



June 2020

# NUCLEAR WEAPONS

## NNSA Needs to Incorporate Additional Management Controls Over Its Microelectronics Activities

# GAO Highlights

Highlights of [GAO-20-357](#), a report to congressional committees

## Why GAO Did This Study

Microelectronics (see figure) form the basis of nearly all electronic products, including nuclear weapons. U.S. nuclear weapons use a unique supply of “strategic radiation-hardened” microelectronics that must function properly when exposed to high levels of radiation. NNSA’s facilities at Sandia are the only source for these unique microelectronics, and the age of the facilities may pose significant risk to NNSA’s capability after 2025.

A Senate committee report accompanying the National Defense Authorization Act for Fiscal Year 2019 included a provision for GAO to review NNSA’s strategic radiation-hardened microelectronics activities. This report (1) describes NNSA’s actions over the past decade to sustain existing facilities and identify future alternatives; and (2) examines NNSA’s ongoing approach to managing its microelectronics activities and the extent to which this approach incorporates key management controls. GAO reviewed documents and interviewed officials and contractor representatives from NNSA and Sandia, toured Sandia’s microelectronics facilities, and reviewed NNSA program and project management controls.

## What GAO Recommends

GAO recommends that NNSA incorporate additional management controls, such as developing an overarching management plan, to better oversee and coordinate its microelectronics activities. NNSA neither agreed nor disagreed with this recommendation.

View [GAO-20-357](#). For more information, contact Allison B. Bawden at (202) 512-3841 or [bawdena@gao.gov](mailto:bawdena@gao.gov).

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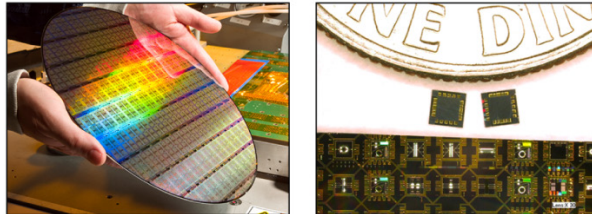
## NUCLEAR WEAPONS

### NNSA Needs to Incorporate Additional Management Controls Over Its Microelectronics Activities

## What GAO Found

Over the past decade, the Department of Energy’s (DOE) National Nuclear Security Administration (NNSA) completed several actions to sustain the condition of its existing microelectronics facilities at Sandia National Laboratories (Sandia), which are NNSA’s only source for producing strategic radiation-hardened microelectronics that can operate in environments with extreme exposure to radiation. In particular, during fiscal years 2012 through 2019, NNSA carried out a multiyear, \$150-million effort at Sandia to replace or refurbish infrastructure and equipment in its primary microelectronics production facility to ensure continued operations through 2025. While NNSA was working with Sandia to sustain current facilities, the agency also began identifying and evaluating options for producing microelectronics after 2025, including constructing a new multi-billion dollar production facility at Sandia. However, because of changes to key assumptions, including longer-term viability of existing facilities, NNSA decided in November 2018 not to pursue any of the identified alternatives and instead stated that the agency was going to assess options to sustain its current capability at Sandia.

#### Photos of Microelectronics on a Silicon Wafer and Diced into Individual Parts



Sources: Courtesy of International Business Machines Corporation, © International Business Machines Corporation (left photo); Sandia National Laboratories (right photo). | [GAO-20-357](#)

NNSA’s ongoing approach to managing its strategic radiation-hardened microelectronics activities includes two key efforts. First, the agency decided in October 2019 to invest about \$1 billion over the next 20 years to upgrade and sustain its microelectronics capability at Sandia through 2040. Specifically, NNSA plans to upgrade its production process as well as complete identified infrastructure (such as electrical distribution) and equipment projects. Second, in November 2019 NNSA created and filled a new full-time microelectronics coordinator position that, among other things, will have responsibility for certain aspects of the agency’s microelectronics activities, according to agency officials. However, NNSA’s approach does not fully incorporate key management controls that NNSA applies to other important activities. For example, DOE and NNSA require their programs and projects to establish an overarching management plan that describes the procedures to define, execute, and monitor a program or project as well as establishing specific requirements in a variety of areas such as cost estimating and performance management. NNSA has not established a similar management plan to oversee and coordinate its microelectronics activities. By incorporating these key management controls, NNSA would have increased assurance that its planned microelectronics activities are clearly defined, efficiently executed, and effectively monitored.

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## Abbreviations

ASIC	application-specific integrated circuits
CHIP2	Center for Heterogeneous Integration, Packaging, and Processes
CMOS	complementary metal-oxide semiconductor
DOD	Department of Defense
DOE	Department of Energy
FPGA	field programmable gate array
LEP	Life Extension Program
MESA	Microsystems Engineering, Sciences and Applications
nm	nanometers
NNSA	National Nuclear Security Administration
SiFab	Silicon Fabrication
TMC	Trusted Microelectronics Capability

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June 9, 2020

Congressional Committees

Microelectronics—commonly referred to as integrated circuits or semiconductors—form the basis of nearly all electronic products, including components of nuclear weapons. The long-term viability of the U.S. nuclear deterrent depends on a trustworthy supply of unique microelectronics, according to the National Nuclear Security Administration’s (NNSA) Fiscal Year 2020 *Stockpile Stewardship and Management Plan*.<sup>1</sup> These unique electronics are referred to as “strategic radiation-hardened” microelectronics, reflecting their ability to function properly in environments with extremely high levels of radiation (such as gamma rays or x-rays).<sup>2</sup> Strategic radiation-hardened microelectronics are essential components of a nuclear weapon’s arming, fuzing, and firing system, which provides the signals that initiate the nuclear explosive chain. In this report, we generally refer to strategic radiation-hardened microelectronics produced by NNSA as simply “microelectronics.”<sup>3</sup>

Producing such microelectronics is a technically challenging task requiring specialized facilities, equipment, and materials. It also entails executing and integrating activities related to research, design, fabrication, packaging, and testing. The primary domestic source of microelectronics for nuclear weapon components is the Microsystems Engineering, Sciences and Applications (MESA) Complex at Sandia National Laboratories (Sandia) in New Mexico, which National

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<sup>1</sup>NNSA is a separately organized agency established within the Department of Energy (DOE) in 1999. NNSA is responsible for the nation’s nuclear weapons, nonproliferation, and naval reactor programs. As part of its nuclear weapons mission, NNSA is responsible for designing and producing nuclear warheads and bombs for the U.S. military. The *Stockpile Stewardship and Management Plan* is NNSA’s formal means of communicating to Congress information on modernization and operational plans and budget estimates over the next 25 years, and it is updated annually.

<sup>2</sup>Radiation hardening is the use of process technology, circuit design, or system techniques (such as shielding) to mitigate the degradation of performance in microelectronics induced by radiation.

<sup>3</sup>In addition to designing and producing strategic radiation-hardened microelectronics, NNSA also conducts other microelectronics activities, such as procuring commercial off the shelf components and conducting reliability testing.

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Technology and Engineering Solutions of Sandia manages and operates under contract for NNSA.<sup>4</sup>

NNSA has identified multiple challenges to ensuring its ability to continue operating its microelectronics capability. For example:

- Sandia’s primary microelectronics production facility within the MESA Complex is the Silicon Fabrication (SiFab) Facility, which was commissioned in 1988 with a 25-year design life. According to agency documentation, the facility’s age and dated physical layout—which result in increased operational costs and extensive production downtime—pose risks to NNSA’s microelectronics capability after 2025.
- NNSA’s microelectronics capability at Sandia uses some of the same materials, equipment, and processes as commercial microelectronics producers. However, trends in the global commercial microelectronics industry increasingly limit NNSA’s ability to partner with industry to meet its microelectronics needs, according to NNSA officials and Sandia contractor representatives. For example, the commercial industry is focused on producing microelectronics for consumer and “smart” devices using the latest technologies with a high volume of production, which means that technologies are rapidly replaced and commercial microelectronics have a relatively limited lifespan. In contrast, NNSA requires a much lower quantity of microelectronics with unique requirements (such as strategic radiation hardening) for which there is no commercial demand. In addition, because the United States must sustain its nuclear weapons for decades, NNSA generally requires its microelectronics to remain functional for much longer than consumer devices are designed to, according to NNSA officials.<sup>5</sup>

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<sup>4</sup>National Technology and Engineering Solutions of Sandia is a wholly owned subsidiary of Honeywell International, Inc. NNSA awarded this contract in December 2016. The prior contractor that managed and operated Sandia National Laboratories was Sandia Corporation, a wholly owned subsidiary of Lockheed Martin, from 1993 to 2017, when National Technology and Engineering Solutions of Sandia took over after a transition period.

<sup>5</sup>In September 2019, the NNSA Deputy Administrator for Defense Programs informed the Congress that there would be significant cost increases and schedule delays for two key nuclear weapon modernization programs, as NNSA testing determined that commercially produced electrical components planned for insertion into nuclear weapons would not meet the agency’s reliability performance standards over the next 20 to 30 years. These commercially produced components were not microelectronics produced at Sandia.

