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**OFFICE OF INSPECTOR GENERAL**

# NASA's Decision Process for Conducting Space Launch System Core Stage Testing at Stennis



OFFICE OF AUDITS

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Paul K. Martin
Inspector General

## Acronyms

| | |
|---|---|
| DOD | Department of Defense |
| HEO | Human Exploration and Operations |
| MOU | Memorandum of Understanding |
| NPD | NASA Policy Directive |
| NPR | NASA Procedural Requirements |
| NRPTA | National Rocket Propulsion Testing Alliance |
| OIG | Office of Inspector General |
| RPT | Rocket Propulsion Test |
| SLS | Space Launch System |

## OVERVIEW

# NASA'S DECISION PROCESS FOR CONDUCTING SPACE LAUNCH SYSTEM CORE STAGE TESTING AT STENNIS

## The Issue

Test stands for large rocket propulsion systems cost hundreds of millions of dollars to build or refurbish and may sit idle for many years after the programs for which they were built end. On April 24, 2012, NASA's Human Exploration and Operations (HEO) Mission Directorate approved a plan to refurbish the B-2 test stand at Stennis Space Center (Stennis) for testing the core stage of the Agency's new heavy-lift rocket, the Space Launch System (SLS).[1] SLS Program management estimated that refurbishing the B-2 stand would take approximately 4.5 years to complete and estimated total costs – which include refurbishing, special test equipment, testing the core stage, and contingency funding – at $352 million. However, an independent NASA team estimated the project's total cost at $407 million. NASA plans the first flight for the SLS in December 2017.

NASA examined two other possible sites for testing the SLS core stage – the Air Force Research Laboratory's 1-125 1C test stand at Edwards Air Force Base in California (1C) and NASA's Advanced Engine Test Facility 4670 at the Marshall Space Flight Center (4670). The estimates available to NASA at the time it selected the B-2 stand indicated that refurbishment of these other two facilities would take 3.5 and 2.5 years and cost $319 million and $251 million, respectively. Unlike the B-2 test stand, NASA did not have an independent cost estimate for renovating and testing at these two facilities. Despite the lower estimated costs and shorter timeframes associated with readying the Air Force and Marshall facilities, NASA chose the B-2 stand citing risks associated with testing the core stage at these sites such as transportation risks to 1C and risks associated with the noise level from testing at 4670, the existence of the independent cost estimate, and the potential benefits of consolidating large-scale testing at Stennis.

NASA's Rocket Propulsion Test (RPT) Program Office manages NASA's rocket propulsion testing activities. The RPT Program Manager serves as the chair of NASA's RPT Management Board (RPT Board) – the Agency's decision-making body for rocket propulsion testing.

[1] The core stage consists of liquid hydrogen and oxygen fuel tanks, subsystem hardware and avionics, and four RS-25 rocket engines.

In addition to NASA's internal process, Federal law requires NASA to coordinate with the Department of Defense (DOD) regarding rocket-testing decisions given their expense.[2] In 1998, the two agencies formed the National Rocket Propulsion Testing Alliance (NRPTA) with the goals of preventing duplication of effort, efficiently meeting national testing needs, and shaping the Government's rocket propulsion testing capability.

In July 2008, the NASA Office of Inspector General (OIG) examined allegations that NASA's plan to build the A-3 test stand at Stennis to test the J-2X engine in connection with the Constellation Program would duplicate the capabilities of an Air Force testing facility in Tennessee. The OIG found that in making its decision on the J-2X, NASA did not follow either its own internal procedures or the NRPTA process.[3] In response to the OIG recommendations, the Agency contracted with The Aerospace Corporation to perform an independent assessment of the A-3's costs and schedule. In addition, NASA established a policy that requires the RPT Board to approve all rocket propulsion-testing decisions and engage DOD about testing decisions to meet national needs.[4]

We initiated this review to examine NASA's decision-making process for SLS core stage testing. Specifically, we reviewed whether NASA's decision to use the B-2 test stand (1) was made in accordance with applicable agreements and policies, (2) resulted in the best value for the taxpayer, and (3) best supported the SLS Program. Details of the audit's scope and methodology are in Appendix A.

## Results

Similar to conclusions we reached 5 years ago in our review of the Agency's decision where to test the J-2X engine, we found that NASA failed to follow its internal policies or its Memorandum of Understanding (MOU) with DOD when it selected the B-2 test stand for SLS core stage testing. Moreover, we found that NASA did not adequately support its decision to refurbish the B-2 given that refurbishing the B-2 stand would be more costly and take longer than the two other options. We also found that by selecting the B-2 NASA may not have chosen the most efficient and cost-effective test site. In addition, although the SLS Program spent considerable time and money studying the B-2 option, NASA gave the RPT and NRPTA Boards minimal time to assess the cost, schedule, and risks of the other test stand options. In addition, driven by the time needed to refurbish the test stand to begin core stage testing in accordance with the SLS Program's development schedule, NASA officials selected the B-2 even though SLS

[2] Public Law 104-201, Section 211(c).

[3] NASA OIG, "Final Memorandum on the Review of NASA's Plan to Build the A-3 Facility for Rocket Propulsion Testing" (IG-08-021, July 8, 2008).

[4] NASA Policy Directive (NPD) 8081.1, "NASA Chemical Rocket Propulsion Testing," February 4, 2010.

Program managers had not yet fully defined the requirements for core stage testing, thereby accepting risks that may negatively affect the Program's cost and schedule.

## NASA Failed to Adequately Assess Options for SLS Core Stage Testing

**NASA Did Not Follow Agency Policy or its Agreement with DOD.** Managers in the RPT Program did not follow Agency policy when selecting the B-2 test facility for SLS core stage testing. Specifically, NASA failed to submit a timely Action Request to the NRPTA, which hindered the NRPTA's ability to comprehensively review estimates for the other testing sites. In fact, it was not until 3 days after the HEO Directorate Program Management Council had approved using the B-2 stand for core stage testing that the Executive Coordinator for the NRPTA – an employee of NASA's RPT Program Office – developed an NRPTA recommendation. However, this recommendation was generated without an NRPTA Board vote on the three options, was not signed by the NRPTA co-chairs, and only briefly summarized the events that led to the decision to choose the B-2 test stand. Moreover, the RPT Board elimination of the Air Force's 1C test stand from consideration conflicts with the overall intent of the NRPTA MOU and Operating Procedures to facilitate the coordination necessary to make informed and efficient investments in rocket test facilities.

**Insufficient Time and Information to Assess Cost, Schedule, and Risks.** The RPT Board and the NRPTA had minimal time to assess the cost, schedule, and risks of testing options for the SLS core stage because NASA failed to provide them with appropriate and timely information regarding the SLS Program's testing needs and requirements. As prescribed in the NRPTA MOU, NASA and DOD agreed to seek the advice and recommendations of the NRPTA Board in time to inform the Agency's decision-making process before spending hundreds of millions of dollars to either build or renovate a test stand. However, NASA did not initiate the process early enough to do so. Rather, it allowed the timetable required to refurbish the B-2 stand to drive the timing of its decision-making process. Specifically, because more than 4 years would be needed to complete refurbishment of the B-2 stand, delaying a decision on which test stand to use beyond April 2012 could have affected the overall SLS development schedule and potentially eliminated the B-2 stand as a practical testing option.

**Presentations Lacked Comparable and Consistent Data.** The methodology employed by the RPT Program and the fidelity of its assessments were inconsistent and resulted in gaps in knowledge that made comparison of testing options unreasonable and arguably inaccurate. Specifically, the B-2 stand received an independent cost estimate and approximately 2 years of HEO Mission Directorate funded assessments. The other two candidate sites had 3 weeks or less to conduct their assessments and received no external funding to conduct these reviews. We also identified inaccuracies in the cost estimates provided to the Council. For example, the SLS Program Manager applied costs to the

4670 and 1C test stands that were specific to the B-2 test stand even though there was no evidence that these facilities would incur such costs.

**NASA's RPT Decision-Making Process Lacks Internal Controls.** Although NASA agreed to the provisions set forth in its MOU with DOD, the Agency has no controls in place to ensure that the appropriate process is followed and an NRPTA recommendation is obtained prior to making a decision and committing funds for rocket propulsion testing. Specifically, project management life-cycle reviews do not require managers of systems that require rocket propulsion testing to plan for or obtain the appropriate RPT or NRPTA Board recommendations.

**Structure of RPT Program Management Contributes to Ongoing Challenges.** The ability of the RPT Program Manager to recommend and the HEO Mission Directorate to approve and fund rocket propulsion testing investments – absent an NRPTA recommendation – highlights a disconnect between the NRPTA MOU and NASA's approval processes. We believe this is due in part to the broad authority NASA invests in the RPT Program Manager. Specifically, as the Chairman of NASA's RPT Board, co-chair of the NRPTA, and member of the NRPTA Senior Steering Group the RPT Program Manager holds all of the most influential positions on the RPT and NRPTA Boards.[5] In our judgment, it is not possible for one person to accomplish all these tasks objectively while considering what constitutes the best value for the taxpayer, the best short- and long-term strategy for the organization, and the best fit for the program in need of rocket propulsion testing.

