potential exists that the requirements to support the new booster may exceed the capabilities of the Mobile Launcher and require NASA to construct an entirely new launch platform.

Because additional modifications to the Mobile Launcher may be required as the SLS Program matures and the vehicle's design changes, it is imperative that NASA routinely update the planned modifications and corresponding cost estimates throughout the life

[7] The studies found that all three options are equally technically feasible. As a result, cost and schedule were the primary determining factors.

cycle of the SLS Program. Such an ongoing review will help identify technical risks and enable the Agency to better understand the full life-cycle costs of necessary modifications to the Mobile Launcher.

Continued Development of an Exploration Systems Integration Strategy Is Needed to Ensure the Mobile Launcher's Success. The evolving configuration requirements for the SLS require ongoing coordination among three programs – SLS, Orion MPCV, and GSDO.[8] The three programs are in different stages of development and the necessity of an interdependent management structure is a significant change for most NASA employees assigned to the programs, many of whom previously worked for the Space Shuttle Program while it was in operations mode for the past 30 years. Moreover, the three programs are managed from three different NASA Centers, further complicating integration efforts. History has shown that failing to establish firm project requirements early in a project's life cycle often results in cost overruns and can delay the completion of a project. To address these challenges, NASA is developing an Exploration Systems Integration structure to assist the three programs in effectively communicating their requirements. As of September 2012, NASA was finalizing the key documents that will define the Exploration Systems Integration structure and govern how it will operate.

In our judgment, development of an effective Exploration Systems Integration structure that includes baseline technical agreements is essential to ensure that requirements are effectively communicated among the SLS, MPCV, and GSDO programs. Additionally, a well-coordinated management structure will help ensure that each program reassesses the budget and cost implications of changing assumptions and configurations as the SLS Program evolves.

Recovery Act Funds Appropriately Used for Mobile Launcher. In 2009, NASA allocated $25 million in Recovery Act funds to advance design work for the Mobile Launcher. We found that NASA properly tracked and accounted for use of those funds.

Conclusion

NASA's decision to modify the Ares I Mobile Launcher is technically feasible and the most cost-effective option for launching the initial SLS vehicles. However, NASA's ability to identify additional technical risks of modifying the Mobile Launcher and accurately estimate future operating costs throughout the SLS Program's life cycle is diminished by the relative immaturity of the SLS Program and evolvable nature of the SLS vehicles. NASA must develop a well-functioning Exploration Systems Integration structure to monitor the planned modifications and corresponding cost estimates

[8] The Orion MPCV Program at Johnson Space Center is building the exploration vehicle that will carry the crew to space. The GSDO Program at Kennedy Space Center manages the ground systems and infrastructure, including the Ares I Mobile Launcher, to process and launch the next generation of rockets and spacecraft in support of NASA's exploration objectives. The SLS Program is based at Marshall Space Flight Center.

throughout the programs' life cycles. Failure of the SLS, GSDO, and MPCV programs to effectively communicate their requirements will compromise the accuracy of the Mobile Launcher's budget and schedule estimates and ultimately the utility of the Mobile Launcher as the SLS Program evolves.

Management Action

We are not making specific recommendations for corrective action, but believe NASA should assess and update the planned Mobile Launcher modifications throughout its life and the life of the SLS Program to ensure that all technical risks are identified and addressed and the true life-cycle costs of the modifications are understood. In discussing a draft of this report, the Deputy Associate Administrator for NASA's Exploration Systems Development Division stated that his office is developing the Exploration Systems Integration structure to ensure that the SLS, MPCV, and GSDO programs are effectively communicating requirements as the SLS Program evolves.

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INTRODUCTION

Background

NASA built the Mobile Launcher specifically for the Constellation Program's crew launch vehicle known as Ares I and the platform would not have been used to launch the Constellation Program's heavy lift vehicle, Ares V. The Mobile Launcher structure took 2 years to construct and was completed in August 2010 at a cost of $234 million.[9] In October 2010, before NASA could use the Mobile Launcher, Congress cancelled the Constellation Program, including the Ares I launch vehicle, and directed NASA to develop a heavy-lift rocket called the Space Launch System (SLS) that will carry astronauts beyond low Earth orbit and provide the cornerstone for America's future human space exploration efforts.[10] Congress also directed NASA to use, to the extent practicable, existing investments and infrastructure in developing and operating the SLS.

Because the Mobile Launcher was originally designed for the Ares I rocket, it will require significant modifications to support the much heavier SLS. In order to evaluate its options for platforms to launch the SLS, officials at Kennedy Space Center (Kennedy) initiated two trade studies in 2010, one conducted by NASA staff, the other by a contractor.

Based on the results of the studies, the Agency concluded that modifying the Ares I Mobile Launcher was the best, most cost-effective option to both meet the initial needs of the SLS and salvage at least some of the $234 million spent to build the Ares I Mobile Launcher. In May 2011, Kennedy officially decided to use the Ares I Mobile Launcher to support the SLS, and the NASA Administrator concurred with the decision in June 2011. As previously discussed, re-engineering the Ares I Mobile Launcher for the SLS complied with Congress' direction to use existing infrastructure for the SLS to the extent practicable.