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- According to NNSA documentation, the nuclear weapons supply chain must be trusted to protect against potential sabotage, among other things. However, production of commercial microelectronics has increasingly moved offshore—primarily to Asia—while a number of domestic producers have been acquired by foreign entities. Our prior work has shown that use of foreign suppliers could increase opportunities for adversaries to corrupt technologies, introduce malicious code, and potentially steal national security-related intellectual property.<sup>6</sup>

According to the 2018 *Nuclear Posture Review*, the United States will pursue initiatives to ensure a continued capability to develop and produce microelectronics beyond 2025.<sup>7</sup> Currently, NNSA plans to begin production after 2025 for three nuclear weapon modernization programs, and microelectronics will be needed for those programs.<sup>8</sup> Historically, NNSA’s weapon modernization programs have been life extension programs (LEPs), which refurbish or replace nuclear weapons components to, among other things, extend the lives of these weapons and enhance the safety and security of the stockpile. However, NNSA is moving into an era in which its weapon modernization programs will also include weapon modification programs and potentially new acquisitions.

A Senate committee report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2019 included a provision for us to review NNSA’s strategic radiation-hardened microelectronics activities specific to nuclear weapons.<sup>9</sup> Our report (1) describes NNSA’s actions over the past decade to sustain existing microelectronics facilities and identify future alternatives for its microelectronics capability and (2) examines NNSA’s ongoing approach to managing its microelectronics activities and the extent to which this approach incorporates key management controls.

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<sup>6</sup>GAO, *Trusted Defense Microelectronics: Future Access and Capabilities Are Uncertain*, [GAO-16-185T](#) (Washington D.C.: Oct. 28, 2015).

<sup>7</sup>Department of Defense, *Nuclear Posture Review*, (Washington, D.C.: Feb. 2018). The Nuclear Posture Review is produced periodically and describes presidential policy on the role of nuclear weapons in national security.

<sup>8</sup>According to NNSA documentation, the three weapon modernization programs currently scheduled to start production after 2025 are the W87-1 Modification Program, the W93 (formerly known as the Next Navy Warhead), and the Future Strategic Missile Warhead.

<sup>9</sup>S. Rep. No. 115-262, at 4154 (2018).

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To address both objectives, we conducted a site visit to NNSA's MESA Complex at Sandia to review and tour microelectronics capabilities and interview contractor representatives who are responsible for managing and operating Sandia's microelectronics facilities. In particular, our site visit focused on MESA's SiFab Facility because, according to NNSA documentation, (1) the facility is the agency's primary source for microelectronics that are integrated into nuclear weapons, (2) the facility's layout and aging infrastructure may limit future production options, and (3) the facility's equipment and infrastructure present ongoing risks to NNSA's nuclear weapon production mission. To increase our familiarity with how microelectronics are developed and produced, we also conducted a site visit to and interviewed company representatives who operate a microelectronics production facility located in Maryland. We chose this facility because it produces microelectronics for national security systems and its construction date and building layout are similar to Sandia's SiFab Facility.

To identify actions NNSA took to sustain existing facilities, we reviewed NNSA and contractor documentation from 2010 (when Sandia submitted its initial sustainment proposal) through 2018 (when NNSA completed its most recent sustainment study). To examine the future alternatives NNSA identified for its microelectronics capability, we reviewed NNSA documentation from 2011 (the start of NNSA's evaluation) through 2018 (when NNSA terminated its evaluation). To further support our analysis of this documentation, we interviewed NNSA officials and contractor representatives from Sandia who either authored or were responsible for reviewing and approving key documents. We also interviewed representatives of NNSA's third-party independent contractor who authored one study on sustaining existing facilities and two studies on identifying alternatives for its capability. Because NNSA's evaluation of future alternatives included coordination with the Department of Defense (DOD), which also requires the microelectronics contained in some of its national security systems to properly function in certain environments (such as space) that have increased radiation levels, we reviewed DOD documents such as the department's plan to accelerate implementation of its trusted microelectronics strategy and roadmap.<sup>10</sup> We also interviewed officials from DOD's Trusted and Assured Microelectronics program office.

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<sup>10</sup>According to DOD and NNSA officials we interviewed, DOD's microelectronics do not have to be as radiation-hardened as the microelectronics NNSA produces for integration into nuclear weapons.



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To examine NNSA's ongoing approach to managing its microelectronics activities and the extent to which this approach incorporates key management controls, we reviewed key planning documentation, such as Sandia's MESA Complex Extended Life Plan and the MESA Complex Fiscal Year 2020 Integrated Program Plan.<sup>11</sup> We also interviewed NNSA officials responsible for managing, overseeing, and coordinating the agency's microelectronics activities. To identify key management controls employed for programmatic and project activities across the Department of Energy (DOE) and NNSA and the extent to which the agency's microelectronics management approach incorporates such controls, we reviewed NNSA's program management directives<sup>12</sup> and DOE's order on project management for the acquisition of capital assets.<sup>13</sup> We also reviewed federal standards for internal control related to risk management and the control environment.<sup>14</sup> We focused on existing NNSA program management directives and the DOE project management order because they provide requirements and guidance for NNSA's management of its programs and projects and are a primary mechanism for how NNSA implements federal internal control standards for its programs and projects.

NNSA's microelectronics activities are currently adapting to a shifting environment, evolving demands, and new priorities, in part because of the agency's 2018 decision to terminate its evaluation for a future microelectronics alternative. Therefore, we focused on identifying key management controls related to front-end planning that were specified in both NNSA's program management directives and DOE's project management order; such controls are most applicable to the current

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<sup>11</sup>Sandia National Laboratories, *Microsystems Engineering, Science, and Applications Complex Extended Life Plan*, SAND2019-13264 (Albuquerque, N. Mex.: October 2019) and *Microsystems Engineering, Science, and Applications FY20 Integrated Program Plan*, SAND2019-13383 (Albuquerque, N. Mex.: October 2019).

<sup>12</sup>National Nuclear Security Administration, *Program Management Policy*, NAP-413.2 (Washington, D.C.: Feb. 2019) and *Defense Programs Execution Instruction*, (Washington, D.C.: June 2019). The February 2019 directive establishes policy for conducting program management activities, while the June 2019 directive provides program execution methods.

<sup>13</sup>Department of Energy, *Program and Project Management for the Acquisition of Capital Assets*, DOE Order 413.3B (Change 5) (Washington, D.C.: April 12, 2018).

<sup>14</sup>In particular, we examined the requirements for management to (1) design control activities to achieve objectives and respond to risks and (2) establish an organizational structure, assign responsibility, and delegate authority to achieve objectives. See GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: Sept. 10, 2014).

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status of the agency's microelectronics activities. In a similar manner, we selected principles in the federal standards for internal control that were most applicable to front-end planning to reflect the current status of NNSA's microelectronics activities.

We conducted this performance audit from November 2018 to June 2020 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.

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## Background

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### Microelectronics Production at Sandia

The MESA Complex at Sandia comprises multiple production facilities and buildings, which total approximately 400,000 square feet (see fig. 1).<sup>15</sup> In particular, the SiFab Facility, completed in 1988, is the primary production facility for microelectronics integrated into nuclear weapons. The SiFab Facility produces application-specific integrated circuits (ASIC) that are custom-designed to control certain nuclear weapon arming, fuzing, and firing functions. The MESA Complex also includes other buildings, such as the Micro Fabrication Facility, which was completed in 2006 and produces strategic radiation-hardened devices for manipulating electronic signals and electrical power.<sup>16</sup> The physical layouts of these two production facilities center around a series of clean rooms that are designed to maintain an extremely low level of dust and other particulates, which can harm microelectronic functionality. The two facilities contain about 375 pieces of specialized production equipment, some of which cost millions of dollars, and have acid exhaust and liquid waste management systems for handling the byproducts of the production processes.

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<sup>15</sup>The MESA Complex includes two main production facilities that produce microelectronics, utility buildings that provide the two production facilities with utilities such as chilled water and compressed air, and other facilities that are used to test and package the produced microelectronics.

<sup>16</sup>Sandia uses its MESA Complex to produce more than ASICs and transistors. In 2019, the MESA Complex produced and delivered approximately 300,000 individual microelectronics parts across 43 different products.

**Figure 1: Aerial View of the Microsystems Engineering, Sciences and Applications Complex at Sandia National Laboratories**



Source: Sandia National Laboratories. | GAO-20-357

The SiFab Facility produces all of the strategic radiation-hardened ASICs currently used in nuclear weapons. ASICs are produced on wafers—a thin slice of semiconductor material such as silicon—using what is referred to as a complementary metal-oxide semiconductor (CMOS) process technology.<sup>17</sup> The production of ASICs requires hundreds of processing steps, which are completed over multiple weeks. For example, according to Sandia documentation, the production of a specific type of ASIC requires over 600 processing steps over an approximately 26-week period.

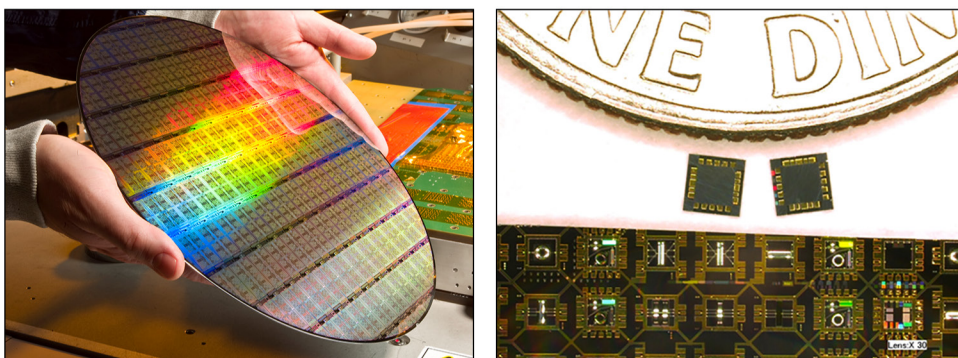
Microelectronics are produced with characteristic dimensions (or “feature sizes”) measured in nanometers (nm), or one-billionth of one meter. The process technology together with an associated feature size is known as a technology “node.” In general, smaller nodes represent more advanced technologies. The SiFab Facility produces microelectronics at the 350 nm node, and NNSA and Sandia refer to the CMOS production process

<sup>17</sup>According to a microelectronics study prepared for NNSA by a third-party contractor, there are several microelectronics production processes used in industry, but nearly all electronic products—including computers, cell phones, and related devices—are predominately populated with CMOS-produced microelectronics.