**B-2 Decision May Introduce Costs and Schedule Risk to SLS Program.** NASA chose the B-2 test stand for SLS core stage testing without assessing complete and comparable data from other potential sites to make a well-informed decision. NASA's limited internal assessments indicated that refurbishing the B-2 test stand was not the most cost-effective or timely choice to meet the testing requirements for SLS. Comparisons presented by the SLS and RPT Programs showed that B-2 was in the lowest state of readiness, would require the longest time to refurbish, and would cost the most of the three options. Although NASA may have a strategic reason for choosing the more expensive B-2 option (i.e., consolidation of rocket engine test facilities and resources at Stennis), we question whether NASA adequately considered all testing options before making its decision.

In a September 2012 audit, the OIG identified NASA's culture of optimism, underestimating technical complexity, and funding instability as challenges the Agency faces in meeting project cost, schedule, and performance goals.[6] We believe these factors

[5] The Senior Steering Group is charged with providing guidance and direction to the NRPTA and serves as a forum for members to present recommendations and proposed actions and obtain resolution of disagreements.

[6] NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012).

affected NASA's choice for SLS core stage testing. NASA chose the test facility with the longest and most expensive development time and is optimistically planning that all aspects of the renovation will come together in time for the stand to accommodate the SLS's test schedule. Furthermore, at the time the Agency chose the B-2 test facility, NASA and Boeing had not yet fully defined SLS core stage technological requirements. To account for the immaturity of the SLS vehicle design and requirements, NASA's independent cost estimate added $86.7 million for special test equipment and risk to account for potential design changes, funding delays, construction issues, and additional testing scenarios. Moreover, the estimate stated that the 6-month schedule margin for the B-2 was very optimistic for such a large, complex project, especially since Boeing hardware access requirements had not been identified, subsystem tests objectives were not defined or budgeted, and special test equipment hardware designs were not yet included in either Boeing or B-2 funding plans.

In November 2013, the B-2 Project Manager noted delays in finalizing core stage requirements needed to refurbish the B-2 and design the required special test equipment. Because B-2 refurbishment is a critical path item for SLS, it is imperative that firm design requirements be established and communicated in a timely manner to mitigate the risks to the SLS first flight and associated costs to the Program.

## Management Action

To increase NASA's ability to make sound cost and schedule estimate comparisons when considering rocket-testing options, we recommended that the Associate Administrator for HEO review internal control processes and implement a strategy for assuring timely coordination with DOD and adherence to requirements of NPD 8081.1; ensure that requirements of NPD 8081.1 are referenced in NASA's project management policies; and revise NPD 8081.1 to include an independent review of RPT and NRPTA recommendations at appropriate life-cycle reviews. We also recommended that the Associate Administrator review the roles and responsibilities of the RPT Program Manager to ensure the position's scope of authority is appropriate for accomplishing tasks objectively and provides consistency with the intent of the MOU with DOD.

In response to our draft report, the Associate Administrator for HEO concurred or partially concurred with our recommendations and agreed to take corrective actions. We consider these proposed corrective actions responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of those actions.

The Associate Administrator also commented that NASA's decision to test the core stage at Stennis was not driven solely by cost, but rather based on a "comprehensive assessment set of all risks, including costs and schedule risks to the program and physical risks to valuable flight hardware." In addition, the Associate Administrator stated that after multiple attempts to engage DOD members in the NRPTA process, the Air Force Research Laboratory provided the only response and NASA ultimately decided that the risk of transporting the core stage flight article to the 1C test stand overruled cost

considerations. In light of these considerations, the Associate Administrator stated NASA is "confident it made the right decision in choosing to conduct SLS core stage testing at B-2."

Management's full response is reprinted in Appendix B.

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# INTRODUCTION

## Background

Test stands for large rocket propulsion systems often cost hundreds of millions of dollars to build or refurbish and may sit idle for many years after the programs for which they were built end. On April 24, 2012, NASA's Human Exploration and Operations (HEO) Directorate Program Management Council (Council) approved a plan to refurbish the B-2 test stand at Stennis Space Center (Stennis) to enable it to test the core stage of NASA's new heavy-lift rocket known as the Space Launch System (SLS). SLS Program management estimated that refurbishing B-2 would take 4.5 years to complete. Total costs, including refurbishing, special test equipment, testing the core stage, and contingency funding, were expected to be $352 million. NASA assembled an independent team that put the total costs of preparing and using B-2 for core stage testing at $407 million.

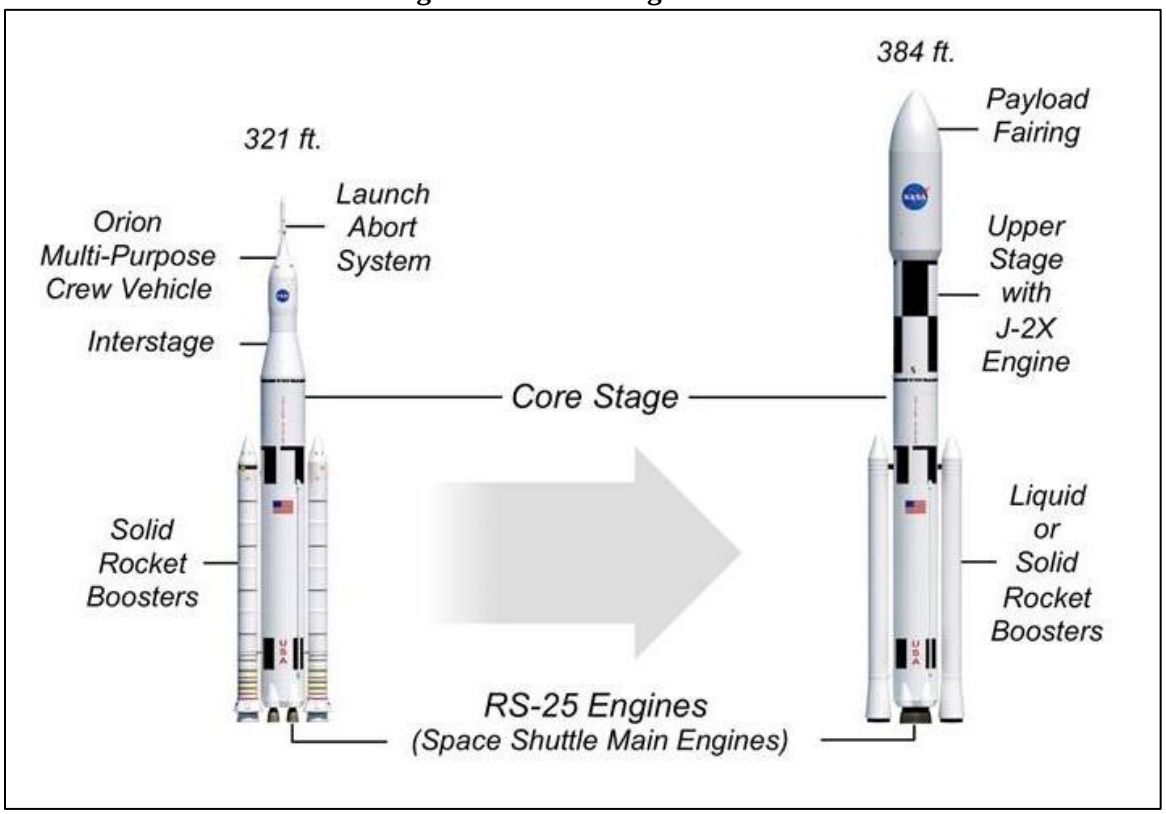
NASA examined two other possible sites for testing the SLS core stage – the Air Force Research Laboratory's 1-125 1C test stand at Edwards Air Force Base in California (1C) and NASA's Advanced Engine Test Facility 4670 at the Marshall Space Flight Center (4670). The estimates available to NASA at the time it selected the B-2 indicated that refurbishment of these other two facilities would take 3.5 and 2.5 years, and total costs to test the core stage were $319 million and $251 million, respectively. Unlike for the B-2 test stand, NASA did not have an independent cost estimate for renovating and testing at these two facilities. Despite the lower estimated costs and shorter timeframes for refurbishing the Air Force and Marshall facilities, NASA chose the B-2 stand citing risks associated with testing at the other two sites, the existence of the independent cost estimate, and the potential benefits of consolidating large-scale testing at Stennis.