The launcher will support the assembly, testing, check out, and servicing of the rocket, as well as enable its transfer to the launch pad and provide the platform from which it will launch. The launch of the initial SLS rocket is scheduled for December 2017. The specific processes and criteria the Agency used for selecting the Ares I Mobile Launcher to support the SLS are discussed in the Results section of this report.

[9] The $234 million is the combined value of all the contracts for the Ares I Mobile Launcher's design, construction, and operational readiness from inception through completion of construction in August 2010.

[10] National Aeronautics and Space Administration Authorization Act of 2010, Public Law 111-267, October 11, 2010.

Design modifications to retrofit the Mobile Launcher for use by the SLS began in February 2012. The primary work that the Ground Systems Development and Operations (GSDO) Program at Kennedy must undertake includes strengthening the supports in the base and widening the exhaust port.[11] The GSDO Program plans to complete these modifications in February 2015 at an estimated cost of $62 million. The installation of ground support equipment (propellants, gases, power, and communications) is scheduled for completion in September 2016 at an estimated cost of $105 million.[12] Finally, the GSDO Program plans to complete validation and activation of the Mobile Launcher in March 2017 (approximately 9 months before the initial launch of an SLS vehicle) at an estimated cost of $7 million. The total estimated cost for the three actions is $174 million.

The modifications to the Ares I Mobile Launcher are necessary because planned versions of the SLS rockets are larger, heavier, and a different configuration than the Ares I rocket that the Mobile Launcher was initially designed to support. The NASA Authorization Act of 2010 required NASA to design the SLS with an initial capability of lifting payloads weighing between 70 and 100 tons and a fully evolved capability of 130 tons or more. As a result, NASA is designing a family of SLS rockets that will evolve over time. The initial 70-ton rocket is planned for cargo missions in 2017 and crewed missions in 2021. The next version will be capable of lifting 105 tons and will be used for missions in 2023 and 2025. The fully evolved version will be capable of lifting 130 tons for launches in the 2030 timeframe. Although the 105-ton and 130-ton vehicles are being designed to meet a variety of crew and cargo missions, the specific configurations of these vehicles is currently under discussion.

As the SLS Program evolves, the vehicle will increase in height and weight. As shown in Figure 2, NASA estimates that the initial 70-ton rocket will be about 320 feet tall with a gross liftoff weight of 5.8 million pounds. The 105-ton version will be slightly larger at 336 feet tall with a gross liftoff weight of 5.9 million pounds. Finally, the fully evolved 130-ton rocket will be about 389 feet tall with a gross liftoff weight of 6.9 million pounds. When compared to the Ares I rocket, the initial SLS rocket will be about the same height, but weigh more than twice as much, and the fully evolved SLS will be nearly 75 feet taller and three times heavier. The heavier weight of the SLS rockets necessitates strengthening the supports in the Mobile Launcher base.

[11] The GSDO Program manages ground systems and infrastructure at Kennedy to support the launch of rockets and spacecraft in support of NASA's exploration objectives.

[12] The installation cost does not include the cost of the ground support equipment because the Agency is still determining which specific equipment to install.