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technology at the 350 nm node as “CMOS7.” Currently, state-of-the-art microelectronics are produced at the 32 nm or below node. For example, the Intel Corporation produces commercial microelectronics at the 14 nm node for use in personal computers and servers. However, such smaller nodes are more challenging to produce and have not been proven to perform at the strategic radiation-hardened level, according to Sandia contractor representatives. Figure 2 shows commercially produced microelectronics on a wafer (left photo) and diced into individual microelectronics parts next to a U.S. dime (right photo).

**Figure 2: Photos of Microelectronics on a Silicon Wafer and Diced into Individual Parts**



Sources: Courtesy of International Business Machines Corporation, © International Business Machines Corporation (left photo); Sandia National Laboratories (right photo). | GAO-20-357

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## Ongoing and Planned Weapon Modernization Programs and Other Modernization Plans Requiring Microelectronics

As shown in table 1, NNSA is undertaking multiple LEPs and weapon modernization efforts, in which Sandia is participating. In addition, the 2018 *Nuclear Posture Review* calls for NNSA to consider additional weapon programs—specifically, a program to develop a modern nuclear-armed sea-launched cruise missile, and another to develop a new submarine-launched ballistic missile warhead (now referred to as the W93). To develop and produce microelectronics for these efforts, Sandia must (1) conduct research and development activities, (2) finalize the design of microelectronics to meet military requirements specific to the weapon program into which the microelectronics will be integrated, and (3) produce the microelectronics. Sandia must conduct all of these activities years before NNSA delivers a weapon program’s first production unit to DOD.<sup>18</sup> According to Sandia documents and contractor

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<sup>18</sup>The first production unit milestone occurs when DOD accepts the weapon’s design and NNSA verifies that the first produced weapon or weapon(s) meets the design.

representatives, microelectronics research and development efforts generally begin 10 to 15 years before a weapon program’s first production unit date, while microelectronics production generally begins 3 to 5 years before a first production unit date.

**Table 1: NNSA’s Ongoing Weapon Modernization Programs, Estimated First Production Unit Dates, and Microelectronics Production Schedules**

Program	Description	Estimated first production unit date (fiscal year)	Microelectronics production schedule
B61-12 Life Extension Program (LEP)	The B61-12 LEP is to consolidate and replace multiple modifications of the B61 gravity bomb. <sup>a</sup>	2022 <sup>b</sup>	Production completed.
W88 Alteration 370 Program <sup>c</sup>	The W88 Alteration 370 program is to replace the arming, fuzing, and firing subsystem and high-explosive main charge for the W88 warhead, which is deployed on the Navy’s Trident II D5 submarine-launched ballistic missile system.	2022 <sup>b</sup>	Production completed.
W80-4 LEP	The W80-4 LEP is intended to provide a warhead for a future long-range standoff missile to replace the Air Force’s current air-launched cruise missile.	2025	Production ongoing.
W87-1 Modification Program	The W87-1 Modification Program is intended to replace the W78 warhead for the Air Force and improve warhead safety, among other things. The current W78 warhead is carried on the Minute Man III intercontinental ballistic missile. When the W87-1 replaces the W78, it will be carried on the Air Force’s missile to replace Minute Man III, known as the Ground Based Strategic Deterrent.	2030	Production scheduled to start in fiscal year 2026.

Source: GAO analysis of National Nuclear Security Administration (NNSA) documentation. | GAO-20-357

Note: The first production unit date is the date by which NNSA plans to manufacture the first unit of a warhead or bomb for insertion into the U.S. nuclear weapons stockpile.

<sup>a</sup>All nuclear weapons in the U.S. stockpile are designated either as warheads or bombs. Historically, the United States has developed families of warheads or bombs based on a single design. Thus, some weapons in the U.S. stockpile were developed as modifications to an already complete design. For example, the B61 bomb has had 12 variations over time, each designated as a different modification.

<sup>b</sup>NNSA originally planned for a first production unit date in fiscal year 2020. However, in September 2019 the NNSA Deputy Administrator for Defense Programs informed the Congress that the first production unit date would be delayed approximately 20 months because of technical issues associated with some electrical components—these components were not microelectronics produced at Sandia.

<sup>c</sup>An alteration is usually a replacement of an older component with a newer component that does not affect military operations, logistics, or maintenance, according to documentation from the Department of Defense. As a result, alterations are of smaller scope than LEPs or other weapon modernization programs. However, NNSA manages significant alterations as LEPs.

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DOD is also undertaking modernization efforts related to nuclear weapon delivery platforms, and Sandia is producing microelectronics to support those efforts. Specifically, DOD is responsible for designing and producing the arming and fuzing components on delivery platforms for certain types of nuclear weapons, and Sandia produces some of these components for DOD at the MESA Complex. For example, according to Air Force and Sandia documentation, the Air Force contracted with Sandia to design and produce microelectronics for its Intercontinental Ballistic Missile Fuze Modernization, which will provide a new fuze for use on both the current Minuteman III missile and its replacement, the Ground Based Strategic Deterrent missile.

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## DOE and NNSA Management Approaches for Projects and Programs

DOE and NNSA distinguish between projects and programs, and the agencies use different management approaches for each:

- **Projects.** DOE's project management order governs NNSA's management of capital asset acquisition projects with a total cost greater than \$50 million.<sup>19</sup> The order states that capital assets projects have a defined start and end point. Capital assets include land, structures, equipment and intellectual property that are used by the federal government and have an estimated useful life of 2 years or more. The order's goal includes delivering projects within their original performance baselines (on time and within budget) and fully capable of meeting mission performance and other requirements, such as environmental, safety, and health standards.

**Programs.** As we reported in 2018, DOE has not established a program management policy.<sup>20</sup> However, NNSA issued its own program management policy in February 2019.<sup>21</sup> The policy applies to all NNSA elements and requires them to establish additional program management requirements for respective NNSA programs based on needs, risk, complexity, and stakeholder involvement, among other things. The NNSA policy defines a program in part as an organized set of activities directed toward a common purpose or goal,

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<sup>19</sup>DOE Order 413.3B. Additional NNSA guidance that supplements DOE Order 413.3B applies project management principles to construction projects with total costs of less than \$50 million.

<sup>20</sup>GAO, *Nuclear Weapons: NNSA Should Adopt Additional Best Practices to Better Manage Risk for Life Extension Programs*, [GAO-18-129](#) (Washington, D.C.: Jan. 30, 2018).

<sup>21</sup>NAP-413.2

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undertaken or proposed in support of an assigned mission area. In addition, some NNSA offices have issued their own program management directives that are more specific than the NNSA policy. For example, NNSA's Office of Defense Programs—which is responsible for, among other things, weapon modernization programs, including LEPs, and associated materials and components, such as microelectronics—issued a program management directive in June 2019 that establishes requirements and processes for managing the office's programs.<sup>22</sup> This directive establishes four program management categories and execution requirements for these categories.<sup>23</sup> These management categories are risk-based and apply different execution requirements commensurate with program risk.

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### Fiscal Year 2020 Funding for Microelectronics Activities at Sandia

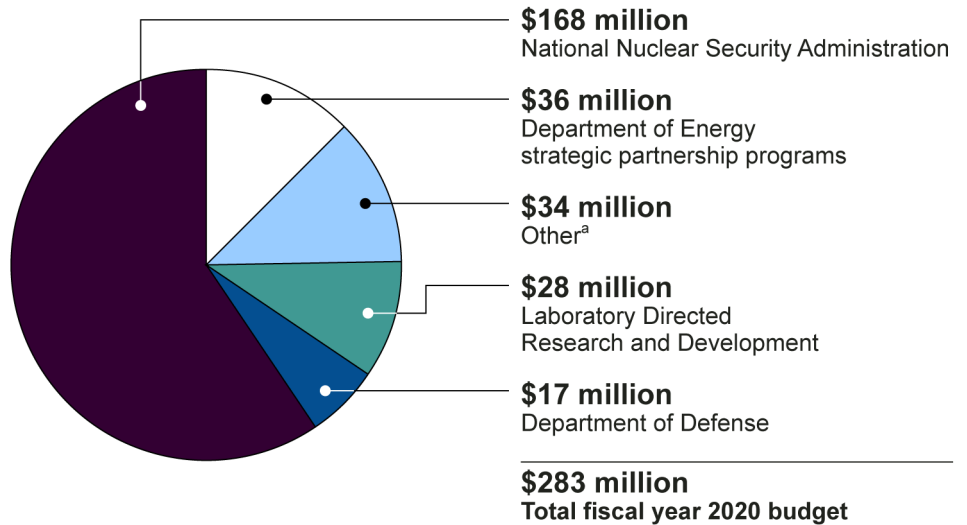
The MESA Complex's estimated fiscal year 2020 budget is \$283 million, according to Sandia documentation. As shown in figure 3, this funding comes from a variety of sources, because Sandia uses the MESA Complex to meet both NNSA's and DOD's nuclear weapon production missions as well as for research and development for those and other federal entities through strategic partnership programs. Sandia documentation states that a portion of the MESA Complex's budget is obtained from other, non-NNSA federal entities that pay Sandia directly to produce microelectronics for, among other thing, research and development purposes, and this amount of funding fluctuates annually. According to Sandia contractor representatives, the laboratory presents MESA's budget as an estimate for this reason.