**NASA's Space Launch System**. The National Aeronautics and Space Administration Authorization Act of 2010 (Authorization Act) directs NASA to develop a heavy-lift rocket to enable human exploration beyond low-Earth orbit.[7] In response, NASA is developing the SLS – the first exploration-class rocket since the Saturn V used to transport the astronauts to the Moon. NASA plans to use the main engine from its retired Space Shuttle – the RS-25 rocket engine – on the SLS and is designing the vehicle with an evolvable architecture that can be tailored to accommodate longer and more ambitious missions. For example, initial versions of the SLS will be capable of lifting 77 tons and use an interim cryogenic propulsion stage (interstage) to propel the crew capsule under development known as the Orion Multi-Purpose Crew Vehicle around the Moon (see Figure 1). Later SLS versions will be designed to lift 143 tons and incorporate an upper

[7] Public Law 111-267, October 11, 2010.

stage, possibly consisting of two J-2X engines, to provide the additional power needed to travel to deep space. Common to all configurations is a core stage comprised of liquid hydrogen and oxygen fuel tanks, subsystem hardware and avionics, and RS-25 engines.

**Figure 1. SLS Configurations**




Source: NASA.

**SLS Core Stage Configuration and Timeline.** The SLS's configuration and development timeline have gone through a number of changes since Program inception. In January 2011, NASA told Congress that the architecture would consist of five RS-25 engines and that due to budget limitations it was not likely the SLS would launch by the 2016 goal set forth in the 2010 Authorization Act.[8] By September 2011, NASA was considering a core stage design that could evolve to incorporate either three, four, or five engines and published its intent to proceed with a sole source acquisition strategy for the core stage by extending its contract for the Constellation Program's Ares I upper stage with The Boeing Company (Boeing).[9] In its justification for a sole source contract,

[8] NASA, "Preliminary Report Regarding NASA's Space Launch System and Multi-Purpose Crew Vehicle Pursuant to Section 309 of the NASA Authorization Act of 2010 (P.L. 111-267)" January 2011.

[9] NASA's Constellation Program was developing the Ares I Crew Launch Vehicle, J-2X engine, and the Orion Crew Exploration Vehicle to facilitate a return of humans to the moon and eventual human spaceflight to Mars. The Ares upper stage consisted of the J-2X engine and components such as liquid hydrogen and oxygen tanks and a delivery system similar to those needed for the SLS core stage.

NASA argued that the core stage was a critical path item and by virtue of its work on the upper stage Boeing was best positioned to deliver the core stage in time for it to be tested and available for a first flight in December 2017. Moreover, NASA stated that a competitive procurement would likely delay the SLS Program by 18 months. Trade studies conducted at the end of 2011 determined that the three-engine configuration did not support initial exploration missions, and in January 2012 NASA established the vehicle's current four-engine design. As of November 2013, NASA planned to receive delivery of the core stage from Boeing in time to commence testing at Stennis in the first quarter of fiscal year 2017.

**NASA's Rocket Propulsion Test Program.** NASA's Rocket Propulsion Test (RPT) Program Office is located at Stennis and is part of the HEO Mission Directorate. The Program Office manages the test assignments and portions of the budget, such as test stand maintenance, for NASA's rocket propulsion testing activities. The RPT Program Manager is responsible for coordinating with the Directors of NASA's four rocket test Centers –Marshall, Plum Brook Station, Stennis, and White Sands Test Facility – and two associate testing Centers – Glenn Research Center and Kennedy Space Center – to create integrated funding, staffing, and facility modification plans; capital asset improvements; test facility modernization and refurbishments; integration for multi-site test requirements; identification and protection of core capabilities; and the advancement and development of test technologies.

The RPT Program Manager also serves as the chair of NASA's RPT Management Board (RPT Board), which consists of representatives from each test Center. The Board serves as NASA's decision-making body for rocket propulsion testing by reviewing, approving, and providing direction on:

- testing assignments;
- capital investment recommendations for rocket propulsion test facilities and equipment;
- facility modifications or refurbishments affecting the Agency's rocket propulsion test capability;
- annual budget requirements (establishment and approval);
- official documentation pertaining to multi-site test activities; and
- key decisions relating to NASA rocket propulsion testing.

**The National Rocket Propulsion Testing Alliance.** In addition to NASA's internal process, Federal law requires NASA to coordinate with the Department of Defense (DOD) regarding rocket propulsion testing decisions. Specifically, the National Defense Authorization Act for Fiscal Year 1997 provides that

> Not later than 90 days after the date of the enactment of this Act, the Secretary of Defense and the Administrator of the National Aeronautics and Space Administration shall submit to Congress a joint plan for coordinating and eliminating unnecessary

> duplication in the operations and planned improvements of rocket engine and rocket engine component test facilities managed by the Department of the Air Force and the National Aeronautics and Space Administration. The plan shall provide, to the extent practical, for the development of commonly funded and commonly operated facilities.[10]

Although NASA and DOD never provided a formal plan to Congress, in 1998 the two agencies formed the National Rocket Propulsion Testing Alliance (NRPTA) with the goals of preventing duplication of effort, efficiently meeting national testing needs, and shaping the Government's rocket propulsion testing capability.

The NRPTA Board consists of representatives from NASA's four primary test sites and from four DOD facilities: Arnold Engineering Development Center near Tullahoma, Tennessee; Air Force Research Laboratory at Edwards Air Force Base in California; Army Redstone Test Center in Huntsville, Alabama; and the Naval Air Warfare Center in China Lake, California. The Board is co-chaired by NASA's RPT Program Manager and a representative of one of the DOD organizations and is charged with reviewing testing needs and recommending solutions that provide the best overall value to the taxpayer.

The NRPTA's Senior Steering Group (Steering Group) is composed of the RPT Program Manager, one representative from NASA Headquarters, and one representative from each of the four DOD member organizations. The Steering Group is charged with providing guidance and direction to the NRPTA and serves as a forum for members to present recommendations and proposed actions and obtain resolution of disagreements.

**Rocket Propulsion Testing Decision Process.** Senior NASA and DOD officials signed the initial Memorandum of Agreement for the NRPTA on January 9, 1998, and the most recent Memorandum of Understanding (MOU) on April 29, 2009. In addition to the MOU, Operating Procedures for the RPT Board and NRPTA provide detailed requirements for decision making about rocket propulsion testing assignments. These Operating Procedures are designed to ensure that testing requirements are adequately addressed in the decision-making process.

**NASA's Internal Process.** The RPT Board's Operating Procedures state that when a NASA organization desires to make a modification to a testing facility that will cost more than $500,000, deviate from a testing facility's baseline capability, or is contacted about potential testing, an "Action Request" and any related information is to be forwarded to the RPT Program Office. The Action Request includes the name and location of the person initiating the request, a description of the requested action, investment requirements, and a cost estimate. The RPT Program Office distributes the Request and supporting information to the RPT Board members, who evaluate the Request against baseline roles, cost, schedule, facility investment, technical requirements, and customer preference to ensure project requirements are considered and addressed in the decision-

[10] Public Law 104-201, Section 211(c).

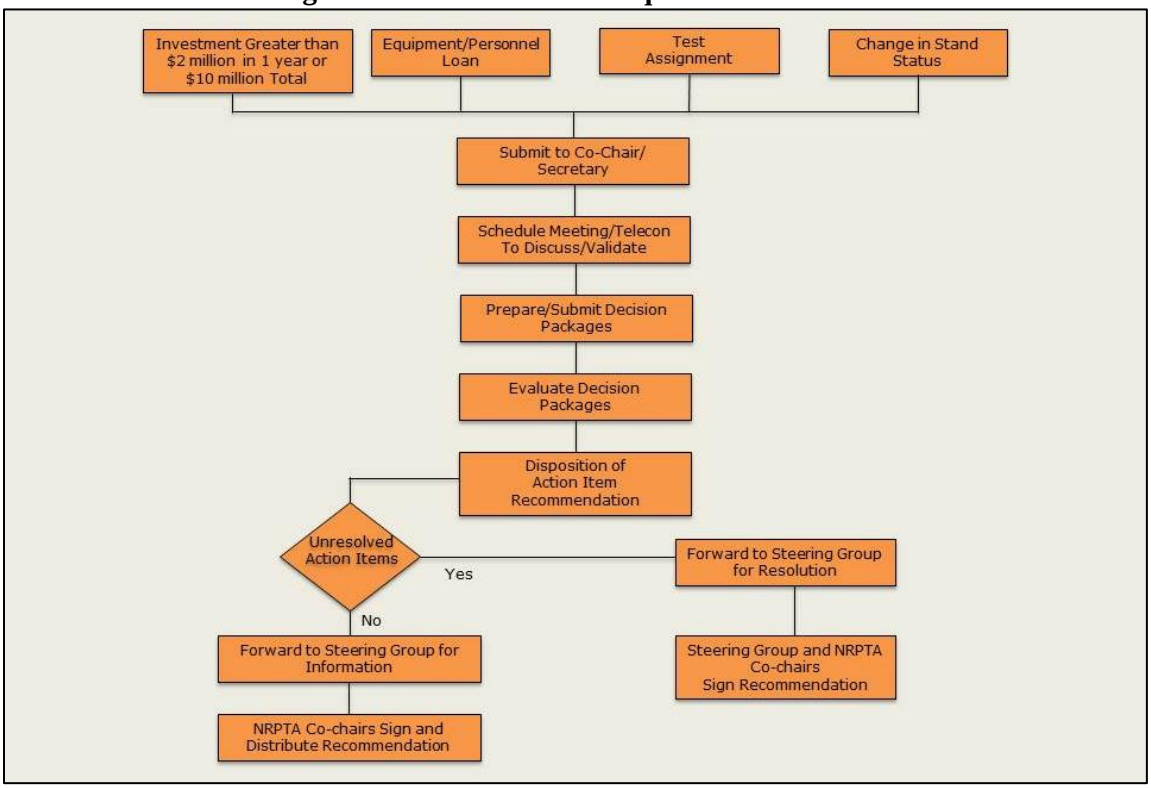
making process. When modifications to a facility or unique equipment investments for a test program exceed $2 million in 1 year or $10 million total, the Board's operating procedures require that the Action Request be shared with and considered by the NRPTA.