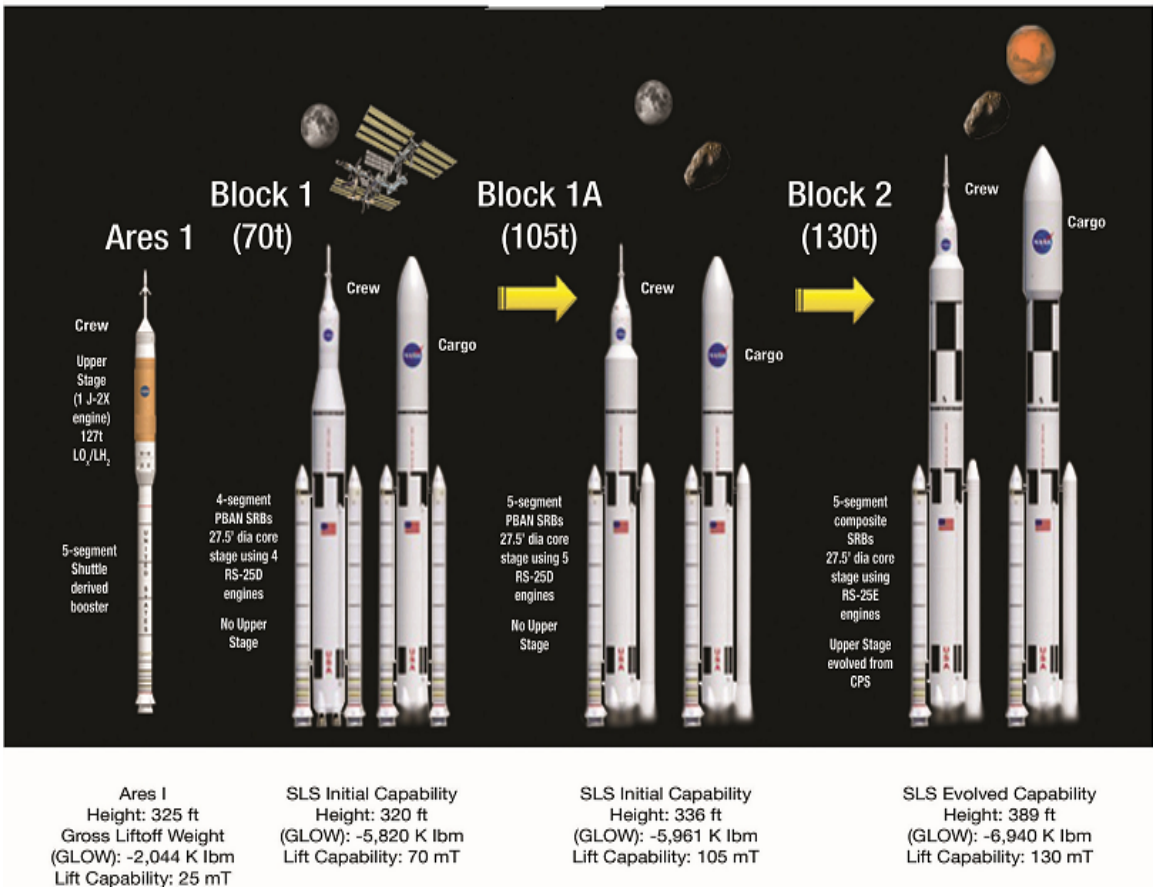

Figure 2. Comparison of Ares I launch vehicle and planned versions of the SLS.

In addition to being bigger and heavier, the SLS rockets are of a different configuration than the Ares I rocket. The SLS rockets will have two boosters attached to a core stage, while the Ares I rocket was an in-line, two-stage rocket configuration. The addition of the two rocket boosters on the SLS design necessitates expansion of the exhaust port on the Mobile Launcher base from a 22-foot square to a 60-foot-by-30-foot rectangle.

The SLS Program is in what NASA calls the formulation phase during which officials assess the program's risk, feasibility, and technology; develop operations concepts and acquisition strategies; establish high-level requirements and success criteria; and prepare plans, budgets, and schedules.[13] Additionally, as previously described, the launch vehicle will evolve as the Program progresses. Therefore, key technical details about the vehicle's design and configuration and how it will interface with the Mobile Launcher and ground support equipment are under discussion. For example, due to the planned varying heights of the SLS as it evolves, changes are expected in the vertical position of different stages of the rocket and, therefore, the placement of vehicle umbilicals on the

[13] NASA Procedural Requirements 7120.5E, "NASA Space Flight Program and Project Management Requirements," August 14, 2012.

Mobile Launcher tower.[14] Additionally, the height of the Orion Multi-Purpose Crew Vehicle (MPCV), which will sit atop the SLS for crewed missions, may change and that would affect the location of the Mobile Launcher tower's crew access arm and the crew emergency egress system.[15]

In 2009, NASA received $1 billion from the American Recovery and Reinvestment Act (Recovery Act) and allocated $25 million to support design of the Mobile Launcher. The Recovery Act was signed into law on February 17, 2009, to help jumpstart the U.S. economy, preserve or create jobs, and spur technological advances in science and health.

Objectives

We evaluated NASA's plans for the Ares I Mobile Launcher to determine whether the Agency sufficiently evaluated all options before deciding that modifying it in support of the SLS was in the best interest of the Government. We also examined whether NASA properly tracked and accounted for Recovery Act funds associated with the Mobile Launcher and reviewed internal controls as they relate to the overall objective. See Appendix A for details of the audit's scope and methodology and our review of internal controls.

[14] Launch stand umbilicals interface with the spacecraft and provide the electrical, gas, and fluids support necessary for launch.

[15] The crew access arm will allow personnel to enter the MPCV from the Mobile Launcher tower. The emergency egress system is the means by which crew would evacuate the tower in the event of a launch emergency.

MODIFYING ARES I LAUNCHER MOST COST-EFFECTIVE OPTION, BUT ADDITIONAL ASSESSMENT NEEDED AS THE SPACE LAUNCH SYSTEM PROGRAM EVOLVES

NASA's decision to modify the Ares I Mobile Launcher is technically feasible and the most cost-effective option for launching at least the initial versions of the SLS vehicles. However, the two studies and corresponding cost estimates that NASA used to support its decision were based on preliminary assumptions and limited information. As a result, the studies may not have addressed all challenges or costs associated with launching the planned larger versions of the SLS rockets. Because additional modifications to the Mobile Launcher may be required as the SLS Program matures, it is imperative that NASA update the planned modifications and corresponding cost estimates throughout the life of the SLS Program. In addition, given the relative immaturity of the SLS Program and NASA's ongoing SLS development efforts, it is essential that SLS, Orion MPCV, and GSDO program officials effectively communicate launch vehicle, spacecraft, and ground systems requirements to ensure the success of each program. Lastly, we found that NASA properly tracked and accounted for Recovery Act funds used to design the Mobile Launcher.