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<sup>22</sup>*Defense Programs Execution Instruction*

<sup>23</sup>The Office of Defense Program's four program management categories, listed in order from most rigorous to least rigorous requirements, are Capital Acquisition Management, Enhanced Management A, Enhanced Management B, and Standard Management. LEPs are considered Enhanced Management A.

**Figure 3: Estimated Fiscal Year 2020 Budget for Sandia National Laboratories' MESA Complex, by Funding Source**



Source: GAO analysis of Sandia National Laboratories (Sandia) documentation. | GAO-20-357

Note: A portion of the Microsystems and Engineering Sciences Applications (MESA) Complex's budget is obtained from other (non-National Nuclear Security Administration) federal entities that pay Sandia directly to produce microelectronics for, among other things, research and development purposes, and this amount of funding fluctuates annually. According to Sandia contractor representatives, the laboratory presents MESA's budget as an estimate for this reason.

<sup>a</sup>Other sources include indirect rates applied to all Sandia programs to support the site and its management and operations.

Specific funding sources are discussed in greater detail below:

- NNSA provides about 60 percent (or \$168 million) of the MESA Complex's total estimated budget for fiscal year 2020. Two NNSA offices account for most of the agency's funding:
  - The Office of Defense Programs accounts for 42 percent (or about \$71 million) and is responsible for ensuring the United States maintains a safe, secure, and reliable nuclear stockpile through the application of science, technology, engineering, and manufacturing activities. This funding comes from multiple sub-offices. For example, the Office of Research, Development, Test, and Evaluation provides funding for microelectronics research and development; the Office of Production Modernization provides funding for, among other things, refurbishing microelectronics processing capabilities; and the Office of Stockpile Management



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provides funding for microelectronics production, according to an NNSA official and NNSA documentation.<sup>24</sup>

- The Office of Safety, Infrastructure and Operations accounts for 46 percent (or about \$78 million), and this office is responsible for ensuring existing facilities are safely operated, effectively managed, and maintained to meet mission needs.
- DOE's Strategic Partnership Programs account for about 13 percent (or \$36 million) of the MESA Complex's fiscal year 2020 budget. These programs include research and development projects sponsored by the Air Force and the Defense Advanced Research Projects Agency.<sup>25</sup>
- DOE's Laboratory Directed Research and Development work accounts for about 10 percent (or \$28 million) of the MESA Complex's fiscal year 2020 budget. Each of DOE's 16 contractor-operated laboratories—including Sandia—may direct a portion of the funding they receive from DOE to scientists who conduct independent research. The statutory limit on this laboratory-directed research and development work is between five to seven percent of funds provided by DOE to the laboratories for national security activities.
- DOD provides about 6 percent (or \$17 million) of the MESA Complex's fiscal year 2020 budget through Strategic Partnership Programs. According to Sandia documentation, this funding comes directly from the Air Force and Navy to support the production of microelectronics that are integrated into nuclear weapon delivery platforms.
- Other sources account for about 12 percent (or \$34 million) of the MESA Complex's fiscal year 2020 budget. Among other things, this funding comes from indirect rates applied to all Sandia programs to support the MESA Complex's management and operations.

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<sup>24</sup>The President's Fiscal Year 2021 budget request, which was issued in February 2020, proposes a new budget structure for NNSA that, among other things, consolidates various funding sources. As such, future microelectronics funding may come from different offices than those described here.

<sup>25</sup>DOE allows the capabilities of its laboratories to be made available to perform work for other federal agencies and nonfederal entities through its Strategic Partnership Program, provided that the work does not hinder DOE's mission or compete with the private sector, among other things. DOE requires that its laboratories fully recover the costs of work done for other agencies.

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## NNSA Completed Actions over the Past Decade to Sustain Its Microelectronics Capability at Sandia and Identified but Did Not Pursue Alternatives for a New Future Capability

Over the past decade, NNSA completed several actions to sustain its existing strategic radiation-hardened microelectronics facilities at Sandia through 2025 while simultaneously identifying future alternatives for its microelectronics capability beyond 2025. In particular, during fiscal years 2012 through 2019, NNSA engaged in a \$150 million effort at Sandia to sustain operations at the SiFab Facility through 2025.<sup>26</sup> NNSA pursued this effort in response to a 2010 study conducted by Sandia that identified the need for millions of dollars in funding to sustain the SiFab Facility through 2025.<sup>27</sup> NNSA's sustainment efforts focused on the following two areas:

- **Infrastructure.** NNSA spent about \$27 million to complete approximately 25 infrastructure projects that support microelectronics production. For example, NNSA installed two new 20,000-gallon tanks for water storage to improve the facility's deionized water system, which provides ultra-high purity water for use in certain processing steps. NNSA also replaced a portion of the facility's acid exhaust system.
- **Equipment.** NNSA spent about \$123 million on production equipment for two main purposes: (1) to replace aging equipment that Sandia classified as being at high risk of failure; and (2) to refurbish existing equipment and procure equipment that will be used to produce microelectronics once Sandia completes its ongoing effort to convert the production process from using 6-inch silicon wafers to 8-inch wafers.

Prior to these equipment investments, the SiFab Facility relied on aging equipment to perform certain processing steps using a manual process. In fiscal year 2018, Sandia refurbished existing equipment and purchased new equipment that is more automated and is intended to increase process reliability. In addition, according to Sandia documentation, Sandia needed to convert its production process to use 8-inch silicon

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<sup>26</sup>In August 2018, the DOE Office of the Inspector General found that NNSA should have classified this multiyear, \$150-million effort as a capital asset project subject to DOE's project management order. The report recommended that NNSA ensure that all ongoing and new Sandia capital asset projects are properly categorized and managed in accordance with this order. See DOE Office of the Inspector General, *The Sandia National Laboratories Silicon Fabrication Revitalization Effort*, DOE-OIG-18-42 (Washington, D.C.: Aug. 9, 2018). According to NNSA officials, this effort was completed ahead of schedule and under budget.

<sup>27</sup>D. Hetherington and J. Custer, *MESA Recapitalization Study*, (Albuquerque, N.Mex., Sandia National Laboratories, Sept. 22, 2010).

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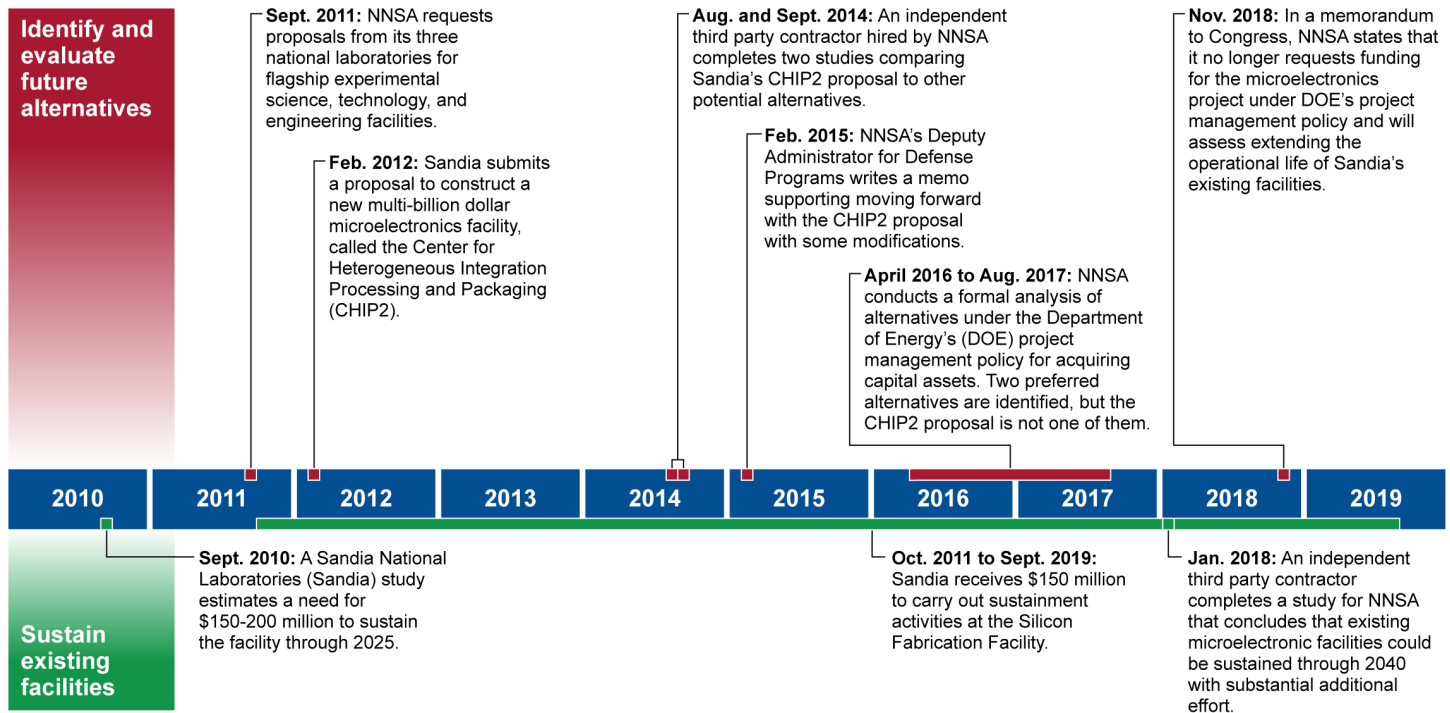
wafers because the commercial sector had increasingly limited maintenance support and service for equipment that processed 6-inch wafers.<sup>28</sup>

While NNSA was working with Sandia to sustain the SiFab Facility through 2025, the agency also began identifying and evaluating options for producing microelectronics after 2025, such as constructing a new multibillion-dollar production facility at Sandia. However, because of changes to key assumptions, NNSA decided in November 2018 not to pursue any of the identified alternatives and instead stated that the agency was going to assess options to sustain its current capability at Sandia beyond 2025. See figure 4 for a summary of NNSA's actions to sustain the SiFab facility and consider alternatives.