**The NRPTA Process.** The governing MOU for the NRPTA provides that the organization "will be notified, and the advice and recommendations of the NRPTA Board will be requested in a timely manner in order to effectively influence the decision-making process." The MOU further states that:

> The NRPTA Board will be requested to provide a recommendation, based on an analysis of alternatives and the Government's cost estimates, to the appropriate decision-making authority, under any of the following conditions:
>
> a) When a new rocket propulsion test facility meeting the foregoing [$2 million in 1 year or $10 million total] threshold is required by elements of either Party.
>
> b) If rocket propulsion test requirements exceed current test facility capabilities within an agency/service and facility construction, modification, or upgrading, exceeding the foregoing threshold, is necessary to satisfy those requirements.
>
> c) When commercial entities seek Government estimates for rocket propulsion testing at member sites, and facility construction, modification, or upgrading, exceeding the foregoing threshold, is necessary to perform the tests.

The NRPTA Operating Procedures contain detailed guidelines applicable to all rocket propulsion test activities conducted at NASA or DOD locations. They provide that NRPTA members submit Action Requests to their respective chairs to document planned actions or investments or to initiate a review of issues raised by the NRPTA membership, including facility investments, test assignments, and changes in test stand status or functionality. All facilities belonging to NRPTA members as well as commercial facilities are to be considered for each new capability, modification, investment, or test. Once NRPTA members have discussed and validated an Action Request, the NRPTA members affected by the proposed action develop Decision Packages detailing facility, cost, schedule, and staffing relative to the testing requirements and distribute the packages to all NRPTA members. Following the co-chairs' determination that sufficient discussion has taken place, members vote on the options. The position with the most votes is forwarded to the requesting agency as the NRPTA recommendation while unresolved issues are forwarded to the Steering Group for resolution. See Figure 2 for a flow chart detailing the NRPTA process.

**Figure 2. NRPTA Action Request Process Flow**




Source: NASA Office of Inspector General analysis of NRPTA Operating Procedures.

According to NASA's RPT Program Manager, the NRPTA has made 66 recommendations since its inception in 1998. Of those, seven have resulted in actual testing assignments. For example, in 2008 an NRPTA recommendation led Orbital Sciences Corporation to select the E-1 test stand at Stennis for verification and acceptance testing of the company's AJ26-62 engines used in its Antares rocket. In another case, an NRPTA recommendation in 2010 resulted in the Missile Defense Agency testing multi-use thrusters at a White Sands test stand.[11] Overall, according to Program officials, coordination through the NRPTA has resulted in $40.7 million of cost savings or cost avoidance.

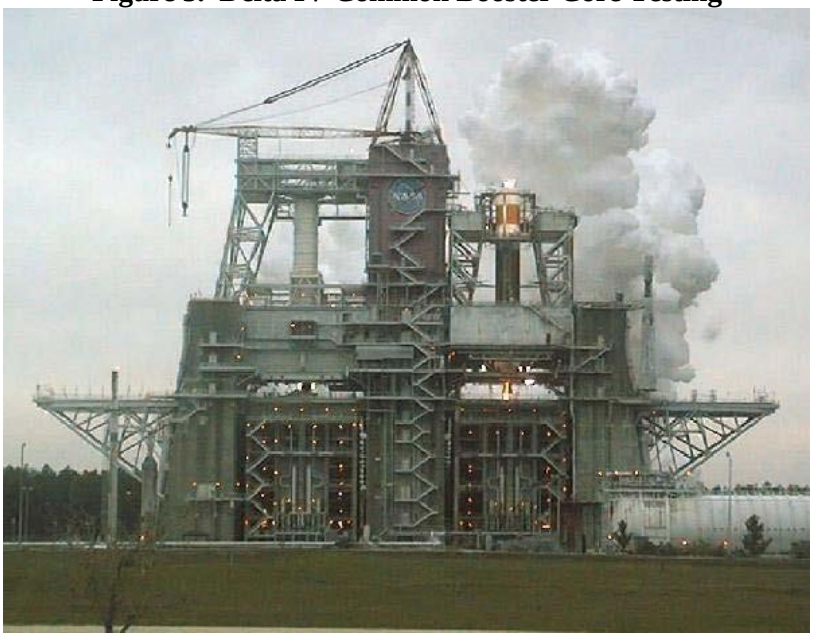
**Rocket Propulsion Test Sites Capable of Supporting SLS Core Stage.** Because of its size and thrust capability, only three existing facilities were candidates for testing the SLS core stage:

- The B-2 test stand at Stennis is the largest, full-scale liquid rocket test stand in the United States. Construction began in 1963 and NASA used the stand to test the Saturn V rocket from 1967 to 1970, the Space Shuttle main engines from

[11] These thrusters were used in missile defense applications and the technology was leveraged for NASA science and space exploration.

April 1978 through January 1981, and the Boeing Common Booster Core in 2001. The stand can accommodate full-scale rocket engine and systems testing (see Figure 3).

**Figure 3. Delta IV Common Booster Core Testing**



Source: NASA.

- Marshall's 4670 test stand was built in 1965 to support the Apollo Program. NASA later modified the stand as part of the Space Shuttle Program, using it to test the Shuttle's RS-25 engine and external tanks between 1976 and 1999, and the Lockheed RD-180 in 1998 (see Figure 4).

**Figure 4. First Stage Testing of the Saturn V Launch Vehicle**

Source: NASA.

- The 1C test stand at the Air Force Research Laboratory was also built to support NASA's Apollo Program and NASA used it to test the Saturn rocket's F-1 engine. NASA transferred control of the stand to the Air Force in 1974, which has used it to test a variety of engines and rocket motors, including the Titan series of rockets used in intercontinental ballistic missiles (see Figure 5).

**Figure 5. Titan 4 Solid Rocket Motor Testing**

Source: U.S. Air Force.

**Prior Review of NASA Rocket Propulsion Testing Decision.** In July 2008, the NASA Office of Inspector General (OIG) examined allegations that NASA's plan to build the A-3 test stand at Stennis to test the J-2X rocket engine in connection with the Constellation Program would duplicate the capabilities of an Air Force testing facility in Tennessee. The OIG found that in making the decision to build the A-3 test stand, NASA did not follow either its own internal RPT Board process or the NRPTA process.[12] In response to the report, NASA officials cited program schedule pressure as the reason for bypassing both processes. Unfortunately, the A-3 test stand ended up costing significantly more and taking longer to build than NASA anticipated. In February 2008, NASA estimated the A-3 test stand would be operational in September 2010 and cost between $163 million and $185 million. However, construction of the test stand took 3 years longer than estimated and costs have risen to $349 million. Moreover, because the Constellation Program was cancelled in 2010 and requirements for the J-2X engine in

[12] NASA OIG, "Final Memorandum on the Review of NASA's Plan to Build the A-3 Facility for Rocket Propulsion Testing" (IG-08-021, July 8, 2008).

the SLS Program differed substantially, the A-3's unique testing capabilities will not be needed and the stand will be mothballed upon completion.

In the 2008 review, the OIG recommended that NASA request an independent review and assessment of the technical and cost risks associated with the A-3 test stand and issue a policy detailing the requirements for NASA organizations to request formal reviews and recommendations from the RPT Board and, as appropriate, the NRPTA for rocket testing. NASA contracted with The Aerospace Corporation to perform the independent assessment, which showed the Agency lacked technical support for construction and development of the A-3 test stand and that its estimates of cost and schedule were overly optimistic.