Two Trade Studies Support Decision to Modify the Ares I Mobile Launcher

Two NASA-sponsored trade studies compared three mobile launcher options to support the SLS: modify the Ares I Mobile Launcher, modify one of the Agency's three Mobile Launcher Platforms used in the Space Shuttle Program, or build a new mobile launcher. Based on the studies, the Agency concluded that modifying the Ares I Mobile Launcher proved the best and most cost-effective option.

The first trade study was an internal study conducted by Kennedy and contractor personnel initiated in October 2010 to evaluate options, selection criteria, and requirements for development of a mobile launcher for a heavy lift launch vehicle. The team reported their initial findings in March 2011 and concluded that each of the three options under examination were technically feasible.[16] The study's cost estimates indicated that modifying the Ares I Mobile Launcher would be the lowest cost option ($54 million) followed by modifying the Space Shuttle Mobile Launcher Platform ($93 million) and finally building a new mobile launcher ($122 million).[17] The cost

[16] "2011 Mobile Launcher Structure Trade Study – Initial Findings," KSC-NE 11477, March 2011.

[17] "2011 Mobile Launcher Structure Trade Study – Initial Findings, Volume 2, Cost Annex," KSC-NE 11477 Volume 2, April 2011.

evaluations for the Ares I Mobile Launcher and Space Shuttle Mobile Launcher Platform were limited to modifying the base; none of the three cost evaluations included estimates for installation of ground support equipment.

The second study, conducted by Reynolds, Smith, and Hill (RS&H), a facilities, infrastructure, and aviation consulting firm with more than 40 years' experience in designing NASA launch platforms, examined mobile launcher and launch pad concepts to support a variety of launch vehicle concepts developed under the SLS architecture. RS&H reported the results of its study in August 2011 and estimated that the cost of modifying the base and tower of the Ares I Mobile Launcher to launch the 70-ton version of the SLS vehicle would be $74 million.[18] The estimate did not include the cost of installing ground support equipment.

The two studies' cost estimates for modifying the Ares I Mobile Launcher ($54 million and $74 million) are not directly comparable due to differences in assumptions about the launch vehicles that would use the Mobile Launcher and whether the Mobile Launcher would include a tower or merely a base.

Trade Studies Were Based on Limited Information and Preliminary Assumptions

The two trade studies relied on preliminary assumptions about the launch vehicles and Mobile Launcher tower because they were initiated before NASA had decided on the launch vehicles that would use the Mobile Launcher and whether the Mobile Launcher would include a tower. GSDO estimated that it would take 6 years to modify, outfit, and activate the Ares I Mobile Launcher or a Space Shuttle Mobile Launcher Platform and 7 years to build a new mobile launcher for the SLS Program. Delaying initiation of the studies until June 2011, when the NASA Administrator approved the SLS launch vehicle architecture, would have jeopardized GSDO's ability to support a 2017 launch. Figure 3 shows significant dates affecting the development of the Mobile Launcher and its projected life-cycle timeline.

[18] "Study: Space Launch System Heavy Lift Launch Vehicle Mobile Launcher and Launch Pad," KSC-NE-11533, August 22, 2011.