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<sup>28</sup>According to a report prepared in January 2018 by an independent third party contractor hired by NNSA, Sandia had a reasonable concern that commercial support and maintenance for equipment that processed 6-inch wafers was becoming increasingly less available, and support and maintenance for equipment that processes 8-inch wafers should remain viable for the foreseeable future.

**Figure 4: Timeline of NNSA’s Actions to Sustain Existing Microelectronics Facilities at Sandia and Identify and Evaluate Facility Alternatives for a New Future Microelectronics Capability**



Source: GAO analysis of National Nuclear Security Administration (NNSA) and Sandia documents. | GAO-20-357

More specifically, NNSA took the following actions during the past decade to identify alternatives for producing microelectronics beyond 2025:

- In 2011, NNSA’s Deputy Administrator for Defense Programs requested proposals from the agency’s three nuclear weapons laboratories for flagship experimental science, technology, and engineering facilities to help ensure that NNSA will have the capabilities to address future national security needs.<sup>29</sup> In response, Sandia submitted a proposal to NNSA in 2012 to construct a new, multibillion-dollar microelectronics production facility, called the Center

<sup>29</sup>NNSA’s three nuclear weapons laboratories are Sandia National Laboratories, Los Alamos National Laboratory, and Lawrence Livermore National Laboratory. See National Nuclear Security Administration, Letter from Donald Cook, Deputy Administrator for Defense Programs, to Paul Hommert, President of Sandia National Laboratories, May 9, 2011.

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for Heterogeneous Integration, Packaging, and Processes (CHIP2).<sup>30</sup> The Sandia proposal estimated that CHIP2 would take 14 years to design and build at an estimated cost of \$2.5 billion. The proposal indicated that the facility would increase microelectronics functionality and trustworthiness by creating a trusted supply chain into the future for design, fabrication, testing, and packaging activities. As a result of the time needed to design and construct CHIP2, investment would still be needed to sustain the MESA SiFab Facility through 2025.

- NNSA commissioned two studies by The Aerospace Corporation, a federally funded research and development center sponsored by the Air Force, to help the agency evaluate Sandia's CHIP2 proposal against other potential alternatives, such as contracting with commercial entities to produce microelectronics.<sup>31</sup> These studies, completed in August and September 2014, generally ranked the CHIP2 proposal at or near the top of the alternatives but also stated that CHIP2 did not stand out as a decidedly better option. Nonetheless, in early 2015, NNSA's Deputy Administrator for Defense Programs issued a memorandum recommending that NNSA pursue the CHIP2 proposal as a formal capital asset project, subject to DOE's project management order on acquisition of capital assets.
- In 2016, in accordance with DOE's project management order, NNSA developed two key documents during the initiation phase of its capital asset project supporting the CHIP2 proposal, which NNSA referred to as the Trusted Microelectronics Capability (TMC) project.
  - NNSA first developed a mission need statement, which is a formal document that identifies a credible performance gap between current capabilities and those needed to achieve the goals stated in the agency's strategic plan.<sup>32</sup> The mission need should be

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<sup>30</sup>Los Alamos National Laboratory and Lawrence Livermore National Laboratory also submitted proposals for new facilities. See P.C. Albright, P.J. Hommert, and C.F. McMillian, *Roadmap for Future NNSA Experimental Facilities (Draft)* (March 2012).

<sup>31</sup>See T.L. Turflinger, L.I. Harzstark, D.C. Mayer, N. Sramek and J.N. Culliney, *Analysis of Alternatives to Support NNSA Evaluation of the Proposed Sandia National Laboratories Center for Heterogeneous Integration, Packaging and Processing (CHIP2) Semiconductor Fabrication Facility*, (The Aerospace Corporation, Aug. 27, 2014); and T.L. Turflinger, L.I. Harzstark, D.C. Mayer, N. Sramek and J.N. Culliney, *Valuation Analysis to Support NNSA Evaluation of the Proposed Sandia National Laboratories Center for Heterogeneous Integration, Packaging and Processing (CHIP2) Semiconductor Fabrication Facility*, (The Aerospace Corporation, Sept. 4, 2014).

<sup>32</sup>National Nuclear Security Administration, *Trusted Microsystems Capability Mission Need Statement, Version 2* (Washington, D.C.: September 2016).

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stated in a way that is solution-neutral. The project's mission need statement stated that, among other things, after 2025 the SiFab Facility faced a severe risk of equipment and facility failures that could have detrimental impacts on future microelectronics production schedules. The statement noted that continued refurbishment of the SiFab Facility beyond 2025 could result in significant downtime during critical weapon development and production cycles, as the facility was constructed in the 1980s and was not sized for modern microelectronics production equipment and supporting infrastructure.

- NNSA next developed a requirements document, which describes the ultimate goals the project must satisfy while also identifying key assumptions and constraints.<sup>33</sup> The requirements document identified several key requirements, including that the TMC project must be able to provide NNSA with trusted access to produce microelectronics in support of the agency's nuclear weapons mission.
- Between 2016 and 2017, in accordance with DOE's project management order, NNSA conducted an analysis of alternatives for the TMC project based on achieving NNSA's mission need statement. Such an analysis identifies, analyzes, and selects a preferred alternative to best meet the mission need by comparing the operational effectiveness, costs, and risks of potential alternatives, according to DOE documentation. During this process, NNSA considered 21 alternatives for meeting the mission need statement, among them the CHIP2 proposal as well as several alternatives that included partnerships with commercial industry and other government production facilities.<sup>34</sup> The final TMC analysis of alternatives report, dated January 2018, did not identify the CHIP2 proposal as a preferred alternative because of the proposal's high life-cycle costs, high total project cost, and long project schedule.<sup>35</sup> Instead, the report identified two preferred alternatives as best meeting NNSA's needs:

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<sup>33</sup>National Nuclear Security Administration, *Trusted Microsystems Capability Program Requirements Document* (Washington, D.C.: October 2016)

<sup>34</sup>The TMC analysis of alternatives team was made up of 19 subject matter experts drawn from other government agencies and federally-funded research and development centers and a support team of 11 members primarily from within NNSA. The team made 11 site visits to U.S. government-owned, industry, and academic institutions to assess the microelectronics landscape and existing U.S. production capabilities

<sup>35</sup>National Nuclear Security Administration, *Trusted Microsystems Capability Analysis of Alternatives* (Washington, D.C.: Jan. 12, 2018).

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(1) partnering with an existing, government-owned, contractor-operated production facility other than Sandia;<sup>36</sup> and (2) entering into an interagency agreement with DOD and at least one member of the intelligence community, as well as a commercial entity, to design, build, and operate a state-of-the-art production facility.

Ultimately, NNSA decided not to pursue either preferred alternative because of changing assumptions. For example, one of NNSA's key assumptions for the TMC analysis of alternatives was that the SiFab Facility could not remain operational beyond 2025. However, NNSA tasked The Aerospace Corporation to validate this assumption, and in January 2018, The Aerospace Corporation completed a study concluding that the SiFab Facility could remain viable until 2040 with prioritized and well-planned infrastructure repairs and equipment replacements.<sup>37</sup> Another example of changing assumptions concerned the preferred alternative under which NNSA would enter into an interagency agreement with DOD and at least one member of the intelligence community to design, build, and operate a state-of-the-art production facility. This preferred alternative assumed that DOD, the intelligence community, or both, would pay to develop and build the production facility (estimated to cost from \$350 million up to \$1.2 billion), while NNSA would pay to equip its portion of the production process. The TMC analysis of alternatives report stated that commitment from DOD and the intelligence community would be vital, and that this alternative carried significant execution risks. In January 2018, NNSA documentation stated that this interagency alternative was no longer viable because other agencies stated they were no longer interested in a potential partnership.

Partly as a result of these changes in key assumptions, in November 2018, NNSA wrote in a letter to Congress that it was no longer requesting funding for the TMC and was assessing what investments were needed to extend the operational life of the SiFab Facility to 2040.

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<sup>36</sup>The TMC analysis of alternatives final report identified three existing, government-owned, contractor-operated production facilities: two of these facilities are owned by the U.S. federal government and produce microelectronics for DOD, and one is a research facility funded by a state government. Of these facilities, the report stated that one facility had a limited production capability with no known expansion upgrades for the near term, another facility had never conducted a full-scale microelectronics production process, and a third facility required upgrades to its production processing line, likely totaling less than \$50 million, to meet NNSA's production requirements..