NASA also established a policy directive that requires the RPT Board to review and approve all rocket propulsion-testing decisions and that NASA engage DOD about testing decisions to meet national needs.[13] The policy outlines the responsibilities of the RPT Program Office, including the requirement to "utilize the NRPTA to conduct DOD facility trade studies, acquire costs estimates, and seek test assignments, as appropriate, to meet NASA customer rocket propulsion testing needs."

## Objectives

We initiated this review to examine NASA's decision-making process for SLS core stage testing. Specifically, we reviewed whether NASA's decision to use the B-2 test stand (1) was made in accordance with applicable agreements and policies, (2) resulted in the best value for the taxpayer, and (3) best supported the SLS Program. See Appendix A for details of the review's scope and methodology, our review of internal controls, and a list of prior coverage.

[13] NASA Policy Directive (NPD) 8081.1, "NASA Chemical Rocket Propulsion Testing," February 4, 2010.

# NASA FAILED TO ADEQUATELY ASSESS OPTIONS FOR SLS CORE STAGE TESTING

We found that NASA did not follow its internal policies or its agreement with DOD when selecting a facility for SLS core stage testing, nor did it adequately support its decision to refurbish the B-2 test stand, which estimates indicate will be more costly and take longer than the other available options. We also found that by selecting the B-2 stand, NASA may not have chosen the most efficient and cost-effective testing option. Although the SLS Program spent considerable time and money studying the B-2 option, NASA gave the RPT and NRPTA Boards minimal time to assess the cost, schedule, and risks of the other test stand options. Moreover, driven by the time needed to refurbish the B-2 stand to commence testing in accordance with the SLS development schedule, NASA officials selected B-2 even though SLS Program managers had not yet fully defined the requirements for core stage testing, thereby accepting risks that may negatively affect the Program's cost and schedule.

## NASA Failed to Follow Agency Policy or its Agreement with DOD

Managers in the RPT Program did not follow Agency policy when selecting the B-2 test facility for SLS core stage testing. Specifically, NASA failed to submit a timely Action Request to the NRPTA, which hindered the NRPTA's ability to comprehensively review estimates for the other testing sites. In fact, it was not until 3 days after the HEO Directorate Program Management Council had approved using the B-2 stand for core stage testing that the Executive Coordinator for the NRPTA – an employee of NASA's RPT Program Office – generated an NRPTA recommendation. However, this recommendation was generated without an NRPTA Board vote on the three options, was not signed by the NRPTA co-chairs, and only briefly summarized the events that led to the decision to use the B-2 test stand. Moreover, the RPT Board eliminated consideration of the Air Force's 1C test stand, an action that conflicted with the overall intent of the NRPTA MOU and Operating Procedures to facilitate the coordination necessary to make informed and efficient investments in rocket test facilities.

## NASA Gave RPT and NRPTA Boards Insufficient Time to Assess the Cost, Schedule, and Risks of the Three Testing Options

The RPT Board and the NRPTA had minimal time to assess the cost, schedule, and risks of testing options for the SLS core stage because NASA failed to provide them with appropriate and timely information regarding the SLS Program's testing needs and requirements. As prescribed in the NRPTA MOU, NASA and DOD agreed to seek the advice and recommendations of the NRPTA Board in time to inform the Agency's decision-making process. However, NASA did not initiate the process early enough to do so. Rather, it

allowed the timetable required to refurbish the B-2 stand to drive the timing of its decision-making process for testing options.[14] Specifically, because more than 4 years would be needed to complete refurbishment of the B-2 stand, delaying a decision on which test stand to use past the end of April 2012 could have affected the overall SLS development schedule and potentially eliminated the B-2 stand as a practical testing option.

**NASA Focused on B-2 for SLS Core Stage Testing.** As early as March 2011, the Project Integration Office at Stennis began studying the level of effort required to refurbish B-2 and better position Stennis to support the SLS flight schedule. Although the estimated costs of the facility modification and refurbishment exceeded the dollar thresholds established in the NRPTA MOU and Operating Procedures, no Action Request was generated to initiate a review of the proposed investment at that time. Instead, on February 24, 2012, SLS Program Managers announced that they had baselined the B-2 test stand as the core stage test location and established a cost estimate for budget purposes. Further, in contrast to NASA policy requirements that Programs "request test assignments and approval for investments in Agency RPT facilities from the RPT Program," the SLS Program Office did not submit an Action Request to the RPT Board prior to this announcement. Instead, only after identifying the B-2 stand as the location for testing in its baseline budget projections did SLS Program managers informally request that the RPT review all test location options and make recommendations.

**NASA Failed to Initiate Formal NRPTA Process.** NRPTA Operating Procedures state that Action Requests are to be submitted to the respective agency chairperson and NRPTA Executive Coordinator to seek recommendations when investments for a test program exceed $2 million in 1 year or $10 million total. Although RPT Program management informally communicated with NRPTA members regarding the need for a test stand to conduct SLS core testing, the SLS Program never submitted a formal Action Request seeking the advice and recommendation of the NRPTA Board for core stage testing. The Stennis RPT Board representative submitted the only formal Action Request on March 12, 2012, to the RPT Program Office, but instead of soliciting the required recommendation, the request simply asked to change the status of B-2 from "Mothball" to "Active Occupied" and to request a test assignment to B-2.[15]

The NRPTA held its first meeting to discuss SLS core stage testing options on March 28, 2012. In the absence of the RPT Program Manager, the NRPTA Executive Coordinator informed members attending the meeting – which did not include representatives from

[14] At an American Institute of Aeronautics and Astronautics conference in July 2005, NASA Propulsion Test Directorate personnel stated that because rocket propulsion testing is a critical long lead item of any space system acquisition, government leaders, test support personnel, and vehicle development personnel need to give early consideration to an appropriate strategy. The presenters also stated that it is advisable to begin technical and programmatic assessments of test capability upgrades and customizations even before authorization for the space system development is official.

[15] NASA defines a facility as mothballed if it is maintained only to the extent necessary to prevent deterioration of essential systems. NASA considers a facility active if it is being used by a current program or near-term program, or for an institutional requirement.

Marshall or the Air Force Research Laboratory – that NASA's SLS Program had solicited the RPT Program Office to provide test cost information for ground testing the SLS core stage.[16] In addition, the NRPTA Executive Coordinator explained that an Action Request had not been generated due to time limitations and the small number of sites capable of handling the core stage tests. He also represented that NASA needed to make its decision on a test stand by the end of April 2012 to meet a congressional funding request deadline and to avoid impacting the SLS Program's first scheduled launch date. However, we found that the main driver for the April deadline was the 4.5 years that would be needed to refurbish the B-2 test stand and did not consider that the other two viable test stand options required less time for refurbishment.

On April 19, 2012, 5 days before the official RPT Program recommendation of a test assignment was due to the HEO Council for final decision, the NRPTA Executive Coordinator generated an Action Request to solicit input on SLS testing options from NRPTA members. That same day, the NRPTA Executive Secretary requested that NRPTA members submit presentations of testing options for the group's next meeting scheduled for April 25, 2012. The original intent of the April 25 meeting was to have the full membership review each candidate's "rough order of magnitude" packages.[17] However, on the day before the scheduled meeting the RPT Program Manager presented a formal recommendation to refurbish B-2 to the Council, explaining that there was not enough time to fully evaluate the other test sites and therefore only the B-2 stand had a comprehensive cost, schedule, and risk estimate completed. We believe that if NASA had provided NRPTA members the same requirements SLS Program management used to baseline their estimates to refurbish B-2, it is likely that a more comparative and complete analysis could have been performed for the other testing facilities.

Although the analysis of all feasible options was incomplete, on April 24, 2012, the RPT Program Manager made a presentation to the HEO Directorate Program Management Council and concurred with the SLS baseline to use B-2 for the core stage testing. The Council concurred with the RPT recommendation and approved SLS core stage testing at B-2. Based on information gathered as part of our review, we determined that the Council had confidence in the estimates for the B-2 test stand and was willing to accept the identified risks rather than wait on a full cost, schedule, and risk analysis of the other two facilities. Following the decision of the Council, the RPT Program Manager contacted the members of NASA's RPT Board to convey "apologies for the rush" and acknowledge that they "did not have enough time to do a complete assessment" of the other two potential test sites.

[16] Marshall representatives stated that active participation in the process was not a priority for them because in their opinion the decision of where to test SLS core stage would be made by the RPT Program Manager.

[17] Rough order of magnitude estimates are used early in a project when there is limited information from which to develop more accurate estimates and are based on top-level requirements and an overall prediction of work to be done to satisfy the requirements.

## Presentations Lacked Comparable and Consistent Data

The methodology employed by the RPT Program and the fidelity of its assessments were inconsistent and resulted in gaps in knowledge that made comparison of testing options unreasonable and arguably inaccurate. Specifically, the B-2 stand received an independent cost estimate and approximately 2 years of study and HEO Mission Directorate funded assessments. The other two candidate sites had 3 weeks or less to conduct their assessments and no external funding. In the end, both Air Force and Marshall managers were only asked to provide "rough order of magnitude" cost estimates to assess the viability of using their stands for the core stage tests. The SLS and RPT Program managers assigned a 70 percent confidence level to the B-2 independent cost estimate and a 50 percent confidence level to the Air Force and Marshall estimates – a difference the RPT Program Manager later cited as a contributing factor for selecting the B-2 test stand.