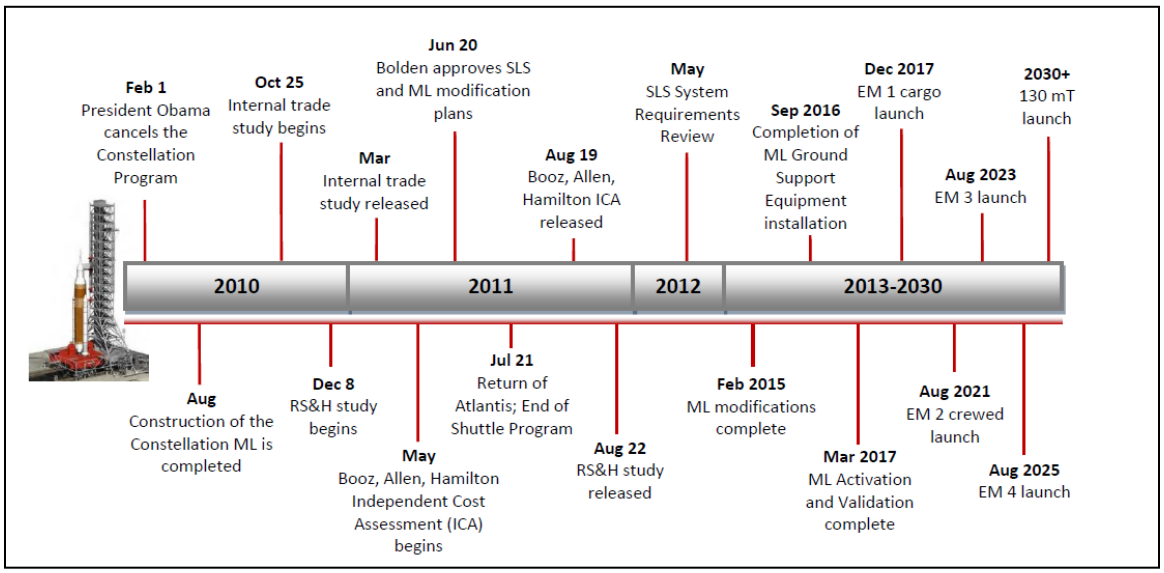

Figure 3. Projected Mobile Launcher life-cycle timeline.

Internal Trade Study. NASA's internal study examined only required modifications to the Ares I Mobile Launcher's base and did not review needed modifications to the tower. Kennedy officials describe the internal trade study as "a snapshot in time" and the study itself states that "Because the initial phase of the effort was to be small in scope and short in duration, basic assumptions about the Mobile Launcher were identified to make the task manageable."

According to GSDO officials, the study was limited to modifications to the base because one option being considered at the time was to operate the SLS launch platform without a tower. In fact, the team's trade study included the cost of removing the Ares I Mobile Launcher's tower because they assumed it would not be needed.[19] NASA has since decided to retain the Mobile Launcher's tower to assist with launching the SLS.

In addition, Kennedy based its study cost estimates on a version of SLS capable of launching payloads of 110 tons even though NASA does not now plan to launch a 110-ton version of the SLS vehicle. Members of the study team told us that the assumptions they made for the 110-ton vehicle provided the most reasonable assurance that the required launch platform modifications would accommodate all evolutions of the SLS. However, the fully evolved 130-ton version of the SLS will be 53 feet taller than the 110-ton version the team assessed, and the assessment team did not evaluate the impact this height difference might have on the launch platform or the Mobile Launcher tower.

[19] The estimated costs to remove the tower did not play a role in NASA's final decision to modify the Ares I Mobile Launcher.

External Trade Study. The initial purpose of the external trade study was to evaluate the feasibility and compare the costs of modifying the Ares I Mobile Launcher, modifying a Space Shuttle Mobile Launcher Platform, or constructing a new launch platform to support several heavy lift launch vehicle concepts being considered for the SLS Program. These concepts included four reference vehicle "teams":

- Team 1 was a Shuttle-derived heavy lift launch vehicle;
- Team 2 was a liquid-only heavy lift launch vehicle;
- Team 3 was a clustered Atlas V and Delta IV configuration;
- Team 4 was a combination of a Shuttle-derived heavy lift launch vehicle and a clustered Atlas V configuration.

However, before RS&H could complete their study of launch platform requirements for all SLS architectures under consideration, the NASA Administrator decided in June 2011 to use a Shuttle-derived configuration for the SLS.[20] In making this decision, the Administrator also approved plans to modify the Ares I Mobile Launcher to support SLS launches based on the internal trade study.

Following the Administrator's decision, NASA requested RS&H to develop a cost estimate for the modifications needed on the Ares I Mobile Launcher to launch the 70-ton and 130-ton versions of the SLS. NASA limited the company's analysis and cost estimates only to the modified Ares I Mobile Launcher and did not ask RS&H to compare the cost of modifying the Ares I Mobile Launcher with the cost of modifying an existing Space Shuttle Mobile Launcher Platform or constructing a new launch platform. However, company officials told us that based on their knowledge of the options, they "very likely" would have concluded that modifying the Ares I Mobile Launcher was the most cost-effective option, at least for the 70-ton version of the SLS.

In their August 2011 report, RS&H estimated it would cost approximately $74 million to modify the Ares I Mobile Launcher for the initial version of the SLS. Unlike the trade study performed by NASA engineers, this estimate included the cost to modify the launcher's tower. According to the company's report, tower modifications for the initial SLS vehicle should include adaptations for a crew access arm and the emergency egress system.

The RS&H study also noted that crewed missions using the larger SLS vehicle would require "an additional level on top of the tower with accommodations for a crew access arm at the higher level including a repositioned porch for the [emergency egress system]." NASA officials told us that they have not yet estimated the costs to modify the Mobile Launcher tower modifications to launch the fully evolved 130-ton SLS vehicle

[20] "MPCV, SLS, 21st [Century Ground Systems] Pre-Formulation Decision Memorandum," signed by the NASA Administrator on June 20, 2011.

because the exact vehicle configuration has not yet been decided. Additionally, SLS managers have not yet decided whether the 130-ton SLS vehicle will be used for crewed missions. That decision will have a significant impact on the tower modifications that will be needed to launch the fully evolved 130-ton version of the SLS.