<sup>37</sup>G.S. Panning, T.L. Turflinger, and L.I. Harzstark, *SNL MESA SiFab Study*, (The Aerospace Corporation, Jan 5, 2018).

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## NNSA Has Decided to Upgrade and Sustain Its Microelectronics Capability at Sandia through 2040, but Its Management Approach Does Not Fully Incorporate Key Controls

As part of NNSA's ongoing approach to managing its strategic radiation-hardened microelectronics activities, the agency plans to upgrade and sustain its microelectronics capability at Sandia through 2040, which it estimates will cost about \$1 billion over the next 20 years. NNSA is also in the preliminary stages of identifying and evaluating options for a microelectronics capability beyond 2040. In addition, NNSA is starting to implement a revised management approach, including appointing a coordinator to guide certain aspects of its microelectronics activities. However, NNSA's approach does not fully incorporate key management controls, such as developing an overarching management plan, which the agency has applied to other important activities.

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## NNSA Plans to Upgrade and Sustain Its Microelectronics Capability at Sandia through 2040 and Is Beginning to Identify Options for a Capability Beyond 2040

In 2019, NNSA made three key decisions related to upgrading and sustaining its microelectronics capability at Sandia through 2040. First, NNSA approved plans to further upgrade its process for producing microelectronics. This upgraded process, called CMOS8, contains some features of the currently employed CMOS7 process, but is a more advanced technology node that also includes many new features, according to Sandia documentation. Second, NNSA approved plans to produce and integrate into future nuclear weapons a more advanced type of microelectronics component called a field programmable gate array (FPGA).<sup>38</sup> According to Sandia documentation, strategic radiation-hardened FPGAs can be produced using the CMOS8 process but not the CMOS7 process. Third, Sandia developed and NNSA approved a plan to identify, prioritize, and provide budget estimates to sustain Sandia's microelectronics infrastructure and equipment at the MESA Complex over the next 20 years.<sup>39</sup> This plan incorporates NNSA's decisions to develop the CMOS8 process and produce FPGAs.

According to NNSA and Sandia documents, the rationale behind and expected benefits of these three key decisions are as follows:

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<sup>38</sup>FPGAs are a common microelectronics component used in the commercial sector and in certain DOD systems.

<sup>39</sup>Sandia National Laboratories, *Microsystems Engineering, Science, and Applications Complex Extended Life Plan*, SAND2019-13264 (Albuquerque, N. Mex.: October 2019).



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- The CMOS8 process will allow Sandia to produce microelectronics at a smaller, more advanced technology node (180nm) compared with the current CMOS7 technology node (350nm). NNSA documentation states that, among other things, the CMOS8 process is expected to produce microelectronics that have twice the processing speed compared with those produced using the CMOS7 process. Such advances are needed to help ensure that future nuclear weapons remain safe, secure, and reliable while operating in increasingly hostile threat environments and that the weapons meet increased performance requirements, according to Sandia documentation. According to NNSA officials, the agency agreed with Sandia's assessment on implementing the CMOS8 production process based, in part, on findings and recommendations contained in an independent study commissioned by NNSA and completed by multiple entities including The Aerospace Corporation.
  - According to Sandia documentation, while FPGAs have never been used before in a nuclear weapon, they may significantly reduce the cycle time for microelectronics research, development, and production compared with cycle times for ASICs used in nuclear weapons. This reduction may be possible because the ASICs currently used in nuclear weapons are uniquely designed and produced to carry out specific functions, whereas FPGAs can be produced using a common design and then programmed after production (but before insertion into a nuclear weapon) to carry out different functions, according to NNSA officials. Reduced cycle time from FPGAs could alleviate schedule pressure on future weapon modernization programs because cycle times for designing and producing ASICs for LEPs have historically been about 10 years before production of the first weapon, according to Sandia documentation.
  - Sandia's plan will provide NNSA with the basis for the investment profile needed to sustain the MESA Complex's infrastructure and equipment through 2040. Because the sustainment effort will last at least 20 years, NNSA officials said that having a long-term planning document that provides a current baseline for the condition of Sandia's microelectronics infrastructure and equipment, identifies challenges, and recommends specific sustainment activities will be a useful management tool.

The plan for extending the life of the MESA Complex at Sandia provides cost and schedule estimates related to sustainment of existing facilities and equipment, as well as installation of new equipment for CMOS8 and development and maturation of the FPGA technology. Overall, the plan

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calls for spending about \$1 billion over the next 20 years. Specifically, the plan identifies spending for the following activities:

- **Sustainment of existing facilities and equipment.** The plan identifies about \$900 million in spending from fiscal years 2020 through 2040—or about \$45 million a year for the next 20 years—to complete identified infrastructure and equipment projects. The plan calls for spending roughly half of the \$900 million on projects to upgrade existing infrastructure within the MESA Complex. In particular, Sandia plans to spend about \$120 million from fiscal years 2020 through 2024 on projects to improve or upgrade infrastructure within the SiFab Facility that is considered to be in “poor condition” based on information contained in NNSA’s infrastructure condition database. The SiFab Facility is to be the physical location for the majority of production tools for CMOS8. Two of these projects would replace electrical power and distribution equipment at an estimated cost of about \$50 million, while another project would replace the facility’s chemical distribution system at an estimated cost of about \$5 million. Sandia plans to spend the other half of the \$900 million on equipment-related projects. For example, Sandia plans to spend about \$85 million from fiscal years 2021 through 2026 on projects to support existing, non-CMOS8 production processes—such as producing transistors in the Micro Fabrication Facility—as well as activities that support microelectronics production, such as laboratory analysis, testing, and packaging. For example, Sandia plans to spend \$1.5 million on a computerized tomography machine to support microelectronics testing.
- **Development of CMOS8 and production of FPGAs.** The MESA Complex extended life plan identifies about \$170 million in spending from fiscal years 2020 through 2027 related to developing, maturing, installing, and implementing the CMOS8 process and the FPGA technology. Sandia contractor representatives told us that the CMOS8 process relies on newer and more advanced equipment to complete critical individual processing steps compared with the current CMOS7 process. As a result, the plan identifies about \$70 million (out of the \$170 million total) to acquire approximately 30 pieces of equipment, which Sandia will need to install and then qualify their performance. In addition, the plan identifies almost \$90 million (out of the \$170 million total) for developing and maturing the CMOS8 production process and

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the FPGA technology.<sup>40</sup> According to Sandia documentation, Sandia plans to begin using the CMOS8 process to produce FPGAs for integration into a future nuclear weapon program at the end of fiscal year 2027.<sup>41</sup>

In addition to upgrading and sustaining Sandia's microelectronics capabilities through 2040, NNSA is in the preliminary stages of identifying and evaluating options to ensure a continued microelectronics capability beyond 2040, according to NNSA officials and documentation.<sup>42</sup> In particular, NNSA has identified the following two key options:

- NNSA is in the initial stages of identifying and evaluating options to construct a new facility for producing microelectronics by 2040 and beyond. In December 2019, NNSA officials provided us with documentation stating that the agency plans to begin evaluating options for a new microelectronics facility in 2021 with the goal of completing construction in 2030, installing needed equipment in the completed facility by 2033, and qualifying the production process and begin producing microelectronics for integration into nuclear weapons no later than 2035. In NNSA's fiscal year 2021 budget request, which was released in February 2020, the agency requested funds to begin evaluation and early planning activities for this new microelectronics facility.
- NNSA is also evaluating whether the agency might be able to leverage a recent investment by DOD in a U.S. commercial microelectronics production facility to help meet NNSA's microelectronics production needs after 2040. Specifically, DOD announced in October 2019 that it had awarded a contract to a U.S.-owned-and-operated microelectronics commercial production facility to, among other things, enhance its radiation-hardened microelectronics production process to meet DOD's microelectronic needs for systems (such as satellites) that operate in environments

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<sup>40</sup>According to Sandia planning documentation, the remaining \$10 million in development costs will be spent on facility investments, among other things.

<sup>41</sup>According to Sandia documentation, there is no opportunity to compress the planned development schedule for these FPGAs, and if the requested budget is not fully funded in each fiscal year, then the CMOS8 production process and the FPGA technology will not achieve a production capability at the end of fiscal year 2027. Sandia documentation states that the FPGA technology is currently at technology readiness level 3, where laboratory-scale studies and experiments have demonstrated the proof of concept.

<sup>42</sup>While 2040 may seem distant, Sandia's previous plans for constructing CHIP2 anticipated a 14-year design and construction schedule.

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with increased radiation levels.<sup>43</sup> Over the next two years, the U.S. commercial microelectronics production facility plans to adapt its current production process and develop a new process that will produce microelectronics at a smaller node, according to DOD documentation. According to NNSA officials we interviewed in February 2020, NNSA and DOD are in preliminary discussions to determine if NNSA could make additional investments in this same facility to potentially produce strategic radiation-hardened microelectronics for integration into nuclear weapons. NNSA officials said that there was no firm timeframe for making an investment decision because such a decision would need to be made after the microelectronics facility begins producing microelectronics at the smaller node.