**SLS Program Review.** The SLS Program Manager said he based his preference to use the B-2 test stand on minimizing schedule and risk impacts to the Program despite the lower estimated costs and shorter timeframes for refurbishing the Air Force and Marshall facilities. As early as March 2011, the SLS Program and Stennis began to assess the B-2 stand's major auxiliary, electrical/mechanical, and structural elements for potential core stage testing. As mentioned previously, the SLS Program and Stennis did not conduct similar assessments of either the Air Force or Marshall testing options.

Table 1 compares the cost and schedule estimates presented by the SLS Program Manager to the Council for the three potential test sites.

| Table 1. SLS Program Comparison of Test Facilities (dollars in millions) | | | | |
|---|---|---|---|---|
| | **Air Force TS 1-125 1C** | **Marshall 4670** | **SLS Estimate for Stennis B-2** | **Independent Cost Estimate for Stennis B-2** |
| **Test Stand Status** | Active standby | Mothballed | Mothballed/ abandoned | N/A |
| **Estimate Fidelity** | 3-week estimate | 1-week estimate | 2-year study | 1-month analysis |
| **Estimated Schedule** | 3 years 5 months FY 2013 start | 2 years 7 months FY 2014 start | 4 years 7 months FY 2012 start | N/A |
| **Estimated Cost** | | | | |
| *Facility and Test Costs* | $158.0[a] | $92.5[a] | $191.0[b] | $246.3[c] |
| *Special Test Equipment* | 28.3 | 28.3 | 28.3 | 28.3 |
| *Risk* | 58.4 | 58.4 | 58.4 | 58.4 |
| *Boeing* | 74.0 | 74.0 | 74.0 | 74.0 |
| **Total** | **$318.7** | **$250.7** | **$351.7** | **$407.0** |

[a] 50 percent confidence level
[b] 50-60 percent confidence level
[c] 70 percent confidence level

Source: NASA OIG analysis of SLS Program presentation.

As illustrated in the table, the SLS Program Manager estimated that B-2 would require 4.5 years to refurbish and total costs, including refurbishing, special test equipment, testing the core stage, and contingency funding, would be $352 million. The Air Force 1C test stand was expected to require approximately 3.5 years and $319 million and the Marshall 4670 stand 2.5 years and $251 million.

The SLS Program Manager stated that given enough time, funding, and technical innovation any of the three facilities could perform the test. However, he noted a high transportation risk with using the 1C test stand and a high acoustic risk with testing at Marshall. The Program Manager said transportation from the manufacturing plant to the Air Force facility in California would require 10 months of lead-time for planning and a 2.5-month round trip – programmatic risks which were determined to be unacceptable for the SLS Program. With regard to Marshall, since the early 1990s a significant number of homes and apartments have been built just beyond the Center's boundaries and very little acoustic impact analyses has been performed to gauge the level of potential noise when test stands are in use. Moreover, because the SLS Program studied the possibility of conducting the core stage tests at B-2 for 2 years, he believed that the B-2 cost and schedule estimates were considerably more mature than the estimates for the other two options.

However, even given this longer analysis period, we identified inaccuracies in the B-2 estimates provided to the Council. For example, the independent cost estimate for the B-2 test facility identified $160.7 million of costs associated with risks specific to that

stand. While acknowledging that some risks applied only to the B-2 site, and absent evidence that the other test facilities would incur such costs, the SLS Program Manager nevertheless applied the costs associated with these risks to both the Air Force and Marshall estimates. He also acknowledged that since both the Air Force and Marshall stands required substantially less time to refurbish, the SLS Program could have taken more time to better define core stage testing requirements prior to beginning the work necessary to test on those stands.

**RPT Program Review.** The cost estimates the RPT Program Manager presented to the Council differed significantly from those presented by the SLS Program Manager. According to the RPT Program Manager, he adjusted each facility's cost estimates based on standard cost estimating practices, yet acknowledged his uncertainty with the cost estimates presented. Table 2 illustrates the cost comparison presented by the RPT Program Manager.

**Table 2. RPT Program Comparison of Test Facilities' Estimated Costs (dollars in millions)**

| | Air Force TS 1-125 1C | Marshall 4670 | RPT Estimate for Stennis B-2 | Independent Cost Estimate for Stennis B-2 |
|---|---|---|---|---|
| **Rough Order of Magnitude Uncertainty** | $54.0 | --- | $44.9 | --- |
| **Facility and Test Costs** | $154 | $110 | $164 | $256 |
| **Special Test Equipment** | $29.4 | $28.1 | $33.0 | $34.3 |
| **Risk** | --- | $15.6 | --- | $15.6 |
| **Boeing** | $49.0 | $49.0 | $49.0 | $49.0 |
| **Post-test Maintenance** | --- | $2.5 | $2.5 | $2.5 |
| **Total** | **$287** | **$206** | **$294** | **$357** |

Source: NASA OIG analysis of RPT Program Manager presentation.

As previously stated, NASA's RPT Board ruled out using the Air Force's 1C test stand after the RPT Program Manager concluded that the facility presented a high transportation and schedule risk. In his presentation to the Council, he also cited the rough order of magnitude cost evaluation and lack of an independent cost estimate for the Air Force site.

One of the primary reasons the RPT Program Manager cited for not recommending SLS core stage testing at Marshall was the potential risk associated with the noise level during testing for residential neighborhoods near the Center. However, we determined that the assessment of this risk was incomplete. Specifically, the limited acoustic evaluations that had been conducted projected only minor window damage and a potential increase in

damage claims in light of population increases near the Center. Although the RPT Program Manager used historical data to estimate 10 claims for structural damage per 1,000 households, he could not show that specific testing for the core stage would generate a noise level that would exceed NASA or Occupational Safety and Health Administration standards.[18] Furthermore, Marshall personnel provided additional justification for why the acoustic risk might not be as high as calculated, including:

- conservative models were used to predict the number of homes that could be affected, resulting in estimates that were likely higher than actuals;
- only a very small area near Marshall's boundary was predicted to experience a high noise level; and
- the number of complaints expected would be difficult to quantify.

The SLS Program Manager acknowledged that the risk of damage claims due to testing at Marshall was low but stated that further study would be required to more accurately quantify the level of risk.

Similar to the SLS Program estimate, the RPT Program Manager assigned the independent cost estimates applicable to B-2 for risk and special test equipment to the 1C and 4670 test stands. For the reasons discussed above, we question this methodology because according to Marshall personnel, although the estimates for refurbishment were produced quickly, they were based on recent work and the assumptions upon which they were based were well-founded. Specifically, previous plans to modify the 4670 test stand to test the J-2X main propulsion test article for the Constellation Program and cost estimates developed for that testing helped inform the estimates for what would be required to perform the SLS core stage testing.

Although the RPT Program Manager conceded that B-2 was the highest cost option, he pointed to well-known requirements for refurbishing the test stand and the intangible and future benefits of consolidating NASA's rocket testing at Stennis. Specifically, he noted that Stennis maintains a cadre of contractors with experience testing large engines and pointed to possible synergies between B-2 refurbishment activities and future large-scale rocket-testing needs. However, he did not identify any specific follow-on rocket propulsion development projects. He also pointed to NASA's 2012 Rocket Test Facility

[18] The Program estimated a maximum offsite noise level of 99 decibels for 550 seconds (approximately 9 minutes). NASA Procedural Requirements 1800.1C, "NASA Occupational Health Program Procedures w/Change 1," October 6, 2009, and 29 CFR 1910.95," Occupational Noise Exposure," 2012, establish limits of 100 decibels for 15 minutes and 100 decibels for 2 hours, respectively.

Right Sizing Study that identified Stennis as the primary location for NASA's large-scale, sea-level rocket engine testing.[19]

## NASA's RPT Decision-Making Process Lacks Internal Controls

Although NASA agreed to the provisions set forth in its MOU with DOD, neither NASA's policies for project management nor its policies for rocket propulsion testing contain adequate controls to ensure that the process is followed and an NRPTA recommendation is obtained prior to making a decision and committing significant Agency funds for rocket propulsion testing.

NASA policy provides overall direction for how project managers execute their responsibilities.[20] The policy outlines NASA's management structure, the life cycle for spaceflight projects, the roles and responsibilities of and the interrelationships between team members, and management requirements by life-cycle phase. In addition, NASA's systems engineering policy provides the requirements that must be followed for successful completion of NASA's life-cycle reviews.[21] Those reviews are designed to ensure management takes an integrated approach to meet customer needs and to improve safety, affordability, and ensure mission success. However, neither of these policies reference NASA's policy for rocket propulsion testing or set a requirement for management to review recommendations from the RPT or NRPTA Boards as part of project life-cycle reviews for programs that involve rocket engine testing.