Trade Studies Did Not Evaluate Impact of New Booster Technology. Given that the fully evolved 130-ton rocket is not scheduled for its first launch until 2030, we acknowledge that it is premature to build a launch platform for a rocket that is not scheduled to launch for another 18 years. However, NASA is moving forward to maximize its use of the $234 million spent on the Ares I Mobile Launcher by repurposing it for use with at least the initial versions of the SLS. Whether the fully evolved 130-ton version of the SLS will be able to be launched from this same modified platform or whether it will require a different launch platform is an open question that will be driven by the final design of the 130-ton rocket.

For example, NASA plans to use advanced booster technology for the 130-ton vehicle to provide a significant increase in thrust compared to currently available liquid or solid boosters. Neither the internal or external trade study included the possible impact of using advanced rocket boosters on the costs or feasibility of modifying the Ares I Mobile Launcher. Therefore, it is possible that the requirements to support the 130-ton booster rocket could exceed the capabilities of the redesigned Mobile Launcher, which would require NASA to either construct an entirely new launch platform or further modify the former Ares I Mobile Launcher.

Because additional modifications to the Mobile Launcher may be required as the SLS Program matures, it is imperative that NASA continue to assess and update its planned modifications and corresponding cost estimates. Without such continual assessments, it will be difficult for the Agency to identify and address all technical risks and understand the true life-cycle costs of any required modifications to the Mobile Launcher, including the potential expense of building an entirely new launch platform for the 130-ton SLS vehicle.

Continued Development of an Exploration Systems Integration Strategy Needed to Ensure the Mobile Launcher's Success

According to the Deputy Associate Administrator for NASA's Exploration Systems Development Division, the management structure created for the development and launch of NASA's heavy lift vehicle is a significant departure from how the Agency managed the Space Shuttle Program. He explained that the Space Shuttle Program had been in operations mode for almost 30 years and consequently most current NASA employees were not working for the Program during its development phase. Under the Space Shuttle Program, the authority to make key program decisions was generally limited to senior-level managers. The Deputy Associate Administrator stated that requiring high-level decision making when a space program is in operations mode is appropriate. He

explained that the consequences to the decisions that were made when the Space Shuttle was operational frequently involved crew safety, and were more significant than the decisions that are commonly made when a program is in the development phase. Although this process helped Space Shuttle managers ensure that they made informed and accurate decisions based on program-wide information, a common complaint was that it was not relatively efficient and not well suited for a program in the development phase.

The Agency's heavy lift program requires close coordination among three primary entities – the SLS, MPCV, and GSDO programs. To enhance efficiency, senior managers have delegated authority to program-level managers to make decisions that, at least in the Space Shuttle Program, were only allowed to be made by senior-level managers. Although "pushing down" the decision-making authority could increase the programs' efficiency, it increases the risk that one program makes decisions without fully evaluating their impact on the other two programs. Additionally, the three programs are at different stages in development and are managed from three different NASA Centers, further complicating coordination efforts.

During our audit, SLS officials shared a significant amount of potential launch vehicle requirements for GSDO personnel to evaluate. Some of these initial requirements were close to exceeding ground system capabilities, such as a proposed vehicle too tall to fit through the doors of the Vehicle Assembly Building or too heavy for Kennedy's Crawler-Transporters.[21] Although it appears that program personnel have resolved these issues for the initial versions of the vehicle, the SLS will continue to evolve and requirements will change. As this evolution occurs, MPCV requirements will also affect the Mobile Launcher, adding an additional layer of complexity with integration efforts among the SLS, MPCV, and GSDO programs.

NASA's ability to effectively communicate launch vehicle, spacecraft, and ground systems requirements between the SLS, MPCV, and GSDO programs will be challenging given the change in management structure, the relative immaturity of the SLS Program, and NASA's ongoing SLS development efforts. NASA has recognized these challenges and is establishing an Exploration Systems Integration structure to assist the three programs in effectively communicating their requirements. As of September 2012, the Agency was in the process of formalizing the key documents that will define the Exploration Systems structure and govern how it will operate. The Deputy Associate Administrator for NASA's Exploration Systems Development Division estimates that NASA will complete the Exploration Systems Integration Structure in time to support the

[21] A Crawler-Transporter is a tracked vehicle used to transport a rocket and its Mobile Launcher from the Vehicle Assembly Building to launch pads at Kennedy.

Cross-Program System Definition Review scheduled for the first quarter of fiscal year 2013.[22]

The development of an effective Exploration Systems Integration structure is essential to ensure that requirements and decisions are communicated between the SLS, MPCV, and GSDO programs. Additionally, if properly functioning this structure can help ensure that each program reassesses the budget and cost implications of changing assumptions and configurations as the SLS Program evolves.

Recovery Act Funds Were Appropriately Used for Mobile Launcher

The Recovery Act was signed into law on February 17, 2009, as a way to jumpstart the U.S. economy, preserve or create jobs, and spur technological advances in science and health. In 2009, NASA received $1 billion from the Recovery Act and officials allocated $25 million to the Mobile Launcher to support its engineering design.