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**NNSA Is Starting to Implementing a Revised Microelectronics Management Approach, but This Approach Does Not Fully Incorporate Key Management Controls**

NNSA is starting to implement a revised approach to managing its microelectronics activities. During our initial interviews with NNSA officials in early 2019, they stated that NNSA had not established a formal management structure to oversee the agency's microelectronics activities. Instead, they said that NNSA had delegated primary responsible for overseeing such activities to two officials within NNSA's Office of Defense Programs, who both served in multiple positions and had other duties within the office. According to these officials, once NNSA formally canceled the TMC project in November 2018, management efforts were focused on making initial determinations on the actions and budget estimates needed to sustain NNSA's existing microelectronics capability at Sandia until 2040. These efforts included coordinating with multiple NNSA offices—such as the Office of Safety, Infrastructure and Operations—to understand their future microelectronics needs and requirements and to review draft MESA Complex sustainment documentation prepared by Sandia.

However, officials from NNSA's Office of Defense Programs told us that in late 2019 they determined that a more coordinated management approach would better position NNSA to oversee microelectronics activities and make informed budgetary and programmatic decisions. Specifically, NNSA officials stated that in November 2019 the Office of Defense Programs created and filled a new full-time microelectronics coordinator position within a sub-office, the Office of Research, Development, Test, and Evaluation. The microelectronics coordinator told us that NNSA has not yet finalized an official position description for the

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<sup>43</sup>According to a DOD official, the total value of this contract is up to \$170 million.

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coordinator role. However, the coordinator said that the position will primarily be responsible for developing the CMOS8 process and the FPGA technology and integrating the research and development activities of the Office of Research, Development, Test, and Evaluation with another sub-office, the Office of Production Modernization.

In addition, officials from NNSA's Office of Defense Programs and Office of Safety, Infrastructure and Operations told us that they continue to use other existing processes to manage microelectronics activities at Sandia. For example, these officials said that they use the annual planning, programming, budgeting, and evaluation process,<sup>44</sup> along with the annual work authorization process,<sup>45</sup> to coordinate across NNSA offices on budgetary matters and work activities associated with microelectronics activities at Sandia. As part of these processes, agency officials told us that they issue annual implementation plans to direct the work of Sandia contractors related to microelectronics activities. NNSA officials then monitor the contractors' progress toward completing the identified scope of work and work activities. For example, NNSA officials said that they conduct monthly meetings with contractor representatives to review status and financial reports. They also said that they hold mid-year and end-of-year program reviews with contractor representatives.

To help management achieve desired results—such as ensuring a continued microelectronics capability—federal agencies design, implement, and operate internal controls, which comprise the plans, methods, policies, and procedures used to fulfill an entity's mission,

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<sup>44</sup>According to NNSA's policy, its process for planning, programming, and budgeting is similar to processes in use across the U.S. government and has four major phases for each budget cycle: Planning, Programming, Budgeting, and Evaluation (includes execution and performance). See National Nuclear Security Administration, *Planning, Programming, Budgeting, and Evaluation (PPBE) Process*, NAP-130.1A (Washington, D.C.: Dec. 9, 2019).

<sup>45</sup>In accordance with DOE's acquisition regulations, each contract for the management and operation of a DOE site or facility must contain a scope of work section that describes, in general terms, work planned and/or required to be performed. These acquisition regulations require that NNSA assign work to be performed under the contract through a work authorization to control individual work activities performed within the scope of work. Work authorizations must be issued prior to the commencement of the work and incurrence of any costs. NNSA's Office of Defense Programs issues work authorizations separately from those issued by NNSA's Office of Safety, Infrastructure, and Operations.

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goals, and objectives. Federal standards for internal control state that management should, among other things:<sup>46</sup>

- design control activities, such as by developing policies, procedures, techniques, and mechanisms that enforce management’s directives, to achieve objectives and respond to risk; and
- establish an organizational structure, assign responsibility, and delegate authority to achieve the entity’s objectives.

NNSA has implemented internal controls at the agency level, in part, by developing and implementing directives that provide an organizational structure for the agency to plan, execute, control, and assess its programs and projects while also assigning responsibility and delegating authority for key management roles. For example, one purpose of NNSA’s 2019 program management directives is to increase management efficiency and effectiveness by, among other things, clearly defining management responsibilities and authorities. In addition, DOE’s project management order for the acquisition of capital assets lists principles for successful project execution such as disciplined, up-front planning; line management accountability; and effective implementation of all management systems (such as risk and performance management) supporting the project.<sup>47</sup>

In particular and as applicable to front-end planning, NNSA’s and DOE’s directives related to program and project management both include the following controls:

- Appointment of a federal manager, who is vested with the authority to carry out assigned responsibilities to meet program or project milestones on schedule and on budget, who manages the coordination of deliverables between the multiple entities (such as different program offices) involved, and who is responsible and accountable for planning, implementing, and executing a program or project, which includes responsibility for developing an overarching management plan;
- An overarching management plan, which establishes the procedures to define, execute, and monitor a program or project, as well as establishing specific requirements in a variety of areas—such as cost estimating, an integrated schedule, performance management, and

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<sup>46</sup>[GAO-14-704G](#).

<sup>47</sup>DOE Order 413.3B (Change 5).

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risk management—to use to develop a baseline and against which to measure and monitor;

- A mission need statement, which identifies a credible gap between current capabilities and those needed to achieve the goals stated in the strategic plan; and
- A requirements document that describes the ultimate goals the program or project must satisfy while also identifying key assumptions and constraints.

However, while some in NNSA and at Sandia have recognized the need to coordinate microelectronics activities to effectively carry them out and meet specific goals by specific dates, as evidenced by the hiring of a coordinator, Office of Defense Programs leadership have not fully developed controls to better manage and coordinate its microelectronics activities. Specifically, NNSA does not have or has not fully developed the following:

- **Federal manager with coordination or oversight authority.** NNSA has not established a federal management position with the authority and accountability to better coordinate or oversee NNSA's microelectronics activities. Instead, as described above, agency officials told us that NNSA's Office of Defense Programs established a coordinator position—within a sub-office, the Office of Research, Testing, Development and Evaluation—in November 2019 to help guide the agency's efforts to develop the CMOS8 process and the FPGA technology, among other things. Moreover, in May 2020, NNSA stated that senior leadership within the Office of Defense Programs have not endorsed the formal role of a microelectronics coordinator and that the coordinator's role and responsibilities are currently under review. NNSA also stated that the coordinator has not been given authority to manage an annual budget for microelectronics activities and that it was unlikely that such authority would be granted.<sup>48</sup> This statement stands in contrast to earlier statements made to us that the coordinator would have responsibility for an annual budget of about \$50 million, subject to future appropriations.

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<sup>48</sup>According to a 2019 Sandia microelectronics planning document, the lack of a single microelectronics federal manager who is responsible for the multiple budget accounts that fund microelectronics activities at Sandia makes it difficult to conduct long-term planning and sustainment efforts. This document recommended that NNSA appoint a microelectronics federal program manager to address this challenge. See Sandia National Laboratories, *Microsystems Engineering, Science, and Applications Complex FY20 Integrated Program Plan*, SAND2019-13383 (Albuquerque, N. Mex.: October 2019).

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- **Management plan.** NNSA has not developed an overarching management plan to guide and coordinate the agency's microelectronics activities. Instead, NNSA officials from the Office of Defense Programs and the Office of Safety, Infrastructure and Operations told us that the agency is in the very early stages of developing a NNSA plan that will incorporate key decisions and approaches outlined in the Sandia's 20-year MESA sustainment plan, among other things. While NNSA officials are still evaluating the specific contents of this plan, they said that the plan may outline specific roles and responsibilities for each NNSA office involved in microelectronics, describe how these offices will interact with the microelectronics coordinator, and provide options for future microelectronics technology development efforts. However, it is unclear whether the document will define the planning approach, procedures, and processes that NNSA will use to ensure coordinated management in multiple areas and across multiple offices, such as developing cost estimates, an integrated schedule, and performance metrics. Agency officials said that this plan, when finalized, will provide a useful tool for coordinating various aspects of NNSA's microelectronics activities, but they did not provide an estimated date for when the plan will be completed.
  - **Mission need statement and requirements document.** NNSA has not developed a current mission need statement or a current program requirement document. In 2016, as required by DOE's project management order on the acquisition of capital assets, NNSA issued a formal mission need statement and a requirements document to guide its assessment of the cancelled TMC project (as described earlier in this report). However, agency officials told us that these 2016 documents are no longer applicable to NNSA's current approach to sustaining its microelectronics capability and evaluating options to ensure a continued capability after 2040. NNSA officials said that they intend to establish an updated set of requirements to guide the agency's future microelectronics capability, and that they will consider these requirements in establishing a future mission need statement. However, NNSA officials did not provide a timeframe for finalizing these documents.

NNSA officials acknowledged the importance of using management controls and that the controls described above would be useful, but they could not identify any specific DOE or NNSA directives, government-wide guidance, or best practices that they follow to manage their microelectronics activities. Instead, they offered three reasons why the agency has not implemented a more coordinated and robust set of management controls to oversee the agency's microelectronics activities:



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- Microelectronics production has historically been managed as a component production effort by an LEP, which is led by an NNSA program manager within the Office of Defense Programs who coordinates directly with other NNSA offices and Sandia contractors.
  - Because NNSA has not designed microelectronics as a formal program, the requirements contained in the agency's program management directives are not binding on microelectronics activities.
  - NNSA officials said that the multiple projects (identified in the MESA Complex extended life plan) to upgrade and sustain the microelectronics capabilities at Sandia through 2040—at an estimated cost of over \$1 billion over 20 years—will not be subject to DOE's project management order, as these projects are for sustainment and not for new facility construction.<sup>49</sup> According to officials from NNSA's Office of Safety, Infrastructure, and Operations, infrastructure investments are being planned and managed as maintenance and repair efforts.