The SLS Program initiated a combined, two-step System Requirements and System Definitions Review in February 2012.[22] To successfully pass the review and move to the next life-cycle stage, the SLS Standing Review Board had to assess the soundness and maturity of the Program.[23] However, no policy requirement exists for the Standing Review Board to review that a program requiring rocket propulsion testing has a plan or obtained a recommendation from the NRPTA or that the Standing Review Board has

[19] Completed in February 2012, the Right Sizing Study compared test stand capabilities (e.g. thrust capacity, propellant type, volume and pressure, environmental simulation capability) and readiness states to identify capabilities overlap in the FY 2012-2017 timeframe. The Study team, chartered by the RPT Program Manager, examined 24 NASA rocket test facilities located at Marshall, Glenn, Plum Brook, Stennis, and White Sands. The review did not examine DOD or commercial test facilities.

[20] NASA Procedural Requirements (NPR) 7120.5E, "NASA Space Flight Program and Project Management Requirements," August 14, 2012.

[21] NPR 7123.1B, "NASA Systems Engineering Processes and Requirements," April 18, 2013.

[22] The System Requirements Review is designed to evaluate whether functional and performance requirements for the system are responsive to the Mission Directorate requirements and represent achievable capabilities. The System Definition Review is designed to evaluate whether the project architecture meets functional and performance requirements.

[23] A Standing Review Board is composed of independent experts who provide assessments of management's technical and programmatic approach, risk posture, and progress against the project baseline and offer recommendations to improve performance or reduce risk.

reviewed the fidelity of analysis that resulted in a decision of where to test. Including such a requirement in NASA's project management and/or rocket propulsion testing policies would add an internal control to ensure managers do not bypass a process designed to assure alignment with national interests and best value for the taxpayer.

## Structure of RPT Program Management Contributes to Ongoing Challenges

The ability of the RPT Program Manager to recommend and the HEO Mission Directorate to approve and fund rocket propulsion testing investments absent an NRPTA recommendation highlights a disconnect between the NRPTA MOU and NASA's approval processes. We believe this is due in part to the broad authority NASA invests in the RPT Program Manager. Specifically, as the Chairman of NASA's RPT Board, co-chair of the NRPTA, and member of the Steering Group, the RPT Program Manager holds all of the most influential positions on the RPT and NRPTA Boards.

The NRPTA MOU states, "[t]he NRPTA Board will be requested to present recommendations, through an NRPTA member, to the final decision-making authority." The MOU also states that the NASA members of the Steering Group are to come from the RPT Program chain of command and the Steering Group is to provide guidance to and resolve issues and concerns of the NRPTA Board. In our judgment, it is not possible for one person to accomplish all these tasks objectively while considering what constitutes the best value for the taxpayer, the best short- and long-term strategy for the organization, and the best fit for the program in need of rocket propulsion testing.

## NASA's Decision to Use the B-2 Stand May Introduce Cost and Schedule Risks to SLS Program

NASA chose the B-2 test stand for SLS core stage testing without assessing complete and comparable data from other potential sites to make a well-informed decision. NASA's limited internal assessments indicated that refurbishing the B-2 test stand was not the most cost-effective or timely choice to meet the testing requirements for SLS. Comparisons presented by the SLS and RPT Programs showed that B-2 was in the lowest state of readiness, would require the longest time to refurbish, and would cost the most of the three options. Although NASA may have a strategic reason for choosing the more expensive B-2 option (i.e., consolidation of rocket engine test facilities and resources at Stennis), we question whether NASA adequately considered all testing options before making its decision.

In a September 2012 audit, the OIG identified NASA's culture of optimism, underestimating technical complexity, and funding instability as challenges the Agency

faces in meeting project cost, schedule, and performance goals.[24] We believe these factors affected NASA's choice for SLS core stage testing. NASA chose the test facility with the longest and most expensive development time and is optimistically planning that all aspects of the renovation will come together in time for the test stand to accommodate the SLS's test schedule. Furthermore, at the time the Agency chose the B-2 test facility, NASA and Boeing had not yet fully defined SLS core stage technological requirements. To account for the immaturity of the SLS vehicle design and requirements, the independent cost estimate for using the B-2 test stand added $86.7 million for special test equipment and risk to account for potential design changes, funding delays, construction issues, and additional testing scenarios. Moreover, the estimate stated that the 6-month schedule margin for the B-2 stand was very optimistic for such a large, complex project, especially since Boeing hardware access requirements had not been identified, subsystem tests objectives were not defined or budgeted, and special test equipment hardware designs were not yet included in either Boeing or B-2 funding plans.

As of November 2013, restoration of B-2 was on schedule to begin testing the core stage in October 2016. However, development of several important test stand components remain on the critical path and the B-2 Project Manager noted that there were delays in finalizing core stage requirements needed to refurbish the B-2 stand and design the required special test equipment, as well as yet to be determined impacts from the Government shutdown. Because B-2 refurbishment is a critical path item for SLS, it is imperative that firm design requirements be established and communicated in a timely manner to mitigate the risks to the SLS first flight and associated costs to the Program.

## Conclusion

NASA selected the B-2 test stand for SLS core stage testing without adequate, objective, and consistent assessments of all three potential test sites and prior to receiving a recommendation from the NRPTA – the second time in 5 years that NASA has bypassed its agreement to collaborate with DOD when making a costly test stand decision. Moreover, NASA did not provide timely information to the NRPTA and rushed its decision based on a timetable needed to refurbish B-2 in time to support the first SLS flight in December 2017. Although the April 2012 deadline may have influenced the decision to select a facility quickly, it appears from the assessments that both the Air Force and Marshall facilities would have required significantly less time and money to refurbish than the B-2 stand. Although the SLS Program flight schedule may explain the timing of the decision if B-2 were the only option, it does not justify a decision to restore B-2 without adequate and comparable assessments of the competing sites.

[24] NASA OIG, "NASA's Challenges to Meeting Cost, Schedule, and Performance Goals" (IG-12-021, September 27, 2012).

In making the determination of where to test the SLS core stage, the Agency circumvented an intergovernmental process designed to aid in identifying the most cost-effective strategy for these very expensive engine tests. Although we are supportive of NASA's efforts to consolidate engine testing and reduce unneeded infrastructure, doing so without fully evaluating the costs and risks of all available options is shortsighted and calls into question the relevance of the NRPTA process.

Over the history of the NRPTA, only two major investments have been made (both by NASA) to create a new or modified test capability – the A-3 and B-2 test stands, both located at Stennis. In bypassing the NRPTA process on the A-3 decision, NASA failed to adequately support its decision to build the test stand and spent approximately $180 million more than initial estimates. By failing to engage the NRPTA in connection with the SLS core stage testing decision, NASA missed another opportunity to benefit from an independent review of cost, schedule, and technical risks and to promote a more cooperative partnership with DOD in the area of rocket propulsion testing.

## Recommendations, Management's Response, and Evaluation of Management's Response

To improve NASA's decision-making process for rocket propulsion testing, we made the following recommendations to the Associate Administrator for HEO:

**Recommendation 1.** Review internal control processes and implement a strategy for assuring timely coordination with DOD and adherence to requirements of NPD 8081.1.

**Management's Response.** The Associate Administrator concurred, stating that NASA will review internal control processes and implement a strategy to ensure programs and projects comply with NPD 8081.1. The Associate Administrator stated that the actions would be completed by September 30, 2014.

**Evaluation of Management's Response.** Management's proposed actions are responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

**Recommendation 2.** In consultation with the Chief Engineer, ensure that requirements of NPD 8081.1 are at a minimum referenced in NASA's project management policies.

**Management's Response.** The Associate Administrator concurred, stating that NPD 8081.1 will be incorporated into the appropriate sections of NPR 7120.5E and NPR 7123.1B no later than September 30, 2014.

**Evaluation of Management's Response.** Management's proposed actions are responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

**Recommendation 3.** Revise NPD 8081.1 to include an independent review of RPT and NRPTA recommendations at appropriate life-cycle reviews.

**Management's Response.** The Associate Administrator partially concurred, stating that a revision of NPD 8081.1 will not necessarily ensure the appropriate review of rocket propulsion testing plans. Therefore, NASA will assess whether obtaining an independent review is best accomplished by revising NPD 8081.1 or other existing program management policies or the actions the Agency is planning to address Recommendations 1 and 2 will ensure the necessary review of propulsion testing decisions.

**Evaluation of Management's Response.** Management's proposed actions are responsive to the intent of our recommendation; therefore, the recommendation is resolved and will be closed upon completion of the assessment and verification that the resulting corrective actions have been implemented.