Our review of the use of these funds found that NASA generally met cost, schedule, and performance milestones for the Mobile Launcher project. In addition, the project adequately addressed the reporting requirements of the Recovery Act and related Office of Management and Budget (OMB) guidance. Consequently, we determined that NASA's use and reporting of Recovery Act funds for the Mobile Launcher was appropriate.

Conclusion

NASA's decision to modify the Ares I Mobile Launcher to launch the SLS, the Agency's heavy-lift rocket for deep space exploration, is technically feasible and the most cost-effective option for launching the initial SLS vehicles. However, NASA's ability to identify additional technical risks of modifying the Mobile Launcher and accurately estimate future operating costs throughout the SLS Program's life cycle is diminished by the relative immaturity of the SLS Program and the evolvable nature of the SLS vehicles.

NASA must develop a well-functioning Exploration Systems Integration Strategy to monitor the planned modifications and corresponding cost estimates throughout all three programs' life cycles. Failure of the SLS, GSDO, and MPCV programs to effectively communicate their requirements will compromise the accuracy of the Mobile Launcher's budget and schedule estimates and ultimately the utility of the Mobile Launcher as the SLS Program evolves.

[22] According to NASA's Space Flight Program and Project Management requirements, the System Definition Review determines whether the maturity of the program's definition and associated plans are sufficient to begin implementation. At the time of the System Definition Review, programs should be in place and stable; have adequately completed formulation phase activities; and have an acceptable plan for the implementation phase.

Management Action

We are not making specific recommendations for corrective action, but believe NASA should assess and update the planned Mobile Launcher modifications throughout its life and the life of the SLS Program to ensure that all technical risks are identified and addressed and the true life-cycle costs of the modifications are understood. In discussing a draft of this report, the Deputy Associate Administrator for NASA's Exploration Systems Development Division stated that his office is developing the Exploration Systems Integration structure to ensure that the SLS, MPCV, and GSDO programs are effectively communicating requirements as the SLS Program evolves.

APPENDIX A

Scope and Methodology

We performed this audit from November 2011 through September 2012 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.

The audit included reviews of two distinct areas: NASA's plans for the Mobile Launcher and its accounting for use of American Recovery and Reinvestment Act (Recovery Act) funds on the Mobile Launcher project. We separated our audit work along these two areas, with separate scopes and methodologies for each.

NASA's Plans for the Mobile Launcher. The scope for this review was NASA's decision to modify the Ares I Mobile Launcher for use with the SLS. The scope included the processes NASA used to select the Ares I Mobile Launcher as the launch platform for the SLS, the technical feasibility of the planned modifications to the Mobile Launcher, challenges that might hinder the planned modifications, and alternative uses for the Mobile Launcher. For this review, we conducted audit work at Kennedy, NASA Headquarters, and Marshall Space Flight Center.

To accomplish our reviews of the processes that NASA used to select the Mobile Launcher and the technical feasibility of the planned modifications, we interviewed appropriate NASA and RS&H officials and reviewed records related to the selection process. We also interviewed NASA officials with the Human Exploration and Operations Mission Directorate, the GSDO Program, and various Kennedy offices. Mission Directorate and GSDO Program officials interviewed included the Mission Directorate's Deputy Associate Administrator for the Exploration Systems Development Division, the Manager for GSDO's Vehicle Integration and Launch Integration Product Team, and the Manager for the Mobile Launcher Project. Kennedy officials interviewed included the Center's Vehicle Integration and Launch Chief Engineer and the Cost Analyst who developed the Agency's cost estimate for modifying the Mobile Launcher. RS&H officials interviewed included a Senior Vice President and a Vice President with the company's Aerospace Services Group.

The records we reviewed included NASA-sponsored trade studies and Kennedy architecture refinement cycle reviews:

- Trade Study KSC-NE-11477, "2011 Mobile Launcher Structure Trade Study - Initial Findings," March 2011, and "2011 Mobile Launcher Structure Trade Study - Initial Findings, Volume 2: Cost Annex," April 2011;
- Trade Study KSC-NE-11533, "Study: Space Launch System Heavy Lift Launch Vehicle Mobile Launcher and Launch Pad," August 22, 2011;
- "21st Century Space Launch Complex Architecture Refinement Cycle 4.0 Final," February 15-17, 2011;
- "21st Century Space Launch Complex Architecture Refinement Cycle 5.0, Closing the Ground Operations Architecture, Final PoD [Point of Departure] Architecture Review," May 26, 2011.