NNSA officials told us that the agency's current efforts provide the necessary structure for NNSA to oversee and manage its microelectronics capability. However, NNSA has recognized the importance of implementing a more coordinated and robust set of management controls for other important activities within its nuclear security mission that similarly have not been treated in the past as specific programs. For example, as we reported in June 2019, while NNSA historically managed its high-explosive capability without a formal mechanism to coordinate activities across multiple programs, it recently implemented a more robust set of management controls to oversee its high-explosive activities.<sup>50</sup> Specifically, in 2018 NNSA appointed an enterprise manager to help coordinate these activities. NNSA also encouraged the enterprise manager to adopt, where appropriate, the program management controls contained in an NNSA directive on managing nuclear weapon life extension and strategic materials

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<sup>49</sup>As described earlier, in August 2018, the DOE Office of the Inspector General recommended that NNSA ensure that all ongoing and new Sandia capital asset projects are properly categorized and managed in accordance with DOE's project management order and found that NNSA's effort to sustain MESA through 2025 should have been managed as a capital asset acquisition even though the effort would not result in construction of a new facility. See DOE-OIG-18-42.

<sup>50</sup>GAO, *Nuclear Weapons: Additional Actions Could Help Improve Management of Activities Involving Explosive Materials*, [GAO-19-449](#) (Washington D.C.: June 17, 2019).

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programs.<sup>51</sup> Subsequently, the enterprise manager issued a strategic plan that provided an organizational structure for the agency's high explosives capability. By taking a similar approach to its management of microelectronics activities and incorporating a more coordinated and robust set of management controls, the agency would have increased assurance that its planned microelectronics activities are clearly defined, efficiently executed, and effectively monitored.

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## Conclusions

NNSA's ability to produce unique microelectronics for nuclear weapons is essential to ensuring a credible U.S. nuclear deterrent. Producing such microelectronics is a complex task, and NNSA is limited in its ability to partner with the commercial sector for such production. Over the next two decades, NNSA will undertake an expensive and ambitious approach to upgrade and sustain its existing microelectronics production facilities and capabilities. Specifically, NNSA plans to spend about \$1 billion over the next 20 years to, among other things, upgrade its process to produce a new type of microelectronic component that has never been integrated into a nuclear weapon. In addition, NNSA officials said that the agency will need to identify and analyze options for a continued capability after 2040, and that effort could begin as early as 2021.

To increase its management and oversight of the agency's microelectronics activities, NNSA has taken some positive steps such as appointing a microelectronics coordinator within the Office of Defense Programs and approving certain long-term planning documents. However, in contrast to other NNSA activities, including programs and projects, NNSA has not fully developed a coordinated and robust set of management controls to oversee its microelectronics activities. For example, NNSA has not established an overarching management plan to manage and coordinate the cost, schedule, and risks associated with its microelectronics activities. By incorporating a more coordinated and robust set of management controls, NNSA would have increased assurance that its planned microelectronics activities are clearly defined, efficiently executed, and effectively monitored.

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<sup>51</sup>National Nuclear Security Administration, *Program Management Policy for Weapons and Strategic Materials Programs*, BOP-06.07 (Washington D.C.: Jan. 17, 2017). According to this directive, strategic materials such as plutonium are generally not available, or are restricted from commercial suppliers, because of their specific properties and use in nuclear weapons, or for national security purposes.

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## Recommendation for Executive Action

The NNSA Administrator should incorporate additional management controls to better oversee and coordinate NNSA's microelectronics activities. Such management controls could include investing the microelectronics coordinator with increased responsibility and authority, developing an overarching management plan, and developing a mission need statement and a microelectronics requirements document. (Recommendation 1)

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## Agency Comments and Our Evaluation

We provided a draft of this report to DOD and NNSA for review and comment. DOD did not provide any comments. In its written comments, reproduced in appendix I, NNSA neither agreed nor disagreed with our recommendation but provided three main comments. First, NNSA stated that by December 2020 the agency plans to complete a strategic management plan that will more clearly articulate the integration of management controls for the various components of its microelectronics activities. NNSA stated that it believes this action is consistent with our recommendation. We are encouraged by this planned action and will evaluate the completed strategic management plan to determine if it meets the intent of our recommendation.

Second, NNSA stated that our report did not clearly convey the differences between the management of microelectronics and other weapons or materials programs and did not include all aspects of its microelectronics activities (such as the procurement of commercial off the shelf components) in our audit's scope. In response, we added references to the various aspects of NNSA's microelectronics activities and clarified that our report focuses on NNSA's strategic radiation-hardened microelectronics activities at Sandia's MESA Complex. As stated in the report, we focused on this specific aspect of NNSA's microelectronics mission because of the language in the Senate committee report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2019, which included a provision for us to review NNSA's efforts to recapitalize its strategic radiation-hardened microelectronics design and production capacity. We also focused on this specific aspect of NNSA's mission because the fiscal year 2020 *Stockpile Stewardship and Management Plan* lists the continued production of strategic radiation-hardened microelectronics as one of four key challenges to the agency's nuclear stockpile mission.

Third, NNSA stated that our audit did not include an assessment of management controls for the range of activities that work together to ensure the effectiveness of microelectronics planning and execution. However, our report identifies and describes these management controls,

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and as part of our work we considered how these controls work together. In addition and as stated above, NNSA intends to complete a strategic management plan to more clearly articulate the integration of its various microelectronics management controls, which is especially important as the agency invests about \$1 billion dollars over the next 20 years while simultaneously needing to meet microelectronics production deliverables for multiple nuclear weapon modernization programs.

NNSA also provided technical comments, which we incorporated in our report as appropriate.

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We are sending copies of this report to the appropriate congressional committees, the Secretary of Energy, the Secretary of Defense, and other interested parties. In addition, this report is available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or at [bawden@gao.gov](mailto:bawden@gao.gov). Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.



Allison B. Bawden  
Director  
Natural Resources and Environment

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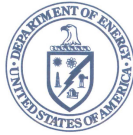
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# Appendix I: Comments from the National Nuclear Security Administration



Department of Energy  
Under Secretary for Nuclear Security  
Administrator, National Nuclear Security Administration  
Washington, DC 20585



May 19, 2020

Ms. Allison B. Bawden  
Director, Natural Resources  
and Environment  
U.S. Government Accountability Office  
Washington, DC 20548

Dear Ms. Bawden:

Thank you for the opportunity to review the Government Accountability Office (GAO) draft report "Nuclear Weapons: NNSA Needs to Incorporate Additional Management Controls Over Its Microelectronics Activities" (GAO-20-357). The report highlights some of the challenges the National Nuclear Security Administration (NNSA) faces in a shifting technological environment, as well as NNSA's mitigating actions including creating a full-time microelectronics coordinator position within the Office of Defense Programs and approving long-term planning documents.

We appreciate changes the auditors made in consideration of our initial comments to more clearly articulate existing management and control activities. However, the report does not clearly convey differences between management of microelectronics and management of weapons or materials programs, and implies that "radiation-hardened microelectronics" includes the vast portfolio of NNSA microelectronics. The radiation-hardened microelectronics considered in this report are only a small portion of a wider range of microelectronics devices manufactured by the nuclear security enterprise and procured from industry to enable NNSA's mission.

Further, the scope of the audit did not include an assessment of management controls for the range of activities that work together to ensure the effectiveness of the microelectronics planning and execution. These include actions by the Office of Safety, Infrastructure and Operations; controls implemented by multiple funding programs; and activities outside of the Microsystems and Engineering Sciences Applications (MESA) Complex, including commercial off the shelf procurements, passive components, reliability testing, and component verification, among others.

The report recommends NNSA "incorporate additional management controls to better oversee and coordinate NNSA's microelectronics activities. Such management controls could include investing the microelectronics coordinator with increased responsibility and authority, developing an overarching management plan, and developing a mission need statement and a microelectronics requirements document." Consistent with the auditors' recommendation, we will develop a strategic management plan that will more clearly articulate the integration of management control for the various components of the



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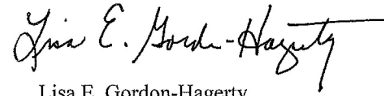
**Appendix I: Comments from the National  
Nuclear Security Administration**

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microelectronics mission. NNSA believes this plan, anticipated to be completed in December 2020, will address the underlying questions raised in the audit report.

Our subject matter experts have also separately provided technical and general comments to enhance the clarity and accuracy of the report. If you have any questions about this response, please contact Dean Childs, Director, Audits and Internal Affairs, at (301) 903-1341.

Sincerely,



Lisa E. Gordon-Hagerty

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# Appendix II: GAO Contact and Staff Acknowledgments

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## GAO Contact

Allison B. Bawden at (202) 512-3841 or [bawdena@gao.gov](mailto:bawdena@gao.gov)

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## Staff Acknowledgments

In addition to the contact named above, Jason Holliday (Assistant Director), Patrick Bernard (Analyst in Charge), and Alisa Carrigan made key contributions to this report. Also contributing to this report were Jonathan Felbinger, Juan Garay, Lisa Gardner, Cindy Gilbert, Cynthia Norris, and Dan C. Royer.



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