**Recommendation 4.** Review the roles and responsibilities of the RPT Program Manager to ensure the position's scope of authority is appropriate for accomplishing tasks objectively and provides consistency with the intent of the MOU with DOD.

**Management's Response.** The Associate Administrator concurred, stating that NASA will revise the RPT Program Commitment Agreement to remove the NRPTA co-chair responsibilities from the RPT Program Manager and rotate the NRPTA Board co-chair responsibilities between the NASA's RPT Board representatives. The Associate Administrator stated that the actions would be completed by September 30, 2014.

**Evaluation of Management's Response.** Management's proposed actions are responsive; therefore, the recommendation is resolved and will be closed upon completion and verification of the corrective actions.

# APPENDIX A

## Scope and Methodology

We performed this audit from October 2012 through November 2013 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.

We obtained and reviewed Rocket Propulsion Test Management Board Operating Procedures; NRPTA MOU and Operating Procedure NPD 8081.1, "NASA Chemical Rocket Propulsion Testing," February 4, 2010; Stennis Policy Directive 1107.1, "John C. Stennis Space Center, SSC [Stennis] Organization, Mission and Responsibilities;" Stennis Work Instruction SOI-8080-0045-LC, "NASA Rocket Propulsion Test Management Board (RPTMB) Operating Procedures;" and the Rocket Propulsion Test Program Commitment Agreement for B-2.

We performed our fieldwork at NASA Headquarters, Goddard Space Flight Center, Marshall Space Flight Center, and Stennis Space Center. We interviewed and obtained documentation from the RPT Program Office and NRPTA site representatives to identify issues relevant to our audit.

**Use of Computer-Processed Data.** Computer-processed data was not used to support the findings or conclusions of this audit.

## Review of Internal Controls

We reviewed NASA's RPT program policy and NRPTA Operating Procedures and interviewed Government personnel with oversight responsibilities for the NASA policy requirements. We determined that NASA has no internal controls in place to ensure that the appropriate process is followed for its RPT decision-making process and an NRPTA recommendation is obtained prior to making a decision and committing funds for rocket propulsion testing. In addition, NASA's RPT decision making is overly concentrated in the RPT Program Manager, who holds all of the most influential positions of the RPT and NRPTA Boards. Implementing the recommendations should correct these deficiencies for future rocket propulsion testing decisions.

## Prior Coverage

During the last 5 years, the NASA Office of Inspector General (OIG) issued one report of particular relevance to the subject of this report: "Final Memorandum on the Review of NASA's Plan to Build the A-3 Facility for Rocket Propulsion Testing" (IG-08-021, July 8, 2008). Unrestricted reports can be accessed at http://oig.nasa.gov/audits/reports/FY13/index.html.

## MANAGEMENT COMMENTS

National Aeronautics and Space Administration
**Headquarters**
Washington, DC 20546-0001

DEC 24 2013

Reply to Attn of: Human Exploration and Operations Mission

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Human Exploration and Operations

SUBJECT: Response to OIG Draft Report, "Review of NASA's Decision Process for Space Launch System Core Stage Testing" (Assignment No. A-13-001-00)

The Human Exploration Operations Mission Directorate (HEOMD) appreciates the opportunity to review and provide comments on the Office of Inspector General (OIG) draft report entitled, "*Review of NASA's Decision Process for Space Launch System Core Stage Testing*" (Assignment No. A-13-001-00) dated November 26, 2013.

In addition to providing responses below to the OIG recommendations identified in the draft report, HEOMD has two general comments. The first comment concerns the risk posture for the Space Launch System (SLS) core stage test. The draft report states that NASA may not have chosen the most efficient and cost-effective test site for the core stage test. However, NASA's decision to conduct the core stage test at the B-2 test stand at the Stennis Space Center (SSC) was not based on a singular cost factor (i.e. test stand refurbishment), but on a comprehensive assessment set of all risks, including cost and schedule risks to the program and physical risks to valuable flight hardware. The core stage test is to be conducted on the first flight unit – the same core stage that will fly Exploration Mission 1 (EM-1). Thus, risk avoidance and the ability to test and ship quickly to KSC played a strong role in the final test assignment.

The second comment concerns the Department of Defense's (DoD) participation via the National Rocket Propulsion Test Alliance (NRPTA) in the SLS core stage test decision. The draft report does not fully reflect the effort made by the Rocket Propulsion Test (RPT) Program manager to involve the NRPTA in the decision. The only DoD member of the NRPTA that provided information to the RPT program manager after multiple attempts was the Air Force Research Laboratory (AFRL) located at Edwards Air Force Base, CA. The information provided by AFRL for test stand 1C was considered in the test stand assignment for the SLS core stage, albeit late. Moreover, the decision to not utilize the AFRL test stand 1C was not based on the lack of fidelity of the information provided on cost and schedule. Rather, the 1C test stand was not selected because of the considerable transportation risk associated with shipping the EM-1 core stage from the Michoud Assembly Facility (MAF) in Louisiana through the Panama Canal to Port Hueneme in California plus the extended over-land transportation considerations moving the vehicle from the port inland to Edwards Air

Force Base. The risk of transportation to the first flight article to and from the Air Force's 1C stand overruled any cost considerations and was the driving factor in ruling out that facility.

In view of these two considerations, NASA is confident it made the right decision in choosing to conduct SLS core stage testing at B-2. NASA's response to the recommendations, including planned corrective actions, is as follows:

**Recommendation 1:** Review internal control processes and implement a strategy for assuring timely coordination with DoD and adherence to requirements of NPD 8081.1.

**Management's Response**: Concur. NASA will review internal control processes and implement a strategy to ensure programs and projects with chemical propulsion requirements coordinate with the RPT Program in order to comply with NPD 8081.1, "Chemical Rocket Propulsion Testing." The review will be accomplished not later than September 30, 2014.

**Recommendation 2:** In consultation with the Chief Engineer, ensure that requirements of NPD 8081.1 are at a minimum referenced in NASA's project management policies.

**Management's Response**: Concur. NASA will incorporate the NPD 8081.1 into Appendix J reference section of NPR 7120.5E "NASA Space Flight Program and Project Management Requirements" and into Appendix I reference section of NPR 7123.1B "NASA Systems Engineering Processes and Requirements." This will be accomplished not later than September 30, 2014.

**Recommendation 3**: Revise NPD 8081.1 to include an independent review of RPT and NRPTA recommendations at appropriate life-cycle reviews.

**Management's Response**: Partially concur. HEOMD recognizes the value of independent reviews. As part of the overall SLS core stage testing decision, a comprehensive package was brought to the HEOMD Directorate Program Management Council (DPMC) on April 24, 2012, for review and approval. The first part of the DPMC approval included a briefing on the need for the SLS core stage testing (Charts 6-8) and was followed by the discussions and reviews of testing options (Charts 22-50). This was in addition to the SLS Standing Review Board (SRB) review held in March 2012, on the core stage testing rationale and associated trade studies from the Systems Requirements Review (SRR) and Systems Definition Review (SDR). However, a revision of the NPD 8081.1 will not necessarily ensure effective review of programs or projects' RPT plans. As delineated in OIG recommendations 1 and 2, programs and projects with chemical propulsion test requirements need to coordinate with the RPT Program very early in the planning process. Likewise, the RPT Program should coordinate with NRPTA, as it did for the SLS core stage decision, when it is notified of a potential requirement that may benefit from the DoD involvement. Therefore, HEOMD will assess whether an independent review like the ones performed is best accomplished with a revision of the NPD 8081.1, a revision of other existing program management policies, or if efforts to comply with recommendations 1 and 2 will ensure the necessary review of propulsion test decisions.

**Recommendation 4**: Review the roles and responsibility of the RPT Program manager to ensure the position's scope of authority is appropriate for accomplishing tasks objectively and provides consistency with the intent of the MOU with DOD.

**Management's Response**: Concur. The RPT program manager will no longer serve as the co-chair of the NRPTA management board. The NASA co-chair to the NRPTA management board will be rotated between the RPT center representatives of the RPT management board. This effort will unencumber the RPT program manager and allow more objectivity. The roles and responsibilities outlined in the RPT Program Commitment Agreement will be revised to remove the NRPTA co-chair responsibilities from the RPT program manager not later than September 30, 2014.

We have reviewed the draft report for information that we believe should not be publicly released, and do not have concerns regarding public release of report information.

Again, thank you for the opportunity to review and comment on the subject draft report. If you have further questions or require additional information on NASA's response to the draft report, please contact Jonathan Krezel at 202-358-1141 or Robert Clay at 202-358-1091.

William H. Gerstenmaier

cc:
Associate Administrator/Mr. Lightfoot

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Major Contributors to the Report:

Raymond Tolomeo, Director, Science and Aeronautics Research Directorate
Greg Lokey, Team Lead
Scott Collins, Auditor
Keren Stick, Auditor

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