To accomplish our review of challenges that might hinder the planned modifications, we interviewed appropriate NASA officials and reviewed records related to potential risks to successful completion of the planned modifications. In addition to interviewing the aforementioned Mission Directorate and GSDO Program officials, we interviewed the Chief Engineer and the Lead Systems Engineer for the SLS Program. The records we reviewed included the GSDO Program's list of Mobile Launcher associated risks and a Booz Allen Hamilton assessment of cost and schedule estimates that the GSDO Program used to evaluate candidates for NASA's post-Space Shuttle manned space flight architecture.[23]

To accomplish our review of alternative uses for the Mobile Launcher, we interviewed appropriate NASA officials and reviewed records identifying commercial companies interested in using the Mobile Launcher for their respective launch vehicles. NASA officials interviewed included the Program Manager for the Agency's Commercial Crew Program and the Manager of Kennedy's Partnerships Development Office. The records we reviewed included a statement of interest in Kennedy assets submitted by ATK Space Launch Systems and Kennedy's response to ATK's statement of interest.[24,25]

Recovery Act Funds Associated with the Mobile Launcher. The review examined the $25 million in Recovery Act funds NASA used toward the engineering design of the Mobile Launcher's mechanical, fluid, and electrical subsystems. The scope included NASA's management, distribution, use, reporting, and closeout of these Recovery Act

[23] "Independent Cost Assessment of the Space Launch System, Multi-Purpose Crew Vehicle and 21st Century Ground Systems Programs, Final Report," August 19, 2011. Booz Allen Hamilton is a consulting firm that provides management and technology consulting services.

[24] "ATK Space Launch Systems' Statement of Interest for KSC Assets," February 21, 2011. ATK is an aerospace firm interested in providing a launch system under NASA's Commercial Crew Program.

[25] "KSC Comprehensive Response to ATK's Request for Use of Government Assets," August 12, 2011.

funds. For this review, we conducted audit work at Kennedy, the NASA Shared Services Center, and NASA Headquarters.

To accomplish our review we interviewed appropriate NASA officials, reviewed applicable records, and verified compliance with Recovery Act requirements. NASA officials interviewed included the Agency's Recovery Act Implementation Executive, the Mobile Launcher Program Manager, and the Kennedy Supervisory Accountant responsible for tracking Recovery Act funds. We also interviewed the NASA Shared Services Center Accounts Payable Lead responsible for the SAP accounting internal control processes that NASA put into place for Recovery Act compliance.

The records we reviewed included the Agency's Recovery Act guidance, fund-related plans, contractual documents, status reports, and billing documents:

- Procurement Information Circular (PIC) 09-06H, "Contracting with Recovery Act Funds including deviation to FAR and NFS Quick Closeout Procedures," November 23, 2010;
- "Recovery Act Plan for Constellation Ground Operations - Mobile Launcher Design," August 21, 2009;
- Task orders under which the Recovery Act-related work was performed;[26]
- Monthly technical and financial status reports, as well as quarterly status reports, submitted by the contractor performing the Recovery Act-related work; and
- Contractor invoices billed to NASA for the Recovery Act work performed.

To assess compliance with Recovery Act requirements we verified:

- Agency payments and accounting entries matched amounts on contractor invoices for the Recovery Act work;
- Quarterly reports were submitted on time using a central government-wide data collection system for Federal Agencies and Recipients of Federal awards per the Recovery Act;
- Key milestones and deliverables were met;
- Recovery Act funds were expended and final invoices received; and
- Mobile Launcher Project status was marked "Fully Complete" in FederalReporting.gov.

[26] Task Order Numbers 625, 626, and 627 under NASA Contract Number NAS10-03006 with ASRC Aerospace Corporation.

Use of Computer-Processed Data. We did not use computer-processed data to perform the review of NASA Plans for the Mobile Launcher, but did use data from SAP (NASA's financial system) for the review of Recovery Act funds associated with the Mobile Launcher. As part of the review, we compared data from source documents against the data in the financial system. Based on the results of those comparisons, we concluded that the data was valid and reliable for the purposes of the review.

Review of Internal Controls

For the review of NASA's Plans for the Mobile Launcher, we reviewed internal controls that Kennedy used to provide reasonable assurance that the selection of the Mobile Launcher for the SLS was in the best interest of the Government. The controls included the process (Architecture Refinement Cycle Reviews) and tools (trade studies and cost estimates) the Center used in selecting the Mobile Launcher for the SLS. Except for the trade studies being based on preliminary assumptions as described in this report, we considered the reviewed internal controls to be adequate.

For the review of Recovery Act funds used on the Mobile Launcher, our review of internal controls included reviews of policies, procedures, and practices that the Agency implemented to provide reasonable assurance of compliance with Recovery Act requirements as identified in Office of Management and Budget guidance.[27] Based on the results of our review, we considered the internal controls over the Recovery Act funds associated with the Mobile Launcher to be adequate.

Prior Coverage

During the past 5 years, neither the NASA Office of Inspector General nor the Government Accountability Office issued reports of relevance to the subject of this report.

[27] OMB M-09-15, "Updated Implementing Guidance for the American Recovery and Reinvestment Act of 2009," April 3, 2009; OMB M-09-10, "Initial Implementing Guidance for the American Recovery and Reinvestment Act of 2009," February 18, 2009; OMB M-10-34, "Updated Implementing Guidance for the American Recovery and Reinvestment Act," September 24, 2010.

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SEPTEMBER 25, 2012

REPORT No. IG-12-022

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